ANALYSIS OF POWER DISTRIBUTION IN A COTTON-SPINNING FRAME

By Albert Walton

CERTAIN general facts have been known for many years concerning the power in the spinning room of a cotton mill and its laws of variation throughout a normal day's run. It has been possible to take more or less accurate measurements at the engine cylinder by indicator cards and, at the expense of much toil and pains, to ascertain that the power is very noticeably higher during the first fifteen minutes of the morning and that after abruptly falling from this starting peak there is a more gradual diminution throughout the remainder of the first hour and a steady but very slight decrease during the entire forenoon. The cards sometimes showed a lesser peak after the noon hour and a very gradual decline throughout the second half of the day, the day's minimum occurring at its end. This, it should be noted, is a day's power history for a unit consisting of a great number of spinning frames, each in turn being an aggregation of many spindles. In fact, to secure reliable data by this method it is imperative that the unit be very large, so that other variables, such as belts, journals and shafts, may not, by undue percentages, mar the accuracy of the results. Not uncommonly these readings and computations were made in connection with spinning departments of fifty thousand spindles, or over two hundred distinct machines. Obviously the figures obtained will be broad averages, and will give no information whatever of the power changes of a single frame. In fact, little is generally known among mill men even to-day in regard to the momentary changes that occur during the repeated cycles of the process of filling a set of bobbins with spun yarn. It is, of course, out of the question to secure any data of this nature in a mill driven as a unit from a large engine, inasmuch as a single frame would not show on the indicator cards, even assuming they could be taken for each stroke of the engine, and it is impossible to cause the cycles of a large group of frames to so synchronize as to raise these fluctuations to a point where they will be measureable on the engine.

The utilization of the large electric motor to drive groups of these frames, though it much simplified the securing of the average values and permitted greater accuracy and refinement, did not in any way contribute to the knowledge of what was occurring in the individual frame. It remained for the simultaneous development of two factors and their combination during the past two years to reveal this very interesting information. Not only was it necessary to wait for the adoption of the individual motor to each frame, but also for the production of an adequate recording meter which would give a continuous chart displaying every fluctuation in power taken by such a motor. Both of these features are now commercial realities, and it has been the writer's good fortune to secure by this method some very interesting data. This meter is shown in the accompanying photograph mounted upon a semi-portable truck, together with other meters and transformers. (Fig. 1.) By connecting this testing set in the motor circuit and properly adjusting the component parts most instructive and reliable data can be secured. We have copied here one of the charts obtained and propose to discuss it in detail.

For the benefit of the "lay reader" who may not be fully conversant with the details of a cotton-spinning frame a few words of explanation may not be amiss to put him in touch with the essentials.

Figure 2 is a photograph of the driving end of a motor-driven ring spinning frame. A rigid tin cylinder "A" runs the entire length of the frame, which is about thirty feet long. It is about seven inches in diameter and is centrally located between the two rows of spindles, "B," on each side of the frame. The purpose of the cylinder is to drive the spinning spindles. This it accomplishes by means of small cords or "bands," "C," which serve as driving belts. Each band passes from the cylinder to the grooved, or "whorl," "D," on the spindle, which is usually less than an inch in diameter. For every revolution of the cylinder, therefore, the spindle makes seven or eight complete turns. The usual practice is to arrange for from one hundred to one hundred and fifty spindles on each side of the frame. Figure 3 is a diagrammatic sketch showing the arrangement of cylinder, bands and spindles, while Figures 10 and 11 show a general view of the spinning frames as installed in modern mill practice. The spinning process is briefly as follows: Two strands of coarse, partially twisted yarn, called "roving," are led from bobbins ("E" Figs. 2 and 3), on which they have previously been wound down between two pairs

