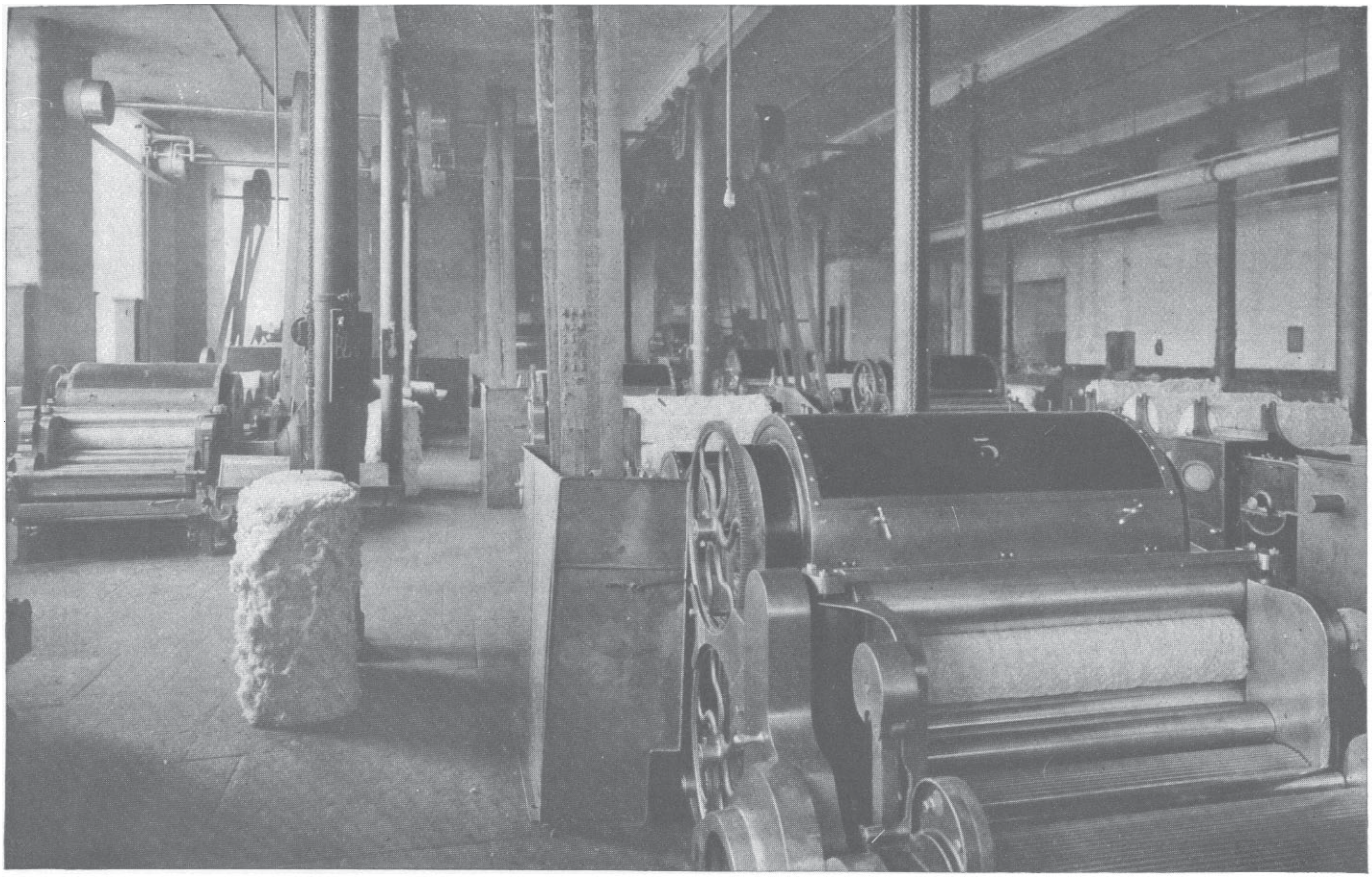

FIG. 10.—BLOWING ROOM.

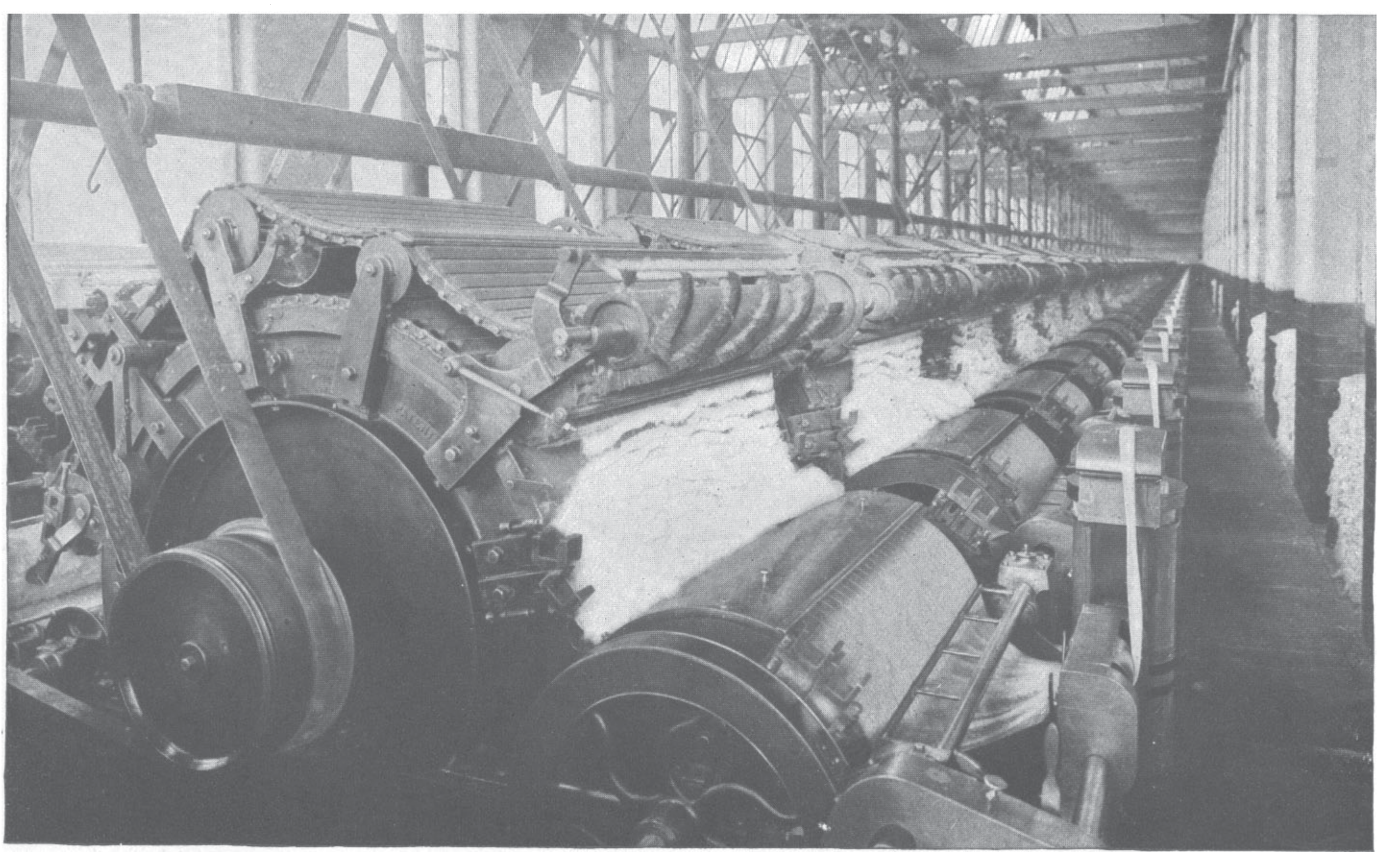

FIG. 11.—CARDING ROOM.

(From Photographs taken in a Manchester Fine Cotton-spinning Mill, by R. Banks.)

