WOOLEN SPINNING

INTRODUCTION

1. The stock, after having been carded and converted into roving of a suitable size, is ready to be spun into yarn of the required run or cut. This involves two principal operations; namely, the drafting, which is a drawing out, or attenuation, of the roving, and the twisting, which, in reality, is the process that forms the roving into yarn. In addition, the yarn thus formed must be wound on suitable bobbins or formed into cops. These operations may be said to constitute the process of *spinning*.

The spinning of yarn from fibers of wool is one of the oldest textile arts known to history and in ancient times was performed by first drawing and twisting the thread by hand and afterwards winding the yarn thus formed on a round piece of wood 18 or 20 inches long. This constituted the first spinning and the piece of wood was the first bobbin, or spindle. The first advance in spinning was the one-thread spinning wheel, which consisted of a large wheel mounted in a frame and carrying a driving band or cord for imparting a rotary motion to the spindle, which was also carried in bearings in the frame. After this came the Hargreaves spinning jenny, which was really an adaptation of the one-thread spinning wheel to spin more than one bobbin of yarn. The next advance was the Crompton mule, which was in reality a hand jack. Following this, Roberts made the mule self-acting and introduced the quadrant for winding the yarn on the bobbins. From these, the present *woolen mule* has been evolved.

Before wool can be spun into yarn, it must be carded and converted into rovings, which, being wound on jack-spools, are placed on the mule; the roving is then unwound from the jack-spools, drafted, twisted, and wound in cops or on bobbins. In order that the resulting yarn may be as nearly perfect as it can be made, the rovings must be as free as possible from twits and bunches and also from foreign substances, such as broken burrs and other minute particles of vegetable matter; they should be round and firm, uniform in structure, and of such a size that the required number of yarn may be spun without an excessive attenuation, or drafting, of the roving during the spinning. As a rule, the longer the fiber, or the better the grade of stock, the greater is the draft that can be given in the spinning; short stock requires more roving to be delivered by the delivery rolls of the mule for every stretch of yarn. Low stock with from 50 to 75 per cent. of waste or shoddy mixed with it also necessitates less draft in spinning; the carder, therefore, must make the roving correspondingly lighter in weight to produce the required yarn. Certain wools also have much better spinning properties than others, owing to their fineness, elasticity, waviness, serrations, and other characteristics that determine the value of wools for different classes of goods. Such stock will spin much better and stand more draft than poorer material.

2. Quality of Roving.—There are, generally speaking, three kinds of roving spun into woolen yarn: (1) Roving made from inferior stock or from stock that is barely capable of spinning to the desired run; (2) roving that has been cut, rolled, or otherwise affected by poor carding; (3) roving that has been properly handled in all the previous processes and that will spin superior yarn.

Regarding the first class of roving little can be said, as it is so plainly inferior and the stock from which it is carded so short, broken, and generally unsuitable, that only uneven yarns irregular in structure and lacking in elasticity and strength can be made from it.

The second class is generally caused by carelessness. It is ordinarily expected that with a good grade of stock the product of the cards will, in spinning, be drawn out to twice the original length, thus greatly assisting in the removal of any possible lumps, bunches, or general irregularities. Good even roving can be easily drawn out to this length, or even more, but poor uneven roving, or that made from low stock, cannot.

The uneven bunches in roving of this class are a great hindrance in producing even yarn and require careful setting of the mule. The twist runs into the thin places in the roving first and twists them hard, thus forming twits in the yarn. At the same time there is a tendency of the mule to regulate uneven roving to a large extent, because as the thin places become twisted hard first they will not be drafted, or drawn out, while the bunches remaining soft are drawn out until they are nearly as small as the thin places, when the twist will commence to run into them. The spindles of the mule are turning all the time that the carriage is being drawn out and a certain amount of twist is put into the roving before the delivery rolls stop and the drafting action commences. Therefore, if the roving to be spun into yarn is full of bunches, it is a good plan to have the carriage come out slowly at first; this puts the twist into the thin places quickly and allows more time for the soft bunches to be evened up by the drafting. However, if roving contains very many large, uneven bunches, it is impossible to produce a perfectly even yarn, although the unevenness may be largely reduced in the spinning.

The third class of roving includes that which is well carded from good, even, sound wools and a round, even roving made. The mule will draw such roving to twice its original length, and even more, with very little trouble.

3. Operation of Spinning.—By the term **spinning** is meant a process that may be divided into three operations as follows: (1) The drafting of the roving, in order to reduce its diameter and increase its length until the desired size of yarn is obtained. (2) The twisting of the attenuated roving, in order to give the yarn sufficient strength to be woven; on woolen mules this is partly combined with the first operation mentioned, namely, drafting. (3) The winding of the yarn prepared by the previous operations on bobbins or in cops in suitable form for the succeeding operations of weaving or spooling.

THE MULE

ELEMENTARY PARTS

4. The machine used in woolen spinning for accomplishing the above results is, owing to its hybrid nature, known as a **mule;** and on account of its practically automatic action is called a **self-acting mule.** It may be divided into two parts, each being equally essential in performing the objects named in the formation of the woolen thread; namely, the *head*, or *headstock*, which receives the driving power and from which all the motions of the mule originate, either directly or indirectly, and which is stationary and connected to the delivery rolls for delivering the roving; and the *carriage*, which bears the spindles that perform the functions of drafting and twisting the roving into yarn and then winding it on bobbins placed thereon, and which is movable.

In order that the principle of spinning and the fundamental action of the mule may be understood, the essential movements of the machine will be described first without reference to the complicated mechanisms that produce the various motions.

5. Referring to Fig. 1*, the jack-spool a, on which the roving to be spun is wound, is placed on a rotating drum a_1,

*The same letters of reference are used in all the illustrations of the woolen mule where the same parts are shown. This will be found a great aid in reading the illustrations and in becoming familiar with the machine. Figs. 4 and 5 are illustrations of the front and rear of the machine and should be frequently referred to in order that separate mechanisms may be associated, wherever possible, with the whole machine.

which turns the spool and unwinds the roving, allowing it to be passed through the stationary guide a_2 to the delivery rolls a_3, a_4, a_5. Thence the roving passes directly to the spindle c_7 and is wound on a bobbin c_8 placed on it; that is, after the roving has been drafted and twisted into yarn.

The delivery rolls of the mule are composed of three parts; the two bottom rolls a_4, a_5 are driven from the head-stock, while the top roll a_3 is made in sections, each consisting of two bosses that rest on the bottom rolls. The bosses may be removed in order to replace rovings that become broken between the delivery rolls and the jack-spool.

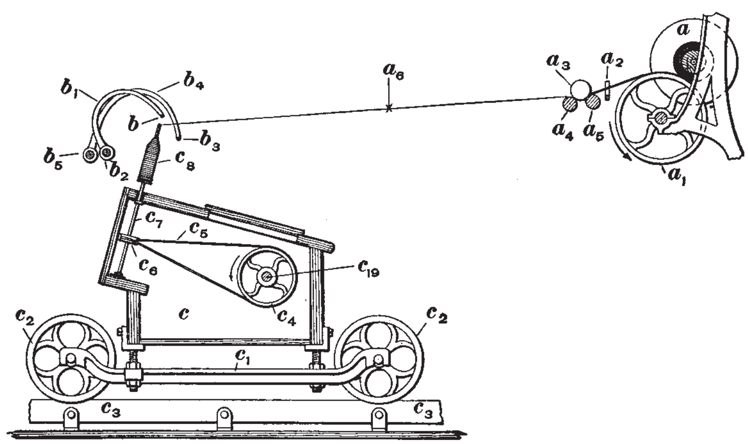


FIG. 1

Although only one spindle and one bobbin are shown, it must be remembered that each mule often contains as many as 280 or 300, and sometimes as many as 400.

The spindle c_7 is carried in two bearings—a bottom, or step, bearing and a top, or bolster, bearing. Between the bolster and the footstep, there is fixed on the spindle a small, grooved pulley c_6, called a *whorl*, that has an endless spindle band c_5 passed around it. This spindle band also passes around a tin cylinder c_4, called a *drum*, which supplies the motive power for turning the spindles by means of the spindle bands. The drum runs the full length of the carriage, each spindle having a separate band that passes around its whorl and around the drum. The spindle is not absolutely vertical, but is inclined at an angle toward the delivery rolls. The spindles and drum are borne in a frame, or carriage, c, that is carried by transverse supports c_1 in the ends of which are bearings for the carriage wheels c_2. The latter run on iron rails c_3, so that if power is applied to the carriage it can readily be moved to or from the delivery rolls.

The yarn passes under a wire b fixed in the *sickle* b_1, which oscillates with the shaft b_2; this wire is known as the *faller wire*, or more definitely, the *winding faller*. Its object is to guide the yarn on to the bobbins during the operation of winding. The yarn also passes above the wire b_3 that is attached to the sickle b_4, the sickle, in turn, being fastened to the shaft b_5. This is known as the *counter*, or *tension*, *faller* and is for the purpose of keeping tension on the yarn during the winding in order to prevent kinks and soft-wound bobbins.

6. Converting the Roving Into Yarn.—The method by which this mechanism produces yarn is as follows: The carriage is brought close to the delivery rolls, so that the points of the spindles are within a short distance of the point of contact between the delivery rolls where the yarn is delivered. As the delivery rolls combined with the drum a_1 begin to deliver the roving, the carriage simultaneously commences to recede from the rolls at practically the same speed as that at which the roving is delivered, and the spindles begin to rotate. When the spindles reach the point a_6, the position of which depends on the draft of the roving, the delivery rolls and the spool drums stop, but the carriage continues to recede until the points of the spindles are about 72 inches from the delivery rolls. By this means the roving is drafted, or drawn out, to twice its original length or thereabouts.

As these operations are taking place the twist is being put into the yarn by the rotating spindles; this is accomplished by the slipping of each turn of yarn over the end of the bobbin and spindle, which is due to the inclination of the latter; Fig. 2

illustrates this point. If the spindle were vertical and the point of delivery at the rolls a_3, a_4, a_5 level with any point on the bobbin c_8, the yarn would tend to be wound on the bobbin at that point when the spindle was put in motion. The spindle, however, is set at an angle and the point of delivery is slightly above the top of the bobbin; thus, when the spindle rotates, the yarn rises on the bobbin in a series of spiral coils, the tendency of the thread being to assume a position at right angles to the spindle, which would be at the point a_7, provided that the spindle and bobbin were long enough.

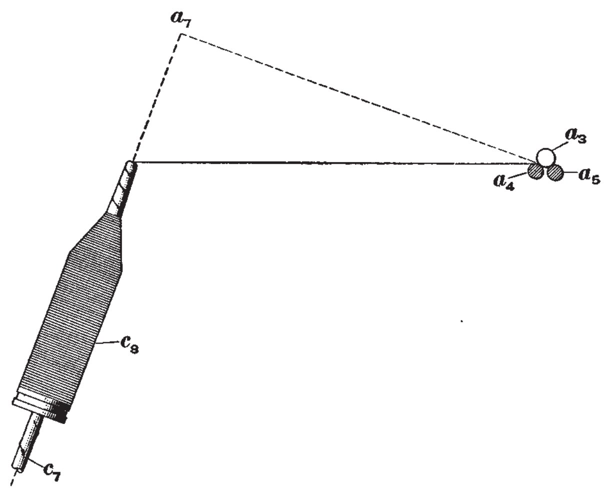


Fig. 2

The tendency of the yarn to rise continues until the top of the bobbin is reached, when the yarn slips over the end of the bobbin, thus putting in one turn of twist. As the spindle continues its rotation, each coil of yarn rises and slips over the end of the bobbin, thus putting as many turns of twist into the yarn as there are revolutions of the spindle.

It is the combined drafting and twisting action of the woolen mule that gives to the woolen thread its distinctive woolen formation, or covered appearance. In spinning other yarns, the roving is first drafted to the required size by means of two or more pairs of rolls, each successive pair running at an increased speed, and then twisted into yarn, the operations of drafting and twisting being entirely separate; in other words, the yarns are *roll drawn*. Woolen yarn, however, is drafted and twisted at one and the same time; the yarn being spoken of as *spindle drawn*, because the spindle draws the roving to the required size, while in the other case this is accomplished by means of rolls.

When the carriage reaches the end of its stretch—when the spindles are at their greatest distance from the rolls—it is stopped and is held while more twist is put into the yarn; the full amount of twist is not put in while the carriage is coming out, because if it were the yarn could not be drawn

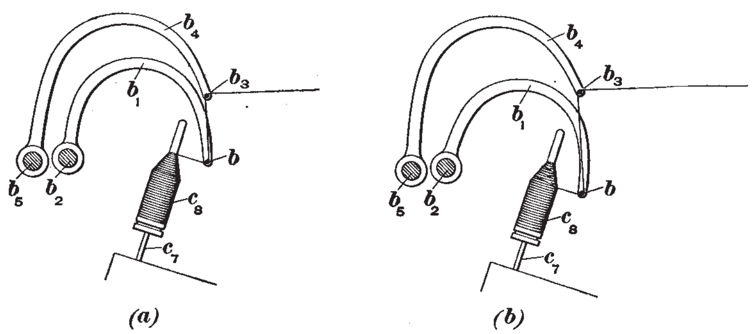


FIG. 3

out, but would break instead, since the twist gives the yarn strength and prevents the individual fibers from being drawn past each other as is necessary in order that the roving may be drafted. This extra twist is sometimes put in by means of an accelerated motion.

At the completion of the twisting motion, the spindle is stopped and reversed for a few turns, so that the few coils of yarn between the top of the bobbin (which is flush with the top of the spindle) and the yarn already spun, are unwound. This operation is technically known as *backing-off;* as it takes place the faller b, Fig. 1, descends and assumes a position for guiding the yarn on to the bobbin, while the counter faller b_3 ascends so as to obtain the requisite tension of the stretch of yarn for winding it on to the bobbin and to prevent the formation of kinks. The position of the winding and counter fallers after the backing-off takes place and just as the stretch of yarn is ready to be wound on the bobbin is shown in Fig. 3 (*a*).

Immediately after the backing-off is completed, the *drawing-in* of the carriage is commenced and the spindles are revolved in their normal direction so as to wind the yarn on to the bobbin as it is released by the inward run of the carriage. As this takes place the winding faller *b* first descends quickly to the position shown in Fig. 3 (*b*) and then rises slowly until it again assumes the position shown in Fig. 3 (*a*). The result of this is that the yarn is first wound on the bobbin in a series of coarsely pitched descending coils and then in a series of finely pitched ascending coils. Thus each stretch of yarn is wound on the bobbin in two layers, the coarsely pitched layer giving the bobbin strength and solidity and the finely pitched layer serving to place the remainder of the yarn in the stretch on the bobbin. This motion of the winding faller is regulated by what is known as the *builder rail*.

When the inward run of the carriage is completed, the winding operations cease; the winding faller and counter faller assume their normal positions clear of the yarn, Fig. 1, and the parts are again adjusted to begin the work of drafting and twisting. The complete outward and inward run of the carriage is technically called a *draw*.

7. The **driving** of the principal parts of the mule may be briefly stated as follows: The roving motion, i. e., the motion for the delivery of the roving, is driven by bevel gears and a cross-shaft from the headstock of the mule. The drum in the carriage, which imparts motion to the spindles, is driven by means of an endless rope, called the *rim band*, from grooved pulleys on the main shaft. The rim band, however, only drives the spindles while the carriage is coming out and while twist is being put into the yarn by the accelerated speed; when the yarn is being wound on the bobbin, the spindles are driven by the motion of the carriage, which unwinds a chain called the *quadrant chain* from a

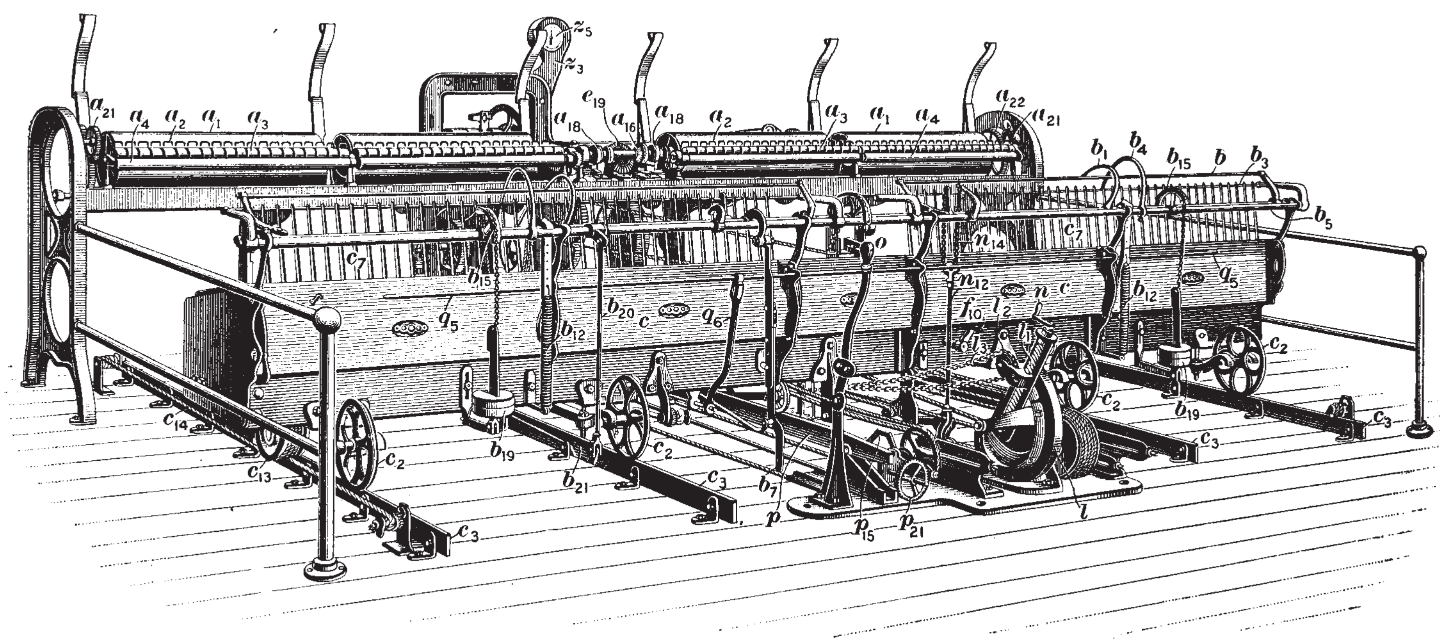


FIG. 4

chain drum connected to the shaft of the drum that drives the spindles. The carriage is drawn out by means of a scroll on the drawing-out shaft of the headstock and is drawn in by means of two scrolls on the drawing-in shaft.

DETAILS OF CONSTRUCTION AND OPERATION OF THE MULE

8. Classification of Operations.—The brief description given enables the movements of the woolen mule to be classified as follows: (1) delivery of roving, (2) drafting and twisting, (3) backing-off, (4) winding, (5) reengagement. It is somewhat difficult to understand the movements of the various parts of the mule at different periods because of the fact that at one time a certain portion of the mechanism may be performing a certain function, while at another time it may be performing a totally different one, both the velocity and direction of its motion being changed. Each of the essential mechanisms of the mule will now be described in detail, and in studying these descriptions reference should be made not only to the illustrations of these various mechanisms, but also to other illustrations in which they may be incidentally shown, and also to Figs. 4 and 5, which show the positions of many of these parts and their relation to the mule as a whole.

9. Headstock.—As has been said, the mule consists of two parts, from one of which, the **headstock**, all other parts receive their motion. The sectional view shown in Fig. 6 illustrates the method of transmitting the power to the various mechanisms.

The main shaft e receives and transmits the motive power by means of which the various operations are performed, and is for this purpose provided with four pulleys e_1, e_2, e_3, e_4. These pulleys are commonly spoken of, in their respective order, as the first, or loose, pulley; the second, or drawing-in, pulley; the third, or drawing-out, pulley; and the fourth, or accelerated-speed, pulley. In addition, the main shaft also carries two grooved pulleys e_5, e_6 and three gears e_7, e_8, e_9.