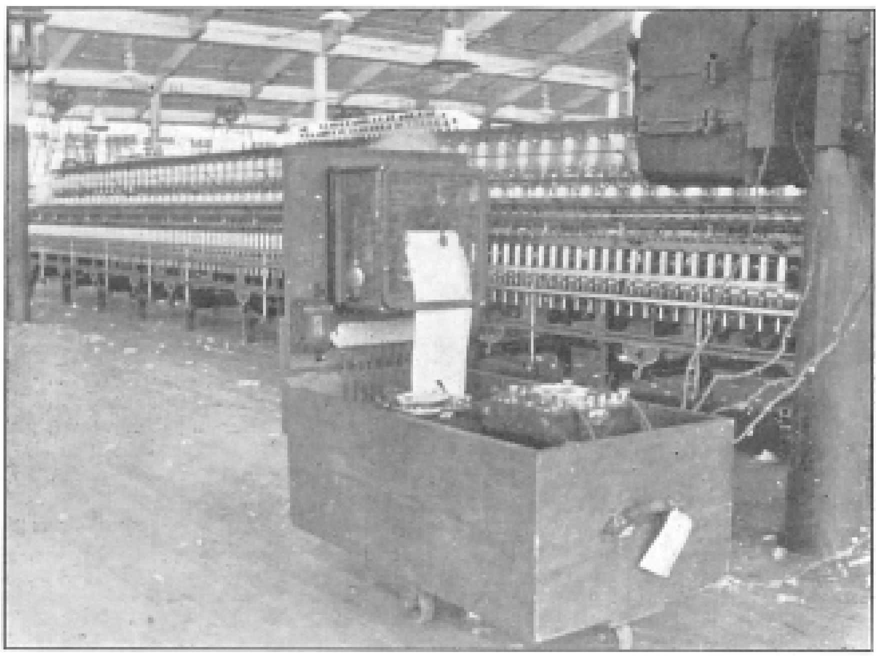


FIG. 1.—TESTING SET IN OPERATION, SHOWING WESTINGHOUSE GRAPHIC RECORDING WATTMETER

of slowly revolving rollers which hold the strands firmly between them while passing them forward to a third pair ("F"), which are similar but revolve seven or eight times as fast. There is thus an attenuation of the strands by drawing the fibres one upon the other. No stretching of the cotton takes place, merely a rearrangement or sliding upon themselves of the fine fibres, so that there are fewer of them side by side. Thus as they emerge from the third rollers they are in the form of a fine, practically untwisted and, therefore, very weak thread. To make them serviceable they must be twisted and neatly wound on a bobbin, and this is done in the following manner: The spindle (Fig. 4) is centrally situated in a ring (Fig. 5) mounted upon a rail ("G," Figs. 2 and 3), which moves up and down the length of the bobbin. Upon this ring is a small "C"-shaped spring-steel "traveler," which, though it is sprung over the side of the ring, as shown in Fig. 6, is yet free to revolve around the ring, the latter being highly polished, to minimize the friction of the traveler. The yarn leaving the rolls, passes down to a guide-eye ("H," Figs. 2 and 3) located exactly over the center of the spindle. From there it is led through the "C"-shaped traveler on the ring to the bobbin. When the frame starts, the rolls feed out the untwisted yarn. The bobbins on the spindle revolving at a high rate of speed, attempt to wind up the yarn. If the traveler were fixed in one position on the ring the yarn would be wound on at a rate tremendously in excess of the rate of feed at the rolls and would be instantly broken. Being free on the ring, however, the traveler is carried around the ring at a speed practically equal to that of the spindle. Were it to travel at exactly the same speed in revolutions per minute the yarn would not be wound on the bobbin at all. Its