COTTON-SPINNING MACHINERY

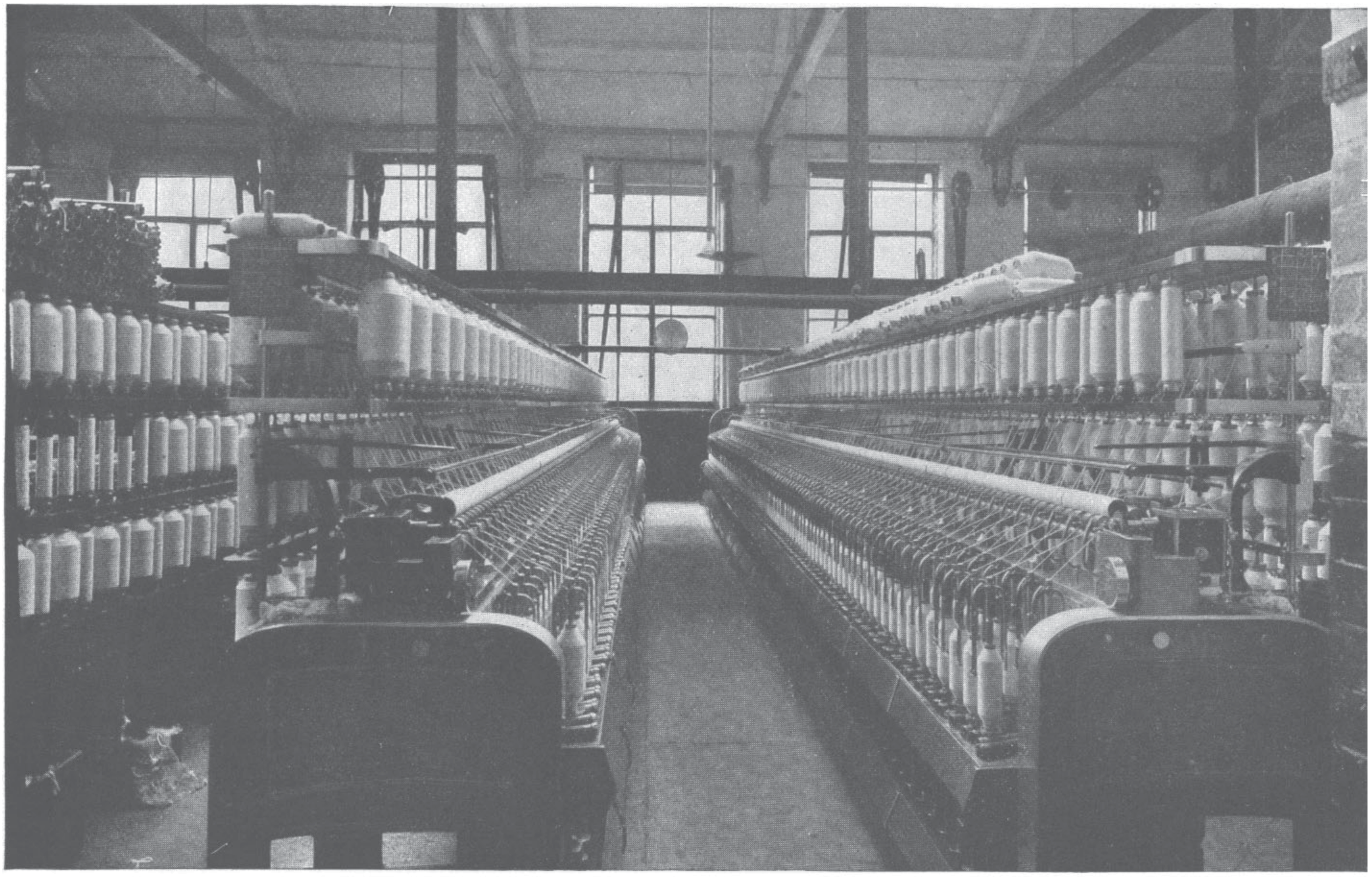

FIG. 12.—JACK-FRAME ROOM.

FIG. 13.—SPINNING-ROOM.

(From Photographs taken in a Manchester Fine Cotton-spinning Mill, by R. Banks.)

COTTON-SPINNING MACHINERY. The earliest inventors of spinning machinery (see SPINNING) directed their energies chiefly to the improvement of the final stage of the operation, but no sooner were these machines put to practical use than it became apparent that success depended upon mechanically conducting the operations preliminary to spinning. Later inventors were, therefore, called upon not only to improve the inventions of their predecessors, but to devise machinery for preparing the fibres to be spun. Arkwright quickly perceived the importance of this aspect of the problem, and he devoted even more energy to it than

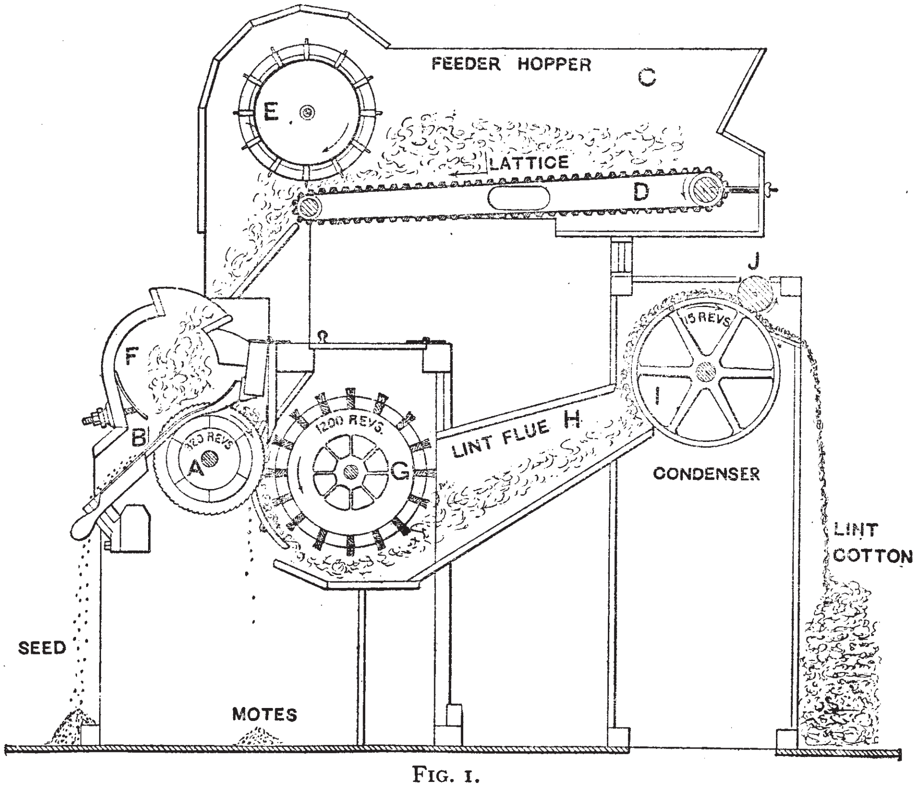

FIG. 1.

to the invention with which his name is more intimately associated. But, given a complete series of machines for preparing and spinning, the cotton industry (see COTTON MANUFACTURE) must have remained unprogressive without the co-operation of cotton growers, for by the then existing methods of separating cotton lint from seed it would have been impossible to provide an adequate supply of raw material. By inventing the saw gin, Eli Whitney, an American, in the year 1792, did for cotton planters what Paul,

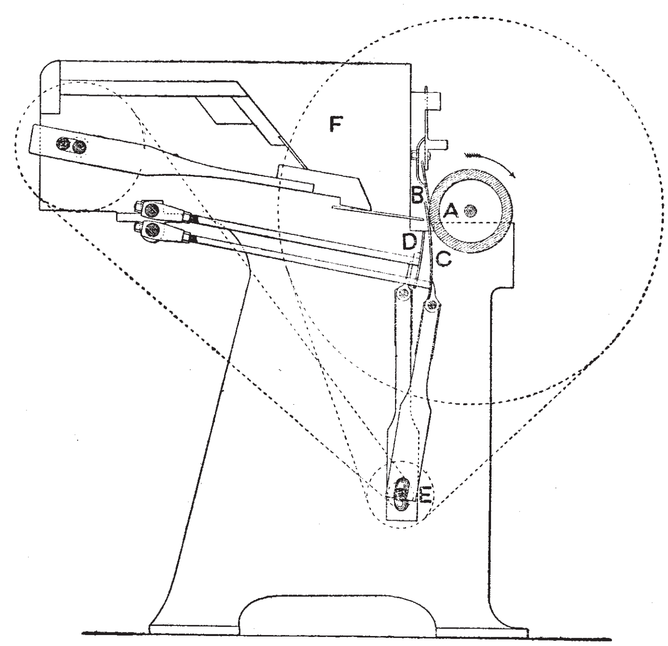

FIG. 2.

