# COTTON MACHINERY.

(*For Description, see opposite page.*)

ROBERTS'S SELF-ACTING MULE. 1866

FIG. 22. FULLER MOTION

(CARRIAGE RUNNING OUT SPINDLES, SPINNING THREADS)

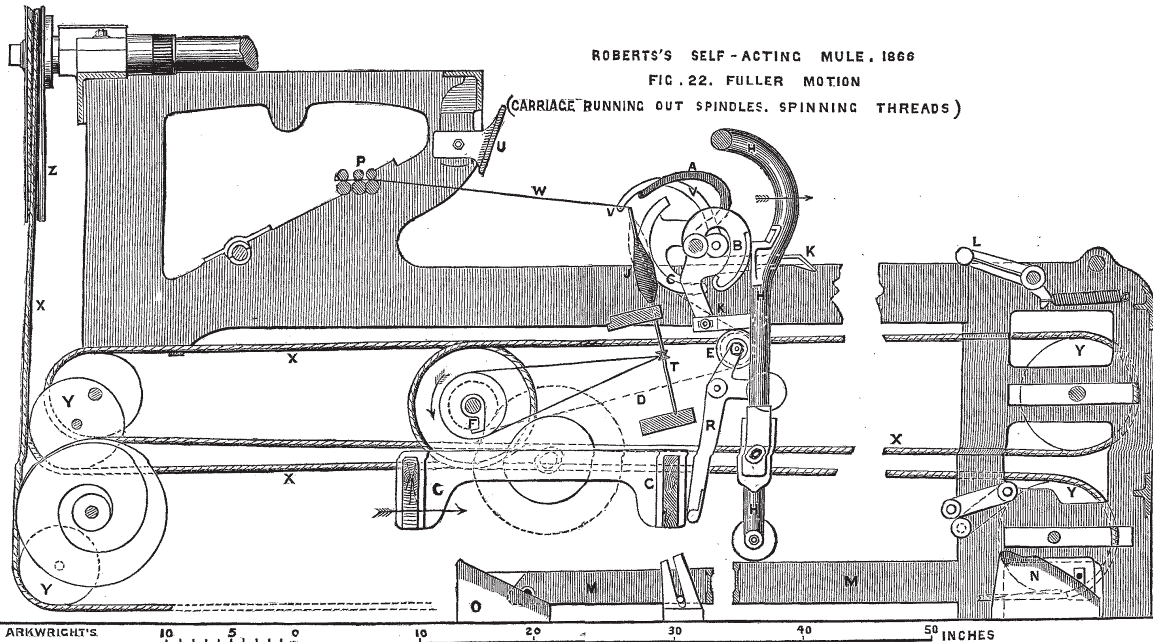



FIG. 1. ARKWRIGHT'S SPINNING MACHINE. 1769.

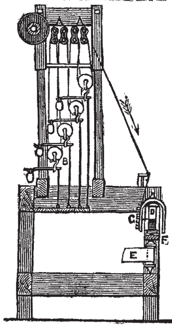


FIG. 2. HARGREAVES SPINNING JENNY. 1770.

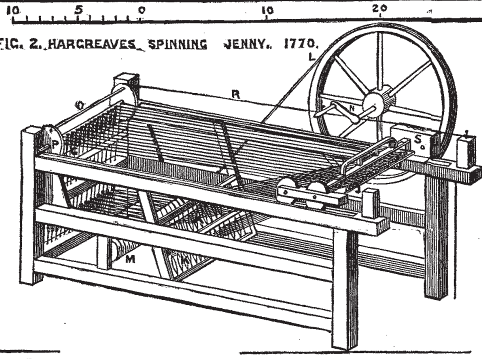
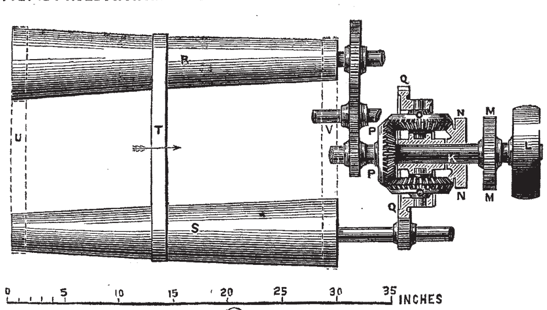


FIG. 18. HOLDSWORTH'S DIFFERENTIAL MOTION. 1826.




EATON'S BACKING. FIG. 19. OFF MOTION. 1818.

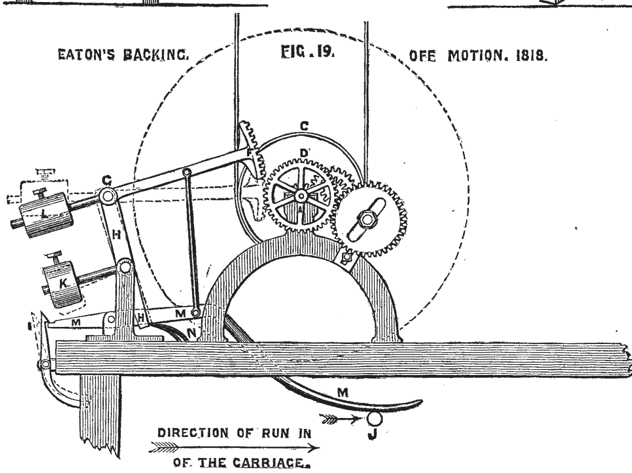



FIG. 20.

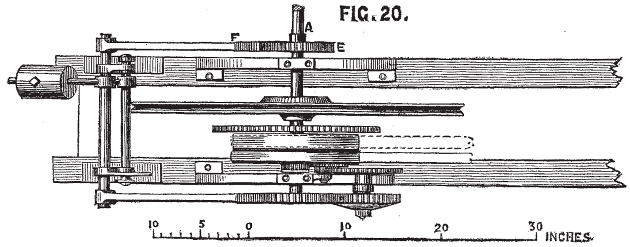
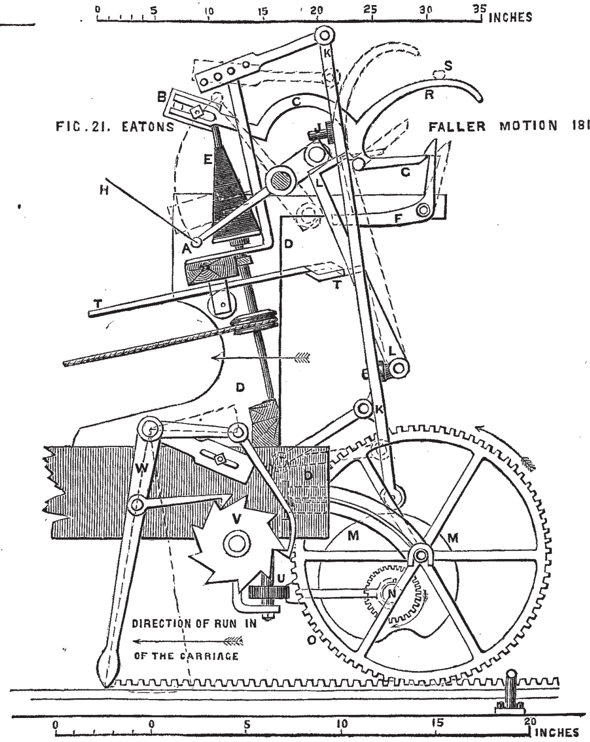



FIG. 21. EATONS FALLER MOTION 1818



## ON MACHINERY FOR THE PREPARING AND SPINNING OF COTTON.*

*By* Mr. JOHN PLATT, *of Oldham.*

THE object of the present paper is to trace the principal mechanical steps by which the application of machinery to cotton spinning has been developed, and which have led to the completion of the present elaborate machines, so remarkable for the perfection of the results produced by them. The modern machines are, in fact, formed of a combination of numerous highly ingenious contrivances, which have been successively designed to meet the special difficulties of dealing by machinery with so delicate and irregular a material as the raw cotton fibre.

The process of spinning involves three essential and distinct operations:

First, *Drawing*,—in which the fibres of the raw material are drawn out longitudinally, so as to lay them all parallel with one another, and overlapping at the ends; as is done by the fingers of the hand-spinner for forming a continuous sliver out of the short fibres lying irregularly in the bundle that is tied upon the distaff.

Second, *Twisting*,—in which the sliver previously formed is twisted into a roving or thread, for giving it longitudinal tenacity by increasing the lateral friction between the fibres; as is done by the hand-spinner by twirling the bobbin on which the portion of thread already twisted has been wound.

Third, *Winding*,—in which each portion of the thread, after it has been sufficiently twisted, is wound upon the bobbin.

In the application of machinery to the performance of these operations, the great difficulties experienced have arisen from the irregular character of the cotton fibre on the one hand, and, on the other, from the unyielding action of machinery, which has to take the place of the delicate feeling of the fingers in hand-spinning, whereby the spinner is enabled to accommodate the action continually to the variations in the material. It is a point of special mechanical interest, however, to note at how early a period in the application of machinery correct ideas were developed as to the principles of action in the important successive steps: so correct, indeed, that they have remained unaltered in principle to the present time, although many highly ingenious improvements in detail have subsequently been effected.