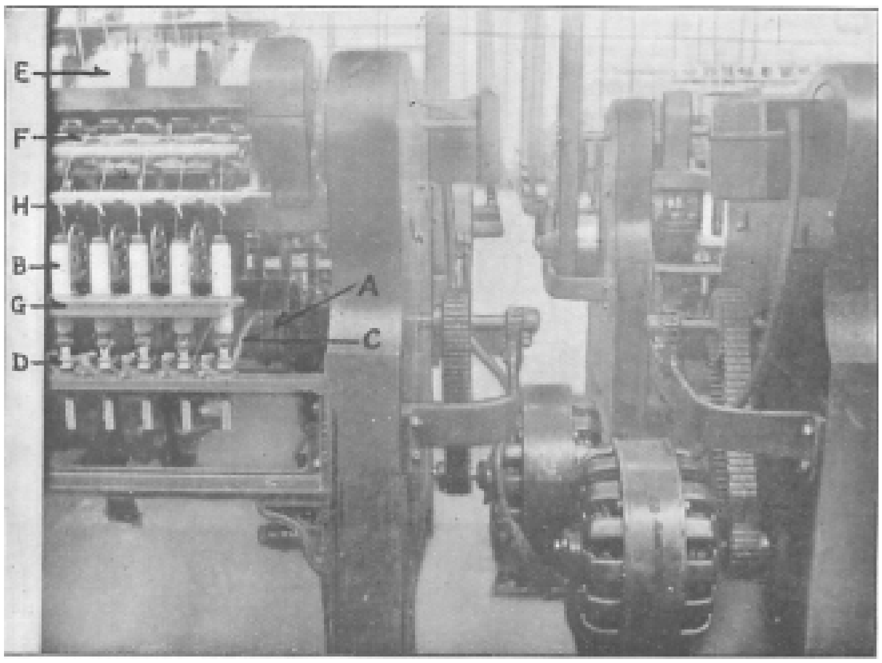


FIG. 2.—MOTOR-DRIVEN RING SPINNING FRAME

A, cylinder; B, spindles; C, bands; D, whorl; E, roving bobbins; F, drawing rolls; G, ring rail; H, guide-eye friction and the air friction of the yarn passing through it cause it to lag behind the speed of the bobbin by enough to wind upon the bobbin the yarn being fed to it by the rolls. For example, if one wrap around the bobbin be three inches and the rolls are feeding one hundred and fifty inches of yarn per minute the traveler would lag behind enough to wind on this one hundred and fifty inches, or fifty revolutions each minute. The spindle meanwhile is revolving at a speed of from five thousand to twelve thousand revolutions per minute, thus twisting the yarn as it descends through guide-eye and traveler to the bobbin. The function of the revolving spindle and bobbin then is to twist the fine filaments into a thread, while that of the traveler is to provide a drag sufficient to wind the yarn on the rapidly revolving bobbin. In order to neatly wind a bobbin in even layers a device automatically raises and lowers the "ring-rail" ("G," Figs. 2 and 3) at a rate that will equal the thickness of the yarn for each wrap that the traveler causes to be wound on the bobbin.

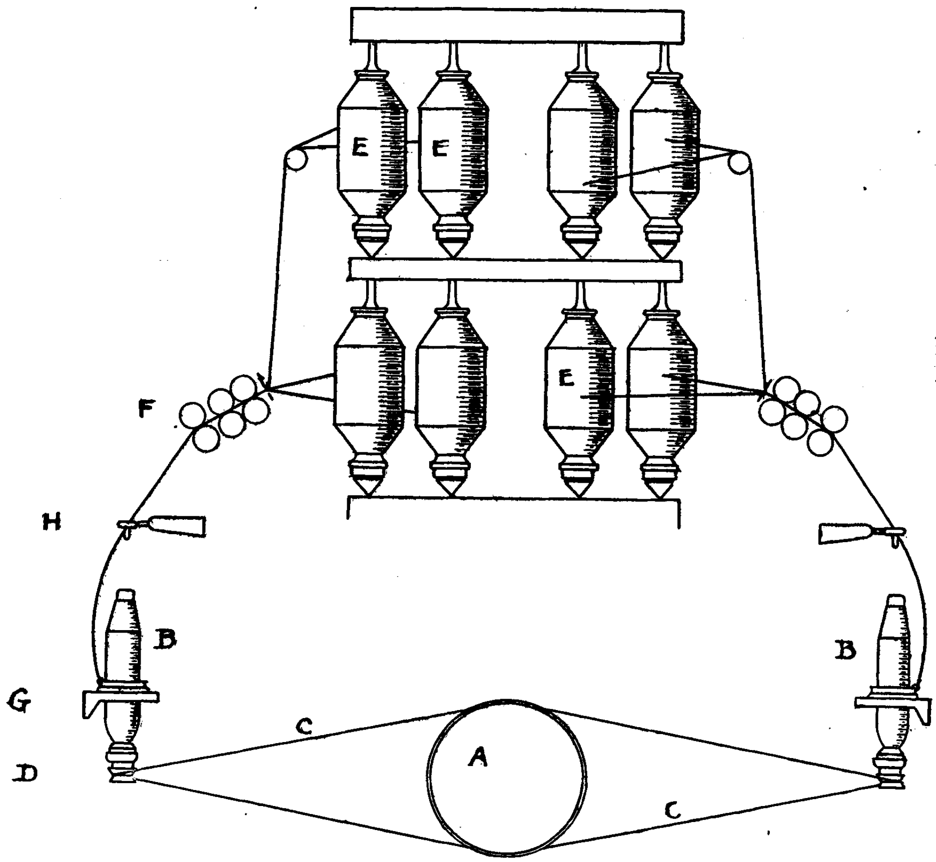


FIG. 3.—COMPONENT PARTS OF A RING SPINNING FRAME
A, cylinder; B, spindle with bobbin; C, band; D, whorl; E, roving bobbins; F, drawing rolls; G, ring rail; H, guide-eye

This, then, is the cotton-spinning process that is carried on simultaneously on each of the two hundred and fifty spindles of each frame, and it is because of the fact that in a room with a great number of frames in operation no two would have their ring-rails "in step," rising and falling together, and because the bobbins are in various stages from the empty wood to the fully wound bobbin ready for removal, that it is impossible to obtain any detailed information in regard to the power fluctuations for a single frame with anything but an individual motor and a curve-drawing meter.

