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THE

STUDENTS' COTTON SPINNING.

BY

JOSEPH NASMITH,

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SECOND EDITION. REVISED AND ENLARGED.

MANCHESTER:
PUBLISHED BY JOSEPH NASMITH, 61, BARTON ARCADE.
JOHN HEYWOOD, DEANSGATE AND RIDGEFIELD, MANCHESTER. 2, AMEN CORNER, LONDON, E.C. 33, BRIDGE STREET, BRISTOL.

JOHN · HEYWOOD
PRINTER STATIONER
EXCELSIOR WORKS
BOOKBINDER PUBLISHER
MANCHESTER

PREFACE TO SECOND EDITION.

In presenting this book to the public the author ventured to say that he did so "with a confidence begot of the success of his previous venture." He is gratified at being able to say that this confidence was well founded, the first edition having been sold in 18 months. It is evident, therefore, that the book has taken a firm position in the appreciation of the public.

The present issue has been thoroughly revised; and the author takes this opportunity of thanking those correspondents who have been kind enough to call his attention to various small errors and ambiguities which had escaped attention. In accordance with a suggestion made, that portion of the book dealing with the production and transmission of power has been much expanded. Among the new features of this part of the book will be found a description of the indicator diagram and what it reveals, and a specially calculated table of powers transmitted by cotton ropes. An Appendix has been added, which supplies information on a few points which were omitted in the first edition, more especially on the commerce of cotton, including information of the weights used in various countries where cotton is grown or spun. Several illustrations have been added. The diametrical measurements of cotton fibres given in the table on pages 458-59 are mostly those of Mr. Hugh Monie.

The author ventures to claim that no book on the subject has ever previously been issued which deals so fully and exhaustively with it; and although the addition of so much matter tends to make the volume a large one, it has been done with the object of placing within the hands of readers the most complete information available.

November, 1893.

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THE STUDENTS' COTTON SPINNING.

CHAPTER I.

THE EVOLUTION OF COTTON SPINNING.

(1) THE theory of evolution is made to account more than plausibly for the existence of things both great and small, animate and inanimate. On the one hand, by means of the nebular hypothesis, the origin of the sun and its planets, including our earth, as well as that of numerous other galaxies, is accounted for; and on the other, the genesis of the minutest speck of animal life. It has often occurred to us that the original progress and subsequent development in not only cotton spinning but in the working of all textiles does not apparently accord with the current doctrines of development. For this reason. The votaries of evolution assert that all progress takes place in order of time in gradual changes, but this is certainly not the case with textile machinery. As regards minor inventions, it is, of course, perfectly true, but it does not satisfactorily explain the fact that the art of spinning with the hand-wheel remained the same for thousands of years, and was entirely revolutionised and rendered obsolete by a few inventions brought out practically within the last century. To be consistent, believers in the theory of evolution must accept as an explanation of this very striking fact the hypothesis that still more wonderful development must take place at some time in the machinery in these industries, not minor improvements in detail merely, but radical improve-

ments in principle. That such will take place at some time or other is firmly believed, and also, that after working on the newly discovered lines for some time another radical improvement will occur. Many will probably smile at a suggestion that any great improvement in the present method of, say cotton, spinning is possible, without considering how vast and extensive an improvement the present system is over the mode that preceded it. Supposing, however, the radical improvements do occur, even if at intervals of thousands of years, the case stands on all fours with the theory of evolution. The greatest step that was ever made in advance in the whole art of cotton spinning was when some untutored savage invented twist, or thought of what to us is the very elementary idea of twisting two or more fibres or filaments together to make (perhaps not yarn) but thread or string, the latter more correctly describing it. It is not possible to discover his name or country, but whoever he was he certainly deserves a niche in the temple of fame. Before his time probably ligatures of some kind were in use, made, most likely, by knotting or plaiting together the strands of bark. Whether the first efforts of making string were with wool as a material, as many believe, or were confined to vegetable fibres, filaments, or strips of bark, cannot be ascertained with exactitude, but our opinion inclines to the latter view. The fact remains, however, that the greatest discovery in spinning was the invention of "twist."

(2) So much having been accomplished, we have the whole basis of spinning. It is probable at first that the filaments, which were twisted, consisted either of pieces of grass, or were obtained by the rotting off by natural means of the bass of fibrous bark. A quantity of this stuff would be gathered together and be twisted by one man, possibly by means of the rotation of a hooked stick, to the hook of which the material was attached, while another man stood by the heap of fibrous matter and fed it out. After working on this plan for some time, one of our ingenious ancestors thought it rather troublesome to have to continuously rotate a plain stick with a

hook at the end, and made a search in the woods for a piece specially shaped something like a crank, which, being held loosely in one hand, could be turned by the other hand, so that the hook or crank was rotated and twist put into the strand. It will be noticed that this plan, which was probably the first mechanism adopted, is a good illustration of the persistence of original inventions, for with the exception of using an iron hook and crank in place of the wooden one, this method of spinning is in use in nearly every foundry in the country, for the purpose of making what are called haybands for cores. Commencing with the twisting together of a few filaments of approximately the same length, the discovery would not be long delayed that by overlapping one set of fibres by another the twist would be successively introduced into each set. This is modern spinning, which differs from the primitive system only by this fact of continuous twisting of fibres round each other.

(3) With the knowledge available, it must be understood that only the probabilities of the order in which things would naturally occur are spoken of. When the art of spinning had been followed for some ages, most likely in the above condition, it is easy to imagine that from making very coarse cords or bands from vegetable fibres, it became possible, with an increase of skill, to produce them tolerably fine, and to spin wool on this system also with a much better and finer result. The product would then be not a rough cord, or even a string; it would approach more nearly what we call yarn, the fineness of which would, of course, depend on the skill of the spinners, for by this method it would always require two to make a yarn. It was however observed that to require the services of two persons to produce a single end of yarn was to expend much labour upon a small result. Consequently, the next great improvement is reached, which consisted in the invention of the distaff and spindle, although, at first, the former was not absolutely necessary. The hook was dispensed with, being replaced by a slit or cleft in the end of the spindle in which the yarn was placed. With this simple apparatus yarn was made in the following way.

Some of the fibre was taken in one hand and some was also placed in the slit. With the other hand the spindle, which was allowed to hang freely and vertically, was revolved. As the yarn was spun the spindle approached the ground, when, a sufficient length having been made, the spindle was taken up and the yarn wrapped upon it, after which, another and succeeding part of the material was fixed in the slit and the operation proceeded with as before. In this case the spindle was perfectly free,

Fig. 1.

and it was, doubtless, soon observed that it was easier to twirl and that it could be revolved for a longer period when its weight was increased by that of the yarn coiled upon it. This led to weighting the spindle with a ball of clay or a lump of metal. The distaff is not an absolutely essential part of the apparatus, being merely a staff upon which some of the raw material is placed, but was commonly employed. The process, as carried out by a Greek spinster, has been described by several classic historians, and is illustrated in Fig. 1, Fig. 2 being a representation of the modern practice. It seems to have been preferred in Europe to the wheel and spindle as a means of spinning until about 200 years ago, so remarkable was its persistence. It is stated in an interesting little book published in 1819, that there were persons using it in North Britain (Scotland) so late as 1817.

Fig. 2.

(4) The distaff consists of a rod of wood shaped with a taper blade to hold the material, which is placed upon the longer part, and is fastened by a garter or string. The lower portion was fixed in the spinner's belt by means of which the distaff is kept steady The spindle was turned quickly by the spinner's right hand, and upon it was twined the fibrous material drawn from the distaff by the other hand. The twisted material was wound upon the

spindle at its upper end, and below the latter point a small wheel, or whorl, generally made of stone, was fixed. This acted as a fly, and the revolution of the spindle on its lower point, which rested on the floor, completed the operation.

(5) The next most important step in advance, was when some one invented the means of multiplying speed by the aid of a small and large pulley, round which a band was wrapped, the large one being driven. The great utility of this invention as a means of revolving the hook is easily recognised. An improvement almost as great, in fact as great, for without it the means of multiplying the speed would not be available, was the discovery that the hook could be dispensed with by slitting the point of the spindle. The yarn when spun was wound on the spindle in an elongated ball, now termed a cop, the strand which was previously attached to the hook being now part of the yarn in the cop revolved with the spindle.

(6) Another remarkable invention consisted in dispensing with the slit previously used. As the process has been so far described, it will be observed that the axis of the thread being operated upon and the axis of the spindle are approximately in a straight line. It was, however, discovered that by holding the yarn at a considerable angle with the spindle, not quite a right angle, it would pass over its point, and for every revolution made by it one twist would then be transferred to the yarn. It is this system which is used in mule spinning, this invention being really the precursor of it. It should be noticed that the mode of spinning just described differs only in degree from that in which a hook is used, and in which the man turning it retreats. With the wheel successive lengths are spun. A spinner with the hook could approximate to spinning with the wheel if after a yard or so had been spun he wound it on his crank and again inserted his hook into the yarn. In this case the difference, as has been said, is only one of degree, but it will be recognised that although very slight, it is really very important.

(7) The earliest machines used for spinning, so far as can be ascertained, were of the rudest construction, having a wooden

spindle driven by a heavy wheel, and at first were used only for producing coarse yarn from a bundle of unprepared fibrous material. But as skill in the art increased and knowledge respecting textile fibres extended, it is easy to see how cotton came to be employed as the raw material. At first the cotton was probably brought to the spindle as it was picked, without any preparation whatever. To spin cotton, a finer spindle, without being absolutely necessary, would be very advantageous, and consequently the wheel was fitted with a metallic spindle, and eventually spinning was done sometimes with and sometimes without the distaff. The following was the mode of operation :—Some cotton being attached to the spindle, the wheel was turned with the left hand. A further quantity of cotton was supplied by the right hand, the fingers of which, according to Baines, were kept dry by the use of a chalky powder. When a piece of yarn had been spun of the required degree of tenuity, which was accomplished by the spinster holding it between the finger and thumb and withdrawing her hand to the extent demanded, twist being meantime put in by the revolution of the spindle, the yarn so produced is wound on the spindle by turning the latter the reverse way to what it ran when spinning. This type of wheel is shown in Fig. 3. With apparatus of this rude character yarns of extraordinary fineness have been for generations produced in India. It has lately been pointed out that Indian cotton as spun in the organised factories now existing cannot be drawn into yarn of any degree of fineness. It is tolerably certain that the materials which the earliest Indian weavers of whom we have records had at their disposal were substantially those existing to-day. It speaks volumes for the cultivated skill of the progenitors of the present Indian operatives that yarns so fine as to produce muslins of the exquisite character of those obtained from India could be spun from cotton which is not now looked upon as a tractable material. A wheel which was extensively used was known as the flax or Saxony wheel, and is shown in Figs. 4 and 5 in side and end elevations. It consisted of a strong frame, which carried a wheel D, from which by a band E the spindle and flyer G was driven. The spindle had a bobbin loosely placed upon it, but with sufficient friction applied to cause it to lag behind the flyer, and so wind the yarn. The spindle was sustained by a post F fixed into the frame, and the wheel was

FIG. 3.

driven by the treadle shown. The material was placed upon the supporting piece K, and was withdrawn thence by the hand of the spinner.

(8) So far the fibre treated had undergone no previous manipulation in the spinning processs, when it was doubtless discovered that the operation would be facilitated and a better product

be obtained if the cotton was brought to the spinner in a more open and fleecy condition. In all probability, therefore, the next improvement was the introduction of a preparatory process. This consists of bowing the cotton, a description of which operation is given. This process of bowing has been in use by some hat

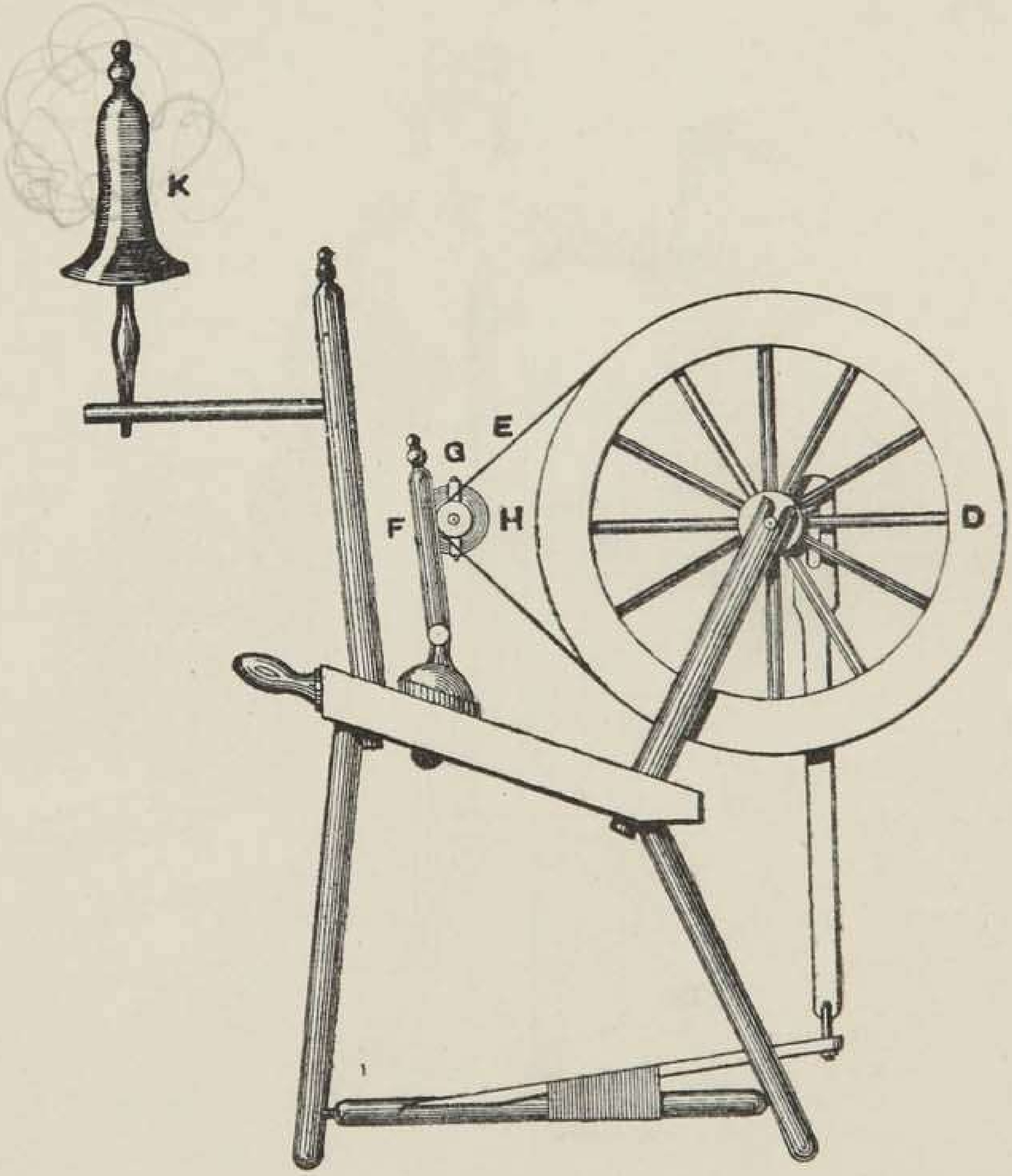

FIG. 4.

makers until quite recently. The bow employed in India was rather different to the hatters' bow, being simpler. It consists of two stretched strings attached to one of the extremities of a crescent-shaped crosspiece fixed on the staff, and tightened by some means at its other extremity. The cotton being spread on a table, the staff is held with one hand, and with the other, by means of a mallet or a rough piece of wood, the workman strikes the stretched cord nearest to him, thereby causing it to vibrate. This causes the other cord to oscillate also, and the latter, being in contact with the heap of cotton, jerks up the fibres to another part of the table almost separately, and effectually clears the

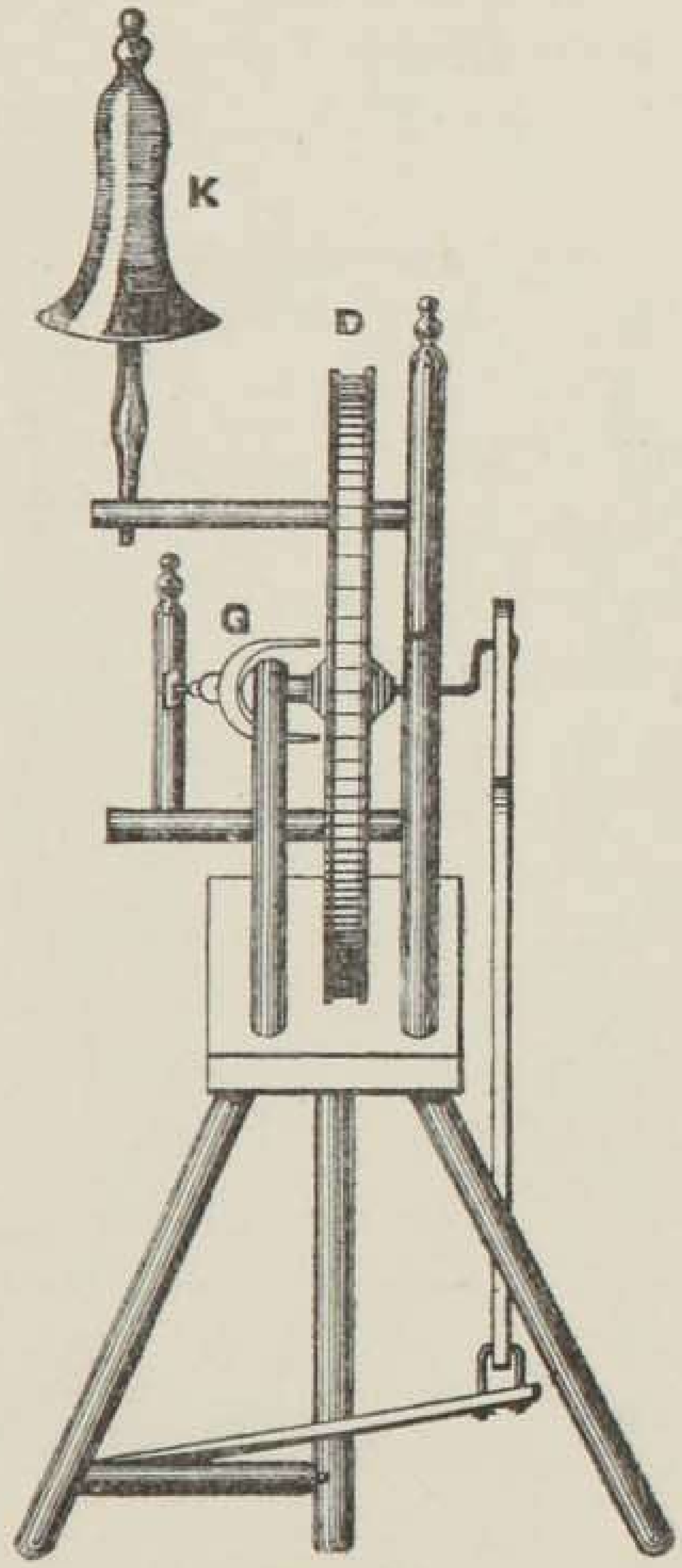

Fig. 5

mass of dirt and knots. All who are acquainted with the modern cotton trade will recognise that the operations of willowing and opening are used mainly for the same purpose. The seeds in the cotton pod were got rid of by another rude form of machine called a "Churka," which consisted of two horizontal rollers with a few longitudinal flutes. The rollers are revolved by a handle attached to the axis of the upper one. The cotton is drawn through the rollers, the space between which is insufficient to allow the seeds to pass, so that the fibre is separated from them. The cleaned cotton, therefore, is delivered at the far side of the rollers, while the seeds remain on the feed side. An illustration of this machine and the bow is given in Baines' "History of the Cotton Manufacture," to which the student can refer.

(9) A still more primitive process is that still pursued in some parts of India, by which a bundle of cotton is placed upon a flat stone, and a roller is passed over it by the foot of the operator —a woman generally. The roller receives a short reciprocal movement, and the seeds are removed by the hand, a sitting stooping posture being adopted for the purpose. The account thus given is on all grounds of probability the order in which the successive stages in cotton spinning, as it is practised in the East, and till comparatively recently in Europe, were developed.

(10) But within a comparatively short period of the introduction of the art into England, of which our earliest records fix the year 1538 as the date, very considerable improvements occurred. The process of carding, however slow and laborious, was making progress towards its present perfection, and was, as far as can be discovered, an entirely English invention. Its origin, however, was due to the workers in wool, from which it was transferred to the cotton trade, to improve the working in which it was subsequently developed.

(11) The employment of cards such as were used for wool to straighten out and make a fleece of cotton marked another epoch in the spinning of cotton. It was a further stage in that development of the art which has found its culmination in the splendid series of inventions of the present century. The preparation of the cotton into a fleece, however short, enabled a greater length of yarn to be spun than was possible when the cotton was taken from the mass, and an approximation to continuous spinning became possible. But the action of any

human being in drawing out the fibres by an extension of one arm during the time a spinning wheel was being manually rotated by the other, necessarily is more or less uncertain. Great as the advance thus made was upon the previously crude method of spinning from a distaff, even when by the addition of a treadle the spinning wheel was revolved, and both hands left at liberty, the element of manual treatment remained. It is true that the Hindoo workers had demonstrated the possibility of overcoming to a large extent the natural defects of such a system, and had produced yarn of the delicate character previously described. The extraordinary skill thus attained was, however, the property of a comparatively limited circle, and it became necessary, as the demand for cotton goods grew, to depend for its supply upon spinners less reliable and skilful. Thus the need arose for some method of drawing out the carded fleece at a regular rate which was independent of human skill. Hence was originated the system of drawing by rollers, with which the name of Arkwright is ordinarily associated, but which undoubtedly, found its originator in John Wyatt, of Birmingham, about the year 1738. Immediately following this was the invention of a method of carding cotton by a revolving cylinder, by Lewis Paul, of Birmingham, in 1748. At this point the modern period of invention is reached, about which a little time may be profitably spent.

(12) If thought is given to the modern system of spinning it will become abundantly clear that the use of rollers by which the requisite degree of tenuity in the yarn is obtained forms the key to it. It is quite clear that if the element of continuous drawing is removed the essence of modern spinning machines is destroyed. Therefore the contrivance of a machine by which the fleece or sliver of cotton could be drawn out while being continuously delivered, at once revolutionised the whole process, and introduced possibilities never before dreamed of. With this system of spinning the name of Arkwright is commonly coupled, but, as has been observed, it is more than doubtful whether he ought to have the credit. The history of

Arkwright up to the time when he was supposed to have invented a spinning frame in which drawing rollers were used is all against the presumption that he had the necessary skill to invent and construct a machine. It is well known and established that he was acquainted with a man named Thomas Highs or Hays, of Leigh, and also with one John Kay of the same place. Now it is alleged that Highs, or Hays, was the real inventor of the use of drawing rollers, and that Arkwright, who afterwards employed Kay, who was also extremely intimate with Hays, perfected the machine by appropriating the ideas of the latter. This at least was alleged at a trial of an action which Arkwright brought against Colonel Mordaunt for an infringement of his patent. That action failed, and it is therefore on record that in the opinion of the jury trying it Mr. Arkwright was not the real inventor. But there is conclusive proof that John Wyatt, of Birmingham, was the real inventor, and in 1738 his partner, Lewis Paul, obtained Letters Patent for his invention. Arkwright did not obtain a patent until 1769, and if it can be shown, as it undoubtedly can, that the mode of operation, if not the precise details, of the two inventions is similar, there can be little doubt of the falsity of the Arkwright claim. Now Lewis Paul in his specification uses these remarkable words: "The wool or cotton being thus prepared one end of the mass, rope, thread, or sliver, is put betwixt a pair of rollers, cylinders, or cones, or some such movements, which being twined round by their motion draws in the raw mass of wool or cotton to be spun in proportion to the velocity given to such rollers, cylinders, or cones; as the prepared mass passes regularly through or betwixt these rollers, cylinders, or cones, a succession of other rollers, cylinders, or cones, moving proportionably faster than the first, draw the rope, thread, or sliver, into any degree of fineness which may be required." Although this document, which is a very remarkable one, is signed by Lewis Paul, there is little doubt that Wyatt was the true inventor. The evidence on this point is conclusive; the establishment of the fact that in 1738, 31 years prior to Arkwright's patent, the principle of using rollers had been not only described but applied, entirely destroys any claim on the part of Arkwright to novelty. There is further evidence that the latter knew of the existence of Wyatt's invention, and being a man who did not stick at trifles he was quite prepared to accept the results accruing from the successful use of a prior invention.

(13) The specification of Lewis Paul, or of Wyatt, has been described as a remarkable document. Let us just look at what it describes for a little. There is first the idea of drawing in the sliver by means of a pair of revolving rollers; next there is the idea of placing in front of these a second pair rotating at a superior speed, thus ensuring the attenuation of the sliver to a degree corresponding to the variation in the speed of the two pairs. Now what is there in the modern system which differs in principle from this? True, the details are altered, but the continuous drawing of a sliver by rollers rotated at defined but different speeds remains to-day the recognised method of procedure. What it is necessary to take especial note of, however, is that this invention is really the commencement of the modern era of spinning, and that without it, so far as cotton is concerned at any rate, the present perfection is impossible. The wide difference between delivering a roving to the spindle in short lengths drawn by the spinner's hand from the mass of prepared fibre, and delivering the same roving at a steady and continuous speed for an indefinite time, is easily recognisable, and placed within the reach of the spinner a mode of working much superior to that previously possible. A little later on the application of this device to various spinning machines will be dealt with, but before doing so it is advisable to say a little upon the development of machines for preparing the material for drawing.

(14) In 1748 Lewis Paul invented a carding machine which consisted of a small cylinder, on the surface of which a number of narrow cards were fastened, and beneath which was a correspondingly curved surface also fitted with cards. The cotton being passed between these two surfaces was carded and was afterwards stripped by a needle stick or comb; and by an

ingenious contrivance the strips of carded cotton which had a length equal to the width of the cylinder were joined into one strand or sliver. The chief points to notice in this machine are the use of a cylinder covered with carding points, the employment of a stripping comb, and the possibility of a continuous operation involved in the easy rotation of the cylinder. In the same year Daniel Bourne invented a machine for the same purpose, and of much the same construction. A few years after the invention by Paul, a machine constructed on his principle was introduced into Lancashire, and was adopted by Mr. Peel, the grandfather of Sir Robert Peel. He, however, employed Hargreaves to construct a machine in which more than one cylinder was used, and the rotation of these in contact carded the cotton. Up to this period the only vital constructive principle adopted was that of the wire covered cylinder. The operations of feeding the uncarded and removing the carded cotton were both manual, and the next step was the provision of mechanical means for this purp se. The apron feed was invented in 1772 by one John Lees, of Manchester, and shortly after Arkwright devised a method of forming the cotton into a lap to feed it, and the doffer to remove it. Therefore, at this early date, 1774, we have got evidence of the existence of a machine which possessed the three essentials of to-day—a continuous feed, a continuous carding surface, and a continuous stripper. The next step was the adoption of a method by which the fleece deposited on the doffer could be taken from it, and about the same time the doffer comb was invented. The web, in its removal, was, as to-day, collected by a trumpet compressed by rollers and collected into a can for further treatment. The carding was done by flats placed above the cylinder and easily removable for cleaning. Before leaving this subject it might be said that the use of rollers and clearers belong to a little later stage in the process with which there is no intention to deal. The revolving can, however, was used by Arkwright to put twist into the rovings, but it was not until the early part of this century that the idea of the coiler was originated. It has been generally asserted that this was the invention of Mr. David Cheetham, of Rochdale, but there is reason to believe that the perfecting of the coiler was the work of his employer, Mr. Tatham. Be that as it may, the point it is desired to emphasise is that before the end of the last century the carding engine possessed all its main features.

(15) It was time for further invention to take place, because the introduction in 1738 of the fly shuttle, by John Kay, of Bury, enormously increased the power of the weaver, and there was hardly yarn enough to be got from all the existent hand wheels. In 1769 Arkwright's spinning machine saw the light, and, in addition to the rollers, it consisted of spindles driven by bands and having flyers upon their upper ends by which the yarn was twisted. The spindles had bobbins mounted upon them—in short, this machine was the progenitor and predecessor of the throstle or fly spinning frame which was so long in extensive employment. Arkwright's machines were gradually improved, but in their main features were unchanged, and owing to the fact that they were usually driven by water power, received the name water frames, whence the phrase water twist. But contemporaneously with the evolution of the water frame was that of the spinning jenny, which was the work of James Hargreaves, of Blackburn, and was invented by him in the period between 1764 and 1767. The jenny consisted of an arrangement of framework which carried a series of spindles to which rotation was given by means of a hand wheel. A band or cord passing over this drove a light cylinder, and a series of cords from these drove the spindles. The spindles were vertical in position and the rovings were attached to them at one end, and at a distance of a few inches were clasped by a holder forming part of a frame sliding on the main framework. The rovings were held in a creel within the framework, and being secured, the sliding frame was drawn back, thus stretching them, the twist being put in by turning the wheel during the drawing out. A wire guide pressing upon the twisted yarn was worked

by the foot of the attendant during the time the winding was taking place, so as to place the yarn properly on the spindle in the form of a cop. With this crude machine as many as 120 threads at a time were spun, but the process was necessarily a slow one. It is well to observe here that this machine of Hargreaves' touches both the period before and after its production. In this machine the old principle of drawing out the yarn in short lengths and twisting as an operation prior to winding it into a cop, was found, the only difference being in the number of threads dealt with. On the other hand, we find here the principle of drawing the roving by its recession from the spindle which, in its reverse form, is the action of the mule in spinning wool to-day; the method of twisting the yarn by the rotation of a vertical spindle, and of winding it on the spindle while guiding it by means of a depressed wire.

(16) Thus we have arrived at a period when machines had been invented by which yarn could be spun in several lengths at once by one person in either of two ways—by a flyer or by a spindle. It has been shown that neither of these methods were novel, hand wheels having been made both with the plain spindle and the flyer, but the idea of utilising these old parts in such a way that several of them could be actuated at once was novel. It will be noticed that the spinning machines of Arkwright and Hargreaves possessed respectively features which were peculiar to them. Arkwright's machine had the power of continuously delivering and twisting the yarn by means of rollers, while that of Hargreaves was constructed to draw and twist a number of rovings of a definite length. Both these are elements of value, and the next step accordingly was taken when Samuel Crompton about the year 1779 produced the machine which from its hybrid nature has been called the mule. The mule as made by Crompton was a crude machine, as an inspection of the original model shows, but it contained within it several of the elements of the modern mule. There was found the delivery by rollers, and the sustainment of the spindles in a carriage to which an alternate motion in a horizontal direc-

tion was given. Although in a very incomplete state, the invention speedily became largely employed. In about the year 1790 the Crompton mule was driven by water power, and it was immediately afterwards made into a double machine with the headstock in the centre, a form which it has retained since that period. The increase in its dimensions speedily led to the adoption of improved methods of drawing out the carriage, and of the adoption of bands by which it was drawn out equally throughout its length. The counter-faller wire, as it is now called, appears to have been invented in a rude and imperfect form about the year 1790, as was also the use of an inclined plate for the guidance of the faller and the shaping of the cop. After this the most important improvement was made by Kennedy, of Manchester, who invented a method of actuating the rollers and spindles by three pulleys, two fast and one loose. Up to this point, however, three of the most essential features of the mule remained manual operations. The actuation of the faller in its guiding of the yarn was done by the spinner, and partook of all the irregularity of hand work. The reversal of the direction of rotation of the spindles, which is necessary to uncoil the yarn between the nose of the cop and the point of the spindle, and to which the name "backing-off" is given, was also done by the spinner. Upon the latter also was thrown the duty of regulating the speed of the spindles during winding so as to ensure a regular rate of taking up the yarn. Mechanicians speedily recognised the fact that although a machine of great complexity it was not beyond their power to make it self-acting, and patent after patent was taken out for various improvements. Of these the most important was an invention of a self-acting copping motion, by Mr. William Eaton, in 1818, by which the three operations just detailed were made purely automatic. We may pass over the intermediate attempts made, and come to the time of Richard Roberts, a mechanician to whom, hitherto, scant justice has been done, but who was undoubtedly one of the giants of an age distinguished for clever mechanics. As we have seen, Eaton had demonstrated the possibility of mechanically operating all the motions of a mule, which was one step in advance, but there were several features in his invention which were imperfect. The differential motion of the spindles was got by mechanism of some complication, and the whole of the arrangements connected with the formation of the cop were faulty. Roberts went into the matter at the request of a number of spinners, and in a period of five years produced a machine which was undoubtedly an enormous advance, and which contains motions which remain to the present day those in common use. Space will not permit us to deal with the Roberts' mule in detail, but it may be pointed out that in this machine the first use is made of the winding quadrant with a traversing nut by which the variation of the velocity of the spindles is so easily regulated. The employment of a cam shaft was also to be found for the first time in this mule, and the faller and counter-faller wires were also actuated in a thoroughly efficient manner. The backing-off friction was also a novelty in this machine. The Roberts' mule soon became recognised as a perfect spinner, and it possessed every essential feature of the present day machine, although it is not, of course, comparable with them in detail. Thus, the development of the mule may be classified. First came the invention of continuous drawing by rollers, followed by the employment of several vertical spindles actuated at the same time. The combination of these two produced the first mule, which had within it the intermittent delivery of roving by the rollers, the rotation of the spindles during the delivery, and their recession from the rollers, the reversal of the direction of the motion of the spindle to unwind the top coils, the depression of a wire to guide the yarn as the spindles were being revolved to wind it, and the drawing in of the carriage during the latter operation. The next step was the application of power, which was accompanied by a change in the position of the headstock. Then came the adoption of the counter faller, and of an inclined plate to guide the faller wires. Following these was the application of the self-acting principle by Eaton to several of the motions, and then the enormous advance of the Roberts' mule, which was automatic in the whole of its movements. Since that day, although there have been improvements in details, there has been no real improvement in principle, and the era of construction rather than invention has been reached.

(17) The water frame of Arkwright, being much more simple in its operation than the mule of Crompton, speedily took shape. At first the guiding of the yarn upon the bobbin was effected by hecks upon the flyers, but it was not long before the traverse rail was adopted, and the heart-shaped cam (in common employment to-day) applied to this object. From the first, the retardation of the bobbins sufficiently to wind on the yarn was effected by the use of flannel washers placed beneath them, so that at that early day the throstle was practically developed. The Danforth cup throstle had for a time considerable popularity, but practically, until the advent of the ring frame the throstle was not endangered. Ring spinning is of modern origin, its inception not having an earlier date than 1828, so that it is not necessary to deal with it in a sketch of this kind. It has had, however, three stages: (1) The employment of spindles of the throstle type, but without flyers; (2) the employment of spindles self-contained, but with a bearing within the bobbin; and (3) the employment of spindles with self-adjusting bearings which compensate for any irregularity in the balance of the bobbins.

(18) While the principal spinning machines were being developed, a like process was going on with those which were employed to prepare the cotton for twisting. In 1793 Mr. Whitney invented the saw gin, by means of which not only was the separation of the seed from the lint much better performed than it had been previously, but the amount produced in a given time was largely increased. This was the first application of machinery to this important object, and to Whitney belongs the honour. In cleaning the cotton from dirt and sticks, the first machine used was called the "willow," and there is little doubt that the machine was so called, because the earliest form

employed was a cylindrical cage, angularly disposed, constructed of willows. After the success of the cylindrical carding machine, it was not a great step to adopt a cylinder surrounded by a grid or cage for the purpose of beating the cotton, and as the lineal successor of the machine just mentioned, it acquired its name. Although the purely cylindrical form had the greatest employment, a conical willow was soon devised, and was extensively adopted. The idea here is that underlying the method of mounting the old willow cage, the axis of which was arranged diagonally. The removal of the dirt and dust speedily became a difficulty, but was solved by the application of a fan which created such a current of air as to draw the dirt away and discharge it. Thus the room in which this operation is carried on became known as the blowing-room. It ought to be pointed out that the shaking of the cotton by the cylinder, and the dropping of the dirt in consequence, is in all essentials the same as the process of bowing previously named. The scutching machine was invented in 1797, by Mr. Snodgrass, of Johnstone, near Glasgow. The name of this machine is evidently derived from the use of scutches or rods to beat the mass of cotton and knock out the dirt, which was another method of procedure. For the same reason the process was called "batting," a name which still lingers in the Southern States of America, and which is incorporated in the French name for the machine, "batteur." The lap machine was the invention of Mr. Crighton, of Manchester, and its use as an attachment to the scutching machine was common early in this century. The employment of perforated cages on which to form the sheet or web was a development of the dust fan, and it is certain that very early in the history of the machine these were applied, only one cage being used, however, in combination with a delivery apron. In 1830 they were in regular employment, and the machine was in most respects of similar construction to that at present adopted. The addition of the feed roller and piano motion by Lord, of Todmorden, about 1862, however, further improved it. Although in many of its details this motion has been materially changed, in its substance it remains practically as it was when it was patented by Mr. Lord. The changes made have materially increased the sensitiveness of the motion.

(19) The drawing frame was a natural growth from the in vention of drawing rollers, and was very early employed by Arkwright as a distinct machine in a series. The twisting of the slivers into roving was at first carried out by Arkwright by means of a machine approximating to the drawing frame in construction. The combined slivers were delivered into a can to which a rapid rotary movement was given, so that as the sliver was delivered it received a certain amount of twist. The roving so produced was drawn from the can and wound on bobbins by a separate operation, and the bobbins thus obtained were placed in the creel of the mule preparatory to spinning. A modification of Hargreaves' jenny was employed for some time for the same purpose, but both of these methods were superseded by the bobbin and fly frame. A contrivance known as the "Jack-in-the-box" was devised to effect the same object, and consisted of a cylinder revolving within a box and carrying a bobbin. By the rotation of the cylinder the sliver was twisted, and was wound upon the bobbin by means of a wire guide eye to which a reciprocating motion was given. It was not long, however, before Arkwright endeavoured to employ the principle of the ordinary flax hand-spinning wheel to the production of roving. The wheel referred to was constructed with a flyer fixed upon the spindle, upon which and within the flyer a bobbin was placed. The twist was put in by the rotation of the flyer and the winding effected by the frictional retardation of the bobbin, the roving being traversed along the bobbin by hand. In Arkwright's fly-frame the bobbin was positively driven at a speed sufficient to take up the yarn delivered by the rollers and the twist given by the rotation of the forked flyer. The difficulty always remained of regulating the velocity of the bobbin, so that it would just take up the right quantity of roving whatever its diameter might be, and this involved the giving of a differential speed, as is now well understood. Several inventors made attempts

to solve this problem, and in 1823 a Mr. Green, of Mansfield, devised a method of driving the bobbin from the rollers, thus ensuring that the alteration of the velocity of the latter necessarily involved a similar variation in the other. He also thought of such a train of gearing as would vary the speed of the bobbins as they filled; but his mechanism was complex, each spindle being actuated independently, and it never came into general use. In 1826 Mr. Henry Holdsworth, of Manchester, patented the present differential motion, by which an accurate variation was obtained. The principle of Holdsworth's motion is practically that of the old sun and planet motion, which, prior to the invention of the crank, had been employed in steam engines. In E. J. Donnell's "History of Cotton" it is stated that the application of this mechanism was the work of Mr. Asa Arnold, a native of Rhode Island, and that he did so in 1822. Mr. Donnell also states that a model of the apparatus was taken to Manchester in 1825, so that there are grave doubts whether the patent taken out by Holdsworth in the next year was not the result of an inspection of Arnold's model. Holdsworth had invented a combination of wheels for coupling the movements of the spindle and bobbin in 1825, but it was not until the next year that the differential motion was patented. The cone which had previously been used to differentiate the speed of the bobbin was retained, but the difficulties of adjustment previously existing when a different amount of twist was required were entirely obviated by the employment of the differential or "equating" motion. At first one cone only was used, and the necessary equal movement of the strap was obtained by the use of a parabolic rack. This was found to be very difficult to make and regulate, and it was not long before a second cone was employed, by which means the same object was attained. In the early stages the roving was wound upon double-ended bobbins of the type employed on the flax wheel, but it was found to be better, on account of the adhesion of the yarn, to use plain tubes, and by coupling the building motion to the lifter a gradual shortening of the traverse of the bobbin rail was obtained, thus producing roving bobbins of the shape now familiar.

(20) The joint effect of these improvements was very great, especially when they were aided by the comparatively enormous driving power given by the steam engine. Prior to the perfecting of the latter, cotton mills were located on the banks of running streams, and many were found in Derbyshire, Nottinghamshire, and even so far afield as Birmingham. The steam engine, however, changed all that. Lancashire became the centre of the industry, and although cotton mills like those of Messrs. Strutt of Belper, Messrs. Evans of Derby, and a few others, are still found in Derbyshire and Nottingham, in the main cotton spinning is confined in England to this county. It it is somewhat interesting to note that in 1697 1,976,359 lb. represented the weight of cotton imported into England. This remained practically stationary for some years, but after the invention of Hargreaves' jenny and Arkwright's spinning machine it rapidly increased. In 1764 3,870,392lb. were imported; in 1774, 4,764,589lb.; in 1784, 11,482,083lb; while in 1795 the amount exported from the United States alone exceeded the whole importation into England in 1774, only 20 years before. In 1815, 82,998,747lb. of cotton were exported from the United States, showing the enormous increase which had taken place in the use of this material. In 1825, the year of Richard Roberts' first patent for a self-acting mule, 199,272,665lb. of cotton were imported into this country, an increase in 30 years of about 1,500 per cent. The first import of cotton from the East Indies was made in 1798. In 1835, five years after the perfecting of the self-acting mule by Roberts, the importation of cotton into Great Britain was 364,000,000lb., or nearly double that of 1825. It may also be of interest to know that in 1789 the steam engine was first used to drive a cotton mill in Manchester, and the parish of Oldham had a population of 13,916 only. In 1790 the production by a spinner of 40s yarn was only one hank per spindle per day; in 1812 it reached two hanks, and in 1830

$2\frac{3}{4}$ hanks. Nothing can be more convincing of the enormous advances made in this art than these figures, which refer to periods of such recent date and within the lifetime of many persons now living. The remark made in the early part of this chapter as to the possibilities of future developments will not, when viewed in the light of those of the past, appear to be so wild or far-reaching as at first sight.

(21) It will be noticed that this brief review shows that the sequence of the development of the art of spinning is as follows: In the first place the fibre was obtained and utilised by plaiting or knotting it, this method of employing it being prior to the discovery of the advantages to be gained by twisting two or more fibres together. When the art of twisting or twining was discovered, the invention of implements by which it could be effected followed as a matter of course. These began with the simplest form of tool and terminated with the best type of hand spinning wheel. Simultaneously with the application of the art of spinning or twisting came the knowledge that with most fibres a drawing process was advantageous, and accordingly the attenuation of the fibre while it was being twisted became recognised as an essential part of the process. In India the purification of cotton by roughly ginning and opening it in the manner described is the precursor of the modern system of cleaning, while the application of the hand card to the formation of a fleece of cotton, in a similar manner to the production of a woollen fleece, still further developed the series of processes which make up the art of cotton spinning to-day. The brilliant series of inventions of the latter part of the last century and the beginning of this transformed what had been a slow manual operation into a speedy mechanical one, and completely revolutionised the industrial system hitherto prevailing. It is, however, worth emphasising in conclusion, that the germ of every modern practice is to be found in the primitive manipulation of cotton, and that modern systems are the mere developments of ancestral treatments.

CHAPTER II.

THE DISTRIBUTION AND VARIETIES OF COTTON.

(22) COTTON is grown from a plant of the natural order of Malvaceae, and of the genus Gossypium, and at the present day is widely distributed throughout the world within certain latitudes. There is abundant evidence to prove that from the earliest historical periods this fibre has been known, cultivated, and worked in India. The earliest writer of history, in its modern sense—Herodotus—mentions the existence of "wild trees bearing fleeces as their fruit" and the making of cloth by the Indians from these trees. The same writer states that a cuirass sent to Sparta from Amasis, King of Egypt, was adorned with gold and with fleeces from trees. It is interesting in passing to note that the German word "Baumwoll"—tree wool—which is used to denote cotton is evidently founded on the idea of the fibre being fleecy like wool. There are therefore two districts in which the cultivation of cotton is extensively practised to-day where it has existed from the earliest historic times. But there is the further significant fact that when the Spaniards obtained a footing on the continent of America they found cotton being used and cloth made of it. Magellan in 1519 found the Brazilians using cotton in making beds, and in 1536 De Vica found the cotton plant in Texas and Louisiana. In 1519 cotton was also cultivated on the coast of Guinea. Now as America had been a *terra incognita* prior to its discovery by Columbus, there is an extreme probability that the plant had existed there for an indefinite period, and thus we arrive at the fact that over a belt of the earth's surface practically coincident with the cotton growing zone of to-day, the plant was found in the earliest ages of which there are records.

(23) At the present day the cotton growing zone includes the whole of India, part of China and Central Asia, the Nile Valley

and Delta in Egypt, Syria, certain of the Southern States of North America, Brazil, Peru, and several of the Islands in the Pacific Ocean. With the exception of Egypt there is little cultivation of cotton in any part of Africa, although there is a vast tract of country which is admirably adapted for it. According to the latest statistics available to us, which relate to the season 1889-90, the whole of the cotton growing lands in the United States are included in the boundaries of ten states, the number of acres in each being as follows:—North Carolina, 1,082,135; South Carolina, 1,678,955; Georgia, 2,969,715; Florida, 267,790; Alabama, 2,850,603; Mississippi, 2,696,718; Louisiana, 1,064,794; Texas, 4,519,079; Arkansas, 1,458,357; Tennessee, 881,473. The total acreage in the United States is therefore 19,469,617, but this was increased to 20,852,000 in 1890-91. In 1870 the total acreage in the same states was only 8,666,217, so that the production has enormously increased. The quality of the cotton produced in each of these states will be dealt with at a later stage.

(24) After the United States, India is the greatest cotton-growing country, and from a statistical treatise published in Bombay in 1889, the following figures of acreage are extracted:—

	Acres.
Bombay	5,350,000
Sind	75,000
Berar	1,960,000
Central Provinces	610,000
Central India	290,000
Rajputana	550,000
North-West Provinces	1,550,000
Oudh	80,000
Punjab	860,000
Nizam's Territory	970,000
Bengal	162,000
Madras	1,675,000
Mysore and Coorg	42,000
Assam	40,000
Burmah (Lower)	8,000
Total acreage	14,222,000

(25) As a matter of fact, almost the whole area of India is more or less a cotton-growing area; but the proportion which the lands devoted to its culture form of the whole varies considerably in different districts. In many of the provinces the percentage is less than ten, and only in a small proportion does it reach more than thirty. Still, the fact remains that there is a large and increasing area in India in which cotton is cultivated. In Egypt the cotton-growing district lies in the Delta and along the banks of the Nile, and the area under cultivation is about 890,000 acres. The Brazilian acreage is not accurately known, and that of Peru is also not accessible. Great efforts have been recently made by the Russian Government to extend the growth of cotton in Central Asia, all sorts of facilities having been created to encourage it. In the provinces of Erivan, Merv, Bokhara, and Turkestan, along the slopes of the Aralo-Caspian mountains, the chief cotton-growing area is found. The country is somewhat sterile, but several good streams flow through it, rendering irrigation comparatively easy. It is not known what is the exact area under cultivation, but it is probably about 300,000 acres.