It appears that the credit of the first invention of the spinning machine is due to Lewis Paul in 1738, little more than a century ago, all spinning having been previously done by hand. In his first machine the raw cotton was passed through a succession of pairs of rollers, each pair running faster than the preceding, so as to draw out the sliver of cotton longitudinally to any degree of fineness required. The machine thus accomplished only the drawing process, leaving the sliver so formed to be twisted and wound afterwards by hand. The great feature of this invention was that the important principle of drawing by rollers running at different speeds was thus established at the outset, to supersede drawing by the fingers in hand-spinning; and this mode of drawing has been adhered to ever since as the fundamental principle in the preparation of fibrous materials for spinning.

In 1748 Paul further invented a carding machine, for carding or combing the raw cotton in preparation for the drawing-rollers. It consisted of a number of flat parallel cards fixed upon a table with spaces between them; and, the teeth of the cards being all bent in the same direction, the cotton was carded by being drawn over them by hand by means of an upper flat carding-board set with teeth bent in the opposite direction. In another arrangement this flat upper card was replaced by a horizontal carding cylinder, made to revolve by hand; and the lower carding table was made concave to fit the underside of the cylinder. When the cotton was sufficiently carded, it was taken off each card separately by hand by a needle-stick, and then connected into one entire roll or lap.

In 1758 Paul further improved his original machine by rendering it capable of performing the two other processes of twisting and winding requisite to complete the operation of spinning by machinery; and he constructed a spinning-machine having a circular frame containing fifty spindles. The cotton was drawn by rollers, as in his previous machine, and the sliver was delivered from the rollers to a bobbin upon each spindle, by means of an arm or flier fixed upon the spindle; and the spindle being so contrived as to go faster than the bobbin, the sliver was thus twisted into thread by the flier, before being wound upon the bobbin.

Although the two mechanical principles, which have formed the basis of all subsequent spinning machinery, namely, the drawing rollers running at different speeds, and the differential motion of the flier and bobbin, were thus originated by Paul, it does not appear that his machines were ever practically successful; and Arkwright's spinning-machine in 1769, shown in Fig. 1, page 220, appears to have the merit of being the first that was brought into successful operation. This machine cannot be called more than an improvement in detail upon Paul's, as the principles of the two were the same; and it is difficult to imagine that Arkwright had not seen Paul's machine. The success of the later machine may be attributed to its superiority both in workmanship and in the material employed, the earlier machine having been composed almost entirely of wood.

The four pairs of drawing rollers, A A, Fig. 1, were made of brass and steel, and geared together by pinions; the bottom rollers were covered with wood and fluted, and the top ones were covered with leather, and pressed down upon the bottom rollers by the weighted cords and pulleys, B B. The sliver delivered by the rollers was then twisted into a yarn or roving by the flier, C, and wound upon the bobbin, D. The differential motion of the flier and bobbin, by which the two operations of twisting and winding were effected, was exactly the same that is still employed for the same purpose, only the motion was obtained by different means. If the flier and bobbin both revolved at the same rate and in the same direction, no winding would take place, and the effect would be confined to twisting the sliver into a roving. On the other hand, if only the flier revolved and the bobbin were stationary, all the motion would wind and also twist, but only a single twist would be put into the sliver for each coil wound on the bobbin. But if the bobbin rotates slower than the flier, the winding is effected at just so much slower rate than the twisting as the two speeds are made to approximate. This was accomplished in Arkwright's machine by the simple means of a friction brake upon the bobbin, D, the bobbin being loose upon the spindle, and dragged round by the thread, whilst the flier, C, was fast upon the spindle, and driven direct by the driving-strap, E, below. The friction-brake to retard the bobbin was made by a worsted cord passed round a groove in the whirl, F, at the bottom of the bobbin, and tightened by hand to the required adjustment by a screw-pin securing the end of the cord. The drag put upon the bobbin by this friction-brake also put a stretch upon the roving, and caused it to be wound tight on the bobbin in solid layers instead of in loose coils. In the arm of the flier, C, were fixed a number of hooks, under which the roving was passed; and the winding on the bobbin was done in successive steps, by stopping the bobbin and shifting the roving successively from one hook to the next on the flier, ae no idea had yet been originated of giving the bobbin a vertical motion upon its spindle so as to guide the roving on regularly in winding.

In 1770 Hargreaves invented the spinning jenny, shown in Fig. 2, page 220, the principle of which is identical with that of the present spinning machinery. It thus presents a remarkable instance of a correct perception respecting the best mode of working having been attained at so early a stage in the application of machinery to a new purpose. The operation of spinning into threads the rovings produced by the machines already described, or by the modern improved machines similar in principle, comprises the two processes of twisting and elongating the roving to form it into a thread, and then winding the spun thread into the form of a "cop" upon the same spindle by which the spinning or twisting has been performed. These two processes still continue to be effected in essentially the same manner as in Hargreaves's spinning jenny.

The twisting of the thread is effected by causing the spindles G, Fig. 2, to revolve, as though for winding up the thread, but allowing the thread to slip off the free end of the spindle once in each revolution. For this purpose the thread is led off from the top end of the spindle at an angle so much greater than a right angle that its tendency to wind in a spiral brings it to the top extremity of the spindle in each revolution, causing it to slip off the end of the spindle at each successive revolution; and the top of the spindle is shaped conical to facilitate the slipping of the thread off the end. The result is that the thread is twisted one turn by each revolution of the spindle, without disturbing or interfering with the portion of spun thread already wound up into a cop on the lower part of the spindle. The crossbar, J, carrying the guiding eyes through which the several threads pass, rests at each end on a carriage that runs along the side framing of the machine; and before the commencement of the spinning by the spindles, G, the crossbar is first draw backwards from the spindles by hand through about one-third the length of the machine, drawing off a continuous supply of roving from the bobbins, K, below, which are free to turn on their bearings. The clasp, H, is then pressed down tight upon the crossbar J, holding the rovings fast, and the spindles, G, are set in motion, twisting the lengths of thread between the spindles and the crossbar; and during the twisting the crossbar is gradually drawn backwards by hand to the end of the machine, thus producing the required elongation of the threads by tension during the spinning, as is done in the case of hand-spinning by the weight of the bobbin or spindle hanging from the twisting thread. The spindles, G, receive their motion from the drum, M, driven by the driving pulley, L, which is turned with the right hand by the handle, N, while the left hand draws back the crossbar, J, by means of the handle upon the clasp, H.

When the crossbar, J, has been drawn back to the extreme end of the machine and the spinning of the threads has been completed, they are then wound up on the spindles by depressing them all simultaneously to the lower portion of the spindles by means of the "faller wire," O, which is brought down upon the threads by the rotation of the discs, P P, in the direction of the arrow. The rotation of the discs is effected by tightening the cord, R, which runs along he side of the machine, and they are turned back again by a counterbalance weight for raising the faller wire when the cord is released; the cord passes round three horizontal pulley on the top of the carriage, S, and is tightened for depressing the faller wire by a transverse sliding movement being given to the middle pulley by means of a hand lever, which is worked by the left hand whilst holding the clasp on the crossbar, J. The threads being depressed by the faller wire, the further rotation of the spindles now causes the threads to be wound up in cops upon the spindles, the sliding crossbar, J, being pushed forwards gradually by hand as the winding proceeds, until it again reaches the spindles, when it is ready for beginning the spinning of a fresh length of rovings. During the winding of the threads already spun between the spindles and the crossbar, J, this length of the threads is secured and separated from the untwisted rovings beyond the crossbar by the pressure of the clasp, H, which is kept pressed down tight upon the threads.

On the completion of the spinning, however, of each length of the threads, and before the change can take place from spinning to winding, it is necessary first to unwind the short spiral of thread extending up from the top of the cop previously wound to the top extremity of the spindle. This spiral is unadvoidably formed at the commencement of the twisting, before the thread can reach the point where it ceases to wind and begins slipping off the end of the spindle at each revolution; but if this portion of thread were not entirely removed before the faller wire, O, is lowered at each time of changing from twisting to winding, an irregular and loose accumulation of thread would take place upon the upper end of the spindle, spoiling the form of the cop, and interfering with the proper slipping-off action in twisting. The motion of the spindles has therefore to be stopped and reversed for a few turns when the twisting is finished, to unwind these few spiral coils; and this was done in the spinning jenny by the spinner stopping the driving wheel, L, and then giving it a partial turn backwards by hand, for "backing off" the thread, before driving forwards again for winding thread on the spindles.

This backing-off motion and the faller wire are identical with those now in use in the modern spinning-machines, the only difference being that they are now made self-acting. In winding the cop each successive layer of thread is so regulated that a conical form is given to each end of the finished cop, in order to prevent the thread from getting loosened upon it at the ends in subsequent handling; while, at the same time, the crossing of the thread in the alternate spiral layers gives firmness to the cop, and still allows the thread to be afterwards drawn off it, when required for use, either by slipping off the end, as in a shuttle, or by unwinding the cop on a spindle. In the spinning-jenny this shape of cop was obtained by regulating the winding of the thread by means of the cord, R, acting upon the discs, P P, raising and lowering the faller wire, O, during the winding, so as to guide the thread upon the spindle as required for producing the desired shape of cop. The same shape of cop and mode of guiding the thread on are still adhered to in the present spinning-machines; but the whole of the movements are now effected entirely by self-acting machinery.

Further improvements in the preparatory processes of carding and roving were introduced by Arkwright, in 1775 which may be said to include the principal features contained in the carding and roving machines now used. The cotton delivered from the preliminary machine was formed into a roll or lap, for supplying a continuous fleece of cotton to the carding-cylinders, the carding operation being repeated until the irregular mass of fibres in the raw material had been combed straight and laid parallel in the fleece of cotton with a sufficient degree of uniformity to allow of proceeding to the subsequent operations. Comb-plates, worked backwards and forwards by cranks, were also added for combing off the cotton in a continuous fleece from the "doffer" or taking-off cylinder of each of the carding-machines. The sliver delivered from the last carding process was passed between a pair of rollers for the purpose of consolidating it by the pressure of the rollers after the loosening action of the doffing comb-plate; and it was then coiled down into a can.