Arkwright, Crompton, Cartwright, Watt and others did for textile manufacturers, for he provided them with the means for increasing their output almost indefinitely.

Cotton-ginning is the process by which cotton seeds are separated from the adhering fibres. The most primitive machine employed in India and China for this purpose is the churka, which consists of two wooden rollers fixed in a frame and revolving in contact. Seed cotton is fed into these rollers and the fibres pass forward but the seeds remain behind. It is a device which does not injure the fibres, but no improvement has been found by which the churka can be converted into a sufficiently productive machine for modern requirements. In a modified form Whitney's saw gin is still used to clean a large portion of the annual crop of short and medium stapled cottons. It consists of from 60 to 70 saws (A, fig. 1), which are mounted upon a shaft and revolve between the interstices of an iron grid (B); against this grid the seed cotton is held whilst the fibres are drawn through, the seeds being left behind. The operation is as follows:—seed cotton is fed into the hopper (C), and conveyed by a lattice (D) to a spiked roller (E), which regulates the supply to the hopper (F). Whilst in (F) the cotton is engaged by the teeth of the saws (A), and drawn through the grid (B), but the bars are too close to permit the seeds to pass. A brush (G) strips the cotton lint from the saws, after which it is drawn through a flue (H) to the surface of a perforated roller (I) by pneumatic action; it then passes between (I) and (J) out of the machine. The Macarthy gin is the only other type in extensive use; it is employed to clean both long and short stapled cottons. In this gin the fibres are drawn by a leather-covered roller (A, fig. 2) over the edge of a stationary blade (B) called a doctor, which is fixed tangential to the roller. Two cranks (E) move two other blades (C, D) up and down immediately behind, and parallel to, the fixed blade (B). The cotton is thrown into the hopper (F) and the fibres are drawn by the roller (A) until the seeds are against the edge of the doctor (B), when the beaters (C, D) strike them off, but permit the fibres to go forward with the roller. Attempts continue to be made so to improve both machines, that production may be increased,

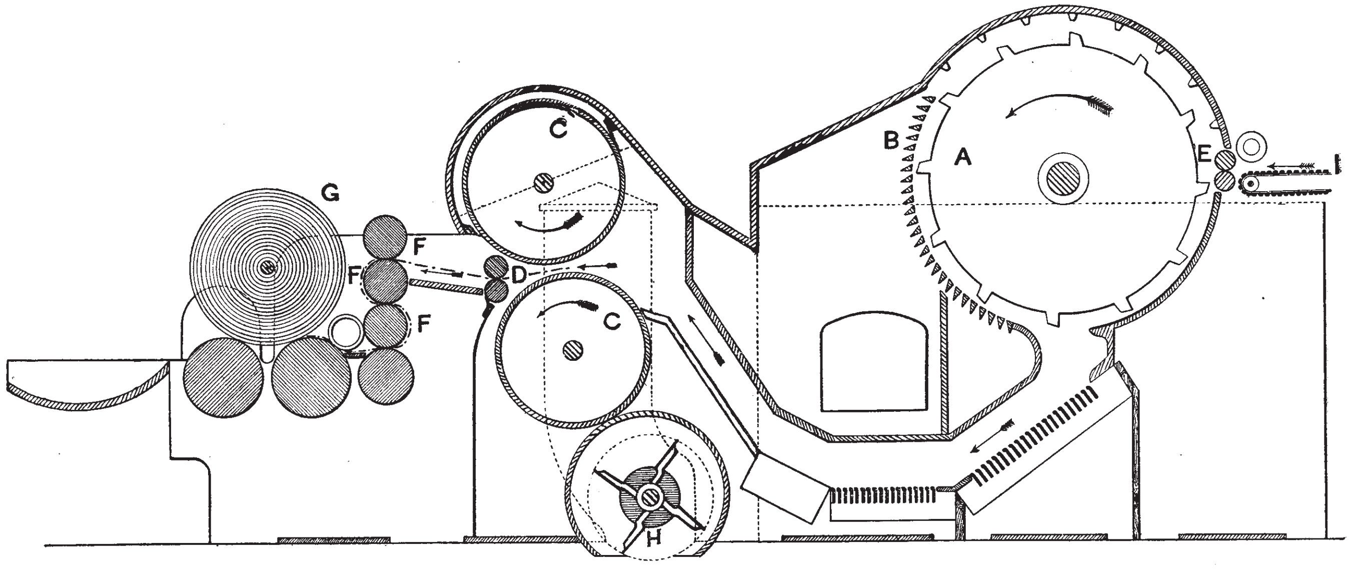

Fig. 3.

and labour charges, and the risks of injuring the fibres, reduced.

Baling.—As cotton leaves the gin, it is in some cases rolled, under compression, into cylindrical bales; but it is usually packed into rectangular bales, that vary in weight from 160 ℔ to 750 ℔, by steam or hydraulic presses. After pressing, the cotton is covered with coarse jute bagging, and the whole secured by iron bands. In this form it arrives at the spinning mills.

In the mill treatment of cotton it soon became an established practice to divide the work into the following operations, namely (1) Mixing the fibres into a homogeneous mass; (2) removing impurities; (3) combing out entanglements in, and ranging the fibres in parallel lines; (4) simultaneous combination and attenuation of groups of parallel fibres; (5) completing the combination and attenuation, and twisting the fibres into a thread; (6) compounding, finishing and making-up of threads. These remain the essential conditions of cotton-spinning. The principal machines used to carry out the foregoing stages are: The bale breaker, opener and scutcher; the card and comber; the drawing, slubbing, intermediate and roving frames; ring and mule spinning; winding, doubling; clearing and gassing the reel, and bundling press, together with several auxiliary machines. All the operations included in this list are not necessarily employed in the production of all kinds of yarn; low counts require fewer, and high counts more processes.

A *bale breaker* is used to disentangle fibres which have been, by hydraulic or steam presses, converted into hard masses that resist manual efforts to disentangle them. It may consist of three pairs of spiked and one pair of fluted rollers. If so, the matted cotton is fed into the first pair, seized by the second pair, which have a higher surface velocity, and pulled, while the third pair reduce the whole to a more or less fluffy mass, and the fluted rollers deliver it upon a travelling lattice by which it is conveyed to, and deposited upon, the floor of the mixing room. Instead of rollers, a *hopper breaker* may be used. In this machine the cotton is carried by a horizontal lattice into contact with a sloping spiked one, whose spikes tear away small tufts and deposit them upon a second lattice for removal to the mixing room. A stack of pulled cotton is formed by superposing thin layers from different bales, and when completed the cotton is drawn from top to bottom of the stack. By this means a thorough mixing of fibres is effected.