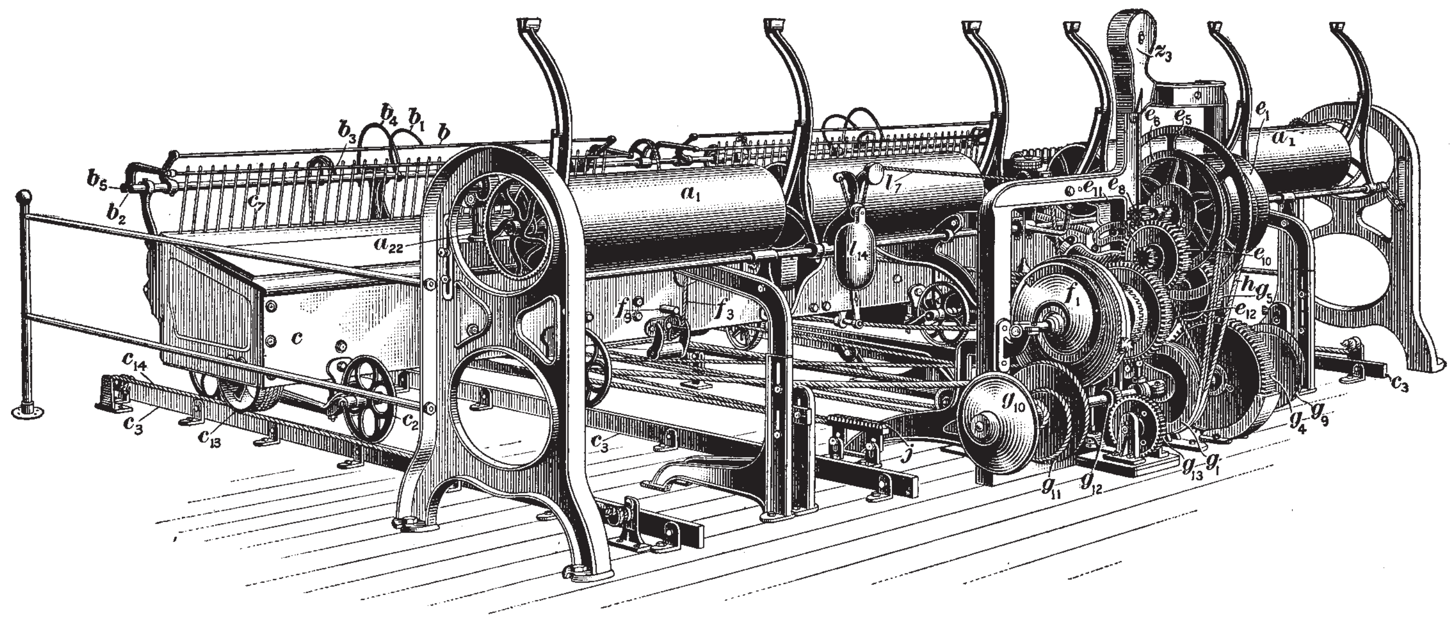
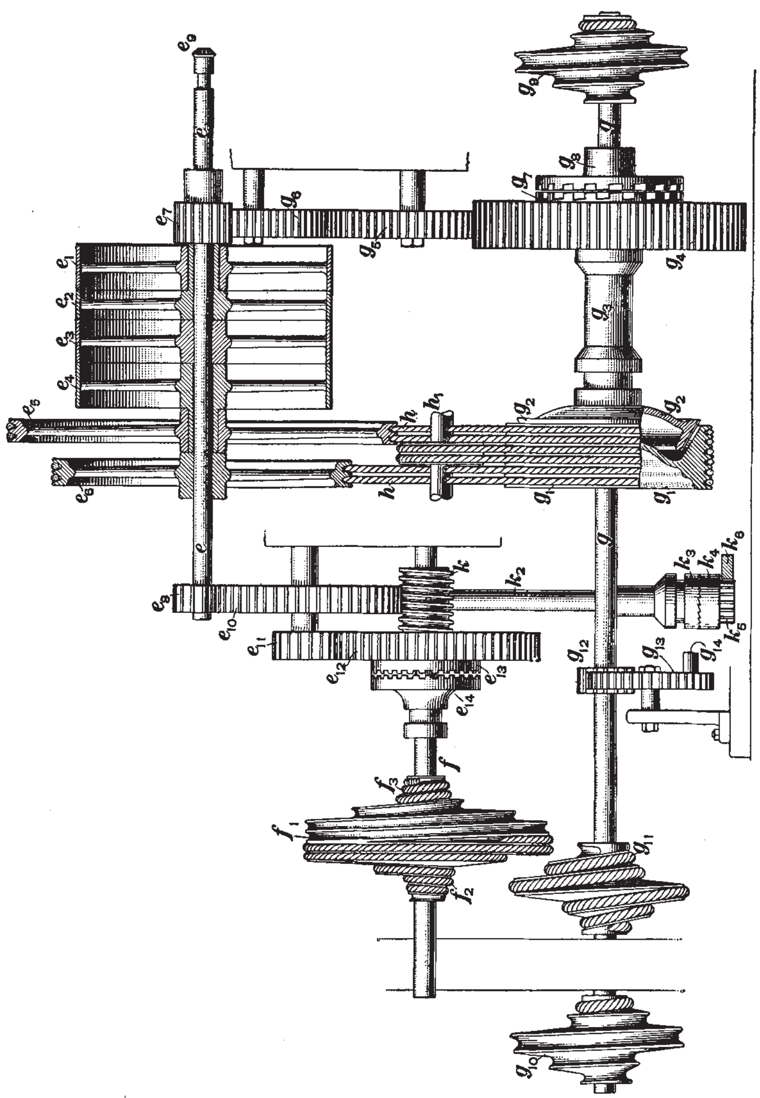


FIG. 5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g13
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k2
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k4
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k6

FIG. 6

The drawing-out pulley e_3, grooved pulley e_6, and gears e_8, e_9 are keyed to the shaft; the others are loose. The pulley e_2 is provided with a sleeve, on which the pulley e_1 runs loose but to which the gear e_7 is fastened; the grooved pulley e_5 is keyed to the sleeve of the pulley e_4. As a result of this arrangement, the pulley e_1 acts simply as a loose pulley and furnishes a resting place for the driving belt when motion is not being imparted to any part of the mule; the pulley e_2 imparts motion to the gear e_7; the pulley e_3, to the gears e_8, e_9 and the grooved pulley e_6; and the pulley e_4, to the grooved pulley e_5. It should also be noted that when the driving belt is on e_4 the pulley e_5 will drive the shaft e and, consequently, the gears e_8, e_9, by means of the rim band h, which passes around the grooved pulleys e_5, g_1, e_6; in this case e_6 is the follower and e_5 the driver. When the mule is not in operation the driving belt runs on the loose pulley e_1, from which it may be moved to the pulleys e_2, e_3, e_4 by means of a belt lever.

ROVING MOTION

10. At the commencement of the spinning operation, the carriage is in near the headstock so that the spindles are close to the delivery rolls, and as the mule is started, two motions are brought into play; namely, the *roving motion*, for delivering the roving, and the *drawing-out motion*, which causes the carriage to recede from the delivery rolls. The roving motion here described is so arranged that the delivery rolls and spool drums on one side of the mule may be stopped independently of those on the other side, thus allowing yarns of two sizes to be spun on the same mule, or allowing the same size yarn to be spun from two different run rovings. For this reason this motion is known as a *double roving motion*. The driving belt at the start is shifted from the loose pulley e_1 to the third pulley e_3, Fig. 6, and the power transmitted to the gear e_{12} through gears e_8, e_{10}, e_{11}. From the gear e_{12}, motion is communicated to the delivery rolls of the mule through gears e_{15}, e_{16}, and e_{17} and e_{19} on the cross-shaft e_{18}, as shown in Fig. 7.

Fig. 8 is a plan view of this double roving motion, while Fig. 9 is a side elevation of one side of the same mechanism, representing Fig. 8 as it will appear when looked at in the direction of the arrow. The bevel gear e_{19} meshes with another bevel gear a_{16}, which, together with the halves a_{15} of two toothed clutches, is fastened to a sleeve a_{13} that is loose

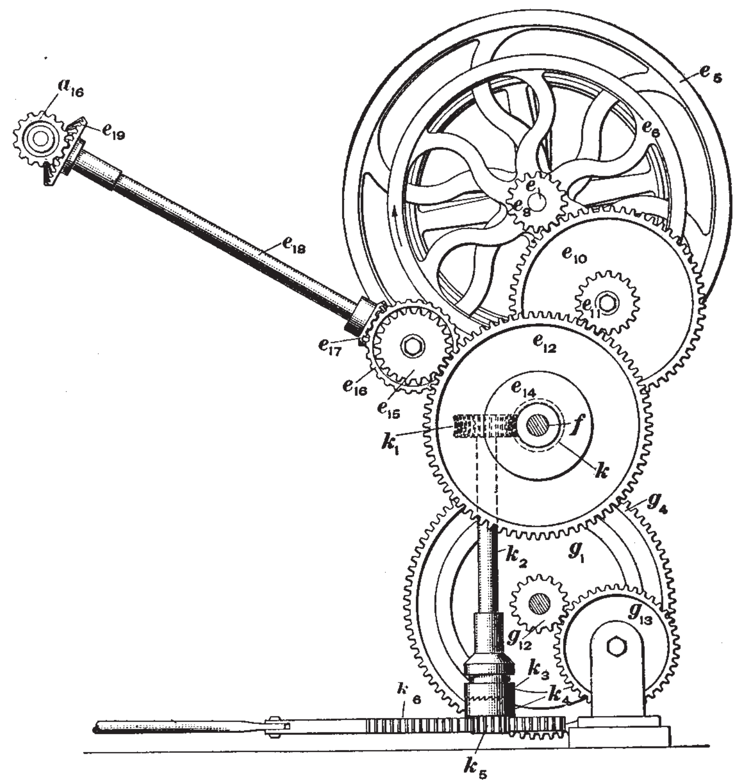


FIG. 7

on the shaft of the rear bottom delivery roll a_5. When these clutches are out of contact, as shown in Fig. 8, no motion is imparted to the delivery rolls of the mule, but when the parts a_{14} are moved in contact with the parts a_{15}, by the yoke levers d_2, the motion of the gear a_{16} is imparted to the rear delivery roll a_5 and also through the gears a_9, a_{10}, a_8, to the

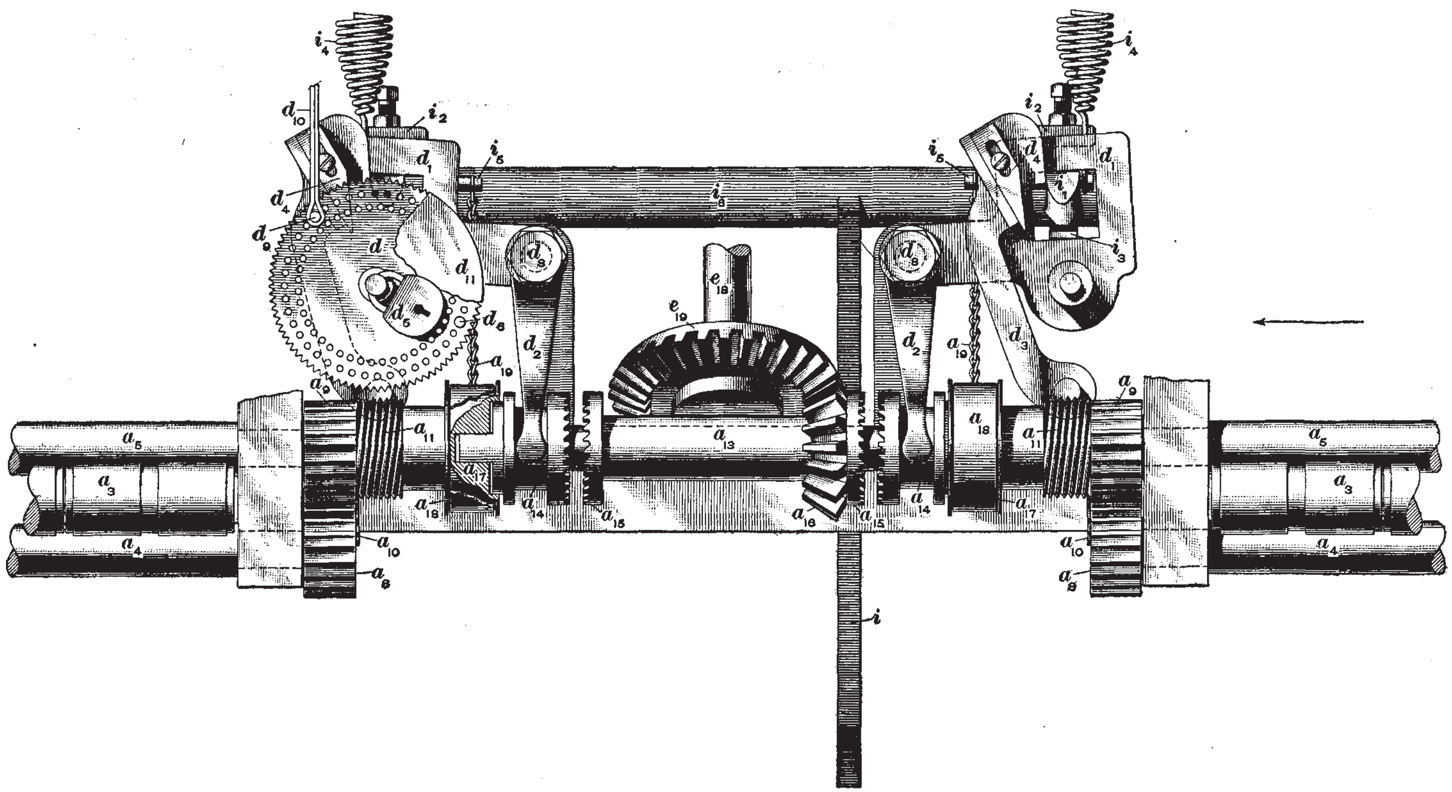


FIG. 8

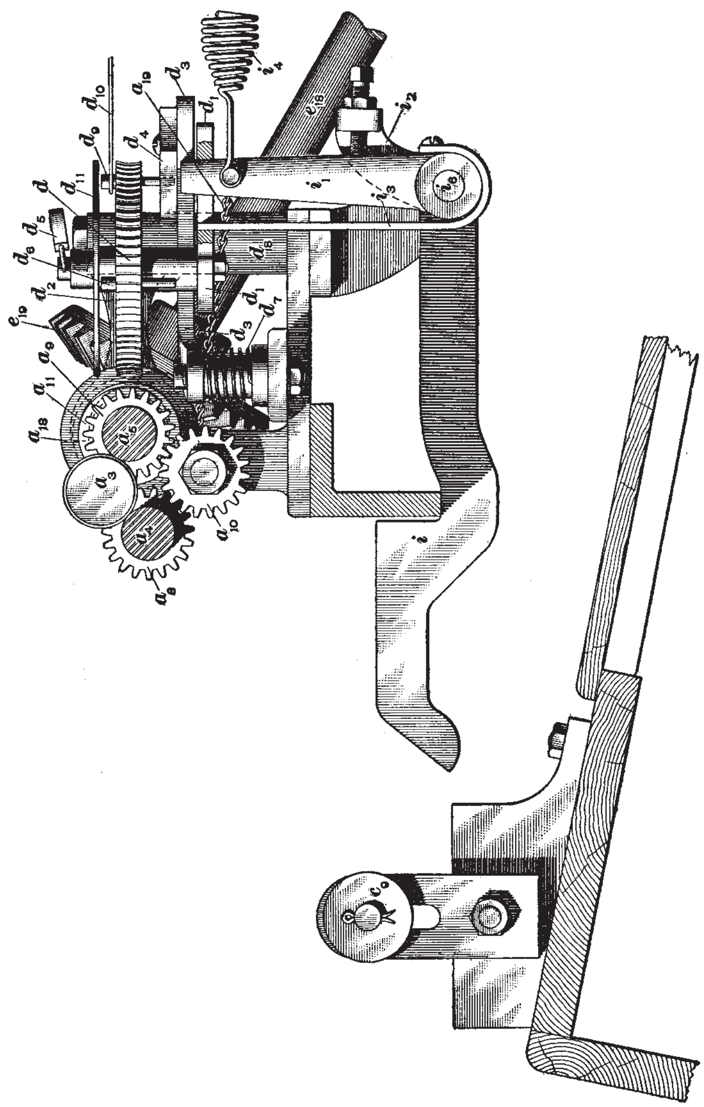


FIG. 9

front delivery roll. The halves a_{14} of the clutches have two projections extending into slots in the brake bosses a_{17}, so that although they are free to be moved along the shaft so

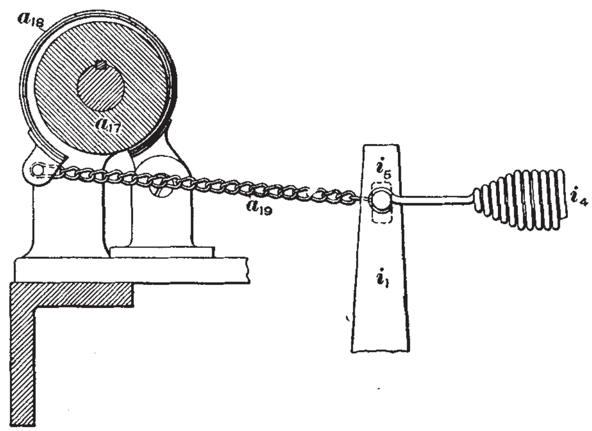


FIG. 10

as to engage with a_{15}, they will impart motion to a_6 when so engaged. The top roll a_3, which consists of loose bosses,

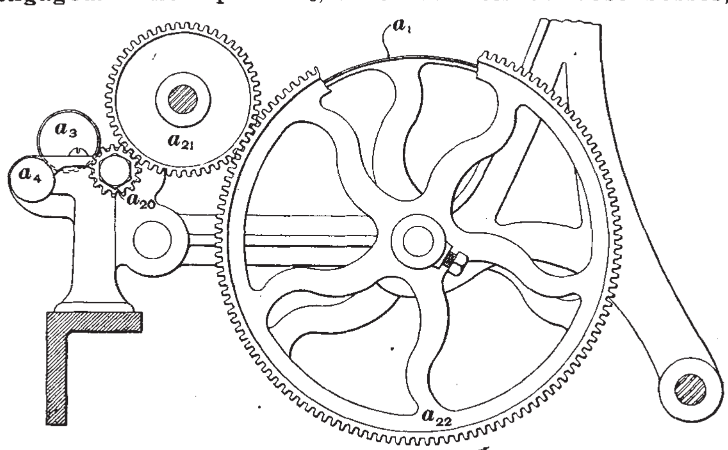


FIG. 11

is not driven positively, but receives its motion from the two bottom delivery rolls, on which it rests, being thus rotated only by frictional contact with the bottom rolls. The spool drums, which carry the spools of roving and unwind it as it is taken by the delivery rolls, are geared from the shaft of the rear delivery roll at each end of the machine. As shown in Fig. 11, a gear a_{20} drives an intermediate gear a_{21} that in turn imparts motion to the gear a_{22} and spool drums a_1. The gear a_{20} is a change gear and may be changed in size if in any case the spool drums unwind the roving faster or more slowly than it is taken by the delivery rolls. The motion of the delivery rolls is of necessity intermittent, since the roving is delivered during only a portion of the time that the carriage is receding from them; this is necessary so that the drafting of the roving may take place in order to reduce its size and produce yarn of the required run.

11. The motion of the delivery rolls and spool drums may be checked by means of the *roving stop-motion*, Figs. 8 and 9, at any point, so that any desired length of roving may be delivered for each draw of the mule. The point at which the delivery rolls stop, and consequently the length of roving delivered, is regulated by means of a roving-pin gear for each side of the mule; the pin gear d for the left-hand side is shown in Fig. 8, while the other is removed in order to show the mechanism of the stop-motion more clearly. The yokes d_2, which operate the sliding portions a_{14} of the delivery-roll clutches, and the castings d_1, which carry the roving-pin gears, are rigidly fastened together, and are fulcrumed at d_8; thus, if motion is imparted to them the clutches will be thrown in contact and the roving-pin gears moved forwards so as to mesh with the worms a_{11}, which are fastened to the shaft of the rear delivery rolls a_5. This is accomplished each time that the carriage comes in to the delivery rolls by means of a roll c_9, Fig. 9, that presses down a lever i cast in one piece with the shaft i_6. The motion of this shaft is imparted to the finger i_1 and a strong, flat spring i_3 by means of the casting i_2, which is cast in one piece with the shaft i_6 and carries a setscrew by means of which the finger i_1 may be adjusted. As the spring i_3 moves forwards, it moves the casting d_1 and yoke d_2 around the fulcrum d_8, thus forcing and holding together the parts a_{14}, a_{15} of the delivery-roll clutch, and also holding the roving-pin gear in contact with the worm a_{11}. As the finger i_1 is moved it is caught and held against the tension of the spring i_4 by a dog d_3 that is constantly pressed against it by means of a coil spring d_7 on the stud on which it is fulcrumed. Motion being imparted to the gear a_{16} as described, the delivery rolls and also the roving-pin gears are rotated. This motion continues until a pin d_6 placed in a hole in the roving-pin gear comes in contact with a wedge-shaped piece of steel d_4 screwed to the dog d_3. When the pin strikes this wedge, the dog is forced from contact with the finger i_1 and a strong spring i_4 attached to the finger pulls it backwards, thus moving the casting d_1 and yoke d_2 and disengaging the delivery-roll clutches and roving-pin gears, so that the motive power is withdrawn.

12. In order that the delivery rolls may stop instantly when the power is withdrawn, friction brakes are applied at the same time, thus checking any momentum that the rolls may have and also firmly locking them in place until they are ready to deliver the roving for another draw of the carriage. These brakes are shown in Figs. 8 and 9 and also, in detail, in Fig. 10. A boss a_{17} that is fastened to the shaft of the rear delivery roll is encircled by a friction strap a_{18}, one end of which is fastened to the framework of the mule, while the other is attached, by means of a short length of chain a_{19}, to the stud i_5 on the finger i_1; thus, as the finger i_1 is pulled backwards by the spring i_4 to disengage the roving motion, it also tightens the chain a_{19} and applies the brake to the delivery rolls.

A strap d_{10} is fastened by a pin d_9 to the roving-pin gear and is carried back over a small pulley. At the end of this strap is attached a weight that revolves the pin gear in the opposite direction as soon as it is released from the worm, thus bringing it back to its initial position, with the pin d_9 resting against the back of the wedge d_4.

In order to prevent tampering with the roving-pin gears, a circular plate d_{11}, partly shown on one side in Fig. 8, is placed over them and fastened with a small padlock d_8. With this plate in position it is impossible for the pin d_6 to be moved from one hole to another or be accidentally displaced.

13. Each roving-pin gear contains two rows of holes with 44 holes in a row. Those in the outside row are known as *full holes*, while those in the inside row, as each is placed between 2 holes of the outside row, are known as *half holes*, since it is possible by their use to obtain an adjustment of the length of roving delivered equal to one-half that obtained by moving the pin 1 hole in the outside row. The setting of the pin d_6 so as to deliver any desired length of roving before the delivery rolls of the mule stop is determined by the fact that for each full hole in the roving gear $2\frac{1}{2}$ inches of roving is delivered, while for each half hole $1\frac{1}{4}$ inches is delivered; that is, by changing the pin from a full hole to an intermediate half hole or from a half hole to the next full hole the length of roving delivered is varied $1\frac{1}{4}$ inches. This may be easily proved by figuring from the diameter of the delivery rolls, as follows: The diameter of the delivery rolls is $1\frac{3}{16}$ inches; therefore, their circumference is $1\frac{3}{16}$ inches $\times 3.1416 = 3.73$ inches. The worm a_{11} is triple-threaded, and consequently moves the roving gear 3 teeth to each revolution of the delivery roll. The roving gear contains 88 teeth and 44 full holes; therefore, 2 teeth in the gear are equal to 1 full hole, and 1 full hole is equal to two-thirds of a revolution of the delivery roll; that is, two-thirds of 3.73 inches, or practically $2\frac{1}{2}$ inches. A half hole of course is equal to one-half of $2\frac{1}{2}$ inches, or $1\frac{1}{4}$ inches.

Knowing the length of roving controlled by each hole in the roving gear, the number of holes to be allowed can be easily ascertained after the desired length of roving to be delivered has been found. For instance, suppose that 40 inches of a certain run roving must be delivered to spin yarn of a required run and it is desired to ascertain how many holes to allow in the roving-pin gear to deliver this amount of roving. All that is necessary is to divide 40 by $2\frac{1}{2}$, which will give 16 holes as the number to allow. With soft roving, however, it is very difficult to figure exactly how many holes will be necessary, but the above method will approximately give the correct result, and then if the yarn spun is too light or too heavy, the pin can be changed a half hole or a full hole, etc., as may be required. If it is desired to change the roving-pin gear so as to spin yarn of different run from the same run roving, or so as to spin the same run yarn from a different run roving, the number of holes to allow may be found by proportion. For instance, suppose that with a certain run roving 18 holes give $2\frac{1}{2}$-run yarn and it is desired to spin 3-run yarn. Letting x represent the number of holes that must be allowed, the proportion is $3 : 2\frac{1}{2} = 18 : x$; x is therefore 15, and 15 holes must consequently be allowed in the roving gear to spin 3-run yarn from that particular run roving. For another example, suppose that with an allowance of 20 holes in the roving gear a mule is spinning a certain run yarn from $2\frac{1}{2}$-run roving and that it is desired to spin the same run yarn from 2-run roving. The number of holes to allow in the roving gear to accomplish this may be found by the following proportion: $2\frac{1}{2} : 2 = 20 : x$; x is therefore 16—the number of holes required.