The doubling and drawing process employed at this stage of the manufacture was also introduced by Arkwright at the same time, the object being to intermingle the fibres more completely in the sliver, and thereby render it more uniform in quality, ready for twisting into a roving. For this purpose two, or generally more, of the slivers from the carding-engine are passed side by side through a series of pairs of drawing rollers, each pair in succession being made to run faster than the preceding; and the last pair of rollers runs as many times faster than the first pair as there are slivers doubled together, so that the single combined sliver delivered from the rollers is drawn down to the same size or weight per foot as one of the original slivers. The doubling and drawing operation is usually repeated three times, and the ultimate sliver so prepared is then ready for the roving-frame, in which it is again drawn and twisted and wound upon a bobbin.

In the roving-frame Arkwright now effected an important advance upon his previous machine, shown in Fig. 1, by introducing the new principle, which has since been adhered to, of driving the bobbin and the spindle independently by separate motions, instead of letting the bobbin be simply dragged round by the thread as previously described. At the same time he also introduced the conical regulating-drum, for reducing the speed of the bobbin in proportion as its diameter was increased by the thickness

* Paper read before the Institution of Mechanical Engineers on the occasion of their meeting at Manchester, in August, 1866. Some of the figures referred to in this paper are given on page 220; the remainder will appear, with the conclusion of the paper, next week.

of the coils of roving wound upon it, so as to avoid increasing the tension upon the roving, as would be the case if the speed of the bobbin were uniform, since the spindle and flier are driven always at a constant speed. This mode of regulating the speed of the bobbin by a conical drum is the same that is still employed in the modern machinery, with modifications only in the mode of application. There appears reason also to believe that the rising and falling motion of the bobbin upon the spindle, for winding the roving on the bobbin in regular coils by a continuous vertical movement of the bobbin, was also introduced by Arkwright at the same time, although no description is given by him of the manner in which this was accomplished; but in the drawing illustrating the series of improvements introduced by him at that period, the flier upon the spindle is shown with a single eye for delivering the roving upon the bobbin, instead of the succession of hooks fixed on the arm of the flier in the previous machine, Fig. 1, for winding the roving on in a succession of steps; and a sufficient space is also left in the drawing for allowing the required amount of vertical movement of the bobbin. The invention of this principle of lifting and lowering the bobbin upon the spindle during the winding, which is employed in all the present machines, has not been traced by the writer to any earlier date than these final improvements introduced by Arkwright in 1775.

By thus making special machines for each process in the preparation of the material for spinning, Arkwright effected a most important division of labour; and the factory system, already introduced in the silk manufacture, became rapidly extended in consequence.

In the preparation of cotton the improvements introduced from time to time in each particular section of the machinery employed have been so numerous and so varied that only a slight reference can be made to them in this paper under their respective heads, in the hope that they may be made the subjects of special papers by some of the members at future meetings.

*Opening.*—The first process in the preparation of the raw cotton was known as "willowing," and took its name from the willow switches formerly used for beating or opening the tufts of cotton by hand. A number of small parallel cords were stretched tight and close together on a horizontal frame, so as to form a sort of table, upon which the cotton to be opened was laid; and the cotton being then beaten with switches made of willow rods kept smooth for the purpose, the fibres of the cotton remained on the cords, whilst the sand and seeds fell through between. Some of the best descriptions of sea-island cotton are still batted in this way, for the finest counts of yarn. Several attempts were made to work the willow beaters by machinery, but they have all been superseded by opening and scutching machines on the modern principle, having revolving cylinders to act as beaters. The most primitive of these is known as the Oldham Willow, and has a revolving cylinder about 36 in. diameter, set with spikes placed in parallel rows, and revolving against a grid of bars set with similar spikes: the cotton is fed upon the grid, and beaten for a longer or shorter time according to its condition, and an exhausting-fan is employed for taking away the sand and bits of dried leaves beaten out. This machine is now used only for separating hard lumps of cotton in bales packed too tightly, and for cleaning cotton waste and the refuse cast out by other cleaning-machines.

Fig. 3 shows a section of the cotton-opener in use at the present time for the purpose of opening out the fibres of the cotton after it has been pressed in the bales, and for extracting the sand, dried leaves, and other impurities imported with it, the object being to do this without entangling or injuring the fibre. The crude cotton from the bales is spread by hand upon the endless travelling lattice, A, which conveys it underneath the iron guide-roller, B, with longitudinal ribs on its surface to the pair of fluted feed-rollers, C. These are pressed together by the weighted lever, D, and deliver the cotton to the picker cylinder, E, set with twelve rows of teeth, which are spaced so that the teeth follow one another spirally round the cylinder, as shown in the plan, Fig. 4. The tufts of cotton being gripped tight between the rollers, C, are caught by the tips of the teeth on the cylinder revolving in the direction of the arrow, and are thus torn open and dashed by the teeth against the circular grid, F, formed of angular bars set with spaces between them, which allow the dirt disengaged by the beating action to fall through. A perforated plate, G, forms the remainder of the casing of the cylinder on the underside, allowing the dust to drop through while the cotton passes over it. The picker cylinder delivers the cotton against the teeth of the beater, H, which has four rows of teeth, similar to those on the picker, E. Here the cotton is further beaten, and passed over a circular grid and perforated plate; and the beater cylinders being covered in at the top by a sheet-iron casing, the current of air produced by their revolution wafts the light fleece of cotton forwards over the straight grid, J. It is whilst the cotton is thus floating in the air that the heavier impurities, loosened by the beaters, drop out and fall through the grid, J, into the dust-box. The cotton then passes between the two wire-gauze cylinders, K, which serve as fine sieves, the interior of the cylinders being exhausted by the fan, L; by this means the more minute particles of dust remaining in the cotton are sifted out, and discharged by the fan through the aperture, M, thereby keeping the rooms where the machines are at work perfectly free from dust. There is thus a continual deposit of impurities taking place throughout the whole passage of the cotton through the machine, from the feed-rollers, C, to the wire cylinders, K. In the drawing only two beater cylinders, E and H, are shown; but the machines are more generally made with four cylinders, for cleansing the cotton more effectually, the two additional beaters being provided with four rows of teeth, the same as the second cylinder, H. From the wire cylinders the loose cotton is collected again, and consolidated into a fleece by the fluted stripping-rollers, I, running close to the cylinders, K, but not touching; and these deliver it to the travelling lattice, N, which discharges it ready to be taken to the next process of scutching, a lap machine being sometimes attached so as to form the fleece into a lap or roll for supplying the scutcher. The beater cylinders, E and H, run at about 1000 revolutions per minute; the feeding lattice, A, travels at 6 ft. per minute, which is also the surface speed of the feed rollers, C; and the surface speed of the wire cylinders, K, the stripping rollers, I, and the delivery lattice, N, is 60 ft. per minute.

*Scutching.*—The scutching-machine now in use for further beating and cleansing the cotton delivered from the opener is shown in Fig. 5, having also combined with it the lap machine for forming the fleece of cotton delivered from the scutcher into a roll or lap. The cotton from the opener is supplied to the scutcher upon the travelling feeding-lattice, A, and in order to produce a uniform fleece for the further processes it is necessary at this stage to regulate the quantity fed into the scutcher, which is effected in two ways. In feeding by hand the tedious method of weighing the cotton supplied has to be resorted to, so as to distribute a uniform weight of cotton over each foot of length of the feeding lattice, which, together with the feed rollers, C, is driven at a uniform speed. But in the improved mode of feeding by laps, B, supplied from a lap machine in connexion with the opener, the top feed roller is allowed to rise and fall according to the variations in the thickness of cotton fed in, and the amount of its vertical movement multiplied by means of levers is employed to regulate by a self-acting arrangement the speed at which the feeding-lattice and rollers are driven. By this means an almost uniform supply of cotton is fed to the beater, H, which is composed of three plain bars, as shown in the plan, Fig. 6, and is driven at about 1250 revolutions per minute. The cotton is beaten as before against the circular grid, F, and perforated plate, G, and the current of air from the beater wafts it forwards over the straight grid, J, to the wire cylinders, K, exhausted by the fan, L, the action being exactly the same as in the opening-machine. The rollers, I, which strip the dust cylinders, deliver the fleece to a set of four calender rollers, O, placed over one another, so that the cotton in passing through them receives three compressions, which consolidate it into a kind of felt; the surfaces of the calender rollers are kept clean by rubbers of iron covered with flannel, which are pressed in contact with them.