(26) Thus the area over which cotton is cultivated is very extensive, and embraces a wide variety of soil. There are well-defined climatic conditions which are essential to the successful production of cotton. The mean temperatures in degrees Fahrenheit, for a period of five years, from 1886 to 1890, in the ten cotton-growing states of America, are for the month of May 71·9, June 77·76, July 80·96, and August 79·14. In the winter months the temperature falls below zero in many of these states; but the summer temperature is high enough to ripen and mature the plant. In India the mean annual temperatures range from 74·3° in the Dharwar district to 81·9° in Madras. The mean annual temperature in Brazil is about 79°F.; that of Egypt is not accessible to us, but probably approximates to that of India. In Central Asia the mean temperature is lower—from 55° to 58°—but rises during the cotton-growing months to a much higher point.

(27) The cotton plant, as will hereafter be shown, produces a better fibre in some situations than in others, and there is no doubt that other conditions—such as the character of the soil and the humidity of the atmosphere—have much to do with the character of the fibre. There is a well-known analysis of the ash produced when Sea Island cotton is carefully burned and the residuum incinerated, which was made by Dr. Ure. The composition of the ash was as follows :—

	Parts.
MATTERS SOLUBLE IN WATER.	
Carbonate of potash	44·8
Muriate of potash	9·9
Sulphate of potash	9·3
MATTERS INSOLUBLE IN WATER.	
Phosphate of lime	9·0
Carbonate of lime	10·6
Phosphate of magnesia	8·4
Peroxide of iron	3·0
Alumina, water, and loss	5·0
	100·0

(28) In Dr. Royle's work on the "Culture of Cotton in India,' two analyses of ash obtained by the combustion and subsequent incineration of Orleans cotton fibre and seed made in 1843 are interesting. The analysis of the ash obtained by burning the fibre is :—

	Parts.
Carbonate of potash	44·29
Phosphate of lime	25·34
Carbonate of lime	8·97
Carbonate of magnesia	6·75
Silica	4·12
Sulphate of potash	2·90
Alumina	1·40
Chloride of potassium, Chloride of magnesium, Sulphate of lime, Phosphate of potash, Oxide of iron (a trace)	and loss 6·23
	100·00

(29) From this it is deduced that in 10,000lbs. of cotton the following amounts of the substances named are abstracted from the ground :—

	Lbs.
Potash	31
Lime	12
Magnesia	3
Phosphoric acid	12
Sulphuric acid	1

(30) The analysis of the cotton seed removed from the same cotton showed that the proportion of phosphoric acid and lime was much in excess of that existing in the cotton. Thus, 45·35 per cent of phosphoric acid existed in the ash of the seed against 12·32 in the cotton ash, the percentages of lime being 29·79 and 17·09 respectively. The fibre of the cotton is pure cellulose, with a chemical composition of $C_6 H_{10} O_5$, while the wax which coats the fibres of American cotton is composed—according to Dr. Bowman—as follows :—

	Per cent.
Carbon	80·38
Hydrogen	14·51
Oxygen	5·11

(31) The particulars thus briefly collated throw some light upon the situations in which the plant may be expected to flourish. From the analysis of Sea Island cotton ash given by Dr. Ure, it would appear that a situation near the sea is most advantageous to the growth of the plant. Many of the salts evidently present in the fibres are such as would be extracted from a saline or marshy soil, and accordingly we find that the land on which Sea Island cotton is grown does contain a proportion of saline matter. In Georgia, the land, which is a sandy loam mixed with much vegetable matter, contains less saline substances, but a fair percentage of lime. In the plains of the states of Mississippi and Alabama, which are unmistakably alluvial in their origin, the soil is of a loamy character. It is stated by Dr. Mallet, in a book referred to presently, that the soil of good lands in Alabama is so tenacious as to polish when a wheel passes over it in dry weather. It is universally

remarked that the nearer the cotton-growing lands are to the sea, the better the staple of the cotton grown, even if it be of one of the inferior varieties. In an extremely interesting book written by Dr. J. W. Mallet, who was Professor of Chemistry in the University of Alabama, a very exhaustive statement is given of a long series of investigations into the composition of the soil in that State. Dr. Mallet selected a sample from a plantation in the cane-brake region, where the number of streams is small. In conducting the tests, he was able to analyse several specimens of Indian soils. The samples were all air-dried, and were treated with water, hydrochloric, and sulphuric acids, in order to extract all the soluble salts. It was found that in the surface soil there was 16 per cent of alumina, and in the sub-soil 20 per cent. In this respect the Alabama soil resembled the Indian, and the presence of so much alumina involves the free absorption of moisture by the soil, which, in an ill-watered country, is important. Of the sesquioxide of iron there was about 8 per cent, and about ·1863 per cent of phosphoric acid in the surface, and ·2376 per cent in the sub-soil. Lime is found in Indian cotton soils on an average of about 7 per cent; while in the case of Alabama the surface soil contained 3·39 per cent, and the sub-soil ·83 per cent. Magnesia is found in Indian soils to the extent of from ·2 to 2 per cent, and in Alabama ·66 in the surface and ·74 per cent in the sub-soil. Potash in the Indian soils varies from ·193 to 2·24 per cent, and in the American ·31 in the surface and ·36 in the sub-soil. It is a notable fact, which is confirmed by the analysis quoted from Dr. Ure, that the earth, from the districts where Sea Island cotton is grown, contains much more potash than soda. The latter substance is found in Indian, Alabama surface and sub-soil in the following percentages respectively: ·5 to 1; ·25; and ·25. The organic matter is easily soluble in water, and consists largely of humus derived from the leaves or stalks which drop on and are ploughed into the soil. Dr. Mallet sums up his examination of the soil of Alabama by saying: "It is shown to be a stiff, aluminous clay, containing moderate amounts of organic matter and of the mineral substances required by the plant as food—of great uniformity, and in an exceedingly fine state of division; above all, possessing a very high capacity for absorbing and retaining heat, moisture, gases, and soluble mineral matter."

(32) Dr. Ure long ago came to the conclusion that the best soil was one which was a compost or loam, and in which there was "neutro-saline matter with alkaline, calcareous, and magnesian bases." It will be noticed that nothing is said by Dr. Ure about the presence of phosphoric acid, but there is no doubt as to this being required. In a statement to which reference will be made at a later stage, Colonel J. M. Thornton, of Alabama, says he used as fertilisers 3½ tons of phosphate of lime and 3½ tons of cotton seed meal on a farm of 70 acres extent. Now, remembering that the soil of Alabama is a rich dark alluvial soil containing much organic matter, and also remembering what a large percentage of phosphoric acid existed in the analysis of the seed, it is not too strong an inference to draw that in addition to the saline, alkaline, calcareous, and magnesian substances detailed by Dr. Ure, the presence of phosphorus is absolutely imperative. This is confirmed by the analysis of the cotton fibre made by Dr. Ure. The condition of the soil is thus seen to be one of extreme interest, and has a determinate effect upon the plant. A loamy soil easily penetrable by the roots of the plant is preferable to a heavy one, and its sustenance will be much affected by the character of the soil, especially as the plant is one of those possessing tap roots. Dr. Mallet states that the average depth of the root is 2ft. 1in., and the lateral spread about 2ft. 9in., so that about 5 cubic feet of soil was penetrated. The tap root, however, sometimes descends five feet. In like manner the process of irrigation is aided by a porous surface or sub-soil, and as there are many places in which cotton can be grown, but in which the atmospheric conditions are fatal to its complete success, irrigation is absolutely essential, and can be made a great help to extended cultivation.

(33) This brings us to consider the question of rainfall, with which that of humidity is closely connected. In the United States of America the rainfall is considerable, and the plant is rarely left without a sufficiency of moisture. The mean annual rainfall for a period of five years, 1886—1890, in the ten cotton-growing States was 3·75 inches in the month of May, ranging from 2·21 inches in 1889, to 5·57 inches in 1890. In June the mean rainfall was 5·19 inches, ranging from 3·97 in 1887, to 7·59 in 1886. In July, 4·99 inches was the mean, with a rainfall in 1888 of 3·02, and in 1889 of 6·06. In August the mean was 4·67 inches, the lowest fall in 1889 of 4·02 inches, and the highest, in 1888, of 6·24 inches. The four months given are those during which the plant is growing, and there is thus a considerable rainfall during that period, sufficient to feed and nourish it. During the year 1880 the rainfall of the Southern States ranged from 50 to 60 inches, so that it is evident the cotton plant in the United States is amply watered. In India there is a completely different condition of things. There the rainfall occurs in one season of the year only, which varies in different parts of the country. The western coast receives the rain during the continuance of the south-west monsoon, which strikes the coast near the end of May, the rains reaching Bombay between the 5th and 15th of June. The Madras district is watered by the north-east monsoon, and receives its rain from the end of September to the middle of October. Thus there is a great difference existing between the rainfalls at various periods of the year. For instance, in the Broach district, the mean rainfall during the months of January, February, March, April, and May amounted only to 0·22 inches; in June 6·67 inches fell; in July, 15·33 inches; in August, 8·87; in September, 7·18; in October, 1·72; in November, 0·13, and in December, 0·5. Thus, 39·77 inches fell in the five months June to October, and 0·4 inch during the remaining seven. Now Broach is a province which lies near the sea coast on the Gulf of Cambay, and the conditions with regard to rainfall are much more favourable there than in many

parts of India. A table is given which shows the mean rainfalls in the five months June to October, and in the other seven months of the year.

TABLE II.

Growths.	RAINFALL IN INCHES.		Number of Observing Stations
	Five Months, June to October.	Seven Months, October to June.	
Dholleras	27·84	·45	5
Broach	39·77	·40	1
Khandeish	28·87	1·38	2
Barsee	25·03	2·62	2
Coomptas and Dharwars	27·22	5·82	4
Westerns	24·34	3·81	8
Tinnevelly	11·60	16·28	3
Sind	5·49	1·28	3
Oomras	28·25	2·28	3
Hingunghat	41·66	4·28	3
Bengals	28·90	3·85	22

(34) In Central Asia, Mr. Henry G. Kittredge, of Boston, U.S.A., states the rainfall in Tashkend and Samarkhand as about 15 inches, and the result is that except by an extensive use of irrigation works the growth of cotton is not possible. In Egypt the rainfall is small, but the cotton being grown on the lands which are annually flooded by the Nile, the growth depends more upon the moisture thus derived than upon the rainfall. In addition to this there are extensive irrigation works which aid in the provision of the necessary moisture. The Brazilian rainfall is considerable, as much as 25 inches falling in a month and 109 inches in the year. Darwin in "The Voyage of a Naturalist" states that 1·6 inches of rain fell in the course of one morning. In addition to this, cotton is grown on the lands along the coast, and this fact has a considerable influence upon its condition.

(35) We now come to consider the question of humidity, which is distinguished from that of rainfall. There is in every district along the sea or pierced by rivers a certain quantity of moisture in the air, and although this naturally differs with the season it is an item which requires taking into consideration. It is quite clear that if the air in which the cotton fibre is ripened possesses a high degree of humidity the lack of rainfall is compensated for, and even where rain falls abundantly the contained moisture is readily absorbed by the leaves and flowers of the plant and by the soil. Thus in situations where the plantations adjoin the sea there is not only the moisture percolating through the soil, which acts advantageously, but there is also a vast amount of aqueous vapour in the air which plays its part in the development of the plant. Thus a warm moist or steamy atmosphere is the ideal one for cotton growing, and wherever it is found a good grade of cotton is produced. Where it does not exist constant and skilful irrigation goes far to take its place, especially where the soil is of an alluvial nature. In short, it may be stated as an axiom that the possession of an insular—that is a humid—atmosphere is the most favourable atmospheric condition for the growth of cotton. It does not necessarily follow that the plantation must be in the vicinity of the sea, although this for the other reasons detailed is preferable, only that it shall be in such a situation as to be acted upon by an atmosphere charged with watery vapour, which is the case when a plantation is situated on rising grounds along which the vapour-charged winds can blow. Thus the relative percentage of humidity on June 8th, 1880, was 85 at Atalanta in Georgia; 82 at Cape Hatteras, N.C.; 77 at Charleston, S.C.; 71 at Galveston, Texas; 78 at Mobile, Alabama; 92 at Montgomery, Ala. (south wind blowing); 86 at Vicksburg, Miss.; and 86 at Wilmington, N.C. The average humidity during the months of July and August for three years in succession was for the South Atlantic States, 74; for the Eastern Gulf States, 76; and for the Western Gulf States, 72. Dr. Mallet puts the conditions as follows: The atmosphere may contain water in a vaporous state up to the point

of saturation. It may be super-staurated so that rain falls from it. The soil may contain a greater or less quantity of water, which can be readily absorbed until the point of saturation is reduced. If the soil is so far saturated as to be muddy, cotton, will not thrive. He further says: Aqueous vapour in the air and abundant hygroscopic moisture in the soil itself are the sources from which the moisture necessary for growth are to be obtained.

(36) The cotton plant is liable to the attacks of a caterpillar, which is regularly developed like all other moths, and is most prolific during a moist season, which is not too hot or too cold. When in the worm form it feeds upon the leaves, bulbs, and bark of the plants, and does an immense amount of damage. The moth is not so destructive, but as it is migratory, the eggs are laid over large areas. The loss of crop has, in some cases, been total, but there may be very little damage done. The most favourite ground for the development of the moth are the low-lying, alluvial lands, in which the plant rapidly attains maturity. There is also a moth which is developed from a worm called the Boll-worm, which is hatched from eggs in the usual way. It hibernates in the chrysalis form in the ground, and many of the species are killed by the exposure caused by ploughing. The boll-worm feeds upon the flowers and bolls of the plant, and by penetration into the latter often completely destroys them.

(37) This very brief survey enables a clear conception to be obtained of the conditions under which cotton can be best cultivated. These are, 1st, a soil of a loamy character, containing saline, alkaline, and calcareous substances; 2nd, a temperature ranging from 68°F. to 82°F. during the months in which the plant is growing and maturing; 3rd, an ample rainfall; and 4th, a humid atmosphere. When these four conditions are found existing together the best results may be confidently expected. It is possible in the absence of some of these features to substitute them by artificial aids, producing the same result. For instance, a light siliceous soil can, by the aid of abundant fer-

tilisers and skilful irrigation, be made to produce a better quality of cotton than is possible in its natural state, but the conditions under which these artificial aids can be profitably applied are, of course, limited. In order to give some idea of the commercial position of cotton growing, a statement is appended which is extracted from the 1890 edition of "Cotton Facts," published by Mr. A. M. Shepperson, in New York. This is the latest authenticated statement we have seen, and is the cost of production and income from a farm of 70 acres belonging to Colonel J. M. Thornton, Talladega, Alabama.

TABLE III.—EXPENDITURE.

	$ c.
Cost of man and mule labour in preparing bedding and putting in fertilizers	150·00
" 3½ tons phosphate (as fertilizer)	67·50
" 3½ " cotton seed meal (as fertilizer)	70·00
" man and mule labour ploughing and cultivating	126·00
" hoeing	136·50
" picking	421·75
" bagging and ties	49·50
" ginning (5 per cent of yield, 1,458 lbs. at 9¼ cents)	134·86
" seed for planting (140 bushels at 15 cents)	21·00
" wear and tear of implements	15·00
" overseeing	50·00
" one-fourth of cotton crop chargeable as rent	650·18
" hauling to market	12·50
Total	$1,905·29

YIELD AND PROCEEDS.

	$ c.
56 bales, weighing 28,116 pounds, lint cotton averaging 9¼ cents	2,600·73
1,848 bushels seed, at 15 cents	277·20
Total	$2,877·93

Profit on the 70 acres $972·64.

Colonel Thornton states he charges 50 cents a day for each mule while cultivating and handling the crop, pays wages, works the crop at regular intervals, but never works the land while wet. He, however, works all through the dry weather, ploughs deep, and runs the plough through the cultivated crops every ten days. It is important to note the extensive use of fertilizers in this case, and to emphasise the fact that where they are used a profit can be easily made.

(38) Having thus ascertained the conditions under which the growth of cotton can be best conducted, a few words may be said about the method of cultivation. What is aimed at is the production of the largest possible quantity of good stapled cotton, of good colour and in a clean condition. In sowing it therefore, all danger of frost is, as far as possible, avoided, and the time of planting is arranged to be after the date at which frosts are expected. A damp condition of the soil when planting, or a good fall of rain subsequently, are advantageous. Two tabulated statements are now given which furnish a number of particulars relating to the cultivation of cotton in the United States and in India. The first is extracted from Shepperson's "Cotton Facts," and in the shape given, the tables are convenient for reference.

COTTON CULTURE IN THE UNITED STATES.

States.	Usual date to begin preparing land.	Usual date to begin sowing.	Usual date to finish sowing.	Usual date to begin picking.	Usual date to finish picking.	Average length of staple (inches).	Average yield per acre (U.S. Agricultural Bureau, Nov., 1885, 1885-86 crop).
North Carolina ..	Feb. 25	April 15	May 10	Sept. 1	Dec. 10	$\frac{3}{4}$ to $\frac{7}{8}$	157
South Carolina....	March 5	,, 15	,, 7	Aug. 15 to Sept. 1	,, 1	$\frac{3}{4}$ to $\frac{7}{8}$	142
Georgia	Feb. 1	,, 10	,, 1	Aug. 15 to 20	,, 1	$\frac{3}{4}$ to $\frac{7}{8}$	150
Florida	Jan. 20	,, 1	,, 1	Aug. 10	,, 1	$\frac{3}{4}$	105
Alabama	Feb. 1	,, 5	,, 10	Aug. 10 to 20	,, 15	$\frac{7}{8}$	145
Mississippi	,, 1	,, 5	,, 10	Aug. 10 to 20	,, 15	1	165
Louisiana	,, 1	,, 1	,, 10	Aug. 1 to 15	,, 15	1	223
Texas (South of 30° 50″ N.)	Jan. 15	March 15	,, 10	Aug. 1	,, 20	1	182
Arkansas	Feb. 15	April 15	,, 15	Aug. 15 to 20	Jan. 15	1	200
Tennessee........	March 1	,, 15	,, 15	Sept. 1 to 10	,, 15	$\frac{3}{4}$ to 1	155
Long Staple or Sea Island Cotton in South Carolina..	Feb. 1	,, 1	,, 1	Aug. 25	Dec. 10	$1\frac{3}{4}$	125

Note.—In the northern part of Texas the date for preparing the ground for sowing is about four weeks later than that given above. Sea Island is sowed a little earlier than that given in Georgia and Florida. The average yield of the cotton-growing districts of the United States during the season 1890-1891 was, according to Ellison, 195lbs. of lint cotton per acre. The termination of the picking season is, to a large extent, determined by the frosts which are prevalent in the early winter. If these are severe enough they rapidly kill the crop. The earliest period at which killing frosts have taken place recently are—October 2nd at Memphis, October 26th at Mobile, December 5th at Galveston, November 18th at Pensacola, and November 8th at Charleston.

COTTON CULTURE IN INDIA.

Districts.	Usual Date to prepare Land.	Usual Date of Sowing.	Usual Date to begin Picking.	Usual Date to finish Picking.	Usual Length of Staple.	Yield of Lint Cotton per acre
					Inches.	
Bengal	May & June	June	Oct —Nov.	Dec.—Jan.	$\frac{1}{4}$ to $\frac{5}{8}$	96
Oomrawattee ..	Do.	Do.	November	January	$\frac{1}{2}$ to $\frac{7}{8}$	52
Broach	Do.	Do.	Jan. Feb.	Mar. April	$\frac{3}{4}$ to 1	$98\frac{1}{2}$
Dhollerah	Do.	Do.	Feb. Mar.	April	$\frac{1}{2}$ to $\frac{7}{8}$	74
Coompta and Dharwar ..	July & Aug.	August	March	May	$\frac{3}{4}$ to 1	50
Tinnevelly	Aug. & Sep.	Oct. & Nov.	Feb.—Mar.	Mar.—Apr.	$\frac{11}{16}$ to $1\frac{1}{16}$	54
Westerns	July & Aug.	Aug. & Sep.	Mar.—Apr.	June	$\frac{3}{4}$ to 1	41
Hingunghat....	May & June	June	Nov.—Dec.	Feb.—Mar.	$\frac{7}{8}$ to $1\frac{3}{16}$	42

(39) In Egypt the preparation for the crop is usually begun in February, and planting takes place in March and April. Picking begins in September, and lasts at times until the 1st January. The staple of Egyptian cotton varies from 1 to $1\frac{1}{2}$ inch, and the yield is about 340 lbs. per acre. In Brazil, planting takes place from December 15th to June 1st, according to the position of the plantation, and picking extends from July to February. About Pernambuco the plants have open bolls during the entire year. The length of Brazilian cotton is 1 to $1\frac{1}{4}$ inch.

(40) The system of cultivation in the United States is to plough deep furrows in the land and make a free application of fertilisers, which are ploughed in thoroughly. A considerable space—from five to six feet—is left between the furrows or ridges, so that when the plants have grown, a clear passage between them is left. The seed is sown by drills or dibbles, the former plan being adopted in the United States, a groove of 1½ to 2 inches deep being made along the crest of the ridge. The seeds are dropped into this groove by the sower in fair numbers, and are immediately covered either by a harrow running along the ridge, or by means of hoes. In dibbling, holes are formed in the ridges, into which four or five seeds are dropped, and immediately covered. In a few days the plant appears, if the weather is favourable, and after it has grown a little, a few are thinned out, leaving two to four together. Subsequently, these are reduced to one, and the plants are periodically banked up by passing a plough between the ridges. Weeds are kept clear by ploughing and hoeing, and constant attention to this point greatly improves the crop. Careful cultivation has a wonderful effect upon the character of the cotton obtained, and even on poor soils the quality can be greatly improved in this way.

(41) As was said at the beginning of this chapter the cotton plant is of the order Malvaceae or mallows, and of the genus Gossypium. It was pointed out that the earliest historic records spoke of wool growing on trees, and it is still found in this shape in India, Arabia, Senegal, and Brazil. For many reasons the tree form, which is known as Gossypium Arboreum, has given way to the shrub and herbaceous varieties, which are most extensively cultivated. There are a large number of apparently distinct varieties of the plant existing in different parts of the world, but it is now generally conceded that most of these are variations of a few well known types. Dr. Forbes Royle, on p. 132 of "The Culture of Cotton in India," and again on p. 151, expresses the opinion that all the existing varieties can be classed under the following four heads: (1) Gossypium Peruvianum; (2) Gossypium Indicum; (3) Gossy-

pium Barbardense; (4) Gossypium Arboreum. The first class includes most of the cotton grown in Pernambuco, Brazil, and Peru; the second, the several varieties indigenous to India; the third includes Bourbon, West Indian, Sea Island, Uplands, New Orleans, Mexican; and the fourth, all the varieties of the tree cotton. There is a more detailed classification made by Professor Parlatore, which is quoted in the works on the "Cotton Fibre," by Dr. Bowman and Mr. Hugh Monie. There is one distinctive feature in connection with the Peruvian species which is worth noting, namely, that it is a perennial plant, whereas all other varieties of cultivated cotton plants are annuals. Further, it does not fully bear fruit until the second year of its growth. The most fruitful and most generally cultivated variety is the herbaceous, and from this the greatest weight of supply is obtained.

(42) It is not intended to give more than a condensed description of the cotton plant and the varieties of products obtained from it, as this has been done so thoroughly in Mr. Monie's book, to which a special reference should be made, that little more requires to be said. It may, however, be pointed out that between the leaf of the cotton plant and that of the black mulberry there is a considerable likeness, and the same remark applies to the leaf of the vine. Theophrastus noted these likenesses when accompanying the expedition of Alexander the Great into India. The leaves of the Indian varieties have five lobes, that of the Barbadoes variety usually three lobes, and the Peruvian variety sometimes three, sometimes five, lobes. When the plant attains maturity, the blossoms form, and, as they mature, burst open. The blossom exists for about a day, and is immediately followed by the seed pod, which develops until the growth of the fibres within it causes it to burst. As soon as this happens, the fruit should be gathered along with the seed; and it is a peculiarity of this plant that the fruit pods do not all burst at one time, but successively, so that it is not uncommon to see ripe and fully matured cotton on the same plant as pods only just begun to develop. In some cases, in India, the pods do not fully open,

but only partially, and this is also the case with cotton grown in Central Asia. All native Asiatic cotton appears to possess this characteristic, the cause of which is probably a defective method of cultivation.

(43) The process of growth commences with the formation of the seed from which the hairs of cotton are gradually built up and developed. The latter absorb in their growth the viscous substance filling the seed, and are formed of a number of cells which are gradually developed until the full length of the fibre is obtained. When it is so formed, a fully ripe fibre is an elongated, hollow, slightly flattened tube, a little oval in section. During growth the hollow space acts as a conduit for the circulating fluid of the plant, but as maturity is approached this is withdrawn into the centre of the seed, so that the previously cylindrical fibre is flattened. Further description of the growth is not necessary, and we only have to point out that the cotton fibre is covered with a waxy sheath, and is always more or less in the form of a spiral on its own axis. The better the quality of the fibre the more pronounced is the convolute structure, this being often accompanied by a serrated formation of the edges, and both of these are of immense value from a manufacturing point of view. The length of the fibre in any particular growth of cotton is known as its "staple."

(44) Remembering what has been said as to the essential characteristics of successful cultivation, we will now proceed to give a brief account of the different varieties of cotton used commercially. The best cotton produced is grown in the plantations along the coasts of South Carolina, Georgia, and Florida, and in some of the islands contiguous to them. Here the soil contains the saline and other substances previously referred to; the temperature is moderately high—from 70 to 80 degrees during the growth of the plant; there is a fair volume of rainfall, about 5 to 6 inches, in each of the four months of growth; and last, but not least, there is a humid atmosphere arising from the contiguity of the sea and the prevailing breezes. Thus the whole of the conditions are favourable, and as a result, the

cotton is fine and silky, with a light creamy tint; the length occasionally reaches 2 inches, but a mean length is 1·7. Its mean diameter is given by Mr. Monie as ·000635 of an inch. The Sea Island variety grown in South Carolina is the finest, but there are several other varieties, such as Florida, Fiji, Tahiti, and Peruvian, which are shorter in the fibre, and not so good in other respects. The mean lengths of the three varieties named are, respectively, 1·58, 1·7, 1·5, and 1·56 inch.

(45) Cotton grown in Egypt is divided into two classes which vary very considerably in quality and length. The best variety, Gallini, is grown on lands adjoining the Nile, which are alluvial in character, and are irrigated to a greater or less degree by water obtained or stored from that river. The climate of Egypt is very dry, but the abundant supply of water brought down the Nile from the inland mountainous regions enables enough moisture to be obtained to produce a high quality of cotton. Gallini is of the same variety as Sea Island—Gossypium Barbadense—and has a mean length of 1·35 inch. Its diameter is ·000675 inch, and it is light golden in colour. Its convolute form is very perfect; it is very strong, and although considerably coarser than Sea Island is a very useful cotton. Brown Egyptian is of the herbaceous variety, and is grown in the Delta of the Nile and at other points further south The colour of this cotton is, as indicated, darker than Gallini, to which it is inferior in many respects, although grown on land of a similar character and under similar conditions of irrigation. The difference is probably a natural one, and could not be cured by cultivation. The fibres are strong and tough but coarser than Gallini, the convolute form being less regular and the wall of the fibre denser. The mean length of brown Egyptian cotton is 1·3 inch and its diameter ·000738. White Egyptian cotton is grown also in the Nile Delta, and is of two distinct species—the native Hirsutum and exotic Peruvianum. This cotton is of a light gold colour with strong and fairly pliable fibres, but the convolute form is not so marked as in the other varieties. The mean length is 1¼ inch, and the diameter ·000769.

(46) The cotton grown in Peru is of three qualities, the best grade of which is of the Sea Island variety, being grown from seed obtained from the United States. It is cultivated principally in the vicinity of the sea coast, and the colour is slightly golden. It is inferior both in fineness and cleanliness to Sea Island cotton, being about ·000675 inch diameter and having a mean length of 1·56 inch. The two principal varieties of cotton grown in Peru are, however, indigenous to the country—Gossypium Peruvianum—and are known respectively as rough and smooth. Between these two varieties so many differences exist that they almost form distinct species. Rough Peruvian, so called on account of a hairy feel, is harsh; the fibres vary considerably in length, and are also more nearly straight than Sea Island cotton. The mean length is 1·28 inches, and the diameter ·000781 inches. Smooth Peruvian is soft, and is not so strong as the rough variety. The lengths of the two varieties are about equal, as are also the diameters. Peruvian cotton is sometimes used in the United States to mix with wool.

(47) It has been previously noted that the species Gossypium Peruvianum grows throughout South America, and there are several other growths, three of which, Pernambuco (shortly Pernams), Maranhams, and Cearas, are largely used. Of these the former is the best in quality, but is harsh in the fibre, which is about 1¼in. long. The convolutions of this cotton are regular, and this fact makes it a good commercial product. Maranhams are structurally inferior to Pernams, and are nearly ¼in. shorter in average length. Ceara cotton is largely grown, and about the same length as Pernams. The colour of these three varieties differs considerably, the first named being light gold, Maranhams much the same shade but dull, and Ceara a dull white. There are several smaller growths of Brazilian cotton which possess the general characteristics of those named, but are slightly inferior. The culture of cotton in Brazil is mostly confined to the vicinity of the sea, but could be largely extended, owing to the enormous number of streams piercing the country in many parts.

(48) In addition to Sea Island, the United States produces a large crop of cotton which is, perhaps, the most reliable product in the world. The length of the staple is more regular and it is marketed in a much better condition. Most of the American cottons are of the species Gossypium Hirsutum, but they are divisible into a few varieties, the quality of which differs considerably with the geographical position of the plantation. Thus, Orleans cotton, which is grown in the States of Mississippi and Louisiana, is the best of the ordinary varieties of American. This fact can be accounted for by the character of the soil, the uniformity of the temperature, the fairly abundant rainfall, and above all the humidity of the atmosphere owing to the immense volume of water in the immediate vicinity of the plantations. Texas cotton, which is obtained from the state of that name, is not grown under such favourable climatic conditions. The temperature in the southern part of the state, at any rate, is higher, but there is an abundant rainfall, and by careful cultivation the staple of cotton produced has been much improved. Uplands cotton, as its name implies, is grown on the rising lands of the states of South Carolina, Georgia, and Alabama, and in the southern part of Tennessee and Arkansas. Here the soil is of a light loamy character, but the temperature is regular and the winds from the south and east carry with them a large amount of moisture. The fourth variety, known as Mobile, from the port whence it is shipped, is generally inferior, and is grown in the States of Alabama, Mississippi, and Louisiana. It has already been pointed out, more than once, that the position of a plantation has a determining effect upon the quality of the cotton grown. No better instance of this can be found than in the various grades of American cotton. Thus, that grown on the Uplands of Alabama and the other states is inferior to cotton grown on the swamp lands in the same states.

(49) Orleans cotton has a mean length of 1·1in. and a diameter of ·000757in. It is white in colour, with soft, pliable, but fairly strong fibres. It is moderately convolute in form and its

pure colour renders it a favourite grade. It, like most American cottons, is carefully cultivated and is, therefore, very uniform in quality. Texas cotton is an instance of how much can be done by care in cultivation. Although the natural advantages of the country are inferior to those of the plantations in Louisiana the attention given to its proper cultivation has made Texas a very fine cotton, with a length of 1in. and a thickness practically equal to that of Orleans. Its colour is tinged with brown and its strength is inferior to Orleans. Uplands cotton consists of fibres which are very pliable and elastic, and of a white or slightly creamy colour. Its mean length is a little under an inch and its diameter equal to that of Orleans. As it is very soft, however, it is not so strong as the other varieties grown in the United States. Mobile cotton is short in the staple, being only about $\frac{7}{8}$in. long. It is a curious fact and worth noting that all the varieties of ordinary cottons grown in the United States are, practically, of the same mean diameter, although they vary greatly in their other characteristics.

(50) After America, the chief source of supply is India, where there are a number of cottons grown of more or less value and merit, all from the herbaceous variety of plant. Generally the cotton is much inferior to that grown in America, which is accounted for by the high temperature prevailing in the greater part of India, and the lack of sufficient moisture. The conformation of India also detracts from it as a cotton-growing country, because there are many districts in which the moisture obtainable is too little to sustain growth properly. Where the plantations are located either on uplands, so that the temperature is modified, or adjoining the rivers or sea, especially the latter, the best results are got. The best quality produced in India is found in the Hingunghat cottons, which are grown on the uplands in the Central Provinces of India, comprising Berar and Nagpur. The rainfall in this province is, during the monsoon, very heavy, being from $27\frac{1}{2}$ to $29\frac{3}{4}$ inches in the months of June to October. Hingunghat cotton is a little dark in colour, but is strong, and the length of its fibre is equal to

Orleans. It is, however, slightly thicker than any American cotton, being ·000833 diameter. The convolute form of the fibre is much less marked than in cottons grown in a humid atmosphere, or a well watered district. Broach cotton is obtained from the Bombay Presidency, principally from the districts of Broach and Surat. In these there is a rainfall of 40 and 43 inches respectively during the monsoon, and they are moreover not far from the sea. This variety of cotton is much esteemed, although it is of a darkish colour, and the fibres are short, being only about $\frac{7}{8}$ inch long. They are, however, regular, but not convolute, and the diameter is nearly equal to that of Hingunghat.

(51) Dharwar cottons are grown in the Bombay Presidency, and are of the same character, but inferior in length, being only about ·8 inch long. Oomrawuttee or Oomra cotton is grown principally in the provinces of Bombay, Berar, and Hyderabad. It is a fairly good variety when cleaned, and the fibres have a mean length of about ·9 inch. It is a little thicker than Broach, but is not so good in many respects. Dhollera cotton, which is perhaps the most widely known of Indian cottons, is also the product of the Bombay Presidency from the districts of Rathrawai, Ahmedabad, Baroda, and Cutch. This variety has a whitish colour, and the fibres are about $\frac{15}{16}$ inch long, and of the same diameter as Dharwar. The strength of Dhollera is less than of some other varieties of Indian cotton, but in structure it resembles them. Coomptah cotton is grown in the Central Provinces of India, and has a weak fibre of about $\frac{13}{16}$ inch long. The fibres are weak and brittle, and are generally inferior, although in diameter equal to Dharwar and Dhollera. The variety produced in Bengal is the most inferior of all Indian cottons, although it has a length of a little over an inch. It is very harsh and wiry, and generally of an inferior character. This is probably due to the conditions under which it is cultivated and to the character of the soil. The fibres are very thick, but are fairly strong. The cotton grown in Sind is cultivated under the worst possible conditions, the rainfall in this district being

only from four to eight inches annually. Irrigation is therefore largely depended on, but the character of the soil does not compensate for the small rainfall and dry atmosphere. In consequence the fibres are short and only about ·65 inch, but are comparatively strong. All the varieties of Indian cotton just described are obtained from the Northern and Central Provinces, but there are two varieties which are obtained from the Madras Presidency. The best of these is Tinnevelly, which is grown in a district in the south of the Presidency, opposite the Island of Ceylon. A certain proportion is also grown in Trichinopoly. Owing to the fact that these provinces lie near the southernmost point of India the influence of the sea is apparent. The heat in all parts of the Madras Presidency is, however, very great. For all that, Tinnevelly cotton is a fairly good variety, the fibres being moderately strong and $\frac{7}{8}$ inch long. In their natural structure they show the influence of their native climate very perceptibly, as the walls are much thicker than is the case with cotton grown in a milder climate, this being also indicated by the absence of the convolute form. The second variety of Madras cotton is known as Westerns, which are very inferior to Tinnevelly, especially in uniformity. Being strong, however, they can be mixed with other varieties.

(52) In addition to the foregoing varieties of cotton there is a small supply drawn from the West Indies, of cotton of the Peruvian type. The West Indian cotton, according to Mr. Monie, has the spiral or convolute formation more perfectly developed than any other variety, and as it is of a good length, $1\frac{1}{3}$ inch, it is valuable in many respects. There is also a small supply obtained from Asia Minor, Queensland, South and West Africa, and the Islands of the Pacific, but the details given nearly cover the ground, so far as the chief commercial qualities are concerned. A good deal of white cotton of fair quality is grown in China, the fibres being fine, from $\frac{5}{8}$ to one inch long. The measurements given are all approximate, and as different observers give different lengths for the same staple, it is

difficult to determine the accurate figures. On the whole, observations made confirm the lengths given by Mr. Monie, but in some cases variations exist which have led to slight alterations.

(53) The description thus given of the various qualities of cotton will enable the following remarks to be more readily comprehended and their significance understood. The commercial value of a cotton is determined by several features, viz.—its length, fineness, strength, pliability, smoothness, uniformity, colour, and cleanliness. As a rule, the cotton which is the longest is the finest, but it is by no means the strongest. Thus Sea Island cotton has the longest fibre with the least diameter, and Hingunghat is much inferior to it in both respects. The strength of the latter, however, is 50 per cent greater than that of the former. As in every other essential, however, Sea Island is in advance of Hingunghat, it is the most valuable, especially for the production of fine yarns. The most regular cotton is Orleans, in which the length of the staple only varies a small fraction of an inch. In consequence a certain loss is experienced in some of the processes through which it is passed, but this loss is much less than is the case with other cotton, the fibres of which vary considerably in length. When the carding and drawing processes come to be dealt with the importance of regularity or uniformity will be seen. Cleanliness is a cardinal point in the commercial creed, because the impurities found in cotton add so much to its weight, as purchased, that their removal involves a serious charge upon the millowner. This defect is a very serious one in most Indian cottons, and many even of the better qualities are deteriorated in value on this account. The waste at the opener and scutcher becomes largely increased if through carelessness or wilful negligence the amount of sand and dirt is increased. There is always in cotton a certain portion of unripe and short fibre which it is impossible to avoid altogether, as they are found in a pod which is to all appearances quite ripe and ready for picking. At a later stage the presence

of broken fibre and its cause will be explained. The question of moisture has also been one over which a good deal of angry controversy has raged. The natural moisture in the cotton fibre varies, as might be expected, from year to year, according to the character of the season and of the weather during picking. Making due allowance for this, however, there is more than a suspicion that the amount is added to wilfully, and this, of course, means a considerable loss to the spinner. In order to set the matter at rest the Cotton Spinners' Association have taken the matter up and have determined upon a certain standard.

(54) A special oven has been designed by Messrs. Hall and Kay, of Ashton-under-Lyne, to deal with this question, it being so constructed that the cotton is subjected to a radiated but not direct heat. In testing cotton, a sample is taken from the centre of several bales, and smaller portions of each of these—as nearly equal in weight as possible—are taken, until their total weight is 1,000 grains. This sample is then opened by hand, care being taken to receive any sand shaken out, and placed on the tray in the oven. The temperature of the air within the latter should be 170° to 180° F., and it should be kept at that heat for the one and a half hours it takes to make the test. At the expiration of that time the cotton is taken out and re-weighed, the difference in its weight before and after drying being noted. Inasmuch as 1,000 is easily divisible by ten, the percentage of loss is arrived at without calculation. Suppose the cotton has lost 110 grains, or 11 per cent, from this must be deducted eighty grains, or 8 per cent (it being found by a large number of experiments, that cotton so dried will recover 8 per cent on exposure to the atmosphere for twenty-four hours); this leaves 3 per cent of moisture in the cotton in excess of the assumed standard. This is not a very excessive loss, some lots having been found to contain 5 per cent and over, whereas in a dry season most cotton shows not more than 1 to 2 per cent of moisture over the standard. Texas cotton not unfrequently shows ·3 to ·5 per cent, and Surat cotton frequently shows ·5 to 1·3 per cent dryer than the standard.

(55) A somewhat similar treatment with cops helps to solve another vexed question where manufacturers buy their yarn. In this case it is better to take a larger weight, say 10,000 grains. This must remain in the oven five hours, and an allowance of 5 per cent requires to be made from the gross loss, experiments having conclusively shown that yarn taken direct from the spinning room will lose 5 per cent at 170° to 180° F., therefore any loss more than this shows what is the moisture gained over the weight when fresh from the spindle. Example:

	Grains.
Weight put in oven	10,000
Weight from oven when dry	9,150
	850
Deduct 5 per cent to bring up to spinning room standard..	500
	350

showing 350 grains, or 3·5 per cent of moisture gained over the weight when fresh from the spindle.

(56) It has been indicated that the character of the different growths of cotton fibre varies considerably. Some are strong and others are weak, some harsh and wiry, others soft and pliable. Accordingly it is possible to divide them into cottons suitable for twist, where a hard strong fibre is wanted, and others for weft, where a softer and more pliable thread is desired. When the fibres are of such a character that when arranged side by side they lie closely together and twist into a perfectly even cylindrical thread, the best results are obtained. Generally speaking, the best yarn is that in which the greatest number of fibres are found in the cross section. There are, of course, exceptions to every rule, but the rule may be a good one, in spite of the exceptions. A list is appended of the cottons suitable for making twist or warp yarns and those suitable for weft yarns.

Twist.

AMERICAN :—

Sea Island.
Orleans.
Texas.

INDIAN :—

Hingunghat.
Broach.
Tinnevelly.
Dharwar.
Oomras.
Westerns.
Bengal.
Sind.

EGYPTIAN :—

Gallini.
Brown.
White.

SOUTH AMERICAN :—

Rough Peruvian.
Pernams.
Maranhams.

Weft.

AMERICAN :—

Sea Island.
Orleans.
Texas.
Uplands.
Mobile.

INDIAN :—

Broach.
Dharwar.
Oomras.
Dhollera.
Coomptah.

EGYPTIAN :—

Gallini.
Brown.
White.

SOUTH AMERICAN :—

Smooth Peruvian.
Maranhams.

(57) It is not an uncommon thing to hear complaints of the quality of the cotton as imported not only on the ground of dampness but also on many others. The brief review given of the method of growth shows that there must always be a certain proportion of short and immature fibre present. The amount of this, however, varies from year to year, and there is every reason to believe that with some kinds of Indian cotton especially it is the practice to mix a certain amount of short staple with the better grades before exporting it. The presence of short stapled cotton is not only detrimental to its value, but it is alike a source of annoyance and a cause of considerable expense in subsequent stages. There are two classes of natural adherent impurities which will always be more or less present, viz., broken leaf and sand or dirt. The latter are present in varying quantities which depend largely upon the character of

the season, and are found in the greatest weight in the various, Indian grades, reaching as much as five per cent. The presence of broken leaf and seed is mainly caused by lack of care in ginning, and is the result of a forced production at the ginning factories. The former especially is bad to eliminate, and does not always finally disappear until the cotton has been considerably treated. To the same cause may be attributed broken fibre and stringy cotton, and there is also caused in the ginning process a good deal of "nep." The latter is the name given to little knots which are composed mainly of dried up fibres. These are very bad to remove, and appear in the sliver even though it may be well carded, only the specially thorough treatment by combing removing them. It is a very rare thing to see a carded web entirely free from the little white specks or "neps," and until methods are improved they are not likely to disappear. There is, however, a good deal of nep which is artificially caused during the whole series of cleaning processes. The cotton fibres are most brittle at their ends, and if they are heavily scutched these points get broken off and are rubbed up into nep. That this action takes place is certain, and a series of careful measurements of fibres before and after scutching show that in many cases the breakage of fibre is very great. This will be referred to at greater length in the next chapter, but it is worth specially noting at this point.

(58) Cotton is picked by hand—no really successful machine having hitherto been applied to this purpose—and the proportion of leaf extracted with the ripe boll is dependent on the dexterity of the picker. The pickers are able to collect a considerable quantity prior to delivering it at the end of the row or furrow in which they work. The cotton thus obtained is collected in bulk and is treated by a gin usually driven by power. The gin may be of two types, the saw or knife roller. Of these the last named is the best, although the Whitney saw gin is the first in order of time. It is, however, liable to damage the fibre, and is rapidly falling into disuse. The roller ginning machine consists of a hopper into which the cotton is pushed, and by which

it is guided into the range of action of a roller provided with spiral blades. By this the fibre is carried forward under a fixed guard, and is brought into the range of a second roller. This roller is covered with a thick grooved covering of walrus hide, which is very tenacious, so that the cotton easily adheres to it, and as the knife and leather rollers rotate in opposite directions the cotton is drawn away from the former. In doing so the seeds are removed by means of a blade or doctor so set as to permit the passage of the cotton but not that of the seeds. The doctor is pressed into position by means of suitably placed springs, and upon the relative setting of the knife and leather rollers and the doctor depends the quality and cleanliness of the work turned out. The construction of the gin is very well explained in Mr. Monie's work, and as it is not a subject that has more than a limited interest for English students, little need be here said about it. The seeds are separated partially by being pulled or scraped off by the leather roller, and partially by the action of the knife roller, and fall through grids into a receptacle provided for them. The construction of the grids depends upon the quality of the cotton treated and the size of the seeds.

(59) Having freed the cotton from seeds, it is made into bales by means of hydraulic power, in which a considerable pressure is obtained. The bales into which cotton is pressed vary considerably in weight. According to Ellison's "Annual Review" for the season 1890-91, the average net weight of American cotton bales exported to Great Britain was 478lbs., the average of all the bales of the crop being 470lbs. East Indian bales averaged 396lbs.; Brazilian, 220lbs.; Egyptian, 720lbs.; Smyrna, 380lbs.; and other growths 190lbs. The growth of cotton for the same season is stated by the same authority as 8,655,000 bales in the United States; 237,000 bales of Brazilian; 539,000 bales of Egyptian; 27,000 of Smyrna; 94,000 of West Indian and Peruvian; and 1,317,000 of East Indian. In all, this is equal to a total of 12,616,000 bales of 400lbs. weight each, the latter being always the standard of comparison.

(60) The various growths of cotton are, according to their qualities, graded in values, and are classified roughly as follows :—

American.	Brazilian.	Egyptian.	Indian.
Good Ordinary.	Middling Fair.	Fair.	Fair.
Low Middling.	Fair.	Good Fair.	Good Fair.
Middling.	Good Fair.	Good.	Good.
Good Middling.	......	......	Fine.
Middling Fair.	......	......	......

Of these, the first-named is always the poorest quality.

(61) The cotton fibre, from its nature, requires different treatment to others, and necessitates the employment of an entirely distinctive set of machines. The number of processes through which it is passed is greater than that needed for any other fibre, this arising from its shorter staple and its peculiarly good spinning qualities. When the various stages are analysed, however, they may be easily grouped, but it will be seen that many of the groups overlap—that is, some of the objects of one are also those of another. The following is a fairly accurate tabulation of the various processes commencing immediately after the cotton is received at the mill. It may, of course, be objected that the earlier of these do not strictly come within the meaning of the phrase "spinning," but they are absolutely necessary, and have such an influence upon the staple that it is difficult to avoid including them :—

1st Stage.—
(A) Mixing or blending.

2nd Stage.—Operation for cleaning fibres.
(B) Opening.
(C) Scutching.
(E) Carding.

3rd Stage.—Operation of parallelising and attenuating collected strand.
(F) Drawing.

4th Stage.—Operation of further attenuating and twisting strand.

(G) Slubbing.
(H) Second slubbing or intermediate.
(I) Roving.
(J) Spinning { (a) Mule. (b) Flyer frame. (c) Ring frame.

5th Stage.—Operation of twisting threads together.

(K) Doubling { (a) Twining. (b) Ring doubling.