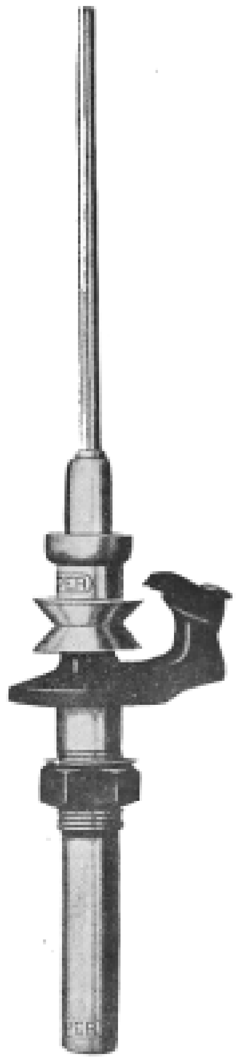


FIG. 4.—SPINNING SPINDLE

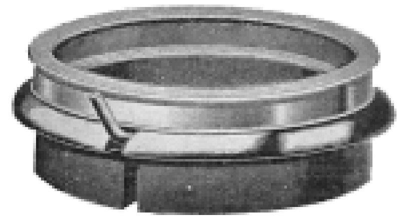


FIG. 5.—DOUBLE RING IN CAST-IRON HOLDER, WITH WIRE TRAVELER CLEARER

The curve shown in Fig. 7 is a reproduction of one drawn by the Westinghouse Graphic Recording Wattmeter shown in the illustration (Fig. 1) mounted on the portable testing truck, and is a true history of the power fluctuations for an entire day for the motor-driven frame, the driving end of which is shown in Fig. 2. To read this chart intelligently it is only necessary to know that the paper is fed out lengthwise under a pen that moves crosswise a distance proportional to the amount of power being measured. Thus, when no power was being used, the pen traced a line which coincides with the bottom or zero line of the paper. Each heavy vertical or cross line on the paper represents the beginning of an hour as marked at the bottom of the chart and each intermediate fine line the intervening half-hour points, while for every 0.2 kilowatts (or 0.268 horse-power) being consumed the pen moves one fine division, the total distance across the sheet denoting six kilowatts (8.05

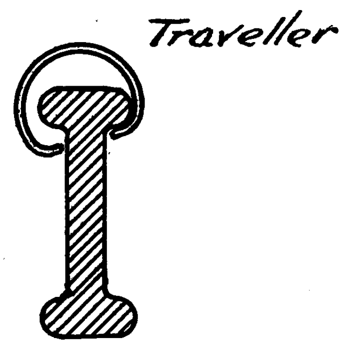


FIG. 6.—ENLARGED SECTION OF DOUBLE RING, SHOWING TRAVELER IN POSITION

horse-power). Both of these scales are marked on the chart for convenience.

These curves show, in addition to the specific details which we will consider later, the general and well recognized characteristics of a spinning frame load. It is plainly visible that the frame took more power immediately after starting up than for any subsequent period. The customary rapid falling away in the first half hour is portrayed and the similar peak just following the noon hour. The very steady average value is also noticeable. There are no violent fluctuations or sudden peaks. In addition to these well known facts are the more striking characteristics of the individual frame, and these will bear minute analysis and explanation.

The curve consists of three main parts, which have the following meaning: The frame was started at 5:55 A.M. with the bobbins three-quarters filled. At 8:07 the bobbins were filled and the frame shut down to permit the removal of these and their replacement by empty bobbins on the spindles, which was accomplished by 8:10. It took until 1:38 P. M. to fill these bobbins, the frame having stood idle during the nooning of about forty minutes. At 1:45 P.M. the frame was ready for a new start with a new set of empty bobbins, which it just completely filled by the end of the day's work, the complete cycle taking about four hours and thirty-five minutes. This process of removing the filled bobbins when replacing them with a new set of empty ones is called "doffing."