The lap machine, for coiling the fleece into a roll or lap, has two fluted driving rollers, P P, running in the same direction, as shown by the arrows; and the lap resting in the channel between them is driven by contact, and wound upon the iron rod, R, guided in a vertical groove at each end. For tightening and closing the coils of the lap, the rod, R, was weighted in the former machines by a heavy weight suspended from the ends of the rod, and it was then necessary to lift the whole of this weight at each time of changing the lap; but this is now effected by the friction-brake, S, pressing against a friction-wheel on the shaft, T, on which are pinions gearing into the vertical racks, U, and these racks carry rollers at the top, bearing down upon the ends of the rod, R, in the lap. By this means, as each successive coil is wound upon the lap, the brake, S, slips and allows the lap to rise; and when the lap is completed, the brake is released by a treadle, and the racks are lifted clear by the hand-wheel on the shaft, T, so as to allow the finished lap to be removed. The driving-pinion, V, from which the calender rollers, O, receive their motion, is held up in gear by the lever, W, supported by a catch; and when the lap is finished this catch is released by a tappet upon the pinion, X, which is driven from the bottom calender roller, the speed of the pinion being so reduced that one revolution of it corresponds to the size of lap required to be made. The catch being released allows the driving-pinion, V, to fall out of gear, whereby the calender rollers, O, are stopped; and the lap rollers, P, continuing to revolve, break off the fleece ready for removing the finished lap from the machine. By changing the pinion, X, carrying the tappet, the size of lap made by the machine can be varied as desired.

The scutcher shown in Fig. 5 is a single machine, and it is usual to pass the cotton first through a double scutcher of similar construction, but having a second set of feed-rollers with beater and wire cylinders, running at a higher speed; the second pair of wire cylinders and stripping-rollers are driven three times as fast as the first pair, so that they deliver a fleece of one-third the thickness first supplied to the machine. Three of the laps from this double scutcher are then fed into the single scutcher shown in the drawing, as at B B B, Fig. 5, being spread upon the surface of the feeding-lattice, A, in three layers on the top of one another, so as to present to the feed-rollers a uniform fleece equal in thickness to that fed into the first scutcher. By thus doubling the laps the fibres are more thoroughly mixed, and the fleece is thereby made more uniform in thickness.

Scutching-machines having a revolving beater composed of two plain bars describing a circle of about 14 in. diameter, were introduced about 1810; and these machines contained also a travelling feed lattice, two pair of feed rollers, and a second travelling lattice for conveying the beaten cotton underneath a perforated revolving cylinder, the interior of which was exhausted by a fan. The cotton passing through this machine was delivered in a loose fleece; and a few years later a lap machine was added for coiling the fleece into a lap. Other improvements have gradually been introduced up to the present time, as regards both design and workmanship: the cylinders and beaters have been put in perfect balance so as to revolve steadily at the high speed required, and the forms of teeth on the cylinders have been arranged for greater strength and greater facility of construction; stronger and simpler gearing has been employed, improvements have been made in the form and construction of the bearings of the beaters and other quick revolving shafts, so as to ensure more efficient lubrication, and air-tight dust-boxes have been added with movable doors for facility of cleaning; and the self-acting arrangements have been introduced for stopping the machine when a given length of fleece has been delivered, and for regulating the rate of feed according to the thickness of the cotton supplied, so as to dispense with the previous plan of weighing the cotton in feeding. Thus by successive improvements through a long series of years the difficulties which originally presented themselves in the successful adaptation of machinery to cotton-cleaning have been overcome; the cotton can now be perfectly cleaned without injury to the fibres, and the laps are produced uniform in length, breadth, and thickness of fleece, and so thoroughly felted that they uncoil at the carding-engine in the next process without any derangement of the felted fleece.

(*To be continued.*)

# COTTON MACHINERY.

(*For Description, see Page* 250.)

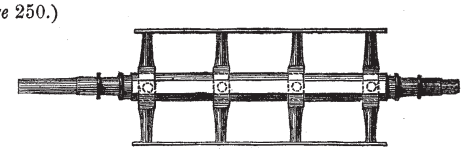


FIG. 6. PLAN OF BEATER.

FIG. 5. SINGLE SCUTCHER AND LAP MACHINE. 1866.

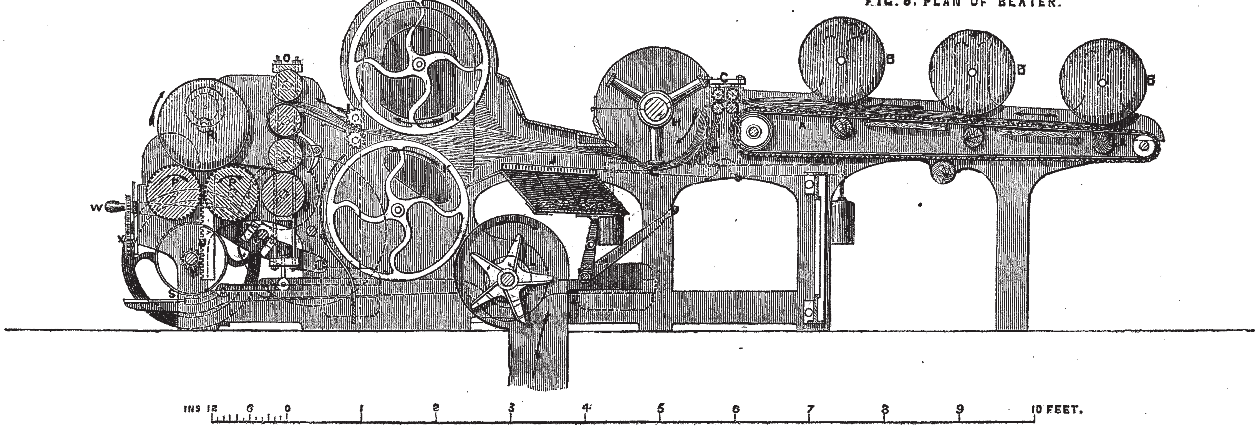



FIG. 8. ROLLER & CLEARER.

FIG. 7. ROLLER & CLEARER CARDING MACHINE 1866.

FIG. 9. CARD. FULL SIZE.

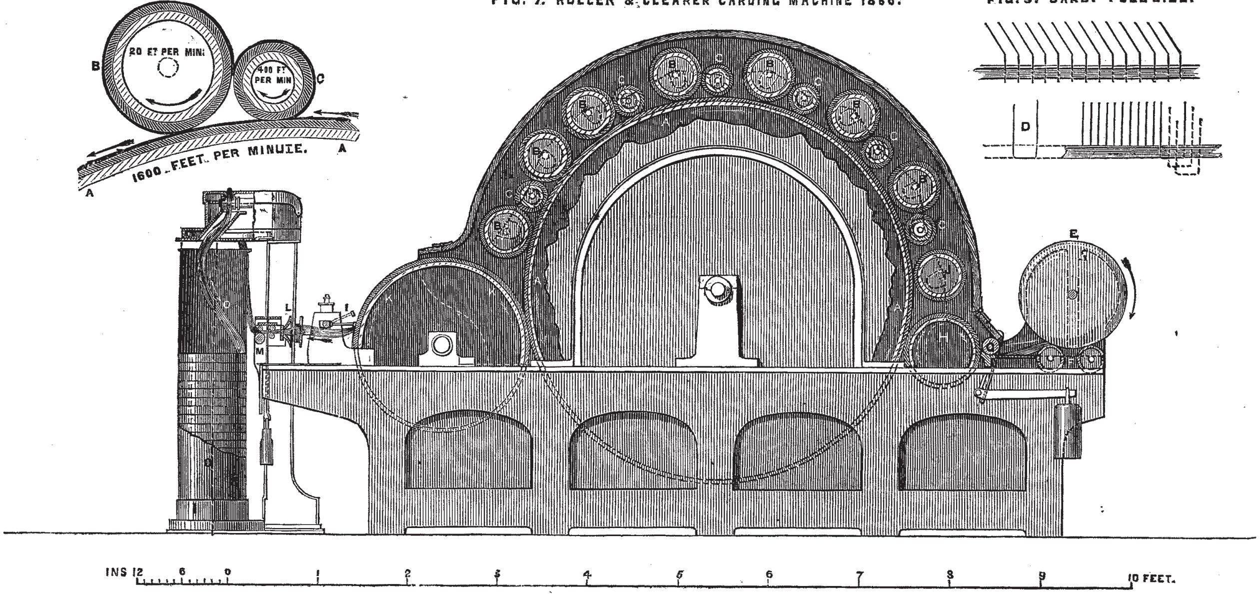
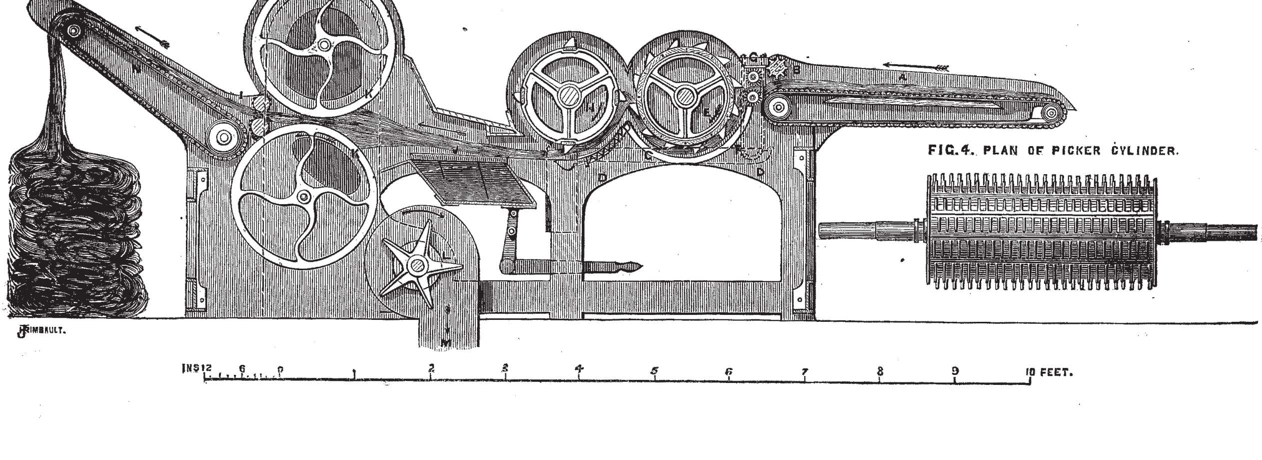



FIG. 3. COTTON OPENER. 1866.