(62) In addition to the above, there is an additional stage, when fine yarns are spun, which may be called the 6th stage. The operation is one of parallelisation and cleaning, which occurs before drawing, and consists of three manipulations :—

6th Stage.—

(L) { Formation of lap from sliver. Doubling and attenuation of laps. Combing.

And in addition also a process by which the partially twisted strand is further reduced and twisted prior to spinning, which may be called

(I^1) Second roving or jacking.

(63) The above form a practical sub-division of the whole process, which is not without some value as a guide to the method of procedure. The object of all the various manipulations is to produce a thread perfectly cylindrical in form without variation in its thickness, and with as many fibres as possible in its cross section. To obtain these results with the minimum of loss of available fibre is the desideratum of the cotton spinners, and the whole of the machines are designed with this object.

CHAPTER III.

MIXING, OPENING, AND SCUTCHING.

(64) When cotton is presented to the spinner it is, owing to the pressure to which it is subjected during packing, in a matted state, and the first operation which is necessary is that of opening out the bale. This is sometimes done by hand, especially in mills which are of small size, but it is becoming the usual practice to effect it by machine. There are many incidental advantages to be derived from the latter

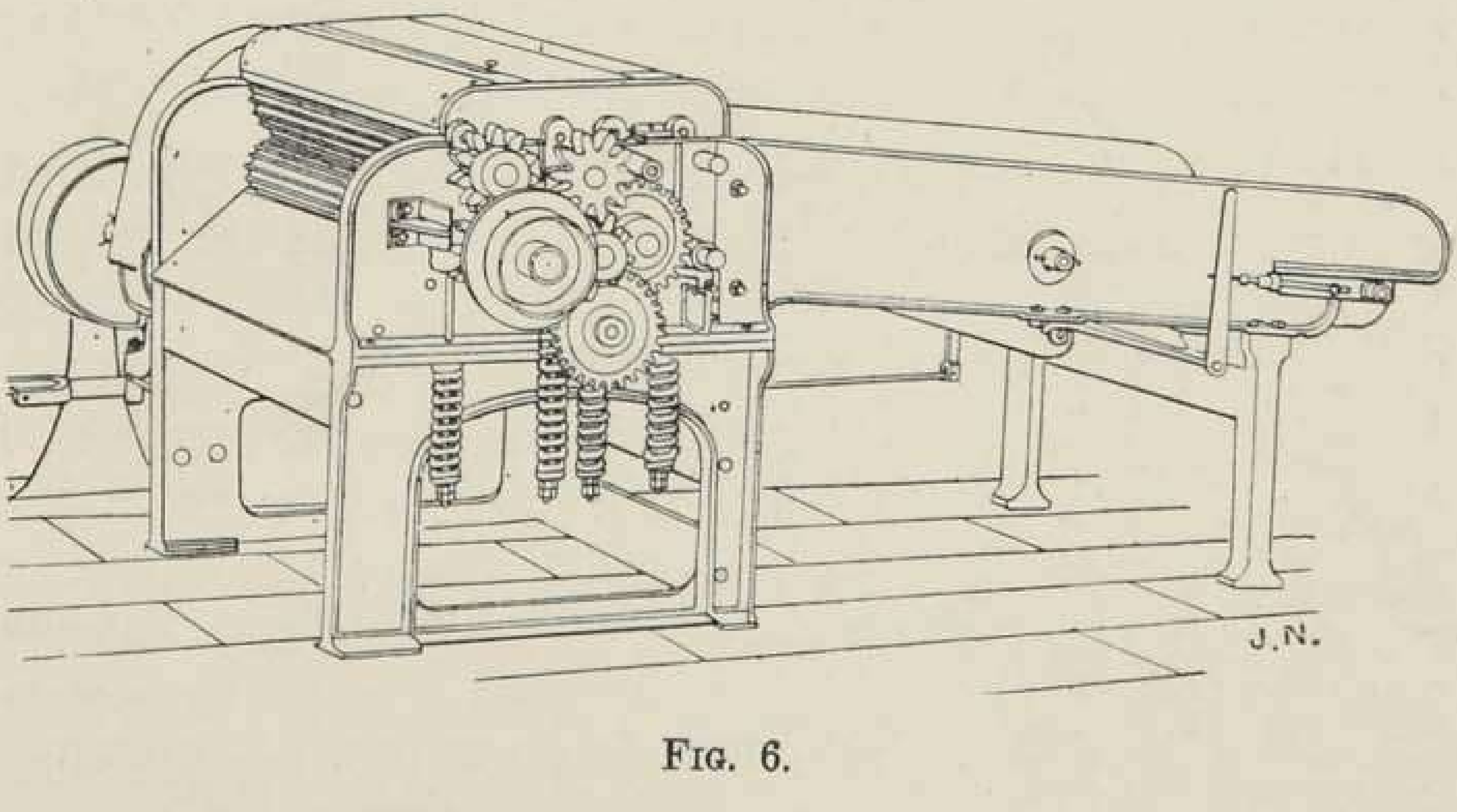

Fig. 6.

procedure, to which subsequent allusion will be made. The bale breaker, of which an illustration is given in Fig. 6, consists of a feed table of the lattice type. This is constructed of a number of slats or laths of wood, which are attached to two endless chains passing over rollers placed at any desired distance apart. One of the rollers is driven, and the lattice apron—shortly, lattice—is moved at a regular rate, and from its construction forms a flexible feed table, admirably adapted for its purpose. The cotton is taken from the bale in moderate sized pieces, and is placed upon the lattice by which it is carried forward and delivered into the range of the first pair of rollers. Of these, there are either two or four pairs, but in either case they are driven by spur gearing at different speeds. The rollers are differently constructed, the first pair being always made with coarsely pitched blunt teeth, by which the cotton is readily seized and drawn into the machine. The next pair immediately grip it, and as they revolve at a considerably higher velocity, the lumps are immediately drawn out. The third pair has finer teeth, and the fourth are, as a rule, formed with longitudinal grooves of coarse pitch. It is customary to make the first three rollers of a number of discs threaded on the shaft and bolted together, so that in the event of a breakage of the teeth they can be easily broken off and a new one added at the end. The top rollers are weighted by spiral springs, so that when an extra large piece of cotton, or any very hard substance passes, the roller can yield, and so avoid damage. The speed of the various pairs, as has been said, increases rapidly, and the effect is that, if four rollers are used, the cotton is well opened before being delivered. The extent to which the length of the cotton is increased is known as the "draft" of the machine, and this phrase is applied to all the processes of attenuation occurring in the whole series of machines.

(65) As has been indicated, there is a divergence of opinion as to the correct draft of a bale breaker, but the balance of advantage lies with the adoption of a large one. It is desired to get the cotton into the best possible condition for opening, and this can be best done by putting it into a free, loose condition at the earliest stage. There are limitations to this procedure, and different cottons require different treatment; but a draft of from 1 in 20 to 1 in 30 is, in the author's opinion, the best for practical purposes. There is an advantage gained when very short stapled cotton is used in partially opening by the bale breaker and completing the operation by a small porcupine cylinder, but for most classes the bale breaker will be found

sufficient. There cannot be in this, as in many other operations in cotton spinning, any hard and fast rule laid down, but the advantages of a large draft are greater than those of a small one. Messrs. Dobson and Barlow Limited apply the principle of the pedal motion used in a scutcher, as afterwards described, by which the cotton is held in sections, so to speak, across the face of the rollers, and thus any danger of large pieces slipping through unopened is obviated.

(66) It has been pointed out that there is in cotton as received a large amount of dirt and sand, and when the bale breaker is constructed so as to open the cotton well much of this is shaken out of it at this stage. It will be shown how important it is to cleanse the material as well as possible at the earliest moment, and anything which removes even a small percentage of dirt prior to the first recognised cleaning process is of considerable value. That such is the result of the restoration of the closely packed cotton to a fleecy condition by the bale breaker no one who will watch its action will deny, and this fact forms an additional reason for the system recommended. It is, of course, necessary to observe every precaution against damage to the fibres, but this is hardly likely to happen if the machine be kept in good condition and if the top rollers are not unduly weighted.

(67) The bale breaker is now almost invariably used in connection with the arrangements for mixing. Before proceeding to deal with its employment in this manner, it will be preferable to describe the methods and principles of mixing cottons. It was shown in the preceding chapters that some of the various grades of cotton possess characteristics which are the complements of those possessed by others. It is therefore possible, instead of using one class of cotton only for spinning, to use two or three, by combining them in a judicious manner. The purpose of this practice is to enable a material to be finally obtained which will be more economical than if any single variety be used, and the object of mixing is a purely commercial one. Thus certain grades of Orleans and Surat cottons can

be employed in combination, which will provide a cheaper raw material than if Orleans cotton only were used, and thus the resultant yarn, while maintaining its strength and commercial value, will be more cheaply produced. In the hands of a man who can skilfully blend various qualities, the economical results obtained are surprising. To be successful, however, a thorough knowledge of the different kinds of cotton available is absolutely necessary, and any one who neglects, or is ignorant of, this side of the subject will make a woeful failure. There are a large number of points to be considered in making a mixing, of which the following are the principal:—Length of staple, spinning qualities, colour, and price.

(68) Of these the first-named is the most important, although the others are also worthy of attention. When the process of drawing is treated of it will be seen how necessary it is to have the fibres in a given sliver as nearly as possible one length. Unless this is the case the setting of the rollers becomes a difficult task and much damage may arise. In twisting, also, the short fibres, not having the same grip of the adjoining ones as those of greater length, are not properly twisted in, and the result is that a hairy "oozy" yarn is produced. The tendency in carding and combing, also, is to separate the short and long fibres and to eliminate the former. Thus a mixture of different varieties which are not of equal length is a practice which is prejudicial to good and economical work. It is absolutely necessary, if full economy is to be obtained, that care should be taken to mix only such staples as work well together, and this is the cardinal principle of mixing. Thus Orleans cotton and Hingunghat cotton mix very well, both having the same mean length. Mobile and Broach will also mix well, so far as length of staple is concerned, but the yarn produced is apt to be high coloured. But if, in addition to the length of the staple, other desirable properties are taken into consideration, it will be seen that cottons which would otherwise mix well are not usable on account of the difference in their spinning qualities or colour. Thus a harsh, wiry fibre like

Rough Peruvian and a soft pliable one like Uplands, however well their length might agree, would make an unsuitable mixture, because the treatment which is absolutely essential in one case would be quite fatal in the other. It is therefore important to remember that the character of the fibre, as well as its length, is an essential item in mixing, and that the facility with which fibres will twist has an important bearing upon the subject. It is quite possible to strengthen a weak cotton by an admixture of a stronger one, and thus obtain a yarn which it would be quite impossible to produce in any other way. The colour of the cottons mixed is also important, as upon it depends the appearance of the finished yarn. Some cottons, like Brown Egyptian and Broach, for instance, are deep coloured; others, like Orleans, of a light shade. It is therefore undesirable, if a white thread is wanted, to use the higher coloured cottons, but if by judicious blending a shade can be obtained which is that desired, there can be no harm in using the higher coloured material. There is another point in which the colour of the material is important, viz., whether it is to be used for twist or weft. A mixing which is to be spun into twist will be several shades darker than if it is spun into weft. The former, it may be explained, is spun with more turns per inch than the latter, and is technically "harder twisted." It is a singular fact that owing to this increase the colour of warp yarn is deeper. The reason for this is not far to seek, and is found in the varying reflection of the light from the surface of the yarn owing to the different disposition of the fibres. It is well known that the difference in colour depends on the number of rays reflected, and there is no doubt of this being the correct solution of the apparent puzzle just stated. It is therefore essential in mixing different brands of cotton to remember the purpose to which it is to be put. The element of price is, of course, an important one, and must not be neglected. Suppose, for instance, that 2,000 lbs. of cotton is being prepared for spinning, and consists entirely of Middling Orleans cotton at, say, 4½d. per lb. This will give a cost for the quantity named of £37 10s. Now let the yarn be spun from a mixture of Middling Orleans and good Broach at, say, 3⅞d. per lb., in equal proportions. The mixing then will cost £34 17s. 11d., a net saving of £2 12s. 1d., or ·31 per lb. Now, suppose this is applied to the case of a mill using 20,000 lbs. per week, there is a weekly saving of £26 0s. 10d., which is a very considerable sum. There is, therefore, a great advantage to be gained from proper mixing, and nothing will be lost by a very careful study of the qualities and values of different grades of cotton. To ascertain the average length of staple a good plan is to detach a tuft, reduce it to a manageable size, and then hold it down upon a rule divided into sixty-fourths of an inch. A knife or chisel is a good thing to hold the cotton by, and by removing the fibres gradually from each side the average length of the staple can be easily got. This method requires a little practice, but is soon mastered, and it is very valuable in enabling a judgment to be formed as to the propriety of mixing two fibres. The four rules for successful mixing are—

First.—Choose cottons of practically equal staple.

Second.—Mix strong harsh fibres with others a little weaker and softer for warp yarn, but only soft pliable ones for weft.

Third.—Select cottons of colours which, blended, produce the right shade when spun into twist or weft.

Fourth.—Take into account the price of the cottons mixed so as to arrive at an average value.

(69) Having determined the character of the mixing, the next thing is to produce it. It is customary to stack the mixed cottons in bins, and for this purpose a special room is generally provided. If the cotton is mixed by hand, a layer of about a foot thick is laid all over the floor of the bin or stack from one lot of bales. Upon this a second layer of the cotton to be mixed is laid, and this procedure is carried out until the stack is completed. In mixing by the aid of a bale breaker, the bales containing the various qualities to be mixed are opened and placed near the machine. A layer from each bale

is taken in succession and placed upon the lattice feed apron of the machine, and is thus opened out at once. The machine delivers it on to a lattice, by which it is carried to an ascending double lattice, which in turn delivers it to other lattices running over the mixing bins. This arrangement is shown in Fig. 7, where A is the bale breaker, B the ascending lattice, and C the horizontal conveyer to the bins E. It will be seen that the cotton can be delivered at any point which may be desired. It is obvious that by a procedure of this kind a much more intimate mixture can be made of the various grades than is otherwise possible, and this is a matter of great moment. It

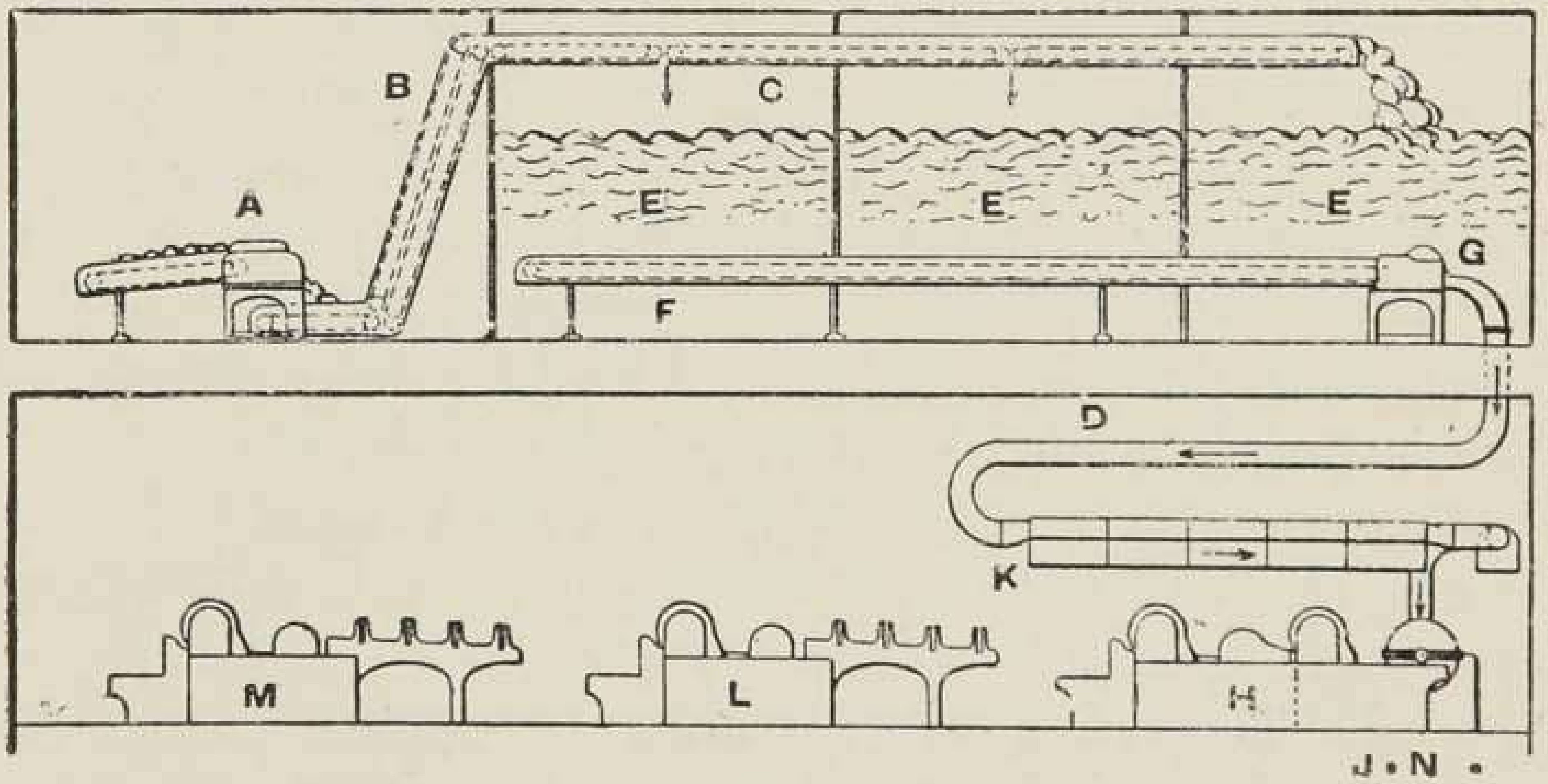

Fig. 7.

is clear that, if any advantage is to be gained from mixing, the earlier the fibres are thoroughly diffused among the mass the better; and much of the work of the earlier machines is removed if this object is attained at this stage. It is very desirable that a mixing should be made large enough to last for several weeks, as in this way more regular spinning is obtained. To test the working qualities, a small stack of a few pounds should be made from the mixture proposed, be passed through the machines, and spun into yarn. In this way it can be ascertained whether any change is required before finally proceeding with the larger mixture. It is only necessary to say, in conclusion, that by means of the lattices used the cotton can be conveyed from place to place without handling, and these useful appliances can be made to run in any desired direction.

(70) It is often the custom to feed the cotton from the stack directly into some form of opening machine, but the trend of modern practice is in the opposite direction. There can be no doubt that the less the work of beating out lumps of cotton is thrown upon the opening machine the more effectually it will perform its function of cleansing. If there is any virtue in the restoration of the cotton to an open fleecy condition, there can be little room to doubt that the earlier this happens the better. Now, in this respect, the use of a feed roller or table is of service, especially when combined with dust trunks. It is not desirable to use a bale breaker for this purpose, as the draft of the rollers is such that the cotton is merely broken up or pulled into comparatively large lumps, and the full effect of the operation is not obtained. A porcupine roller of 15 or 18 inches diameter is much preferable when revolving at a speed of from 800 to 1,000 revolutions per minute, and receiving the mixed cotton through the agency of a pair of feed rollers suitably speeded. The treatment thus given opens the cotton fairly well, and delivers it into the dust trunk, or on to a lattice, in a moderately open or fleecy condition. Thus, even assuming that no further action takes place between the feed table and the opening machine, the material is in a much better condition than it would otherwise be, and the work thrown upon the opener is considerably reduced. This arrangement is shown in Fig. 7, where the cotton is taken from the bins and conveyed by the lattice F to the porcupine feed roller G, by which it is effectually opened.

(71) The full benefit of this mode of procedure is not, however, derived, unless the feeder is combined with a dust trunk. It is well known that it is customary to place the opening and scutching machines in a different room to that in which mixing takes place, and that by the action of a fan the cotton can be

conveyed within a tube or trunk D, Fig. 7, from one room to another. The dust trunk is ⌓ shaped, with the flat side down, for a part of its length, as at K, Fig. 7, and is not merely employed as a conduit, but it is for a certain length fitted with fins or plates, against which the cotton strikes in its onward course and is temporarily retained. The effect of this arrestment is that the fibres receive a sudden check or shake by means of which the intermingled dirt is shaken out to a certain extent and falls into the spaces below, from which it is periodically removed.

(72) The action within the dust trunk has recently been increased in one instance by the addition in the curved part of the trunk of small brackets, to which the name of "dashers" has been given by the inventor, Mr. W. Catterall, of Preston. The arrangement consists of curved toothed brackets riveted to the crown of the trunk. The brackets are about four inches long, and the teeth are of such a shape that, while arresting, they do not hold the cotton. They are fixed with a gap equal to, or a little larger than, their own length between each pair, this gap being covered at the distance of 8 to 12 inches further along the trunk by another of the series of brackets. Thus the cotton is subjected to an additional series of checks, which render substantial aid in the removal of the dirt and seed. At Messrs. Catterall's mill, where a mixture of Egyptian and American cotton of medium quality is passed at the rate of 5,000 lbs. per day, a weight of droppings amounting to 34¼ lbs. is obtained. These droppings are exceptionally free from fibre.

(73) In dealing with dust trunks it is essential to remember that they require regular cleaning, for if the dirt is allowed to accumulate until the spaces are full, it is drawn onward by the air current, and part of the object of the trunk is destroyed. In this respect the travelling self-cleaning lattice made by Messrs. Platt Brothers and Co., is of service. It is essential that the whole of the joints of a trunk shall be smoothly made and air-tight. In the event of any projection

occurring at the joints, cotton is apt to accumulate, more especially if there is an opening between the lengths, and the trunk becomes choked; while, if air finds entrance, the effect of the fan is partially destroyed, and the cotton travels too slowly and collects. It is indeed often found that after the covers have been opened for the removal of the droppings the pneumatic action is not perfectly restored until enough dirt has again fallen to seal up the joints made by the cover. The dust trunk, properly used, plays an important part in the economy of a cotton mill, and it is obvious that this early removal of a large proportion of the dirt reduces the work required in subsequent stages, and materially enhances the possibility of adequate cleaning in the opener and scutcher.

(74) Having got the cotton into the dust trunk, it is in modern practice delivered into the opening machine. There are three principal forms of this machine in general use—the Crighton, the porcupine, and a modified willow—which may be distinguished from each other by the construction and position of the beater cylinder. In all of these the cotton is treated by rapid blows from revolving beater arms which fling it against specially prepared surfaces. The blow given should be quick and clean, so as to detach the fibres from each other without rupturing them, and the grids against which they are flung must be constructed so as to give the best results by permitting the easy fall of dirt, etc., during the period of arrest of the fibres. Many elements go to make up a successful opening machine. The manner in which the cotton is introduced, the construction, size, and speed of the beaters, are all essential features constructively. The cleansing power of a machine depends mainly on two points, viz., the quantity of cotton passed into it in a given time and the shape and position of the projections on the dirt grid. Upon these depends the commercial success of the machine—that is, whether it can be used so as to restore the material to its naturally open fleecy condition without damaging it, and at the same time enable the various impurities to be easily dropped.

(75) The machine illustrated in Fig. 8 is a modification of the willow, and is made by Messrs. Dobson and Barlow Limited. It consists of a cylinder, the surface of which is fitted with a number of teeth placed in rows a few inches apart. The cotton is fed along the lattice table L, and is delivered to the cylinder by means of a feed roller disposed above a pedal nose by which the rate of feed is regulated as afterwards described in dealing with the scutcher. As the cotton is thrust past the feed roller the teeth on the cylinder strike it and pitch it against a circular grid K nearly surrounding the cylinder. It should be remarked at this point that, contrary to all other machines, this type is constructed so as to strike the cotton upwards and not downwards, it being urged for this practice that less damage is caused to it than when it is struck in the ordinary way. The data for this claim appear to the author to be somewhat unconvincing, but there is no doubt that the work is as well done as by any other type. The area of the grid K is large and provides an ample cleaning surface, and to this feature may be

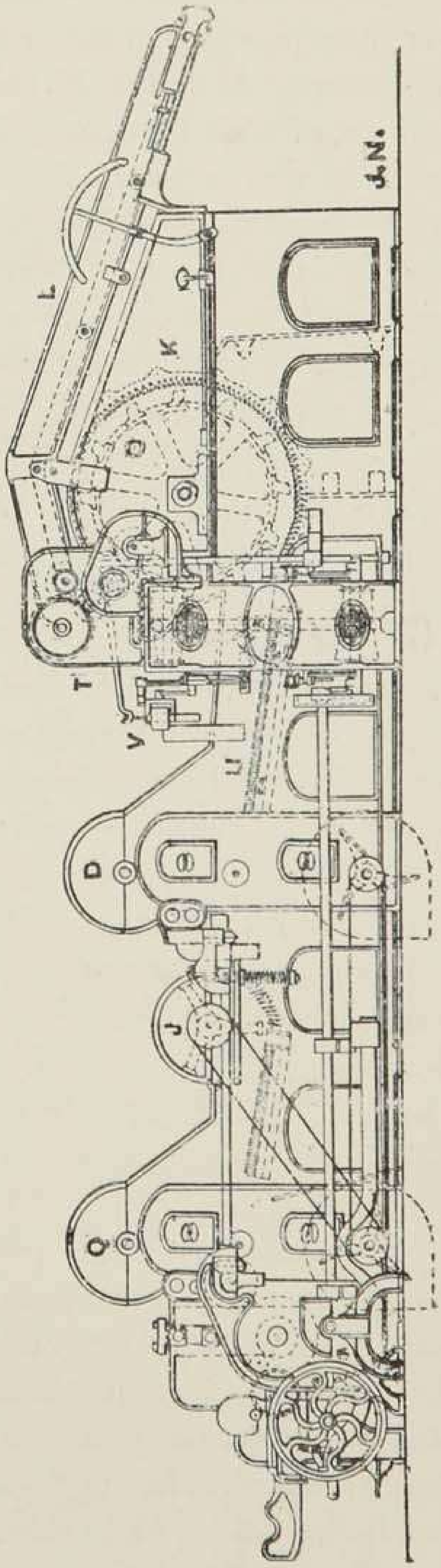

Fig. 8.

attributed the good cleaning property of this machine. After leaving the grid K the material passes on to a grid U, which is disposed at such an angle that the material passes readily over it and a great part of the dirt is deposited at this point. After leaving the grid U the cotton passes to the scutching machine, of which a description will be given later.

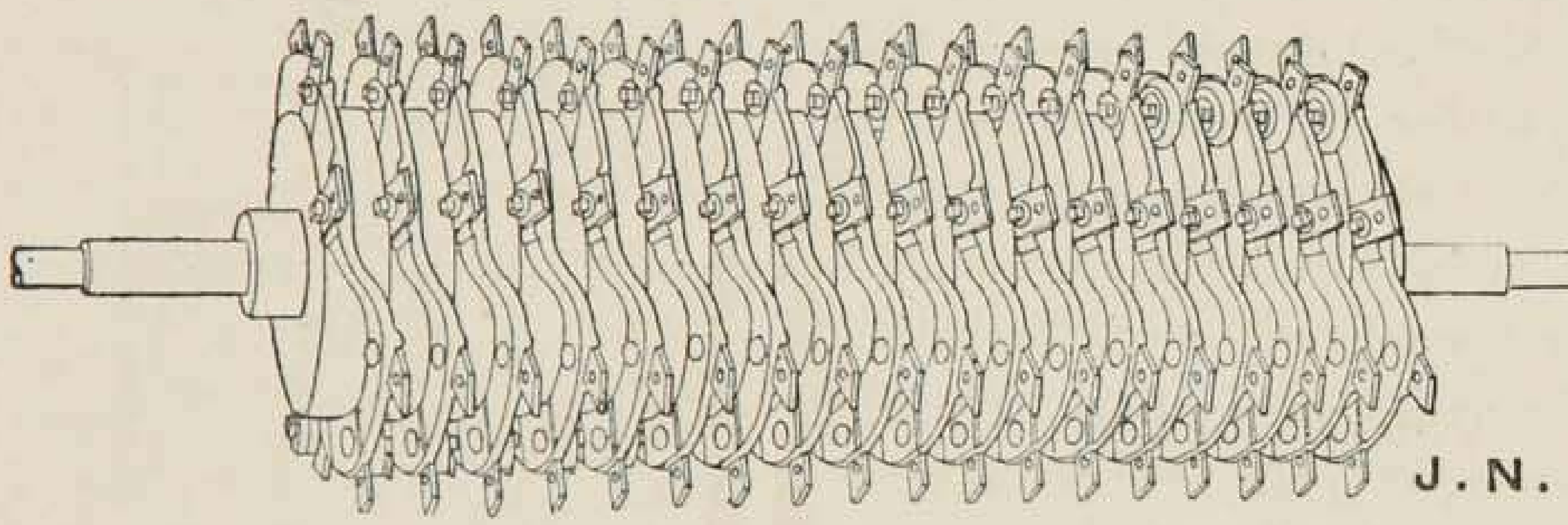

FIG. 9.

(76) The porcupine beating cylinder is usually placed just beyond the exit of the dust trunks, and is made in one of two forms. That shown in Fig. 9 is used for long-stapled cotton, and consists of a number of beater blades secured to discs, which in turn are fixed on a central shaft with which they revolve.

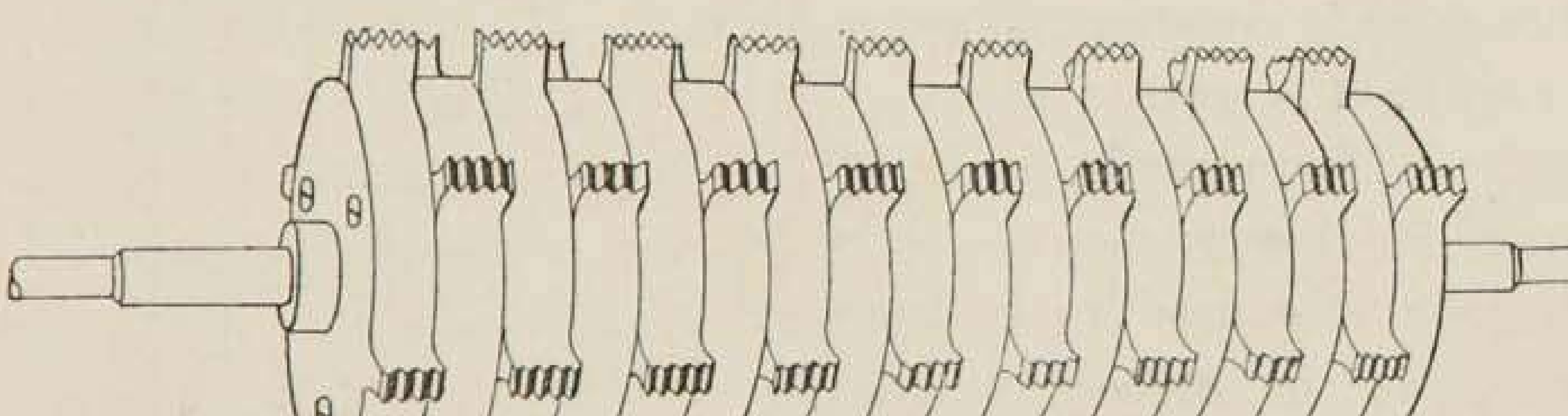

FIG. 10.

The blades are constructed so as to be easily reversed when worn. The form shown in Fig. 10 is used for short-stapled cotton, like Indian, and is made in a similar manner to the bale-breaker rollers, of a number of discs securely bolted and fitted together so that they can be easily replaced. Porcupine beaters are made from 18in. to 24in. diameter, and revolve from 800 to 1,200 times per minute. A dirt grid is fitted below the cylinder, so as to clean the cotton by the checks given to its onward progress.

(77) The Crighton opener is of different construction to either of the two just described. It is shown in section in Fig. 11, and consists of a conical beater constructed

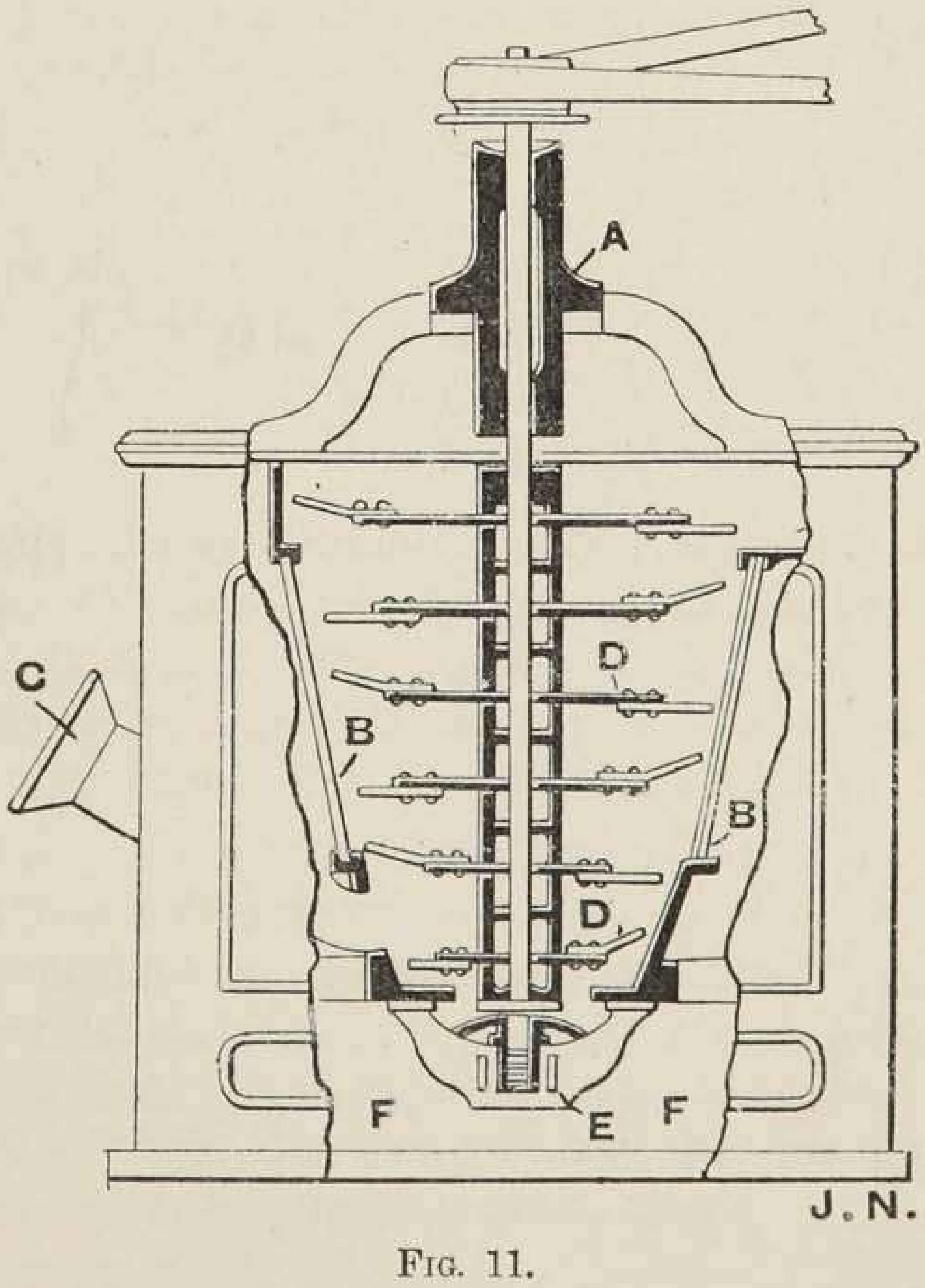

Fig. 11.

with a number of strong discs secured to the shaft. In lieu of discs two arms in one piece with, and radiating from, a central boss are used, but in either case blades D are secured to them. The length across the points of the blades increases from 18in. to 33in., the smallest diameter being at the bottom. The beater arms are surrounded by a case or grid, which is also conical, in exact accordance with the increase in the diameter of the beaters. The grids rest upon a truncated conical dish into which the cotton is fed by the tube C. The latter at its exit into the dish is given a slightly upward direction so as to guide the cotton upwards, and the dish is corrugated on its inner surface. The shaft of the beater is sustained by a footstep E, which is constructed so that the foot of the shaft constantly revolves in some lubricant. The upper end is kept in position by a long bearing A, and the driving pulley is placed above this point. Immediately below the orifice of the tube C a fan is placed, when the opener is combined with a feed-table and dust trunk, so that the suction of the cotton to that point is independent of that which carries it through and out of the machine. The blades D are now usually made reversible, so that they can be easily turned round when worn at one end.

(78) Before passing on to say anything of the action of the beater, it is worth while specially noting that in most cases it is now the custom to provide a fan at the very commencement of the machine, the function of which is to draw the cotton onward to that point and deliver it within the range of action of the beater. In the machines as made by Messrs. Crighton and Sons this is the course adopted and recommended; and in like manner both Messrs. Platt Bros. and Co., Limited, and Messrs. Asa Lees and Co., Limited, who make machines with porcupine beaters, adopt the same course. The reason for this procedure is obvious. The exhaust fan placed at this point brings the cotton gently within the action of the beater, which is thus enabled to strike it with considerable force. Assuming the fan to be placed beyond the beater, it is clear that to convey the cotton into the sphere of its influence, the air current must be also strong enough to draw the cotton past the beater and place it upon the cage, if a lap is to be formed, or to eject it, if not. A little reflection will show that in this case there will be a chance of the material being drawn over and past the beater without receiving that amount of treatment which is

essential to proper cleaning. Both theory and practice justify the fan being placed in the position named, and it is, as was remarked, practically universal.

(79) The cotton, when brought within the range of action of the beaters, is struck by the arms or blades and flung against the grids, through the interstices in which much of the dirt is ejected. In connection with this part of the subject there are two or three of the mechanical details which may be noted. These are—the shape of the beater blades, the setting of the grids, and the construction of the latter. For most varieties of cotton—indeed, almost without exception—when it is struck loosely, the flat beater blade, such as is shown in Fig. 9, is preferable. It strikes the cotton fully and with considerable force, and it can, moreover, be easily reversed when worn. It should always be remembered that it is bad practice to strike cotton with a blade which is too dull to give it a sharp blow, and that the risk of damage is much increased if the blade is shaped so as to crush the fibres. For very short stapled cotton, more especially if it is formed into a sheet, the porcupine beater shown in Fig. 10 can be advantageously employed.

(80) With reference to the setting of the dirt grids, there is necessarily a different procedure with the various types of machines. The Crighton beater, being placed vertically and being conical in shape, has similarly shaped dirt grids surrounding it. These grids are made with raised surfaces, against the face of which the cotton strikes, and between each pair of these an opening is made through which the dirt can be easily ejected. The distance from the points of the blades and the inner surface of the grids should not be too great, as, in that case, much of the cotton will be drawn upwards by the air current without being beaten. On the other hand, if the space be too far reduced, the cotton is likely to be crushed and damaged, thus producing considerable waste. A space of about $\frac{3}{8}$in. is, in most cases, ample, and this should be preserved. The dirt bars behind a porcupine beater do not require setting specially,

otherwise than to fix them so as to subject the cotton to checks, and thus permit the dirt to fall freely without running the risk of fibre being passed.

(81) The construction of the Crighton grid has been much improved recently, and the form now made by Messrs. Crighton

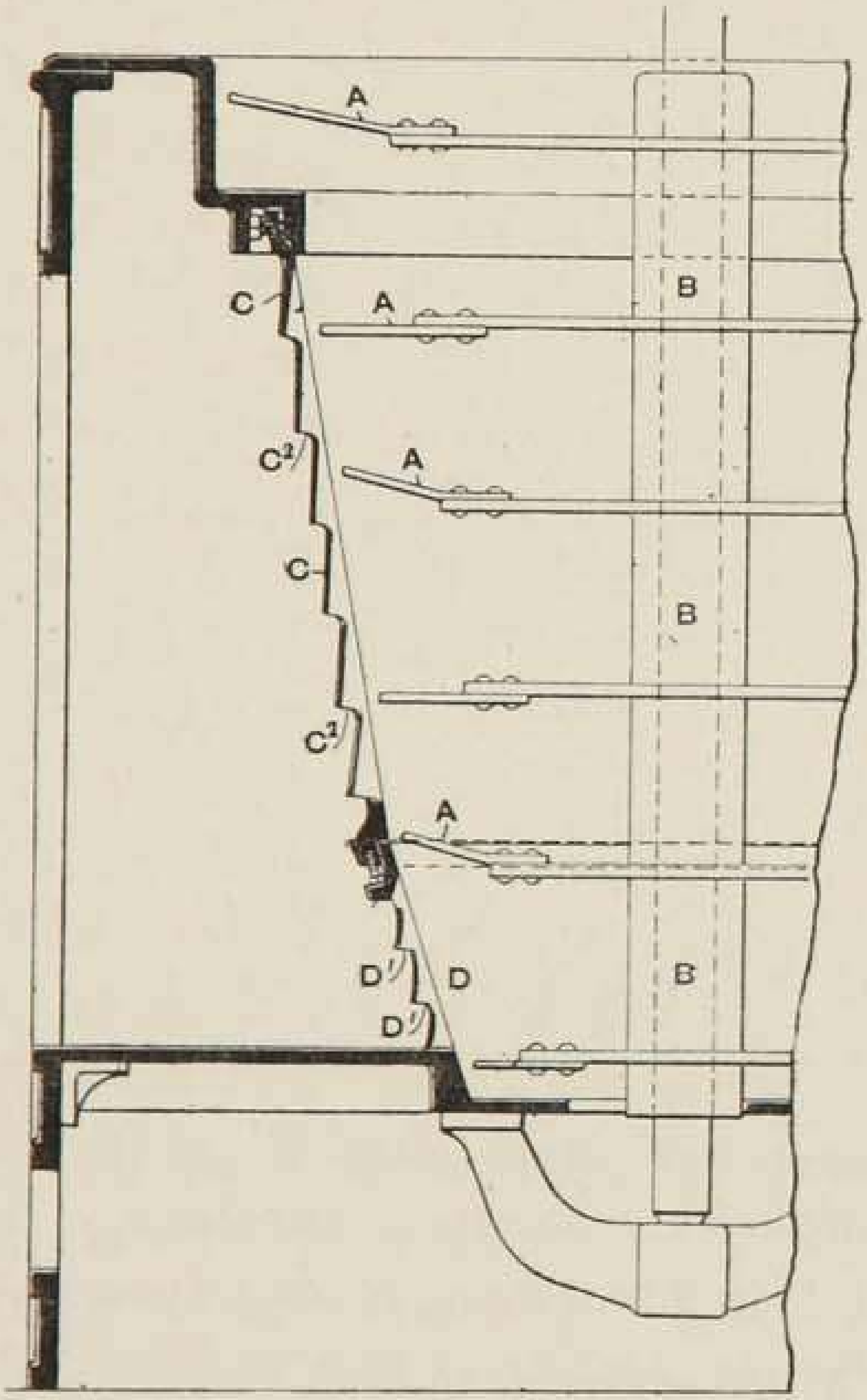

Fig. 12.

Fig. 13.

and Sons (sections of which are given in Figs. 12 and 13) possesses many advantages. It is so shaped that pockets are formed in which the cotton periodically rests until the beater arm has passed, after which it is drawn out by the air suction thus induced. The brief periods of rest thus given allow the dirt to fall freely, and the cleaning is more effective. The velocity of the air-current should be regulated so as to provide sufficient power to carry the cotton through the beater chamber in the Crighton, and if a combined machine is used, place it on the cages. This part of the subject will be again reverted to at a later stage. The velocity of the beater in a Crighton machine varies from 520 revolutions per minute when used for American cotton to about 720 revolutions for Indian. All other things being equal, the longer the staple cleaned the slower the revolution of the beater. The porcupine cylinder can be run at a velocity of about 800 revolutions per minute with advantage with most lengths of staple, when 18 inches diameter

(82) It is the custom to form the opened cotton into a "lap" at as early a stage as possible, instead of ejecting it loosely into the room. There are a number of advantages in this course, especially when the machine is combined with a scutching machine. Whether this course be followed or not there is much to be gained by forming a lap, because however uneven in weight that may be, it is not likely to be so variable as a mass of loose cotton placed on a lattice. As will be shown hereafter, the earlier an evenly weighted feed is obtained the better the chances of obtaining laps which are equal in substance. In addition to this there are all the advantages arising from easier handling, which reduces the cost for labour to a considerable extent.

(83) The scutching machine is designed to provide means by which the removal of the dirt and sand is still further facilitated, and if properly constructed and worked there should practically be nothing left for the carding engine to remove but nep, short fibre, and motes. A sectional elevation of the machine is given in Fig. 14, and some detailed drawings will be afterwards referred to. It is constructed with a revolving beater A, which is enclosed within a case, and is driven from a counter shaft at a speed of about 1,200 revolutions. The beater consists of solid arms, forged with a central boss, which is bored to fit the shaft and is securely fixed thereon. There may be either two or

three arms, but whatever may be the construction in this respect they are accurately made and smoothly finished. Upon feet formed on the ends of the arms blades of a special section—shaped so as to present a comparatively sharp beating edge to the fibre—are secured. The beater is most carefully balanced both before and after the attachment of the blades, and it is highly important that this should be so, as otherwise the velocity given to the beater would set up considerable vibration, which is detrimental to good work.