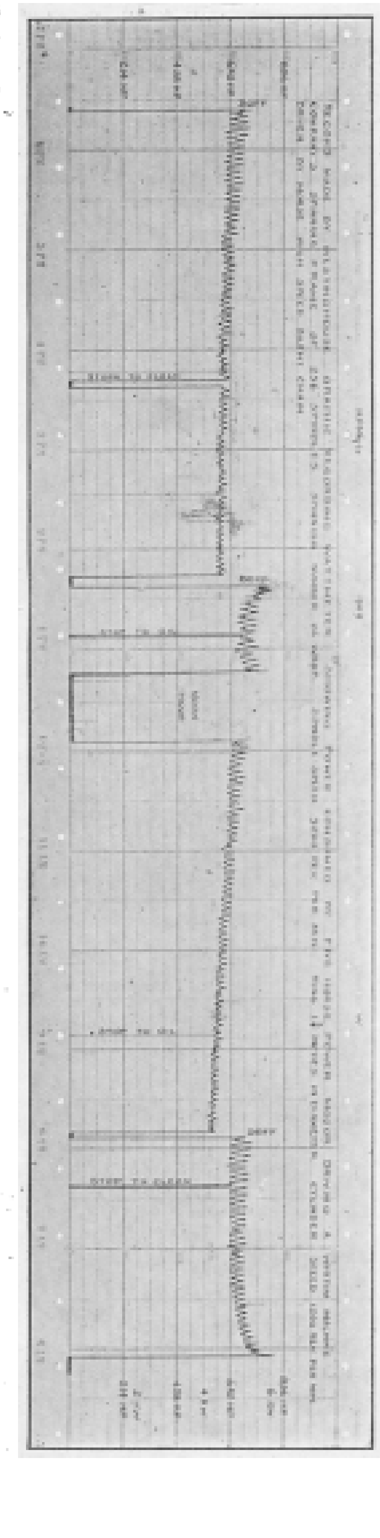
Three salient features of the curve challenge immediate attention and require explanation:

(1.) The power is greater by about twenty per cent. when the bobbins are full than when empty.

(2.) The curve is a regular recurrence of small waves or peaks.

(3.) The form, of these waves changes as the bobbin fills.

There are one or two items of



minor importance, also, which we will mention later. Our principal interest here, however, lies in the discussion of these three statements.

Why should the power be greater with the full bobbin than with the empty? The writer has put this question to many practical mill men, and with perfect unanimity they have all replied that it is due to increased weight on the spindles. Our experience leads us to believe this has little or nothing to do with it. In order to check our theory out we disconnected all the moving parts of a motor-driven spinning frame except the cylinder, bands and spindles and connected a meter into the motor circuit to register the exact power consumed. The bobbins were full, but there was no spinning in progress since the rolls had been disconnected. There was, therefore, no traveler drag and no roll nor creel power to consider. The power was noted and found to be 4.9 H.P. The full bobbins were then removed and the bare spindles continued in motion. The power then read 3.92 H.P., or a loss of 0.98 H.P., by removal of the full bobbins, each of which weighs approximately three ounces, only about one half of which is cotton, the remainder being wood. If, now, the weight on the spindle is the factor to be considered the power will increase by one half of what it fell off if we put the empty bobbins back on the bare spindles in place of the full ones. When this was done, however, the rise was not appreciable, indicating that weight on the spindle is not the factor causing the rise in power with the filling of the bobbin, and we must look elsewhere for our explanation. It is the writer's opinion that this increase is almost wholly a fanning action at the surface of the bobbin, and, as will be seen later, the alteration of the form of the peaks tends rather to bear this out. Neither the bare spindle nor the polished wood bobbin causes any appreciable disturbance of the air in its immediate vicinity. The surfaces are too smooth to have any fanning effect worth considering. As soon as this smooth surface is covered with a few layers of cotton yarn, however, the immense numbers of minute fibres projecting into the air from the surface of the cop have great faculty for stirring up the air. Simultaneously with this change of surface the peripheral velocities are augmented with increasing diameters, and this change in itself makes for marked difference, since the power