FIG. 4. PLAN OF PICKER CYLINDER.




JRIMBAULT.

# COTTON MACHINERY.

(*For Description, see Page* 250.)

FIG. 11. STRIPPING BRUSH.

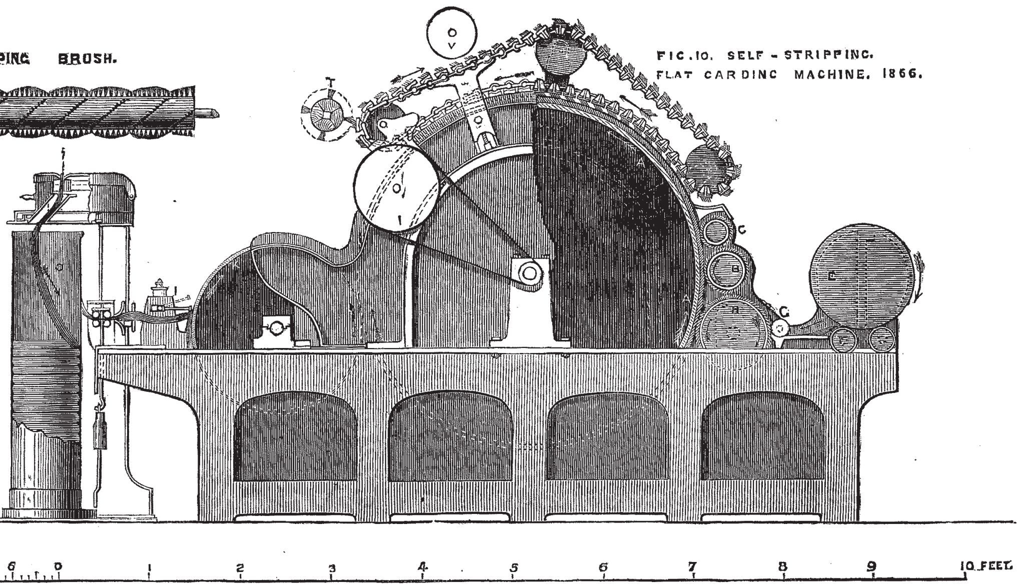


FIG. 10. SELF-STRIPPING FLAT CARDING MACHINE, 1866.

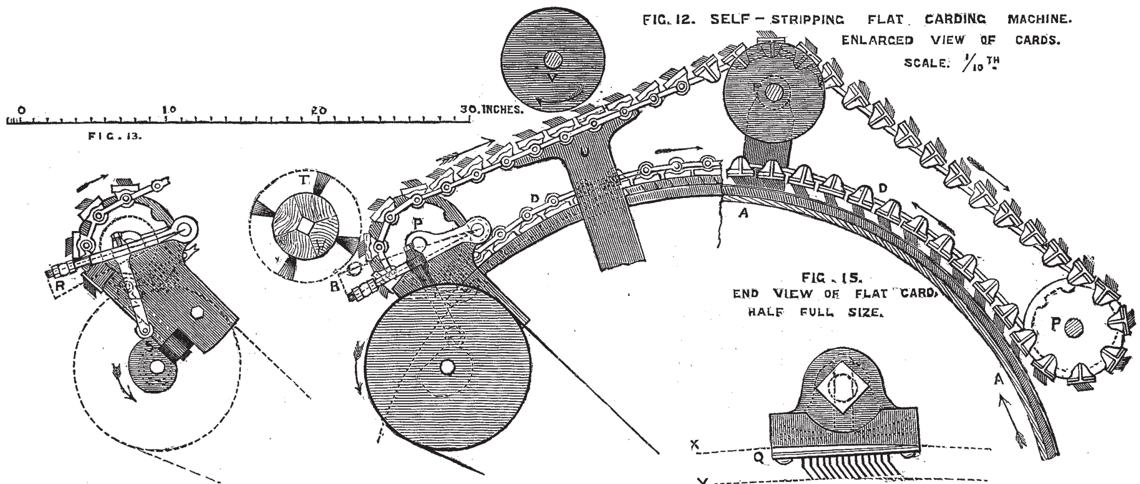


FIG. 12. SELF-STRIPPING FLAT CARDING MACHINE. ENLARGED VIEW OF CARDS. SCALE: 1/10TH.

FIG. 13.

FIG. 15. END VIEW OF FLAT CARD. HALF FULL SIZE.

FIG. 14. FRONT VIEW OF FLAT CARD SCALE 1/5TH

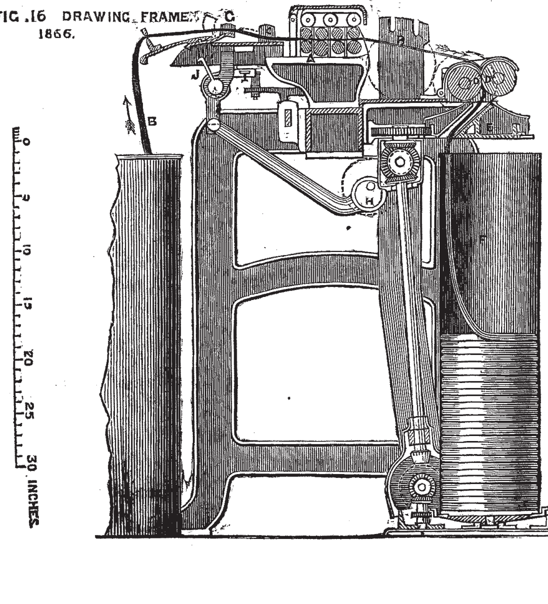


FIG. 16 DRAWING FRAME, 1866.

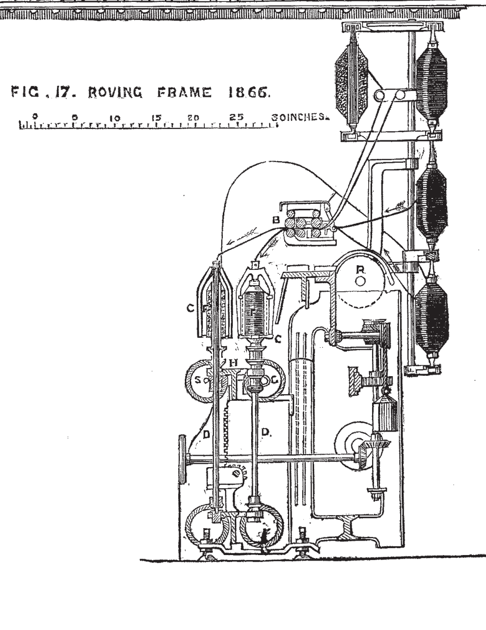


FIG. 17. ROVING FRAME 1866.

(*Cotton Machinery continued from page* 251.)

Hargreaves' jenny, combining the drawing roller arrangement in the former with a modification of the sliding crossbar and spinning spindles in the latter. In this machine the spindles were placed in a movable carriage, which had a stretch or run of about 54 in., and the rovings delivered from the drawing rollers in a soft state were further drawn by the spinner in pulling the carriage backwards from the rollers, and completely twisted by the receding spindles, ready for being wound upon the spindles during the run-in or return traverse of the carriage and spindles. In the spinning-jenny each successive lengths of the rovings was held by the clasp on the sliding crossbar, and the stretching of the rovings was done entirely by drawing back the crossbar by hand from the spindles; and in Arkwright's machine the stretching was performed entirely by the rollers; but in Crompton's mule the stretching was accomplished partially by the drawing rollers, when the carriage and spindles began to recede from the roller beam, and partially by the continued run-out of the carriage after the rollers had been stopped. The rollers were stopped when the carriage had receded nearly the length of its run, and they then acted as a clasp to hold the threads during the completion of the stretching and twisting.

Crompton's first mule contained about thirty spindles; and the threads spun by it were far superior in regularity, strength, and fineness to any ever spun before. They realised about double the prices obtained in 1743 for the same counts of yarn spun by other machines, and must therefore have been very superior in quality, having been produced much more cheaply; and, in order to show what could be done with the mule, small quantities were spun as fine as No. 80, which is such a quality of thread that 80 hanks of 840 yards each weigh together 1 lb. The adoption of these mules extended so rapidly that in 1811, thirty-two years after the first was made, there were 600 mills containing 4,209,000 spindles working on this plan, and only 310,500 spindles on Arkwright's plan, and 155,900 spindles on the spinning-jenny plan.

Many of the principal movements, however, in the working of Crompton's mule still required to be performed by hand by the spinner, the same as in the previous machines. This was the case with the backing-off motion, and with the working of the two faller wires, a second or counter-faller having now been added underneath the threads, which was lifted for the purpose of taking up the slack in the threads after the backing-off, the first faller being depressed for guiding the threads upon the cops during the winding. The speed of the spindles also required regulating by hand during winding, so as to correspond with the increasing diameter of the cops formed on the spindles, and to suit the conical-shaped ends of the cops. Great skill was therefore necessary on the part of the spinner, in order to make the cops regular in shape, size, and hardness, suitable for transport and for being uncoiled without waste. To supersede this skilled labour and render the mule self-acting was therefore the great aim in the subsequent improvements.

