ELECTRIC DRIVING FOR MULE SPINNING

By Albert Walton

In a recent issue of this magazine the relative advantages of rope and electric transmission with individual motors for textile mills was discussed, and it was shown that the question demanded the exercise of skilled engineering ability and experience applied to each particular instance to determine the proper plan to be adopted. In the present paper Mr. Walton discusses the manner in which the difficult problem of driving the self-acting mule by electricity has been treated, and the results of experience are placed at the disposal of engineers and manufacturers.—THE EDITOR.

OF the two methods of spinning yarns involving the use of "ring spinning frames" and "mules" or "jacks," the latter, though the older and more complicated, is so superior for certain classes of work that its simpler rival has never been able to entirely replace it. In the August, 1909, issue of this magazine we took up the subject of the power requirements of the ring frame in detail, and while we showed that the subject is not so simple as a superficial observation would indicate, the problem of properly driving the mule is vastly more complicated. This machine is a mechanical development of the old hand spinning-wheel methods, where the spinning and drawing are separated from the winding process, and while this is a relatively simple matter, with a single strand of yarn and a single spindle under control of the human hand and brain, it required wonderful ingenuity to construct a series of cams, gears, ropes, belts and levers to handle nearly a thousand strands and spindles at once, and that entirely automatically. The result—"Crompton's self-acting mule"—has come down through the generations as a machine fearfully and wonderfully made, full of strange starts and stops, reversals and accelerations, whose mechanism one cannot hope to fully comprehend but by months of apprenticeship and study.

It is these frequent changes that make the driving of a mule difficult. To comprehend the problem fully, it is first necessary to understand the cycle of operations as they occur under normal working conditions.

Referring to Fig. 1, which shows an end view of the essential parts of a cotton mule without the operating mechanism, it is seen that the prepared "roving," or coarse, partially twisted strands wound on bobbins, are mounted above and in front of the carriage on a rack or creel. The strands are brought forward over clearing bars to the feed rolls and then down between the "faller wires" to the spindle. This spindle, inclined at an angle of about 15 degrees toward the creel, is revolved at the proper time by a cord or "band" passing around a long tin driving cylinder to a small grooved pulley or "whorl" on the spindle. In the starting position the carriage is, as shown in the heavy lines, close up to the rolls, and all parts of the machine are standing still. The carriage now starts back very slowly, the spindles being almost instantly brought up to their full speed of from 6,000 to 9,000 revolutions per minute. Simultaneously the rolls start to draw the cotton from the creel, or the wool from the spools, and feed it out, the rate of feed being a trifle less than that of the retreating carriage. The distance the carriage travels to reach the position shown in the light outline varies from 48 to 60 inches. In woolen mules, when it has proceeded from two-thirds to seven-eighths of this distance the rolls stop feeding, the yarn being thus drawn for the remaining portion of the run back. In the outer position the carriage stands for a second or more while the spindles continue to revolve and put more twist in the yarn. The spindles now stop and reverse for three or four turns to unwind that portion of the yarn that has wound itself between the top of the spindle and the top of the cop or wound portion of previously-spun yarn on the spindle. The faller wires then assume the position shown in Fig. 2 and the carriage starts in, the lower wire rising and falling by just the right amount to guide the yarn onto the spindles, so as to properly form the tapering cop. The spindles during this run-in are revolving with just sufficient speed to take up the yarn and keep it taut as the carriage approaches the rolls. Here the faller wires resume their position as in Fig. 1, and the process is repeated.

Obviously the greater power is called for when the run-out commences and all the spindles have to be brought from rest to full speed in the first fraction of a second. The peak is so abrupt as to be in the nature of a blow. So sharp is it that the best belts will slip, the "shrieking" caused by the slippage being a sound almost inseparable from the operation of the larger mules. For the run-out the high rate of speed of the spindles consumes considerable power, about one horse-power being required for each fifty spindles. For an instant at the end of the stretch the power falls to nearly zero, and as the faller wires are moved the three reverse turns are made. During the run-in the spindles are revolving slowly, and, while the carriage travels much faster than in the run-out, the power is not great. The conventional power curve for a worsted mule, as shown by electrical instruments, is as shown in Fig. 3, though there are certain minor fluctuations with which we need not concern ourselves here.