(84) The cotton is fed in all cases in which laps have been previously formed from two to four laps F. which rest upon a lattice apron G, by which they are unrolled. The lap end is passed between a feed roller suitably weighted and the nose of a pedal lever B, to which reference will be made a little later. The cotton is thus thrust into the range of action of the beater, and is struck by it, so that tufts of the fibres are flung upon the grid H, which surrounds the beater for a certain portion of its path. After leaving the bars or grid H, the cotton passes over a grid consisting of a number of longtitudinal bars with spaces between them and is conveyed to the dust cages J J^1. These are drums, the surfaces of which are formed either of wire netting or perforated sheet zinc, and which are connected at their ends to vertical dust trunks, by which the air is exhausted from them by a fan I, placed in the position shown. Care is taken in constructing and fixing the cages that no air can be drawn out between their ends and the framing, and one method—that of Messrs. Crighton and Sons—is well arranged for this purpose. They recess the frame-work, and fit the cage into it, fixing a guard ring which makes a perfect joint. The cotton is laid upon the cages in such a way that when taken off it is in the form of a fleece or sheet, which is then passed between two smooth "calender" rollers K, by which it is somewhat compressed. After undergoing this treatment it is rolled up into a "lap" M, as shown, being wound on to a round bar or "lap rod." The ends of this are fitted under a bracket formed at the upper end of a vertical bar T, on which is a rack

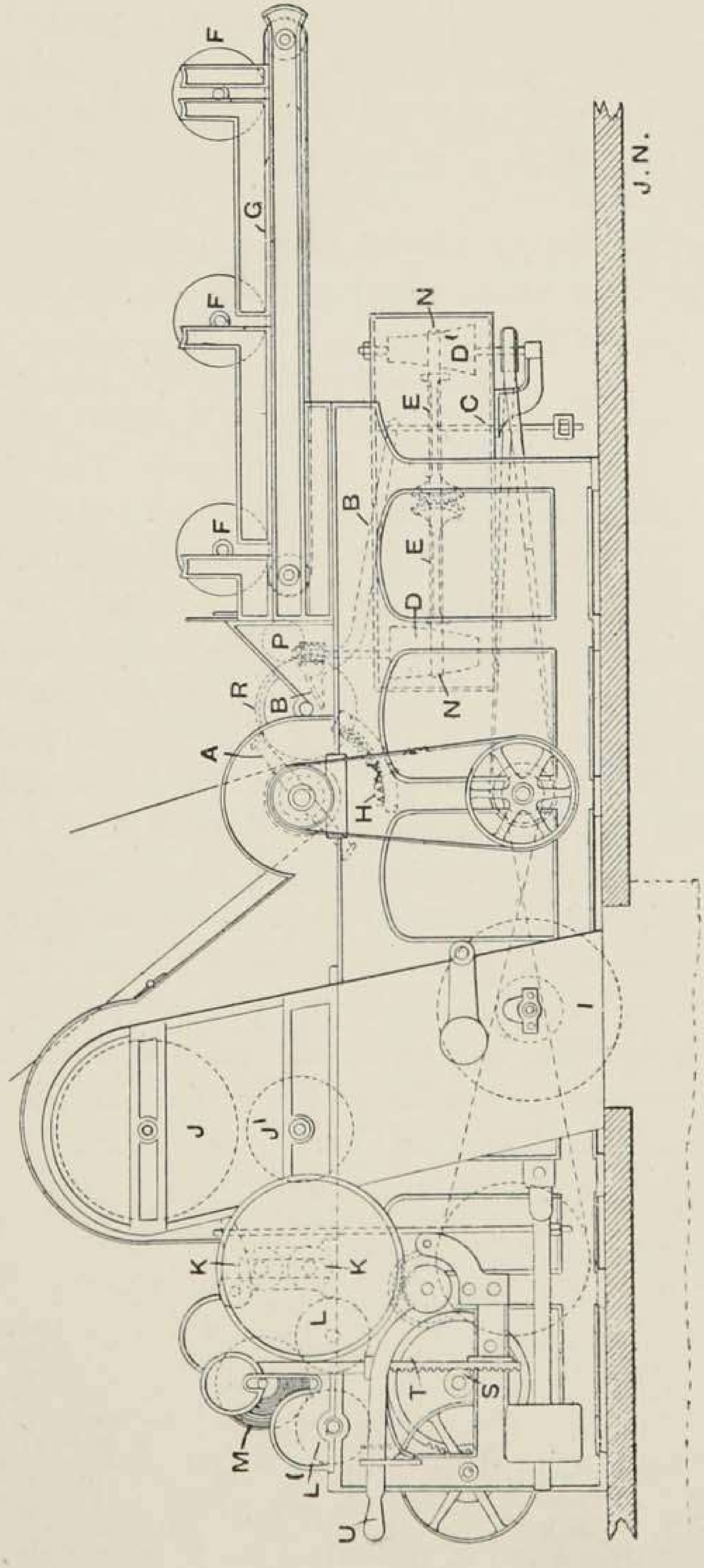

FIG. 14.

with which the pinion S engages. The latter forms part of a train of gearing shown in the drawing, and as soon as the right size of lap is made—that is, when a definite number of yards is wound—a catch is released and the handle U falls, thus transferring the belt from the fast to the loose pulley and stopping the machine.

(85) The feed motion is shown in side elevation, plan, and end view in Fig. 15. The feed roller D is placed so as to rotate above the nose of the "pedal" lever B. The latter is loosely

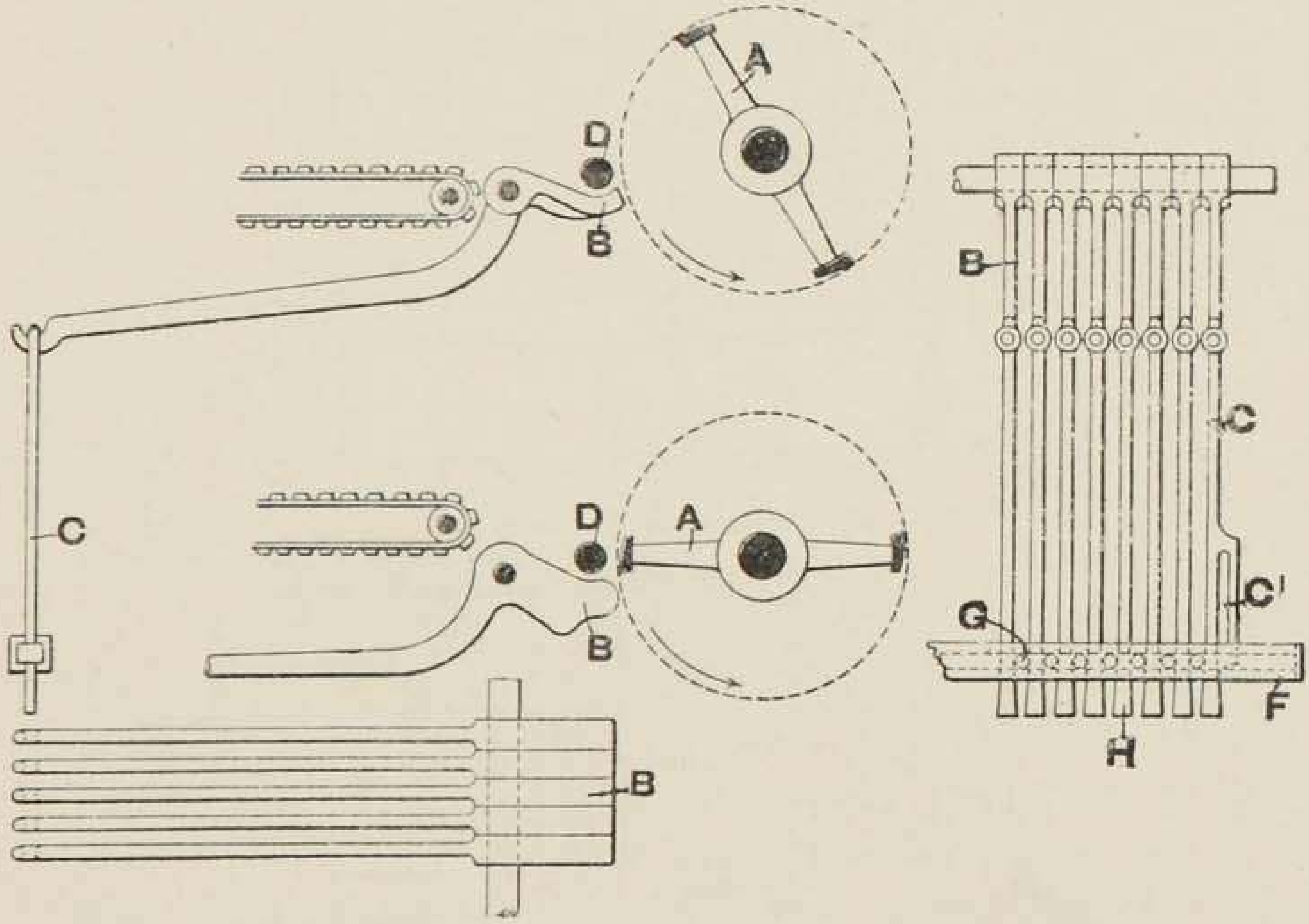

Fig. 15.

pivoted on a shaft, or, as is much better, upon a knife-edged fulcrum, and has at its tail end a pendant lever C hung upon it. The pedal noses extend across the whole width of the machine, as shown in the end view in Fig. 16, and partially in the plan view in Fig. 15. The lower ends of the pendant levers pass through a box or frame F, and are slightly swelled as shown at H. Between each pair a friction roller G is placed which is borne by bars sliding in grooves formed in the box F. The last of the series of pendants C^1 is formed with a slot to which is coupled, as shown in Fig. 16, a lever O forming the first of a series which are coupled to sectors E (Fig. 14), which control the movement of a strap N upon the cones D, D^1. When a pendant lever rises, which it does when the nose B of the pedal is depressed owing to the passage of a thick piece of cotton between the feed roller and pedal, the swelled portion H of the

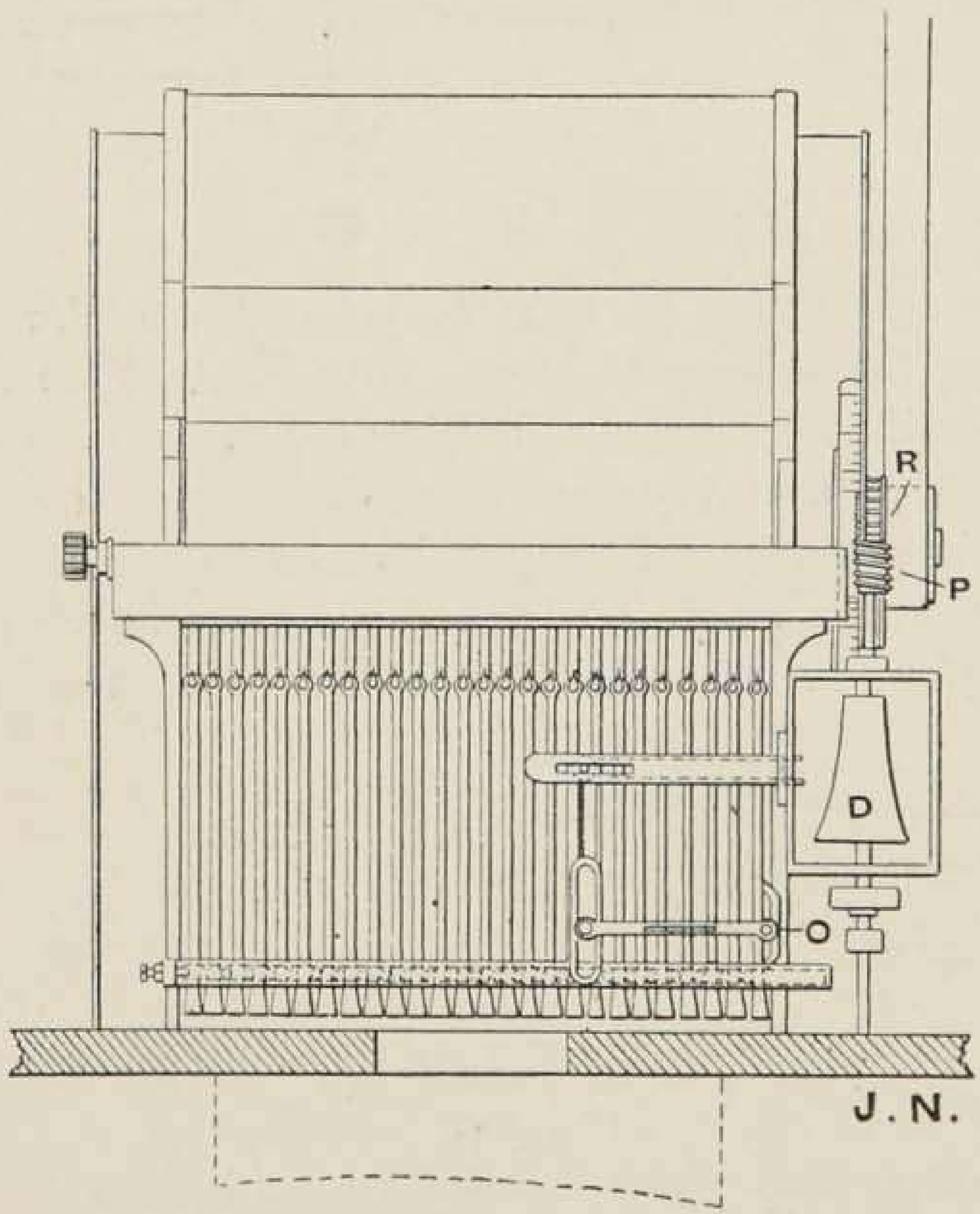

FIG. 16.

pendant, being unable to pass between the space between the two adjoining bowls, sets up a pressure which causes the bars holding the bowls to move and the whole series of pendants to swing in one direction. This movement is communicated to the strap N in the way described, and it is thus moved on the cones D, D^1. When the pendant falls, which it does as soon as the pressure is relieved, the pedal nose again rises, and the weight of the various parts again restores the strap to its normal position. In the event of a thin place occurring the action is the reverse of that described. The cone D^1 is driven as afterwards shown, and drives D by the strap N. Upon the upper end of the shaft of D is a worm P which engages with a worm wheel R on the axis of the feed roller. Thus any varia-

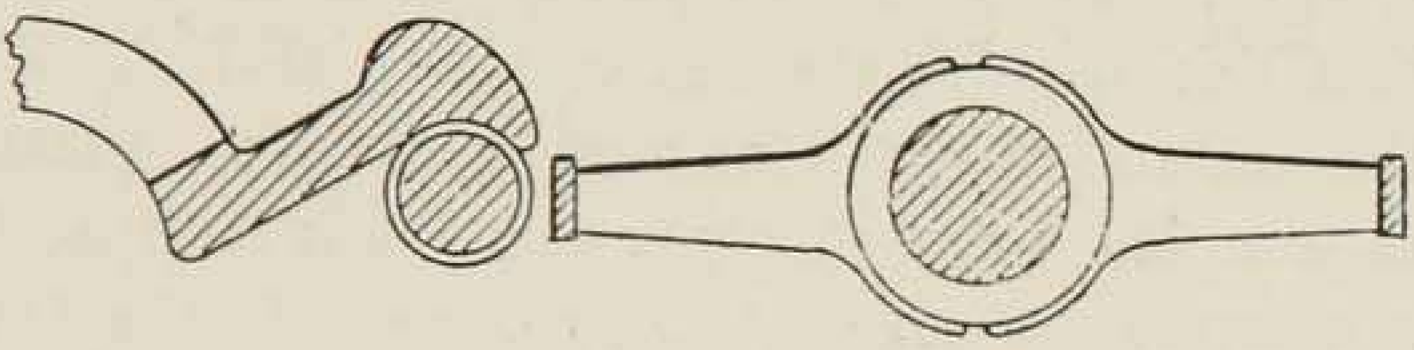

FIG. 17.

tion in the position of the strap caused as described, reduces or accelerates the velocity of D, and thus rotates the feed roller at a proportionately slower or quicker speed.

(86) There are two chief methods of construction adopted in arranging the pedal levers and feed roller. The one is to use a single roller, which rotates above the nose of the pedal and feeds the cotton by the pressure

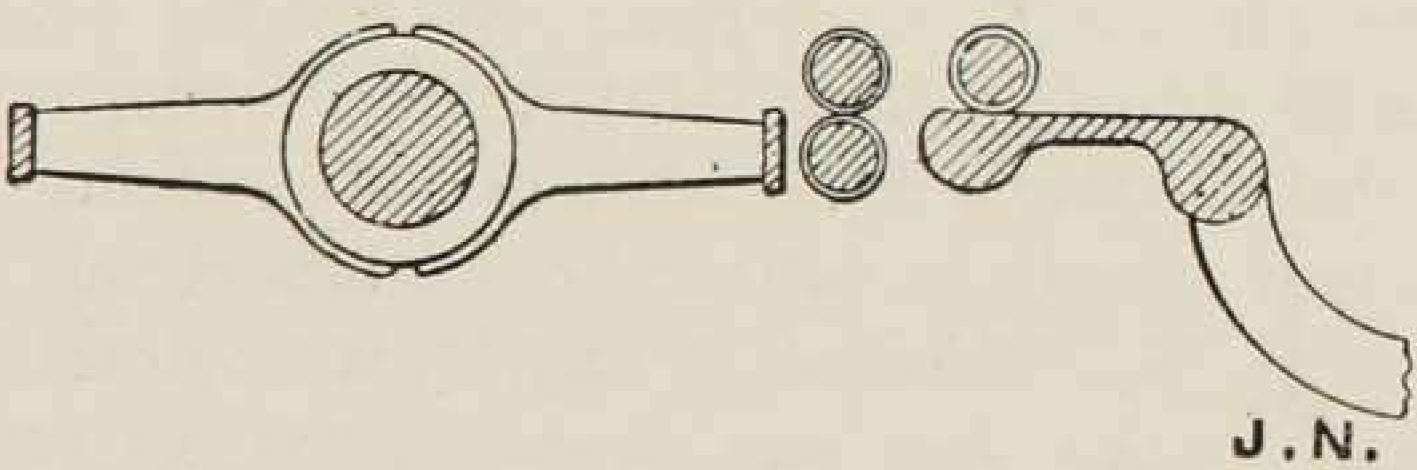

FIG. 18.

exerted on it as it passes between them. The other plan is to feed the cotton by a combination of a roller arranged as described and a second pair of rollers rotating between the nose of the pedal and the beater. These different methods are shown respectively in Figs. 17 and 18. It is the practice for short stapled cotton to use the former, and with longer staples the latter, the theory being that the cotton being struck round a less acute surface is less liable to damage. There is ample justification for the theory, but not so much for the practice. The whole thing resolves itself into a question of expediency; and it must be remembered that this is not a case where, as in the carding engine, the fibres are removed in groups by the action of a combing tooth, but one where they are struck off across the whole face by a transverse bar. It is therefore necessary that the blow of the beater blade shall be able to strike off the cotton without breaking it, and the question of the distance from the point at which the lap is held and that at which it is struck becomes of importance. If the distance between these points is too great, the blow of the beater first bends down the lap end and then strikes off the fibres. It is obvious that unless the cotton is removed regularly in this way there exists a danger in the second blow of some bruising of the material. It is the practice of many makers to shape the nose of the pedal in such a way that the necessary rounded surface for the deflection of the fibres, which must take place in any event, is provided without using the three-roller principle. Accordingly in Fig. 15 two forms of pedal nose are shown which possess the characteristics necessary for different staples of cotton. A careful examination of the profiles of the two types will show that, the staple of the cotton being in each case equal, it will be bent round the bottom roller when struck from a pair, as in Fig. 18. When, as in Fig. 15, it is struck from a pedal nose, it is quite clear that the end of the lap, although projecting from the nip of the roller as far as in the other case, is sustained by the pedal in a nearly horizontal position, and consequently receives the blow of the beater blade more squarely. There is thus no possibility of the crushing action which has been mentioned, and on the whole, the arrangement shown in Fig. 15 meets all the requirements of the case. It will be easily understood that the distance between the path of the beater blade and the edge of the roller or pedal nose is comparatively small, so that if a beater is not well balanced, and vibrates at all, it will tend to crush the fibres between the beater blade and roller or pedal. This furnishes another reason for care in the construction of the beater, and for careful attention to the condition of the bearings.

(87) There is now an almost universal practice in connection with the bowls used in the pedal motion, which consists in the use of two or three bowls between each pair of pendants instead

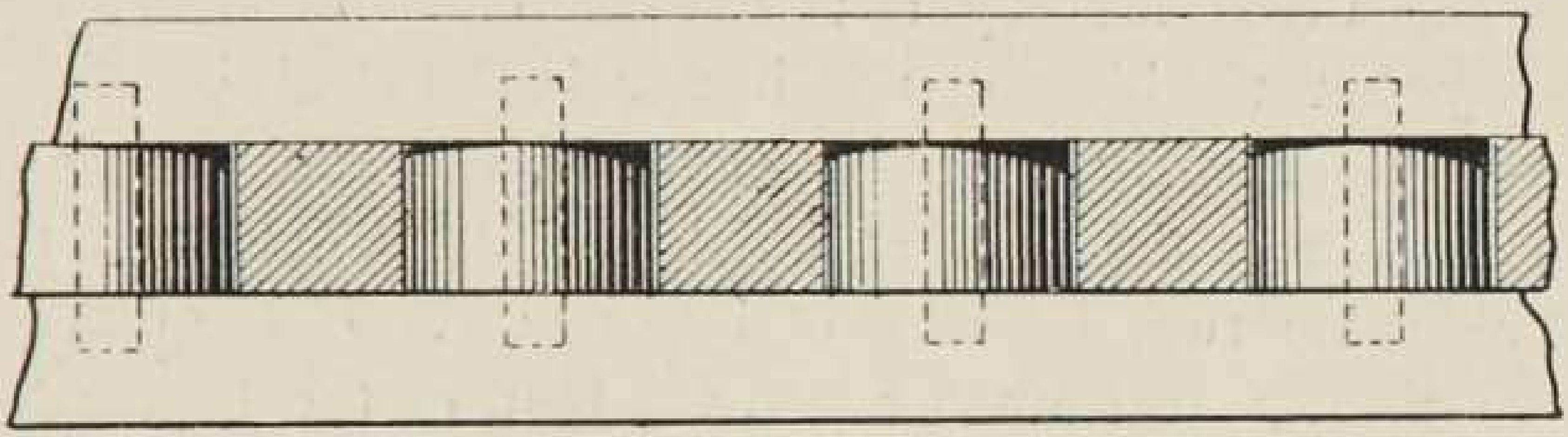

FIG. 19.

of one. The reason for this practice is to take off the friction which naturally arises when one bowl only is used, and adjoining pendants are moving in opposite directions simultaneously. In Figs. 19 and 20 two alternative methods are illustrated, the three-bowl system being Messrs. Howard and Bullough's, and it will be noticed that one of the pendants has a special rib cast

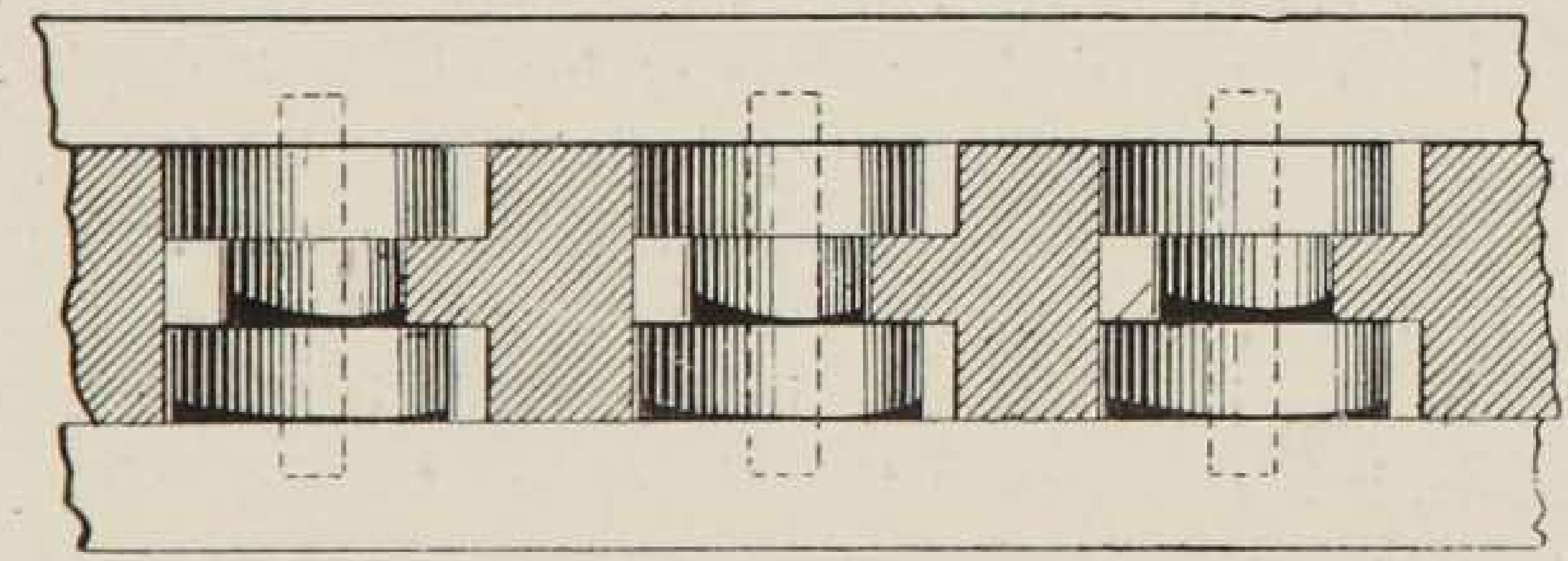

FIG. 20.

on it to engage with the small bowls. The use of two bowls, fixed so as not to rub against each other, has the same effect.

(88) It is absolutely imperative to keep the whole of the parts of the regulator quite clean. The custom of using knife-edged fulcrums renders it necessary to see that no fly collects on or about them, and every joint wants the most careful attention to ensure that it is kept free and unclogged. The bowls should

be removed frequently, as often as once a week, and well treated with black lead, being at the same time freed from everything likely to impede their rotation, the boxes being cleaned at the same time.

(89) There is some difference of opinion with regard to the employment of two or three winged beaters. The former is more easily made and more accurately balanced, and is ordinarily about 14 inches diameter. The three-winged beater is made 16 to 18 inches diameter, and is revolved at a slower rate than the two-winged. The respective velocities are 900 to 1,000 revolutions, and 1,200 to 1,500 revolutions. Thus the two-winged beater gives a sharper blow, leaves the cotton more quickly, and is not so liable to vibrate. For these, among other reasons, it is preferable, and gives quite as regular a blow as the three-winged type.

(90) When a two-winged beater is revolved at a velocity from 1,200 to 1,500 per minute the blow given to the cotton is sharp, regular, and clean. It is essential that the bearings of the beater shaft are kept in good condition, and the beater blades, which are sometimes made so as to be readily reversed, should be kept with a good edge for the reasons given in dealing with the opening machine. As the blow given by the scutching machine beater is transversely of the fibres, it is essential that it should neither be given by a blade which will cut the fibres nor by one which will crush them, and care must therefore be taken to avoid either of these defects. The setting of the feed rollers and the construction of the pedal nose both bear upon this subject, and care should be taken to see that these are set correctly. The same rule holds good as in the case of the dish feed plate in a carding engine, and the correct setting depends practically upon the length of staple being scutched. In every case the avoidance of a sharp angular surface over which the cotton can be bent is desirable, but it is possible to use a much more abrupt surface in dealing with a cotton with such a short staple as Indian than it would be if Egyptian or American of the better qualities were being used.

(91) The setting of the dirt bars below the beater is a matter of importance. The earlier of the series, as shown in Fig. 21 at C, should approach the path of the beater more closely than those further round as at D. The arrangement shown in

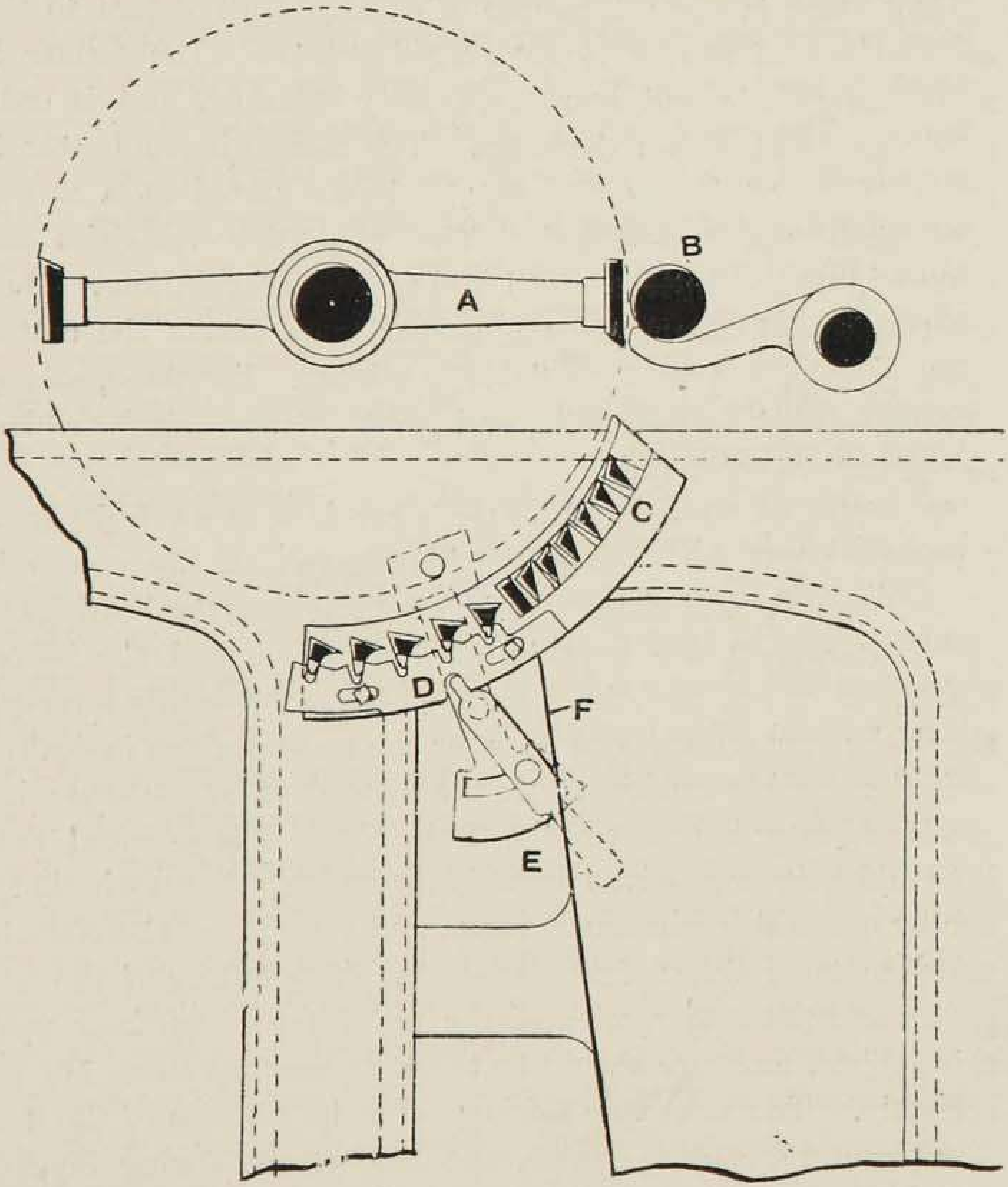

Fig. 21.

Fig. 21 is that adopted by Messrs. Howard and Bullough, the position of the bars and the spaces between them being regulated by the handle E. At first the cotton requires to be arrested quickly, so that it receives a shock which frees the dirt and sand. The bars should subsequently subject the cotton to a scraping action, for which reason the angle presented to the cotton by the face of the bar should become less acute, so that the cotton can roll over the bars. In this way many of the motes and a good deal of leaf are removed. The space between each pair of bars should in a similar manner be graduated, as there is less dirt to fall at the last than at the first of the series. The exact setting of the bars cannot be empirically stated, as this is a matter of practice; but if the earlier bars are set with their upper forward edge rather in advance of a radial line drawn from the centre of the beater to the lower edge, and this angle gradually reduced until the last of the set has this edge a little behind the radial line, an approximately correct setting is obtained. When dirty cotton is being scutched an opening of one-eighth inch is permissible between the bars. It is perhaps needful to say that the edges of the bars should be kept sharp and clean.

(92) It is now necessary to deal with the question of the air current and its proper regulation, and in connection with this question will come a series of others of more or less importance. The problem of the regulation of the current of air in a scutching room is a most important one, and its proper solution depends upon such a number of points that constant watchfulness is wanted both in laying down and working the machines. Broadly stated, the principle underlying this subject is that such a balance of pressure must be established that only sufficient suction is set up to draw the cotton evenly upon the cages. For this purpose large fans running slowly are better than small fans running at a high velocity. The propulsion given by the beater is sufficient to throw the cotton forward to the cages, and all that the fan is required to do is to attach it to the surface of the cage. The efficiency of a large fan for the removal of a given volume of air is much greater than that of a small fan. The importance of this element is found in the fact that an excessive current of air would prevent the falling of the dirt through the grids, the air, which is confined in the chamber

below the grids, being quiescent and therefore in a good condition to permit the easy fall of the dirt. It is therefore advisable to leave an inlet for the air below the feed rollers so that a current can be created by the rotation of the beater. The American custom of admitting air by the beater shaft—which is made hollow for the purpose—does not appear to the author to possess many advantages, as the air is liable to enter at a point and in a manner which is not calculated to attain the object aimed at.

(93) There are a number of important considerations to be borne in mind in arranging the air passages leading from the blowing-room to the open air. It is not unusual to find the air discharged into a passage or flue in which there are several sharp turns, each of which offers an obstruction to the passage of the air and increases the friction. An instance coming under the personal observation of the author may be cited. The scutching machines were placed longitudinally of the room and the air was discharged into flues running in that direction. These flues terminated in a flue at a right angle to them, the second flue being carried a short distance—in fact, the width of the room—afterwards discharging into a third one at right angles to but parallel to the first. The third flue ran the whole length of one side of the room and terminated in the upcast flue, by which the air was discharged into the atmosphere. Although there are worse schemes in existence than this there are not many. It is quite evident that for some reason or other the machines are wrongly placed, because it would have been quite easy by reversing them to have avoided two of the bends, and to have carried the flues from the scutching machine into the side flue by a curved passage.

(94) This case has been cited because it is by no means uncommon. Each of the corners formed is, in plain terms, a trap for the accumulation of dirt and fly, and a cause of obstruction to the air. It is often a source of annoyance and complaint that laps are uneven in substance, although the mechanism is in perfect order. In the majority of cases the

cause will be found in the construction and condition of the flues. Great care should be taken to keep these clean, and in building them easy curves and ample areas should be substituted for sharp angles and contracted sections. This is of the more importance if the plan is adopted of having a slow velocity of air current, as the effect of an obstruction is proportionately greater. The area of the dust flues should always be a little in excess of the combined areas of the fan outlets. Thus, if the latter have an area of 300 square inches, an area of 310 square inches is about the right one for the dust flue.

(95) Sometimes a lap has a ragged, uneven, or thin edge, the cause of which is difficult to discover. It may be fairly presumed either that one of the fans is not working properly, which may arise from an obstruction such as that named, or that the dampers—which are fitted to the cages—are not properly set. In either case the effect is that the cotton is drawn on to one side of the cage only. This fault may also arise from a back pressure set up when the wind is blowing in a certain direction if the outlet is not perfectly free to discharge, or is subjected to down draughts. It is absolutely imperative that the closest attention is given to this point, and instances are not rare where a slight alteration of the size, construction, or direction of the flues has resulted in making a scutching machine work admirably where previously it had been impossible to get good work. The system of gradually diminishing the width of the machines is not without its advantages. Thus, if a lap 45 inches is formed at the opener, it will be fed to a machine, say 42 inches wide on the cage, and the laps then made to a 40 inch machine. In this way good "selvedges" are obtained, but these can be got if the draught is arranged so as to draw the cotton equally across the whole face of the cage.

(96) Sometimes laps lick on the cages and afterwards split. When one cage only was used this fault was most rare, the reason being that there was only one surface on to which it was drawn. At present the cotton is drawn on both the upper cage

J and the lower cage J^1, and as a result the laps sometimes divide when unrolled. The cause of this is undoubtedly that the air current is strong enough to cause the attachment of the cotton to both cages equally. The remedy is obvious, viz., to ensure that the draught is so regulated that the suction is principally through the top cage, or, at any rate, that the preponderance is there found. This is very often a structural defect, and machines are made in which the tendency to split appears to be inherent, while there are others where it is practically absent. This defect is aided by any irregularity in the proper relative speed of the beater and feed roller, and the latter is a fruitful source of uneven laps—that is, laps in which the weight of a yard varies in different portions. The scutching-room should be kept dry and at a temperature of about 75° F.

(97) In dealing with the scutching machine, it is desirable to say a few words about the speeds of the various parts, and for this reason the diagram given in Fig. 22 has been prepared. By its aid it will be possible to show how the relative velocities of the various parts of the machine are obtained, and the trains of gearing, employed for the purpose, can be clearly followed. It is also useful to enable the changes, which it is necessary to make when it is desired to vary the weight or substance of the lap, to be clearly comprehended. The sketch given is a representation of the gearing of a single scutching machine, as made by Messrs. Lord Brothers. In this, as in most others, the feed and lap parts of the machine are, to all intents and purposes, independent, although the necessary driving for each is obtained from the same point. It is, however, as will be shown, quite possible to obtain the necessary regulation of one part without interfering with the train of gearing driving the other; or, if desired, both can be regulated simultaneously.

(98) The pulley A is fixed on the beater shaft, as is also the pulley F, which is the key to all the movements of the machine, and drives by means of a strap the pulley F^1 fastened on an intermediate shaft. From this shaft the two portions of

the machine are driven, the feed part by the strap driving the feed cone D^1 and the lap part by the strap driving the pulley H, from which all the rest of the gearing of the lap end obtains its motion. The spindle of the cone D^1 has fixed on it a pulley G^1 which is driven from the pulley G on the intermediate shaft. The cone D^1 drives the cone D by the usual strap, and at the upper end the spindle of D has a worm P fixed which drives the worm wheel R fastened

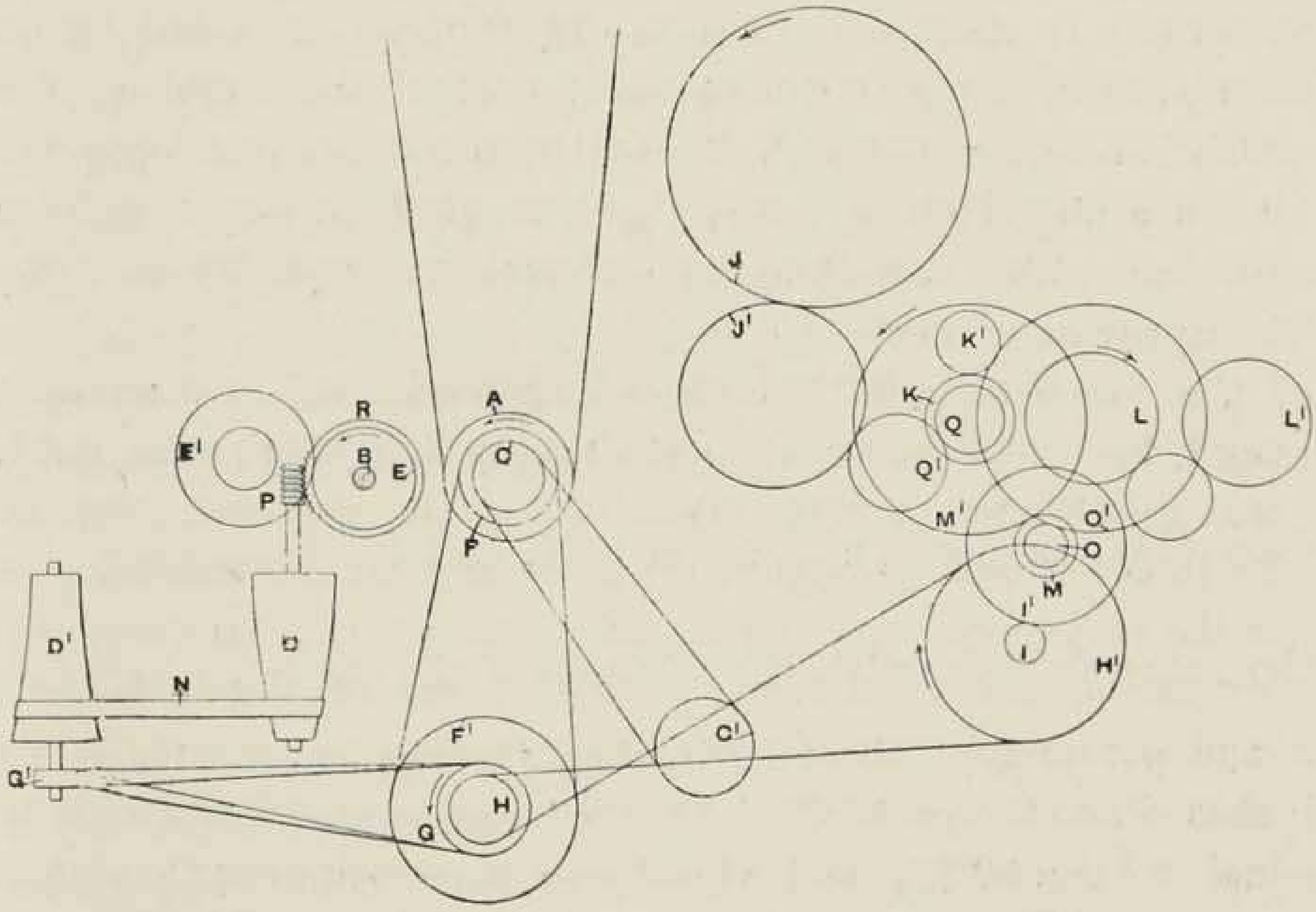

FIG. 22.

on the feed roller spindle. By means of the wheels E and E^1 the lattice roller is driven. In order to ascertain the velocity of the feed roller it is only necessary to multiply the diameters or number of teeth of the driving wheels or pulleys and divide that product by the product of the driven wheels, afterwards multiplying the quotient thus obtained by the velocity of the beater shaft. Putting this into the shape of a formula, and assuming the beater to revolve at a speed of 1,500 revolutions per minute, the calculation is as follows:—$\frac{F}{F^1} \times \frac{G}{G^1} \times \frac{D^1}{D} \times \frac{P}{R} \times 1500.$

To ascertain the velocity of the lattice the product of the above formula must be multiplied by $\frac{E}{E^1}$. It is only necessary to substitute for the letters given above the diameters of the pulleys and the diameters or number of teeth in the wheels to ascertain the requisite velocity of the feed roller or lattice.

(99) The lap machine includes three distinct parts which require driving, viz., the cages, the calender rolls, and the lap rolls. The whole of these are driven by trains of wheels from the pulley H^1 driven from a pulley H. The cages are driven by the train consisting of the pinion I which drives the wheel I^1 which is compounded with the pinion M driving the wheel M^1 M^1 has a pinion Q on its axis which engages with a wheel Q^1 engaging with a wheel J^1 on the spindle of the lower cage. The upper cage is driven also from J^1 by a wheel on the spindle of the lower cage. The formula for the two can be thus stated, beginning as before at the beater shaft. For the lower cage (1) $\frac{F}{F^1} \times \frac{H}{H^1} \times \frac{I}{I^1} \times \frac{M}{M^1} \times \frac{Q}{J^1} \times 1500$, and for the upper cage the same formula with the addition of the factor $\frac{J^1}{J}$. (2) Let a and y represent the results, then the upper cage being 19 inches diameter or 59·69 inches circumference its delivery is equal to $x \times 59{\cdot}69$, and the lower cage being $11\frac{3}{4}$ inches diameter with a circumference of 36·92 inches its surface velocity is $y \times 36{\cdot}92$. These two products should as nearly as possible correspond, but it is of course difficult to get them to do so absolutely.

(100) The calender rolls are driven by a train of gearing which consists of the same factors to the pinion Q, which is fixed on the axis of the lower calender roll. The formula for this train is (3) $\frac{F}{F^1} \times \frac{H}{H^1} \times \frac{I}{I^1} \times \frac{M}{M^1} \times 1500$. The lap rolls are driven by the same train up to the pinion M, which in this case is substituted by a second pinion O, which gears with a wheel O^1, fixed on the axis of one of the lap rolls. The second

lap roll is driven by a carrier wheel from the first at the same speed. (4) If the factor $\frac{O}{O^1}$ be substituted for $\frac{M}{M^1}$ in the formula given, the velocity of the lap rolls can be obtained. (5) The calender rolls are 5in. diameter and 15·7in. circumference, so that if the product of formula (3) be multiplied by the latter figure the delivery in inches of the calender rolls will be got. The lap rolls are 9½in. diameter and 29·84 circumference, and the product of formula (4) and the latter gives the delivery of the lap rolls.

(101) The foregoing brief description will have made it clear that the controlling element in the speeding of this machine is the velocity of the beater shaft. By changing the pulley F^1 on that shaft the velocities of both the feed and lap portions of the machine are altered, although that of the beater is unaltered. This is the method of obtaining the variation when it is desired to produce a greater or less weight of laps without altering their individual weight. If it is required to produce laps varying in weight from those for which the machine is set the pulley H is changed for one of the necessary diameter, the size of which can be easily calculated. This procedure gives a longer or shorter lap for the same length of feed, which, of course, gives a corresponding variation in the weight. As a rule this is all that is required to make the changes, but if it is found desirable to alter the speed of the feed and so produce a heavier or lighter lap for the same length of rollers the pulley G is changed.

(102) The drafts in a scutching machine are of importance. There is a slight draft between the lattice and the feed roller, a larger one between the feed roller and the cages, and a draft between the cages and the calender rolls, and between the calender and lap rolls. A good draft for ordinary cotton is three, for Egyptian four, and generally the draft should be equal to the number of laps fed.

(103) Sometimes scutching machines are made with the cones driven from the gearing at the lap end of the machine by means

of a side shaft. In this case it is convenient to change one of the bevel pinions on the shaft so as to give the required variation in the speed of the driving cone.

(104) It is a very common practice to combine the opening and first scutching machines, as shown in Fig. 8. There is the advantage in this procedure that the cotton is very early made to assume the lap form, in which it is much more easily treated than when in a loose condition. In doing this it is, after leaving the opener, passed over pedal noses in some cases, as in Fig. 8, and the regulation of the beating at once commences to take place. The cotton when rolled into a lap is so much more easily handled, and it lends itself, also, to the process known as doubling. The latter is the plan of feeding the finishing scutcher from two to four laps, and is a very convenient method of obtaining a lap in which the inequalities existing in those first made are reduced. This is the theory of doubling, and it is to a certain extent true, but not wholly so. The pedal motion is much more to be relied on for this purpose than the mere feeding from two or three laps. The most important feature of the practice is that it greatly aids the incorporation of the cotton, and still further mixes the various constituents of a bin. After cotton has been scutched a second time, the machine being fed from laps, the mixture of the cotton is very complete. This appears to us to be the chief advantage of doubling. Before leaving the question of combined machines, such an arrangement as that shown in Fig. 7 enables the finished laps for carding to be obtained with a minimum of handling, while, at the same time, the weight of the laps does not vary more than five per cent. The finished lap should be straight on the edges and even in substance, and no other should satisfy the manager of a mill.

CHAPTER IV.

CARDING.

(105) WHEN cotton is presented to the action of the carding machine it has been, as stated, cleaned and opened, although it has not been thoroughly freed from all impurities. The proportion of the latter, however, speaking comparatively, is not large, and with the improvements gradually taking place in the scutching machine is yearly growing less. Owing to the method in which the material has been dealt with in the earlier stages, it is not in a fit condition to be sent to the machines for drawing and spinning, there being in the lap a good many short fibres and "nep" or knotted pieces, the effective removal of which is absolutely essential to the production of a good yarn. Thus the operation resolves itself into one of cleansing, alike by the removal of any remaining "motes," short fibre or "nep." That machine best fulfils the object of the spinner which removes the whole of the impurities referred to, with the least admixture of fibres which could be advantageously used in spinning. Of course this is elementary, but at the same time, it is absolutely necessary to bear it in mind in properly estimating the value of various machines or duly appreciating the mechanical contrivances designed to effect the object.

(106) A reference to Fig. 23 will enable the essential parts of a carding engine to be understood. The main operating instrument is a cylinder marked A, which is made from 40in. to 50in. diameter and from 37in. to 50in. wide. It is now invariably made of cast iron, and is built up. Its periphery is a light cylindrical shell, with an internal flange at each end at

right angles to the shell and strengthened between the ends by light longitudinal and cylindrical ribs. The ends are bored out and a spider, which is turned to correspond, is fitted in and secured by bolts. The spider consists of a number of arms attached to a central boss which is bored previously to the end of the arms being turned to fit the shell. The cylinder so constructed is accurately and carefully turned on its periphery, and is afterwards drilled with several rows of small holes, into which plugs of wood are inserted for the purpose of attaching the wire fillets. After completion the cylinder is carefully balanced, and is finally tested for its accuracy in this respect.