In 1818 the entire operation of winding up the spun threads into cops on the spindles was rendered altogether self-acting by Mr. William Eaton. This involved both a self-acting method of performing the backing-off, which has to be done at the conclusion of the twisting of each stretch, before the winding begins; and also a self-acting arrangement in connexion with the faller-wire, for guiding the threads regularly upon the cops during the winding, and a self-acting contrivance for regulating the speed of the spindles according to the increasing size of the cops.

The arrangemrnt of Eaton's backing-off motion is shown in Figs. 19 and 20, page 220. The main shaft, or "rim-shaft," A, from which the driving motion of the spindles in the travelling carriage is derived, is itself driven in the forward direction during the twisting, and again during the winding, by the driving-strap running on the fast-pulley, B, as shown by the dotted lines in Fig. 20. The loose pulley, C, communicates a slow motion through intermediate pinions to the wheel, D, revolving loose upon the shaft, A, but in the contrary direction; and at the other end of the shaft, A, is a corresponding wheel, E, fast upon the shaft. The two toothed sectors, F F, are keyed upon a shaft, G, which is carried in the rocking-frame, H; and the weight, K, on the rocking-frame is constantly acting to draw the sectors back out of gear with the wheels, D and E; while the sectors themselves are only partly counterbalanced by the second weight, L, and are ready to fall down into gear with the wheels as soon as the catch, I, by which they are held up out of gear, is released. When the twisting of the threads is completed, the driving-strap is shifted to the loose pulley, C, and the forward motion remaining in the shaft, A, is arrested by a friction-brake carrying a ratchet-wheel, which is caught by a hook falling into gear at the moment of reversing the strap. The pull upon this hook extends a spiral spring, the recoil of which is made to release the catch, I; and the sectors, F, falling into gear with the wheels, D and E, a backward motion is then communicated to the shaft, A, from the loose pulley, C, running forwards, whereby the spindles are made to turn backwards through the few revolutions necessary for backing off the spiral coils of thread at the top of the spindles, preparatory to winding. As the form of cop employed was a simple cone, increasing in height at the same time as in diameter (as shown in Fig. 21), the length of the spiral coils that require backing off at the top of the spindles becomes less with the increasing height of the cops on the spindles, and the number of backward turns in the backing-off has therefore to be gradually diminished as the cops approach completion; this is effected by an adjustible stop underneath the sectors, F, which is gradually elevated in proportion to the increasing height of the cops. This stop is connected with a lever catching against a stud at the lower extremity of the arm, H, of the rocking-frame; and the downward movement of the sectors, F, while in gear with the wheels, D and E, depresses the stop until at length the arm, H, is liberated; the weight, K, then withdraws the sectors out of gear, whereby the backward motion of the shaft, A, is stopped. By then shifting the driving-strap to the fast-pulley, B, the shaft, A, is again driven in the forward direction, and the threads previously spun are wound up on the spindles as the carriage runs inwards. The pin, J, fixed upon the carriage, travelling inwards in the direction of the arrow, now comes in contact with the tail of the lever, M, and lifts the sectors up again into their highest position, in which they are retained as before by the catch, I, at the other end of the lever, M; and when the run-in of the carriage is nearly completed, the same pin, J, comes in contact with the tail of a second lever, N, bearing against the extremity of the arm, H, of the rocking-frame, whereby the sectors are thrown forwards again in readiness for the next time of backing off.

Eaton's faller-motion is shown in Fig. 21, page 220, and was almost identical with that in use at the present time, the difference being that the faller-wire, A, was depressed by a weight, B, instead of, as in the present mules, by a chain passing round a pulley upon the faller-shaft, C. The direction of the run-in of the carriage, D, carrying the spindles and cops, E, is shown by the arrows; and during the run-out in the opposite direction the weight, B, is held up in the position shown by the catch, F, holding the tail of the lever, G. This catch is withdrawn by the downward movement of the sectors in the backing-off motion, and the weight, B, then brings the front end of the lever, G, down upon an arm on the front side of the faller-shaft, C, depressing the faller-wire, A, upon the threads, H. The roller, I, carried upon an arm on the back of the faller-shaft, is thus brought up against the pin, J, fixed in the parallel-motion bar, K, and is "locked" by the latch, L; so that by the vertical movement of the bar, K, the faller-wire, A, is raised and lowered during the winding of the threads, for guiding them upon the cops from end to end. The reciprocation of the bar, K, is obtained by its bottom end resting upon the shaper fusee or long tapered cam, M, which is driven by the pinion, N, from the toothed wheel, O, travelling along a rack, P, fixed upon the floor. As soon as the carriage has begun to run in, the weight, B, is lifted off the faller and raised again to its original position by the tail, R, of the lever coming in contact with a fixed stop, S. When the carriage arrives at the end of its run-in, the sliding-bolt, T, coming against a fixed stop, pushes back the latch, L, and unlocks the roller, I; and a balance-weight upon the back of the faller-shaft, C, raises the faller-wire, A, clear off the threads into the extreme position shown by the dotted lines. For regulating the shape of the cop as its size increases, the shaper fusee, M, is gradually traversed endways along its shaft, N, by the rack and pinion, U, driven by a worm-wheel from the ratchet, V, which is turned round one tooth at a time by the lever, W, coming against a stop, X, fixed on the floor at each end of the run of the carriage.

In 1825 further improvements were introduced by Mr. Maurice de Jongh, the backing-off motion being driven by a rack instead of by sectors; and with the backing-off was combined the process of putting down the faller-wire to the required part of the cops for the commencement of the winding. The working of the faller for guiding the threads during winding was effected by an arm on the back of the faller-shaft, carrying a roller, which travelled along a template or "copping-rail" extending the whole length of the stretch. The upper edge of this copping-rail was shaped according to the form of cop required, and the entire rail was gradually lowered by a regulating-screw at each end as the cop was built up. The winding of the threads on the cops was done by employing a slack strap or friction-strap for driving the main shaft, or "rim-shaft," of the mule during the run-in of the carriage; and this strap was tightened by a weight and two friction-pulleys pressing against it, the weight being adjusted so as to make the strap drive or slip as required for keeping the threads in proper tension.

It was also in 1825 that the late Mr. Richard Roberts's self-acting mule was first brought out, which, with the addition of further improvements subsequently introduced by himself and others, is the form of self-acting mule almost universally employed at the present time for spinning cotton. In this mule the faller-wire was for the first time put down by the agency of the "rim-shaft," or main driving-shaft of the machine, during the time that the shaft is turning the reverse way for backing off.

The arrangement of faller-wire motion as employed in the present spinning-mules is shown in Figs. 22 to 25, pages 220 and 256. A is the top-faller arm, which is made of the sickle shape shown in the drawing for the purpose of enabling it to put down the faller-wire to the bottom of the cops, J, without the arm itself being required to pass down between the cops, so as to save room in the length of the mule. On the front of the faller-shaft, I, is keyed the sector, C, and a chain, D, attached to the sector passes round the pulley, E, to a snail, F, upon the shaft of the tin roller, which is a long hollow cylinder made of tin, and driving by separate cords the whole row of spindles, T. The snail, F, is geared to the tin roller by a ratchet-clutch, with the teeth set so as to engage only when the tin roller is driven the reverse way for backing off, as shown by the arrow in Fig. 23. Whilst the tin roller is running forwards during the spinning, and again during the winding, in the direction shown by the arrow in Fig. 22, the snail, F, is not in action; but as soon as the carriage, G, of the mule has run out to the end of the stretch, as shown in Fig. 23, the tin roller is turned through part of a revolution in the reverse direction, as indicated by the arrow, sufficiently for unwinding the coils in backing off; and the snail, F, then comes into action and winds up the chain, D, thereby bringing the top-faller wire, A, down upon the threads, W, and depressing them towards the bottom of the cops. On the back of the faller shaft, I, is fixed the curved arm, B, against which bears the vertical locking bar, H; and when the arm, B, is lifted by the depression of the faller, A, its extremity is caught by the recess in the bar, H, which is thrown forwards by the bell-crank lever, K, as shown in Fig. 24; the tail of this lever having been brought, by the run-out of the carriage, G, under the corresponding bell-crank, L, fixed in the end frame of the mule, has previously extended the spiral spring attached to the bell-crank, L, Fig. 23, the recoil of which throws the locking bar, H, forwards as soon as the arm, B, is sufficiently raised, Fig. 24. The pulley, E, is carried on a rocking lever, R, the tail of which presses against the stop, S, in the end frame of the mule during the time that the chain, D, is depressing the faller, Fig. 23; but at the moment when the locking bar, H, is thrown forwards to lock the faller arm, B, the stop, S, is lowered, as shown in Fig. 24, clear of the tail of the lever, R, allowing the pulley, E, to yield to the further pull of the chain, D, until the reverse motion of the tin roller in backing off is stopped; by this means the snail, F, Fig. 23, is prevented from depressing the faller wire, A, beyond the required distance down the height of the cop.