DRAWING-OUT MOTION

14. The **drawing-out motion** is in operation at the same time that the roving motion is delivering the roving, and causes the carriage to recede from the delivery rolls so as to draft and twist the roving into yarn. The driving belt during this period is in contact with the third pulley and imparting motion to the gear e_{12}, Fig. 6. Attached to the gear e_{12} is one-half e_{13} of a toothed clutch; the other half e_{14} may slide along a key on the shaft f so as to engage with e_{13}, in which case motion will be imparted to the shaft f and to the draft scroll f_1 fastened to it. The draft scroll is made with two separate and opposite scrolls, to one of which the rope f_2 is attached, as shown in Fig. 12. This rope, or

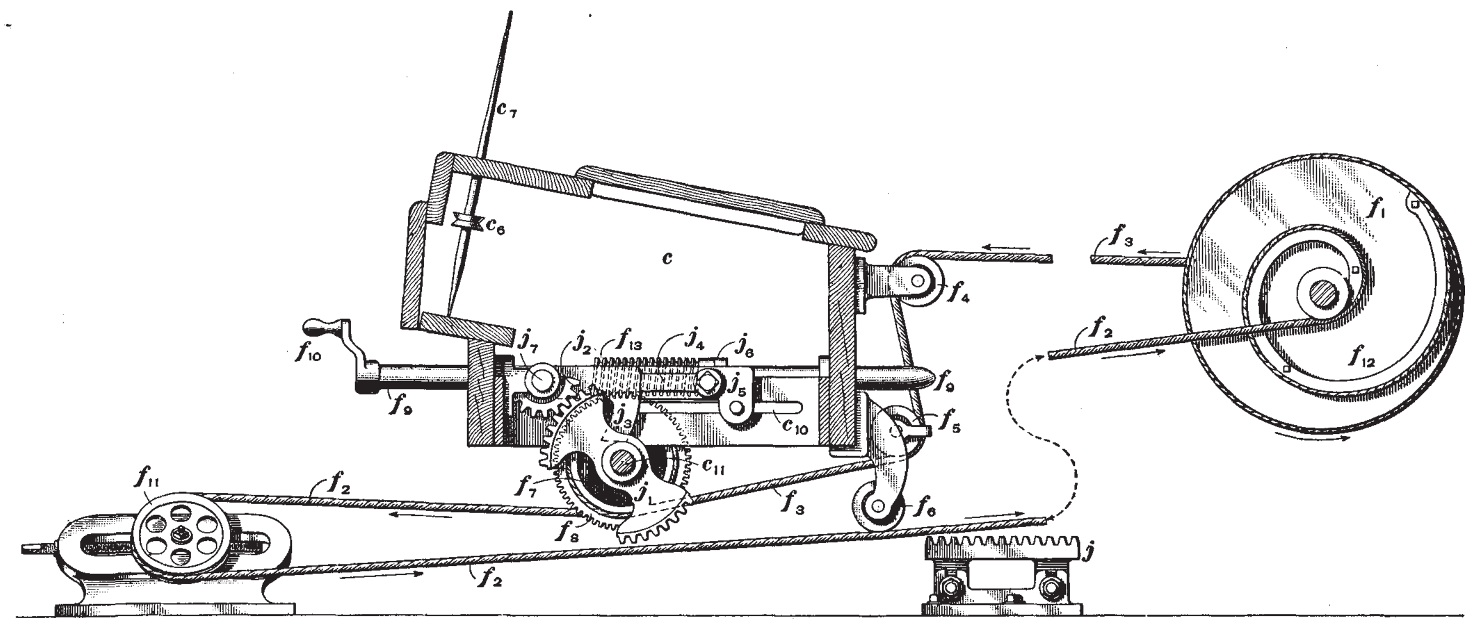

c
c_6
c_7
c_{10}
c_{11}
f_1
f_2
f_3
f_4
f_5
f_6
f_7
f_8
f_9
f_{10}
f_{11}
f_{12}
f_{13}
j
j_1
j_2
j_3
j_4
j_5
j_6
j_7

Fig. 12

band, as it is called, passes from the scroll around a binder pulley f_{11} and is attached to the carriage. As the middle part of the rope f_2 is omitted, a dotted arrow has been inserted to indicate the connections between the two ends. The binder pulley is movable in a slotted casting attached to the floor and is adjusted by means of a screw, to which a crank-handle may be attached for the purpose of tightening the band. Another rope f_3 is attached to the other scroll and is also attached to the carriage. These ropes are so connected with the scrolls that when the rope on one scroll is winding up, it is unwinding on the other. The result is that when one scroll is full, as the front one in Fig. 12, the other is empty. In Fig. 6 also the scroll f_1 has been shown in this condition. The diameters of the active parts in both scrolls, however, are always equal; otherwise, one of the ropes f_2 or f_3 would at certain times either be slack or too tight. Therefore, when the rope f_2 is winding up on the small diameter of its scroll, the rope f_3 is unwinding from the small diameter of the other scroll, and vice versa. The greater the diameter of the active part of the scroll, the greater will be the speed of the rope and, consequently, that of the carriage. When the carriage is being drawn out, the band f_2 is being wound up on the scroll and, as it passes over the binder pulley f_{11} and is attached to the carriage, it is this band that really draws out the carriage. The other band f_3 on the draft scroll has no real function in connection with actually drawing out the carriage, but simply furnishes a positive connection between the draft scroll and the carriage. This prevents any liability of the momentum of the carriage carrying it forwards faster than it is drawn out by the draft scroll and rope f_2; prevents the draft scroll from overrunning when the carriage comes in again; and also enables the position of the draft scroll to be changed, as will be explained later.

15. In order fully to appreciate the method adopted for drawing out the carriage by means of a draft scroll, it is well to understand the reason for its adoption. In the first place, the carriage moves out very fast in the first part of its motion, in order to keep pace with the delivery of roving by the delivery rolls of the mule. When the delivery of roving stops, the speed of the carriage is immediately checked, and spinning, or the combined drafting and twisting of the roving, commences. Such an action is necessary for the carriage, since, if it commenced the draw by moving slowly, there would be so much twist put into the roving at the start, before it was drafted, or drawn out, at all, that it would be impossible afterwards to draw it to the required size of yarn. The variable speed thus necessitated is provided for by the draft scroll.

When the mule is started, the rope f_2 is on the large diameter of the scroll, at its center, and the carriage is thus given the speed necessary for keeping the delivery of roving at the required tension. As the delivery of roving is stopped, however, the drawing-out band commences to be wound down on the smaller part of the scroll, so that the speed of the carriage is gradually checked, thus allowing for the drafting and twisting of the roving. The carriage runs very slowly when near the end of its outward movement. The point at which the speed of the carriage is slowed by allowing the drawing-out band to wind on the smaller part of the scroll is controlled by the position of the scroll, which is regulated to suit different conditions of stock and roving.

16. The band f_2, Fig. 12, after passing around the binder pulley f_{11} is attached to a drum f_7, which is loose on the shaft c_{11}. The band f_3 passes over guide pulleys f_4, f_5 attached to the carriage, and is also fastened to the same drum as the band f_2, but is wound on it in the opposite direction. In the center of the drum f_7 is a worm-gear f_8 that engages with a worm f_{13} fastened to a shaft f_9. This worm may be turned by means of the crank f_{10}, which will rotate the drum f_7, winding up the band f_2, and unwinding the band f_3, or vice versa. This changes the position of the draft scroll relative to that of the carriage. It is sometimes desirable to do this, in order to adapt the drafting, or the speed of the carriage during the earlier part of its movement, to the particular stock in hand. For instance, if roving that will not admit of much drafting is being spun and an extra amount of roving is being delivered, it will be desirable to turn the drum f_7 in such a direction that the band f_2 will start to wind on the draft scroll in such a position that a greater length of time will be required before it commences to wind down on the low part of the scroll, thereby making the carriage move rapidly for a greater distance at the start. This has the effect of allowing less twist to run into the roving before the drafting of the roving into yarn commences. This means of adjustment is only used, however, where a small change in the speed of the carriage is desired. The position of the draft scroll may be changed while the carriage is coming out or while the accelerated speed is in operation, but should not be changed while the carriage is in and the clutch e_{13}, e_{14}, Fig. 6, locked, as this puts an extra strain on either band f_2 or f_3 while the other becomes slack; this is apt to strip the teeth from the worm-gear f_8.

The small roll f_6, supported by brackets fastened to the frame of the carriage, prevents the drawing-out band from chafing on the carriage when it is in.

The part of the draft scroll where the drawing-out band winds down on to a smaller diameter, and where the speed of the carriage is thus checked, is composed of a flat, malleable-iron spiral, or wing, f_{12} that is bolted or screwed to the side of the scroll, so that it can be removed and a wing of different shape substituted, to accommodate the speed of the carriage to any particular stock. The draft scroll is the only scroll that needs removable wings, as this scroll controls the motion of the carriage while the yarn is being spun, during which the character of the resulting yarn and the ease with which it is spun is largely dependent on the motion of the carriage.

17. The drum f_7 is made in halves that are provided with toothed ends, which lock them together after the manner of a toothed clutch; a coil spring on the shaft c_{11} presses the halves together and thus keeps them locked. Cast in one piece with the half on which the band f_5 is wound is the worm-gear f_8. The object of this arrangement is to allow an adjustment, in addition to the movable sheave f_{11}, for taking up the slack of the drawing-out bands as they stretch through wear. If the sheave f_{11} has been moved as far as possible and the drawing-out bands are still slack, the sheave may be moved back, so as to slacken the bands as much as possible, and then the two halves of the drum f_7 separated and the shaft f_9 rotated by the handle f_{10} until all the slack is taken out of the bands; this still allows a full length of travel of the sheave f_{11} for further adjustment of the tension of the drawing-out bands should they continue to stretch.

DWELL MOTION

18. The object of the **dwell motion** is to afford relief to the roving as the carriage starts away from the delivery rolls, since there is a tendency for the carriage slightly to strain the roving at this point, owing to the fact that it tends to start rather abruptly on its outward journey. As no twist has as yet been inserted in the roving, it is also more liable to be strained at this time than at any other. The dwell motion, therefore, is an important mechanism, especially if the roving is soft and tender, since it prevents twits and unevenness in the yarn that would otherwise be unavoidable except with very strong roving. This relief is given the rovings by causing the carriage to dwell for an instant before attaining its maximum speed, which necessarily occurs during the first part of its motion away from the delivery rolls. The dwell motion is shown in detail in Fig. 13, but, as shown in Fig. 12, is really a part of the drawing-out motion.

In Fig. 13, the various parts of the dwell motion are shown in the positions that they assume when the carriage is drawn in, just previous to its outward journey. The shaft f_9 is free to move for a limited distance in the direction of its axis; that is, it may be thrust forwards or backwards, carrying with it the worm f_{13} and thereby imparting a slight motion to the worm-gear f_8 and drum f_7. The effect of this motion therefore is the same as though the crank f_{10} were turned, with the exception that the effect is not permanent, as will be explained. A rack j is fastened to the floor in such a position that as the carriage reaches the end of its inward motion and approaches the delivery rolls it is engaged by a segment gear j_1 that is loose on the shaft c_{11}. As this segment gear engages with the rack the motion of the carriage imparts a movement to it that is transmitted to the segment gear j_2 and shaft j_7, to which j_2 is fastened. An

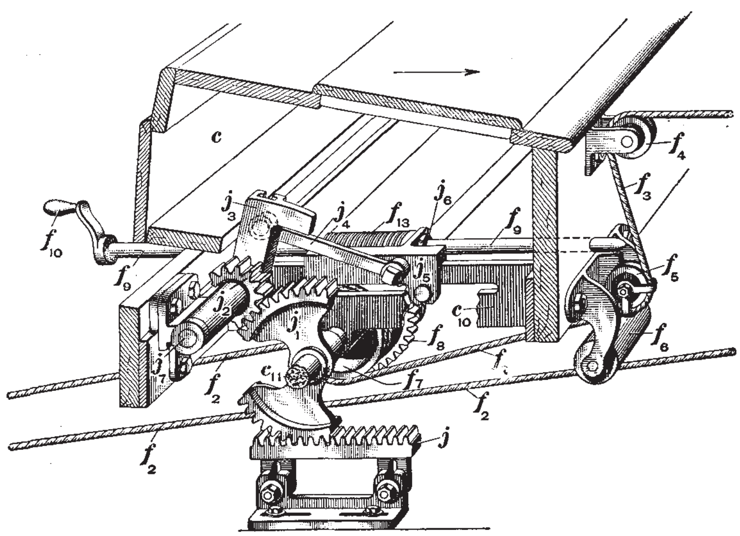


Fig. 13

arm j_3 is also attached to the shaft j_7 and is connected by a link j_4 to a slide j_5 that is free to move in a longitudinal direction on a girt c_{10} extending from the front to the back of the carriage frame. This slide is connected to the shaft f_9 by an extended arm fitting between the worm f_{13} and a collar j_6 setscrewed to the shaft. The effect of the motion imparted to the segment gear j_2 is to turn the shaft j_7 and raise the arm j_3, as shown in Fig. 13, which results in the connecting link j_4 drawing the slide j_5 and, therefore, the shaft f_9 and worm f_{13} forwards, or toward the front of the carriage. This imparts a slight motion to the worm-gear f_8 and drum f_7, and thus winds up a short length of the band f_2 and likewise unwinds some of the band f_3. Normally, that is, when the carriage is away from the delivery rolls and the segment gear j_1 disengaged from the rack j, the arm j_3 is lowered and, as it rests on the link j_4 just below the dead center, it locks the shaft f_9 in its backward position; that is, in a position thrust away from the front of the carriage.

The way in which this mechanism imparts an initial dwell to the carriage is as follows: When the carriage is drawn in, the segment gear j_1 engages the rack and moves the drum f_7, raising the arm j_3, as shown in Fig. 13. As the carriage starts on its outward motion the draft scroll commences to wind up the rope f_2, but instead of drawing out the carriage, the initial movement of the rope f_2 turns the drum f_7, thus forcing the worm f_{13}, shaft f_9, and slide j_5 from the front of the carriage, drawing down the link j_4 and arm j_3 to their locked positions, and, through the segment gear j_2, imparting a motion to the segment gear j_1 in the opposite direction to that imparted by the rack j. The result of this is that the movement of the segment gear against the stationary rack imparts a slow movement to the carriage until the arm j_3 is lowered to its locked position and the segment gear is clear of the rack, whereupon the full speed will be imparted to the carriage by the draft scroll in the ordinary manner. All this movement is accomplished in a comparatively short time, but it allows just sufficient dwell at the start of the outward movement of the carriage to prevent any undue strain on the roving. More or less dwell may be given by raising or lowering the connecting link j_4 in the slotted casting j_3, which allows more or less thrust to the shaft f_9 and worm f_{13} and, consequently, a greater or less movement to the drum f_7.

SQUARING BANDS

19. It is impossible to construct the carriage of the mule so that it will be perfectly rigid, on account of its great length; consequently, since it is driven in the center only, there is a tendency for the carriage to warp so that the spindles will not form a line parallel to the delivery rolls. This tendency, which exists when the carriage is being drawn in as well as when it is being drawn out, is overcome by means of squaring bands. Several drums, one of which, c_{13}, is shown in Fig. 4, are keyed to a shaft that is carried in bearings just beneath the carriage and extends its whole length. The number of drums placed on this shaft depends on the length of the carriage, but generally there are three, one at each end and one in the center. A rope, or band, c_{14}, Fig. 4, is wrapped several times around each drum to prevent any slipping; one end of the band is fastened to a casting bolted to the floor at the front of the mule, while the other is fastened to a similar casting at the back of the mule.

As a result of this arrangement, whenever the carriage moves, the motion of any one portion is immediately transmitted by the shaft to each drum and squaring band, so that all parts of the carriage will move in unison. In order to work properly the squaring bands must be kept tight; this may readily be accomplished by means of ratchets and pawls attached to the castings to which the bands are fastened.

DRIVING OF SPINDLES

20. During the time that the carriage is receding from the delivery rolls, and also while the twist is being placed in the yarn by the accelerated speed, the spindles are being turned by a rope h, known as a **rim band,** which is driven by means of the two grooved pulleys e_5, e_6, Figs. 6, 7, 14, and 15, on the main shaft e. The spindles are, of course, turning all the time that the carriage is being drawn out, being driven in this case by the smaller grooved pulley e_6, which is fast on the main shaft e, as is also the third

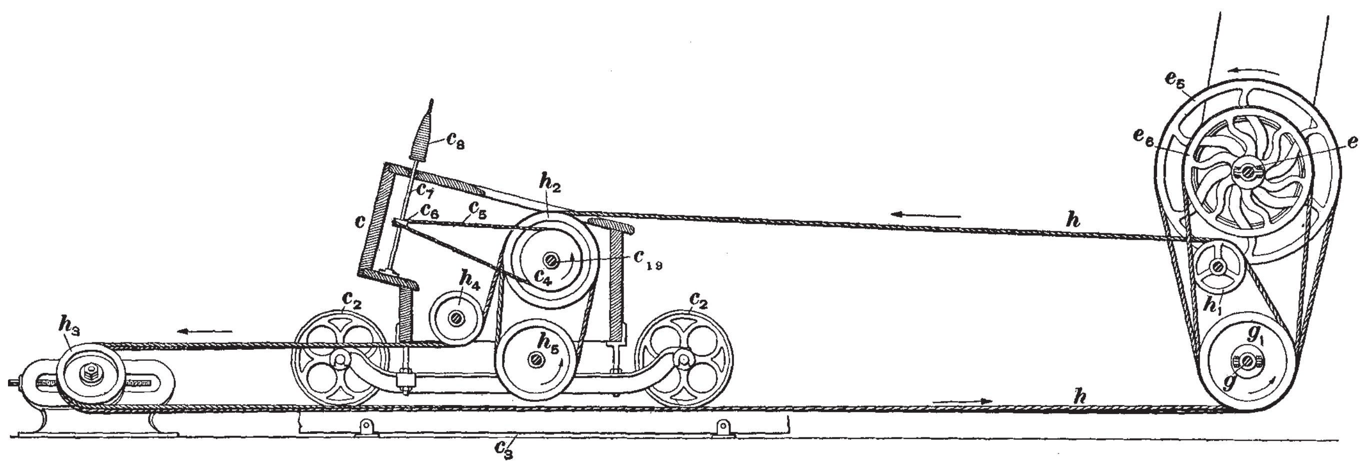


Fig. 14

pulley e_3, to which the belt is at that time furnishing the power for drawing out the carriage. While the rim band is driven by the smaller grooved pulley e_6, the larger grooved pulley e_5 is simply a follower; but when the carriage is drawn out to its full extent, the driving belt is shifted from the third

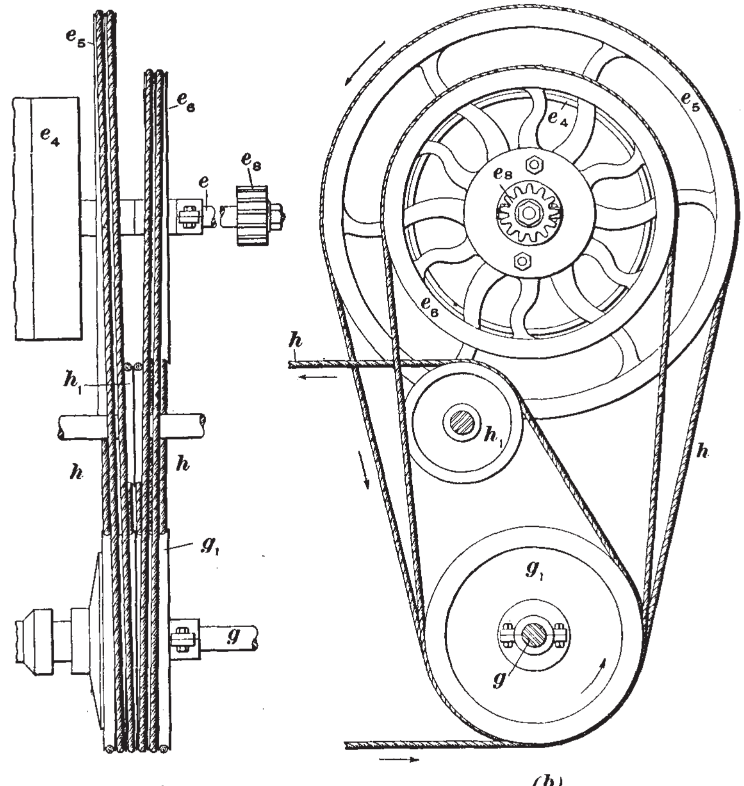


FIG. 15

to the fourth driven pulley e_4, and the rim band is driven by the larger grooved pulley e_5, the smaller grooved pulley e_6 being a follower. In this case motion is imparted to the main shaft e by e_6, since e_4 and e_5 are both loose on the shaft. When the larger grooved pulley is the driver, the spindles are driven at a higher velocity than when the smaller grooved pulley is the driver; this is called the **accelerated speed** and is for the purpose of saving time in putting in the requisite amount of twist after the yarn is drafted. The rim band in this mule is carried through the machine twice, and is known as a *double rim band*. Besides the grooved pulleys on the main shaft, the rim band is passed around a grooved pulley g_1 on the drawing-in shaft g, by means of which the direction of rotation of the spindles is reversed when the carriage backs off. It is also passed around the guide pulleys h_1, h_4, h_5, Fig. 14, around the grooved pulley h_2 on the drum shaft of the carriage, by means of which the motion is communicated to the spindles, and around a binder pulley h_3 that may be moved in a slotted stand attached to the floor for the purpose of adjusting the tension of the band.

21. The driving pulleys e_5, e_6, Fig. 6, on the main shaft are each made in different sizes, so that almost any speed of the spindles may be obtained without altering the speed of any other part of the machine. The slow-speed, or smaller, grooved pulley e_6 is made 11, 12, 13, 14, 15, 16, 17, 18, or 19 inches in diameter, while the fast-speed pulley e_5 is usually made 19, 21, or 22 inches in diameter. The grooved pulley h_2 on the center, or cylinder, shaft of the carriage is 10 inches in diameter. The spindle-band cylinder c_4, Fig. 14, is usually about $6\frac{1}{4}$ inches in diameter and the whorl c_6 on the spindle, 1 inch.

22. In order to find the speed of the spindles, therefore, the following rules are necessary.

To find the speed of the spindles when the driving belt is on the third pulley:

Rule I.—*Multiply the revolutions per minute of the main shaft by the diameter of the smaller grooved pulley and by the diameter of the spindle-band cylinder; divide the result thus obtained by the product of the diameter of the driven grooved pulley on the cylinder shaft and the diameter of the whorl on the spindle.*

EXAMPLE 1.—The main shaft e, Fig. 14, makes 320 revolutions per minute and the smaller grooved pulley e_6 is 18 inches in diameter; the driven grooved pulley h_2 on the cylinder shaft in the carriage is 10 inches in diameter; the cylinder c_4 is $6\frac{1}{4}$ inches; and the whorl c_6 on the spindle is 1 inch in diameter. What are the revolutions per minute when the driving belt is on the third pulley?

SOLUTION.— $\frac{320 \times 18 \times 6\frac{1}{4}}{10 \times 1} = 3{,}600$ rev. per min. of spindles.

To find the revolutions per minute when the belt is on the fourth pulley and twist is being put in the yarn by the accelerated speed:

Rule II.—*Multiply the revolutions per minute of the main shaft by the diameter of the larger grooved pulley and by the diameter of the spindle-band cylinder; divide the result thus obtained by the diameter of the driven grooved pulley on the cylinder shaft multiplied by the diameter of the whorl on the spindle.*

EXAMPLE 2.—What would be the accelerated speed of the spindles in the mule given in example 1, if the larger grooved pulley e_6 were 22 inches in diameter?

SOLUTION.— $\frac{320 \times 22 \times 6\frac{1}{4}}{10 \times 1} = 4{,}400$ rev. per min. of spindles.