(107) The cotton is fed from the finished lap Q, resting on a roller B, and which is delivered over a specially-shaped feed-plate C—to which further reference will be made—by means of a feed roller D. The feed roller revolves in the curved part of the feed-plate C, and is from 2in. to 3in. diameter, having its peripheral surface covered with longitudinal and circumferential flutes on that part of it between its bearings. The end of the lap is brought by the feed roller into the range of a number of teeth fixed to a small roller E, which is called the "taker" or "licker-in." This is usually from 8in. to 9in. diameter, and is the same width as the cylinder. Like the latter it is made of cast iron, and is equally carefully constructed, being mounted on a wrought-iron shaft on which it revolves. The direction of the rotation of the licker-in is shown by the arrow. Its function is to strike off the fibres from the end of the lap in detail and present them to the action of the wire points on the cylinder.

(108) At the other side of the cylinder is a smaller cylinder J, constructed in a similar manner, and of the same materials; its diameter being from 22 in. to 26 in., usually 24. It is prepared with equal care to the cylinder, and is also covered with a similar material, as will be afterwards described. The doffer rotates in the direction indicated by the arrow. In front of the doffer is a thin bar of steel, slightly serrated on its under edge, which is fastened on the end of short arms affixed to a rocking shaft, to which a rapid oscillating movement, through an arc

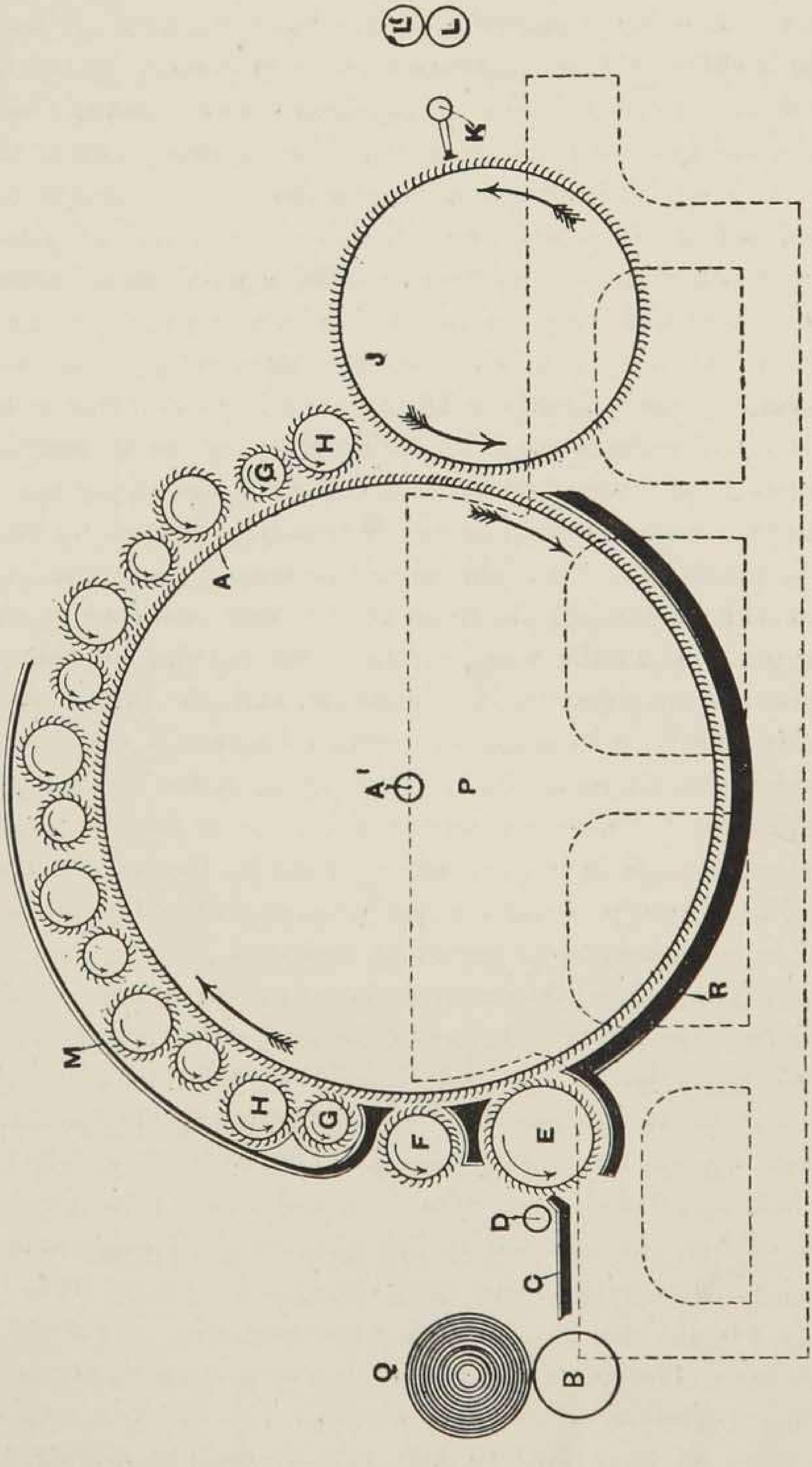

FIG. 23.

of about an inch, is given by means of an eccentric suitably driven. A short distance past the "doffer comb" K, as the blade is called, a trumpet-shaped guide is placed, by means of which the carded web is collected into a sort of rope, the collection being aided by a specially-shaped plate. A short alternate horizontal traverse is given to the trumpet guide which moves in front of a pair of steel calender rolls L L^1, by which the cotton is slightly compressed. The cotton is then passed to the coiler, of which an illustration is given in Fig. 24.

(109) The coiler consists of a light framework, within which is a vertical shaft B, driven by means of the bevel wheels C C^1 from the calender rolls. The coiler plate M has an angularly disposed tube formed in it, the centre of the upper opening of the tube being directly below the trumpet, through which the cotton enters the coiler. Between this opening and the upper end of the tube small calender rolls O are fixed (one of these being removed in the view). The lower opening of the tube is almost at the edge of the plate M, and the latter has an annular rack L on its edge, with which a wheel K engages and by which it is driven. At the lower end of the frame a light circular disc J is arranged, and is driven by a train of gearing from the shaft B in a direction contrary to that of the coiler plate M. The disc J carries the can, in which the cotton is coiled in a manner to be presently described.

(110) The parts just described are common to most carding machines whatever may be their remaining constructive details. The cylinder, doffer, licker-in, feed-plate, and roller, and the calender rolls are sustained by a strong frame securely fastened together by transverse stay beams. The cylinder revolves in long bearings bolted to the framing and lined with phosphor bronze bushes, the diameter of the cylinder shaft being usually about 3½ inches. The velocity of the cylinder ranges from 160 to 200 revolutions per minute, according to the variety of cotton being treated, a long staple necessitating a slower speed than is permissible with a short staple. The licker-in revolves at a speed of from 350 to 400 revolutions per minute, the

velocity being carefully adapted to suit the length of fibres in the cotton being treated. The doffer revolves at a slow speed, varying from 6 to 27 per minute, and the doffer comb makes about 1,100 beats per minute.

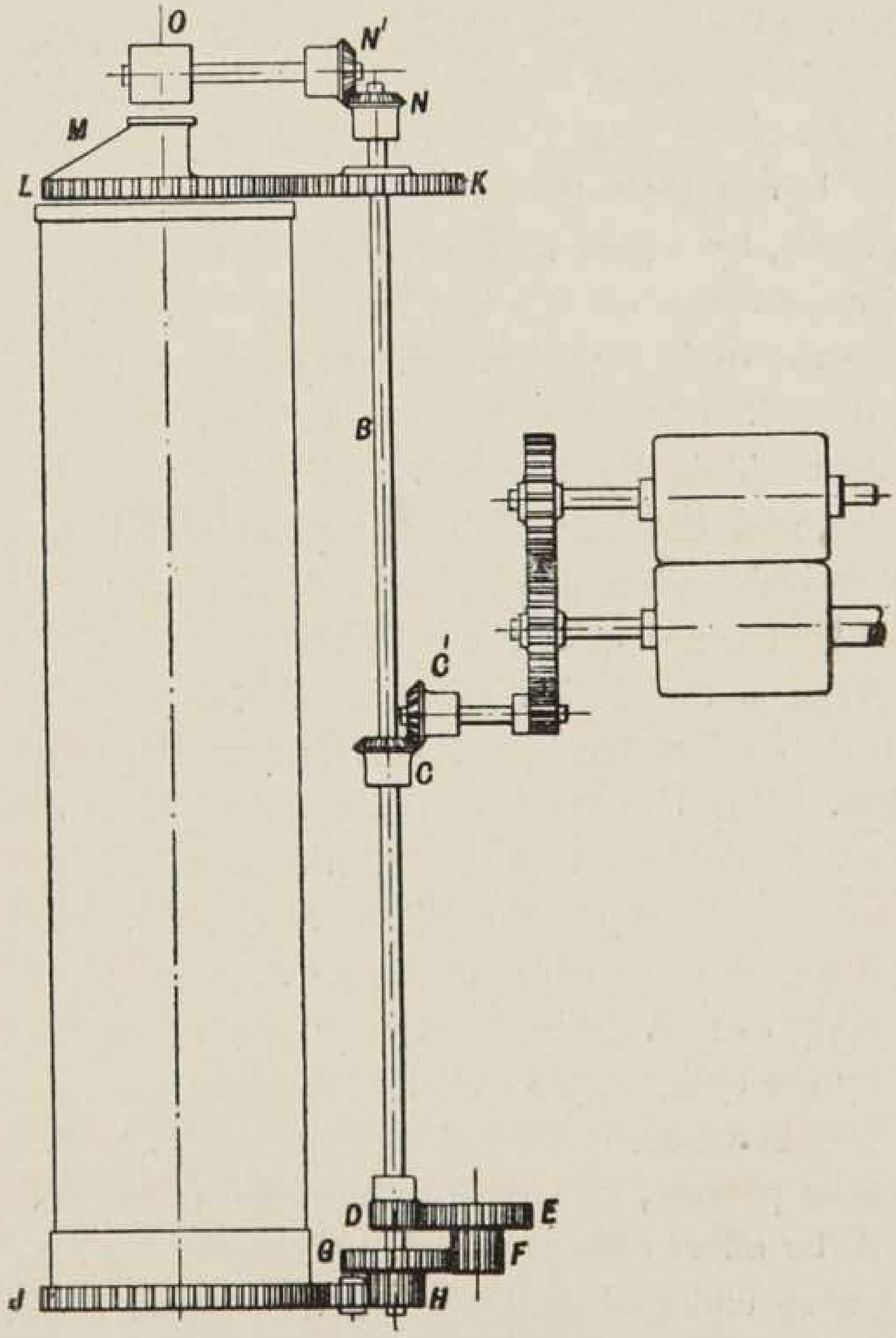

FIG. 24.

(111) The action of the parts just described is simple. The scutched lap is carried on a rod and is placed upon the top of a roller to which a slow rotatory movement is given at a definite speed equal to or a little slower than that of the feed roller

The lap rod projects beyond its end, and takes into vertical slots in brackets attached to the framing, shown at Q in Fig. 26, so that the rotation of the lap is not followed by its forward movement. The lap is thus unrolled, and is gradually drawn forward by the feed roller along the dish feed plate, over the front lip of which it is pushed. If two-feed rollers are used the action is identical except that the lap end is projected beyond their nip. The lap is thus thrust into the range of action of the licker-in teeth, by which it is struck, and the fibres beaten off. The latter are thrown down and brought into the path of wire teeth upon the cylinder, by which they are carried round until they are deposited as a thin fleece upon the wire-covered surface of the doffer. This fleece or web is beaten off the doffer by the doffer comb, and is collected by the plate and trumpet into a sort of rope which after passing the calender rolls is laid in coils in the can by the action of the coiler.

(112) This is the action of the machine as it would be if there were no other treatment of the fibres by any additional mechanism. But the treatment thus accorded to the cotton would result in nothing more than an attenuation of the lap to an extent depending upon the difference of the velocities of the parts, and the cleaning effect would be very small. It is therefore necessary to provide between the point where the fibres are received by the cylinder, and that where they are removed from it, some means whereby they are subjected to a cleaning and straightening process, so that the impurities and imperfections named will be effectually removed. This can only be done by providing a special surface, by which the cotton fibres as they lie upon the cylinder are combed or carded as they are carried round with it. There are two main methods of effecting this object; first, to surmount the cylinder between the points named with a number of revolving wire-covered rollers; or second, to surmount it with a series of bars with their under surfaces covered with wire. The second class may be subdivided into systems in which (*a*) the flats move simultaneously with the cylinder, or (*b*) they remain stationary. Of these the latter system is now

rapidly becoming obsolete, although it still lingers in the United States and on the Continent, and need not be treated in detail.

(113) The first of the two main divisions of mechanism is employed when what is called the roller and clearer carding machine is used. This is shown diagramatically in Fig. 23, already referred to. It consists of a series of small rollers disposed above the cylinder surface, between the taker-in and the doffer. The first of these, F, is usually called the "dirt" roller, and is from 5in. to 6in. diameter, being covered with a wire fillet, the teeth in which are set in the direction shown. The direction of the rotation of the dirt roller is shown by the arrow, and its object is to remove from the surface of the cylinder wire the heavy impurities, such as motes and sticks. After passing the dirt roller (of which there may be two), the cotton is treated by a series of rollers H, known as "worker" rollers, which are from 5in. to 6in. diameter, and have their wire teeth set at such an angle that that they receive the fibres from the cylinder and draw them bodily away. The surface velocity of the worker rollers is only about 20ft. per minute, so that the cotton is easily deposited on them and stripped from the cylinder. They carry the fibres with them in the direction indicated by the arrows until the material is caught by the teeth on a small roller, G, called a "clearer," which is about 3in. to 3½in. diameter, and has a surface velocity of about 400ft. per minute. The teeth of the clearer roller are set in the reverse direction to those of the worker, so that the cotton is easily transferred from the latter. The whole of the rollers are borne in brackets fixed to a semicircular frame bolted on the lower frame P, and known as the "bend," the brackets having open bearings formed at their heads, and being set, as shown in Fig. 25, by screws of fine pitch. In this way an easy and accurate adjustment is obtained, which enables the various wire surfaces to be brought into close proximity to each other. The worker rollers are driven by means of small, double flanged pulleys fixed on their spindles at one end, over which an endless band, passing over a pulley on the driving shaft, is stretched.

In some cases toothed chain-wheels are used instead of pulleys, and the driving is obtained from the doffer shaft, or ropes may be employed. The clearers are driven in a similar manner at the other side of the machine, this arrangement enabling the driving gear to be compactly arranged. The whole of the worker and clearer rollers are encased in a cover, M, so as to avoid as far as possible a discharge of short fibre into the air.

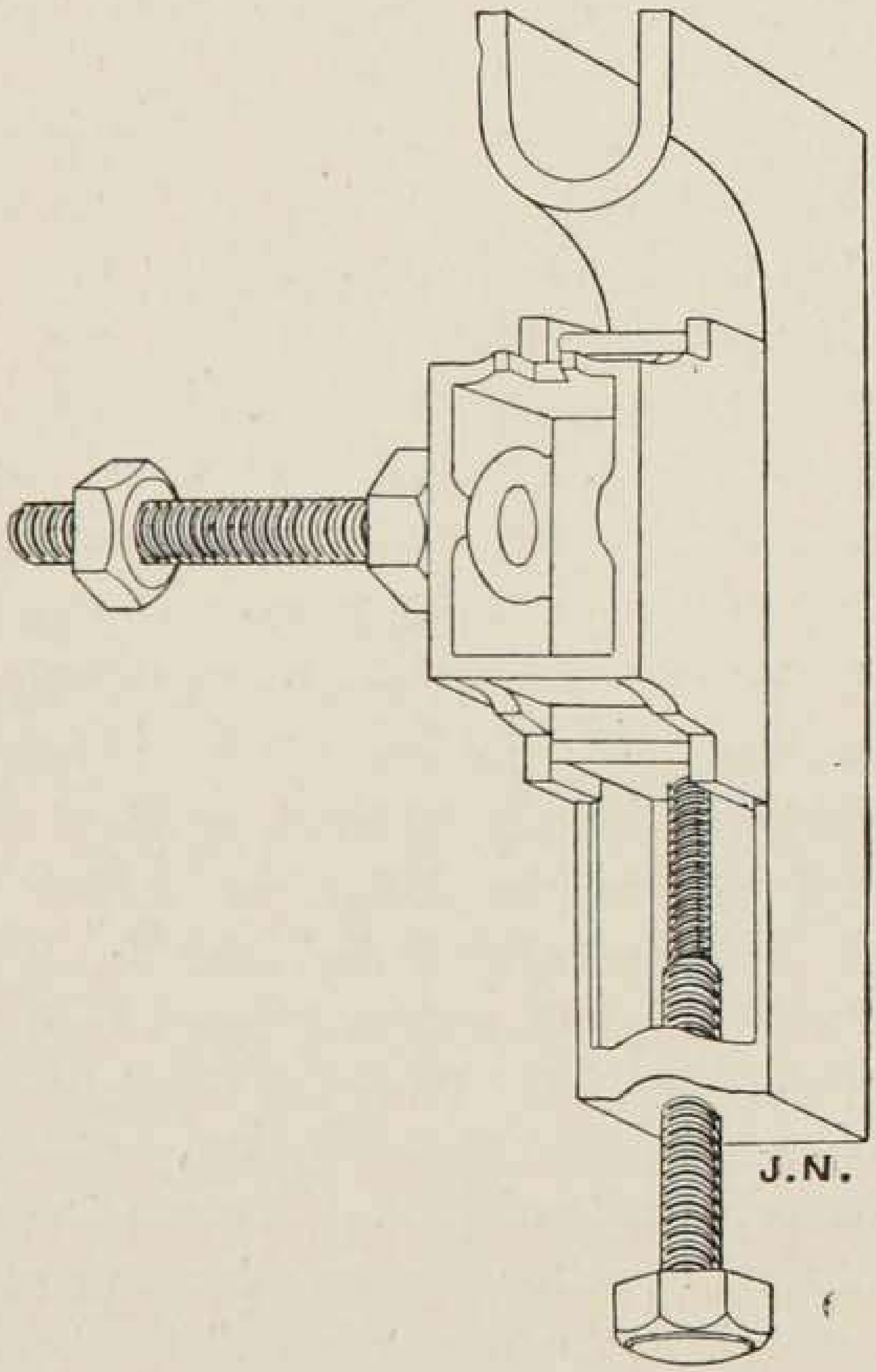

Fig. 25.

(114) The action of this type of machine is as follows: The lap being fed by the feed roll, say at a speed of seven inches per minute, is struck by the teeth of the licker-in, and those fibres which are held loosely enough are beaten down by them. As the licker-in, if 8in. in diameter, and with a velocity of 350

revolutions per minute, has a surface speed of 8,796in. per minute, it is obvious that the substance of the cotton will be reduced 1,256 times at this point. The cylinder which, if 50in. diameter and revolving 180 times a minute, has a surface velocity of 28,273in., thus travelling 3·21 times as fast as the licker-in, the lap being, therefore, attenuated up to this point 4,039 times. Now, as the worker roller is only revolving at a surface speed of 20ft., it follows that the difference between this and that of the rapidly revolving cylinder will cause the fibres to be laid upon the worker, and that, in short, a condensation of the layer of cotton will occur. As this fleece, which is 471 times as thick as the layer on the cylinder, is carried round, it is caught by the more rapidly revolving and contrary set teeth of the clearer, and is again attenuated 20 times, thus being practically restored to its original thickness prior to being taken off the clearer by the cylinder. These alternate condensations and attenuations of the fleece continue throughout the whole passage of the fibres, from the licker-in to the doffer. The result of this undoubtedly severe treatment, is that the short fibres and nep are removed, and are capable of periodic stripping from the worker rollers, in which they become embedded. When the cotton reaches the doffer, the surface velocity of which is 904in. per minute, it is deposited upon this slower moving surface, and is again condensed into a web 31 times as thick as that on the cylinder. Thus the lap has in its passage become attenuated 130 times, and is finally produced as a sliver, thinner in that ratio than the lap from which it is produced. In other words, the "draft" of the card worked under these assumed conditions is 130.

(115) When double carding is resorted to—that is, when the cotton is passed through two carding engines—the latter are usually placed one behind the other on the same framing, the cotton being transferred from the first to the second cylinder by a small drum similar to the doffer, which is called a "tummer." In some cases, however, a number of slivers produced on the carding engines are combined in a special machine

called a "Derby doubler," and are formed into a lap, which is fed to the finishing carding engine. So far as this country is concerned this practice may be fairly described as obsolete, and need not be dealt with at length. At a later stage something will be said of the principle of this system of treating cotton.

(116) The first (*a*) of the second division of machines is what is now known as the "revolving flat" card. This name is given to it because the carding surface is a series of narrow bars or flats sustained and sliding upon a circular surface or plate attached to the framing of the machine. This plate is called, like the frame itself in the roller and clearer machine, the "bend," and is differently constructed by various machine makers. It is not intended to describe at length the numerous methods of making the bend, it being sufficient to say that there are two main types, viz., that in which it is so constructed as to require setting manually throughout its length, as in that form commonly known as a "flexible bend," and that in which it can be set by means of mechanism from one or more points. The flexible bend is a segmental plate which is specially constructed so as to permit of easy flexure. It is bolted to the frame side, and has attached to it setting screws by which the adjustments can be made with ease. Many carders prefer it to any other form of adjusting mechanism, and in some respects it possesses advantages over its rivals. The mechanism of the "Simplex" machine, by which the setting is effected by the flexure of a segmental ring borne on specially prepared surfaces, has also certain advantages. Another form of card is that of Messrs. Howard and Bullough, in which the setting is effected by means of the sliding in or out of a segment of a ring with an inclined surface upon which the ring or segment forming the flat course rests. The adjustment in both these cases is done by means of indicators which enable the extent of movement to be visibly ascertained. Another form of machine, made by Messrs. Ashworth Bros., permits of the flats being set by the withdrawal

or introduction of thin steel bands, which are stretched tightly over the upper edge of the bend. This method of setting is combined with the power of adjusting the position of the cylinder centre. In the carding engine made by Mr. Samuel Brooks the flats rest on the edge of revolving discs, which are mounted on a bush adjustable to the cylinder centre, and which can have their diameter reduced by milling with specially placed and adjustable circular cutters. In order to effect the setting special arrangements are provided to ascertain the amount required, and there is little doubt that this arrangement is, in principle, the nearest approach to the establishment of a uniform concentricity which has yet been practically employed. In either case the object is the same. The flats are formed at each end with specially prepared surfaces upon which they are borne, and which rest upon the upper edge of the "bend." The object of the bend is to provide a surface which shall be concentric with that of the cylinder whatever may be the relative distance of the wire surfaces of the latter and of the flats from the centre of the cylinder. In setting it therefore it is necessary to maintain this relative position throughout the whole of the length of the bend. There are several devices for this purpose, as has been said, but it is only the principles of the procedure with which it is intended to deal. The flats are usually ⊥ shaped in section, and have their horizontal surface covered by strips of wire fillets or cards which constitute the carding surface. The method of attaching these fillets and their construction will be explained in detail at a later stage.

(117) Referring now to Fig. 26, which is a perspective view of a carding engine on this principle, it will be seen that the flats U are arranged in an endless chain, and are coupled by means of screws at each end to chains with pitched links which are driven, in a manner to be afterwards described, at a slow speed in the same direction as the cylinder. They are guided by rollers, and at the doffer end of the card are stripped of their accumulations of short fibre, etc., by a comb X, making 60 double strokes per minute and are afterwards brushed out by a revolving

spirally arranged brush V. Each flat has its bearing surfaces so arranged that when sliding upon the bend its wire surface assumes a tangential position to the cylinder periphery—that is to say, it is further from the latter at the edge nearest to the point from which the cylinder wires approach it, and nearest the latter at the point where they leave the flat. This arrangement of bearing surface is technically called putting in the "heel," and the part of the flat nearer the cylinder is spoken of as the "heel of the flat." The object of this arrangement is to ensure that the fibres will readily enter the space beneath the flat, without rolling up at the front of it, thus ensuring their thorough carding.

(118) In treating cotton by a machine of this description the action of the various parts common to this and roller machines is identical. The flats act however as a sort of scraper or comb, as afterwards shown, and effectually remove the short fibre and neps as they pass below them when the cylinder is revolving. The steady onward movement of about an inch a minute is sufficient to ensure that the flats will continue, so long as they are above the cylinder, to comb or card the cotton, without becoming so charged with fly or motes before being stripped as to cease to discharge that important duty. It is absolutely necessary to take care of the flats, and to see that as far as possible their bearing surfaces are kept in good condition, and that cleanliness of the whole of the parts is preserved. At one time it was the practice to make flats about two inches wide, but it is now not often that they are found wider on their carding surface than $1\frac{1}{8}$in. There are many important advantages in this course. The cotton is treated by a greater number of carding points, the flats are not so heavy, and the space between each pair is not so great in working.

(119) The brief description just given of the two principal types of machine at present in use will suffice to enable the following remarks on its operation to be easily understood, and as points relating to various other parts arise their construction will be explained.

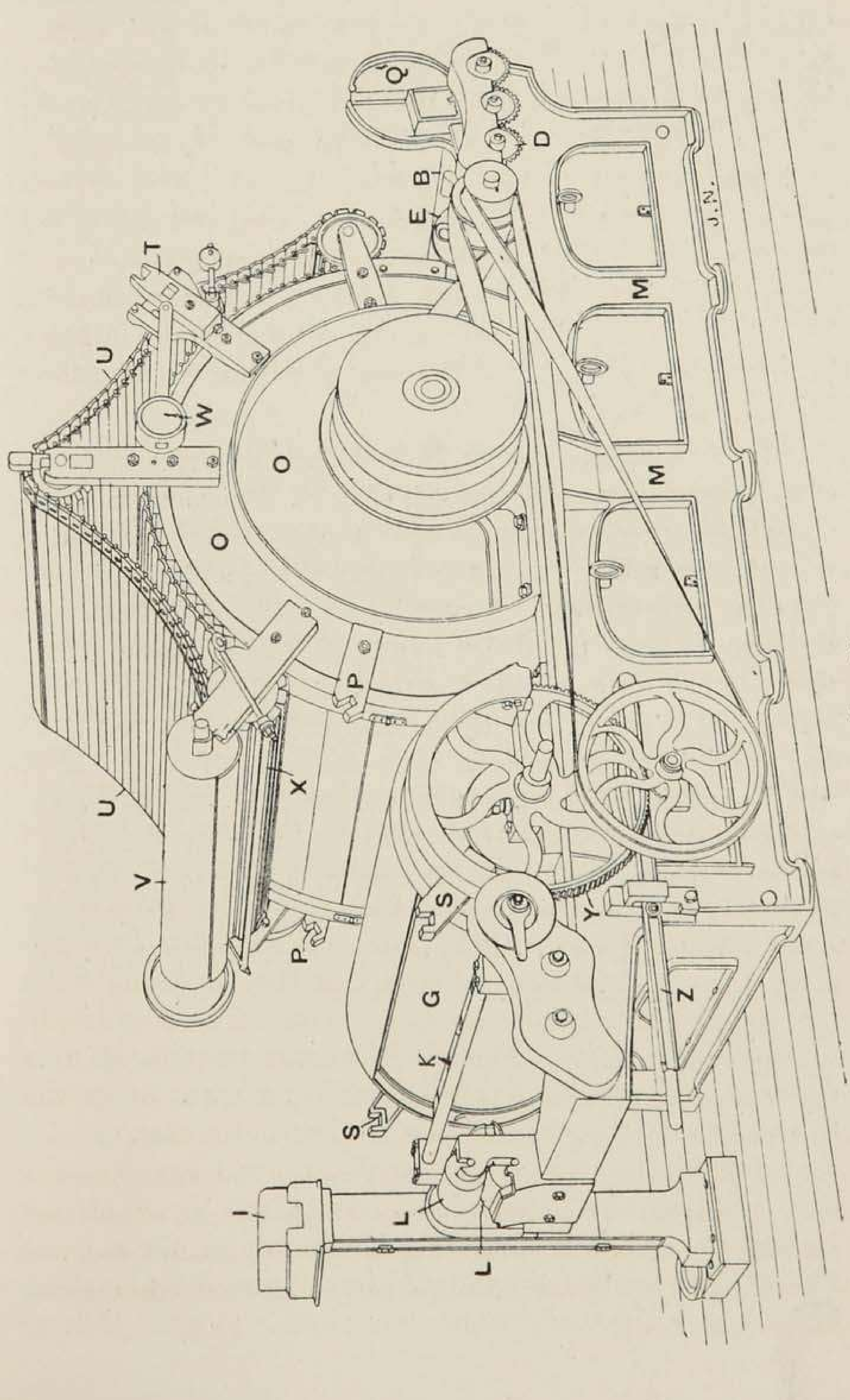

FIG. 26.

(120) A twisted strand of cotton—that is, yarn—possesses a certain strength which arises to a large extent from one factor, viz., the number of fibres in its cross section. It is true that the length of the staple has a very important bearing upon this subject, because it enables the successive sets of fibres contained in a length of yarn to be more readily twisted or bound together; but, in the main, it is the sum of the individual strength of each fibre in a strand of yarn which gives it its strength. That being so, it follows that the larger the number of fibres in any cross section, the greater will be the strength. There are, of course, exceptions to this, as to every other general principle, but as a broad statement it is accurate.

(121) Admitting, therefore, that this is a correct statement of fact, its bearing upon carding is obvious. The yarn eventually spun depends for its evenness upon the roving from which it is twisted, the roving upon the drawn sliver, and the drawing upon the carded sliver. Now it is quite clear that if the fibres are stripped from the doffer in a tangled or crossed condition they will not lie so closely together when first drawn as they will if laid in the practically parallel order of a combed sliver, and the labour involved in reducing them to parallel order will be much increased. It is true that in combing cotton a large amount of waste is produced which it is impossible to sanction in a carding machine working under the commercial conditions of to-day, but it is worth considering whether anything can be done to obtain a further parallelization of the fibres in the carded sliver.

(122) The first point which requires consideration is the condition of the lap as it is fed to the carding engine. At one time this subject did not receive the attention it deserved, and laps were fed which were neither so well cleaned nor so even in weight as they should have been. It cannot be too strongly insisted on that it is absolutely imperative for the complete success of a card that the material when presented to it should be in as perfect a condition as it is possible to get. It is not

enough that the cotton should be made into a lap of the required thickness. Every impurity which can be expelled by the beating action of the opening and scutching machines should be eliminated, and the only work thrown upon the card teeth should be the removal of short fibres and those adherent impurities which, without breaking the fibres, cannot be detached during scutching. If the extreme delicacy of the fine points of the carding surface be borne in mind, it will be seen that to put upon them the task of removing heavy impurities is at once an error in principle and practice. It is a noteworthy fact that, in this country at least, it is widely if not universally recognised that the improvement in the instrument for carding cotton must be accompanied by a like amendment in the machines employed to prepare the cotton for that process. Accordingly, as was shown in the last chapter, by careful attention to the details of the scutching and opening machines cotton is now submitted to the action of the carding machine in a much more perfect state than at one time was thought possible. This is one of the causes for the large productions got from modern cards, and is by no means the least important.

(123) Not only, however, must there be a perfectly clean lap, but it should be very regular in weight. The means adopted in the scutching machine for regulating the passage of the cotton so that thick places are beaten out are absent in the carding machine, and, whatever may be the inequalities in the lap, no means are at hand by which they can be removed during carding, although they are, of course, reduced by the attenuation of the cotton before it is coiled in the sliver can. The end of the lap is presented to the action of the teeth of the licker-in at a steady rate, and, if one part in the lap is thinner than another, fewer fibres will be removed during each revolution of the licker-in than when the thicker part is being presented to its action. Consequently, during the time the cylinder is revolving, the number of fibres presented to it varies according to the thickness of the lap. Assuming the cylinder to be charged

with cotton, is it unreasonable to suppose that it will retain more fibres at one period than at the other, and consequently that when these are transferred to the doffer the number on the surface of the latter will vary in like manner? It must not be understood that all the fibres taken up by the cylinder are necessarily transferred to the doffer during their first revolution with the cylinder, but, that if it were possible to attain this object it would be of material advantage. At any rate, whether this be so or not entirely, it is so to a large extent, and it is easy to understand that a limitation of the fibres fed would necessarily be followed by a diminution in the number of fibres doffed after a due interval had elapsed. If the variations in the lap were great and prolonged, this point could be easily demonstrated, but as the difference in the thickness of the lap is, in the present day, not great, and as the thin places are not of great length, it is more difficult to trace their effect.

(124) Broadly speaking, however, there is no doubt that the irregularities of the lap are reproduced in the sliver, and that, while the irregular weight of the latter is not wholly attributable to this factor, it plays an important part in connection with it. Further, as the sliver is very thin, any variation in the number of fibres delivered to it speedily becomes of importance, and the percentage of variation noticeable. It is not a good thing to lay too much stress upon this argument, but it is necessary to emphasise the fact that an uneven lap cannot possibly be an aid, and may be an immense hindrance to the production of a regular sliver. It may be taken as an axiom that the avoidance of intermittent work by the card teeth is a necessary factor in the successful performance of their duty, and nothing can tend more directly to bad work than to have the cylinder choked with cotton at one time, and nearly bare at another. The abolition of the old plan of weighing the cotton in scutching does not necessarily imply uneven laps, because, thanks to the ingenuity, perseverance, and skill of our mechanicians, the machines now do better work than at any previous time. Having secured an evenly weighted lap, the next thing

necessary is to so feed it that the fibres shall be removed with the minimum of risk of damage. Now upon this it will be necessary to say a few words.

(125) The general arrangement of the licker-in relatively to the cylinder is shown in Fig. 27. The licker-in B is surrounded by a cover F, which is jointed to a similar plate, acting as a cover to the cylinder when the revolving flat type is used. In roller and clearer machines the cover is of a different construc-

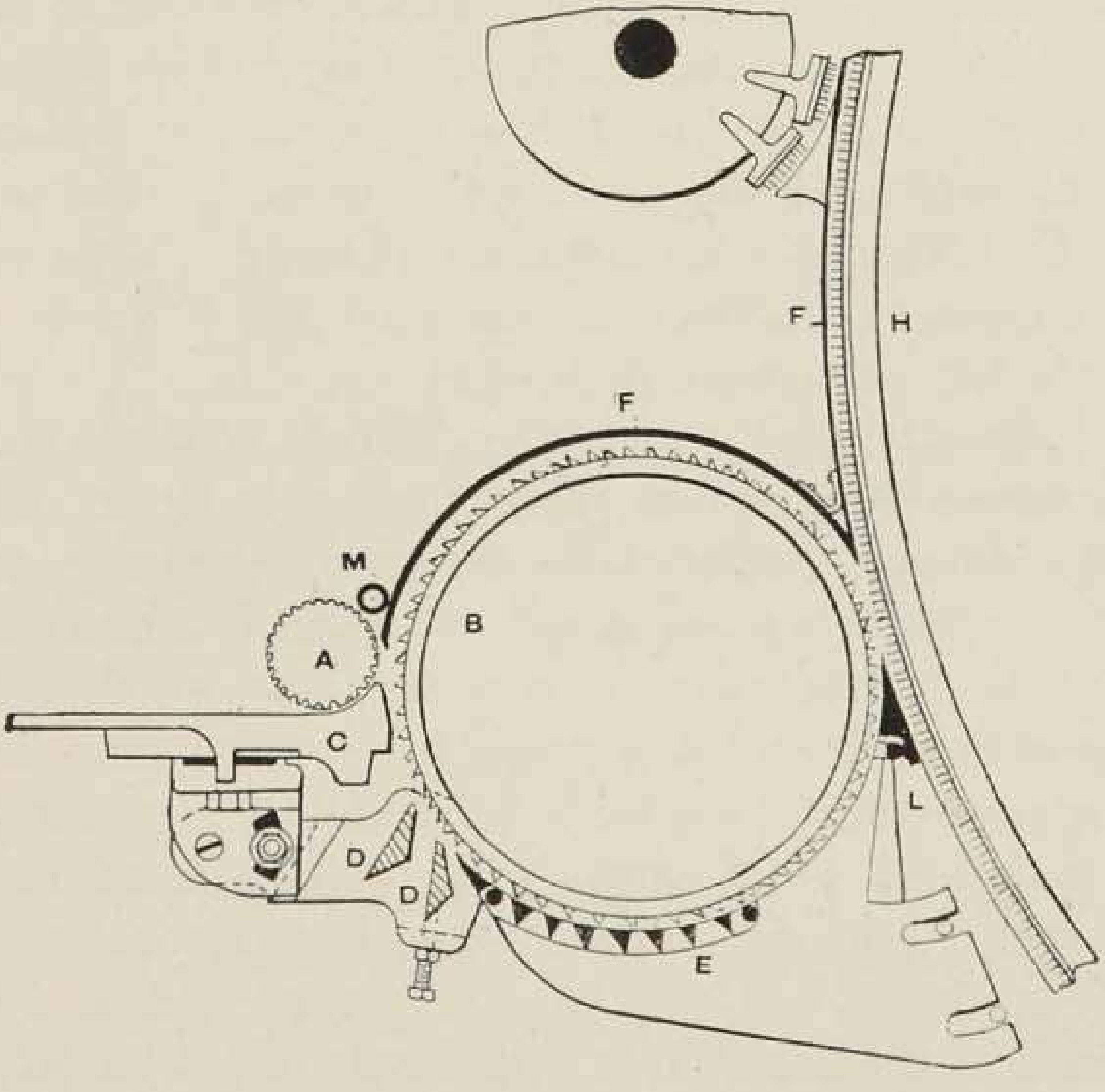

FIG. 27.

tion. The dish feed-plate C, of which something more will be said presently, is fixed as shown, so as to be readily adjustable, and two blades D called "mote knives" are placed immediately beneath it. These are intended to scrape off the motes from the cotton as it is struck down by the licker-in, and they are arranged to be easily adjusted along with the feed-plate and the grid or casing E, from the outside of the frame of the machine. The casing E and the knives are, as shown carried by a frame, which is supported at the inner end by pins taking into curved slots, thus ensuring that when the plate is pushed in, in consequence of the necessary setting in of the licker-in after the length of the cylinder teeth has been reduced by grinding, or those of the licker-in from wear, the relative position of the dish feed-plate, knives and undercasing are accurately preserved. Below the licker-in a

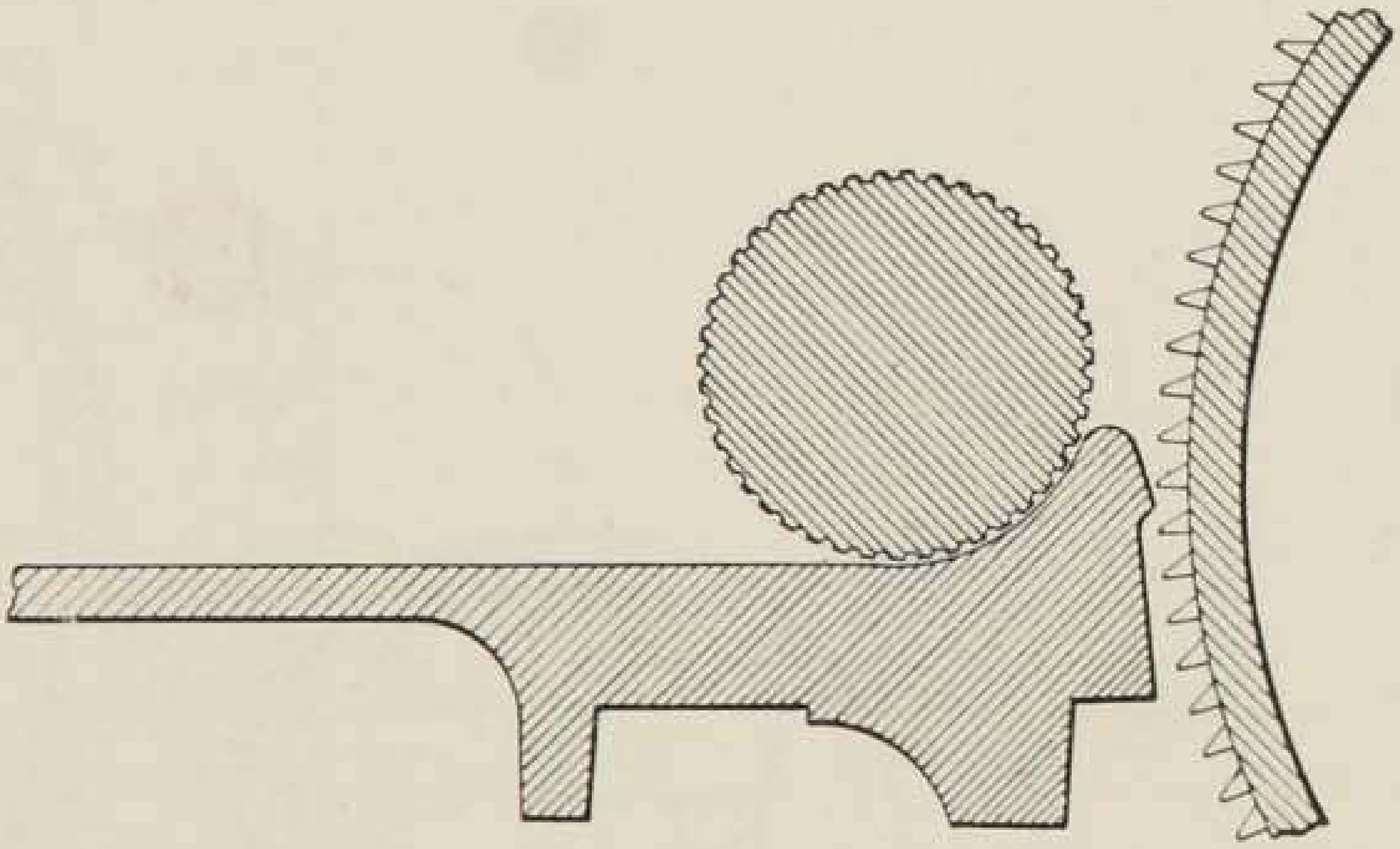

FIG. 28.

packing piece L is fitted which closes the gap which would otherwise be left, and thus prevents any gathering of fibres which might occur if this care were not taken to prevent it.

(126) The ordinary method of feeding the lap is by the dish or shell feed. This is shown at C in Fig. 23, and is also shown in detail in Figs. 28, 29, and 30, and consists of a flat polished plate, over which the lap is drawn, and which at its inner end is curved upwards to correspond with the curvature of the feed roller. Between the periphery of the latter and the surface of the dish plate the lap is passed,

and a definite downward pressure being maintained on the roller, which is revolved at a regular rate, the lap is carried forward and its end thrust into the path of the teeth of the licker-in. It is obvious that this action may be so carried on that large lumps or pieces of the cotton would be struck from the end of the lap. This, however, would be fatal to the efficiency of the machine, and the removal of the material should be as nearly as possible the detachment of the fibres separately and not in

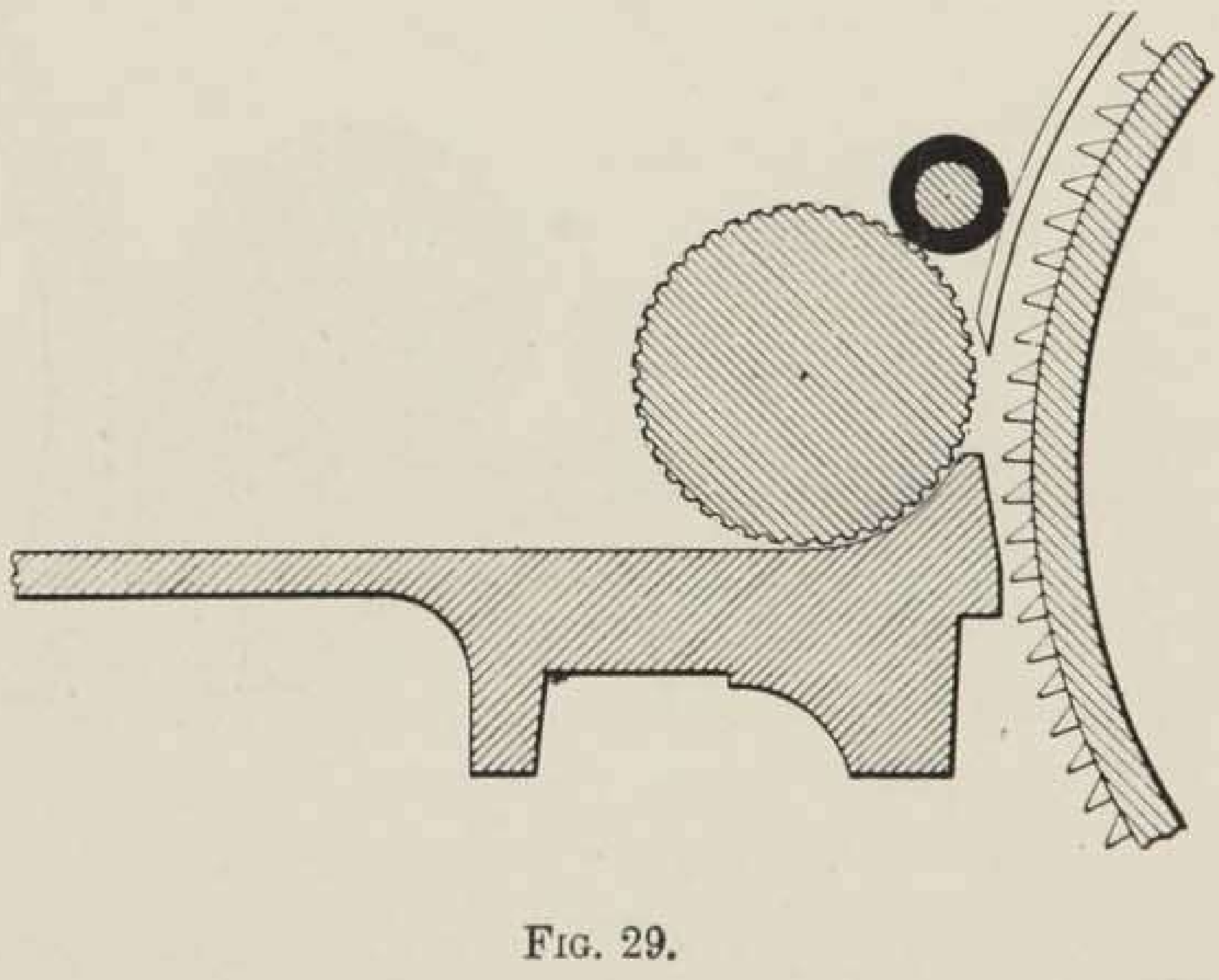

FIG. 29.

bulk. In point of fact, the action of the licker-in teeth should first be one of combing out the end of the lap, in this way detaching the fibres without running the risk of breakage. In the attainment of this object the dish feed plays an important part. It is desirable that only those fibres which are practically freed from the nip of the feed roller should be removed by the teeth of the licker-in, and from the fact that only when they are projected over the edge of the feed plate are they released, they are not so likely to be forcibly removed as if the fibres were struck from the nip of two rollers. This can be very readily understood, as it is obvious that a much greater length of cotton necessarily exists between the nip of a pair of rollers and the extreme point of the projecting part of the lap, than is found lying over the nose of the dish feed plate. In other words, the teeth of the licker-in have less material to pull at, and are therefore more liable to remove the fibres in detail. This can very easily be seen if vertical lines be drawn through the nip of either the feed roller and feed plate, and of the two

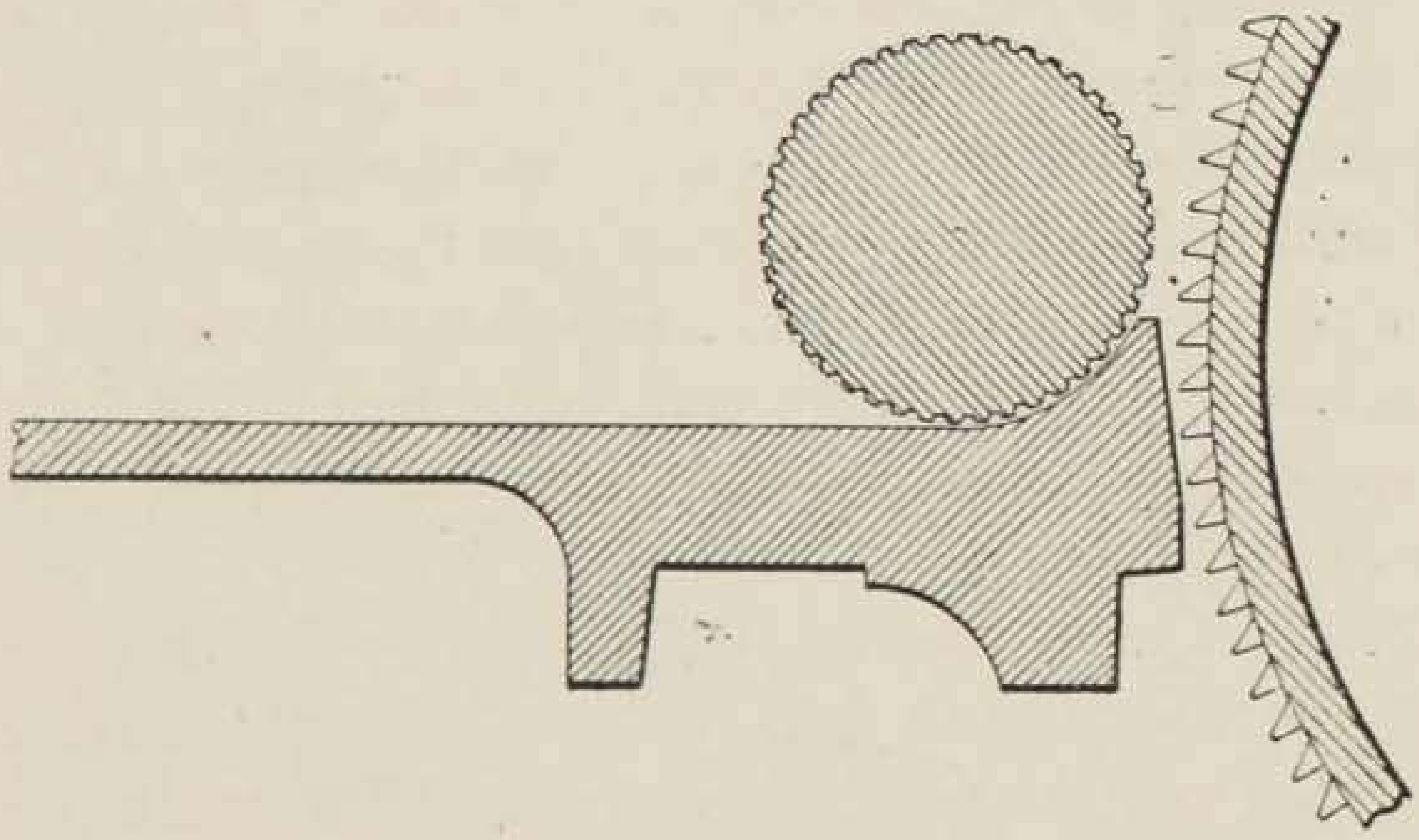

Fig. 30.

feed rollers, when it is made visually evident how much greater the length is in the latter than in the former case. The shape of the nose of the dish feed is varied to suit the cotton treated. Thus, Fig. 28 shows the shape for Surat cotton, Fig. 29 for American, and Fig. 30 for Egyptian.