The oldest method of driving groups of mules was by belting from a countershaft, which, in turn, was belted to the heavy main-line shaft, which was driven by belt or ropes from the engine, and this method is still being installed in mills where electric drive is not used. It is a very successful and simple system, the enormous momentum of the huge flywheel and mass of revolving shafts and machines being sufficient to absorb the violent peaks caused by the number of mules getting in step and starting at the same time. Without the momentum of the mill to call upon, no engine, already loaded up, would have sufficiently good overload speed regulation to prevent a very noticeable check in speed. That this momentum is called upon is a well-recognized fact, and is frequently advanced as the chief argument for the system. A close analysis of the matter may serve to throw another light on the case. The momentum or flywheel effect of any mass can be of assistance in absorbing sudden peak loads only by surrendering part of its stored energy to the part making the demand. It can give up this energy only by reducing its velocity. The greater the mass the less will be the reduction in speed called for to supply a given demand, but an increased mass means only a greater volume of shafting and machinery. Thus, while we increase the momentum to help out, we also increase the number of machines to be affected. The eye and ear cannot detect a speed variation of plus and minus 5 per cent. from the normal, which is of only a few seconds' duration, and until recently this fluctuation was not known to exist. The elaborate tests of Mr. William Woodhouse in English cotton mills with a specially devised and very sensitive speed-recording instrument have shown that double this variation is suffered many times in a period of five seconds in an engine-driven mill. (Westinghouse Electric & Manufacturing Company, "Textile Motor Talk" No. 10.) This fluctuation is

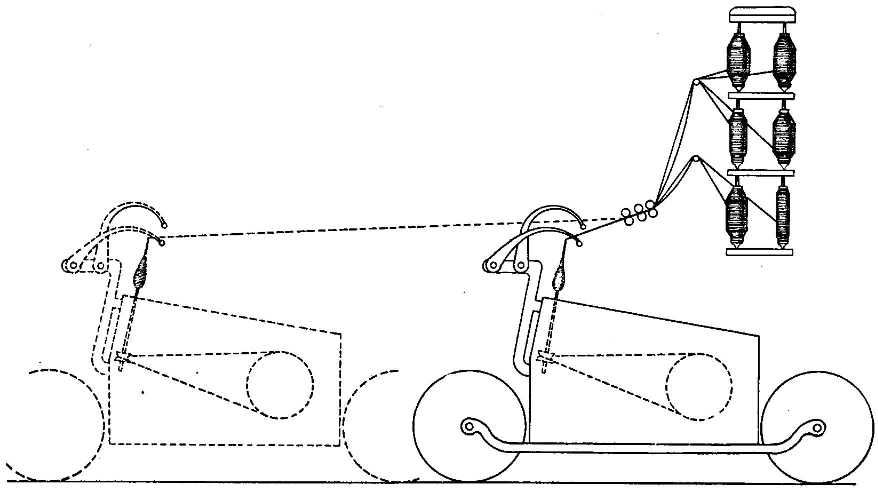

FIG. 1.—OUTLINE SKETCH OF END VIEW OF MULE

Showing relative positions of creel, rolls, carriage and faller wires at beginning (solid lines) and end (dotted lines) of run out.