In the case of example 1, the spindles would revolve from 1 to 2 per cent. more slowly than figured, owing to the carriage and the rim band traveling in the same direction. This does not happen when the accelerated speed is on, because the carriage is drawn out to the full extent before the belt is shifted on to the fourth pulley. However, in a machine of so complicated a nature as the mule, there is more or less slippage and loss of power, and it is therefore customary to deduct 5 per cent. from the foregoing results in each case, in order to approximate the actual speed of the spindles. This also allows for the fact that the diameter of the whorl and drum should be taken at points representing their effective diameters; that is, for more accurate calculations the thickness of the spindle band should be added to the diameter of both the tin drum and the spindle whorl.

23. Since the rim band is a continuous band running through the machine twice, in different grooves on the same pulleys, it must necessarily be crossed at some point, in order to bring it back to its starting place. If the band were not crossed it would necessitate the use of two bands running side by side and having two splicings, whereas the crossing of the band makes only a single splice necessary. The rim band is crossed, as shown at Fig. 14, between the binder pulley h_3 and the grooved pulley g_1 on the drawing-in shaft.

The band runs in the direction indicated by the arrows on Fig. 14 during the slow speed of the spindles; that is, while it is driven by the pulley e_6, and also while the spindles are being driven at an accelerated speed by the large grooved pulley e_5. During the backing-off of the spindles, however, the rim band is driven by the grooved pulley g_1 on the drawing-in shaft and its direction reversed, in order to reverse the motion of the spindles and wind the yarn down the bobbin previous to winding the stretch of yarn on it.

Fig. 15 (*a*) is a view of the rim band as it appears from the front, or carriage, side of the mule, showing the method of passing the band around the driving pulleys, and Fig. 15 (*b*) is a side view of same. The part of the rope that passes from the right-hand groove of the pulley h_3, Fig. 14, passes to the left-hand groove of the pulley g_1, Fig. 15 (*a*). From this pulley the rope passes around the larger grooved pulley e_5, then back around g_1, then around e_5, then around g_1, until it finally passes over the grooved guide pulley h_1 to the carriage. The other part of the rope, which is in the left-hand groove of the pulley h_3, Fig. 14, passes to the right-hand groove of the pulley g_1, Fig. 15 (*a*), and then around the pulley e_6 in the same manner as the rope on the other side was passed around e_5, both parts of the rope emerging together over the pulley h_1 between the ropes passing from e_5 and e_6 to g_1.

Occasionally the rim band will fly from the pulleys, especially if it is run too slack. When replacing it, first be sure that it is crossed; then, commencing on the outside grooves of the pulley g_1 on the drawing-in shaft, pass the ropes around e_5, e_6, constantly working toward the center from each side until the ropes finally come together over the guide pulley h_1.

EASING-UP MOTION

24. The **easing-up motion** is in operation during the time which the accelerated speed is putting the twist into the yarn. When twist is put into yarn, the yarn grows shorter in length, or, as the effect is technically designated, the yarn *takes up*. Thus, while the accelerated speed is rapidly putting twist into the stretch of yarn, there must be some method of moving the carriage inward slightly, in order to accommodate the twist and ease the tension that the twist generates between the spindles and the delivery rolls. This necessary easing, or drawing in, of the carriage is performed by the easing-up motion, which, as shown in Figs. 6 and 7, derives its motion primarily from the drawing-out gear e_8, which in this case receives motion from the pulley e_4 that is fastened to the pulley e_5 but is loose on the shaft e; the motion is transmitted by means of the rim band h from the pulley e_5 to e_6. The gear e_8 through the gears e_{10}, e_{11}, e_{12}, and clutch

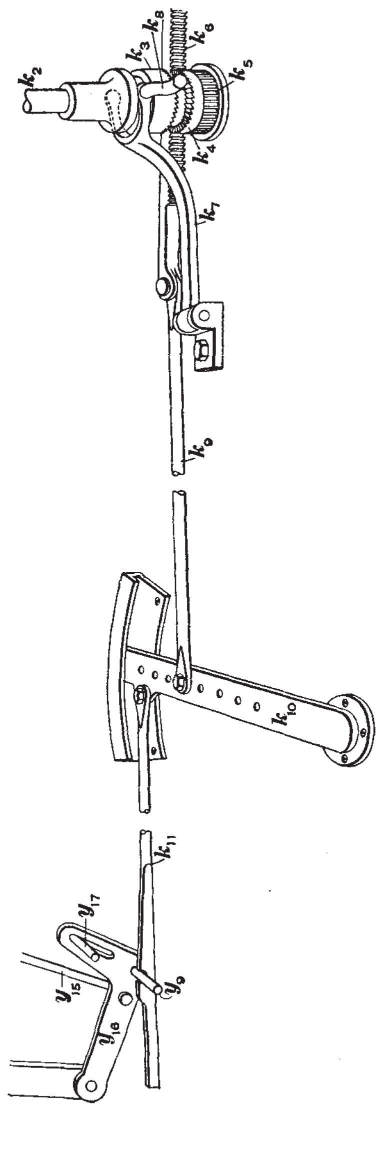


FIG. 16

e_{13}, e_{14} drives the shaft f, on which is fastened the worm k, which meshes with the worm-gear k_1, fast to the upright shaft k_2.

Referring to Fig. 16, the upper part k_3 of a clutch is keyed to the upright shaft k_2, but is movable on the shaft, so that it may be disengaged from the lower half k_4 when the easing-up motion is not in operation. A pinion k_5 that is fast to the lower half of the easing-up clutch meshes with a rack k_6. The two halves of the clutch are allowed to come in contact by the release of the yoke k_7 that controls k_3; this is effected by the removal of the support of the pin k_8 that is attached to the yoke, as will be explained later. The rack k_6 is connected with a rod k_9 that is connected with a lever k_{10} pivoted to the floor. Attached to the outer end of this lever is another rod k_{11}, which connects with the carriage by means of a slot in the rod, with which a pin y_9 attached to the carriage engages. This pin is lifted from the slot at the right time by a suitable mechanism. The object of the lever k_{10} is to furnish a ready method of changing the amount of easing up. The rod k_9 connecting with this lever may be inserted in any of the holes with which the lever is provided, so that any desired amount of motion may be imparted to the carriage. The amount of easing up necessary depends on the amount of twist that is put into the yarn, the most being necessary when the twist is greatest.

The motion is imparted to the carriage by the easing-up mechanism when the two halves of the easing-up clutch k_3, k_4 are in contact, in which case the pinion k_5 draws in the rack k_6 because of its rotation and, consequently, the carriage is also drawn in slightly.

BACKING-OFF MOTION

25. After the completion of the twisting motion, the actual spinning process is completed and it becomes necessary to wind the yarn on the bobbins or cops before another stretch can be spun. Before this can be done it is first necessary to reverse the direction of rotation of the spindles

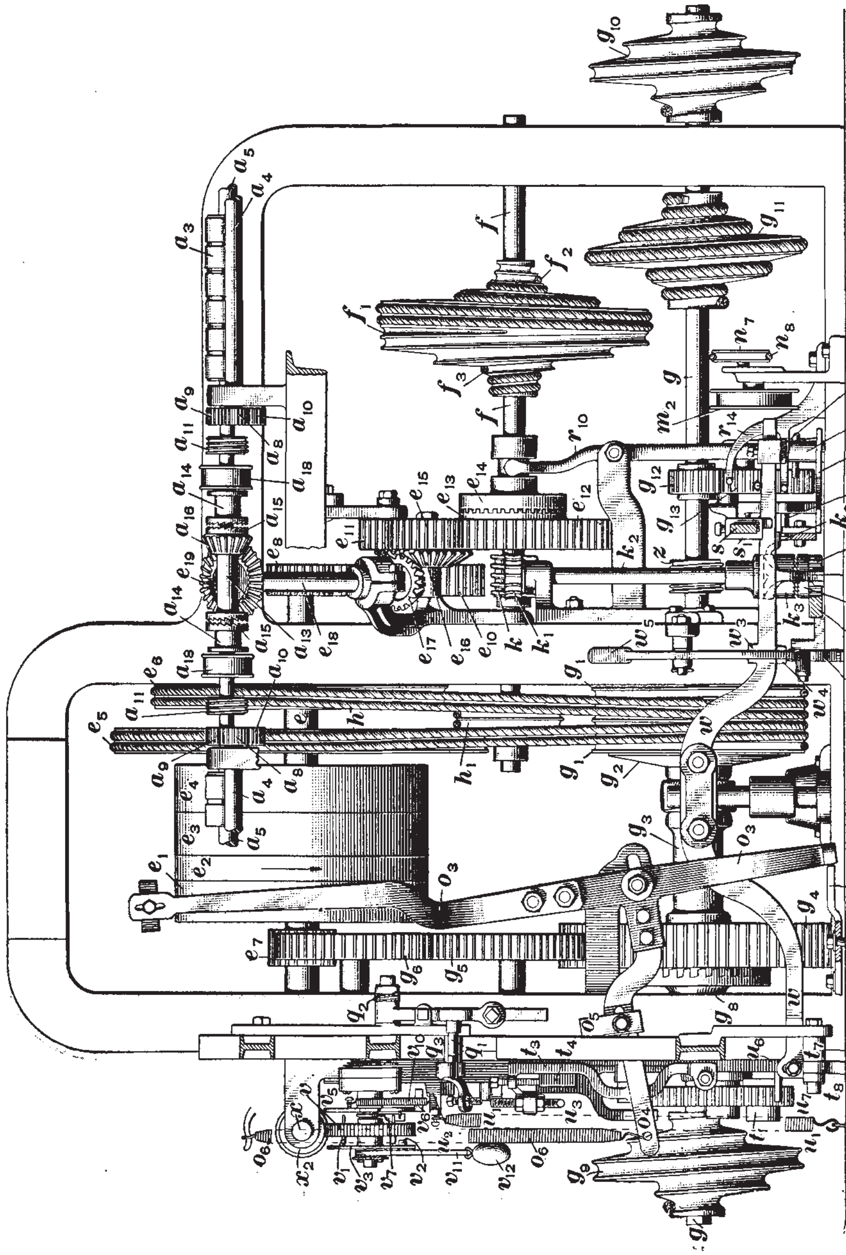


FIG. 17

for a sufficient number of rotations to unwind the coils from the top of the bobbin, but not enough to run over and unwind any of the yarn spun and wound on the bobbin at the previous draw of the carriage. The reason for this unwinding is that, when the spinning process has been completed, a number of irregular coils remain around the top of the bobbin that must be removed before the winding of the bobbin can begin.

In order to reverse the direction of the spindles, the direction of the rim band must be reversed. This is accomplished by driving the band from the grooved friction pulley g_1, Figs. 6, 14, and 17, loose on the drawing-in shaft g. The inside of this pulley is made conical and forms one-half of a friction clutch. The power for the back-off motion originates from the second driven pulley e_2, which is fast to a sleeve that is loose on the main shaft.

Fast to the same sleeve as the pulley e_2 is the gear e_7, which drives the gear g_4 through the intermediates g_6, g_5. The gear g_4 is fast to a sleeve g_3 that is loose on the drawing-in shaft. On the other end of the sleeve is a friction cone g_2 that fits into the grooved friction pulley g_1. In Fig. 6, the back-off friction cone g_2 is not shown in contact, but when the sleeve g_3 is operated on by the back-off lever w, Fig. 17 (which fits into the groove in the sleeve), the friction cone is thrust into the friction pulley, thus transmitting the power from the second pulley e_2 on the main shaft to the grooved pulley g_1 and driving the rim band in the opposite direction. From this it will be seen that the rim band is driven by three agencies during the time in which it is turning the spindles; namely, the grooved pulleys e_6, e_5, g_1, which are driven respectively by the pulleys e_3, e_4, e_2.

At the same time that the backing off is taking place, the winding faller descends, in order to guide the yarn on the bobbin during the next operation—that of winding on. When the winding faller descends, the counter faller simultaneously ascends, in order to keep the tension on the yarn and prevent its kinking up into snarls. The mechanism of the fallers will be considered later, as will also the builder rail, which governs the motion of the faller while guiding the yarn on the bobbin during the winding. It will be sufficient to say here that the winding faller descends quickly in order to make a hard bobbin and one that will unwind easily; it then ascends slowly until the carriage is drawn in.

DRAWING-IN MOTION

26. Leaving out all consideration of the fallers, it will be well to consider how the carriage is drawn in after the backing off and change of the fallers have taken place. The power for drawing in the carriage is derived from the second pulley e_2, Fig. 6, which imparts motion as explained in connection with the backing-off motion to the gear g_4 on the sleeve g_3. However, while the carriage is being drawn in, the backing-off friction cone is not in contact, but the sleeve g_3 is thrust in the other direction and one-half g_7 of the drawing-in clutch on the gear g_4 is in contact with the other portion g_8, which is fast to the drawing-in shaft g, thus imparting motion to the shaft when the belt is on the second pulley and the drawing-in clutch is in contact.

Referring to Fig. 17, which is a view of the headstock, showing the principal parts as seen from the front, or carriage side, of the mule, it will be seen that there are two scrolls g_9 and g_{10} fastened to the drawing-in shaft g. The drawing-in bands are attached to these scrolls and also to the carriage; thus, when motion is imparted to the gear g_4 and the drawing-in clutch is in contact, the scrolls will wind up the drawing-in bands and draw in the carriage.

The drawing-in scrolls have a different action from that of the draft scroll. With the draft scroll, it will be remembered that the band commences on the large diameter and, when imparting motion for the drawing-out of the carriage, is wound down on the small diameter. With the drawing-in scrolls the action is the reverse; the band is wound first on the small portion of the scroll, then on to the greatest diameter, when the carriage receives its greatest speed, and then on to a smaller diameter on the other side of the scroll, The small diameter with which the scroll commences enables the heavy carriage to be started easily and afterwards moved more quickly, while the band running down again on to a small diameter enables the momentum of the carriage to be easily checked. Abruptness of action and the consequent strain on the bands and carriage are thus avoided and still the carriage is drawn in as rapidly as possible, the start and finish being slow. At the same time that the carriage is being drawn in, the spindles are being turned by a special device and are winding the yarn on the bobbins.

27. Check-Band.—It will be seen that there is an extra scroll g_{11}, Figs. 6 and 17, attached to the drawing-in shaft. The band is wound on this scroll in the opposite direction to the bands on the drawing-in scrolls and is known as the **check-band.** The check-band is unwound from its scroll while the drawing-in bands are being wound up, and vice versa. The check-band passes over a binder pulley that is fixed in a slotted casting attached to the floor and is then attached to the mule carriage. The binder pulley may be moved in the slotted casting by means of a screw for adjusting its tension.

The object of the check-band is to exercise a drag and avoid overrunning the carriage, which may readily occur, owing to its high and variable speed, while it is being drawn in by the drawing-in scrolls and bands; that is, the drawing-in scrolls might, were it not for the check-band, give the carriage such a high velocity that the momentum would cause it to overrun itself and go in faster than the scrolls could wind up the drawing-in bands.

The check-band also prevents the carriage from *banging in*, as it is technically called, when the carriage stops with a shock at the end of the draw. To prevent this, the check-band requires delicate adjustment, in order that the carriage may work smoothly while being drawn in, and come gently against the back stops without any shock. The more tension placed on the check-band by screwing back the binder pulley around which it passes, the more gently the

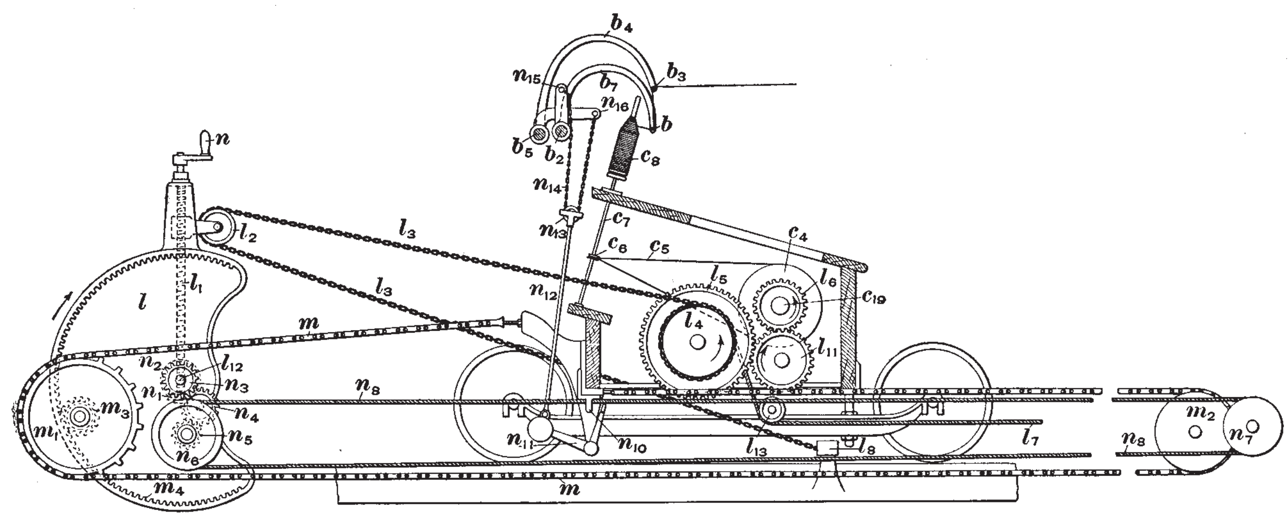

b4
b3
n15
b7
n16
b
b5
b2
c8
n
n14
n13
c7
l2
l3
c6
c5
c4
l5
l6
l1
l
n12
l3
c19
m
l4
l11
n2
l12
n1
n3
n8
m3
n4
m1
n5
n6
n11
n10
l13
l8
l7
m2
n8
n7
m4
m

Fig. 18

carriage will come to a stop at the finish of the drawing-in; and, vice versa, the looser the band, the harder the carriage will bang in.

QUADRANT

28. At the same time that the carriage is being drawn in, the spindles are being turned so as to wind the stretch of yarn between the delivery roll and the spindle on to the bobbin as it is released by the inward run of the carriage. It will be readily seen that in order to wind a stretch of yarn that is of a constant length for each draw of the carriage the spindles must make more revolutions at the start, when the bobbins are empty, than when sufficient yarn has been wound on the bobbin to give it its full size. This is owing to the varying diameter, which is only that of the barrel of the bobbin at the start and larger when the base of the bobbin has attained its maximum diameter; that is, when the *cone*, shown by the dotted lines in Fig. 23 (*a*), has been built. Between these two points the number of revolutions of the spindle required to wind the stretch of yarn is constantly decreasing. This variable speed of the spindles renders it necessary that some device other than the rim band be used for turning the spindles during the drawing in of the carriage. This is accomplished by means of the **quadrant** and accompanying mechanism, shown in Fig. 18. The turning of the spindles for the winding on of the yarn during the drawing in is in reality performed by the motion of the carriage itself, which, pulling against the quadrant l, unwinds the quadrant chain l_3 from the drum l_4, thus of course producing a rotation of the drum l_4 on its shaft. Attached to l_4 is a gear l_5 that meshes

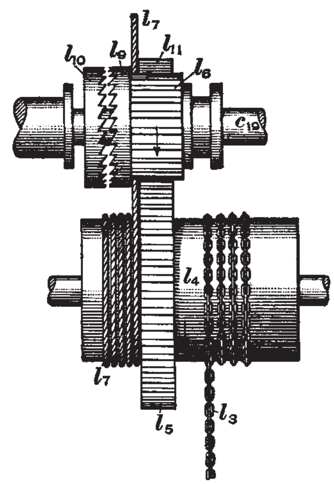


FIG. 19

with an intermediate gear l_{11}; this, in turn, meshes with the gear l_6 loose on the cylinder shaft c_{19}.

Referring to Fig. 19, which is a plan view of the drum l_4, the gear l_6 is fast to one-half l_9 of a clutch; both l_6 and l_9 are loose on the shaft c_{19}. The portion of the clutch marked l_9 is moved in contact with that portion marked l_{10}, which is fastened to c_{19}, immediately after the spindles have backed off and the carriage has started in. Thus, when the drum l_4, on which the quadrant chain l_3 is wound, is rotated, the motion is imparted to the drum c_4, Fig. 18, around which the spindle bands pass, thus imparting motion to the spindles.

The quadrant, as shown in Fig. 18, is driven by means of a chain m that is attached to the carriage. This chain passes around a pulley m_2 and then around the sprocket gear m_1, from which it is conveyed back to the carriage. Attached to the sprocket m_1 is a pinion gear m_3 that meshes into teeth m_4 cut on the inside of the circumference of the quadrant. By this mechanism the quadrant is revolved on its axis around the shaft l_{12}. Thus, when the carriage is drawn in, the quadrant turns toward the carriage. As the carriage comes out again, the quadrant recovers itself, because the chain m pulling over the pulley m_2 turns the sprocket m_1 in the opposite direction.

The quadrant chain l_3 is fastened to a casting l_8 attached to the floor and passes over a pulley l_2 attached to the quadrant before being wound on the chain drum l_4. The pulley l_2 is attached to a differential screw l_1 by means of a block, and by this means may be raised from a point nearly at the axis of the quadrant to a point outside its circumference. The entire quadrant is operated at each inward run of the carriage independently of the position of the pulley l_2.

Suppose that the pulley l_2 is at the bottom of the screw l_1, or *wound down;* then as the quadrant revolves, owing to the movement of the carriage, the position of l_2 will remain nearly the same, owing to its being practically at the axis of the quadrant. Under these conditions the spindles will receive the maximum number of turns, and the amount of the chain l_3 unwound from the drum l_4 will nearly equal the traverse of the carriage on its forward run.

Suppose, however, that the pulley l_2 is raised by means of the screw l_1 until it assumes the position shown in Fig. 18. In this case, the pulley will be carried forwards as the quadrant is turned by the carriage, owing to its being out of center in regard to its position on the quadrant, and less chain will be unwound from the drum l_4; consequently, there will be fewer revolutions of the spindles.

After a full set of bobbins has been doffed from the mule, the pulley l_2 is wound down as far as possible on the screw l_1 by means of the crank-handle n so as to give the maximum number of turns to the spindle. As the winding of the yarn on the bobbin in building the base proceeds, the pulley l_2 is wound up on the screw l_1 in proportion to the increasing diameter of the bobbin.

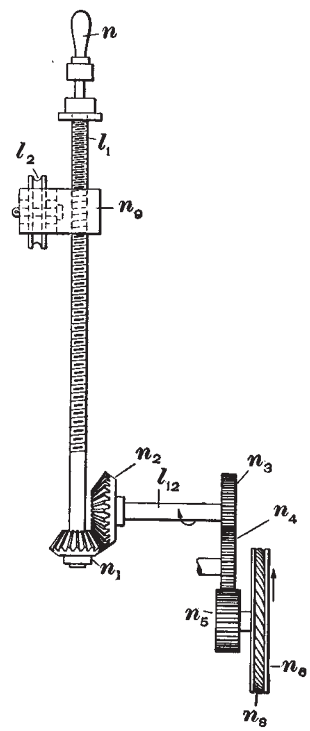


Fig. 20

29. Quadrant Regulator.—The differential quadrant screw is turned by an automatic device that is regulated by the tension of the yarn. If the yarn becomes too tight, as it will if the spindles make too many revolutions, the quadrant screw is turned so that the pulley l_2 will be raised, thus reducing the turns of the spindles and consequently allowing the yarn to be slackened. The pulley l_2 turns in bearings in the block n_9, Fig. 20. Owing to the fact that the screw l_1 is differential, that is, has a constantly changing pitch, it would be impossible to have a thread cut in the block n_9 that would fit the screw at all places; the block therefore has a smooth hole through which the screw passes, having only a pin projecting into the thread of the screw. Attached to the bottom of the quadrant screw is a bevel gear n_1 that meshes with a bevel gear n_2 fast to the shaft l_{12} on which the quadrant is centered. Attached to the same shaft is a gear n_3 that meshes with a gear n_4, this gear, in turn, meshing with a gear n_5. Fast to the same stud as this gear is a grooved pulley n_6.