(127) The action of the licker-in tooth is, indeed, one of extreme interest. There is a dual operation always going on, viz. : a cleaning and a combing or straightening of the fibres. Owing to the shape of the teeth and the manner in which they are set, there is no danger of their becoming choked, and they are, therefore, always in the best possible condition for acting upon

the lap. When they strike the projecting end of the lap, they pass through it at such a velocity that the heavy adherent impurities are struck down and partially removed. At the same time the teeth remove the fibres which are sufficiently loosened, but it is important to note that those which are not so ready for detachment are simply divided and combed by the rapidly revolving teeth. Thus, after a few revolutions of the licker-in, the end of the lap is so far straightened and combed out that the removal of the fibres is much easier, and the risk of damage to them proportionately reduced. Now, it is obvious that the preparation of the end of the lap in the manner described would be much more difficult if so great a length of fibre projected beyond the nipping point that there was any likelihood of the cotton being removed in tufts or lumps of considerable size. This detailed or separate detachment of the fibres is aided by the dish feed, and, when thoroughly carried out, is of great importance in diminishing the work thrown on to the cylinder and flat teeth.

(128) The full advantage of the dish feed, however, is only obtained when the surface from which the fibre is struck is specially shaped and set to suit the staple of the cotton which is being worked. When a short stapled cotton is being dealt with, the space between the inner face of the dish plate and the tips of the licker-in teeth is very small, and the projection of the fibre over the nose of the feed plate is immediately followed by the combing action of the teeth which has been described. As the staple of the cotton treated becomes longer, the extreme end of the fibres can be attacked at a greater distance from the nip of the feed roller, and, it being desirable to comb out the cotton as described, the nose of the dish plate is shaped to allow of this being done. Although the dish feed is attended with so many advantages, it is quite possible to so manipulate it as to break and damage the cotton. It is, therefore, essential in setting it that due regard is given to the staple which is being carded, and a little observation will speedily lead to the determination of the correct setting distance. The gradual and not

the sudden detachment of the fibres is what is wanted, and to this end the action of the licker-in teeth in combing out the end of the lap is very useful. It must not be supposed however, that in speaking of the detailed removal of the fibres it is meant that they are struck from the end of the lap singly, because this is not the case. They are thrown down in combinations, which can hardly be called tufts, but which comprise a number of fibres, as can be seen if an examination is made of a card in work. Still, the condition of the detached portion is so open that the fibres are readily taken up by the cylinder teeth in their revolution. More depends upon the feeding of the cotton to the cylinder than is sometimes thought.

(129) Assuming the fibres to have been delivered to the cylinder, it is desirable to get a clear understanding of the treatment they undergo before being finally stripped from the doffer. It is necessary to know something of the construction of the fibre itself to get a rational idea of its manipulation by a carding machine. The cotton fibre, as was shown in Chapter II., is possessed of a natural twist which causes it to endeavour to curl round any adjoining fibre, a tendency which makes it much more difficult to straighten. Even when it is drawn straight it requires little provocation to twist up again, and it is in this fact that much of the difficulty of carding is found. For a moment or two let us consider the process of combing, which will be described in full later, from which some useful hints can be obtained. In combing, the end of the lap is caused to project for a certain distance beyond the feed rollers, and is firmly held while the circular combs are passed through it. The construction and arrangement of the combs is such that the short fibres are at once removed from the end of the lap, the remaining fibres being straightened by the successive passage of needles of decreasing diameter and pitch. Before the fibres composing the straightened end of the lap have time to bend up they are gripped by the half lap and detaching roller. Indeed, as only one end of each fibre is free, the other end being firmly held as described, the fibre is not able to assume its natural position.

As the comb cylinder continues to rotate, it completely detaches a tuft of cotton, and in the course of doing so draws the uncombed end through the points of the top comb which has dropped into the lap. During the latter part of this period the first portion of the combed tuft is joined on to the previously formed sliver, so that at no time are the fibres free to fall into their natural position or to curl round each other. Now what it is desired to specially point out is that the straightening of the fibres in combing is effected by treating a small number at one time, and that immediately they have been drawn out by the action of the comb, they are so held that it is nearly impossible for them to fall out of the parallel order into which they have been reduced.

(130) A calculation, which can be readily made, will show that it is not easy for the licker-in to feed sufficient cotton to the cylinder to enable the latter to be always taking up fibres. The number of teeth on the licker-in and cylinder and their respective velocities render it practically impossible for each point on the cylinder to take up at each revolution one fibre, which it is theoretically supposed to do. Indeed it is more than probable that there are considerable periods—that is, comparatively—during which the teeth in various parts of the cylinder do not take up any fibres at all. In short, there are not enough fibres to go round, and they will be held by the carding points in a practically free manner. A properly made card tooth should only grip the fibre for a short distance, and the hold which it retains upon it will depend very largely on the "keen" of the tooth, that is to say, the angle to which it is bent between the foundation and the point. There cannot be any such thing as a film or complete covering of cotton, and on this point the author agrees with Mr. B. A. Dobson, being strongly of opinion that it would be fatal to efficient carding if the cylinder had taken up so many fibres that every tooth was charged, and that it is when such a condition is approached that a cylinder becomes overcharged and its work becomes bad. It is necessary that a certain freedom from restraint should be left to the fibres,

or otherwise they could not be effectively treated by the flat or roller teeth; for it is obvious that if a fibre were embedded in a mass of others it could not be easily raised from the surface so as to be combed along its free portion. Herein lies at once the strength and weakness of carding. The strength is found in the fact that the fibre can be readily drawn through the superposed teeth on the flats, or can be easily lifted by the roller teeth and cleansed. Unless this freedom existed not only would the actual work of carding be badly done, but there would be a considerable risk of the rupture or fracture of the fibres owing to the excess of power required to detach them. Now if the description of the process of combing, given a short time since, be borne in mind, it will be seen that the state of the cotton fibre in carding is nearly the reverse of what it is during combing. In the one case each fibre is free, or nearly so, being held only slightly at one end, while in the other it is firmly gripped during the whole of its treatment. In other words, the natural inclination of the fibre to twist is left uncurbed during carding, which is the exact opposite of its condition during combing.

(131) With regard to the character of the treatment undergone by the fibre as it is drawn through the wire teeth on the flats, there is not much probabilty of that effect of centrifugal action which is sometimes laid stress upon. It is certainly true that the velocity of the cylinder is so great that the fibres, if left at liberty, will tend to be thrown outwards, but it is more than probable that owing to the method in which they are held, and to the resistance of the air surrounding the cylinder, they would be bent back so as to lie on the surface of the cylinder in nearly circumferential lines. It is obvious that even the comparatively coarse setting of the flats which is often made could not be easily effected if the fibres stood straight out in the manner sometimes imagined, and the importance of the accurate settings of the flats now obtained lies mainly in this fact. What happens is that the fibres being held by the cylinder wire, and to a certain extent raised from the surface, are subjected to the

combing action of the superposed teeth, their free portion being drawn along the points and thus cleansed. The other end of the fibre—that is, the part held by the cylinder, is combed or carded when it is transferred to the doffer, the slower running of which causes the fibre to be received and held so firmly that its transferral from the cylinder to the doffer is easily accomplished. In addition to this the number of wire points on the doffer are in excess of those on the cylinder, and the fibres are therefore easily held. The action of the roller teeth is entirely different to that of flats, because they are so set as to lay hold of and remove the fibres from the cylinder, to which they are again restored by the action of the clearer. In these alternate and repeated transferrals the fibre is effectually cleaned, and every time it is flung into the roller wire the short fibres and motes accompany it and remain.

(132) Between the moment of leaving the flats and being deposited on the doffer there is a period of time during which the carded fibre is free at one end. The tension into which it has been put during carding naturally causes it to contract as it is released, and this, along with its natural tendency to curl, is largely responsible for the manner in which it is placed upon the doffer. Remember a fibre is being dealt with which, when it flies over as it is released by the wire, falls on to a surface provided with points, by which it can be tenaciously held, so that if it once falls out of the circumferential line it will have some difficulty in assuming it again. Remember also that although every care is taken to prevent currents of air from forming, it is impossible to prevent air from entering, and a slight draught would be sufficient to influence the disposition of the fibre. It is to the causes thus detailed that we mainly attribute the lack of parallel order observable in the fibres composing the sliver from a carding engine. It will be noticed that the individual fibre is permitted to assume a position which it is entirely debarred from taking in combing, and that while on the one hand it is held sufficiently to enable it to be well carded, on the other it is sufficiently free to enable it to assume

a position which is controlled as described. Although the lack of parallel order in the fibres constitutes one of the evils of the system of carding, yet, if the explanation given of its cause be a sound one, it is better not to so load the cylinder with cotton as to prevent the fibres from having this free action. The alternate attenuation and condensation of the cotton during carding is not of great importance, except in so far as it tends to permit of the establishment of the freedom named. It may, however, be pointed out that as the doffer surface moves so much slower than that of the cylinder, the cotton on a large area of the latter is deposited on a much smaller area on the former. Thus, although it is true that the charging of the cylinder is not a regular, but in a sense an intermittent process, any inequalities which are likely to arise in this way tend to be removed by the difference of the peripheral velocities of the two parts named.

(133) The existence of air currents plays an important part in the work of a carding machine, and it is surprising how rapidly they act upon the material. The modern method of forming and setting the flats, and the general arrangement of the framework, on the whole, prevents any blowing out of the air at the sides until the fleece or web is deposited on the doffer. The framing is now either brought close up to the edge of the cylinder, or the bend is put in that position, or the gap between the framing and the cylinder edge is closed in some other way. This tendency to blow out and towards the formation of air currents is much greater in roller than in flat cards. But there are a few points at which the air can enter, and it does not need much thought to show that the great velocity of the cylinder will set up very powerful induced currents. Now, in this fact an explanation can be found of the cloudiness often noticed in the carded web, and of the existence of thin or bare places.

(134) The web is often marked or dotted with white specks, which, as can be plainly seen, are neither motes nor sticks. There is not much doubt that these are neps formed from damaged or broken fibres, which become knotted or matted

together, and escape the cleaning action of the flats. This appearance, however, is very different from the cloudiness referred to, which is often visible over a large space. There is a ready explanation of this defect, which arises from an aggregation of fibres which have become overlaid and matted, being much worse in their lack of parallel order than the ordinary web. It is quite clear that if, in any given space, the fibres, when laid upon the doffer, are bent over, or deposited transversely, they will present quite a different appearance to that which they assume when laid in parallel circumferential lines. This, however, is what happens, and it remains to discover its cause.

(135) Between the last roller or flat and the doffer there is a considerable space, this part of the cylinder being covered by a metal plate correspondingly curved. In Figs. 26 and 31, this plate is shown, and it will be noticed that it completely covers the breast of the cylinder and is jointed to the cover which surrounds the doffer. As shown, the plate or cover descends into the space between the doffer and cylinder, and it quite fills it up, thus preventing the accumulation of fly, which otherwise takes place. There is great care taken to fit the covers to their places, and they are provided with ample means for accurate adjustment. The surface of the steel plates, of which they are made, is kept bright and smooth, this being a matter of great importance. At the upper end of this plate there is a mote knife or sharp edge, by means of which a little further cleaning is obtained. If this plate or cover were not fixed in the position named there would be nothing to prevent the fibres from standing out in radial lines while held by the wire, and it is obvious that if they did so project they would be at the mercy of every current of air. This furnishes the explanation of cloudy webs. If by any possibility the air can be put into such motion as to traverse across the face of the cylinder, the fibres will be immediately bent over in the same direction. A case is known where, in consequence of the existence of a considerable space between the wire on the cylinder and this covering plate, the

fibres could be seen to gather up and bend over, often becoming practically doubled. The webs produced on the first series of cards put in were badly clouded, but by setting in the cover, so that the fibres were not able to rise radially, the defect was quite remedied. It may be taken as the first thing to look for if cloudy webs are found, whether there is any possibility of transverse air currents.

(136) The same cause, probably, accounts for thick and thin

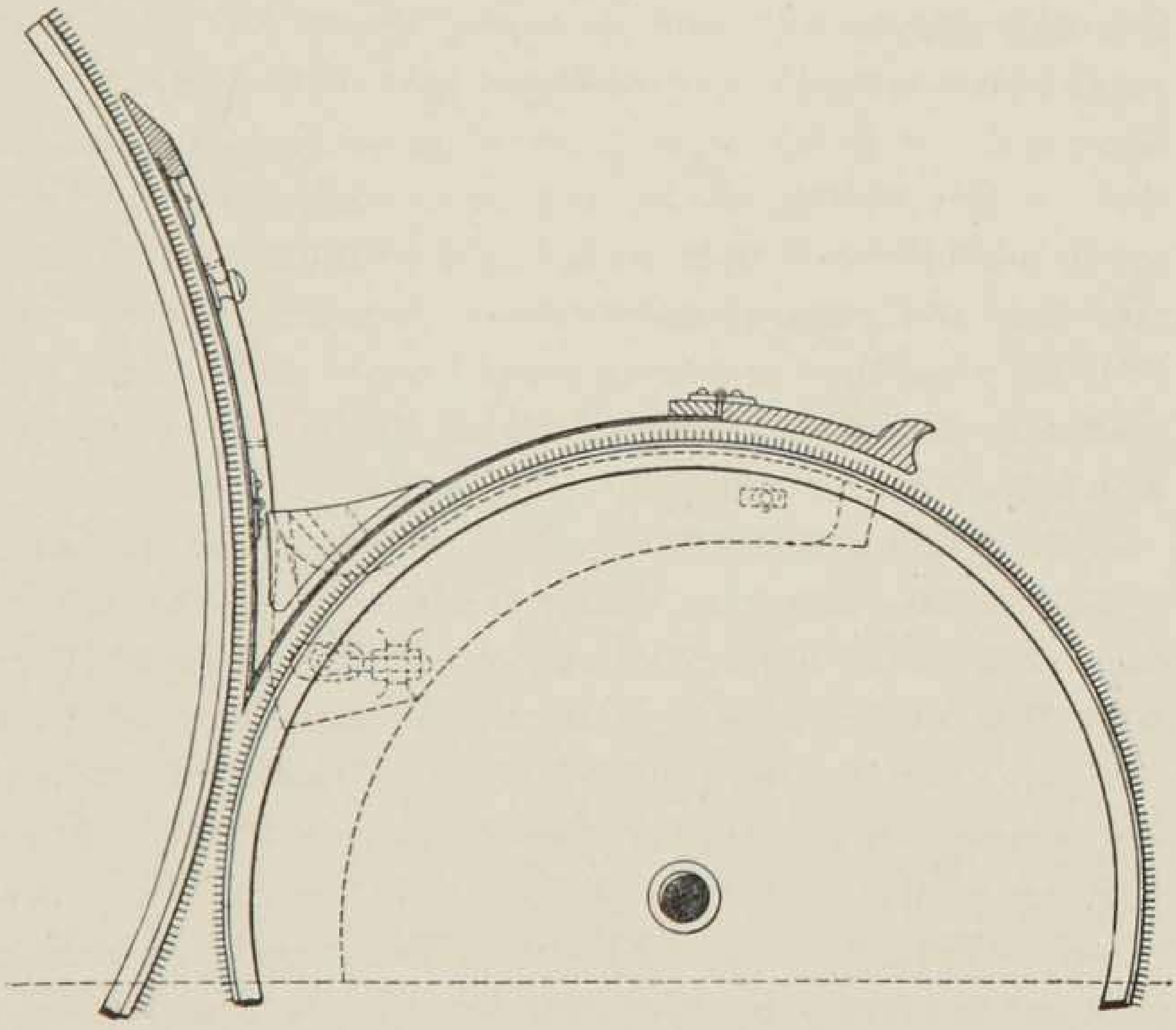

Fig. 31.

places, or rather contributes to their formation. It has been previously said that an uneven lap is a fruitful source of uneven slivers, and there is little doubt that this element is the principal one, but it is clear that if the fibres can, before being placed on the doffer, be moved across the cylinder so as to be aggregated, so to speak, there must be a thin place left in the web. To the existence of air currents may be attributed not only the ordinary position of the fibres in a well formed web, but many of those abnormal features which are sometimes found in carding.

(137) Another point upon which a few additional words may be said is the action of the rollers and flats in removing short fibres and neps. With reference to rollers, their action, as was shown, is that of absolutely removing the fibres from the cylinder, and again transferring them to it by the intervention of a second roller. This involves the complete turning over the fibres, and as they cannot be so treated unless a considerable space is provided, the chances of the action of the air are considerably increased. But it is specially to be noted that the short fibres having a less tenacious hold on the cylinder or roller wire, and not being, after they are embedded in it, so long as those of full growth, are at once more easily removed from, and much more difficult to transfer to the cylinder. With reference to motes and neps, as they cannot penetrate deeply into the cylinder wire, they are easily picked up by the rollers, and are gradually forced into the interstices of the wire covering, from which they can be stripped.

(138) Making due allowance for the fact that the stripping surface is a stationary or nearly stationary one, the action of a flat, so far as the removal of impurities is concerned, is practically that of the roller. But where flats are used they are stripped more frequently, and there is therefore a chance of observing the quality of their work throughout the whole of the working period. As was pointed out, the flats are given a "heel"—that is to say, they are caused to assume an angular position relatively to the cylinder. It is thought by some spinners, that the "heel" of the flat should vary with the length of staple carded. There might have been some force in this contention in the old days when flats were nearly double the width they are at present, but the difference which it would be possible to make with the present width of flat would be very slight. The character of the strippings or "strips" which are taken from the flats as they leave the cylinder, is a very good indication of the setting and condition of the flats. If these strippings be observed it will be noticed that at the edge which

receives the cotton first the "strip" is thinner than it is at the edge where the cotton leaves. This is what would be expected from the setting and construction of the flat, and it affords a perpetual means of ascertaining the condition of the flats while they are working. If the "strip" from one flat is heavier than that from another, the former is either doing too much or the latter too little work. If the thickness of the strip at the receiving end of the flat varies with different flats, it is a proof that the distance between the wire is not the same in both cases—that is, the "heel" varies. Thus a close observation of the strips enables two important points to be decided, and gives a guide to the carder which is invaluable. The examination of the strips carefully is a very profitable exercise, and the revelations of a strong magnifying glass are sometimes startling.

(139) The undercasings are of great importance in the working of a carding machine. These are grids placed as shown at R in Fig. 23, and which are constructed as follows. Circular frames corresponding practically to the curvature of the cylinder are connected by transverse bars, and are so mounted that they can be easily and accurately adjusted in a short time. They are preferably made of tinned iron, and the bars are of a shape which permits the ready transmission of the fly without leading to any adhesion. Reference has already been made to the mode of setting the licker-in casing, and Messrs. Dobson and Barlow, Limited, whose arrangement is illustrated in Fig. 27, now attach one-half of the cylinder undercasing to that of the licker-in, so that they are set simultaneously. It is perhaps as well to say here that the licker-in pedestal and the casings are usually coupled, so as to move together. The cylinder undercasing is in the arrangement named in two pieces, one attached to the licker-in and the other separately adjustable. Special guides are formed at their adjacent extremities, so that they maintain, when set, the correct relative position to the cylinder. The undercasings made by Messrs. Platt Brothers and Co. Limited, are specially constructed, the bars being secured to segmental wrought iron rings turned to the correct size. As the

purpose of these casings is the provision of means by which the emission of "fly" and other impurities is possible, it is necessary in setting them, as in setting other parts of the machine, that special care should be taken. Full liberty should be given to the short fibre to be ejected through the grids, but damage to the cotton must be sedulously guarded against. No empirical rule can be given by which this can be made, and only close observation will enable the best distance to be fixed. A distance of about $\frac{3}{100}$in. is a good one for most varieties of cotton, but this is a point which is always open to variation according to the necessities of the case. It is requisite to say, however, that this is a matter of great importance and should be closely watched, as otherwise a considerable increase of waste results.

(140) The flats have, as has been indicated, to be set very closely to the cylinder surface, and this a matter which involves the consideration of one or two points. There are several machines made for which it is claimed that they are so constructed, mechanically, that the wire surface on the flats can be brought within $\frac{1}{1000}$in. of that on the cylinder. Now, it is not necessary to do more than point to the fact that this is a setting which closely approximates to the diameter of the fibre, and that if, therefore, these lie upon the surface of the cylinder as described, a very slight elevation of their free ends will draw them through the teeth on the flats. It is not, however, by any means a universal practice to make these close settings, and, as a matter of fact, it is very probable that in the majority of cases the two surfaces are much wider apart. It is customary to furnish the carder with three carefully ground slips of steel, called "gauges," which are, respectively, ·013in., 011in , ·007in. thick. In setting, the carder chooses a time when the mill is quiet, and there is not the vibration existing which is always found during working hours. By means of his setting screws, in the case of a flexible bend, and of the adjusting mechanism, when other forms of the machine are used, he lowers the flats until by slowly turning the cylinder a slight click, caused by the contact of the wire, can be heard. When, by this means,

it has been ascertained that the two surfaces are in contact over the whole of the working face of the flats, the screws are reversed and the contact destroyed. In setting by gauge this removal is carried on until the gauge can be slipped in between the faces without undue pressure, and it depends, of course, upon which of the gauges is employed, how great the distance is between the two surfaces. A similar procedure is pursued in setting rollers and clearers, the bearing brackets of which are provided with screws for this purpose. In setting flats by the special arrangements of mechanism previously named, the reverse movement is regulated by means of an indicator, dial, and finger, the dial being graduated by divisions, each representing $\frac{1}{1000}$in. After the operation is completed the various screws are securely locked by means of nuts or some other similar or equivalent device, and the machine is ready for work. The real basis upon which this operation rests is the audible click made when the wire surfaces are in contact, and in endeavouring to obtain this great care should be taken to see that the contact is of the slightest character.

(141) The coiler, as was shown, has within it two revolving parts, viz., the coiler-plate and the can disc. These rotate in opposite directions, and their velocity is duly regulated by the train of wheels shown. Assuming the doffer to be delivering 900in. of web per minute, and the peripheral speed of the calender rolls to be the same, it will follow that there will be 900in. per minute delivered into the can, but, as a rule, there is a slight draft between the calender rolls and the coils. If the laying of this sliver in the can depended upon the rotation of the coiler solely it would be placed in a series of ascending coils, as at one time it was. The result of this is that nothing like the same length is laid as should be, in addition to which the coils become entangled, and are liable to be broken in drawing out. By giving to the can a slow rotation in the opposite direction to the coiler-plate, the coils are laid in various positions and the centre of each succeeding coil is a little removed from that of the one preceding it. The result is that a much greater length is deposited, and

the coils are quite free from one another, and can be withdrawn with ease. Referring now to Fig 24, the coiler can is 9in. diameter, and is driven from the shaft B which, we will assume, revolves at a speed of 100 revolutions per minute. The can disc J is driven by the wheel train shown, of which D has 16 teeth; E 48; F 16; G 48; H 14; and J 84. The speed of J is therefore $\frac{16 \times 16 \times 14}{48 \times 48 \times 84} \times 100 = 1{\cdot}85$. The coiler plate M is driven by the engagement of the wheel K with the annular rack L. K has 42 teeth and L 108, the velocity of the coiler plate being therefore $\frac{42}{108} \times 100 = 39$. The coiler will therefore lay a

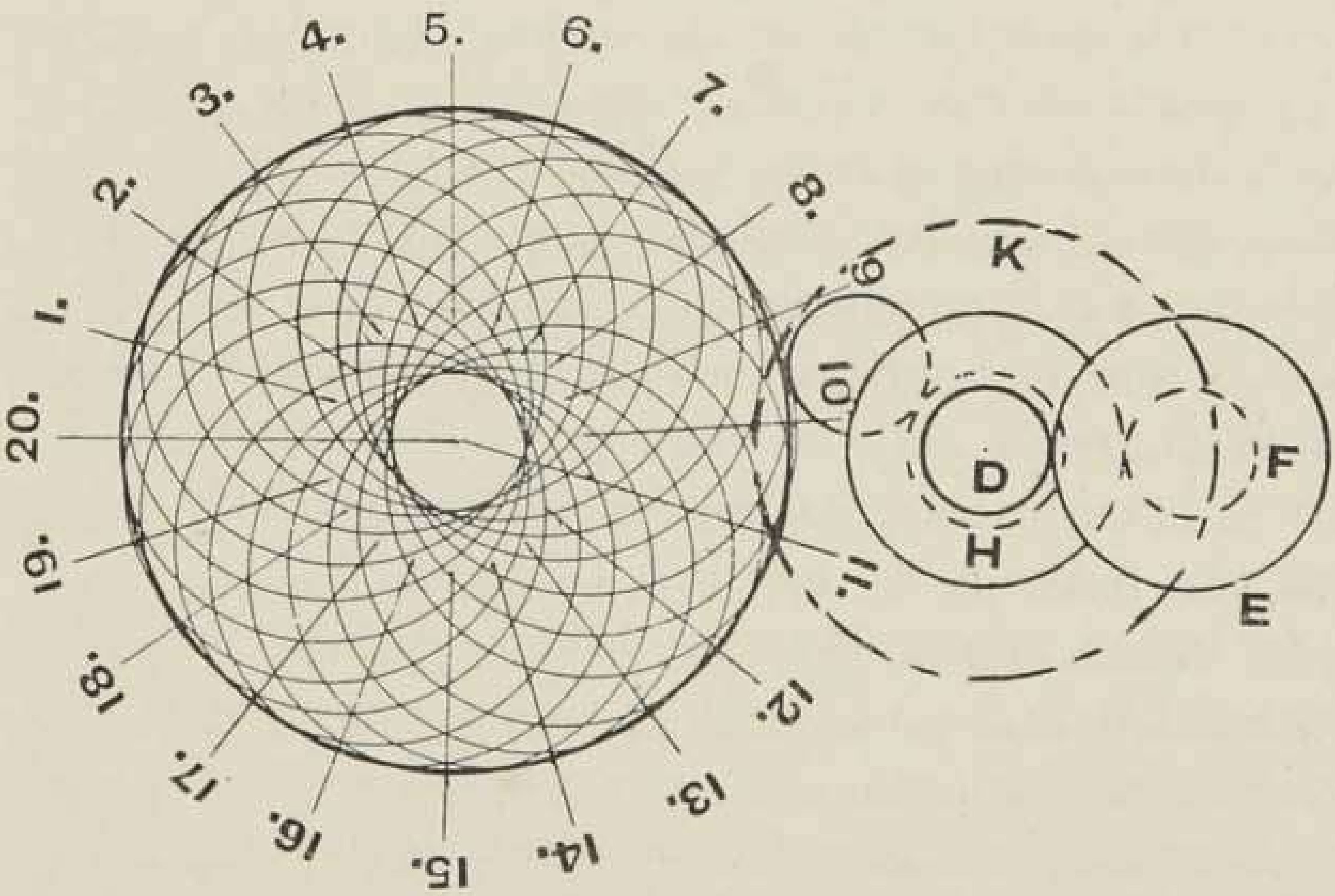

Fig. 32.

complete coil in the can in $\frac{1}{39}$th of a minute, in which time the can will make ·0475 of a revolution. Thus in a complete revolution of the can 21 coils will be laid, and the sliver will receive 21 turns in the length of sliver delivered by the calender rollers during that period. Thus, if the calender rollers are $2\frac{1}{2}$in. diameter they, being driven at an equal speed to the upright shaft, will deliver 785·4in. per minute, and during one revolution of the coiler 424in. As 21 coils are laid in that time, the length in which one twist is introduced is $\frac{424}{21} = 20{\cdot}16$, which is about the ordinary amount. The illustration given in Fig. 32

shows graphically the method of laying the coils. It is seen that the successive coils touch the edge of the can at one point, and the distance traversed by the can before the next coil touches it is shown by the space between the successive points indicated by the figures 1 to 21. It will be understood that the size and number of coils depends upon the eccentricity of the tube, and the relative velocities of the coiler plate and can, but the principle is illustrated by the sketch given. It is good practice to use two discs connected with a spiral spring within the can, as in this way a good deal of the strain on the sliver, as it is deposited, is removed.

(142) Having thus explained the various points connected with the operation of carding it is now necessary to deal with the various problems which are subsidiary to it. The preceding explanation will have shown that the whole of the working surfaces of the cylinder, doffer, flats, and rollers are covered with wire points, by which the cotton is treated. These are embedded in some sort of material which is technically termed the "foundation." It may be differently constructed, being composed in some cases of a combination of cotton and woollen cloths, the latter being interposed between two layers of the cotton. The whole of these fabrics are specially prepared, and when securely cemented together, form a very firm but flexible foundation, wherein to fix the wire. Another form of material used is all cotton, and yet another consists of a thin layer of indiarubber, securely cemented to the cotton and wool backing. The rubber used is pure Para, and the object in each case is to provide a firm elastic foundation, in which the wire teeth are securely held while having liberty of movement to a certain degree. There is a difference of opinion with reference to the merits of these various foundations. Of the three, cotton-wool-cotton is probably the best, as while being quite as flexible as the indiarubber, it is not so liable to disintegration by heat and oil. There is no doubt that indiarubber foundations do become useless if subjected to the direct heat of the sun, and there is no doubt that their lasting qualities are not superior to those of the cotton-wool-cotton foundation.

(143) Cards are now usually made in long strips, or "fillets," about three inches wide, these being of sufficient length to cover the whole surface of a cylinder. The wires are made now almost wholly from a specially drawn and tempered steel wire, which is made of various sections, each maker apparently having a liking for a special section. The wires are made in pairs, and are formed into a sort of staple consisting of two points or crowns coupled by a cross piece inserted and bent to the requisite angle by a machine of great complexity and ingenuity, which, however, performs the whole of the operations of setting and inserting the wire points at a speed of 300 pairs per minute. The wire points are, as has been indicated, slightly bent after leaving the foundation, and this is illustrated in Fig. 33. There does not appear to be any rule prevailing amongst makers of cards which regulates the angularity of the tooth, and even in cards made by the same maker differences exist of several degrees. The principle is to give such a set, or "keen," as shall enable the wires to readily lay hold of and card the fibres, and the limits within which this can be effected are necessarily small. It is obvious that if the wire is bent forward at too acute an angle it will hook itself into the fibres, which it will be difficult to detach, while, on the other hand, if the angle is too obtuse the wires will not properly lay hold of and card the material. Practice, therefore, speedily determines the angle which is the best, and each maker adopts a different and distinctive angle, which, however, is not always adhered to. It is probable that the speed at which the setting of the teeth is conducted is not sufficient to give the steel tempered wire in all cases a permanent set, or to overcome the resilience of the material. The variations existing in card clothing can only be accounted for, we think, in that way. Whatever may be the correct setting, however, there is one rule which is firmly established. As shown in Fig. 33, the wire is inserted in the foundation D in an angular direction. The point where it leaves the foundation is marked E, and through this a perpendicular line A B is

drawn. The tooth is shown by the line B¹ E C A, and it will be noticed that the point B¹ is at one side of the line A B, and the point C at the other side, and that the line A B is intersected at E, where the tooth leaves the foundation B. The reason of this is to enable the tooth to be scarcely held, while, at the same time, it can, if pressed at its free end, bend back without difficulty. From C to A the wire is bent forward, and the point A is perpendicular to E. This is about the correct setting, for this reason. If the wire surface so adjusted be

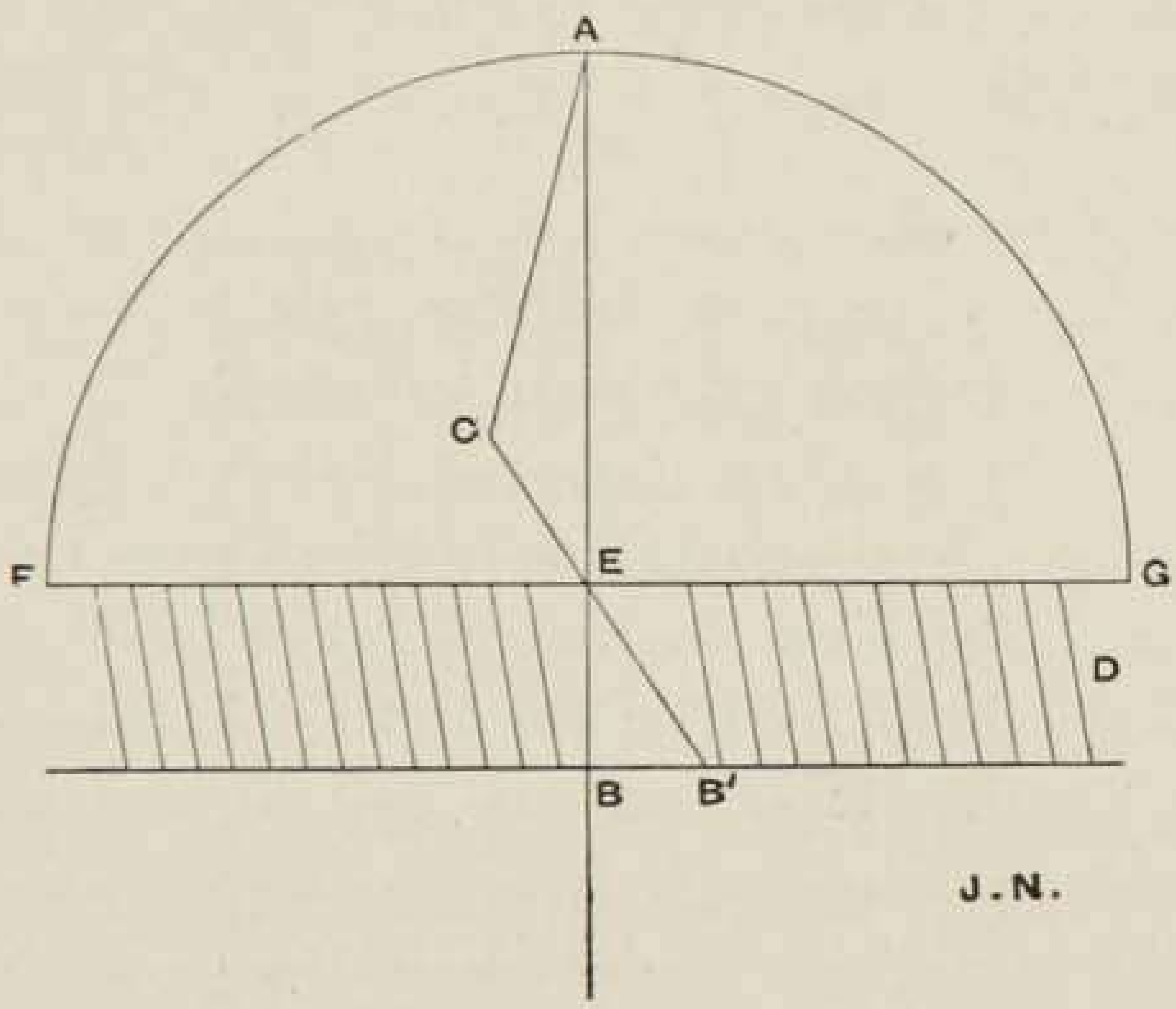

Fig. 33.

superposed or placed beneath a similar one, and pressure be exerted on the point A, the consequent flexure of the tooth will cause it to move backward, so as to radiate about the point A, and thus be removed from the sphere of the superposed or underlying teeth. In this way damage is prevented to the wires, while the carding is uninjured. Remembering what has been said about the manner of setting the flats, the importance of this procedure will be manifest. Of course there are permissible variations to this principle of setting, but the rule is approximately a correct one.

(144) The teeth, as was said, are inserted in pairs in the foundation, and upon the peculiar disposition of them depends the value of the clothing for the purposes of carding. It will be easily recognised that, if the teeth were inserted so that their points were arranged in a series of straight lines, the carding would most probably result, in many cases, in the formation of a web well carded in places but very badly carded in others. This variety of setting is called "plain," and is shown in Fig. 34, but is now very seldom employed. The two most common arrangements are either "twilled," Fig. 35, or "ribbed," Fig. 36. The fillets employed for covering the cylinder and

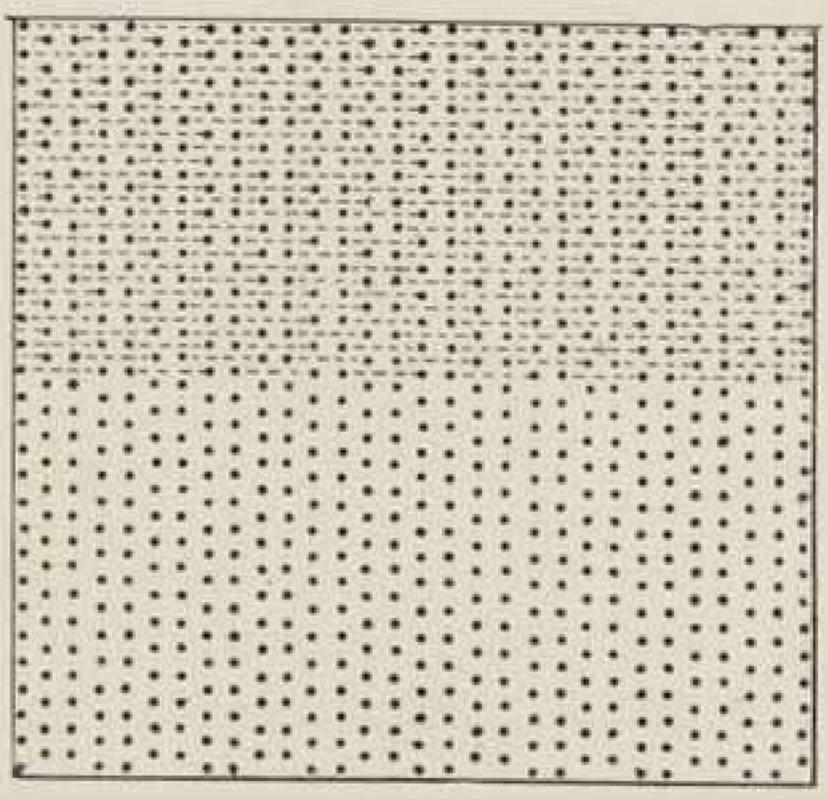

FIG. 34.

doffer are ordinarily covered with ribbed, but in some cases the flats are covered with twilled set clothing, especially when the teeth are made of mild steel wire. The strips for the flats are usually made in broad sheets of the requisite width in which the teeth are set in straight lines right across. After one row is set the next follows, and so on, until the required number are fixed to make up the width of the flat strip, when the cloth is rapidly drawn forward so as to leave an ample margin for attaching the strip to the flat. The plan of each of these systems of setting is clearly shown in the illustrations, the dots showing the points, or "crowns," of the teeth, and the dotted lines the back. Card clothing is said to be of certain "counts," this phrase indicating the pitch of the teeth. The method of computation is based upon the number of teeth which are found in a width of four inches, which was the size of sheet formerly made. It is assumed that there are always ten "crowns" to the inch, longitudinally. Thus, if in the width named there were

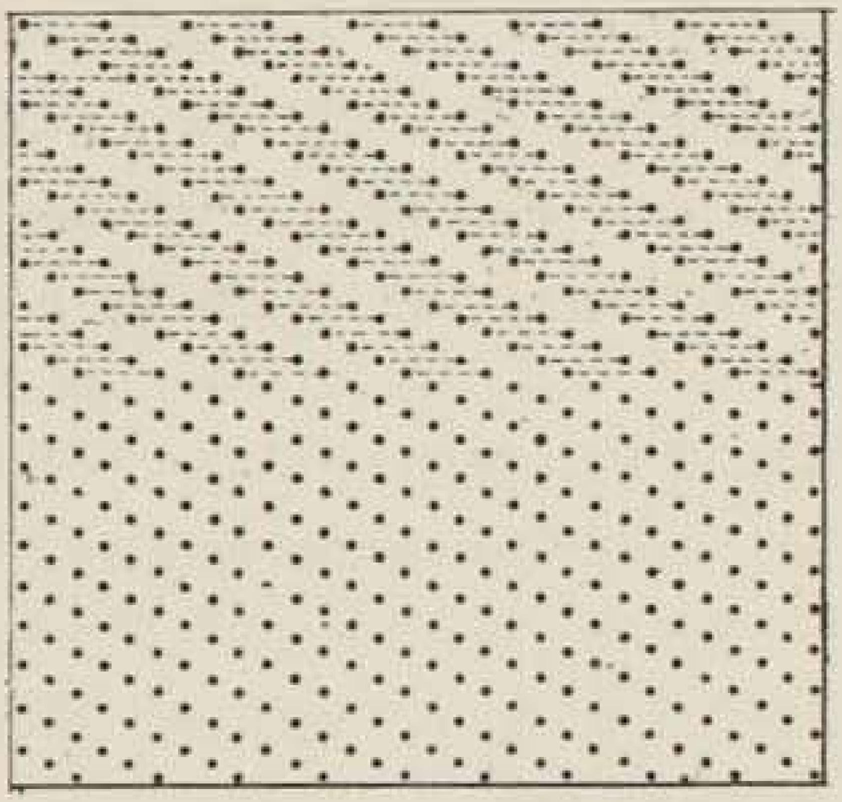

FIG. 35.

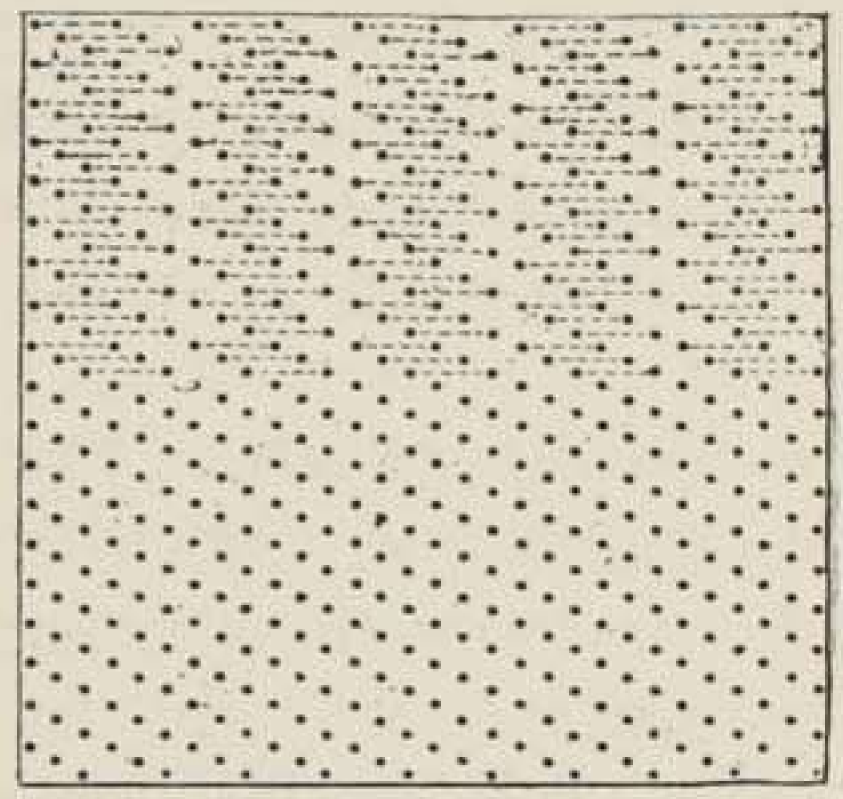

FIG. 36.