The Opener.—Mixed cotton may be thrown upon a lattice and conveyed to a spiked roller to be pulled, beaten, discharged into a trunk, and drawn by pneumatic force to the opener. Or it may be spread (fig. 3) upon a lattice (I), and carried between feed-rollers (E)

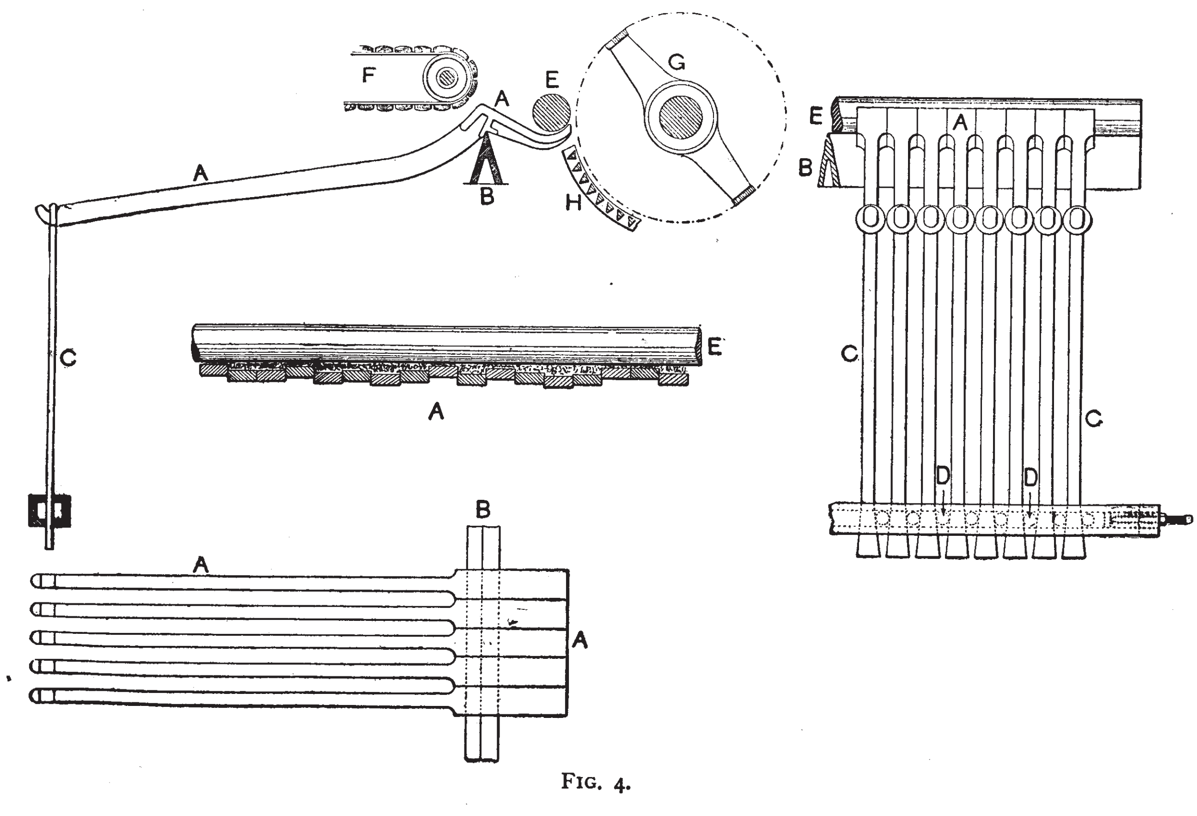

Fig. 4.

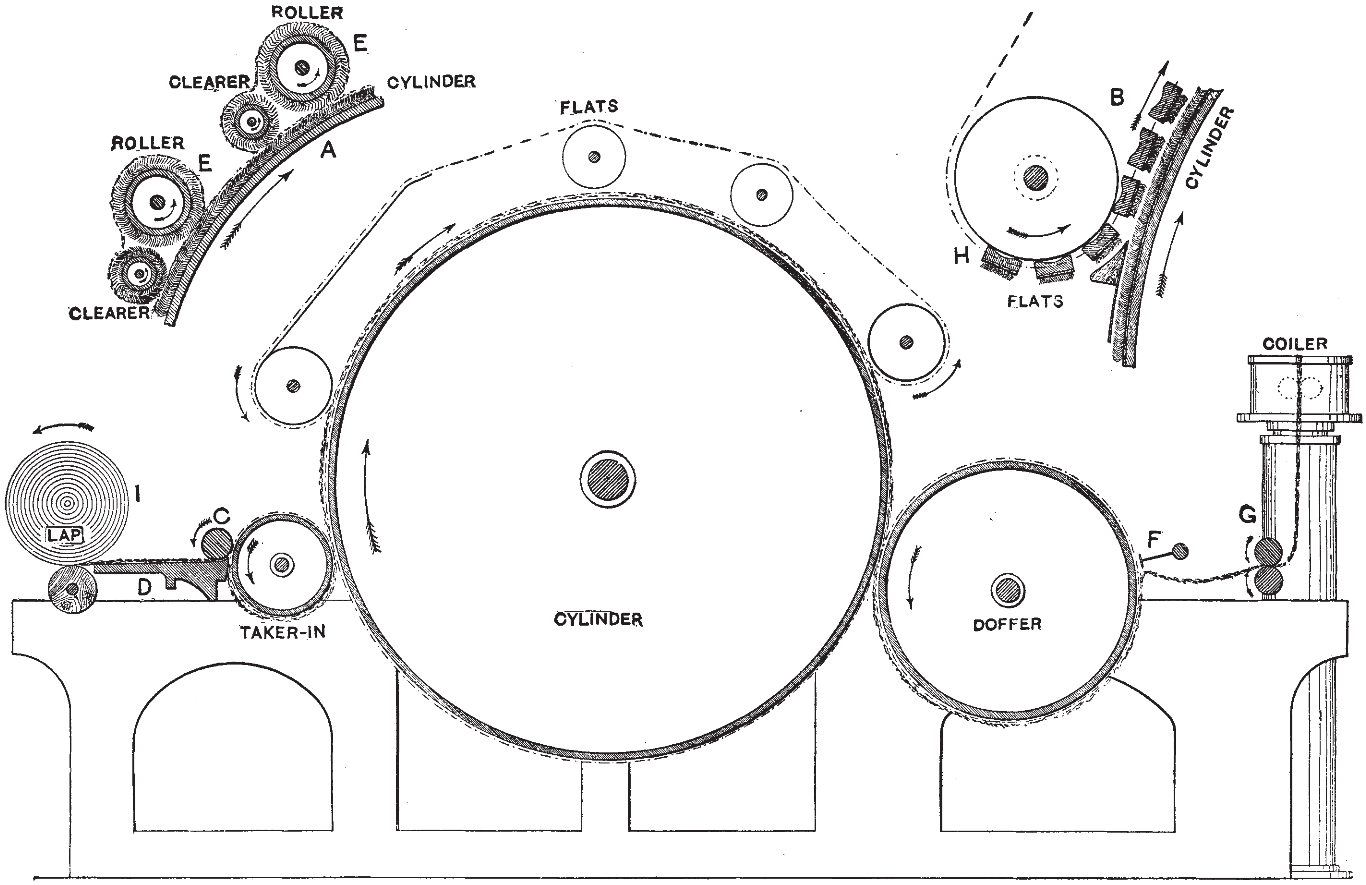

Fig. 5.

to be subjected to the action of a beater (A) whose teeth first seize tufts of cotton and then fling them upon a grid (B), to be subsequently seized by other teeth and again flung off until dirt and other impurities pass between the grating. The beater may be cylindrical (as at A) or in the form of a truncated cone; in either event, from four to twelve rows of teeth project from its surface. It is from 18 in. to upwards of 36 in. in diameter, approximately 40 in. wide, and the largest cylindrical beaters make from 300 to 700 revolutions; whilst conical beaters make about 1000, and small ones make from 1000 to 1500 revolutions per minute. The opened cotton is carried, in the direction indicated by the arrows, upon a strong blast of air which is generated by a fan (H), and this deposits it in patches upon the surfaces of two perforated zinc or wire cylinders (C), but dust and foreign particles pass through the interstices. As these cylinders revolve towards each other the cotton passes between them in the form of a sheet to a pair of feed-rollers (D), which may again deliver it to a beater with two or three blades; if so, from this beater the cotton is next borne on an air current to, and between, a second pair of perforated cylinders. In either event, the final cages (C, C) deliver the cotton to feed-rollers (D) and they pass it to calender-rollers (F), by which it is compressed into a sheet, and finally coiled into a lap (G). Various kinds of openers have been patented, all of which differ in some important respects; for example, a hopper feed may be substituted for the trunk or the lattice feed, in which event the cotton from the mixing room is conveyed mechanically upon lattices, and deposited in a hopper affixed to an opener. In this hopper a sloping spiked lattice elevates the cotton to an evening roller, whose office is to sweep back the surplus supply from the spikes, but allow the requisite quantity to pass forward to the beater. A regular supply of cotton to an opener is of great importance, and in order to insure it a table is often formed by substituting for the lower roller (E) a series of levers (A, fig. 4) all mounted upon a fulcrum (B), and having their free arms weighted by wedge-shaped pendents (C), that are separated by bowls (D). A fluted feed-roller (E) is fixed above this table and the cotton is led over the lever but beneath the roller. If the cotton is unequally distributed, thick places will press down the levers and thin ones will permit them to rise (as at A′, E′). The rise of one pendent may be cancelled by the fall of another, but any balance of their movements is transmitted to a belt fork which governs a belt running upon a pair of inverted cones, and by this means the belt is traversed to and fro to drive the feed-roller (E) at a superior speed when the supply of cotton is insufficient, and at an inferior speed when the supply is excessive.