The parts referred to are also shown in Fig. 18, where it will be seen that there is an endless feed-band n_8 passing around the pulley n_6 and also around a pulley n_7. This band passes directly beneath a casting n_{10} on the carriage, and an elbow lever n_{11}, known as a **grab lever,** is so arranged that under certain conditions it will pinch, or hold, the band against the casting n_{10}. The bite will only hold the band when the carriage is being drawn in. This mechanism does not move the quadrant pulley l_2 at each draw unless the tension of the yarn is such as to make it necessary. The band n_8 is not attached to the carriage; and if the grab lever n_{11} does not hold it against the carriage, there is no motion of the quadrant screw and pulley l_2.

The grab lever is controlled by the position of the fallers. Attached to the outer end of n_{11} is a rod n_{12}, at the top of which is a pulley n_{13}. Around this pulley a chain n_{14} passes and is attached to arms n_{15}, n_{16} fastened, respectively, to the faller shafts b_2, b_5. If the spindles revolve too fast, the yarn will become too tight during the winding as the carriage runs in; this will cause the counter faller b_3 to be lowered, and will allow the lever n_{11} to drop, which it will readily do, owing to its weighted end. The grab lever then assumes such a position that the band n_8, instead of passing freely between n_{11} and n_{10}, is gripped. The motion of the carriage on its inward run then pulls the band n_8 and imparts motion to the quadrant screw l_1 through the train of gears previously mentioned. The direction of this motion is such that its effect is to raise the roll l_2 around which the quadrant chain l_3 passes, thereby allowing less chain to be unwound and thus less turns of the spindles to be made, which will relieve the tension of the yarn by winding less yarn on the bobbin.

The device just explained only works until the base, or cone, of the bobbin is built, after which it takes the same number of revolutions of the spindles for each draw in order to wind on the stretch of yarn. After the cone is built, the spinner usually turns over the end link of the chain n_{14} on the lever n_{15}, thus raising the lever n_{11} from all possible contact with the rope n_8, as if the pulley l_2 is wound up to the top of the screw l_1, the band n_8 is liable to be broken if caught by the lever n_{11}.

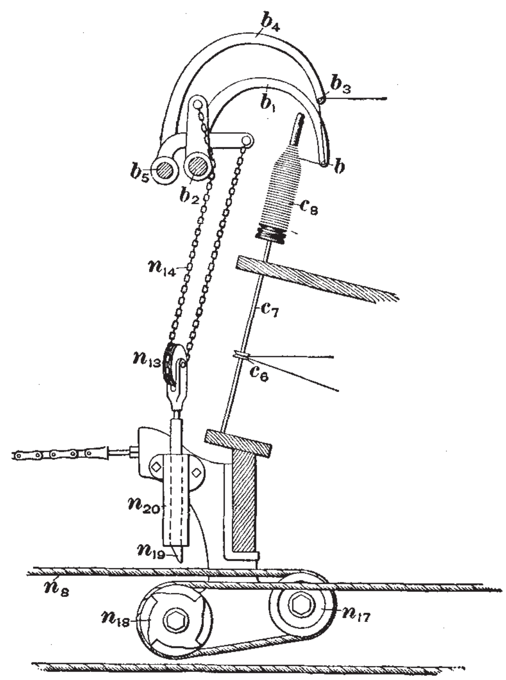


FIG. 21

The reason for having the quadrant pulley moved by a differential screw is that the motion is thus made proportional to the increasing amount of yarn wrapped around the bobbin as its diameter increases; that is, the thickness of a single layer of yarn around an empty bobbin will increase its diameter more, proportionally, than the same thickness when the cone of the bobbin is nearly built. The motion just described for controlling the position of the quadrant-chain pulley is called the **quadrant regulator** and sometimes the **quadrant governor.**

The quadrant-regulating device shown in Fig. 18 is somewhat unreliable, since after the mule has been in operation for some time, the band n_8 will wear grooves in the grab lever n_{11} and projection n_{10}, so that its operation becomes uncertain, as the band n_8 cannot then be as securely gripped. Another defect of this arrangement is that a frayed place or splice in the band will sometimes cause the band to be held and the pulley l_2 raised when in reality there is no necessity for so doing.

A better device for accomplishing the same purpose as the grab lever is placed on the latest-model mules. As shown in Fig. 21, when this device is used the band n_8 is led around a binder pulley n_{17} and then around another pulley that has attached to it a 4-tooth ratchet n_{18}. The chain n_{14} that connects with the fallers governs the motion of a rod n_{19} that is free to rise and fall through a slotted casting n_{20}. During the ordinary running of the mule, the ratchet n_{18} is rotated as the carriage is drawn in, but should the tension of the yarn in winding become so tight as to cause the counter faller to be lowered so as to slacken the chain n_{14} and lower the rod n_{19}, the latter will engage one of the teeth of the ratchet n_{18}, checking its motion and causing the band n_8 to be moved with the carriage and wind up the quadrant pulley l_2, Fig. 18.

Many spinners do not rely on the quadrant regulator, but raise the quadrant pulley l_2 by hand while the bottom of the bobbin is being built, giving the crank n a turn now and then as the height of the counter faller and the tension of the yarn dictate.

30. Action of Quadrant After Cone is Built.—While the cone, or first part of the bobbin, is being built, the quadrant pulley is constantly rising, but when the bottom of the bobbin has attained its final diameter, the quadrant pulley has reached the limit of its upward movement. The quadrant, however, has another function in winding the yarn, without reference to the building of the cone. The top of the bobbin is, of course, always cone-shaped, and the winding-faller wire, when the carriage is drawn in, first descends rapidly, and then rises slowly, being operated by the builder rail, which will be described later. Thus the yarn in being constantly shifted on the cone-shaped top of the bobbin is also being constantly wound on different diameters.

In order to accomplish this successfully, it is evident that the spindles must have a constantly increasing speed as the faller guides the yarn from the large diameter of the bobbin upwards to the nose, where the diameter diminishes to that of the shaft of the wooden bobbin or, if the yarn is being spun into cops, to the diameter of the spindle. This is accomplished by the throw of the quadrant as it moves forwards at each draw of the carriage, which in itself produces a variable speed of the spindles even when the position of the chain pulley on the quadrant is fixed.

When the quadrant pulley has been raised to the top of the quadrant screw and is stationary, there is a definite amount of chain unwound at each draw of the carriage and consequently a definite number of turns of the spindles. But, at the same time, the spindles have an accelerated speed in order to give them a greater number of turns at the finish of the draw when the faller is guiding the yarn on to the bobbin at its nose, where the diameter is smallest. The action of the quadrant itself is responsible for this, without the action of the quadrant screw.

The pulley on the quadrant, around which the quadrant chain passes, moves, in consequence of the motion of the quadrant, in the arc of a circle. This circular motion is composed of a lateral and a vertical motion; thus, as the quadrant pulley is moved while in the top part of its throw, the lateral motion, which is carrying it toward the carriage, allows a smaller amount of chain to be unwound from the chain drum than would be unwound if the quadrant were stationary, and, consequently, the spindles make a smaller number of turns.

As the quadrant continues to turn, the path of the quadrant pulley becomes more and more nearly at right angles to the motion of the carriage during drawing in; thus, a greater amount of chain will be unwound and there will be more turns of the spindles. The speed of the spindles will therefore constantly change in accordance with the positions the faller may occupy relative to the cone of the bobbin.

After the chain has been unwound from the drum, there must be some mechanism for rewinding it before the next inward run of the carriage. This is performed by means of the rope l_7, shown in Figs. 18 and 19, which is wound on the drum l_4 in the opposite direction to that in which the chain l_3 is wound, so that it winds up as the chain is unwound. From the drum l_4 it passes over a guide pulley l_{13}, Fig. 18, and thence to the rear of the machine, where it is fastened and the weight l_{14}, Fig. 5, hung on it. After the carriage is drawn in, the clutch l_9, l_{10}, Fig. 19, is released, so that the drum l_4 is free to revolve independently. As the carriage is drawn out, the rope l_7 is unwound, turning the drum l_4 in the opposite direction to that in which it revolves during the inward run of the carriage, and winding up the chain l_3, as it is slackened by the outward movement, ready for the next inward run of the carriage.

The quadrant chain is thus kept wound on its drum at all times when the clutch l_9, l_{10} is out of contact.

BUILDER MOTION

31. The object of the **builder motion** is to build on the bobbin the yarn spun at each successive outward movement of the carriage. As the carriage is drawn in, the quadrant mechanism imparts the necessary movement of the spindles, and the builder motion guides the yarn on to the bobbin in such a manner as to produce a bobbin of the required shape and size. The guiding of the yarn on to the bobbin is performed entirely by the winding faller, the counter faller simply keeping the yarn at the required tension and preventing slack yarn, which would form kinks.

32. Builder Rail.—The position and motion of the winding faller, therefore, regulate the shape and size of

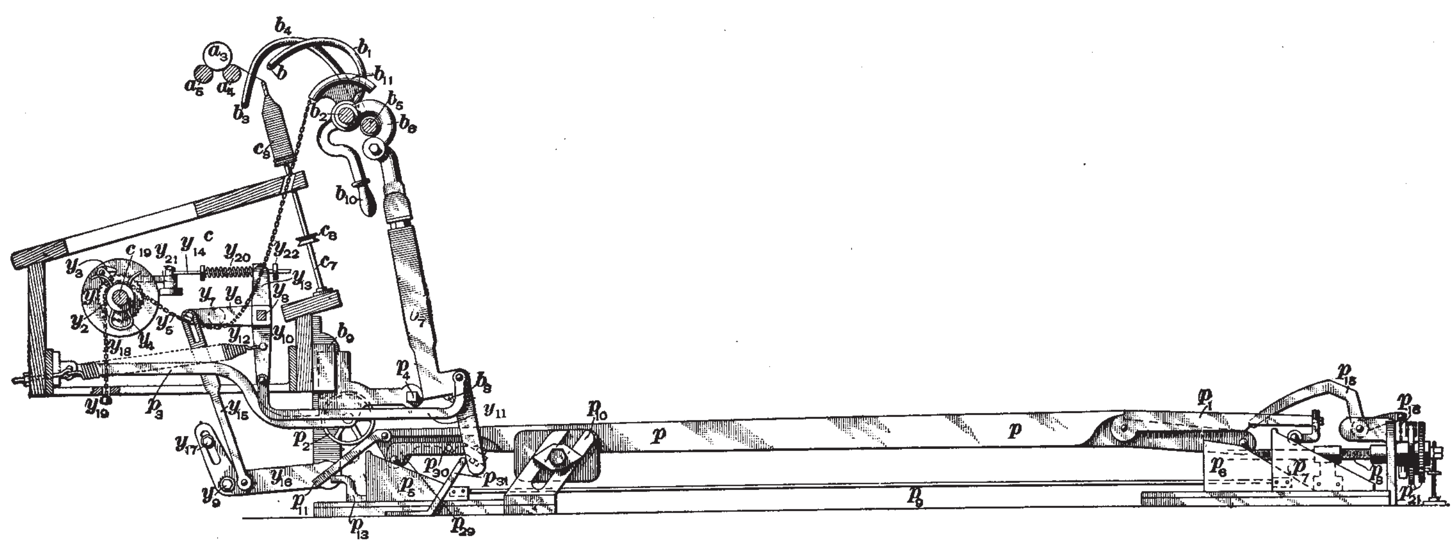


FIG. 22

the bobbin, and in performing its function of guiding the yarn on to the bobbin it is controlled by the position and shape of a rail known as the **builder rail.** The mechanism of the builder motion is shown in Fig. 22, in which the carriage is represented as being drawn completely in to the delivery rolls and the fallers as having just resumed their positions clear of the yarn, as when the drawing-out mechanism is in operation. A short arm b_6 attached to the shaft b_2 of the winding faller b is connected with a bar, or lever, b_7, known as the *faller leg*. A small wheel p_2 known as the *builder-rail traveler* is carried in bearings in the end of a lever p_3 and runs on the surface of the builder rail p when motion is imparted to the carriage. In order that the builder-rail traveler shall not have any lateral movement that would tend to cause it to slip off the builder rail, a projection of the lever p_3 fits into a slot b_9. By means of this arrangement the builder-rail traveler is free to move in a vertical plane but in no other direction, except as it is carried forwards and backwards by the movement of the carriage.

A stud p_4 is fixed in the lever p_3, and during that period of time in which the carriage is being drawn in and the yarn guided on to the bobbin, this stud fits into the angle b_8 of the faller leg, thus supporting it and allowing any vertical motion of the builder-rail traveler to be imparted to it and, through the arm b_6, shaft b_2, and sickle b_1 to the winding-faller wire b. The faller leg is held firmly in contact with the stud p_4 not only by its own weight and the tension of the yarn, which tends to throw the winding faller upwards, but also by means of the springs b_{12}, not shown in Fig. 22 but shown in Figs. 4 and 31, that tend to turn the shaft b_2 in such a direction as to keep the faller leg constantly pressing downwards. From this description it will be seen that the shape of the builder rail p, Fig. 22, and its altitude govern the vertical movement of the builder-rail traveler p_2 as it rolls along the surface of the builder rail while the carriage is being drawn in, and that the position and movement of the winding-faller wire b are governed by the same agency. The movement of the winding faller, however, is in opposition to that of the builder-rail traveler; that is, if the latter rises, the faller wire is depressed, while if the traveler is lowered the faller wire is raised.

The front part p_1 of the builder rail is inclined upwards for a short distance, while the main part p slopes backwards to the end of the inward run of the carriage, so that the traveler in moving over its surface first rises rapidly and then descends slowly, thus producing just the opposite effect on the faller wire; that is, the faller wire first descends rapidly and then rises slowly. Consequently, the yarn is first wound down on the bobbin in a series of coarsely pitched spirals and then wound up again in a series of finely pitched spirals. This method of winding each length of yarn formed at a single draw of the carriage gives the bobbin sufficient firmness to enable it to withstand all ordinary handling without unraveling or slubbing off at the nose.

The builder rail is composed of two parts p, p_1, the latter being in the form of a loose rail hinged to the rail proper. As the yarn is spun and wound on the bobbin it must constantly be wound higher and higher as the bobbin forms, and as this necessitates a corresponding movement of the winding faller, it is evident that as the formation of the bobbin proceeds the builder rail, since its movement is contrary to the movement of the faller wire, must be constantly lowered. This movement of the rail is obtained by means of the *shoes* p_5, p_6, p_7 on which it rests, the main part of the rail p being supported by the shoes p_5, p_6, and the loose rail p_1 by the shoe p_7. These shoes are all rigidly fastened together and when they are operated by the builder gears, which will be described later, they all move backwards in unison, thus lowering all parts of the builder rail. The motion of the shoes is intermittent, one movement taking place at each draw of the carriage; therefore, each stretch of yarn is wound on the bobbin in a slightly higher position than the previous stretch, thus accomplishing the building of the bobbin. When a new set of bobbins is started, the builder rail rests on the highest part of the shoes, but as the formation of the bobbin proceeds, the shoes are moved backwards and the rail lowered until, when the bobbin is finished, it is resting on the lowest part of the shoes. On some mules the builder rail is made in one solid piece, that is, without the loose rail p_1, and since in this case only two shoes, one at each end of the rail, are necessary, it is known as a *two-shoe builder rail*, whereas the one shown in Fig. 22 is called a *three-shoe builder rail*. The object of the three-shoe builder rail is to furnish a convenient method of readily adjusting the rail to form differently shaped bobbins and to relieve the yarn of any undue strain during the winding.

33. The immediate object accomplished by the loose rail p_1 is the lengthening of the *chase* as the cone, or bottom part, of the bobbin is building. The term chase refers to the length of the vertical movement of the winding faller during the time that it is operated by the builder rail; that is, the **chase** is the distance on the bobbin occupied by a single layer of yarn. If the layer of yarn is wound on $1\frac{1}{4}$ inches of the length of the bobbin, the length of the chase is $1\frac{1}{4}$ inches, etc. The lengthening of the chase is due to the difference in the shape of the shoes p_6, p_7, and only takes place while the cone of the bobbin is being built. It will be noticed that for a short distance at the top, the shoe p_6 is inclined at a lesser angle than the shoe p_7; thus, as both shoes are moved backwards at the same speed, the end of the loose rail p_1 will be lowered faster than the main part of the rail p during the first part of the movement. The effect of this is to increase the inclination of the loose rail and therefore the length of the vertical movement of the builder-rail traveler, of the winding

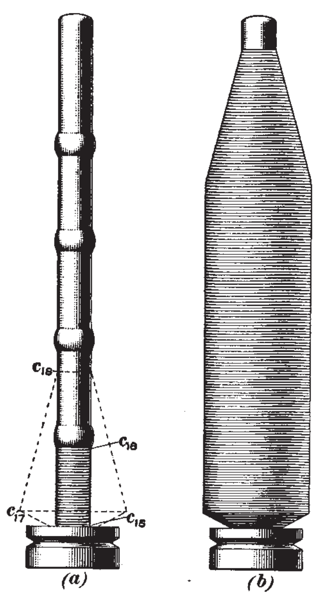


Fig. 23

faller, and the length of the chase. Thus, as shown in Fig. 23 (*a*), the first stretch of yarn will be wound on the bobbin between the points c_{15}, c_{16}, and as the builder rail is lowered, each succeeding layer will be wound on the bobbin slightly higher and the length of the chase also increased, until a layer c_{17}, c_{18} is formed. When this point is reached the shoes will have been moved backwards so that the builder rail is just commencing to move down the steeper part of the shoe p_6, Fig. 22, and the cone of the bobbin, shown by the dotted lines in Fig. 23 (*a*), will have been formed. From this point the slant of each shoe is the same; therefore, all parts of the builder rail will be lowered an equal distance at each draw of the carriage and the length of the vertical movement of the builder-rail traveler, of the winding faller, and the length of the chase will remain constant. Each successive stretch of yarn, however, because of the constant lowering of the builder rail, continues to be wound on the bobbin slightly higher than the previous stretch, until a full bobbin, as shown in Fig. 23 (*b*), is obtained.

As the builder rail is lowered it is guided by a slotted steadying bracket p_{10} with which a stud on the rail engages. The slot in this bracket slants in the opposite direction to the inclination of the shoes, so that as the rail is lowered it is thrown against the shoes, thus giving it greater stability and steadiness. The inclination of the slot also has the effect of moving the builder rail backwards in a horizontal direction as it is lowered, which will result in the rail being lowered somewhat more slowly than if a vertical slot were used; this backward motion of the rail will also increase the length of the short incline of the rail and shorten the long incline, because it will move the highest point of the rail nearer to the center of the movement of the carriage. This will result in the winding faller performing its downward motion at a slower rate of speed and its upward motion correspondingly quicker. This is beneficial, because as the bobbin is built higher there is less slack yarn caused by the backing-off motion unwinding the coils of yarn between the yarn already spun and the top of the spindle, on account of the diminished distance for such coils to form, and consequently there is greater strain on the yarn during the initial, or downward, movement of the winding faller. Therefore, by causing this downward movement of the winding faller to become slower as the bobbin increases in size, this strain on the yarn during the initial movement of the winding faller is mitigated.

At the back end of the builder rail a casting p_{11} known as the *flip* is hinged, the loose end resting on a casting p_{13}. As the rail is lowered the flip becomes raised relative to the rail, since the end attached to the rail is lowered with it, while the other end, resting on the casting p_{13} remains stationary. As a result, the angle, or corner, of the flip becomes raised above the surface of the builder rail and as the carriage comes against the back stops, the builder-rail traveler strikes the projection thus formed, and imparts a sharp snap, or *flip*, to the winding faller. The effect of this is to wind a few turns of yarn down over the nose of the bobbin, thus making a firmer nose and preventing the yarn slubbing up the bobbin. As the bobbin increases in size the amount of this movement of the winding faller will be increased, because the greater the distance that the builder rail is lowered, the farther the flip projects above its surface. The pin supporting the back end of the builder rail on the shoe p_6, instead of being fixed in the rail, is attached to a casting p_{29} that is fulcrumed at p_{30} and is adjustable by means of a setscrew. By this means it is possible to adjust the back end of the rail so that it will be higher or lower as may be desired. Raising the back end of the builder rail has the effect of shortening the length of the upward movement of the winding faller, and lowering it lengthens this movement, thus shortening or lengthening the taper of the bobbin.

34. Builder Gears.—The movement of the shoes that control the builder rail is imparted by means of the builder gears, of which Fig. 24 (*a*) is a front and Fig. 24 (*b*) a side view. A roll c_{12} is attached to a bracket fastened to the front of the carriage in such a position as to engage

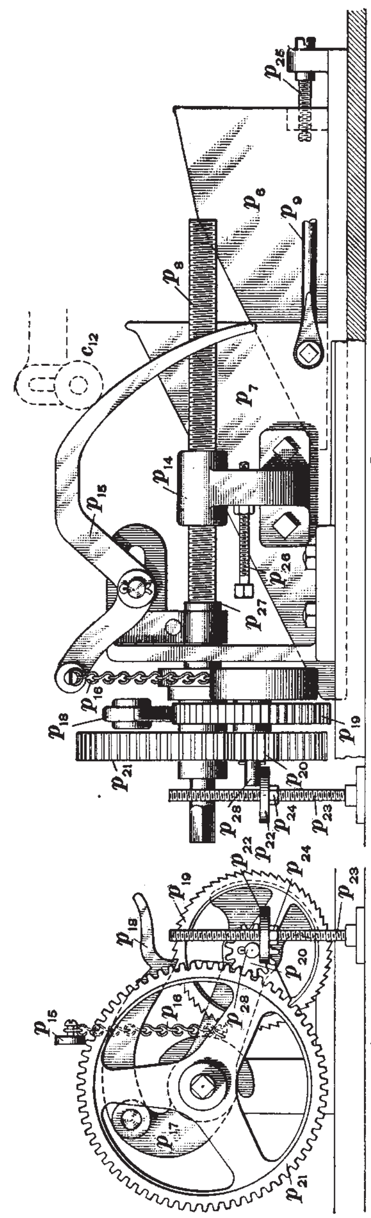


Fig. 24

a lever p_{15} at each draw of the carriage. As the lever p_{15} is engaged by the roll c_{12} the chain p_{16} will raise an arm p_{17} that is loosely supported on the shaft of the screw p_8. In one end of the arm p_{17} is a stud p_{28} that carries a ratchet p_{19} compounded with a gear p_{20} that meshes with a gear p_{21} that is fastened to the shaft of the screw p_8. At the other end of the arm p_{17} is fastened a pawl p_{18} that engages with the ratchet p_{19}. As the arm p_{17} is raised (together with the ratchet p_{19} and gear p_{20}), in consequence of the roll c_{12} engaging the lever p_{15}, the gear p_{21} will be turned, because the teeth on the ratchet p_{19} are inclined in such a direction that the pawl p_{18} will prevent it and, consequently, the gear p_{20} from rotating. Since the gear p_{21} is fastened to the shaft of the screw p_8, this will impart a slight rotary motion to the screw, and as the latter is threaded in a casting p_{14} attached to the shoe p_7, the shoe will be moved backwards, allowing the builder rail to be lowered slightly.