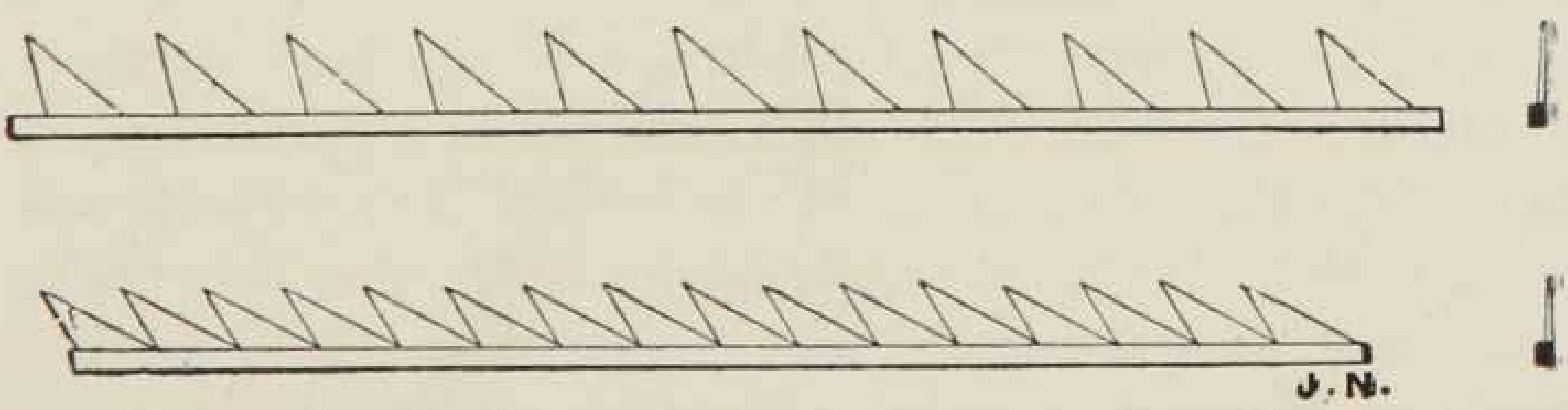

FIG. 37.

110 "crowns," the "counts" would be 110's, and the number of crowns per square inch would be $\frac{110 \times 10}{4} = 275$. The number of rows sometimes varies, especially in ribs and twills of finer counts.

(145) It is customary to cover the licker-in with a set of teeth which are constructed on one of the two plans shown in Fig. 37. These are called "Garnett" teeth, and are, as

noticed, of two shapes, one being finer pitched and a little more hooked than the other. The finer tooth is used when no undercasings are fitted to the licker-in, it being better adapted to carry round the fibre to the cylinder, thus avoiding it being dropped on the way. It is, however, much preferable as a practice to use an undercasing, and the coarser pitched wire is therefore mostly employed. The counts of wire used for the cylinders and doffers vary with the quality of cotton employed. For the ordinary medium qualities used in spinning yarns from 30's to 50's, the cylinders may be covered with 110's, and doffers and flats with 120's, when revolving flat machines are employed. If roller machines are used the cylinder and rollers can be covered with 90's to 100's, the clearers with about 110's, and the doffer's from 100's to 120's. In spinning coarse counts from Indian cotton the wire should not be finer than 100's for the cylinder, and not more than 110's for the doffers and flats. The general rule for card clothing is that the better the quality and the longer the staple of the cotton the finer should be the counts of the wire clothing.

(146) In covering cylinders, doffers, and rollers, it is necessary to exercise great care. The fillets before being put on should be kept for some time in some place where the temperature is equal to that of the card room. If this is not done they begin, when fixed, to expand and rise in particular places, forming what are technically called "blisters." It was pointed out that the cylinders and doffers are carefully prepared to receive the clothing, and have what are practically smooth surfaces. Opinion differs as to whether it is desirable to prepare these by covering them with a thin coating of paint or thin calico. If the latter practice is carried out, care must be taken to paste it in position, so that it lies evenly over the whole area. There is, however, an increasing tendency to wrap the fillets on the bare surface, and it is now believed that the fillet can be so fixed as to avoid any danger of slipping, which is the only motive for preparing the cylinder surface. It will be at once recognised as very important that, once the cylinder is covered,

the clothing should be firm and immovable, as otherwise the setting of the various parts to the exactitude previously described would be impossible. Assuming that the cylinder is left without special preparation, it is advisable to mark on it in chalk the date of covering it, so that the wear of the clothing can be ascertained. The method of covering the cylinder is as follows. The fillet is fastened at one end by means of a tack driven into one of the wooden pegs which fill the holes drilled in the periphery, and is then wound on by the rotation of the cylinder. The fillet may be put on manually or by a specially constructed machine, which exerts a definite but adjustable tension upon it as it is being wound. The latter plan is, by far, the better one, as the machine is so constructed that a very regular drag is exerted, and the fillet is, therefore, stretched equally throughout. As soon as the whole surface is covered the other end of the fillet is secured in the manner as described, and the cylinder is allowed to stand for a few hours to permit the elasticity of the foundation to adjust it over the whole surface. The clothing is then tacked down by means of a special tool, which drives a tack into the various wooden plugs referred to. Before covering the cylinder it is advisable to mark on a staff the position of the plugs transversely, so that the tacks may be driven without having to run the risk of damaging the clothing. If this operation is properly conducted the fillets will lie close together, without gaps, and will be firmly and solidly bedded on the surface of the cylinder. A similar procedure is followed with the doffers and rollers. Flats are covered with strips made as indicated, which can be attached in several ways. The most common method is to drill a number of small holes near the edges of the flats, and to pass through these, and similar holes made in the strip, lead rivets. One side of the strip is first fastened by these rivets, care being taken that it is absolutely in contact with the under side of the flat throughout its length. The strip is then stretched by a suitable instrument and the other edge is riveted. Another method is to secure the strip by clasps which pierce it, and are clenched rapidly on the underside. This plan is an improvement on riveting, as it protects the strip from the action of the revolving brush which otherwise frays it. Yet another method consists of a clip which passes quite round the sides of the flat, being closed at the top and bottom by a special machine. In any case, the object is to hold the wire to the various parts in such a way that they cannot rise or blister, so that an unvarying carding surface is presented.

(147) The foregoing description will have enabled a clear understanding to be obtained of the construction and method of attachment of the wire clothing, and it is now necessary to consider the most important question of grinding or forming the tooth. It is often said that the clothing supplied for any purpose is needle pointed. This is evidently an exaggeration, because the conditions under which the clothing is formed and applied entirely prevent the construction of any such point. A needle point must of necessity be round and gradually tapering, and it is difficult to conceive of clothing being made in which this type of tooth was inserted. It certainly could not be done by machine, and would involve the manual setting of each pair of teeth. But suppose the teeth to be fixed, they could not be resharpened when the points were worn, because the pitch of the teeth is only $\frac{1}{10}$in. longitudinally, and from $\frac{1}{22}$ to $\frac{1}{37}$in. transversely. A needle tooth being circular—although its original formation is easy—could not be ground at its point while in position, and unless this can be done its use is impracticable. If a true needle point could be practically adopted there is no doubt of its immense value, but as it cannot the next best system must be taken.

(148) The usual solution of the difficulty is found in the formation of a tooth with a chisel or knife edge, which is presented to the action of the cotton. This is usually obtained by what is called "plough grinding"—that is, a method of passing between the teeth of the clothing a thin emery disc, which "ploughs" deeply between them and grinds them on each side until they present a sharp edge to the cotton. The

wire of which the teeth are made may be round, oval, triangular, or any other section preferred. These give it strength in the part embedded in the foundation, but the emery disc as it passes through produces a flat or oblong section in that part of the tooth above the point C in Fig. 33. This process of shaping the tooth by grinding is confined to the preparation of the fillets or sheets for sale, and is not conducted when the clothing is fixed in position on the machine. It does not require pointing out that when the machine has been working a short time the teeth become dulled at their points, and require to be sharpened. This is effected when the cylinder is dealt with by removing the cover above the doffer and bringing a grinding roller carried in bearings P (Fig. 26) into contact with the wire on the cylinder. By slowly rotating the cylinder and rapidly revolving the grinding roller the whole of the teeth on the former are ground. A similar procedure is pursued with the doffer. Rollers and clearers are removed from the carding machine and are ground in a special machine constructed for the purpose. The flats of revolving flat carding engines are ground in position. There are two points connected with the operations thus briefly summarised about which something may be said.

(149) The cylinder is, as has been intimated, rotated at a slow velocity while being operated on by the grinding roller. At first sight it would appear that if the cylinder was revolved at its working speed during grinding the finished surface would be consequently much truer. This, however, is a fallacy, as the experience gained in grinding all kinds of articles to a true cylindrical shape shows that a slow velocity of the article operated on, and a quick one of the grinding wheel, give the best result. It is found that only in this way can a true cylinder be made, and what holds good in other cases is equally applicable to this. The cylinder is, therefore, reduced to a velocity of from $1\frac{1}{2}$ to 4 revolutions per minute by various arrangements of wheel-work or other gearing. Some of these necessitate the use of a separate and detachable piece of mechanism, in order to effect the reduction, while others are

permanently attached to the machine, and can be thrown in or out of gear as desired. The general result of them all is, however, to give to the cylinder that reduction of motion named, and damage to the wires is thus reduced to a minimum.

(150) The grinding rollers employed are of two types. In the first the roller is made of equal width to the cylinder, and is covered over its whole surface either with emery or emery filleting. In the second the grinding is effected by a narrow roller which is mounted upon a cylindrical roller or shaft on which it can slide. By means of an ingeniously arranged spiral keybed at the bottom of the key grove, in which a fork fixed in the emery roller engages, a reciprocal sliding motion is given to the latter as the shaft is revolved. Thus not only does the rotation of the shaft drive the roller, but it also gives this to and fro-movement to the roller. It should also be stated that the continuous grinding roller receives a similar reciprocal motion. Either the broad or narrow roller may be covered with ordinary emery or by fillets or strips of emery cloth. The latter is the plan which is most preferred, and special arrangements are made for retaining the fillet in position. A groved emery filleting made by Messrs. Dronsfield Brothers Limited, in which the surface is formed of several raised parts or ridges, is in much request, and for the tempered steel wire now employed is found very serviceable.

(151) The flats, as has been said, are ground in position. In Fig. 26, brackets T are shown fixed to the framing at each side of the cylinder, and act as bearings for the grinding roller, which rotates above the flats. At this point the latter have their wire surface upward, and they are held up by means of weighted levers which press upon their undersides and force their working faces against brackets placed for the purpose. There is involved in this operation a joint which is of interest and importance. The flats are constructed, as previously shown, with their bearing surfaces parallel with the surface upon which the wire strip is fixed. This is shown diagramatically in Fig. 38, where A B D C represents the end of the flat which ordinarily

rests upon the "bend." The wire surface is represented by the line E F, and this it will be seen is parallel with the line C D which represents the bearing surface, but angularly disposed to the surface A B, which is the back or upper edge of the flat. Now it is obvious that if the flat is held on the surface A B while it is passing under the grinding roller, the surfaces E F and A B will gradually become parallel with each other; and the heel, although remaining in the surfaces C D will, so far as practical purposes are concerned, be entirely destroyed. It is, therefore, the practice to sustain the flats, while being ground, in such a manner that their surfaces C D are pressed against the guide-plate, and the parallel relation of C D and E F is thus maintained. It must be remembered that during the whole period the flats are being ground they are moving onwards, so

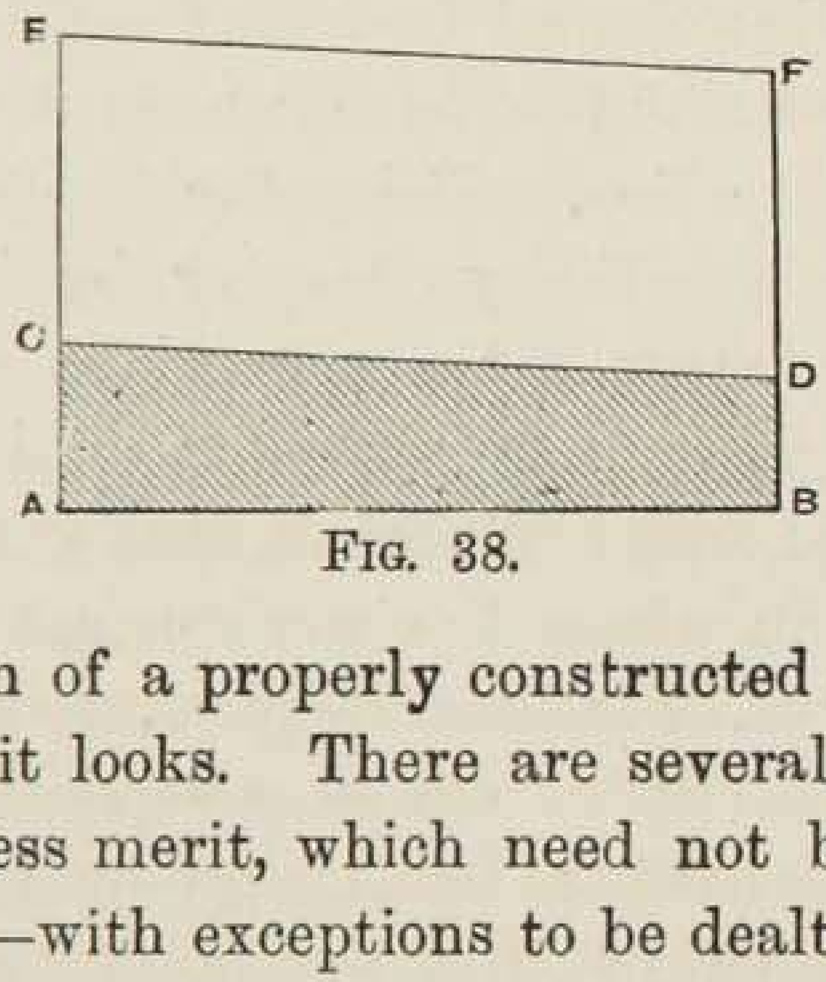

FIG. 38.

that the provision of a properly constructed guiding surface is not so simple as it looks. There are several devices for doing this, of more or less merit, which need not be here described. They are mainly—with exceptions to be dealt with presently—based on two devices. First, the provision of a plate with an angular surface so arranged as to give the requisite angularity to the wire surface, or maintain it in one plane during grinding; or second, the provision of a surface of the required angle which moves with the flat until the latter is ground, when the bearing surface is released and returns to engage with the next of the series of flats. The object in all these devices is the same, although their mechanism differs, viz., to keep the surface E F in a plane which is coincident with that which the grinding edge of the roller moves while sustaining the flat on the face C D.

(152) In these various arrangements, however, the flats are turned with their faces upward, and although they are strongly constructed with a strengthening longitudinal rib, there is yet a little deflection occurs in the centre, between the sustaining points. Now it is obvious that, however little this deflection may be, the wire surface will be affected by it, and that, although it is very slight, not more than ·003in., yet the points of the wires will be arched to that extent. In other words the centre will, while face up, have less ground off than the ends. The evil does not, however, stop here, because when the flat is again turned face downward, as it is when in working position, there will be a similar deflection in the opposite direction, so that the centre of the flat will be practically about ·005 to ·006in. below its ends. When the setting is supposed to be made to ·001in. it is clear this a matter of importance. For this reason, therefore, mechanism has been designed by which the flat is ground with its face downward, while moving on a surface designed to preserve the heel. In one or two cases this involves the lengthening of the chain of flats, but by a recent arrangement Messrs. Dobson and Barlow have overcome this difficulty in an ingenious manner, by so attaching the flats to the chain that at the usual point for fixing the grinding bracket and roller the flat is turned over and is pressed upon a surface corresponding to that on which it ordinarily travels. By a simple arrangement the grinding roller, which is placed in the space between the working and idle flats, is pressed up to the wires, and is, as the flat travels gradually, raised a little higher to an extent equal to the heel required. After the flat is ground it is released and automatically resumes its normal position, all the parts of the apparatus assuming the necessary adjustment to recommence the arrangement.

(153) All the brackets carrying the grinding rollers are supplied with the necessary adjusting screws by which the roller can be brought into contact with the wire surface. The greatest care should be taken in setting this roller. The procedure is similar to that of setting the flats to the cylinder, as described in par. 140, but in this case the guages are preferably

thin slips of paper, by pulling which the equality of the pressure upon the roller can be ascertained. It is essential for reasons which will be presently detailed that the contact should be a light one, but with ordinary care there need be no difficulty about this.

(154) Having thus described in all essential detail the construction and method of setting the wire fillets, the mode of fixing them, and the various plans adopted for grinding, it now remains to discuss the principle underlying the operation of setting and grinding cards, and the various essentials of successful work.

(155) It has already been intimated that the tooth is ground for the purpose of producing a chisel or knife edge, which is the nearest approach possible to a needle point. The purpose for which a needle point is required is to provide a carding surface which is of so delicate a character that it is able to deal with each fibre separately. It is easy to see that if the carding points were say quarter-inch broad the fibres would practically be scutched instead of carded, and any such construction would be fatal to efficiency. What is wanted is a point which will easily travel along a single fibre, or through a number, so as to scrape without injuring it, and thus complete the cleansing process. It is obvious that the finer and smoother the tooth is the more likely it is to fulfil this important object. Now it is well established that the effect of any grinding process upon the material ground is to leave upon its surface grooves, scratches or scores, the depth and pitch of which depends entirely upon the character of the material used to grind with. The material which it is necessary to employ, or, at any rate, which is always employed, is emery, and even the finest grades which are commercially usable will have a considerable effect upon the surface to which it is applied. Thus all plough-ground wires are more or less abraded and scratched on the side of the teeth, and, if left untouched, are apt to produce an ill effect upon the cotton. It will be

remembered that the cotton fibre is sheathed in a coating of wax, the preservation of this sheath being absolutely necessary for efficient working in the after processes. A rough tooth will present a saw-like surface to the fibre and will scrape off some of the wax from it. Whenever this happens a fine white powder will be found about various parts of the machine, particularly about the trumpet guide and the mouth of the coiler. This is a certain sign that the fibre is being damaged, and whenever it is observed an examination of the wire should be made. It is a very much preferable practice to burnish the wire periodically by means of a wire brush, as in this way the roughened surface is made smooth and a much better carding tooth is obtained. The use of a brush of this character in which the bristles penetrate the teeth at intervals is very advantageous, and can be recommended to all who wish to get the very best effect.

(156) Having got a side ground tooth which has smooth sides, and having fixed it in position on the cylinder, the next thing is to grind it on the point. The mechanism for effecting this has been described, and it will have been noticed that the grinding roller can be set so as to exert any desired pressure. It is however, extremely injudicious to grind heavily, as there is great danger of bending or barbing the wire teeth. If the emery roller is pressed too hardly down upon the tooth, the metal is made to flow over the front edge of the tooth and leave a barb or hook. The effect of this is that as the wire moves it gets hold of the fibres in such a way that they cannot easily be withdrawn, and they begin to collect until they are forcibly detached and many of them broken. Bad carding is the inevitable outcome of hooked wires, and nothing is more fatal to good work, the essential condition of which is the freedom of the passage of the tooth through the cotton. If this be not the case it is idle to look for an even web composed of fibres of full length and strength. In practice it is infinitely preferable to grind lightly and often than to wait for the card points to get dull and then grind them heavily. The diagrams

given in Fig. 39, will illustrate this. A is the shape of the upper part of a card tooth the carding edge of which is sharp and clean; B is a tooth which is badly worn at the front so as to be quite rounded, and the dotted line across the top shows the amount which requires to be ground off; C is the result of heavy grinding, a hook or barb being formed existing at the front edge; and D is a tooth only slightly worn, which, when ground will show a sharp clean carding point like A. It must be understood that these are merely diagrammatic representations of what happens, but they illnstrate the point being dealt with. It is clear that if a barb is formed at all the chance of effective

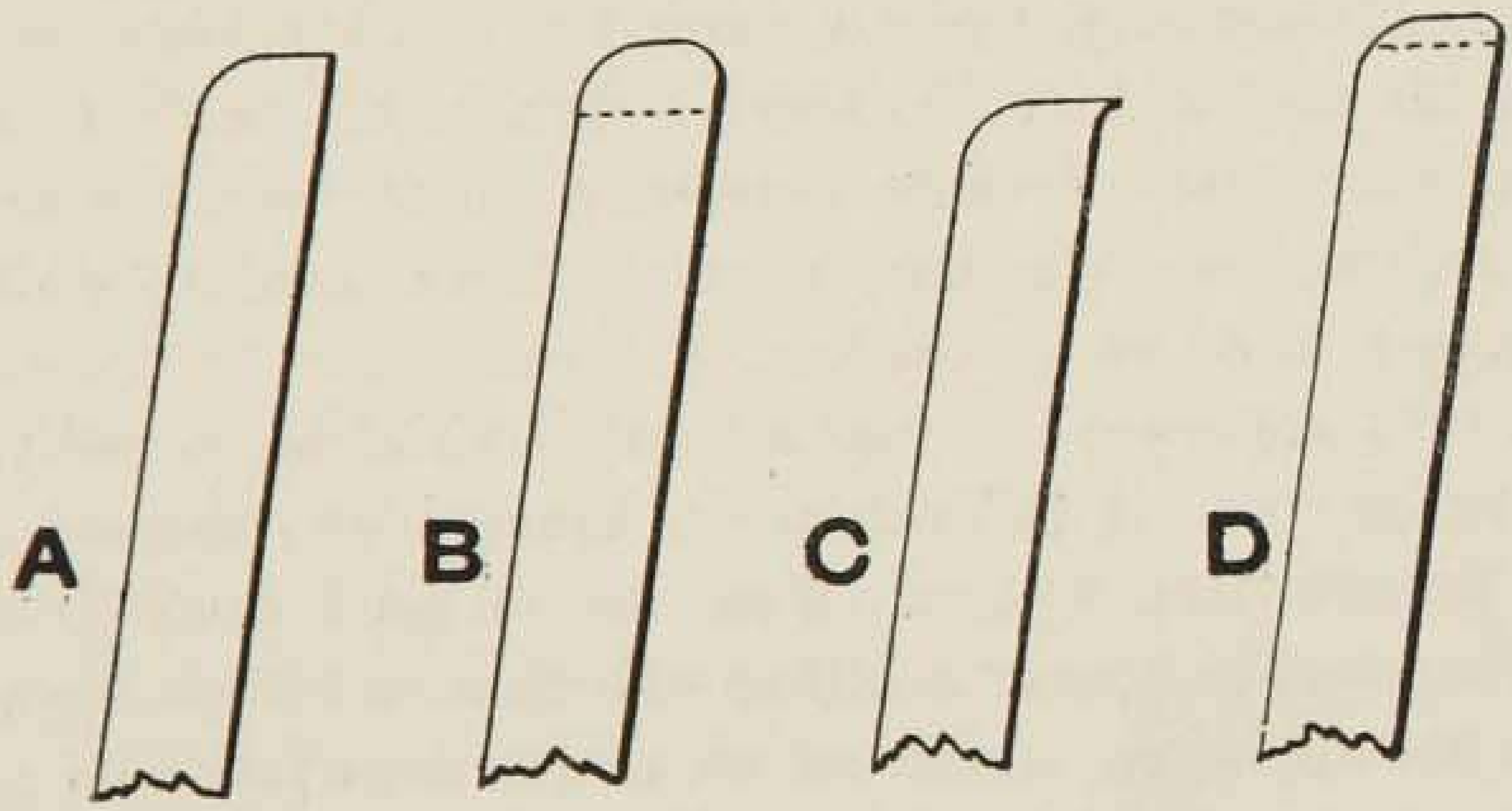

FIG. 39.

carding is lessened, and it is also clear that if the wire is allowed to become so far worn as to necessitate heavy grinding, the chance of forming a barb is greatly increased. It is, therefore, a preferable plan to grind the cylinder lightly once a month than to grind heavily at longer intervals. Very much more depends upon attention to this matter than many carders appear to think, and observation is the only guide to correct practice Two slivers which shall be produced from laps formed of the same mixing of cotton made up at the same time will yet be entirely different in their appearance. They may both be perfectly well carded so far as motes and short fibres are concerned, and yet one will be bright and lustrous, and the other dull and dirty looking. Many such slivers have been inspected, and in almost every case it is found that it is from the setting and condition of the wire that the difference in result arises. Any roughness or want of sharpness of the wire speedily affects the quality of the product. It is therefore essential for good work that the condition of the wire should be the very best it is possible to obtain.

(157) Not only is it essential for the proper conduct of carding that the wire teeth should be sharp and smooth, but they should periodically be thoroughly freed from the accumulation of short fibres, neps, and motes with which they become charged. Everything depends upon the maintenance of the freedom of the wire tooth, and it is obvious that if it is embedded in a mass of waste material it cannot be as effective as when quite free. The flats, in revolving flat carding engines, are stripped after every passage they make over the cylinder, so that they are always in the best and most cleanly condition. The cylinder wire, which does not do much more than act as a carrier for the fibre, will, of course, be in good working condition for a much longer time than the flats or rollers, because a little accumulation is not of so much importance as it is in wires which have actually to card. The proper period of stripping depends also upon the character of the cotton used, and this is a factor which varies from year to year, as was pointed out in Chapter II. In a season when the pods burst open before many of the fibres it contains are fully matured, there will always be a large percentage of short fibre, so that a rule which holds good one year is of very little service the next. Cotton which, like Indian, contains a good deal of immature and short fibre, necessarily fills the wire much sooner than a cleaner variety, and stripping must be carried out oftener. It has already been pointed out that the character of the strippings is a fair indication of the quality of the work done, and they should be carefully looked to to see that good fibre is not being removed with the bad. For very fine work stripping is carried out several times a day; while with good, clean American, for

ordinary work, once or twice a day is sufficient. It is very good practice to strip the cards in regular rotation, so that there is always a fair proportion of the machines with clean wire, and the carding throughout the room will be evener in quality, as an average. The use of a wire roller for stripping cylinders and doffers is preferable, not only because it is more convenient, but also on account of the burnishing or polishing effect upon the wire. Before leaving this point it may be repeated that "good carding is absolutely essential to good work. With it a good even yarn can be made. Without it no

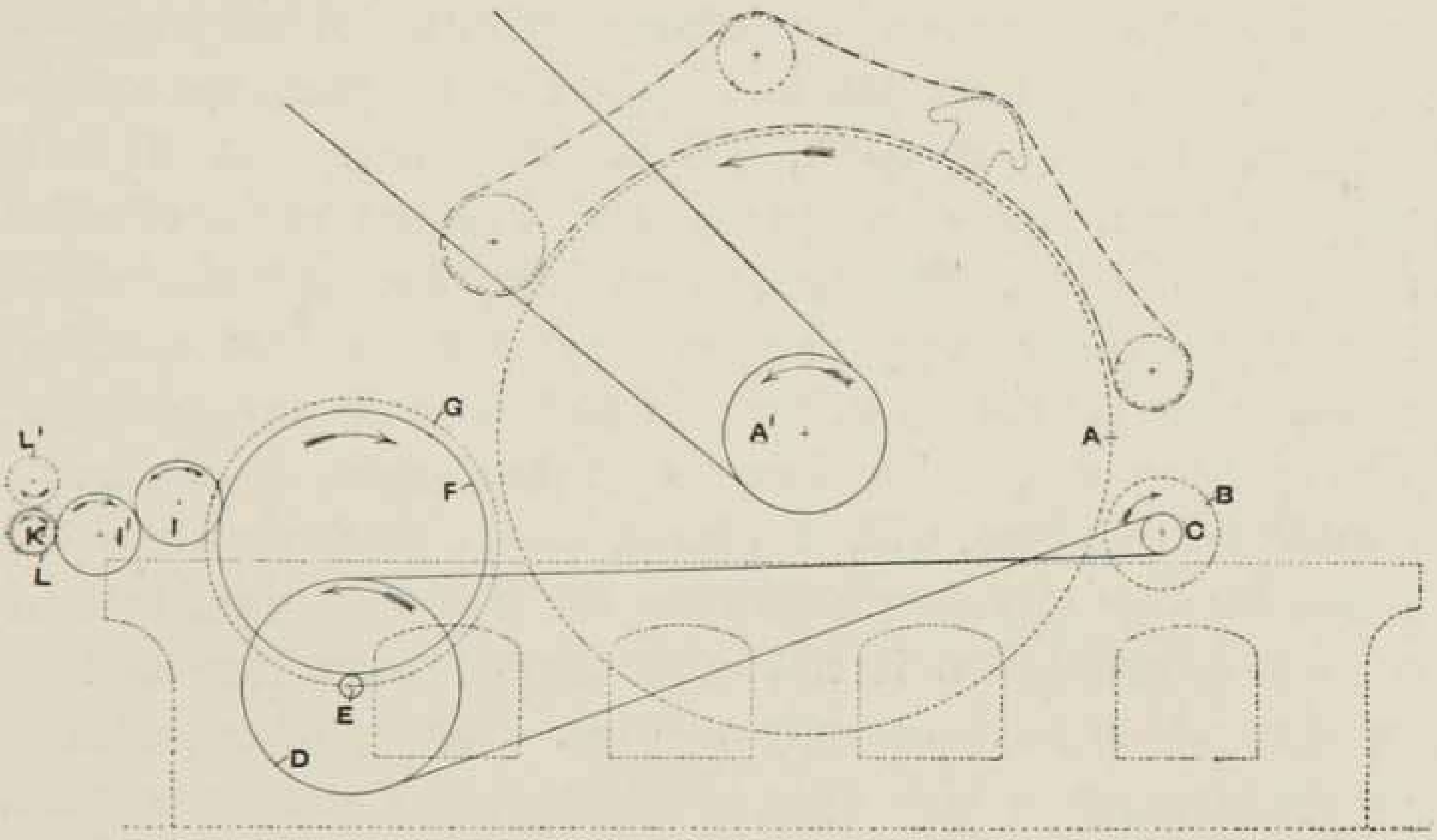

FIG. 40.

such result need be looked for. It is impossible to lay too much stress upon this point, and the care bestowed upon the machine and its clothing will amply repay the spinner."

(158) It now only remains to show the method of driving the various parts, and in order to illustrate this the two diagrams given in Figs. 40 and 41 have been furnished. These represent the Simplex revolving flat carding engine, and the mode of actuating the mechanism. The cylinder A is driven from the driving shaft by means of a pulley A^1. Adjoining this there is a loose pulley on to which the belt is moved

when the machine is stopped. Referring now more particularly to Fig. 41, which is a diagram of the opposite side of the machine to that shown in Fig. 40, it will be seen that the licker-in B is driven by a crossed band passing over the pulleys R on the cylinder shaft and R^1 on the licker-in. The doffer is driven on the other side of the machine from the licker-in, as shown in Fig. 40, by means of a crossed belt passing over the pulleys C and D. On the shaft forming the axis of D a pinion E is fixed—called the barrow wheel—which engages with the wheel F fixed on the doffer

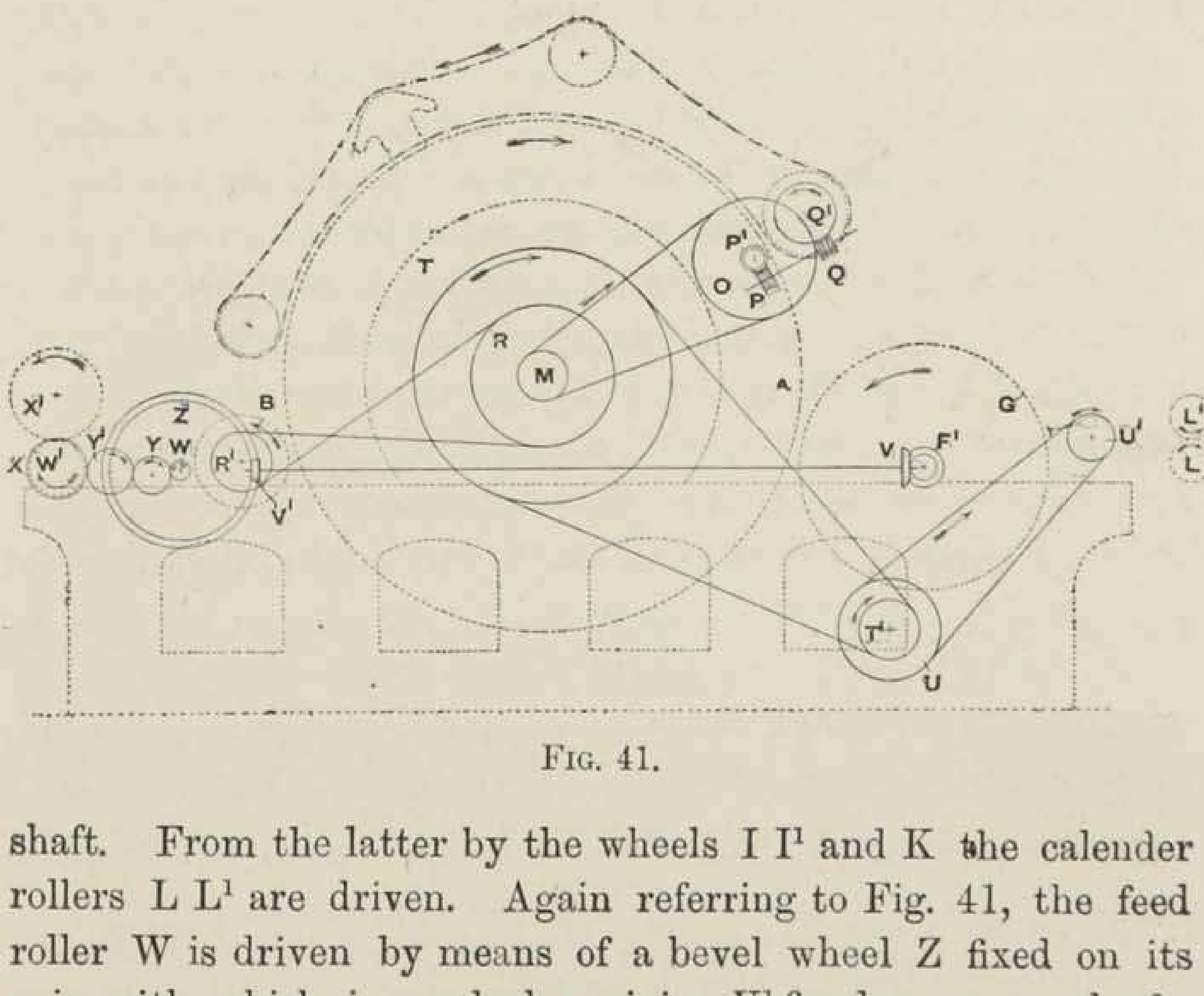

FIG. 41.

shaft. From the latter by the wheels I I^1 and K the calender rollers L L^1 are driven. Again referring to Fig. 41, the feed roller W is driven by means of a bevel wheel Z fixed on its axis, with which is meshed a pinion V^1 fixed on one end of a horizontal shaft on the other end of which is a bevel wheel V engaged with a similar one F^1 keyed on the doffer shaft. By the train of wheels W Y Y^1 W^1 the lap roller X upon which the lap X^1 rests is driven. The driving of these parts does not greatly differ in carding engines generally, and a clear grasp of this arrangement will enable others slightly modified to be easily understood. The chain of flats is driven by a band or cord which passes over a pulley M fixed on the cylinder shaft, by which through the pulley O, worm P^1, worm wheel P, worm Q, and worm wheel Q^1 motion is given to the pitched chain wheel actuating the chain of flats. The doffing comb is driven from a grooved pulley T by a band passing over the pulley T^1, which is compounded with a second pulley U. The latter drives a pulley U^1 fixed on the shaft on which is mounted the eccentric or cam giving motion to the doffer comb.

(159) It will be noticed, if the arrangements just described are studied, that between the motion of the cylinder and that of the feed and delivery mechanism a close connection exists. Thus the doffer and licker-in are connected directly, so that a change in the rotation of the former is followed by one in that of the latter. In like manner the feed roller is driven from the doffer and a close connection is thus established between that of the two parts. By changing the pinion E, or pulley D, the velocity of the doffer can be easily regulated, so that it can be run quicker or slower as desired. All the calculations about this machine are of a simple character and can be readily made. If a = the number of revolutions of the cylinder, then those of the licker-in are $a \times \frac{R}{R^1}$. In like manner the velocity of the doffer G is $a \times \frac{R}{R^1} \times \frac{C}{D} \times \frac{E}{F}$. Let this latter quantity be called b then the velocity of the feed roller is $b \times \frac{F^1}{V} \times \frac{V^1}{Z}$. If in place of the letters used the diameter of the pulleys and the diameter or number of teeth of the wheels which are indicated by the letters are substituted, a ready calculation can be made of the relative velocities of the parts.

(160) The following rules will be sufficient to enable the necessary calculations to be made. It has been explained that the lap is reduced by the variation in the speed of the different parts to a thin web, and that the amount of this reduction gives the "draft" of the card. To find this, multiply together the

number of teeth of the driven wheels and the diameter of the doffer, and divide the product by that of the driving wheels and diameter of feed roller. In this case, referring to Fig. 41, the formula would stand thus $\frac{V \times Z \times G}{F^1 \times V^1 \times W}$. The small pinion V^1 can be changed when required to vary the velocity of the feed roller. There is a slight draught between the doffer G and the calender rolls L, which is arrived at by dividing the product of the driven wheels and the diameter of the roller L by the product of the driving wheels and the diameter of the doffer.

(161) There are two ways in which changes can be made in the weight of the sliver produced on a carding engine, viz., either by changing the pinion V^1 on the side shaft, or by altering the speed of the doffer by changing the barrow wheel E. Of these the former is the more convenient and usual course, and it is a simple proportion sum to ascertain the correct pinion required to make a change. If, for instance, a change was wanted from a sliver 65 grains to the yard for one 75 grains, the pinion V^1, of whatever number of teeth it was, would be changed for one $\frac{75}{65}$ of V^1. Thus, if V^1 had 20 teeth it would be $\frac{15}{13}$ of $20 = 23$ about. The speed of the doffer is however important, for although it is quite true that all necessary changes can be made by reducing or increasing the rate of feed, whenever it is desired to get a bigger production, the doffer must be speeded also. This matter is of some importance, and its *rationale* may be dealt with in a few words. If the feed-roller has its velocity increased or diminished the effect is that more or fewer fibres are beaten down by the licker-in, and that, therefore, the delivery of cotton to the cylinder is increased or diminished. This means that the sliver will be affected proportionately. Now, while it is possible to increase the quantity of cotton so brought within the range of the cylinder teeth to an extent which is only limited by the capacity of the latter to receive them, it is obviously not so easy to diminish it beyond a certain point. If the delivery of the lap is too far reduced,

the effect would be that there would be a number of bare places, and that a sliver very irregular in substance would be produced. But any change made must be accompanied by an adjustment of the speed of the doffer, if it is desired to produce merely an additional quantity of a sliver of some specific weight. If the feed is increased while the doffer speed remains constant a heavier sliver will be produced, while by speeding the doffer in the same ratio the quantity produced, but not the weight per yard, is affected. If the substance of the sliver is known it is easy to ascertain the production of the machine by calculating from this and the surface velocity of the doffer. If a doffer 24in. in diameter is used, its diameter when clothed would be 24¾in. This would when making 12 revolutions per minute have a surface speed of 25yds. This in 56 hours will give 84,000yds. delivered, and by multiplying this by the weight per yard of the sliver, say 50gr., we get a production of 600lb. per week. In the same way the production of any given weight of sliver can be ascertained.

(162) There are one or two other rules which may be given, and which are likely to prove useful. To find the draft required to produce a given weight of sliver, when the weight per yard of lap is known, reduce the weight of one yard of lap to grains and divide by the number of grains in the same length of sliver. This gives the draft. It may be preferable to take two or three yards instead of one, but the rule remains the same. To find the hank of the sliver, take a few yards (3 to 6) of the sliver as delivered into the coiler, ascertain its weight in grains, and divide into the dividend for the number of yards taken.

(163) The dividend is obtained by obtaining the weight in grains of a pound. This number is 7,000, and as there are seven leas in a full hank, each lea weighs 1,000gr., if one hank weighs a pound and is 120yds. long. One yard, therefore, weighs $\frac{1}{120}$ of 1,000gr., or $8\dot{3}$, which is the dividend for one yard. By multiplying this number by the number of yards taken a constant dividend is obtained, thus—that for six yards is $8{\cdot}3 \times 6 = 50$.

(164) To ascertain the length of fillet required to cover a cylinder multiply the circumference of the cylinder by its width and divide by the width of the fillet. It is advisable to add to this a length equal to one circumference, as a certain waste is made.

(165) The following table gives the hank of slivers of various weights and will be useful for reference :—

Number of grains per yard.	Decimal Hank Sliver.	Number of grains per yard.	Decimal Hank Sliver.	Number of grains per yard.	Decimal Hank Sliver.
40	·208	58	·144	72	·116
45	·185	60	·139	74	·113
50	·167	62	·134	76	·1095
52	·160	66	·126	78	·107
54	·154	68	·122	80	·104
56	·148	70	·119		

(166) The whole of the points which it is necessary to deal with at length have now been treated, and it only remains to be said that the attention of the carder should be especially given to the question of cleanliness. In an operation of this kind the prevention of the emission of fly is practically impossible, and it finds a lodgment on all parts of the machine. It is, therefore, of high importance to prevent choking of the parts and the collection of dirt, in places where it will be drawn into the lap, and that the utmost vigilance should be observed to keep everything free from any accumulation of fly. Especially is this the case with revolving flat machines, as the chain very speedily becomes stiff, unless great vigilance is exerted to keep it clear. Good carding requires vigilance, and the student of cotton spinning ought to be Argus-eyed in order to see every neglect of the small but essential duties required.

CHAPTER V.

COMBING AND DRAWING.

(167) As was shown in Chapter II., the process of combing is one which is only carried out when the finer qualities of yarn are to be spun. The manipulation of the material is so thorough that a large proportion of waste is made, so that, except when a high priced good yarn is to be spun, economic reasons forbid the combing of the cotton. It was briefly intimated in paragraph 129 that combing was a method of dealing in detail with the fibres, and that its result is to effect a much greater parallelisation of the fibres in the carded sliver. Not only so, but the setting of the mechanism leads to a species of sorting of the fibres by which all below a certain length are rigidly cast out. Thus, after cotton has been subjected to the action of a machine of this character, two of the essentials of perfect yarn are produced, viz., the presence within the thread of a number of fibres laid in parallel order relatively to one another, and so selected as to be practically uniform in length. Thus the cylindricality of the thread when twisted is, if not absolutely obtained, much more nearly approached than is usually the case.

(168) In order to ensure the proper treatment of the material it is the usual practice to combine a number of slivers, and form them into narrow laps of 7½ or 8½in. wide. The carded slivers, in number from 12 to 16, are drawn from the cans, and after passing over spoon guides forming part of a stop motion, are passed between drawing rollers, by which they are consolidated and attenuated, after which they are rolled into a lap by means of suitable mechanism at the end of

the machine. The precise action of the stop motion and drawing rollers will be discussed at length when the operation of drawing is considered. After the laps have been formed on the Sliver Lap Machine, as it is called, six of them are passed through a second machine called the Ribbon Lap Machine, also constructed with drawing rollers. In this machine the laps are attenuated considerably, and are laid upon each other before being passed through calender rollers, and formed into a roll or lap for feeding to the combing machine. The advantages derived from this treatment are that the fibres in the laps are drawn into an approximately parallel order, so that the needles of the combing cylinder can very readily pass through them without any danger of damage, either to the needles or the fibres. The method in which this parallel order is induced will be dealt with at length a little later on in this chapter.

(169) The combing machine is a very intricate one, and possesses a number of interesting features. A transverse section of the machine is given in Fig. 42, this representing one head, of which, in a complete machine, there are either six or eight. The whole of the various heads are actuated from mechanism at one end of the machine, as will be hereafter described. The rolls from the Ribbon Lap Machine are placed upon two wooden rollers A, having coarse corrugations formed longitudinally of their surface, and slowly revolved by suitable mechanism. The lap is conveyed within a shallow trough B into the sphere of action of two feed rollers C C^1, which receive an intermittent movement. The lower roller C is formed of steel, with finely pitched longitudinal flutes, the upper roller C^1 being kept in contact with it by hooks passing over its necks and suitably weighted. The top rollers are cloth and leather covered, having a true cylindrical surface. Some firms prefer to use a porcupine roller to feed the lap instead of a pair of rollers. Whatever may be the device employed, the object is the same, to feed the end of the lap in such a manner as to project the latter into the path of needles fixed in a revolving comb cylinder. In order that the

needles shall be able to pass freely through and remove the short fibres from the lap the latter is held by a pair of jaws which are opened and closed by the action of a cam. The nipper jaws H and D are made of steel, and are fixed in a suitable manner. H is fastened to a lever J, which has at its upper end two arms, one being fitted with a screw and lock nut by which it can be limited in its backward movement induced by the pull of springs. It ought perhaps to be explained that the lever J is a double one, giving support to each end of the nipper jaw H. The effect of this arrangement is that there is always a steady upward pull exercised on H, while at the same time it can yield when a pressure is exerted on it. The nose of H is sometimes rounded, and covered by a soft cloth or leather, which is very smoothly laid and carefully applied. The upper nipper jaw D is fixed to the lever E, which has a free oscillating motion on the centre E^1, and receives such a motion from a cam, by means of a connecting rod G jointed to the tail end of E and coupled to a lever G^1 fixed on a rocking shaft driven from the cam shown. In Messrs. Dobson and Barlow's machine, which is shown in Fig. 42, the lower nipper jaw is formed of steel, with a longitudinal groove, and the upper jaw has a strip of indiarubber fitted in, by which the nip is effected. The above constitutes the feed portion of the mechanism.