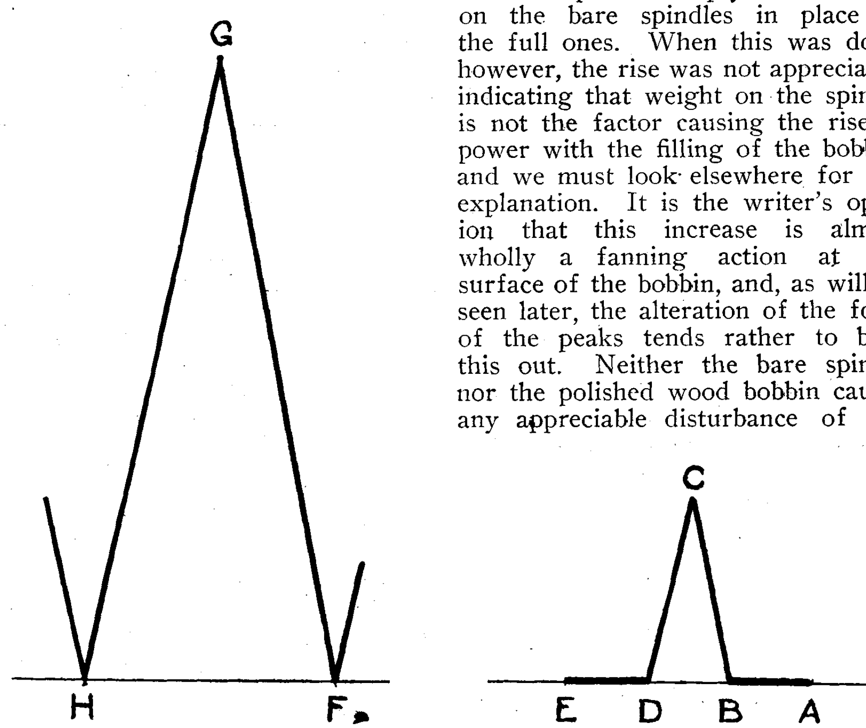


FIG. 8.—FORM OF CURVE FOR FULL BOBBIN, AND FORM OF CURVE FOR EMPTY BOBBIN

required to move air varies with the cube of the speed. If we add these two effects together we can readily understand that the power may well be influenced to a much greater extent from this cause than by mere increase of weight due to a small addition in the shape of yarn wound on the bobbin. This is farther borne out by the crude method of feeling the effect upon the bare hand or face or by holding a fine strand of yarn near the spindles. When empty almost no air motion is perceptible, while when full a strong, vigorous circulation is set up, the air being violently agitated for the entire length of the frame. A piece of fly or dust in the air will frequently be seen to be driven for many feet by these currents before settling to the floor. This, then, we believe, accounts for the steady rise in power from empty to full bobbins. It is seen to be an item of importance, although it is one which, so far as we know, has never been given any prominence whatever. We have examined many treatises and text books without finding the matter mentioned, yet it affects the power of the frame by a full twenty per cent.

The second item of interest shown by the chart, namely, the recurrence of the small peaks, is due to the "traverse" or rise and fall of the ring-rail which guides the yarn onto the bobbin during the winding process. The weight of this rail is counterbalanced by a number of cast-iron weights beneath the frame. At first thought it would appear that these peaks existed because of over-counterweighing, since the power increased as the rail descended and *vice versa*. In fact, this was the explanation given by several mill men to whom the curves have been submitted. But were this the case the peaks would consist of a series of short horizontal lines connected by short vertical lines, since at the top of the traverse there would be an abrupt rise in power, due to lifting the excess weight of the counterweights. This would be constant till the bottom was reached and then would come to an abrupt drop to the low value, which would again be constant throughout the rise. Furthermore, the curves would be decreasing in amplitude as the bobbins were filled, since the leverage on the bobbing-forming device, or "builder," is constantly shortening and therefore making it easier for the cam to operate the rail. But exactly the reverse of this is the case, the amplitude increasing in spite of this feature. We must, therefore, look to some other condition, also changing gradually throughout the filling of the bobbin, and occurring in synchronism with the rise and fall of the ring-rail. Light is thrown on this by the third item we have mentioned.

Third Item. The form of these waves changes as the bobbin fills. We have sketched and enlarged view of these peaks to show their differences. (Fig. 8.)