The shoe p_7 has an extended base, to which the shoe p_6 is attached by means of an adju :ing screw p_{25}; the shoe p_5, Fig. 22, is attached to the shoe p_7 by means of the rod p_9. Thus the motion of the screw p_8 is transmitted to each of the shoes, and the builder rail thereby lowered.

As the carriage is drawn in, the roll c_{12} is drawn away from the lever p_{15}, and in consequence the tension on the chain p_{16} is relieved and the arm p_{17} falls, because of the weight of the ratchet p_{19} and gear p_{20} at its extremity. As this takes place the gear p_{20} is turned and the pawl p_{18} takes up on the ratchet p_{19}, assuming a new position for moving the gear p_{21} at the next draw of the carriage. In order to prevent any movement of the shoes and builder rail other than that imparted by the correct working of the builder gears, the screw p_8 turns in a friction plug, or bushing, p_{27}, which causes the screw to turn with sufficient difficulty to prevent any movement from vibration or the shock of the builder-rail traveler on the rail when the faller leg is locked.

The distance that the builder gears fall when released by the inward run of the carriage is regulated by means of a table p_{22}, which is threaded on a fixed screw p_{23} and supports the weight of the arm p_{17} by means of an extension of the stud p_{28} on which the ratchet p_{19} and gear p_{20} are centered. The lower this table is adjusted on its screw support, the greater the number of teeth that the pawl p_{18} will take up in the ratchet p_{19} at each fall of the builder gears, and consequently the faster the builder rail will be lowered. The faster the builder rail is lowered, the greater the speed at which the winding faller will rise, and the faster the winding faller rises, the smaller in diameter will be the bobbin; hence, the table p_{22} furnishes a ready means of regulating the size of the bobbin. The higher this table is adjusted on the screw, the larger will be the diameter of the bobbin, since in this case the builder rail will be lowered at a slower speed and the corresponding speed of the winding faller in rising will allow more yarn to be placed on the bobbin. A check-nut p_{24} locks the table p_{22} in any desired position and prevents accidental changes in the size of the bobbins.

The diameter of the bobbin may also be changed by setting the roll c_{12} on the carriage in a higher or lower position. In the former case a larger bobbin will be made, since less motion will be imparted to the builder gears and rail, while in the latter case a smaller bobbin will be made, because the builder gears will be lifted higher and will consequently lower the builder rail to a greater extent.

35. It is not out of place in connection with the size of the bobbin to mention the factors governing its hardness or firmness of structure, since this element governs the diameter of the bobbin to a certain extent, in that a soft bobbin is of larger diameter than a hard one, in consequence of the individual layers of yarn not lying so closely together. The hardness of the bobbin may be regulated by means of the weights b_{19}, Figs. 4 and 31, which by their connection with the counter-faller shaft b_5 govern the force that the counter-faller wire b_3 exerts on the yarn, and consequently its tension during winding. If more weight is applied to the counter faller, a greater tension is produced on the yarn during winding; hence, a harder bobbin will be formed. These weights are made similar to the weights of a pair of scales, and as many may be used as will be necessary to produce a bobbin of the required hardness, provided that the strength of the yarn is sufficient to withstand the amount of tension necessary to produce a bobbin as firm as desired. As the number of weights used and the consequent tension of the yarn depends largely on the strength of the yarn, coarse yarn requires more tension than finer yarn. Sometimes when running out lots there will remain only two or three jack-spools to be spun, in which case the weight on the counter faller should be correspondingly decreased.

OPERATION OF THE MULE AS A WHOLE

36. So far only those mechanisms that deal with the essential operations of the mule have been considered, and nothing has been said of other mechanisms that enable the parts performing the different functions of the mule to be put in operation at certain periods, nor of those mechanisms by means of which one motion is discontinued in order that another may begin. The action of the mule will now be considered during a complete cycle of the movements of a single draw, commencing with the carriage drawn in with the spindles in close proximity to the delivery rolls and ending with the reengagement of the parts previous to the next draw of the carriage.

37. Shipper Lever.—The movement of the mule as a whole is controlled primarily by means of the shipper lever o, Fig. 25, which is fulcrumed on a stand bolted to the floor at the front of the machine. A sliding incline o_2 attached to the shipper lever by means of a rod o_1 controls the movement of the belt lever o_3 and, consequently, of the driving belt, the end of the belt lever being pressed against the incline by means of a spring o_6 that is attached to an arm o_4 of the belt lever, also shown in Fig. 17. By pushing in the upper end of the shipper lever o toward the carriage the incline o_2 will be drawn forwards, as shown in the illustration, throwing the belt on to the loose pulley e_1 and stopping the mule in whatever position the carriage is, without regard to what motion is in operation at that time. Drawing the upper end of the shipper in the opposite direction will have the opposite effect and, with one exception that will be noted later, will start the mule in operation without regard to the position of the carriage or other parts, so that the motion of the mule will commence at exactly that period of its complete action in which it was previously stopped.

STARTING OF MULE

38. As the mule is started, therefore, the shipper lever is pulled away from the carriage and the incline o_2 moved backwards, which will allow the spring o_6 to pull the belt

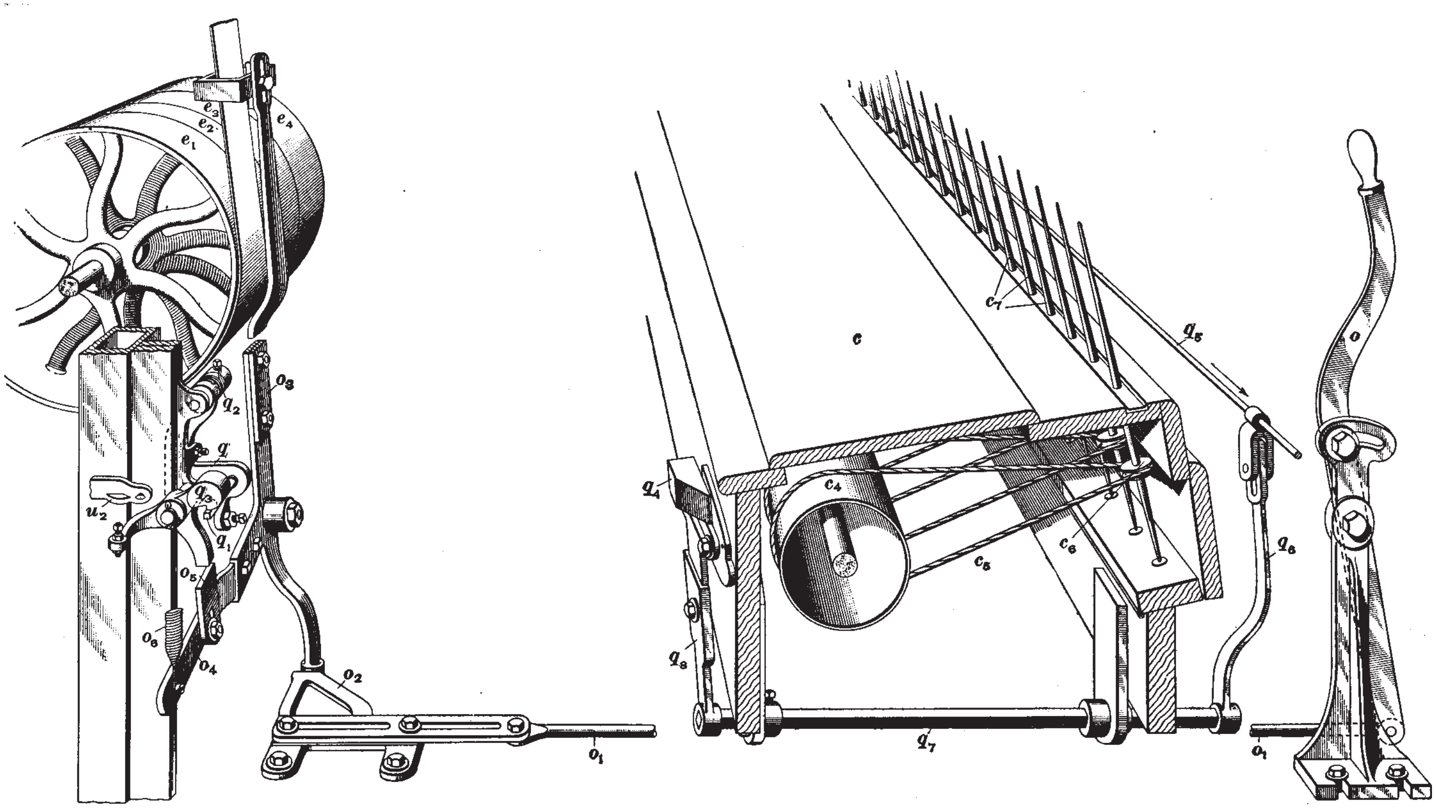


Fig. 25

lever o_3 over and thus throw the driving belt on to the driving pulleys. This movement of the belt lever is checked when the driving belt reaches the third pulley e_3 by an adjustable stop t_4, Fig. 27 (a) and (b), attached to the end of the lever t_3. The belt is moved over the pulley e_2, Fig. 25, but does not remain in contact with it for more than a fraction of a second; moreover, the pulley e_2 is virtually loose at this time, since neither the backing-off friction cone nor the drawing-in clutch are in contact, as the backing-off lever is in its neutral position. The motion of the driving belt, therefore, is at the start communicated to the third pulley e_3, which transmits the power to the draft scroll f_1, Figs. 6 and 17, the delivery rolls, and the smaller grooved rim-band pulley e_6. Thus three operations are commenced at the start—the carriage begins to recede from the delivery rolls, first slowly, by virtue of the dwell motion; the roving is delivered by the delivery rolls; and motion is imparted to the spindles.

39. Detent Mechanism.—The one instance in which the mule will not be started if the shipper handle is pulled away from the carriage is when the **detent mechanism,** shown in Figs. 25 and 27 (a) and (b), is unlocked. A lever q in which is fixed a stud q_1 tends to be forced forwards by a coil spring q_2, but may be locked back by means of a detent catch q_3 that engages with the stud q_1 whenever the lever is forced backwards far enough to allow this catch to drop over the stud. When, however, the detent catch q_3 is unlocked and the lever q is in its forward position, as shown in Fig. 25, its lower end is directly above a casting o_5 bolted to the arm o_4 of the belt lever, making it impossible for the mule to be started, because the casting o_5 will come in contact with the lower end of the lever q and prevent the arm o_4 from rising high enough to allow the belt to be shipped to the third pulley e_3. When, however, the lever q is moved backwards and the stud q_1 locked by the detent catch q_3, the lower end of the lever will be back far enough so that the casting o_5 will escape it and the belt lever be free to move the belt to the third pulley e_3 and also the fourth pulley e_4, if desired.

The lever q is locked by means of a movable wedge q_4, Fig. 25, on the carriage that is operated by a sliding rod q_5 on the front of the carriage, through the lever q_6, the shaft q_7, and the lever q_8. The wedge q_4 comes in contact with an adjustable setscrew in the lever q and if the rod q_5 is moved in the direction of the arrow, will assume such a position as to force back the lever q and allow it to becme locked. It will be seen, therefore, that when the carriage is drawn in, if it is desired to start the mule, not only must the shipper lever o be drawn forwards, but the rod q_5 must also be moved in the direction of the arrow, or to the left of the spinner.

The object of this detent mechanism is to allow the spinner to stop the mule at the end of any draw—that is, when the carriage is drawn in—from any position in which he may be. For instance, if he was at one end of a long mule and desired to stop the carriage in order to piece up several broken ends, or to place a new spool of roving in the mule, it would be very inconvenient to accomplish this with the shipper lever, as this would be 25 or 30 feet away. It should be particularly noted that the rod q_5 if moved to the right of the spinner, or in a direction opposite to the arrow, will stop the mule only when the carriage has been drawn completely in; that is, the mule will continue in operation and complete the draw, but will stop at the end of its inward motion. While the mule is running, therefore, the rod q_5 must be kept to the limit of its movement in the direction of the arrow, so that the wedge q_4 will be in position to lock the lever q each time that the carriage comes in, as otherwise the mule will stop. The lever q is unlocked at every draw of the carriage by means of a projection u_2 attached to the twist slide—a mechanism that will be described presently—which, when the twist slide drops, strikes an adjustable setscrew in the detent catch q_3, thus freeing the stud q_1 and lever q. Thus, if the wedge q_4 is not in position to lock the lever q again, the carriage must stop.

40. Roving Stop-Motion.—With the belt on the third pulley e_3, the roving motion, drawing-out motion, and rim band continue in operation without change until the requisite length of roving is delivered, whereupon the delivery rolls are stopped by the roving stop-motion, while the motions of the carriage and rim band still continue.

DISCONNECTION OF DRAWING-OUT MOTION

41. Disengagement of Drawing-Out Clutch.—The next change that takes place is the checking of the outward movement of the carriage. When the carriage is drawn out until the spindles are 72 inches, or about that distance, from the delivery rolls, a bunter on the carriage comes in contact with a lever r, Fig. 26 (a), forcing its upper end forwards and moving the rod r_1 attached to its lower end backwards. At the other end of the rod r_1 is a wedge r_2 that slides in a slot in the draft slide r_3, as shown in detail in Fig 26 (b). As the wedge r_2 is forced backwards it raises from a notch r_4, Fig. 26 (a), in the draft slide a stud s_4 that is attached by a lever s_3 to a rod s known as the *latch rod*. As this takes place the draft slide is drawn forcibly backwards by a spring r_7 attached to it and to the stand r_{14}, its motion being checked when it has moved the proper distance by a casting r_9 against which it strikes. The draft slide is cast with a recess r_5 in one end [see Fig. 26 (b)], which, together with the wedge-shaped end r_6, serves as a guide for the lower end of the lever r_{10}. The upper end of this lever r_{10} is fitted with a yoke to operate the movable half e_{14} of the toothed drawing-out clutch, also shown in Fig. 17. As the draft slide is drawn backwards, therefore, the lower end of the lever r_{10} is forced into the recess r_5 in the slide, and its upper end disengages the drawing-out clutch e_{14}, thus checking the outward movement of the carriage. A spring r_{12} keeps the drawing-out clutch in contact when the lever r_{10} does not hold e_{14} away from e_{13}.

42. Easing-Up Motion.—At the same time that the drawing-out motion is disengaged, that is, when the draft slide is released, the easing-up motion is put in operation. This is accomplished by means of a raised place r_{13} on the edge of the draft slide, on which rests the stud k_8 that holds

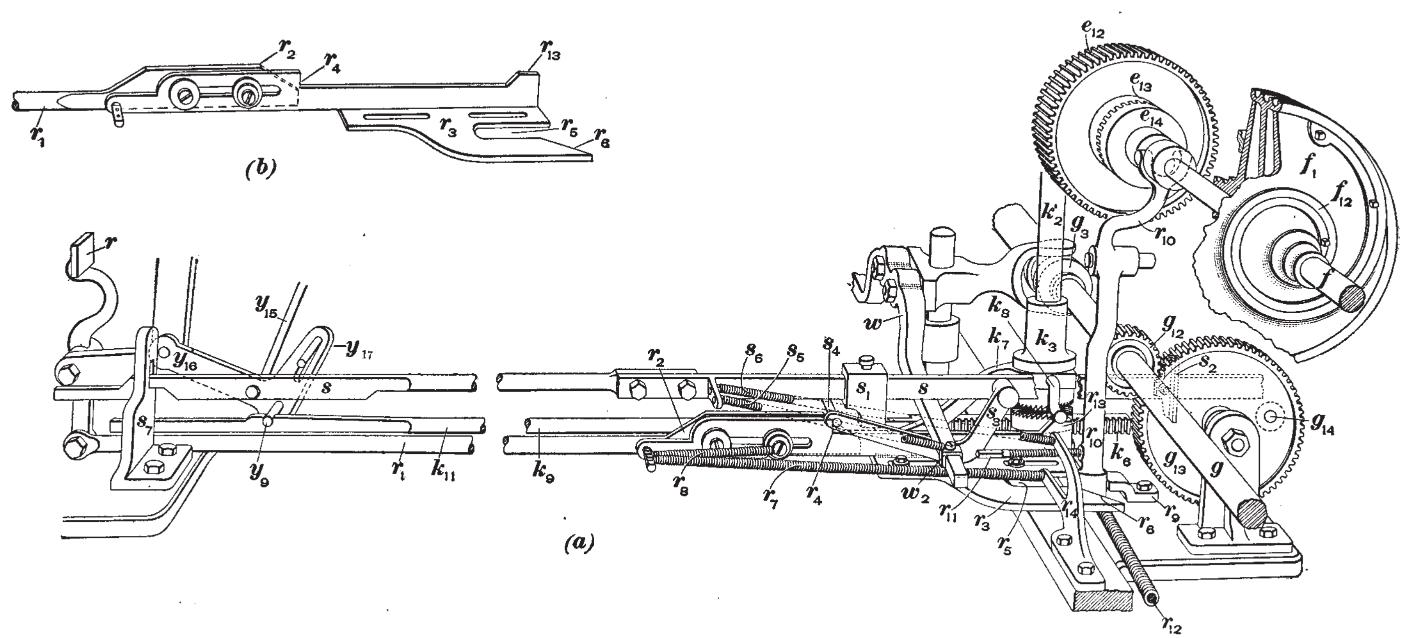


FIG. 26

the easing-up clutch k_3 out of contact when the easing-up motion is not in operation. As the draft slide is released, this raised edge r_{13} moves out from under the stud k_8, thus allowing the part k_3 of the easing-up clutch to drop in contact with k_4, Figs. 16 and 17, and the carriage to be eased up.

It will be noted that as the carriage is drawn out, the stud y_9 drops into the notch in the rod k_{11} and thus replaces the rods and consequently the rack k_6 in their initial positions.

43. Accelerated Speed.—At the same time that the easing-up motion is in operation the spindles are being driven at the accelerated speed, which necessitates that the belt be shifted to the fourth driven pulley e_4, Fig. 6, in order that the large grooved pulley e_6 may drive the rim band. This is accomplished at about the time that the carriage reaches the end of its outward movement, in the following manner: When the belt is on the third pulley, the arm o_4, Fig. 27, of the belt lever rests against the stop t_4 on the lever t_3. As the carriage is being drawn out, motion is imparted to the drawing-in shaft g by reason of the drawing-in bands being unwound from their scrolls; in consequence, motion is imparted to the gear g_{15}, which is fast to the drawing-in shaft, and transmitted to the gear t, which meshes with g_{15}. On the back of the gear t is a projection t_2 that as the gear rotates comes in contact with an adjustable setscrew in the end of the lever t_3, thus forcing the lower end of the lever t_3 outwards, against the pressure of a flat spring t_5, and releasing the arm o_4 of the belt lever. When this release takes place, the spring o_6 will pull the arm o_4 upwards until it is stopped by an adjustable **T** piece u_3, thus shipping the driving belt to the fourth pulley e_4.

DROPPING OF THE TWIST SLIDE

44. The Twist Slide.—The accelerated speed continues to put twist into the yarn until it is checked by the dropping of the twist, which is accomplished by means of the mechanism shown in Fig. 27 (*a*) and (*b*). The gear e_9, which is attached to the main shaft e of the headstock, drives a gear x_1

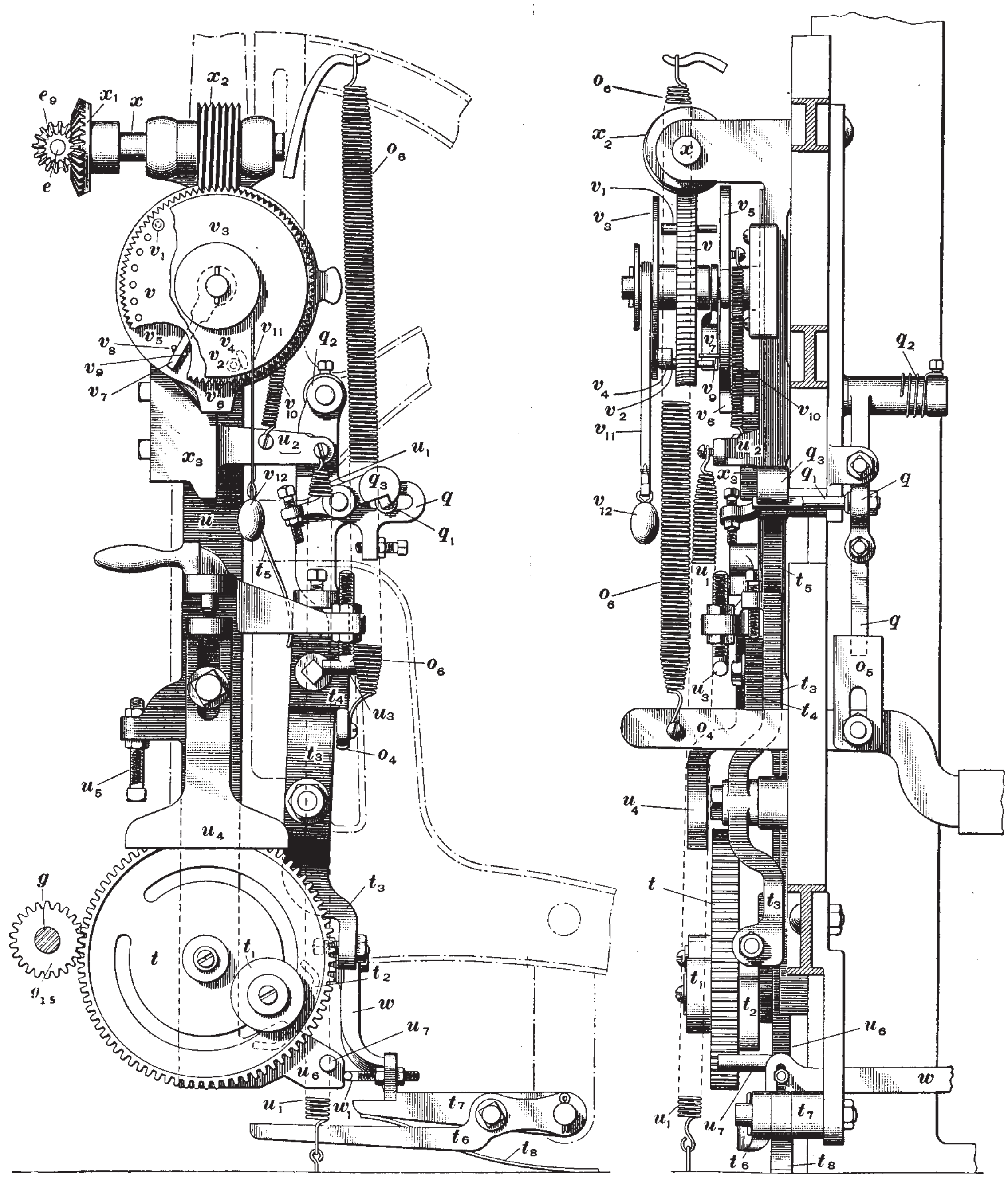


FIG. 27

15429 § 37

fastened to a short cross-shaft x, to which is fixed a worm x_2 that imparts motion to the twist-pin gear v; this gear is loose on a stud fixed in the twist slide u, which is simply a casting free to fall in a vertical direction through a limited distance unless locked. The stud that supports the twist-pin gear v also carries a lock-plate v_5 and a cover-plate v_3, both of which are loose on the stud. The lock-plate has a projection v_6 that rests on a casting x_3 bolted to the framework of the mule, and in this manner holds the twist slide u in a raised position so that the pin gear v will mesh with the worm x_2. In addition, the stud on which the lock-plate is supported carries a knock-off v_7 that is supported between two pins v_8, v_9 on the lock-plate in such a position as to be engaged by the pin v_1, which may be placed in any one of the holes with which the twist gear v is provided. As motion is imparted to the twist-pin gear, the lock-plate remains stationary until the pin v_1 comes in contact with v_7, whereupon the lock-plate will be moved, against the tension of a spring v_{10}, sufficiently to allow the projection v_6 to slip off the casting x_3 and a strong spring u_1 to pull the twist slide u and all parts connected with it to a lower position, thus among other results allowing the twist gear to become clear of the worm x_2.