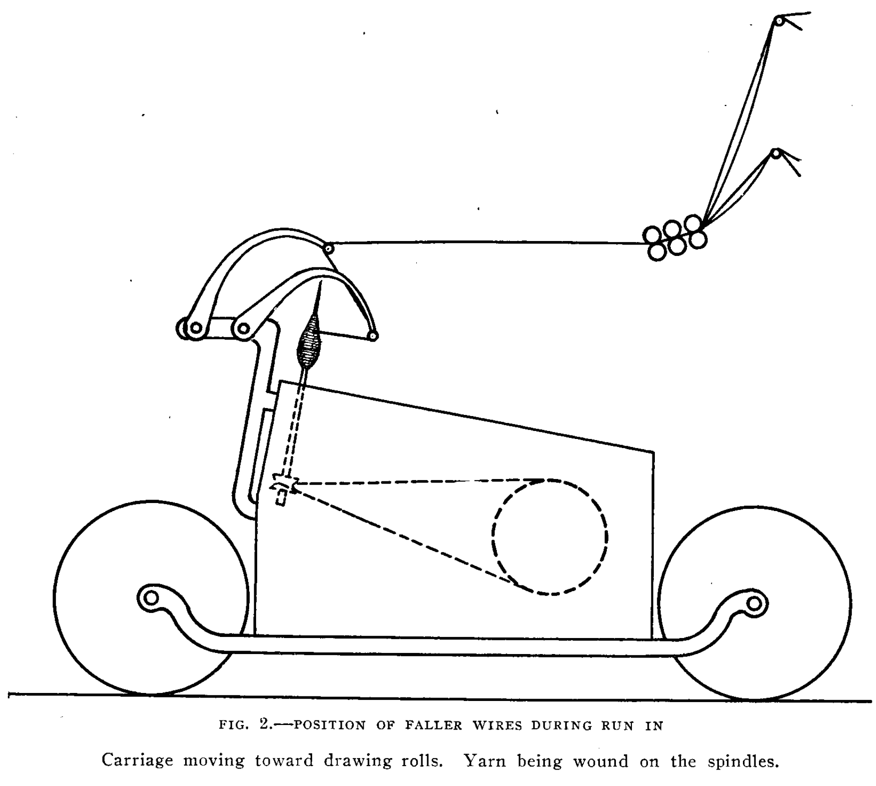

FIG. 2.—POSITION OF FALLER WIRES DURING RUN IN

Carriage moving toward drawing rolls. Yarn being wound on the spindles.

reflected on every machine in the mill, although to the eye they are running at the absolutely constant speed the work demands. When it is realized that the mules are making from one to five complete cycles each minute, the frequency of the occurrence of these vicious surges may be appreciated. Furthermore, it should be stated that approximately half the power required by the mill is used in the spinning room. Thus, a sudden increase of even 25 per cent. of the demands made by the mules means no less than an eighth of the entire power for the mill to be superimposed on an already fully loaded system, and yet the peaks will frequently be found to exceed this percentage. To obviate this difficulty, certain mills have separated the mule drives from the preparatory processes and the weaving by driving them by a separate engine. While this relieves the situation for the other machines, it aggravates it for the mules by the loss of momentum, nullifies the argument for the large-unit drive, and creates an entirely new problem.

This separation has more frequently been accomplished by use of electric motors in one way or another. In at least one New England mill the mules are driven as a group by ropes from one engine. It is a yarn mill, and the mules occupy two entire floors, while the preparatory processes occupy a third. As there is no weaving, this means that the mules constitute two-thirds of the total load and the fluctuations form a proportionately greater percentage. With the steadying effect of the weave room lacking, it was thought best to insure a steady speed for the drawing frames, combers, roving frames, etc., by the use of motors. A second engine is direct connected to an alternator, which drives motors of from 20 to 150 horse-power, distributed over the floor where the preparatory machines are installed, driving them in suitably large groups.

Other large mills employ motors throughout. In most cases the mules are arranged in groups of four, six or eight to each motor. Small worsted mules average about 3 horse-power each, and the large cotton mules will average about 8 horse-power apiece, so the motors vary in