Owing to the fact that the force necessary to overcome the frictional resistance of the traveler as it is dragged at its high speed around ring must come from the bobbin through the strand of yarn passing from traveler to bobbin (this force remaining constant, since the speed is constant) the total pull on the yarn will vary widely from empty to full bobbin. The component of the yarn pull which drags the traveler around the ring is the component tangential to the ring's circumference. ("A," Fig. 9.) To maintain this component constant the total pull, "b," will be greater when the yarn is pointing nearer the center than when the bobbin is full and the total pull is more nearly tangential. Thus, when the bobbin is empty, this greater tension on the yarn prevents that part of it from guide-eye to traveler from "ballooning," or flying out in a bow driven from the bobbin's axis by its own centrifugal tendencies. The reduced tension at the full bobbin is not sufficient to hold this strand close to the revolving bobbin, and a pronounced ballooning takes place. Plates have been placed between the spindles to prevent the yarn on adjacent spindles from interfering at this period. The force necessary to propel this strand of yarn through the space about the bobbin is small but appreciable, and when multiplied by two-hundred and fifty, the number of spindles, is an item that must be considered. When no ballooning takes place this section, about eight inches long, lies close to the spindle, and is, therefore, revolving in the air that is propelled by the spindle itself at the same rate the yarn is traveling. The yarn, therefore, really cuts very little air for this reason. When it flies out as a "balloon," however, it not only passes out of the immediate whirlpool of its own spindle into the dead air outside its influence, but on the sides toward both its neighboring spindles it cuts into the whirlpools set up by these other spindles and by the other revolving sections of yarn similar to itself, and these eddies, being adverse in direction, each segment of yarn is cutting either dead air or air moving rapidly against its direction of rotation.

In confirmation of this theory it was noticeable that the tracing of the power curve bore a direct relation to the time ballooning occurred. Referring to the enlarged curves we have at "A" (Fig. 8) a reproduction of the curve with the empty bobbin. With the ring-rail at the top position the power was a minimum ("a"). It remained constant till the rail had passed somewhat beyond the mid-position ("b"), when the stretch of yarn from guide-eye to traveler had sufficient length to start ballooning. Immediately the power rose and continued ascending till the rail turned the lowest position ("c"), when the ballooning was at its maximum. As the rail rose, shortening the length of revolving yarn, the balloon was drawn in and the power decreased until the yarn assumed the straight line form, when the power again reached its minimum ("e"), where it remained constant until the rail again reached the top position.

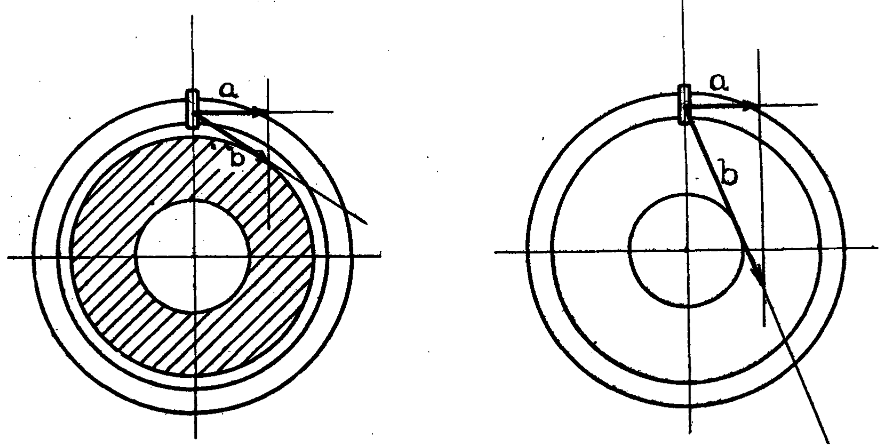


FIG. 9.—FULL BOBBIN AND EMPTY BOBBIN
b, Total pull; a, Tangential component

With the full bobbin a curve like that shown at "B" is traced. Ballooning starts immediately when the rail leaves the top position and the power immediately starts to increase and continues to rise as the balloon increases with the descending ring-rail, the condition reversing as the rail again ascends.

This appears to be the only logical

explanation of the difference in power requirements for the beginning and end of the winding process. The total curve, then, is a combination of the two features just described, namely, the fanning of the air, due to increased bobbin diameter, and the air friction, due to ballooning. It is commonly stated by spinners that the "traveler drag" is an important portion of the power required by ring frames, but the fact that this drag is constantly decreasing as the bobbin fills up and yet the power is as constantly increasing would seem to confirm our conclusion that it is rather the air resistance than the traveler drag which is of moment.

Incidentally our chart shows one or two minor items of interest. It will be noticed that just before the doff or removal of the full bobbins at 8:07 A.M. and again at 1:38 P.M. the curve becomes ragged and irregular. This was caused by the fact that the bobbins were allowed to over-fill and rub against the ring and traveler. In the run from 8:07 A.M. to 1:38 P.M. we can count seventy-eight traverses of the ring-rail, while from 1:40 P.M. to the close of the day, when the frame was again ready to doff, but seventy-five traverses occurred and no interference was noted.