During the time that the gear v has been turning it has been imparting motion to the cover-plate by means of a pin v_2 that engages a projection v_4 cast on the inside of the plate; this motion of the cover-plate winds up a weight v_{12} that is attached to it by means of a leather strap v_{11}. When the twist gear is removed from contact with its driving worm, the weight v_{12} turns the plate v_3 and, consequently, the gear v in the opposite direction until the pin v_2 comes in contact with v_7, thus resetting the twist-pin gear in its initial position. The lock-plate is returned to its initial position by the spring v_{10}, the projection on the lock-plate engaging with the casting x_3 immediately that it is raised above it.

45. With the dropping of the twist several changes are made in the action of the mule, the immediate result being the stopping of the accelerated speed and the commencement of the backing off of the spindles. As the twist slide u is drawn down by the spring u_1, the **T** piece u_3 that is threaded in an extended arm of the slide casting forces down the arm o_4 of the belt lever until the driving belt is carried from the fourth to the second driven pulley. In order that the arm o_4 shall be carried down just far enough to bring the belt to this pulley, an adjustable setscrew u_5 is threaded into another extended arm of the slide casting u and by striking against a stop on the framework of the mule governs the extent of the fall of the twist slide and, consequently, the length of movement of the **T** piece u_3.

As the arm o_4 is carried below the stop t_4 on the lever t_3, the spring t_5 swings the lever t_3 to the right to its original position at the beginning of the drawing-out motion ready to receive the arm o_4 again when the belt is shipped to the third pulley at the next draw of the carriage.

46. As the pin v_1 in the twist gear controls the dropping of the twist slide, it also controls the checking of the accelerated speed and, consequently, the amount of twist placed in the yarn. By moving v_1 away from v_7 more twist will be placed in the yarn, while setting the pin forwards will have the opposite effect. It might be thought that instead of the knock-off v_7 that is carried loosely on the stud and secured to the lock-plate v_5 by the pins v_8, v_9, a simple projection on the lock-plate would serve to unlock the twist slide. This arrangement, however, has a special purpose in that it allows the pin gear v to make more than a single revolution if it is desired to place a greater amount of twist in the yarn than can be obtained in the ordinary way. This extra amount of twist is obtained by removing one of the pins v_8, v_9 that support the knock-off v_7; suppose, for instance, that the pin v_9 is taken out. When the twist gear v is reset by the weight v_{12}, it will be rotated until the pin v_2 strikes the knock-off v_7 and forces it against the right-hand side of the pin v_8. Ordinarily the twist gear v revolves while the twist is being placed in the yarn until the pin v_1 strikes the knock-off v_7 so as to turn the lock-plate v_5 and disengage the projection v_6 from the casting x_3, which allows the twist slide u to drop; but in this case since the pin v_9 is removed, no support is given v_7 to accomplish this result until v_1 has pushed it around one complete revolution and forced it against the left-hand side of the pin v_8. The twist gear therefore makes one complete revolution before the twist slide drops, in addition to the number of holes that the pin v_1 is set. This, consequently, gives an adjustment whereby the amount of twist in the yarn can be greatly increased or even doubled if so desired. For instance, suppose that 70 holes of twist are wanted and the twist gear contains only 50 holes; then all that is necessary is to set the pin v_1 for 20 holes and remove the pin v_9, which will give 20 holes plus one revolution of the twist gear (50 holes) or 70 holes of twist. The number of holes of twist required by yarns of different sizes varies, and it may be generally stated that coarse yarn requires fewer holes of twist than finer yarn. Much also depends on the stock, as yarn made from poor and weak stock naturally requires a greater amount of twist to give it sufficient strength to withstand the weaving operation. Warp yarn also is generally harder twisted than filling yarn.

47. Engagement of Backing-Off Motion.—When the belt has been shipped to the second driven pulley e_2, Fig. 6, by the dropping of the twist slide, the power is transmitted through gears e_7, g_6, g_5, g_4, and sleeve g_3, Figs. 6 and 17, to the backing-off friction cone g_2. As the twist slide falls, another extended portion u_6, Fig. 27 (a), of the slide casting, which has previously held the back-off lever w in its neutral position, is lowered so as to pass from contact with an adjustable **T** piece w_1 threaded in the end of the back-off lever. The back-off lever, being now free to move, is drawn forcibly over by a spring s_5, Figs. 26 and 32, putting the back-off friction cone g_2, Figs. 6 and 17, in contact with the grooved friction pulley g_1. The rim band is then driven slowly in the opposite direction by the pulley g_1, so that the spindles, also being turned in the opposite direction, will unwind the coils of yarn between the top of the bobbin and the yarn already wound on it, thus preparing for winding the stretch of yarn on the bobbin.

48. Unlocking of Detent Catch.—Another function performed by the falling of the twist slide is the unlocking of the detent catch q_3, Figs. 25 and 27, which makes it impossible for the arm o_4 to rise sufficiently to ship the belt to the third pulley and thus draw the carriage out again, unless the wedge q_4, Fig. 25, is in a position to lock the detent catch when the carriage comes in. This is accomplished by the projection u_2 that comes in contact with the adjustable setscrew in the end of the detent catch q_3, thus raising it from the stud q_1 in the detent lever q.

It will be understood that all of the various functions performed by the dropping of the twist occur simultaneously with the fall of the twist slide and not in consecutive order as it is necessary to describe them.

BACKING OFF

49. Changing of Fallers.—As the backing-off motion is put in operation and the center shaft of the carriage thereby reversed, the fallers are changed so as to assume a position for winding the yarn on to the bobbin. A ratchet y_2, shown in Figs. 22, 29, and 30, and in detail in Fig. 28, is fast to the center shaft c_{19} of the carriage and is provided with an extended hub, around which a leather-lined steel clipper spring y_4 is placed. One end of this spring is extended between two pins in a pawl y_3 attached to a flange y loose on the shaft c_{19}. While the shaft c_{19} is being driven in the

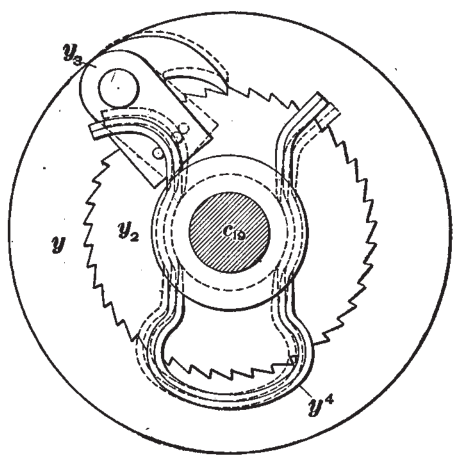


FIG. 28

ordinary direction, shown by the arrow in Fig. 29, the pressure of the spring y_4 on the pawl y_3 is such as to keep the pawl out of contact with the ratchet y_2, but immediately that the backing-off motion starts in operation and the direction of rotation of the shaft c_{19} is thereby reversed, the pressure of the spring y_4 will be in the opposite direction, and the pawl y_3 will be thrown in contact with the teeth of the ratchet gear, which will therefore impart motion to the flange y, since the pawl is attached to the flange. This flange forms part of a drum y_1, which is loose on the shaft and has attached to it a chain y_5 known as the *back-off chain*, the other end of which is attached to a segment b_{11} fastened to the winding-faller shaft b_2. As motion is imparted to the drum y_1 the chain y_5 is tightened and the shaft b_2 of the winding faller turned until the faller leg b_7, Fig. 22, rises so that it will slip over the stud p_4; this is accomplished by means of a strong spring y_{12} attached to a lever y_{10}, to which the faller leg is connected by means of a connecting-rod y_{11}. The winding faller b is therefore lowered so that it will assume the correct position for winding the stretch of yarn, which of course is governed by the position of the builder rail, through the traveler p_2 and faller leg b_7.

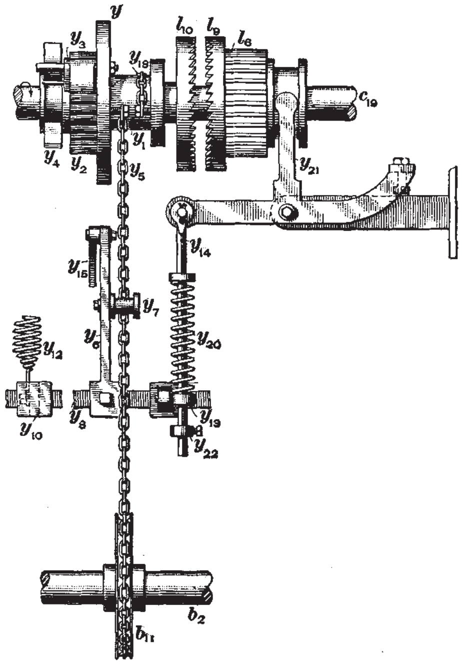


FIG. 29

At the same time that the winding faller descends, the counter faller must ascend, in order to keep the proper tension on the yarn and prevent the formation of kinks. The mechanism allowing this to be accomplished is shown in Fig. 31 (*a*) and (*b*). While the carriage is being drawn out and until the backing-off motion changes the fallers, they are locked as shown in Fig. 31 (*b*), so that neither faller wire is in contact with the yarn, leaving the spindles free to perform their function of drafting and twisting the roving into yarn. The winding faller b is held above the stretch of yarn by means of a spring b_{12} that is attached to the shaft b_2 of the faller by a leather strap in such a manner

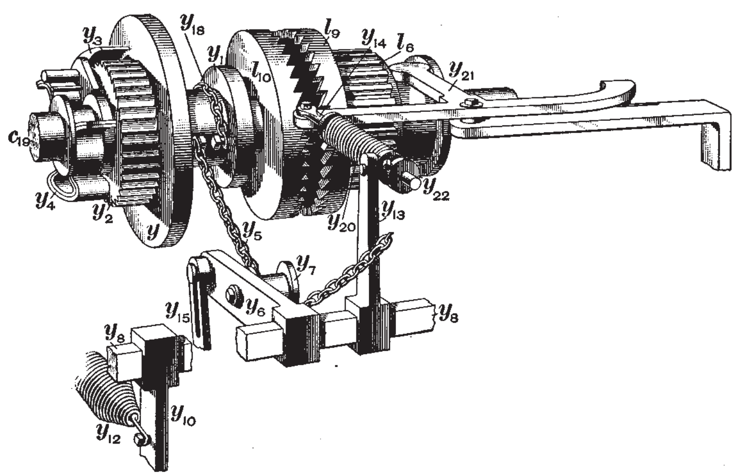
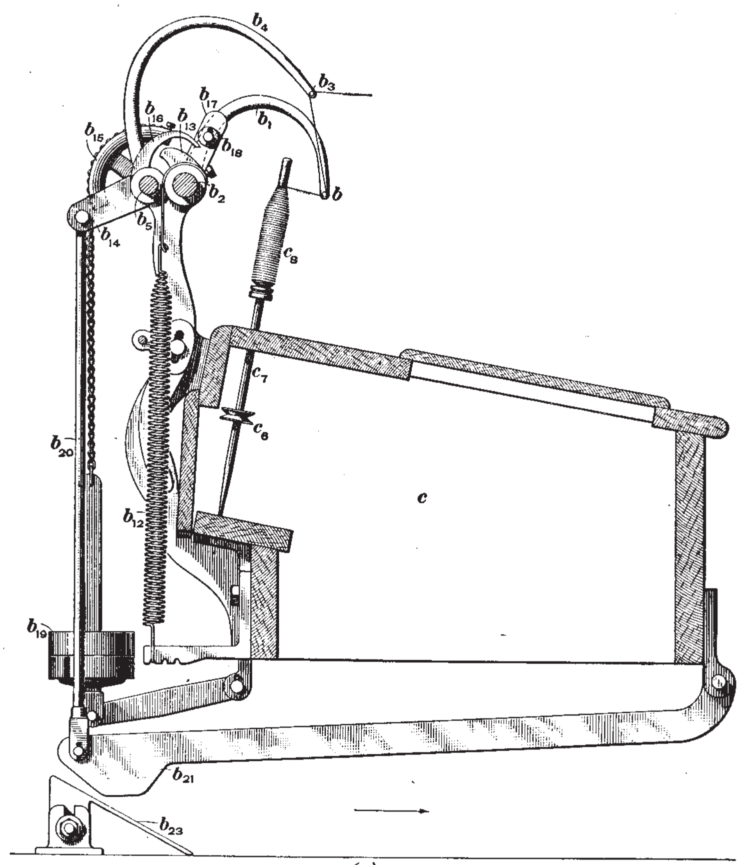


FIG. 30

as to give the faller wire a constant tendency to move upwards. The height to which the winding faller rises is limited by a stop b_{13} that is setscrewed to its shaft b_2 and rests on the top of the counter-faller shaft b_5 when the winding faller b is in its highest position. The counter faller b_3 also has a tendency to be raised, because of the pull exerted by the weights b_{19} on the segment b_{15} which is attached to the counter-faller shaft b_5. Previous to the change of fallers by the backing-off mechanism, however, the counter faller is locked just below the top of the spindles by a locking finger b_{16}, which is fastened to the counter-faller shaft b_5 and is prevented from rising by a roll b_{18} supported by a casting b_{17} fastened to the shaft b_2 of the winding faller.

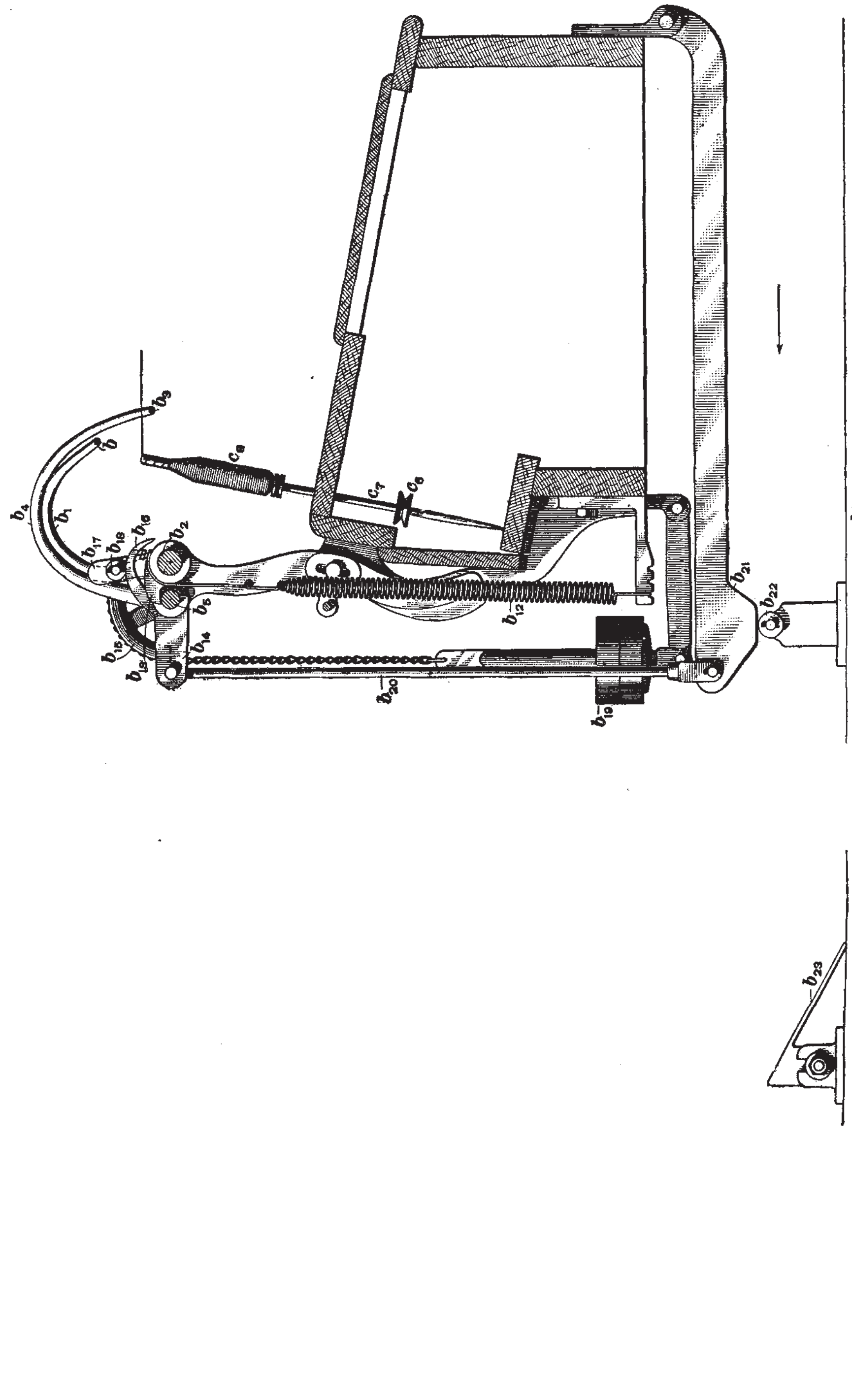
When the winding-faller shaft is operated by the tightening of the back-off chain, the fallers assume the position shown



(a)

FIG. 31

in Fig. 31 (a). As the winding-faller shaft is turned to lower the winding faller and lock the faller leg, the roll b_{18} is moved from the locking finger b_{16}, thus unlocking the counter faller and allowing the weights b_{19} to raise it into a position that is governed only by the tension of the yarn.


b_4
b_1
b
b_9
c_8
c_7
c_6
b_2
b_{16}
b_{18}
b_{17}
b_5
b_{14}
b_{15}
b_{12}
b_{20}
b_{19}
b_{21}
b_{22}
b_{23}

(b)

FIG. 31

There is a tendency for the counter faller when unlocked to rise too abruptly and with considerable force, and since this is liable to strain the yarn and break the ends, its initial upward movement is checked by an incline b_{23} bolted to the floor in such a position that when the fallers change, it will be directly under a lever b_{21} connected to the counter faller by a rod b_{20} and casting b_{14}, which is setscrewed to the counter-faller shaft. As the fallers change and the counter faller rises, the lever b_{21} will fall on the incline, which will thus support the weights b_{19} and prevent any further upward movement of the faller wire. As the carriage is drawn in the lever b_{21} will slide down the incline b_{23} until the tension of the yarn on the counter faller becomes sufficient to support the weights b_{19}.

50. Disconnection of Easing-Up Motion.—In addition to its other functions, the movement of the square shaft y_6, Figs. 22, 29, and 30, known as the *rocker-shaft*, also disconnects the easing-up motion. As the mule backs off and the rocker-shaft is turned by the action of the spring y_{12} it will raise the connecting-rod y_{15}, which will also raise a lever y_{16} fulcrumed on a casting bolted to and extending below the bottom of the carriage. The stud y_9 [see also Figs. 16 and 26 (*a*)], which is fastened in the lever y_{16}, by engaging with the notch in the easing-up rod k_{11}, communicates the easing-up motion to the carriage. As the lever y_{16} is raised, however, this stud is withdrawn from the notch in the easing-up rod k_{11}, and the easing up of the carriage thereby discontinued.

51. Engagement of Winding Clutch.—Still another function performed by the backing off is the putting-in gear of the winding clutch, by means of which the quadrant mechanism imparts motion to the spindle-band cylinder. Referring to Fig. 22, it will be seen that as the back-off chain y_5 raises the faller leg b_7 so that it will slip over the stud p_4, motion will be imparted to the rocker-shaft by the spring y_{12} as it pulls the lever y_{10} toward the back of the carriage. The result of this is that the lever y_{13}, which is also attached to the rocker-shaft, will be moved toward the front of the carriage. As this takes place, a rod y_{14} that is passed through a hole in a casting attached to the upper end of the lever y_{13} and held in position by a spring y_{20} and collar y_{22} will also be drawn toward the front of the carriage, thus operating the lever y_{21}, Figs. 29 and 30, to which it is attached, and throwing the part l_9 of the winding clutch in contact with l_{10}. With the clutch in contact, motion will be imparted to the spindles as the carriage runs in, by the quadrant chain. A chain y_{18} attached to the drum y extends through a hole in a girt and has a weight y_{19}, Fig. 22, attached to its extremity. The object of this is to keep the drum in position and the slack out of the chain y_5 when the pawl y_3 is disengaged from the ratchet y_2.

It will be understood that all of the movements depending on the backing-off motion take place simultaneously with the tightening of the back-off chain as the spindles are reversed, and occupy but a comparatively short period of time.

DRAWING IN

52. As the carriage is now ready to be drawn in, the backing-off motion is discontinued and the drawing-in motion put into operation, as follows: The movement of the stud y_9, Fig. 26 (*a*), in being lifted from the notch in the easing-up rod k_{11} is great enough to allow the stud to strike and raise the latch rod s, thus unlatching it from the casting s_7, which has previously held it in a forward position. As the latch rod is released, a strong spring s_6 pulls it forcibly backwards, and a casting s_1 setscrewed to it comes in contact with the back-off lever w; this moves the back-off friction cone g_2, Figs. 6, 17, and 32, from contact with the pulley g_1, thus stopping the backing off of the spindles, and also throws the half g_7 of the drawing-in clutch in contact with g_8, putting the drawing-in motion in operation. The back-off lever is prevented from moving in this direction until after the twist slide has fallen and pushed down the catch t_7, which until this occurs is held in the position shown in Fig. 27 (*a*) by the flat spring t_8. When the twist slide falls, however, a stud u_7 fastened to it strikes a lever t_6 and thus releases the catch t_7 which is fastened to this lever. This is a safety device that prevents the drawing-in motion from being accidentally put in operation at the same time that the drawing-out motion is working, which it will be understood would cause a serious smash.

When the latch rod has been drawn back and the casting s_1 has forced the backing-off lever over so that the drawing-in motion is in operation, the lever is locked in this position by means of a catch w_6, Fig. 32. This catch, which forms one

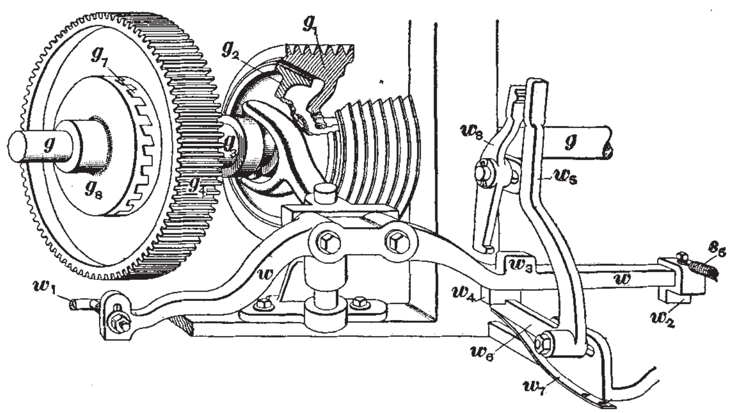


FIG. 32

arm of an elbow lever w_5, is held in a raised position by a spring w_7, so that it engages a projection w_4 of the back-off lever when the latter is forced backwards, which of course is against the tension of the spring s_5. This locks the back-off lever with the drawing-in motion in operation.