The faller being thus locked, the carriage, G, begins to run in in the opposite direction to that indicated by the arrows in Fig. 22; and while the spindles wind up the threads on the cops, the faller-wire is gradually allowed to rise by the locking-bar, H, running down the inclined copping rail, M, the curved arm, B, being kept constantly pressed home in the notch of the locking-bar by a counter-balance weight or spring acting on the back of the faller shaft, I, to raise the faller, A. The length of the stretch or run-in of the carriage, G, is 63 in., which is therefore the length of thread to be wound upon the cop, J, at each time of winding; and this whole length of 63 in. of spun thread in each stretch is wound upon the cop during each stroke of the faller-wire. The mode of building up the cop in successive stages is shown half full size in Fig. 26, page 256; and in order to allow for the increasing diameter of the cop, the successive layers of thread are wound upon it in more open coils as the size increases, as indicated by the dotted lines, which is effected by gradually increasing the range of the faller wire; at the same time the ends of the cop are made of the conical form shown in the drawing. The length of range or "chase" of the faller wire at the commencement of the cop upon the bare spindles is only from A to B; but this is gradually increased until the cop has attained its full diameter, C C, when the length of range is from C to D; after which the range is slightly diminished again to the length, E F, in finishing the cop. For the purpose of obtaining the requisite motion of the faller wire for giving these successive shapes to the cop during the winding, the extremities of the copping rail, M, Fig. 22, are supported on the two sliding wedges, N and O, which are kept at an invariable distance apart by a connecting-rod. In commencing the winding of a set of cops upon the bare spindles, as shown at A B, in Fig. 26, the copping rail is set at the top of the wedges, and is at its smallest inclination; and after each successive layer has been wound on, the two wedges are slided from under the rail by a traversing screw worked by a ratchet-wheel, which is advanced one or more teeth during each run-out of the carriage, G, Fig. 22. By this means the copping-rail, M, is gradually lowered at both ends, and at the same time its inclination is increased by the outer wedge, N, being made with a rather smaller angle at the top than the inner wedge, O, for the purpose of forming the cop with a more gradual taper at the top than at the bottom, as shown in Fig. 26. This increase of inclination continues until the cop has attained its full diameter, C C, and has assumed the shape, A C D; after which the inclination slightly decreases again until the cop is completed to the finished shape, A C E F, by the latter part of the outer wedge, N, being made slightly steeper than the corresponding portion of the inner wedge, O, as shown in Fig. 22. The inner end of the copping rail being the lowest, the winding of each stretch leaves off at the top; and at the commencement of winding each stretch the faller wire puts down the thread to the point at which the winding of the new layer is to be started, about three coils being wound on during the descent of the faller, as indicated by the spiral dotted line from F to E, in Fig. 27, and the remainder during the rise of the faller. When the spindles arrive at the rollers, P, as shown in Fig. 25, having wound up the 63 in. stretch of threads, the stop, U, pushed back the locking bar, H, thereby releasing the faller, A, which immediately rises clear of the threads, W.

The counter-faller wire is carried by the arm, V, from a second shaft behind the top-faller shaft, I, and during the winding it bears up constantly against the underside of the threads W, as shown in Figs. 23 and 24, with a slight pressure from a counterbalance weight or spring acting on the shaft, so as to ensure keeping the threads in proper tension; during the spinning the counter-faller is held up just beneath the threads, but without touching them, as shown in Fig. 22. The arm, V, of the counter-faller is curved as shown in the drawing, so as to reach over the shaft, I, of the top faller, and also to avoid passing down between the cops; and the curved arm, B, on the back of the top-faller shaft, I, is shaped so as to clear the shaft of the counter-faller. The height of the counter-faller wire is employed as a means of regulating the speed of the spindles in winding, in the manner afterwards explained, so as to avoid the occurrence of any slack in the threads.

Roberts' Backing-Off Motion as employed in the present mules is shown in Fig. 28, page 256, which is a plan of the main driving shaft or "rim shaft," A, of the machine, carrying the large "rim wheel," Z, or double-grooved pulley driving the whole of the mule spindles by the endless cords, X X, Fig. 22, passing round the pulleys, Y Y. On the boss of the loose pulley, B, is a pinion, C, which through a train of intermediate wheels, D D, drives in the reverse direction and at the required slower speed the spur wheel and friction cone, E, also running loose upon the shaft, A, and sliding longitudinally upon it. This friction cone engages in a corresponding hollow cone inside the fast pulley, F, and when the driving strap is shifted from the fast pulley, F, to the loose pulley, B, for the purpose of backing off, the friction cone is also brought up against the fast pulley, thereby first arresting by friction the forward motion of the driving shaft, A, and then giving it the reverse motion for backing off.

Roberts' Winding Quadrant for regulating the winding of the threads by diminishing the speed of the spindles in proportion as the diameter of the cops increases, is shown in Fig. 29, page 256. This very ingenious contrivance has never been superseded, and is employed in almost every self-acting mule at the present day. The quadrant, A, turns upon a fixed centre, C, in the frame of the mule, and a pinion, B, gears into it, which is driven by a band and pulley receiving motion from the traverse of the carriage, G, the arrows indicating the direction of motion during the run-in of the carriage. The grooved arm, D, of the quadrant contains a double-threaded screw, by which the sliding nut, E, is traversed outwards from the centre of motion, C, towards the extremity of the arm, D. When the carriage is at the outer end of its stretch, the arm, D, stands inclined 12° outwards from the vertical, as shown by the dotted lines; and during the run-in of the carriage it turns inwards through an arc of 90°. A chain, F, attached to the nut, E, is coiled round a drum, H, inside the carriage, G, and as the carriage recedes from the quadrant arm during the run-in, the chain thus causes the drum to rotate, and thereby drives the spindles, T, through the intervention of the tin roller, I, geared to the drum, H. At the commencement of a set of cops, the nut, E, is at the bottom of the quadrant arm, D, nearest to the centre of motion, C, as shown dotted, and the number of revolutions then given to the drum, H, by the uncoiling of the chain during the run-in of the carriage is nearly as many as if the end of the chain at the nut were held stationary, and is sufficient to wind up on the bare spindles the length of threads spun in one stretch.

As the cops increase in diameter from their original size, A B, to their full diameter, C C, Fig. 26, the nut, E, is gradually advanced outwards along the quadrant arm, D, Fig. 29, so as to increase its arc of motion and thereby diminish the number of revolutions of the drum, H, and the speed of the spindles, T. This advance of the nut is obtained from the counter-faller, V, bearing against the underside of the threads, W, during the winding. The depression of the counter-faller towards the lower part of the cop, J, brings down the end of a governing lever upon a horizontal strap, which passes round a pulley on the headstock of the mule and round another on the centre shaft, C, of the quadrant; and on this shaft is a bevil pinion gearing into a second bevil pinion on the end of the double-threaded traversing screw in the arm, D; so that when the governing lever is depressed upon the strap by the counter-faller, the forward motion of the lever as the carriage runs in drags the strap along with it by friction and turns the shaft, C, forwards, sliding the nut, E, outwards towards the circumference of the quadrant. At the moment when the backing-off motion has ceased and the carriage begins to run in for winding up the stretch of thread spun, as shown in Fig. 24, the counter-faller wire, V, is at its highest working position, compensating for the additional length of thread that has been uncoiled from the top of the spindle in backing-off after the spinning of the stretch was completed. The nut, E, however, Fig. 29, is still at the same distance from the centre, C, of the quadrant as it was at the conclusion of winding the previous stretch; and therefore as the diameter of the cop is now greater by winding the new layer of thread outside the previous one, the winding of the new stretch commences rather too fast, and begins at once to take up the length of thread given out in the backing-off. The counter-faller, V, is thus depressed, and by means of the governing lever slides the nut, E, further out from the centre, C, until the speed of winding is sufficiently diminished to allow the counter-faller to rise again high enough for lifting the governing lever off the strap. It will be seen that, in consequence of the arm, D, describing the quadrant of a circle, the horizontal motion of the nut, E, in the winding of each stretch is greatest at the commencement of the winding and gradually diminishes as the carriage runs in; and the effect of this is that the speed of winding is gradually increased towards the end of each stretch. By this means the threads are wound uniformly upon the cops, with an equal degree of tightness throughout.

The whole mule is driven by a strap $3\frac{3}{4}$ inches broad, running over the fast pulley, F, Fig. 28, on the rim shaft, A, and travelling at about 1670 ft. per minute, or about 19 miles per hour. The driving power required is about 1 indicated horse power per 230 spindles, or $4\frac{1}{4}$ horse power for each mule containing 1000 spindles. The speed of the endless cord, X, passing round the rim wheel, Z, Fig. 22, is 2640 ft. per minute, or about 30 miles per hour. The carriage of the mule makes 3 to $3\frac{1}{2}$ double journeys out and home per minute, the length of stretch being 63 inches; but the velocity varies at different parts of the traverse, the carriage being taken in by a pair of scrolls in the centre of the machine, and drawn out by three spiral grooved pulleys keyed upon a shaft running the entire length of the mule, one pulley being in the middle of the shaft and one at each end. The length of the carriage being upwards of 100 ft., a parallel motion is required for keeping the carriage straight; and this is obtained by a horizontal traversing pulley at each end of the carriage, traversing along fixed cords and thereby made to revolve; and these two pulleys being also coupled together by a crossed cord are compelled to revolve at the same rate, and consequently cause each end of the carriage to travel at the same rate. There are three pairs of drawing rollers, P, Fig. 22, by which the rovings are drawn about 8 times before being delivered for spinning. The last pair of rollers delivers the rovings at a speed of 26 ft. per minute, until the carriage, G, has run out the 63 in. length of stretch, when the rollers are stopped, and hold the threads fast during the winding up as the carriage runs in again. The actual length of roving delivered by the last pair of rollers for each stretch of 63 in. is about 61 in.