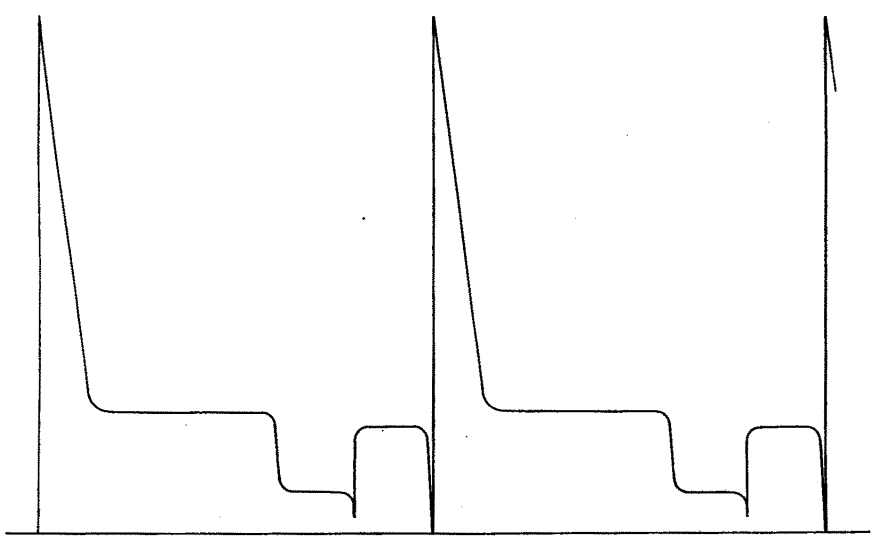

FIG. 3.—TYPICAL POWER CURVE OF WORSTED MULE

Showing the peak due to acceleration of spindles, power during run out, putting in twist and run in.

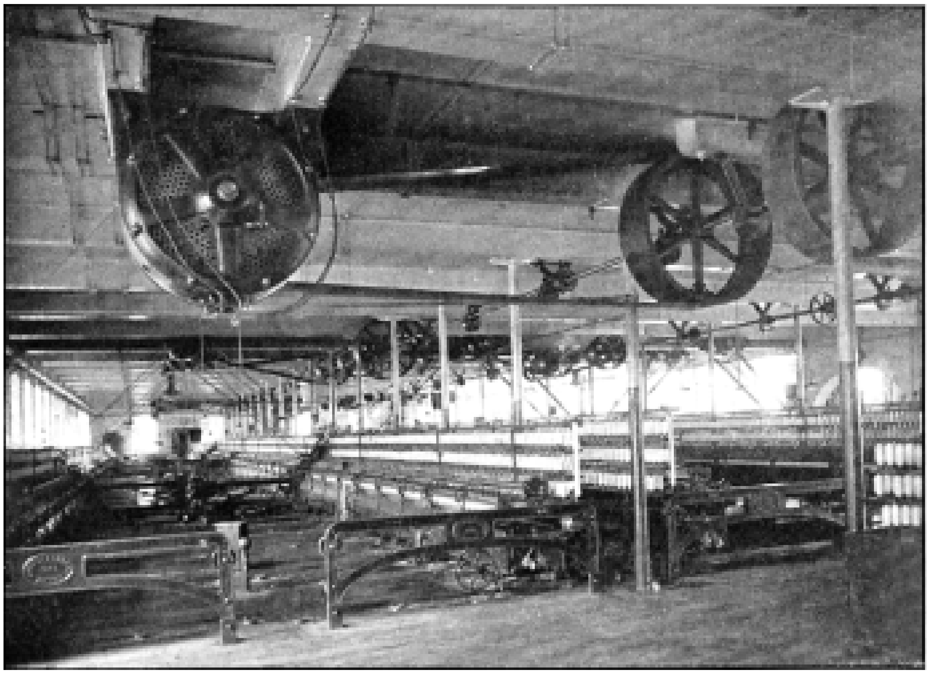

FIG. 4.—A CAREFULLY-ARRANGED ROOM WHICH EMPLOYS MOTORS OF 50 AND 70 HORSE-POWER

size from 10 horse-power to 150. The most carefully arranged room that has come to the writer's attention employs motors of 50 and 70 horse-power, driving groups of three and four mules, respectively, the surplus power being designed to care for the peaks which occur when the mules get "in-step" (Fig. 4). To further assist in providing for these emergencies and to provide a substitute for the old mill momentum, a 600-pound flywheel is placed on each countershaft, from which a mule is driven. These are 30 inches in diameter and make about 350 revolutions a minute. This weight, combined with the mass of the short stretches of shafting and the necessary pulleys and the momentum and overload capacity of the motor, provides a very successful drive. That these flywheels are not a necessity, however, may be seen from the accompanying photograph, where a similar and equally successful drive is shown without other momentum than the driving parts. This installation has been in daily operation for the better part of a decade with most excellent results. As will be shown later, the use of flywheels is at least open to question. Such difficulties as have arisen in applying motors to group drives have come from providing an insufficient reserve power in the motor rather than from lack of momentum in the transmission.