The adjustable stud y_{17}, Fig. 26 (*a*), in the lever y_{16} is simply a safety stud that rests just above the latch rod s and thus prevents its becoming unlatched until the mule backs off and the lever y_{16} is raised, since a smash would occur if the latch rod should accidentally be unlatched.

53. Locking of Twist Slide.—While the carriage is being drawn in several mechanisms are replaced in their initial positions preliminary to the next draw of the carriage. The twist slide is raised by means of the roll t_1, Fig. 27 (*a*), on the gear t. This gear is of course now turned, by the gear g_{15}, in the opposite direction to that in which it revolved while the drawing-in shaft was receiving motion from the unwinding of the drawing-in bands during the drawing out of the carriage. As the gear t is revolved the roll t_1 comes in contact with an adjustable casting u_4 on the twist slide u and thus raises the slide to its original position. Although the **T** piece u_3 is raised with the twist slide, the arm o_4 of the belt lever will be prevented from changing its position by the detent lever q (see also Fig. 25), which was unlocked at the dropping of the twist. As the twist slide is lifted it raises the twist-pin gear v, so that it will again mesh with the worm x_2, although no motion will be imparted to it until the gear e_9 is again revolved by the driving belt being shipped to the drawing-out pulley. The twist is locked in position by the projection v_6 of the lock-plate v_5, which is returned to its position on the casting x_3 by the spring v_{10}.

54. Replacing of Latch Rod and Draft Slide. When the carriage has been drawn about half way in, the latch rod and draft slide are moved forwards and locked in the following manner: As previously described, the draft slide r_3, Fig. 26, was drawn backwards by the spring r_7 when the stud s_4 was raised by the movement of the rod r_1 and wedge r_2 that results from the pressure of the carriage on the bunter r at the completion of the drawing-out motion. As soon as the easing-up motion is put in operation the pressure on r is removed. This allows a spring r_8 to pull the rod r_1 and wedge r_2 forwards so that the recess r_4 will be clear to receive the stud s_4. Then as the latch rod is unlatched by the upward movement of the stud y_9 and drawn back by the spring s_6, the stud s_4 is carried back into the recess r_4 in the draft slide. Any forward movement now imparted to the latch rod will also move the draft slide to its initial forward position. This movement of the latch rod is obtained from a roll g_{14} attached to a gear g_{13} that is driven from a gear g_{12} fastened to the drawing-in shaft. As the gear g_{13} rotates, the roll g_{14} engages with a casting s_2 setscrewed to the latch rod, which is thereby forced forwards, together with the draft slide, until it latches on the casting s_7, so as to be held forwards.

It might be thought that replacing the draft slide would allow the spring r_{12} to pull the lever r_{10} over and throw the drawing-out clutch e_{14} in contact; this is not so, however, since as the draft slide is replaced, the lever r_{10} is held by a long-headed screw r_{11} attached to it, that when the drawing-in motion is in operation extends behind a casting w_2, Figs. 26 and 32, setscrewed to the back-off lever w, which of course is then locked in such a position that the casting will be far enough backwards to accomplish this. This long-headed screw r_{11} is also a safety device, since it will not permit the drawing-out clutch to lock until the drawing-in clutch disengages. As the draft-slide is replaced the stud k_8 is lifted on the raised part r_{13} of the draft slide. This raises the upper part k_3 of the easing-up clutch from the lower part, in which position it remains until the draft slide is again released and drawn back by the spring r_7 at the end of the next outward run of the carriage.

REENGAGEMENT

55. Disengagement of Drawing-In Motion.—As the carriage reaches the end of its inward run the several parts are reengaged for the next draw, but first of all the drawing-in motion must be disconnected. This is accomplished by means of the lever w_5, Fig. 32, which is struck and forced back by a bunter on the carriage. As this happens the arm w_6 is lowered and the back-off lever released, whereupon the spring s_5 draws it over and throws the drawing-in clutch out of contact, moving the back-off lever until the **T** piece w_1, Fig. 27 (*a*), strikes u_6. As this movement takes place the catch t_7 is raised by the spring t_8 and thus locks the back-off lever so that the drawing-in motion cannot go into operation until the twist slide drops again; as it is also prevented by u_6 from moving in the opposite direction so that the backing-off friction cone will engage, it occupies what is termed the *neutral* position.

In order to make the disengagement of the drawing-in motion positive, so that there will be no liability of a smash should the spring s_5 fail to operate the back-off lever, a lever w_8, Fig. 32, is placed in such a position that it is struck at one end by the lever w_5 as the latter is forced back by the bunter on the carriage. The other end of the lever w_8 engages with a projection w_3 on the back-off lever, so that the drawing-in motion is disconnected in any case when the carriage strikes the lever w_5.

56. Engagement of Drawing-Out Motion.—When the drawing-in is discontinued, the drawing-out motion is put in operation, so as to move out the carriage for the next draw, as follows: When the spring s_6, Fig. 26 (*a*), moves the end of the back-off lever w forwards, the casting w_2 slips off the screw r_{11} and allows the spring r_{12} to operate the lever r_{10} and put the part e_{14} of the drawing-out clutch in contact with e_{13} and the drawing-out motion in operation. At the same time that this is accomplished the driving belt is shipped from the second to the third driving pulley and another draw commenced, provided of course that the wedge q_4, Fig. 25, was in such a position when the carriage came in as to lock the detent lever q so that the arm o_4 of the belt lever may rise until stopped by t_4 in the position shown in Fig. 27 (*a*). If the detent lever is not locked the belt will remain on the pulley e_2, but as the drawing-in clutch and back-off friction are out of connection, no motion will be imparted to any part of the mule except the loose train of gears e_7, g_6, g_5, g_4, Fig. 6.

As the carriage reaches the end of its inward motion several other important reengagements take place. The roving motion is thrown into gear again by the roll c_9, Fig. 9, on the carriage striking the lever i. The dwell motion is also operated by the segment gear j_1, Fig. 13, coming in contact with the rack j. The fallers are also caused to resume their position clear of the yarn preliminary to the next outward run of the carriage, in the following manner: As the carriage reaches the end of its inward run the faller leg b_7, Fig. 22, strikes a casting p_{31} bolted to the floor and is thus unlocked from the stud p_4. This allows the spring b_{12}, Fig. 31 (*b*), attached to the winding-faller shaft b_2 to raise the winding faller until clear of the yarn; that is, until its motion is checked by the stop b_{13}. The counter faller is lowered at the same time by means of a roll b_{22} attached to a casting that is bolted to the floor. This roll engages the inclined part of the lever b_{21}, raising it and also the rod b_{20} and lever b_{14} and thereby lowering the counter faller. As the counter faller is lowered the locking piece b_{16} attached to the counter-faller shaft engages with the roll b_{18} and locks the faller in position. When the faller leg b_7, Fig. 22, is struck by the casting p_{31} and unlocked, the rocker-shaft y_8 is operated and the half l_9, Fig. 30, of the winding clutch disengaged from l_{10}, and as the carriage starts to be drawn out again the center shaft c_{19} will be driven by the rim band.

This completes the cycle of movements of the mule during one draw of the carriage. The mule is now ready to repeat its operations for the next draw.

SPECIAL POINTS

DOFFING

57. When a set of bobbins becomes filled with yarn they must be removed and empty bobbins substituted; this operation is known as **doffing.** When doffing a full set of bobbins from the mule, the builder rail is first wound up while the carriage is coming out. This is accomplished by lifting the pawl p_{18}, Fig. 24 (*a*) and (*b*), and winding back the builder gear p_{21}, screw p_8, and consequently drawing the shoes p_5, p_6, p_7, Fig. 22, forwards by means of the crank-handle *n*, Fig. 18, which is removed from the quadrant screw for this purpose and placed on the screw shaft of the large builder gear, the end of which is square in section to allow this. As the shoes are moved forwards the rail is raised, which causes the winding faller to go to the base of the bobbin when the fallers are changed by the backing-off motion. The mule is allowed to continue in operation until the fallers change, when it is stopped immediately by means of the shipper lever *o*, Fig. 25. The shipper lever is then given several sharp jerks, so that sufficient motion will be imparted to the mule to allow the spindles to make four or five revolutions. As the winding faller is down, this winds, or ties, the yarn around the base of the bobbins, thus preventing their unraveling during subsequent handling. The winding faller is next locked down by pressing it below the bobbin and fastening it by means of a small catch on the carriage provided for this purpose. Then by leaning over the carriage and pulling the rim band toward the carriage, motion is imparted to the spindles; this will wind the yarn around them and thus tie it so that the ends will not be broken down when the full bobbins are removed. It is well to tie the yarn firmly around the spindles, and as the turning of the spindles by means of the rim band gives slack quadrant chain, because the spindle drum is turned without drawing in the carriage, the carriage may now be *jerked* in by power until the quadrant chain is tight. This gives slack yarn because this movement of the carriage is accomplished without turning the spindles, the quadrant chain being slack. The counter faller is now locked down with the winding faller by means of the catch mentioned and the full bobbins removed from the spindles and placed in a basket. Empty bobbins may now be placed on the spindles and, by means of a short length of board, pressed down until their tops are flush with the tops of the spindles. Care should be taken in pressing down the bobbins in this manner to avoid bending the spindles or splitting the bobbins.

After all the bobbins are placed on the spindles, the quadrant pulley l_2, Fig. 18, is wound down to the bottom of its screw l_1 by means of the crank-handle n and the link in the quadrant-governor chain n_{14} turned down. The fallers may now be unlocked. Then by leaning over the carriage and drawing the rim band toward the carriage a half turn of yarn may be wound around the new set of bobbins. After making sure that the quadrant chain is tight, the carriage is run in slowly, checking the power with the shipper lever; otherwise, the carriage will bang in hard against the back stops. If the quadrant chain is not tight, the faller leg b_7, Fig. 22, may be pulled out of contact with the stud p_4 by hand. This pulls over the rocker-shaft y_8, releases the winding clutch from contact, and allows the weight l_{14}, Fig. 5, to drop, turning the drum l_4, Fig. 18, by means of the rope l_7 and taking the slack out of the quadrant chain l_3. After the quadrant chain is tightened, the faller leg may be locked again by depressing the winding faller with the handle b_{10}, Fig. 22. Immediately that the carriage is drawn in against the back stops, the shipper lever may be pulled forwards and the mule started in operation.

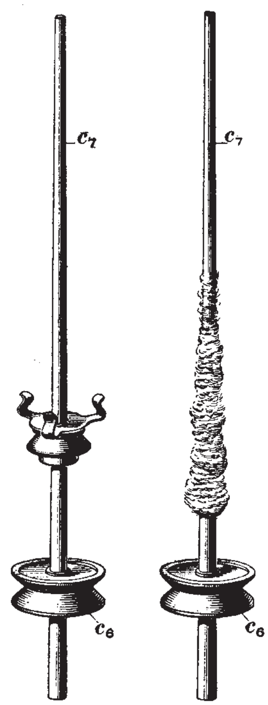


FIG. 33

BOBBIN CLIPS

58. In order to spin the yarn well, the bobbin must be level, or flush, with the top of the spindle; the usual method of accomplishing this is to wind packing yarn around the spindle so as to make the bobbin fit tight and be held at the right height. A better way to accomplish this result, however, is to use a **bobbin clip**, or holder, of which there are several kinds on the market. Fig. 33 shows a spindle packed with yarn in the old way and also one equipped with an ordinary type of bobbin holder.

Among the advantages of the bobbin clip may be mentioned the following: (1) It saves the packing under the bobbins and the time in putting it on. (2) It causes the bobbin to run true by being held firmly and at a common center; that is, not allowing the bobbin to wabble in consequence of uneven yarn packing. (3) The bobbins are always flush with the top of the spindles and are not split or broken by being thrust over the packing. It also saves the use of a stick for pounding the bobbins down to their proper level. (4) It saves time in cutting off the excess of waste and packing from around the spindles.

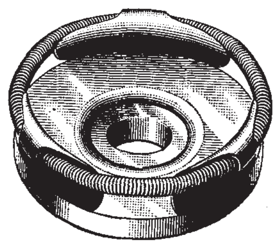


FIG. 34

59. An improved device for holding the bobbin on the spindle is shown in Fig. 34. This consists of a clip that is placed on the spindle and holds the base of the bobbin by means of three steel lips that are pressed on the bobbin by a spring.

SPINDLE BANDS

60. In regard to the **spindle bands,** great care should be taken to replace loose bands, as they make soft bobbins, which greatly increase the amount of waste. The best band to use is an endless fulled-wool band. These may be purchased or may be made at the mill if the mill owns a spindle-band machine. Knotted bands are undesirable.

WASTE

61. The amount of **waste** made in a spinning room is governed to a large extent by the degree of care with which the draft is set to accommodate different batches and kinds of stock. If the draft is not adjusted properly, the ends will be constantly breaking, thus increasing the waste and also the labor of the spinner in piecing up ends.

Generally speaking, the longer and coarser the stock, the quicker the carriage should be drawn out. If the ends break close to the delivery rolls, it is an indication that the drafting is too slow. This is especially apt to be so in the case of long stock, as the long fibers take the twist more rapidly and thus become hard to draw out to the required size of yarn. On finer stock, if the roving breaks about half way between the delivery rolls and the spindles when drawing, it is an indication that the carriage is being drawn out too fast. Short stock, or stock in which there is a liberal supply of waste, must be drawn much more slowly than the longer grades of wool.

Large alterations in the draft may be made by means of the draft gear e_8 or the intermediate draft gear e_{11}, Fig. 7. A larger gear in either case increases the speed of the draft scroll and consequently of the carriage, and a smaller gear has the opposite effect. The finer adjustments of the draft are made by changing the position of the drawing-out, or draft, scroll by means of the handle f_{10}, Fig. 13, or by changing the wings of the draft scroll.

With the draft set to conform to the grade of the roving, a mule should make very little waste. Waste in the spinning room is expensive, and as most of it is partly twisted and the rest has been mixed with hard ends on the floor, it is swept up and put with the hard waste at night. The spinners should be required to keep the waste off the floor and to keep the hard and soft waste separate.

It is a good plan to have two boxes or baskets attached to each mule, one for hard and one for soft waste. In this manner the spinner can keep the hard and soft waste separate and the latter can be mixed with good wool and run through the cards again.

CLOCK

62. A **clock** for registering the amount of yarn spun is generally applied to all modern mules, although it is of great value in cases where the spinners are paid according to the amount of yarn that they spin; but is often disconnected when spinners are paid by the day or week. As shown in Fig. 35, the clock motion is driven from the drawing-in shaft g, on which is fastened a worm z (see also Fig. 17) that imparts motion to a segment gear z_1 cast in the form of a bell-crank lever. To one arm of this lever is attached a rod z_2 that has

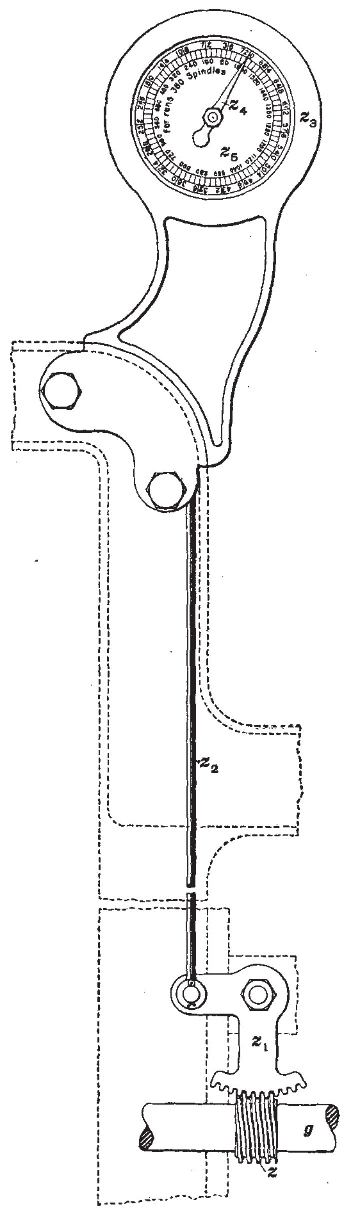


FIG. 35

on its upper end a pawl engaging with a 10-tooth ratchet gear contained in the clock case z_3. Compounded with this ratchet is a single-threaded worm meshing with a 160-tooth worm-gear, to the shaft of which the pointer z_4 is attached. As the carriage is drawn out, the rod z_2 is raised, but as it is drawn in, the motion of the shaft g is reversed and the rod lowered, the pawl on its end moving the ratchet 1 tooth. Ten draws of the carriage will therefore impart one revolution to the ratchet gear, as the latter contains 10 teeth, and since the 160-tooth worm-gear is driven by a single worm, 10 times 160, or 1,600, draws of the carriage will be required to move the indicator z_4 one complete revolution. The dial z_5 contains two rows of figures; the inside row is numbered from 0 to 1,600 and simply indicates the number of draws the carriage makes. The outside row of figures varies according to the number of spindles that the mule contains, and indicates the number of pounds of 1-run yarn spun. If the mule is a 360-spindle machine, the outside row of figures is numbered from 0 to 720, whereas if the mule contains only 280 spindles, the highest number of the outside row would be 560; that is, the outside row of figures will register a number equal to twice the number of spindles, because the length of yarn spun at one draw by each spindle is 2 yards; or in other words, in 1,600 draws, or one revolution of z_4, a number of pounds of 1-run yarn equal to twice the number of spindles will be spun. If a mule is spinning yarn of any other size than 1-run, in order to find the number of pounds produced it is simply necessary to divide the reading of the clock by the size of the yarn. For instance, if a mule is spinning 3-run yarn and the clock registers 288 pounds, only $288 \div 3 = 96$ pounds of yarn has been spun; or if 4-run, 72 pounds, etc.

SIZE, GAUGE, SPEED, AND HORSEPOWER

63. The size of woolen mules is designated by the number of spindles, and mules are constructed with any number of spindles that may be required, the usual custom being for a mill to order mules of a size suited to its requirements. Such sizes as 120-, 160-, 200-, 220-, 260-, 300-, 320-, 360-, and 400-spindle mules are common sizes.

The gauge of a mule is the distance between the centers of two consecutive spindles. Ordinary woolen mules are generally constructed with a $1\frac{3}{4}$- or 2-inch gauge, although any gauge may be made, according to the requirements of any particular case. Heavy mules for spinning carpet yarns are usually made with a wider gauge than ordinary mules. Any increase in the gauge increases the length of the machine relative to the number of spindles.

The driving pulleys of the mule are 14 inches in diameter, and for ordinary woolen spinning should make from 320 to 360 revolutions per minute. Mules with a smaller number of spindles may be speeded faster than larger mules, which are generally speeded slower on account of the increased weight of the carriage in the latter case. Wide-gauged and heavy carpet mules should be speeded slower.

The horsepower consumed by a mule is a variable quantity, since while certain motions are in operation a very much larger amount of power is necessary than while certain other motions are in operation. Thus, when the carriage starts away from the delivery rolls the power consumed is very great, whereas while the mule is backing off the power amounts to practically nothing. It may be stated that on an average a 300-spindle mule will require from 3 to 4 horsepowers.

WOOLEN SPINNING

EXAMINATION QUESTIONS

(1) What two actions on a woolen mule, when in combination, aid in imparting to the thread its distinctively woolen formation?

(2) What is the object of inclining the spindles of a mule toward the delivery roll, and how does the inclination of the spindles accomplish this result?

(3) A mule is spinning 40 inches of $2\frac{1}{2}$-run roving into 72 inches of yarn; what run is the yarn? Ans. $4\frac{1}{2}$-run

(4) (*a*) Why is a variable speed necessary in drawing out the carriage of the mule? (*b*) How is the motion obtained?

(5) (*a*) If it is desired to spin $3\frac{1}{4}$-run yarn with the mule letting out 44 inches of roving and having a stretch of 72 inches, what should be the size of the roving? (*b*) 40 yards of yarn from a mule weighs 28 grains; what is the run of the yarn?

Ans. $\begin{cases} (a) \text{ 2-run (practically)} \\ (b)\ 6\frac{1}{4}\text{-run} \end{cases}$

(6) What is taking place when the belt is on the fourth pulley?

(7) With the belt on the fourth pulley, which is loose on the shaft, how is the small bevel gear e_9 that drives the twist motion being driven?

(8) What is the function: (*a*) of the winding faller? (*b*) of the counter, or tension, faller?

(9) What is meant by a double rim band?

(10) The main shaft of a mule is driven 320 revolutions per minute; the grooved pulleys on the main shaft are 17 and 21 inches in diameter; the grooved pulley on the center shaft of the carriage is 10 inches; the spindle-band drum is $6\frac{1}{4}$ inches in diameter; the whorl is 1 inch in diameter. (*a*) Find the speed of the spindles while the carriage is coming out. (Subtract 5 per cent.) (*b*) Find the accelerated speed of the spindles. (Subtract 5 per cent.)

Ans. $\begin{cases} (a) \text{ 3,230 rev. per min.} \\ (b) \text{ 3,990 rev. per min.} \end{cases}$

(11) Explain, fully, the object of the easing-up motion.

(12) State the use of squaring bands.

(13) What is the object of the backing-off motion?

(14) Is the direction of the rim band reversed during the backing off of the spindles? If so, how is it accomplished?

(15) (*a*) Explain the action of the quadrant during the formation of the base of the bobbin. (*b*) How is the position of the quadrant-chain pulley automatically regulated?

(16) How may the hardness of the bobbin be changed?

(17) (*a*) What effect does the check-band have at the end of the inward run of the carriage? (*b*) If the carriage bangs in too hard, how can the difficulty be remedied?

(18) How is the belt lever shipped from the fourth to the second pulley?

(19) If while the mule is in operation the sliding rod on the front of the carriage is moved to the right of the spinner, what will take place?

(20) Describe the movement of the winding faller while the carriage is running in.

(21) How is the quadrant chain rewound on the drum after being pulled off in winding the yarn on the spindles?

(22) What would happen if, through any cause, the quadrant-chain pulley should fail to be raised while the cone of the bobbin was being built?

(23) (*a*) How should the speed of the carriage be altered if, after spinning short stock, a batch of longer-fibered stock were to be spun? (*b*) How may the above change be accomplished?

(24) State two methods of altering the size of the bobbins being spun on the mule, and state how each method will affect the size.

(25) What would you consider the cause of the ends breaking down badly close to the delivery rolls?

(26) What stops the carriage at the end of its outward motion?

(27) What would be the effect on the bobbin if the ratchet p_{19}, Fig. 24, should become fast so that it would not turn on its axis?

(28) What is the object: (*a*) of the screw r_{11}, Fig. 26 (*a*)? (*b*) of the lever w_8, Fig. 32?

(29) Is there any better way of holding the bobbins on the spindle than by packing the spindles with yarn? If so, explain it.

(30) What method would you employ in taking care of the waste in a spinning room?