The spindles make about 1260 revolutions in twisting each stretch of 63 in., thus putting about 20 twists per in. into the threads; and the total time occupied is about $12\frac{1}{2}$ sec. In winding up the threads, as the total length to be wound up remains constant, namely, 63 in., the number of revolutions is diminished in each successive stretch, according to the increasing size of the cop, from about 70 revolutions at the commencement to 23 revolutions at the full diameter of the cop, with cops of an average size winding an average number of yarn, such as No. 32, which is such a quality that 32 hanks of 840 yards each weigh together 1 lb.; the time of winding each stretch is about $3\frac{1}{2}$ sec. The velocity of the spindles is about 390 revolutions per minute in winding, and in twisting the speed ranges from 8000 down to 3000 for coarse work, a common average being about 6500 to 7000 revolutions per minute. In backing off the velocity of revolution is about 1-20th of that in twisting. The direction of rotation of the spindles is the same in twisting and in winding, and the thread is wound on in a right-handed spiral when spinning twist, and left-handed when spinning weft. Fig. 27, Plate 81, shows full size the conical form of the top of the spindles for the purpose of letting the thread slip off freely at each revolution in twisting; and the two lines, G and H, show show the extreme inclinations of the thread to the spindles during the twisting. The larger angle shown by the dotted line, G, when the spindles are nearest to the drawing rollers, is about 145°; and the smaller angle shown by the full line, H, is about 105°, when the spindles are at the outer extremity of the stretch. The spindles themselves are inclined inwards towards the drawing rollers at an angle of about 12° from the vertical, as shown in the drawing.

In a mule invented by Mr. John Robertson in 1834, and brought out with other improvements in 1839 by Mr. Smith, of Deanston, the chief feature was the use of a mangle wheel for performing the principal motions and changes, including a method of increasing the amount of twist put into the threads during the last few inches of each stretch. The mule of Mr. James Potter also possesses some features, which, although they have not been largely adopted, have much merit in them. The carriage is moved in and out by an arm travelling through half a revolution, so that the motion begins and ends slowly and is quickest at the middle of the stretch. The winding on is effected by an adjustable conical drum, the larger end of which is of the proper size for winding upon the bare spindles, and the smaller for the full cops; the drum is traversed longitudinally on its shaft by a screw of differential pitch, to the nut of which is attached the winding chain that coils on the drum; and the position of the chain on the drum is changed rapidly at the commencement of a set of cops, and more slowly as they fill up. This spiral cone drum was subsequently replaced by a contracting spiral pulley, which at full diameter drove the bare spindles, and gradually contracted as the cops approached completion.

The number of spindles in the self-acting mules has been gradually increased, until at the present time many mules contain 1000 spindles each. One pair of these mules requires the attendance of only one man and two boys, for cleaning the machines, setting in the rovings, attaching the broken threads, taking off the cops when full, and starting the machines, to work again. In spinning No. 32 yarn (in which the weight of 32 hanks, each containing 840 yards, is 1 lb.), the production of the pair of mules per week of 60 hours is 45,000 hanks, or 21,477 miles, per week, weighing 1406 lb. The floor space occupied by one of the mules containing 1000 spindles is about 116 feet by 10 feet, leaving about 4 feet for passages at the ends of the mules in the modern mills of 120 feet width. The cost of a modern cotton mill for spinning No. 32 yarn, including building, machinery, and accessories, steam-engine and shafting, with fire-proof floors in the scutching and carding rooms, and timber floors in the spinning rooms, averages 18s. per spindle; and one mill was built, during the cotton panic caused by the American war, for 15s. per spindle.

The progress made in cotton manufacture during the last century is strikingly shown by the following comparison between the following comparison between the years 1760 and 1860:

| | 1760. | 1860. |
|---|---|---|
| Total value of cotton yarn produced | 200,000l. | 85,000.000*l*.—425 times greater. |
| Weight of cotton imported . . | 3,870,000lb. | 1,083,000,000lb.—280 times greater. |
| Value of 1 lb. of No. 42 yarn. . . | 10s. 11d. | 11d. —12 times cheaser. |
| ,, ,, No. 100 ,, . . | 38s. | 2*s*. 6*d*. — 15 times cheaper. |

As an illustration of the present extent of the manufacture, it may be mentioned in conclusion that the number of spindles employed at the present time in the cotton manufacture of Great Britain exceeds 36 million; and taking them as spinning on the average No. 32 yarn, when each spindle produces per week $22\frac{1}{2}$ hanks of 840 yards each, there is a regular production from the whole, of 64 million miles of yarn per day of 10 hours when in full work or a length of thread equal to more than four times round the earth every minute.

# COTTON MACHINERY.

*(For Description, see Page 250.)*

ROBERTS'S SELF-ACTING MULE 1866

FIG 25 UNLOCKING OF FALLER AT END OF WINDING

FIG.24. LOCKING OF FALLER PREVIOUS TO WINDING

FALLER MOTION
FIG 23 PUTTING DOWN OF FALLER DURING BACKING—OFF.

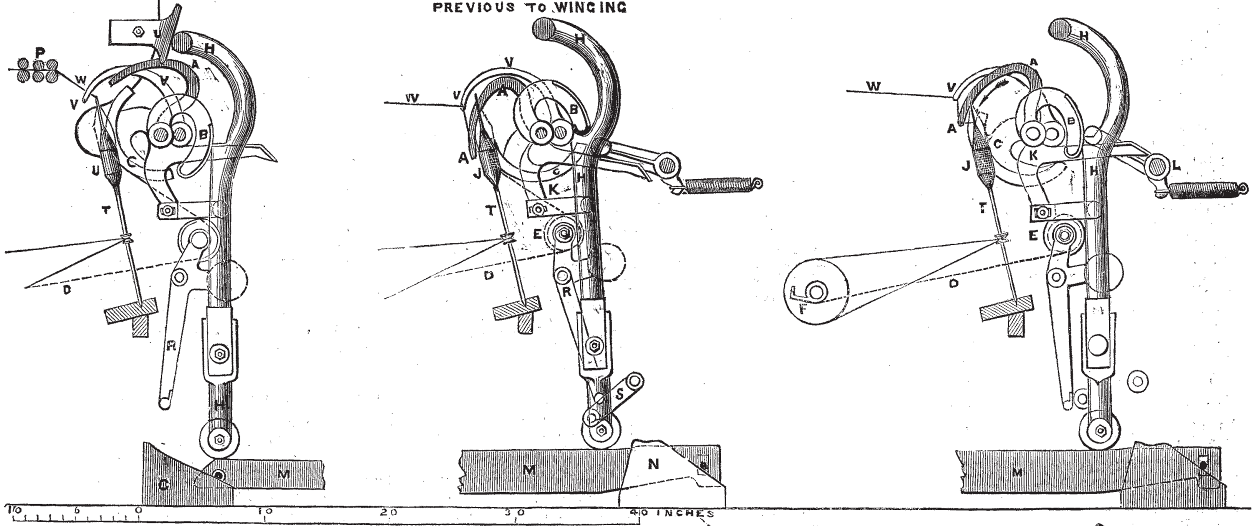


FIG.28. PLAN OF BACKING OFF MOTION.

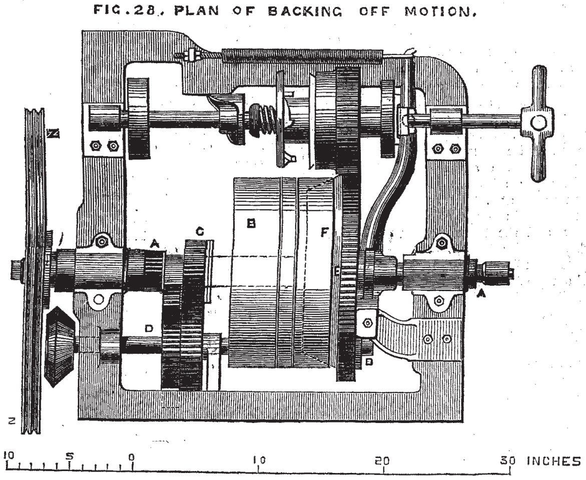


FIG.27 EXTREME INCLINATIONS OF THREAD TO SPINDLE IN SPINNING FULL SIZE.

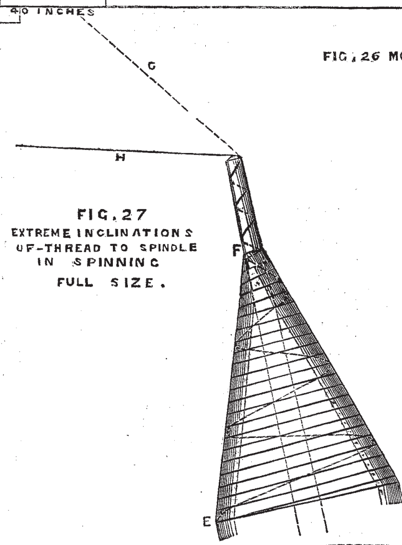


FIG. 26 MODE OF BUILDING UP COPS HALF FULL SIZE

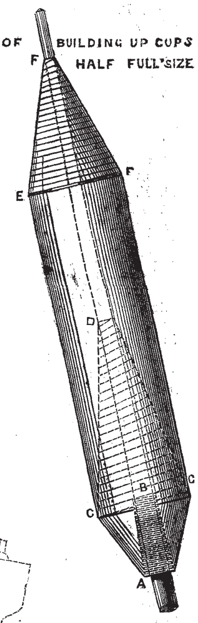


FIG 29 QUADRANT FOR REGULATING SPEED OF WINDING.
CARRIAGE RUNNING IN SPINDLES WINDING UP THREADS.)