As in other power problems, the most intimate knowledge of the requirements of the situation has come with the application of the individual motor. At least one woolen mill has adopted this method on all its mules and has had it in operation for several years. Recently several other mills, both East and West, have taken up the matter seriously in connection with the recent extension of individual drive in other departments of the textile industry. Considerable experimenting has been done with various forms of motors, and a wide variance of opinion exists as to the merits of the drives involved. Three distinct types are contesting for supremacy and are raising some interesting questions in engineering. One of the large electric companies is consistently recommending a motor with very good speed regulation and with a 250-pound flywheel mounted on the motor shaft on one side, while on the other is a wide-faced pulley, from which belts run to the mulehead (see Fig. 5). Another large electric company makes one of two recommendations, according to conditions, but no flywheel is used in either. In cases where speed considerations will permit it a slow-speed motor of moderately good speed regulation is used and belted directly to the mule. In installations where this method cannot be used to advantage a high-speed motor is belted to a countershaft driving the mule. The recommendations of the engineers are so radically opposed that it is interesting to see how each justifies his opinion. One advances the following reasons: The load is a violently fluctuating one, running from zero to four times average value. It is eminently desirable that the speed of the drive be as little affected by these fluctuations as possible, in order that the spindles and drawing rolls may revolve at a constant speed while the spinning is in progress, or from start to finish of the run-out. As an induction motor has the property, inseparable from its design, of falling off in speed under load, it cannot be expected to remain unaided at constant speed when such a violent momentary overload is forced upon it; but with a heavy, high-speed flywheel it can meet this instantaneous call with little or no appreciable check in speed. Furthermore, the flywheel smooths out the load curve from an electrical standpoint, and a much less severe peak is imposed on mains and generators than would be the case if it were omitted. Consequently, also, the motor capacity may be less, and only the necessary size to care for the average load need be provided.

The arguments brought in support of the yielding drive with lower speed regulation and no flywheel are no less interesting. It is held that the flywheel and close-speed regulation defeat their own ends. A large amount of power is required to accelerate so many spindles with their cops of spun yarn from rest to, say, 7,500 turns per minute in a single second, while probably more than four times this would be required to do this in half a second. As a matter of fact, no matter how much power one could apply to the driving cylinder, it is doubtful if better or even as good results as this could be obtained, since the inertia of the spindles will cause the small driving bands to slip momentarily on the spindle pulley or "whorl" if too rapid acceleration is attempted. But if this were not the case and the perfect speed of the flywheel motor could be imparted instantly to the spindles, as its supporters believe to be true, it would be an example of "the immovable body being struck by the irresistible mass." Something would have to give. Following this line of argument, its supporters hold that the motor should give way at this crisis somewhat, though not too much. By easing over this point and relying on the inherent overload capacity and high "pull-out" properties to supply to the belts, ropes and bands as much power as they are capable of carrying, they are disposed to assert that the net result will be a quicker acceleration of the spindles than with the irresistible flywheel drive. They also believe that the poorer regulation of the motor is not a detriment in the spinning, since, once the spindles are accelerated, they provide a constant load until they reach the end of the stretch; and a constant load means a constant speed, no matter what the regulation may be. The fact that the motor speed is slightly higher during the run-in than during the spinning is held to be no detriment, but rather an advantage, the two actions being entirely indepen-