FIG. 10.—SPINNING FRAMES AT THE CHICOPEE MFG. CO. MILL, CHICOPEE FALLS, MASS. DRIVEN BY WESTINGHOUSE TEXTILE TYPE MOTORS

Our curve also shows that stops were made at irregular intervals to put on broken bands and to clean the frame at the driving end.

As explained in our opening remarks, it is only within the last few months that instruments for making such records have been available.

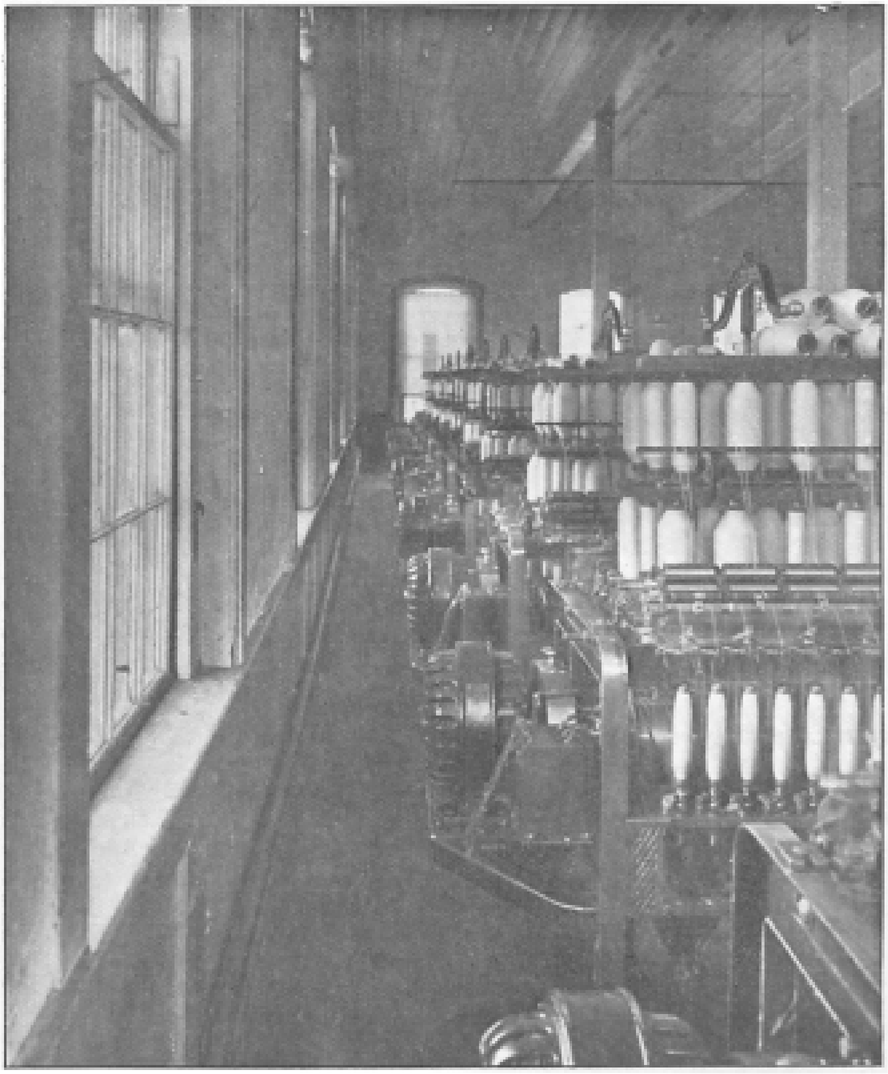


FIG. 11.—SPINNING FRAMES MADE BY LOWELL MACHINE SHOPS. DRIVEN BY WESTINGHOUSE MOTORS IN MILL OF WEST BOYLSTON MFG. CO., EASTHAMPTON, MASS. (TAKEN WHILE IN OPERATION, HENCE RING RAIL DOES NOT SHOW)

A minute analysis of the power changes taking place in a frame has been impossible, though it has always presented a field for interesting speculation. This is one of a multitude of cases where the individual motor has enabled the investigator to compel machines to give up their secrets and show forth in black and white all that has for years been taking place unsuspected and concealed from even the most inquiring minds.

Similar power curves have been made on all the other machines in a cotton mill, and these will be discussed in a similar manner in subsequent papers.