The Scutcher.—In many respects a scutcher resembles an opener; its function is to continue the cleaning and form laps of uniform weight and density for the carding engine. Occasionally the scutcher is the first cleaning machine, in which event cotton, in a loose fleece, is spread evenly upon a lattice. But in order to carry the combination of fibres one stage further, three or four opener laps are generally placed upon the feeder, so that, as the laps unroll, three or four sheets of cotton will be superposed, and in this form are passed by the lattice (F, fig. 4) and the feed-roller (E) to either one or two beaters, which are furnished with two or three blades. The beater (G) flings the cotton against the bars of a grid (H) to loosen, and cause the dirt to pass between the bars, after which the cotton is carried forward upon an air current, in the same manner as in an opener, and formed into a lap. In case two scutchers are required, the laps from the first are fed into the second, where they are similarly treated; in both machines the lever and pendent mechanism furnishes the means by which uniformity is attained. A beater may consist of a straight, smooth blade (as at G), or of a blade provided with stout teeth; in the latter event the operation resembles combing rather than beating. Two-bladed beaters revolve from 1200 to 1500 times per minute; those with three blades from 900 to 1000 times per minute.

Carding Engine.—The functions of a card (see Carding) are: to place the fibres parallel; to remove remaining impurities and immature fibres; and to form mature fibres into a porous band, called a sliver. A carding engine consists of three cylinders which are covered with cards; the first, or taker-in (see fig. 5), is the smallest; the second and largest is the main cylinder; and the third is the doffer. If the main cylinder is surmounted with a series of small ones (as at A), the engine is called a roller and clearer card. If a series of fixed strips of card are placed above the main cylinder, the engine is known as a stationary flat card. But if the strips move forward (as at B), it is a revolving flat card. In a roller and clearer card the small cylinders (E) are also covered with cards, but their teeth are bent to oppose those on the main cylinder, and they revolve with a different velocity. The taker-in is covered with saw teeth cut in a strip of steel which is fixed in the surface of that cylinder; it receives the cotton (I) from a feed-roller (C) that turns above a smooth iron table (D) called the feed plate, and strikes out the heaviest particles of remaining dirt. In passing through the fringe of lap, the teeth comb the attached fibres but deliver the loose ones to the main cylinder. The latter carries them into contact with the teeth on the rollers (E), by whose lower surface velocity combing is again effected. Short fibres become fixed amongst the teeth of (A) and (E), but those lying crosswise are transferred from (A) to (E) and from (E) to the clearer, which again presents them to the cylinder.

When long fibres are turned to point in the direction of rotation they advance upon the cylinder A to the doffer teeth, where the scattered fibres on the surface of A are collected into a light fleece. In this condition they are stripped by a vibrating comb (F), drawn together by a funnel, formed into a sliver, and deposited in a can (G). This machine is now chiefly used to card waste and low-class cotton. If such a card is made with two main cylinders, a connecting cylinder called a tummer collects the fibres from the first and passes them on to a second main cylinder, where they are again treated as already described. In a stationary flat card the teeth in the flats are bent to oppose those on the main cylinder, and by this means the fibres are combed and straightened. In a revolving flat card the flats (H) are formed into an endless chain, and they travel slowly in the same direction as the cylinder. In other respects both flat cards are similar to a roller and clearer card. Formerly double carding, namely, two passages of the fibres through separate cards, or one passage through a double card, was general, but single carding is now employed for most purposes.

Combing.—For counts from 60^s upward, and for exceptionally good yarn of lower counts, from 14 to 20 cans from the carding engine are taken to a *sliver lap machine* where the slivers are drawn alongside each other, passed between three pairs of drawing rollers and two pairs of calender rollers, and formed into laps that vary in width from $7\frac{1}{2}$ in. to 12 in. This machine is provided with mechanical devices for stopping it on the failure of a sliver, and on the completion of a predetermined length of lap. When the sliver lap machine furnishes laps for the comber, the slivers are previously put through one head of drawing, namely, between four lines of drawing rollers, to straighten out the fibres. The more general practice is to pass sliver laps to a *ribbon lap machine*, at the back of which six laps are placed, end facing end, in one long line and simultaneously unrolled to feed each web between four pairs of drawing rollers. From the rollers the cotton passes in separate films over curved plates to a smooth table where one is superposed upon another, and in the combined state it is led between two pairs of calender rollers and formed into a lap from $7\frac{1}{2}$ to $10\frac{1}{2}$ in. wide. In the cotton industry the *Heilmann comber*, or some modification of that machine, is used to straighten thoroughly the fibres of carded cotton, to cast out all below a certain length, and leave only those that are perfectly clean and approximate to uniformity in length. For fine yarns of medium quality only part of the slivers required to form a thread are combed. But for fine yarns of good quality all slivers are once combed, and those for superfine yarns are twice, or "double combed." This machine is made with six or eight heads, each of which is supplied with a ribbon lap. One end of every lap is fed by a pair of rollers between the open jaws of a nipper which immediately closes upon the sheet of cotton, but a fringe is left protruding into the path of a cylinder, on whose periphery either one set of 17, or two sets of 13, graduated needle combs, and one, or two, fluted segments are secured. The first comb to reach the cotton may have as few as 16, and the last 90 teeth per inch. After the combs have passed successively through the overhanging fringe of fibres, the nipper opens and a fresh length of about $\frac{3}{16}$ to $\frac{4}{10}$ of an inch is fed in. Meanwhile, a fluted segment on the cylinder has moved up to support the fringe; a top comb, which was inoperative when the cylinder combs were acting, has descended into the fringe, and three rollers first return a portion of the material already combed so that it may overlap that last treated. The rollers then reverse the direction of their rotation; one of them and the segment engage the fringe, and draw the tail ends of all free fibres through the teeth of the top comb. The product of all the heads is next united, condensed, formed into a continuous sliver, and deposited in a can. One cycle of movements, therefore, only combs from $\frac{3}{16}$ to $\frac{4}{10}$ of an inch of each fibre; the top comb deals with the tail ends, and the major portion of the work is done by the cylinder combs. The foregoing operations are repeated at the rate of from 85 to 90 times per minute, during which from 15% to upwards of 25% of carded material is removed; but this is capable of being spun into coarse yarns. A comber invented by John W. Nasmith is a modification of the foregoing. In his machine the cylinder combs act upon the forward ends of the fibres whilst under the control of the nipper, after which two pairs of rollers return a sufficient portion of the previously combed film to overlap, and to enable the front rollers to engage the fringe. The rollers then draw a part of the fringe through the teeth of the top comb, which, as a sequence, treats all but the forward ends of the fibres. Since one passage through the cylinder and top combs completes the operation for one set of fibres, this machine gives a higher production; it also gives a wider range of adaptability, and a lower percentage of waste than the Heilmann machine.