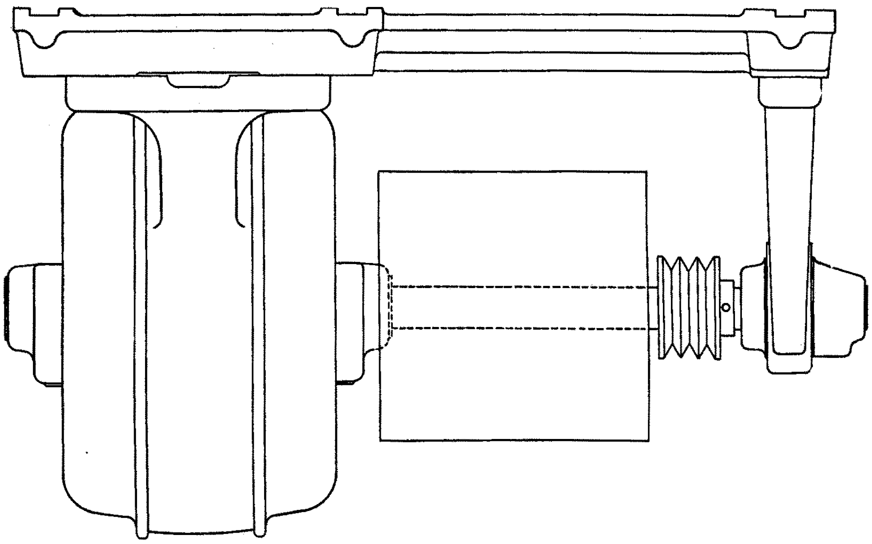

FIG. 5.—OUTLINE OF SPECIAL MOTOR FOR DIRECT BELT DRIVE TO WORSTED MULE

dent of each other and the run-in being practically lost time, like the return stroke of a shaper or planer in a machine shop .

Just how the two work out in practice the writer had a very good opportunity to observe recently where a demonstration of both methods was in progress. The mules were identical in all details of construction, and both were spinning No. 50's, soft worsted yarn, with all the adjustments made as nearly the same as possible. Both motors were on the same mains of a three-phase, 60-cycle, 550-volt circuit, and both were 6-pole, 15-horse-power motors with a no-load speed of 1,200 revolutions per minute, built especially for this demonstration. One carried at one end a 250-pound flywheel, and had a rated full-load speed of 1,140, or a slip of 60 turns, 5 per cent. of the no-load speed. The other had no flywheel, and had a full-load speed of 1,080 revolutions per minute, or a slip of 10 per cent. The pulleys of both motors were the same diameter, 10 inches, and the same results were shown with both paper and iron pulleys. Five minutes' observation made simultaneously on the two motors showed that the flywheel motor exceeded the other in average working-load speed by 2 per cent., yet the mule driven by the slower motor made seventeen trips while the mule driven by the flywheel motor was making sixteen. Thus, in spite of a 2 per cent. slower motor pulley speed, it was running 6 per cent. faster by actual count. To check up the theoretical explanation it was only necessary to climb a ladder to a point near enough to the motor to hear distinctly the click of the belt lacings as they passed over the motor pulley. On the flywheel type motor when the peak occurred it was observed that the pulley continued to revolve with apparently undiminished speed, but lost its tractive power on the belts by very bad slipping. The clicking of the belt lacing dropped from its regular speed instantly, the next trip of the belt taking certainly twice as long as the normal period and the next nearly as long, while from then on the trips rapidly resumed their normal time. The sound of slipping was very noticeable, and the pulley was very hot from friction. A similar observation made at the pulley of the other motor disclosed no such state of affairs. A slight slip at the mo-