The Drawing Frame.—For fine counts the slivers from the comber, and for low or medium counts those from the card, are passed to the drawing frame, because in both conditions the material is irregularly distributed throughout the several slivers, and it is the function of the drawing frame to eliminate all such irregularities by drawing several slivers down to the dimensions of one, for here the processes of combination and attenuation are carried further than in any other machine. A drawing frame consists of three or four heads, each of four pairs of drawing rollers (A, B, fig. 6). The lower rollers (B) are fluted longitudinally and the upper ones (A) are covered with leather, and weighted as at (H) to give the two a proper hold of the cotton. Each head contains several deliveries. Six or eight slivers (C) are put up to each delivery and drawn down into one by causing succeeding lines of rollers (A, B) to move at an accelerated speed; the front one revolving about six or eight times faster than the back one. On leaving the front roller the sliver is conducted to a trumpet-shaped tube (D), thence between a pair of calender rollers (E), and, finally, through a diagonal passage in a plate (F);

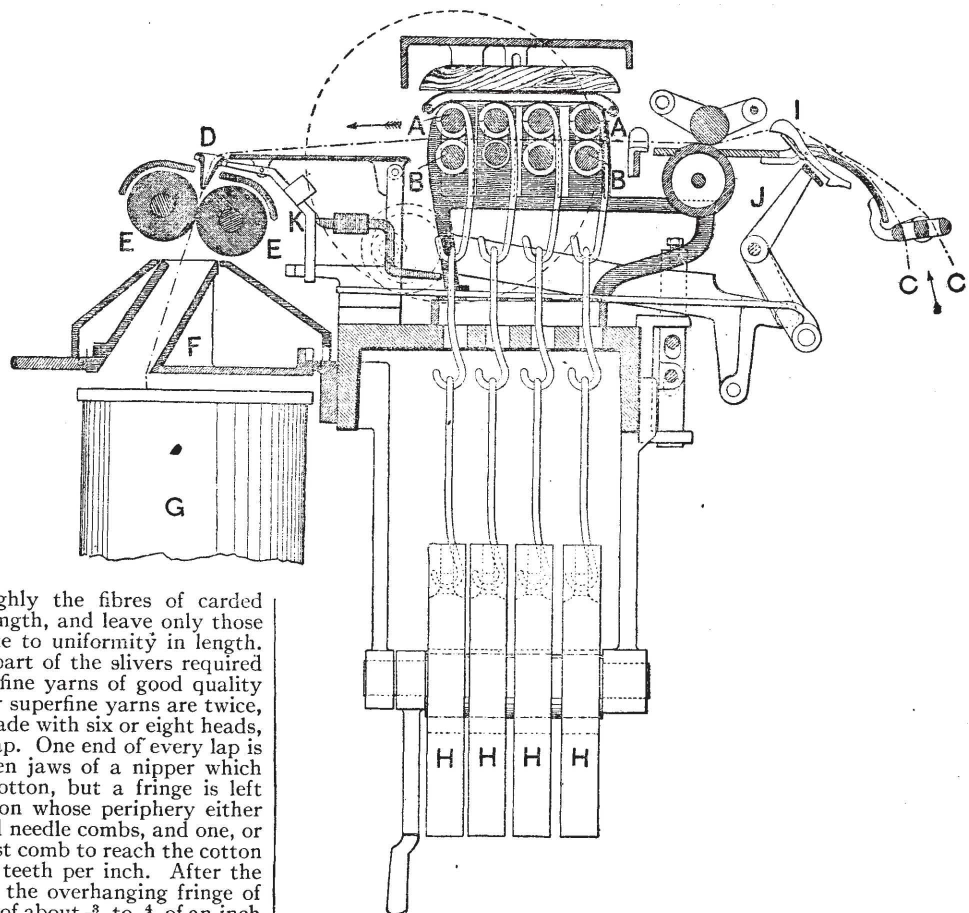

Fig. 6.

the latter coils the sliver into a rotating can (G). Back and front devices are provided to arrest motion in this machine when a sliver fails. At the back, each sliver passes over and depresses a separate spoon-shaped lever (I), thereby lifting the hooked lower end of (I) high enough to allow an arm (J) to vibrate. On the failure of a sliver the hook of (I) engages with (J) and dislocates the driving gear. In front, the trumpet-shaped tube (D) is mounted on a lever (K), and so long as a sliver presses down the mouth of (D), the machine continues in motion, but when a sliver fails, the lever (K) causes the driving gear to stop the machine. Six or eight cans containing once drawn slivers are put up to the second head and similarly drawn, and finally, a similar number of twice drawn slivers are fed into the third head and again drawn, giving in all $6\times6\times6=216$ doublings; or $8\times8\times8=512$ doublings. Occasionally four heads of drawings are used and eight slivers drawn into one, which gives $8\times8\times8\times8=4096$ doublings; hence, irregularities in an original sliver have been minimized by successive combination and attenuation.

Flyer Frames.—Cotton in cans, from the final head of drawing, is transferred to the *slubbing frame*, by which it is attenuated, slightly twisted, and wound upon spools. Each sliver is drawn out by means of three pairs of rollers, and as it emerges from the front pair, a flyer (A, fig. 7), which revolves uniformly upon a spindle (B), carries the sliver (C) round with it to twist the fibres axially. This flyer coils the twisted material upon a wooden tube (D) in close-wound spirals and in successive layers. The tube is loosely mounted upon, but driven independently of, the spindle, in order that as the tube increases in diameter the number of revolutions it makes may be reduced to suit the constant delivery of the roving. This is effected by a differential motion which usually consists of a large wheel, within which two other wheels are made to work; the interior wheels have a regular motion, but the large wheel is driven from a pair of cone drums at a decreasing speed.

The intermediate frame comes between the slubbing and roving frames and is of similar construction to the slubber, but has a larger number of spindles and smaller tubes. Instead of having cans put at the back, the slubbing tubes are mounted vertically in a creel, passed in pairs through the rollers, and drawn down to a smaller diameter than a single slubbing. In this machine, therefore, the fourfold processes of combination, attenuation, twisting and winding are effected consecutively and continuously.

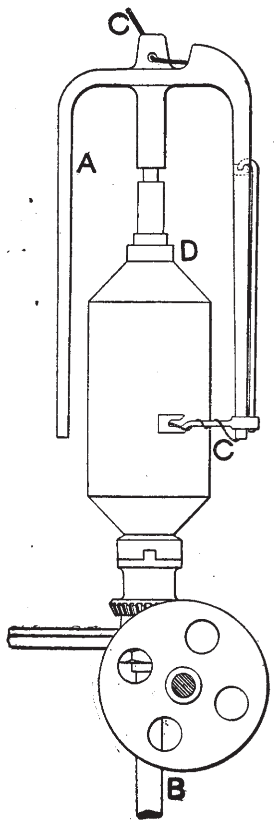

FIG. 7.

The roving frame is similar in principle to the slubber and intermediate machines, but it contains a greater number of spindles, and the tubes are smaller than either. It receives the rovings from the intermediate frame, draws two into one, twists them and winds them upon tubes. This machine is usually the last employed to prepare cotton for spinning, but for spinning fine yarns from the best Egyptian and Sea Islands cottons, a second roving, or *Jack frame* may be required, in which event pairs of rovings from the first machine are similarly treated in the second in order to render the final product sufficiently fine for spinning yarns of the requisite counts.

Spinning (see SPINNING).—Improvements upon the Saxony wheel caused continuous spinning to become a mechanical art at an earlier date than intermittent spinning. Arkwright's water-twist frame was gradually changed to the *throstle*, which was a duplex machine furnished with one set of drawing rollers, and one set of spindles and flyers at each side of the frame-work. All the bosses of one line of rollers were connected so that one driving gear would serve for the whole length, and all the spindles were driven by bands from a central cylinder. The roving spools were placed vertically in a creel between the two sets of rollers, and the rovings reduced to the requisite fineness by the latter; after which each was passed through a coiled eye at the lower end of a flyer leg, and attached to a double-flanged spool which was loosely mounted upon a spindle. At each revolution of a flyer a twist was put into the attenuated roving, and the flyer wrapped as much thread upon a spool as the rollers delivered. The spools rested upon a piece of woollen cloth stretched over a rail, and this rail rose and fell through a space equal to the length of the spool barrel. On account of a thread having to pull a spool round, it was not possible to spin finer counts than 60^s, and since each flyer was mounted upon the top of an unsupported spindle, vibration increased with speed. In order to avoid such vibration Mr Danforth, in or about 1829, placed an inverted cup upon the top of a stationary spindle, and upon the spindle a freely fitting sleeve and wharve; the former to receive a spool, the latter to rotate both. By a traverse motion all the spools were simultaneously raised or depressed, so as to have their barrels, when at the highest point, entirely within the cup, and when at the lowest entirely below it. A thread passed from the drawing rollers, outside the cup, to a spool. As a spool rotated its thread was uniformly twisted, the lower edge of the cup built the yarn equally on every part of the spool barrel, and the requisite drag resulted from friction set up by the thread rubbing against the surface of the cup. The throstle has almost disappeared from the cotton industry, and Danforth's cap frame entirely so, but the latter is still used to spin worsted.

Ring spinning is practically the only system of continuous spinning used in the cotton industry; it was first patented in the United States of America by J. Thorpe, in 1828, and in that country was extensively used long before it became established in England. Its chief feature consists in the substitution for the flyer, or the cap, of a smooth annular ring (A, fig. 8) formed with a flange at the upper edge, over which a light C-shaped piece of wire (B), called a traveller, is sprung. The rings are secured in a rail (C) that rises quickly and falls slowly, but at each succeeding ascent and descent it attains a higher point than that previously reached. A spindle (D) is supported by, and turns in a bolster secured to a fixed rail (E). If the bolster only provides a bearing for the centre of the spindle, and so leaves the foot free to find its own position of steadiness, it is known as a self-balancing or gravity spindle. A recess in the bolster is filled with oil to automatically lubricate the bearing. A spindle is placed in the centre of each ring; it has a sleeve fitted upon it which carries a wharve (F) that covers the upper part of the bolster, and a band from a pair of drums is drawn round the wharve to drive the spindle. So perfect is the construction of these spindles that they can be run without appreciable vibration at speeds far beyond the ability of operatives to attend them; although a speed of 11,000 revolutions per minute is a practicable one. After passing the drawing rollers (G), the roving (H) is twisted, hooked into the traveller (B), and made fast to a spool (I) placed upon the spindle. As spinning proceeds the traveller is pulled round the ring by the thread; it thus puts a drag upon, and holds the thread at the winding point. In all continuous spinning the number of twists inserted into a given length of thread is governed by the surface speed of the front roller, relatively to the revolutions of the flyer, or to the speed of the winding surface.

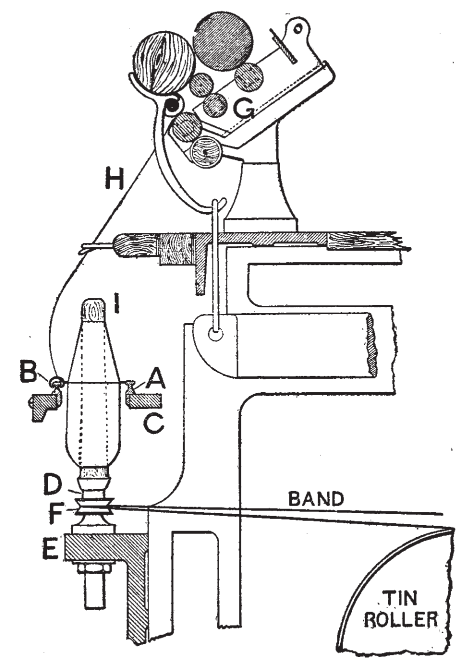

FIG. 8.

Intermittent Spinning.—The essential difference between continuous and intermittent spinning is that the former draws and twists consecutively, whilst the latter draws and twists simultaneously. In the *mule*, a creel (A, fig. 9), fixed at the back of the machine, is designed to hold the rovings (B) in three or four tiers, from whence they pass between three lines of drawing rollers (C) and two faller wires (D). They are next led to spindles (E) mounted in a carriage (F) whose wheels run upon rails (G) called slips. As the rollers (C) feed the partially attenuated rovings the carriage recedes from the rollers a little faster than the rovings are delivered, thus completing the attenuation. Meanwhile, the spindles are revolved rapidly by bands passing from a tinned cylinder (H) and the threads are twisted. This twist goes first to the thin places where least resistance is offered to it, leaving thick places almost untwisted; the pull of the carriage, therefore, causes the fibres to slip most readily where there are fewest twists, and gives to a thread an approximation to uniformity in diameter. For fine yarns the rollers cease to rotate slightly before the carriage has attained the end of its outward run, or stretch, and at such times all attenuation is due to the pull of the spindles upon the threads. On the termination of a stretch the carriage stops, the twisting is completed, the spindles reverse the direction of their rotation to back off, or remove the yarn which is coiled round the spindles above the winding point, and whilst one faller wire (D), operating on all the threads at once, descends to the winding position of each spindle, the other rises to take up the yarn delivered by the spindles. This completed, the carriage returns to the roller beam, and in doing so the spindles revolve in their normal direction to wind the stretch of 48 to 66 in. of yarn spun in the outward journey. All the foregoing movements are regulated to succeed each other in their proper order, the termination of one operation being the initiation of the next.

Crompton's original machine was controlled manually throughout, but later he devised means for moving the carriage out mechanically, for stopping the rollers at the proper time, and for locking the carriage whilst the spindles added the final twist to the threads. After which all parts became stationary and the manual operations commenced. These consisted in backing off, operating the faller wire, rotating the spindles and pushing the carriage home. In the year 1785 the first steam-engine was employed for cotton spinning, and in 1792 William Kelly placed the headstock of a mule, in which the chief mechanism is situated, in the middle of the carriage, instead of at one end. By this device one machine was doubled in length, and shortly afterwards two mules, each of 300 to 400 spindles, were allotted to one spinner and his assistants. Kelly also attempted to control all parts of the machine mechanically, but in

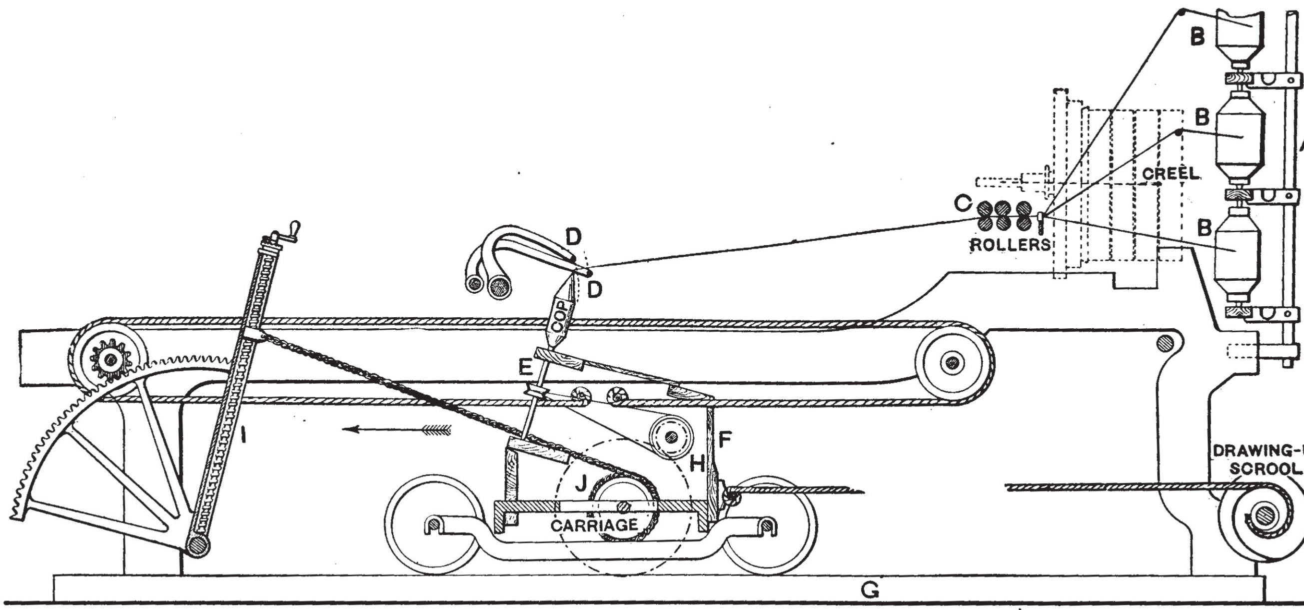

FIG. 9.