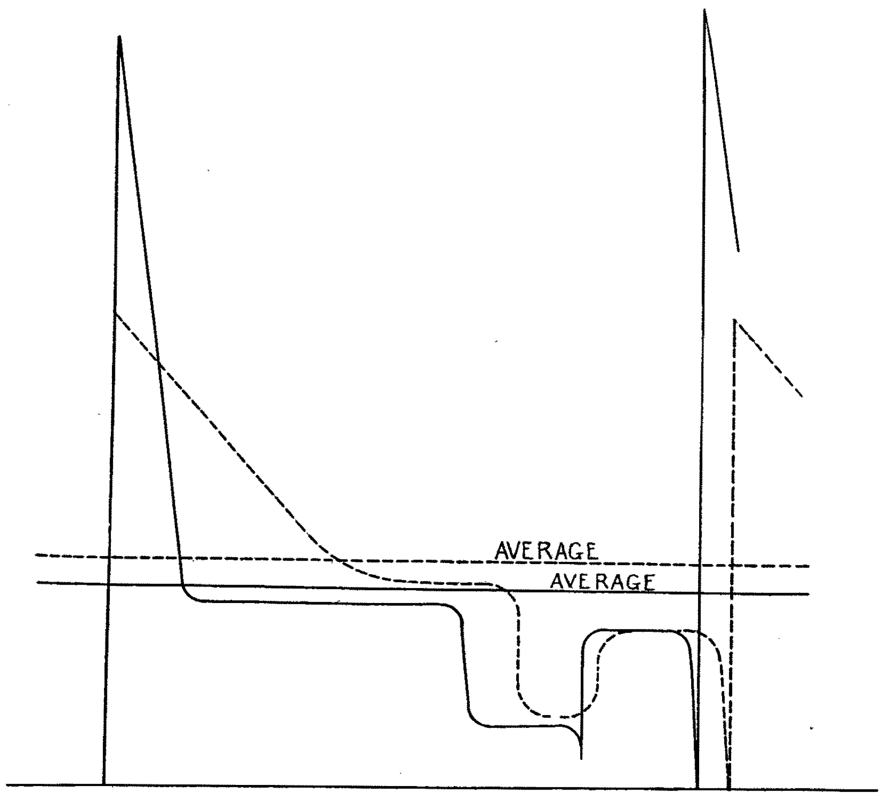

FIG. 6.—CURVES SHOWING EFFECT ON POWER REQUIREMENTS DUE TO USE OF FLY-WHEEL ON MOTOR DRIVING MULE OF 600 SPINDLES

Solid line shows power input to motor without fly-wheel; dotted line for motor with fly-wheel.

ment of starting occurred, but the extra load pulled the motor speed down to a point where it could hold the belts. The inherent overload power of the motor delivered to the belt which was then adhering to the pulley enough more power than the other motor could transmit to the slipping belt to bring the whole machine to speed much more quickly.

Further importance attaches to this feature by reason of the fact that the carriage and all the auxiliary are controlled by the belts, while in certain types of mules the spindles are driven through a separate system by small ropes over a grooved pulley on the motor shaft. Although subject to the same sort of slipping, the ropes will slip to a different degree from the belts, and the twist put into the yarn will not be the desired amount. When the slip of the belt is reduced, as with the motor without the fly-wheel, this feature is practically eliminated. On the usual cotton-mill mule the rope drive for the spindles does not go back to the motor, but receives its power through the belts, so that the principal gain for these machines in eliminating slip is in production.

The accompanying curves are roughly representative of the power history of the two systems (see Fig. 6). They are average values from a large number of readings on an indicating wattmeter at intervals of two seconds. These were checked by a like number of observations on the time required by the mule carriage to execute the various parts of its cycle. Although such a method cannot be absolutely accurate, it shows conclusively that while the flywheel effectively cuts down the electrical peak it does so by prolonging the reduced maximum to such length that the net result is a greater power demand than is required by the other motor, thus defeating its purpose in this respect, as well as in the main object of its use.

There is also the objection that a number of motors suspended from the ceiling, each with a 250-pound balance wheel revolving at such high rate of speed, provide an element of danger that might well be eliminated. In one instance within the writer's knowledge one of these flywheels was dislodged in the course of regular operation and fell to the floor, bringing up violently against the mill wall after a short and rapid trip across the floor, with, fortunately, no more serious results than a broken floor and a dented wall.

It seems, then, that when motor drive is used a motor that will yield somewhat in speed is a better engineering proposition than the flywheel type with a very high speed regulation. In the attempt to reproduce the old conditions of great momentum in the drive one vital feature was overlooked. The high speed of the motor necessitates a pulley of smaller diameter than the mule pulley, and this introduces a new problem, which is solved by introducing a new feature in the driving system. With the old shaft drive the counters run about 350—too slow for an electric motor—and the pulleys are, consequently, 36 inches or more in diameter, which prevents any slippage except at the mule pulleys themselves. Thus a great deal more power can be transmitted at the instant of impact than with the unyielding motor. In spite of this, however, and owing to features already brought out in the early part of this article, either of these motor drives will produce more yarn than will the large and fluctuating group system.

A third system is a combination of the two and retains the good features of both. This employs simply a constant-speed standard textile motor driving the old countershaft above the mule. This retains the large driving pulleys and permits the use of a high-speed motor of no "special" design and obviates all necessity for balance wheels. It is our opinion that this is the drive which will be proven most successful in the long run. In a recent competitive demonstration of the two systems this latter drive was finally adopted as yielding greater production of more uniform yarn and involving not over two-thirds of the first cost, including countershafts and belts.

Thus, as usual, the most successful application is found by retaining as many of the good features of the old and tried methods as possible while bringing as many of the undoubted advantage of the new as may be.