this he failed, as did Eaton, Smith and many others, although each contributed something towards the solution of the problems involved in automatic spinning. Eventually the hand mule became a machine in which most of the work was done automatically; the spinner being chiefly required to regulate the velocity of the backing off, and the inward run of the carriage, and to actuate the fallers. As a result of these alterations the machine was made almost double the length of Kelly's. In this state many mules continued to be used until the last decade of the 19th century, and a few are still in use. Between the years 1824 and 1830 Richard Roberts invented mechanism that rendered all parts of the mule self-acting, the chief parts of which are shown at (I,J), and they regulate the rotation of the spindles during the inward run of the carriage. At first his machine was only used to spin coarse and low-medium counts, but it is now employed to spin all counts of yarn. Although numerous changes have since been made in the self-acting mule, the machine still bears indelible marks of the genius of Roberts.

For many purposes the threads as spun by the ring frame or the mule are ready for the manufacturer; but where extra strength or smoothness is required, as in threads for sewing, crocheting, hosiery, lace and carpets; also where multicoloured effects are needed, as in Grandrelle, or some special form of irregularity, as in corkscrewed, and knopped yarns, two or more single threads are compounded and twisted together. This operation is known as doubling. In order to prepare threads for doubling it may be necessary to wind side by side upon a flanged bobbin, or upon a straight or a tapering spool, from two to six threads before twisting them into one.

Winding machines for this purpose are of various kinds. There are those in which the threads are laid evenly between the flanges of a bobbin, and those that coil the threads upon a straight or a tapering tube to form "cheeses." In the latter the tubes may be laid upon diagonally split drums and rotated by frictional contact. By placing each group of threads to be wound in the slit of a rotating drum, it is drawn quickly to and fro and coiled upon a spool. If solid instead of split drums be used, the guides for all the threads on one side of a machine are attached to a bar, which is traversed by a cam placed at one end of the frame. Or independent mechanism may be provided throughout for treating each group of threads to be wound. The bobbins or tubes may be filled from cops, ring spools or hanks, but a stop motion is required for each thread, which will come into operation immediately a fracture occurs.

Doublers.—In action doublers are continuous and intermittent. The former resemble throstle and ring spinning machines, but since they do not attenuate the material, only one line of rollers is provided. The folded material is placed in a creel and led through the rollers to the spindles to be twisted in a wet or dry condition. If wet, the moisture flattens down most of the protruding ends of the fibres and produces a comparatively smooth thread; if dry, the doubled yarn retains some of its furry character. There are two types of continuous doublers, which are known respectively as English and Scotch. By the English system of dry doubling the yarn from the creel may be treated, on its way to the spindle, in various ways to obtain the desired tension. It may be led under a rod, over a guide, round and between the rollers, and round a glass peg. For wet doubling, a trough containing water is placed behind the rollers, and the yarn passes beneath a glass rod in the water, thence over a guide, beneath, between and over the rollers to the spindles. By the Scotch system the trough is placed below the rollers, and the bottom roller is partly immersed in water. It is claimed that this system wets the fibres more thoroughly than the English one. For the purpose of twisting the strands together the spindles may be provided either with flyers, as in throstle spinning, or with rings and travellers, as in ring spinning. The twist is generally in the opposite direction to that in the single threads. When more than three strands are required in a compound thread it is customary to pass the material more than once through the doubler, as, for example, in a sixfold thread, two strands may be first twisted together in the same or in the opposite direction to the spinning twist; after which the once-doubled thread is "cleared," folded, and three strands of twofold yarn are twisted in the opposite direction to that employed in the first operation. In some machines folding and twisting proceed simultaneously, and some are furnished with an automatic stop motion. But when twisting two threads together to oppose the spinning twist, the failure of one causes the other to untwist and break, therefore, under such circumstances a stop motion is unnecessary.

Intermittent doublers are known as twinners, and these are of two kinds, namely, English and French. In the former the spindles are fitted in a stationary rail, but the creel, containing the cops or ring spools, is mounted upon a carriage and moves in and out, as in Hargreaves' spinning jenny (see SPINNING). French twinners have a stationary creel, and the spindles move in and out with the carriage, as in the spinning mule. The material to be folded is often subjected to the action of steam in order to render it less resilient, after which it is mounted upon skewers in the creel, and two or three threads are passed to each spindle to be twisted together and formed into a cop. Between the creel and the spindles all the strands are kept equally tense by drawing them over flannel-covered boards and under porcelain weights. For wet doubling, the strands pass through a trough containing water, and the flannel surfaces are also wet.

Clearing.—After the first, or the final, doubling it is often necessary to remove lumps, imperfect knots and loose fibres from a thread. This is accomplished by passing each through a slit, or clearer, whose width is adjusted to the diameter of the thread to be treated. By this means anything which gives a thread abnormal bulk will be prevented from passing the slit. Once through the slit, a thread is coiled upon a friction-driven, double or single-headed bobbin. If the former, the coils are evenly laid; if the latter, they are disposed into a bottle shape Or, again, cheeses may be wound.

Gassing.—In cases where a thread with a smooth surface is required the extending ends of fibres must be burned off. Thus: each thread from a creel is drawn over a tension rod to two freely mounted pulleys, having parallel grooves cut in their surfaces and axes in the same horizontal plane. After bending a thread forward and backward in the grooves of both pulleys, it passes through a Bunsen flame and is coiled upon a tube, which is held against the face of a rotating drum, while a vibrating guide distributes the thread across the tube. The gas-burner is situated midway between the grooved pulleys, and so mounted beneath the thread that it will automatically swivel sideways and thus move the flame away from a stationary thread. Winding begins slightly before the flame moves beneath a thread, and the rapid motion of the latter permits the flame to burn off undesirable matters without injuring the thread.

Reeling.—Doubled or gassed yarn may be wound upon warpers' bobbins and made into warps for the loom, or it may be reeled into hanks for the preparing and finishing processes. But a reel hanks yarns for bleaching, dyeing, printing, polishing and bundling, and is adapted for cops, ring spools, doubling bobbins or cheeses. From cops, ring spools and cheeses the yarn is usually drawn over one end, but flanged bobbins are mounted upon spindles and the yarn is drawn from the side. A reel has a circumference of 54 in., and after making 80 or 560 revolutions it automatically stops; the first gives a lea of 120 yds. and the last a hank of 840 yds. For grant reeling, however, a hank may be from 5000 to 10,000 yds. long. Reeling is of two kinds, namely, open and crossed. Open reeling forms leas, and seven of these are united in one hank by a lease band which retains the divisions. In cross reeling a thread is traversed over a portion of the reel surface by a reciprocating guide to form a hank without divisions. On the completion of a set of hanks the reel is made to collapse and thus facilitate the removal of the yarn.

Bundling Press.—Hanks are made into short or long bundles, each weighing 5 or 10 lb. In short bundles it is usual to form groups of ten hanks, and these are twisted together, folded and compressed into bundles; but in long bundles the hanks are compressed without being folded. A press consists of a strong table upon which a box, with open ends, is formed. The bottom of this box is grooved transversely and made to rise and fall by wheel gearing or by eccentrics. The sides and top are made of vertical and horizontal bars, set to coincide with the grooves in the bottom. To one set of vertical bars a similar number of horizontal top pieces are hinged, and to the other set levers are jointed, which hold the horizontal bars in position. When the hinged bars are turned up, strings are drawn through the grooves, and the bottom is covered with stout paper. The hanks are then laid in the box, another paper is placed above them, and the hinged bars are drawn down and locked. The bottom then rises a predetermined distance, and automatically stops. While in this position the strings are tied, the bottom of the press next descends, and the bundle is removed. (T. W. F.)