(170) The combing is effected by two combs, one L, called the top comb, having a slight upward and downward movement, being dropped into the lap as afterwards described. The chief part of the combing is, however, done by a series of combs fixed in a revolving cylinder N. This is built up with a barrel or comb stock, so shaped as to permit of the easy attachment of the combing needles. There are seventeen rows of these, each a little wider than the lap, and each imbedded in a metallic matrix or bed, called the "half lap," which can be bolted to the comb stock. The pitch of the needles varies, becoming gradually finer, and ranges from $\frac{1}{30}$ to $\frac{1}{90}$in. The object of this is to permit them to enter the cotton freely and gradually treat the whole of the fibres without running the risk of

an undue amount of waste being produced. These combs are, when the end of the lap is protruded and held by the nipper, passed through it, so as rapidly to comb out the short-stapled fibres, which are thus removed, and are brushed out by a rotating brush O, which is fixed below the comb cylinder, so as to pass through the combs at every revolution. The brush, in turn

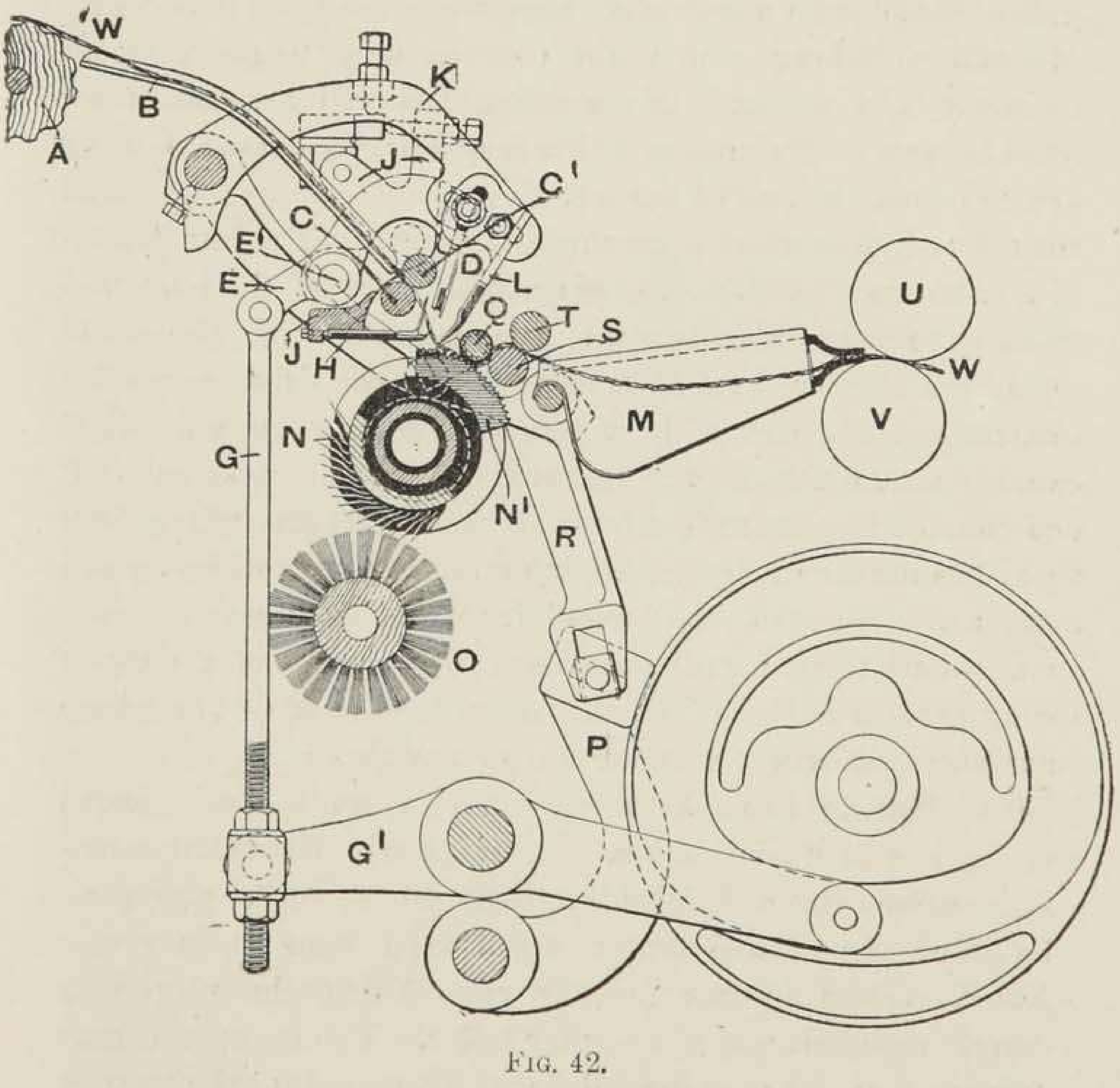

Fig. 42.

transfers the fibres to a doffer, from which they are beaten off in a continuous sheet by a comb.

(171) Placed at a point beyond the nipper are three rollers Q, S, and T. The roller S is called the "steel detaching" roller, and receives an intermittent motion from a cam. The roller Q is called the "top detaching" or "leather" roller, and is, as

its name implies, covered with a smooth sheath of cloth and soft leather. It is sustained in bearings formed in levers R, which are coupled by connecting rods to levers fixed on a rocking shaft, to which an oscillatory motion is given from a cam. The leather roller receives a rolling motion round the steel detaching roller, and is, when moved forward, brought into contact with a segment N^1 on the comb cylinder. This is formed with longitudinal flutes on its outer surface, so that when it is in contact with the roller Q it will communicate to the latter a rotary motion which is utilised to detach a tuft of cotton from the end of the lap.

(172) The method of driving the various parts, just detailed, is shown in Fig. 43, which is a plan view of the mechanism fitted to the machine in the spinning department of the Manchester Technical School. The driving shaft A carries on one end of it a pair of pulleys, one fast and the other loose, by which the machine is driven. By means of a pinion B the wheel D is driven. D is fixed on the cylinder shaft, and has on its inner face a peg or pin E fixed, which engages in its rotation with a star wheel J, which is thus given a partial and intermittent rotary movement. By means of a pinion G, gearing with the wheel H, the feed roller C is driven, and means are provided by which the extent of this forward movement can be regulated. From a second pinion L on the driving shaft the brush shaft is driven. As is clearly shown, the wheel I is driven from D, being fixed on a shaft, which may be called the cam shaft, as it has fixed upon it three cams, N, F, and K, which operate respectively the nipper, the detaching roller, and the leather roller. The stripper comb is driven from the crank R, which actuates the rocking levers Q, on which the comb is fixed. There is a special arrangement with regard to the detaching roller which requires notice. It is shown in detail in Figs. 44 and 45. In this view the cam F has engaging with it a bowl borne on one end of a rocking lever C, the other end of which is shaped as a toothed segment D engaging with the pinion B

sliding upon the axis of the detaching roller. The latter forms one part of a clutch E, which engages with a similarly constructed part fastened on the spindle of the detaching roller. The clutch is usually held in gear by a long helical spring coupled to the sliding half of E. With a ring groove, formed on the boss of the pinion B, a bowl fixed at the end of a rocking lever G engages, the other end of G carrying a

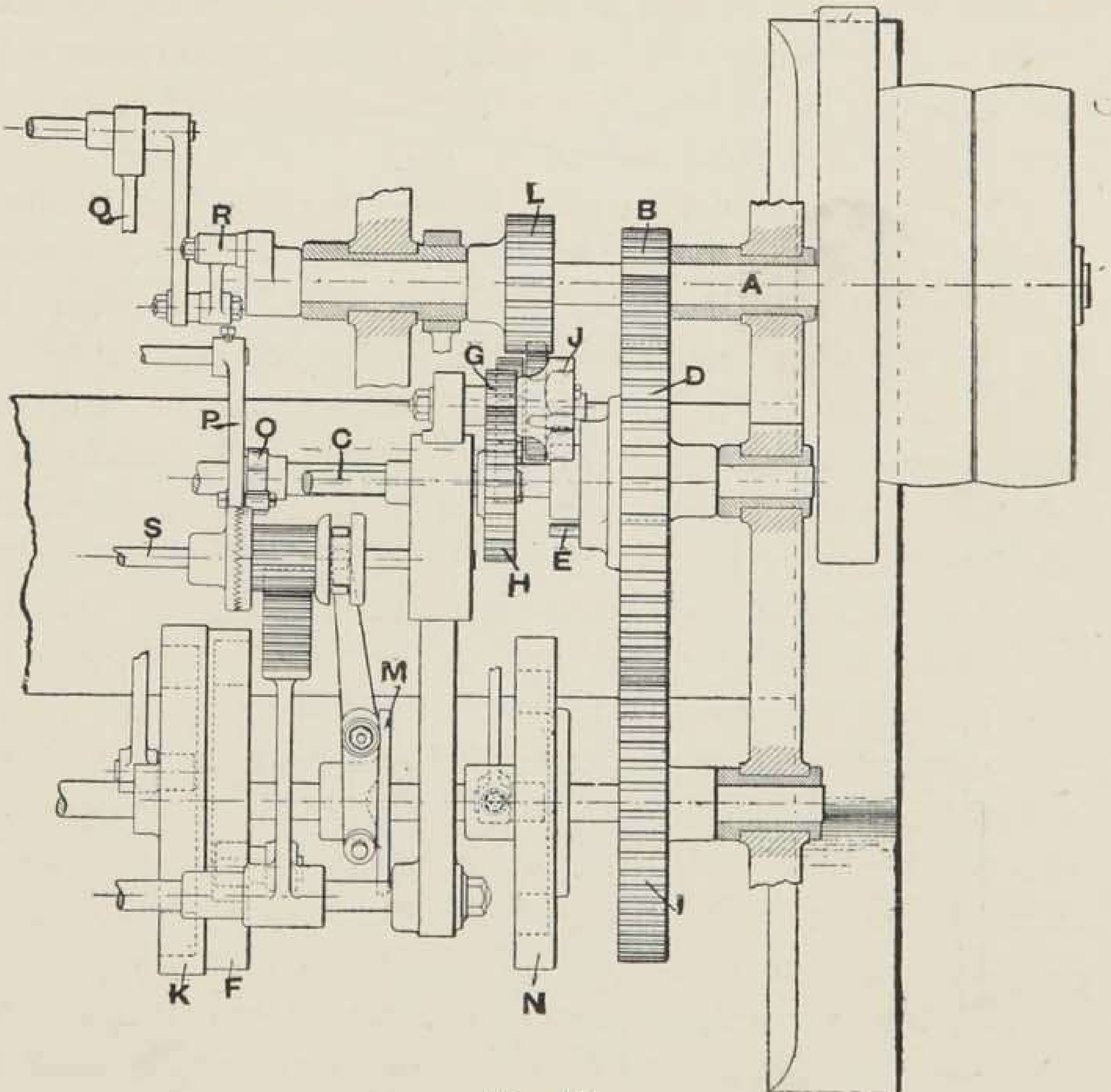

Fig. 43.

bowl constantly in contact with the face of a cam M also rotating with the cam shaft. It will be noticed that the cam F is so shaped that for a great part of its rotation it communicates no motion to the lever C, but that when it does cause the latter to oscillate it moves it in both directions alternately, the engagement or disengagement of the clutch regulating the period of the rotation of the detaching roller C^1.

(173) The action of the mechanism so described can now be dealt with. Before doing so, it must be premised that what is done in combing is to treat the cotton in successive lengths or tufts, which are combed at one end, detached from the lap, then combed at the other end, and subsequently attached

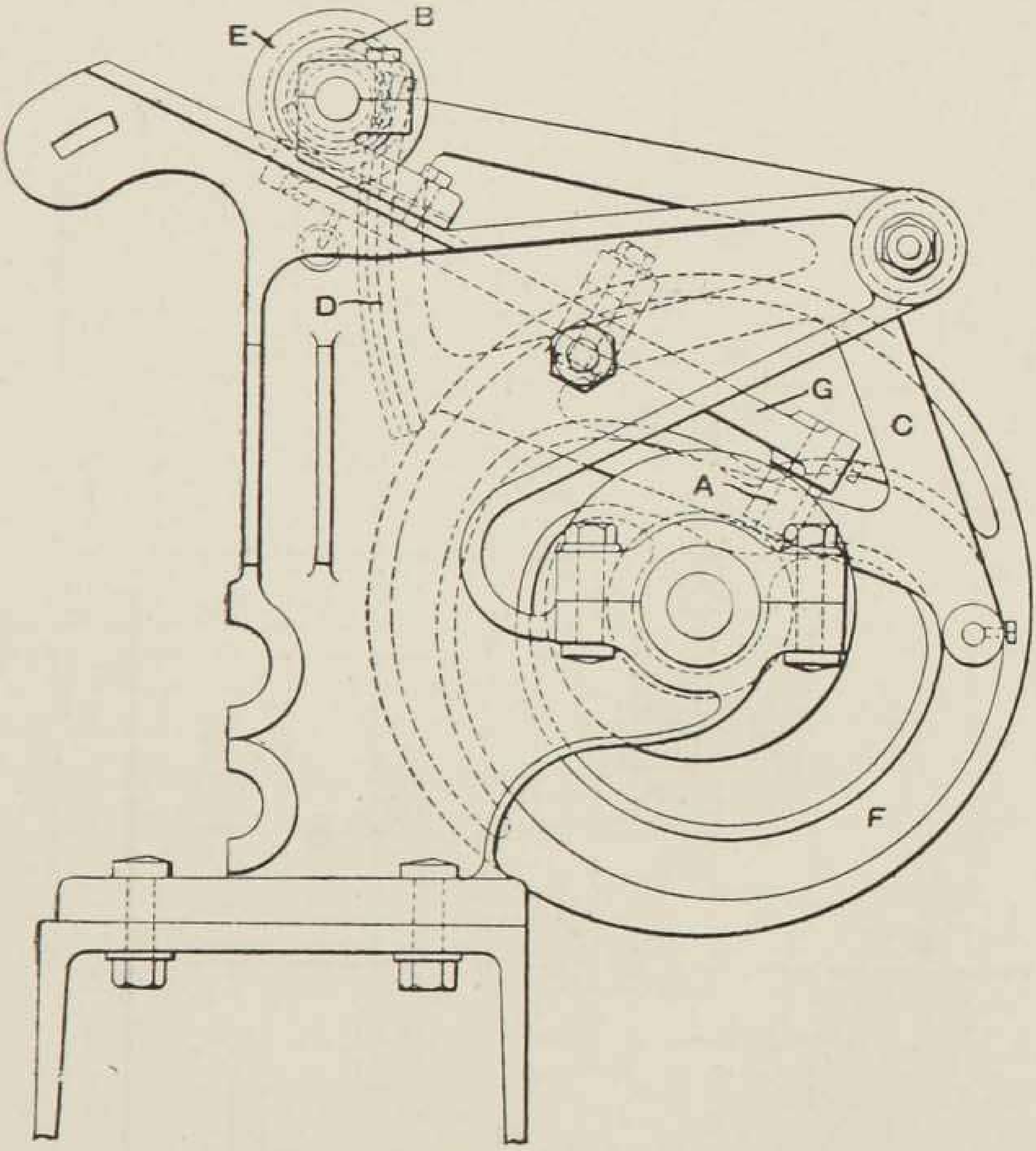

FIG. 44.

to the combed sliver. As was done with carding, it is always as well to speak of the cotton as it is fed, as the lap, and as delivered, the sliver. Unlike the carding process, there is a gap existing between these two in combing, the sliver being intermittently and not continuously fed. There is a moment of time when the tuft or length of cotton—which is, of course, the full width of the lap—is entirely unattached either to the lap or sliver. The lap is fed, as has been indicated, by the feed rollers in short lengths. The revolution of the peg E causes the star wheel J to be revolved to the extent of one tooth for every revolution of E. The effect is to give a rotary motion to the feed roller, the extent of which depends upon the arrangement of gearing between it and the star wheel.

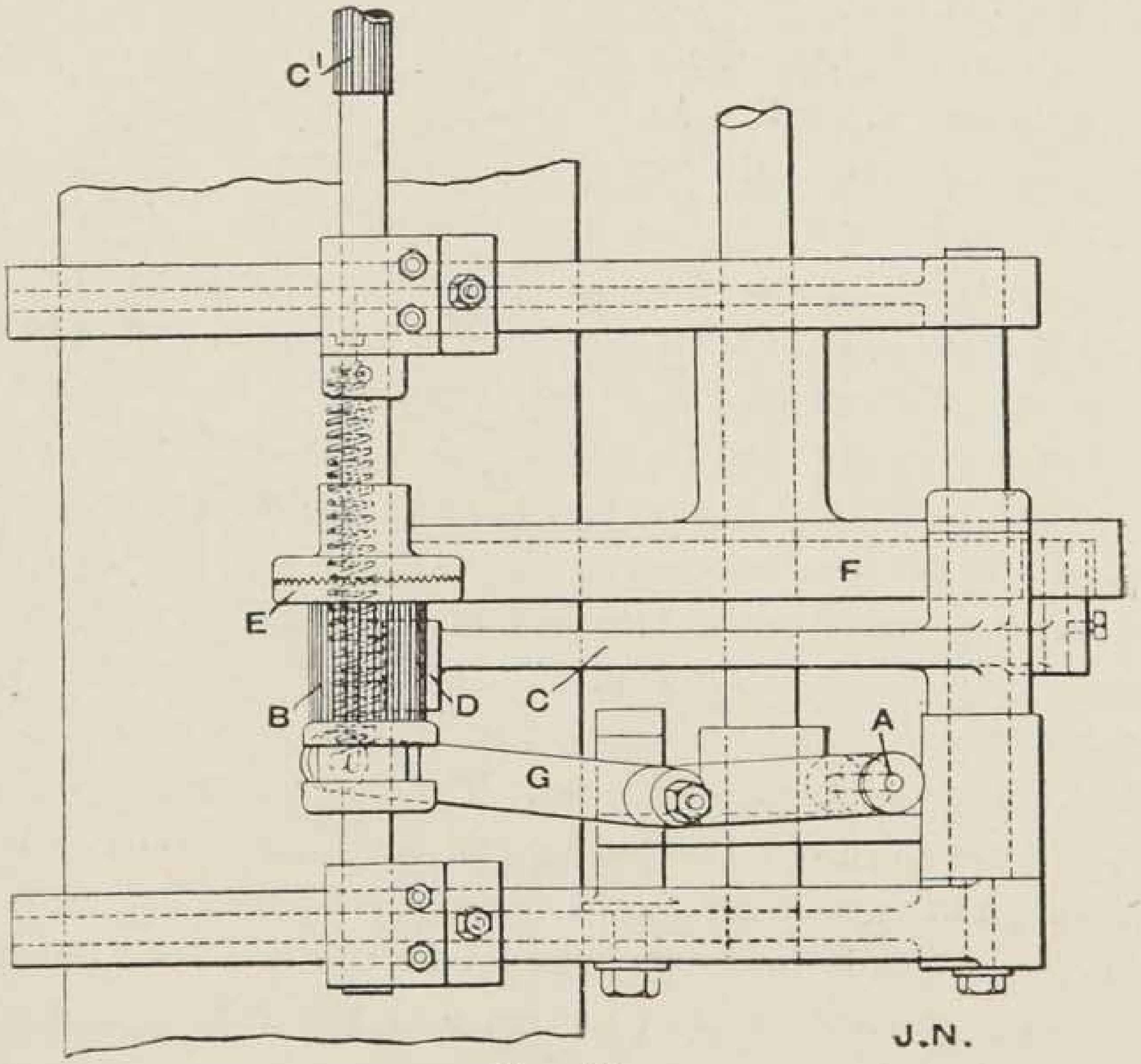

Fig. 45.

The length of fibre treated regulates the feed, and the feed roller is ordinarily rotated from $\frac{1}{8}$th to $\frac{1}{10}$th of a revolution. During this period the nippers are open and the top comb is up, but immediately the feed has terminated the cam K (Fig. 43) operates and closes the nipper. In the ordinary type of machine there is a continued movement of the top nipper upon the lower one, which causes the whole of the nipper to oscillate, thus bringing the end of the lap over the needles.

The comb cylinder is so driven and timed that immediately the nip is completed the needles pass through the lap end, and carry away with them the short fibres. Immediately this occurs the cam K carries the nipper slightly forward, so as to lay the combed end of the lap upon the segment N^1 (Fig. 42). The top comb, which is operated separately by a small cam O on the cylinder shaft, and the lever P (Fig. 43) is now dropped into the material a little in advance of the uncombed portion, and during this time the leather roller Q is being moved round the detaching roller S. At the moment the segment N^1 is presented to the end of the lap, Q is pushed upon it, and the rotation of the latter while this contact is established causes the detachment of the tuft of cotton. The end attached to the lap is, as it is detached, drawn through the top comb, and only the fibres of sufficient length to be engaged by the segment of leather roller are drawn away. A little earlier than the establishment of this second nip, the nipper jaws are opened so that the cotton can be easily pulled away. In order to attach the sliver properly to the detached cotton, the detaching roller is given, by means of the cam F, a backward movement—that is, one towards the cylinder—during the time the leather roller is approaching the segment. The extent of this movement is about one-third of a revolution, and is sufficient to carry back such a quantity of sliver as will enable the combed length to be laid on it when it is drawn forward in the manner described. As soon as the segment has passed, and the tuft is separated and combed by the top comb, the detaching roller is rotated in the opposite direction for about two-thirds of its revolution, the leather roller at the same time travelling back to its initial position. It will be seen, if a careful note be taken of the action of the detaching roller, that the newly-combed fibres are always laid on what may be called the single part of the sliver, because when the overlap is made for a length equal to one-third the circumference of the detaching roller, double that length of sliver is carried onward in the forward rotation of the detaching roller. Thus, when the return revolution of the detaching roller to the extent of one-third is made, it is only the single thickness of the sliver—that is, that portion where there is no overlap—that is carried backward. Thus there is an even thickness of sliver produced throughout, and the detachment and attachment is perfectly conducted. The end of the tuft which is detached from the lap is, as was said, drawn through the top comb, and the whole of the short fibres, nep and other impurities, are prevented from passing and are carried away at the next passage of the rotating needles. The attachment of the tuft is completed by the top brass-covered fluted roller T, the weight of which is great enough to sufficiently compress it. After leaving this point the combed sliver is gathered by a trumpet shaped guide and passed to a coiler, as in the case of a carded sliver, being first compressed by a pair of calender rolls U V.

(174) Such is the construction and action of this most intricate machine, and a few words may profitably be said on several special points in connection with its working. There are a large number of setting points provided, and there is perhaps no textile machine in which greater care is taken in this respect. Further, these settings are all extremely delicate, because it is necessary to deal with the cotton in short lengths, which practically implies setting the various parts to small fractions of an inch. Thus there are adjusting screws provided at various points, by which the range of action and position of the different parts can be accurately determined. As the rotation of the rollers is effected by cams, once these are set and fixed nothing can be done with them, but there are a few little points about them which can be treated with advantage. The condition of the needles is a most important matter. They should be carefully looked to, and if by any chance any of them have got broken or bent, especially if bent forward so as to be hooked, they should be immediately replaced, or at least removed. It is a good plan to overhaul the comb cylinders periodically, and the time for such an examination should not be greater than three months. It ought to be unnecessary to

say that the cylinders should be kept absolutely clean, and the spaces between the needles free from knots or accumulated dirt, and a thorough cleaning should take place not less than twice a week. The top comb needles should be well looked to, and broken ones replaced, as otherwise a stringy sliver will be produced.

(175) Perhaps the most important point in connection with the manipulation of a combing machine is the condition and setting of the various rollers. When the construction of the machine is considered it will be seen that, as all the rollers have to deal with the same length of cotton, it is an absolute essential for good work that their axes shall all be parallel to each other. It is obvious that if, for instance, the axes of the detaching and feed rollers were angularly disposed to one another, the cotton would be drawn away unequally along the face, and that a much greater pull would be exercised on the fibres at one side of the lap than at the other. Thus the parallel relation of the feed rollers, comb cylinder, detaching and leather rollers must be absolute. It is always possible to ensure the correct setting by adjusting the vertical position of the feed roller, and an examination of the sliver as it leaves the detaching roller will soon show whether the setting is correct. If this is cloudy or uneven it is a sign that the settings want looking to, as otherwise it will be found that there is a good deal of broken fibre in the sliver. The top brass detaching roller should be accurately adjusted so that its flutes are parallel to those of the detaching roller. This parallel relation should be as accurate as it would be if the flutes had to be inter-meshed. Unless this setting is adopted there will be a great danger of cutting the fibres, because the weight of the top roller would, if it were set crosswise, practically make it act as a spiral cutter. It is quite easy to ascertain if the two rollers are properly set if they are tried when cotton is not passing. By rotating them slowly their relative adjustment can be ascertained, and by means of set screws it can be made quite accurately.

(176) The cushion plate—*i.e.*, the bottom nipper plate—should be accurately set also, both as to its parallel relation to the feed rollers and to the upper nipper jaw. It is quite clear that if the nipper is not quite parallel to the feed roller the end of the lap will be unevenly combed. On the other hand, if the nip is not equal throughout the length some of the fibres are drawn out by the comb, and the sliver is materially weakened, in addition to which the waste is increased. The nippers should therefore be so adjusted that when a gauge is applied it will be equally gripped along the whole length. The use of an india-rubber strip in the top nipper jaw—as is done by Messrs. Dobson and Barlow—is attended by the advantage arising from a more even nip throughout if the setting of the two jaws is not quite correctly made, this arising from the yielding nature of the india-rubber. In combing machines of the ordinary construction care must be taken to see that the leather covering is in good condition and evenly laid. Any inequality in or damage to these speedily affects the working of the machine, and it is one of the points requiring special care. In like manner the covering of the leather roller must be looked to, and special efforts made to preserve its cylindricalness and smooth finish. The leather should be well coated with a good quality of varnish, and if these points are not attended to it will be found that cloudy webs will be produced. If the web has a curly appearance it is a demonstration that the setting of the rollers is not correct, but leads to a gathering up of the fibres instead of the disposition of them in straight lines. In addition to these special features it may be said that every working point should be carefully attended to. No loose joints of any kind are permissible, and the removal of all accumulations of fly or dirt is absolutely imperative. The very delicacy of the setting in itself furnishes ample reason for incessant vigilance.

(177) In order to facilitate setting, the wheel D is divided into 20 equal parts, which are marked and numbered on the rim, so as to be easily set to a pointer finger. In setting the machine the following procedure is adopted. The segment is

set when the index is at 5 by means of the $1\frac{1}{8}$th gauge. The feed actuating mechanism is arranged to gear when the index is at $4\frac{3}{4}$ and the top comb is down at $5\frac{1}{2}$. The detaching rollers are set so that when the finger is at 1 they are moving back, and forward at $6\frac{1}{4}$, the top detaching roller being fully down at $6\frac{3}{4}$. The nippers are arranged to close at $9\frac{1}{4}$. If the machine is making too much waste the feeding and nipping operations should be made at an earlier period; if the waste being extracted is not enough, then the reverse procedure is followed. It is always desirable that the top comb should be put into the cotton before the leather rollers commence to move forward. There is always a set of gauges provided to adjust the various parts relatively to each other, and the following are those to be used for the various parts :—

Combs set to 20th gauge.

Nippers set to 20th gauge.

Nipper pins set to first stop on stepped gauge.

Cushion plate set to $1\frac{1}{4}$ gauge from steel rollers.

The above are all for Egyptian cotton, and there is a slight variation for Sea Island. A speed of from 80 to 90 nips per minute is obtained with a machine of modern construction, and a production of 170 to 350lbs. per week of $56\frac{1}{2}$ hours can be obtained. The waste made varies of course considerably with the material used, but on an average is from 15 to 17 per cent. Although these strippings are of inferior quality to the cotton combed, they are good enough to stand working up again into yarns.

(178) We now come to deal with the process which is, in many respects, the most important in the whole range of spinning. We refer to the process of drawing. Upon the proper carrying out of this depends the fact whether the resultant yarn is truly cylindrical or not, and whether its proper strength is obtained. It is, in addition, the first stage, in the proper sense, in the formation of a thread, because, although it is true that no twist is introduced into the sliver at this stage, it is so far reduced that it can be readily formed

into a thread. Further, the drawing process is the last one in which any correction of the inequalities existing in the slivers can be made, so that when they leave the machine any irregularity of diameter or weight will thereafter be perpetuated. Finally, it is the treatment received by the cotton at this point which gives parallel order to the fibres in a sliver, especially if the slivers are collected from carding machines. As the web is produced on the latter, it consists of a thin sheet of fibres, disposed in all directions. The reduction of these to something approaching parallel order is one of the chief functions of the drawing machine.

(179) The drawing frame is, as shown in Fig. 46, which is a transverse section of the machine made by Mr. Samuel Brooks, a very simple machine, consisting of four pairs of rollers placed with their axes in one plane, but parallel to each other. The bottom rollers are made of a good quality of iron or steel, and are at intervals turned down to form the necks on which they revolve, leaving bosses between them. These bosses are longitudinally fluted with finely pitched flutes. The roller necks revolve in brass steps, fixed in brackets B, called "roller stands," fixed to a longitudinal "roller beam" C, and the bearings are so arranged that they can be readily adjusted relatively to the respective lines of rollers as desired. The lower rollers are made in sections, which are coupled by a special socket and spigot joint, so as to form a continuous "line" throughout the length of the machine. The upper rollers are made of cast iron in short lengths, and are formed with bosses, to correspond with the lower lines. They are placed above the lower rollers, against which they are kept pressed by weights E, suspended from hooks D which pass over the arbors of the rollers. The top rollers are made of cast iron, accurately turned, and are covered with a sheath of a specially woven cloth, surmounted with a cover of soft, smooth surfaced leather. Great care is taken in preparing the rollers to make them truly cylindrical and smooth, any adhesiveness of their surface being absolutely fatal to success. The top rollers are almost

universally made for the front line of a drawing frame of the Leigh loose boss type. This is called in America the "shell roll," and, as shown in Fig. 47, consists of a central roller of cast iron, formed with collars, the shanks of which are specially shaped to receive a cylindrical shell of cast iron, turned and

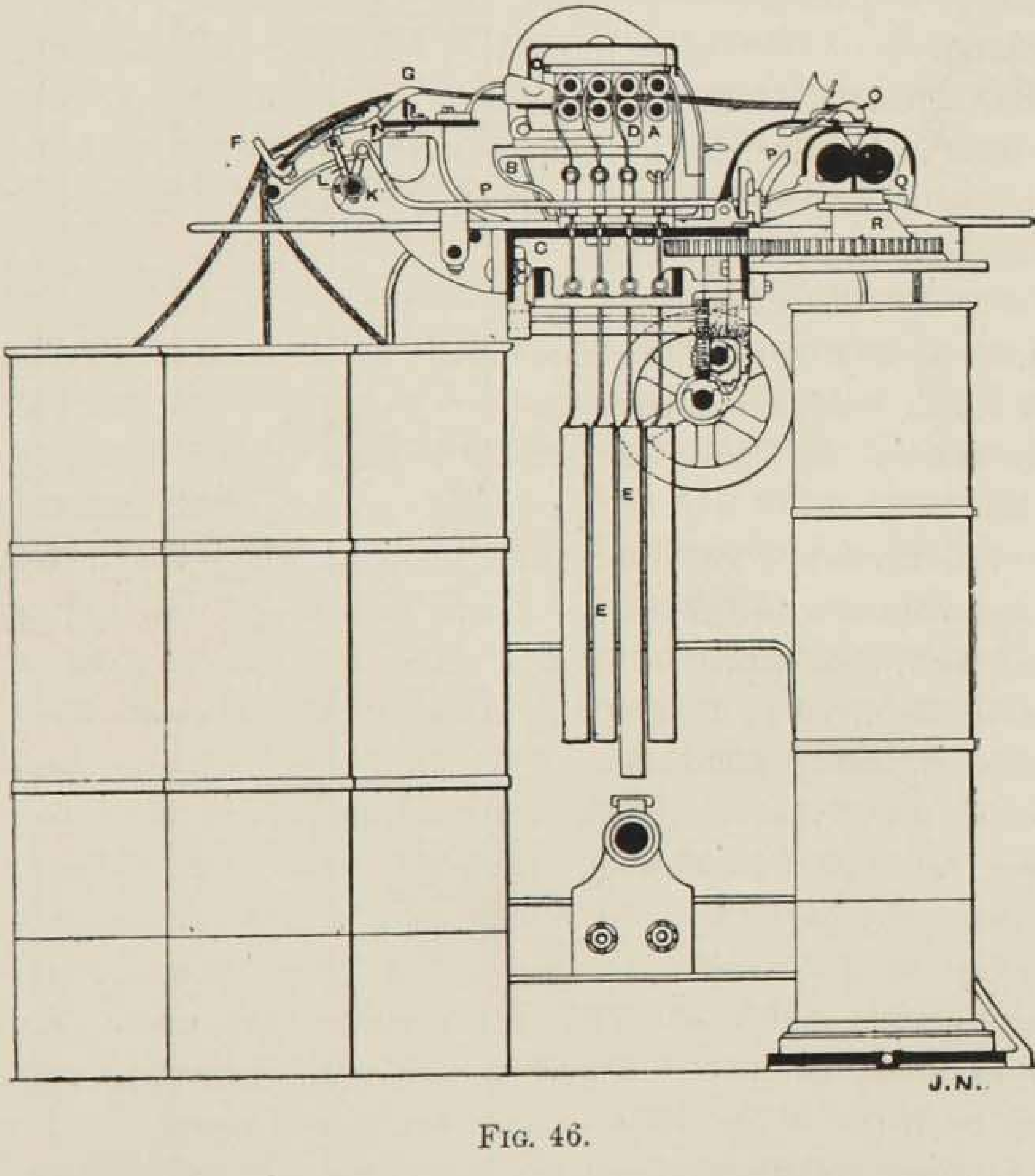

FIG. 46.

covered as described. The shape of arbor shown is the best for this type of roller, as it ensures steadiness of the shell. The advantage of this class of roller is, that as the body or shank on which the weights are hung does not revolve, but only the shell, the friction set up in rotating the roller is much lessened, and this is still further reduced by the facility with which the roller can be regularly and continuously lubricated. There is an ingenious method of securing the shells on the shanks, which consists of a small split ring of steel, which can close as the shell is pushed on, afterwards opening out and securely holding it. The upper rollers are kept in position by means of upper bearings formed in "cap bars."

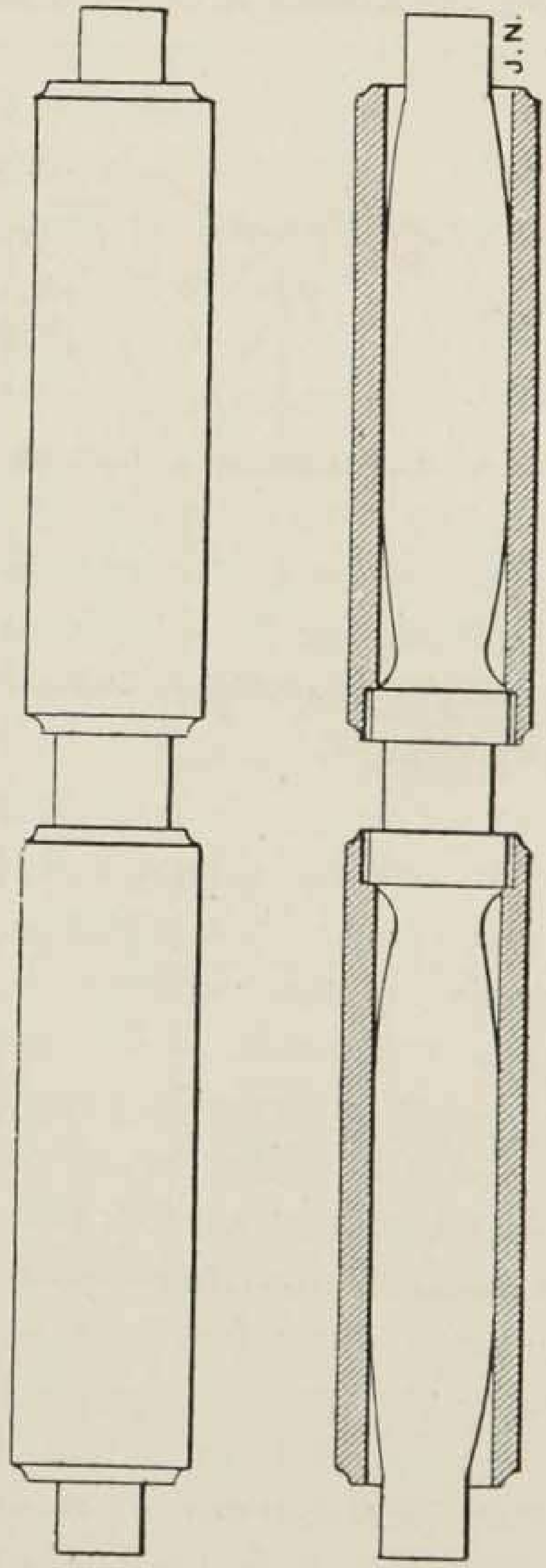

Fig. 47.

(180) A drawing frame is usually described as consisting of a certain number of "heads" with so many "deliveries." A "delivery" is the term applied to each sliver delivered at the front of the machine, and in each head there is a certain number of deliveries; in other words, so many completed slivers are passed. The lower roller is formed with as many bosses in each section as there are deliveries, so that if there are three of the former there will be three of the latter. The upper rollers have, of course, the same number of bosses as the lower rollers with which they are in contact. There may be a number of heads, but this is determined by several considerations to which special reference will be hereafter made.

(181) All the gearing of the drawing frame is placed at the

end of the machine. A view of this is given in Fig. 48, and will enable the description to be followed. This view has been sketched from the drawing frame in the Manchester Technical School. The frame is driven by a belt from the driving shaft, passing over a pulley on an intermediate shaft. By a second pulley fixed on the same shaft as the driven pulley the pulley T is driven. This is fixed on the arbor of the front roller A, on which also is a small spur pinion E, driving the crown wheel F, which is compounded with a pinion G, gearing with a wheel H on the back roller arbor D. Thus the front and back rollers are directly connected. The second line C is driven, as shown in a separate view 2, from the back line by means of the pinion I, carrier wheel J, and pinion K on the second line. The third line B is also driven from the back line D by the pinion L, carrier wheel M, and pinion N, on the arbor of the third line B. The coiler which is in this case employed is driven by the train of wheels O, P, R, and the bevel pinions shown.

(182) The four lines of rollers are driven, as will have been seen, at different speeds, and the statement of this fact at once brings us face to face with the very essence of the operation. The object of this variation in velocity is to procure a continuous attenuation of the sliver as it passes, and the amount of attenuation depends entirely upon the ratio of variation. Thus, if the surface speed of the back roller is 20 in. per minute, and that of the front one 120 in., the sliver would, as it emerged from the front roller, be six times as long and thin as it was when it entered the nip of the back rollers. Because the speed of the front roller is always the superior one, all the remainder are driven from it, the reason of this being very obvious, it requiring so much less power to reduce than to increase the speed of revolving bodies. It is the rule to effect the major part of the drawing by the front roller, and the draft between it and the third line is much greater than that between either of the others. The reason for this procedure is not far to seek. It is customary, as will be afterwards shown,

for several carded slivers to be fed to each delivery at one time, and when they reach the rollers they consequently form a thick strand. An excessive draft put upon these slivers at this point would probably be destructive. They are compressed and flattened out, and are only subjected to a slight attenuation between the first and second lines of rollers. Between the second

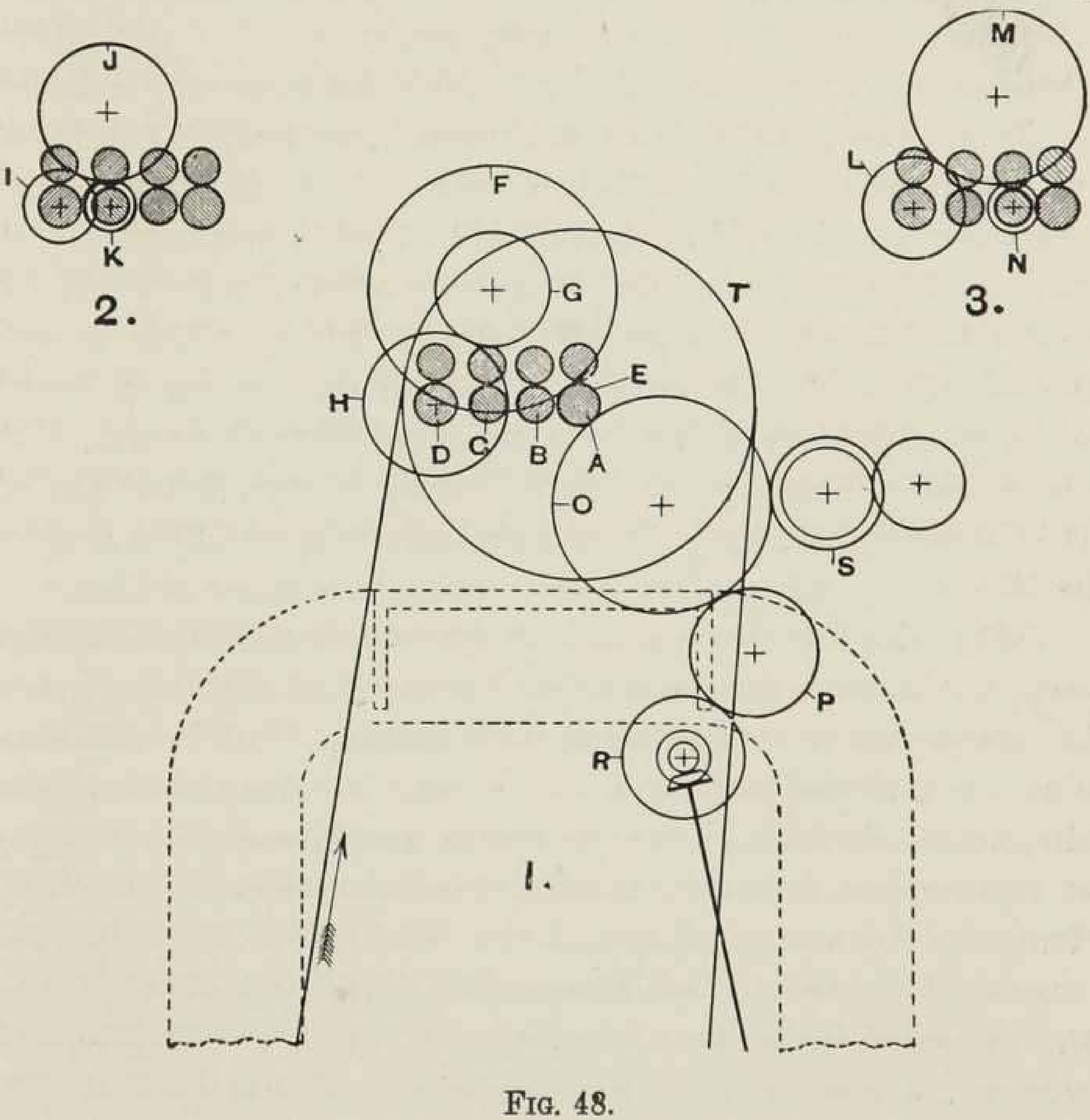

Fig. 48.

and third they are drawn a little more, and this gradual acceleration results in the establishment of an approximately parallel order. By the time the combined sliver leaves the third line of rollers it has usually been reduced to a little over twice its length, and the gentle pull so exercised puts the fibres into good condition for receiving the greater draft of the front line.

(183) To make this clear an examination of the operation in detail can be profitably made. The first thing to determine is what drawing is intended to do. It has a two-fold object, but the second is really a consequent of the first. Drawing is intended to reduce the number of fibres in the cross section of the combined sliver fed to a defined extent, and as a corollary, to place these fibres in the resultant sliver in practically parallel order. To effect the first result the increasing velocity of the various lines of rollers is necessary, and when combined with a proper relative setting of the centres of the rollers is practically perfect. The last-named point is really the most important, and an improper setting of the rollers results either in broken or imperfectly drawn fibres. The theory underlying the whole process is that of exercising such a pull upon the fibres as will enable them to be straightened, and cause them to be disposed longitudinally in the finished sliver. It is obvious that, if the fibres were laid even partially crosswise in the sliver, the greater part of the advantage of drawing would be lost. For, as has already been pointed out, the strength of a thread depends upon the number of fibres existing in its cross-section relatively to its diameter, and it is therefore clear that, unless they are drawn so as to lie lengthwise of the sliver, the chances of a strong thread are materially reduced. It is therefore necessary to submit them to such a pull as will straighten but not break them.

(184) When cotton is first taken from the bale the length of the various fibres differs considerably. The shorter fibres are removed during carding and combing, and the longer ones remain. They are not, however, so long when presented to the drawing frame as when passed into the opener, the reason of this being that many of them are broken at their points by the severity of the action of the scutcher. There is in almost every fibre near its point a part which is more brittle than the body, this being the result of the manner in which it is developed. This brittle portion easily breaks off, and the result is that when the fibre reaches the drawing frame it is ordinarily from 5 to 10

per cent shorter than as first presented to the spinner. This fact must be borne in mind in setting the rollers, and it is well to ascertain the average length of the staple in the carded sliver prior to adjusting them. When this has been done the rollers may be set, and in every case they should be arranged a little further apart than the length of the fibres. The proportion of excess varies with the character of the fibres. Harsh, wiry fibres which require a longer period of draft to pull them straight can have wider set rollers than the finer qualities, which are easily reduced. But in the former case the reduction of the cotton to proper order necessitates more repeated drawing than in the latter. The distance apart is also influenced by the class of sliver drawn. If a combed sliver is drawn the work of parallelisation is unnecessary, and only that of attenuation is required. This work is also considerably reduced by the mere fact of the parallel order of the fibres, because they slide easily alongside one another as the pull is exercised. It is desirable to take into account a large number of circumstances in setting the rollers, all of which influence the result. Thus the length of the roller bosses, and the sharpness of the flutes affect their drawing power materially, and it is possible when this is large to pass the fibres from roller to roller in a shorter time than when it is smaller. As a rule, if the fibre be an inch long the distance between the centres of the front and third lines of rollers should be $1\frac{1}{16}$in., that between the second and third $1\frac{1}{8}$in., and between the second and back lines $1\frac{3}{16}$in., or $1\frac{1}{4}$in.

(185) The question may be asked why it should be necessary to set the rollers so that at one period during the passage of a fibre no pull is being exercised on it except that induced by the secondary traction of the surrounding fibres. To this there is an obvious answer, but the question opens up the whole subject of the treatment of the fibre as it passes through the machine. In order to illustrate this point the diagram given in Fig. 49 has been prepared. This represents, on a reduced scale, the passage of a fibre an inch long through four sets of rollers, the

centres of which are indicated by the letters A, B, C, D, A being the front line. In order to condense the size of the diagram, the line marked E is repeated at the upper part of the diagram, and the remainder carried on in regular sequence. The fibre is supposed to have moved $\frac{1}{8}$in. for each line drawn, and the spaces between the rollers are arranged as described in the last paragraph. That is, the distance between A and B is $1\frac{1}{16}$in., between B and C $1\frac{1}{8}$in., and between C and D $1\frac{1}{4}$in. Now, it will be noticed that as the fibre approaches the nip of the back line at the point D, it is subjected to the pull of that pair of rollers for a considerable time. There is a slight pull at this point, because the slivers are being drawn out of the cans, and the weight of the sliver acts as a slight check upon the drawing in of the cotton. Gradually, however, the fibre is carried forward until it reaches a point where it lies wholly between the rollers C and D, without there being any grip exercised on it by either of these rollers. At this point what is happening is that the fibres which are actually gripped at C are being drawn forward, and in so doing are, in consequence of their adhesion to those adjoining them, not only held back at their free ends, but exercise a certain pull upon their neighbours. Thus the fibres which are free from any grip by the rollers, are not quite free from traction, although the extent of this is necessarily limited. The compression of the combined slivers, as they pass through the back rollers D, certainly creates an adhesion which is more or less effective for the purpose named, according to the quality of the cotton used. The fibres are gradually carried on until they pass into the nip of the rollers C, when the action just described begins to occur. We now come to a period when the fibre has passed partially through the nip of one pair of rollers, but has not yet come fully within the sphere of the next pair. Thus, assuming that the fourth fibre from the point E be taken as an example, about one-half having passed between the nip of the rollers C, what is the influence of the rollers B upon the end which has passed? There can be nothing more than an induced action created by the frictional or adhesive contact of contiguous fibres, but this is very considerable. The fibre is therefore carried forward by the rollers C, while at the same time its free end is being pulled in the manner described. The resistance which it encounters is, paradoxical as it may seem, the resistance of the rotating rollers C, which practically act as a retaining nipper. Thus, until it finally passes out of the influence of C, there is a pull exercised on it which is practically a retarding one—that is, the frictional contact is sufficient to enable the fibre to be drawn against the resistance of the delivering nip of C. In like manner, when the fibre finally passes forward clear of C, and is laid hold of by the next pair of rollers, the adhesive

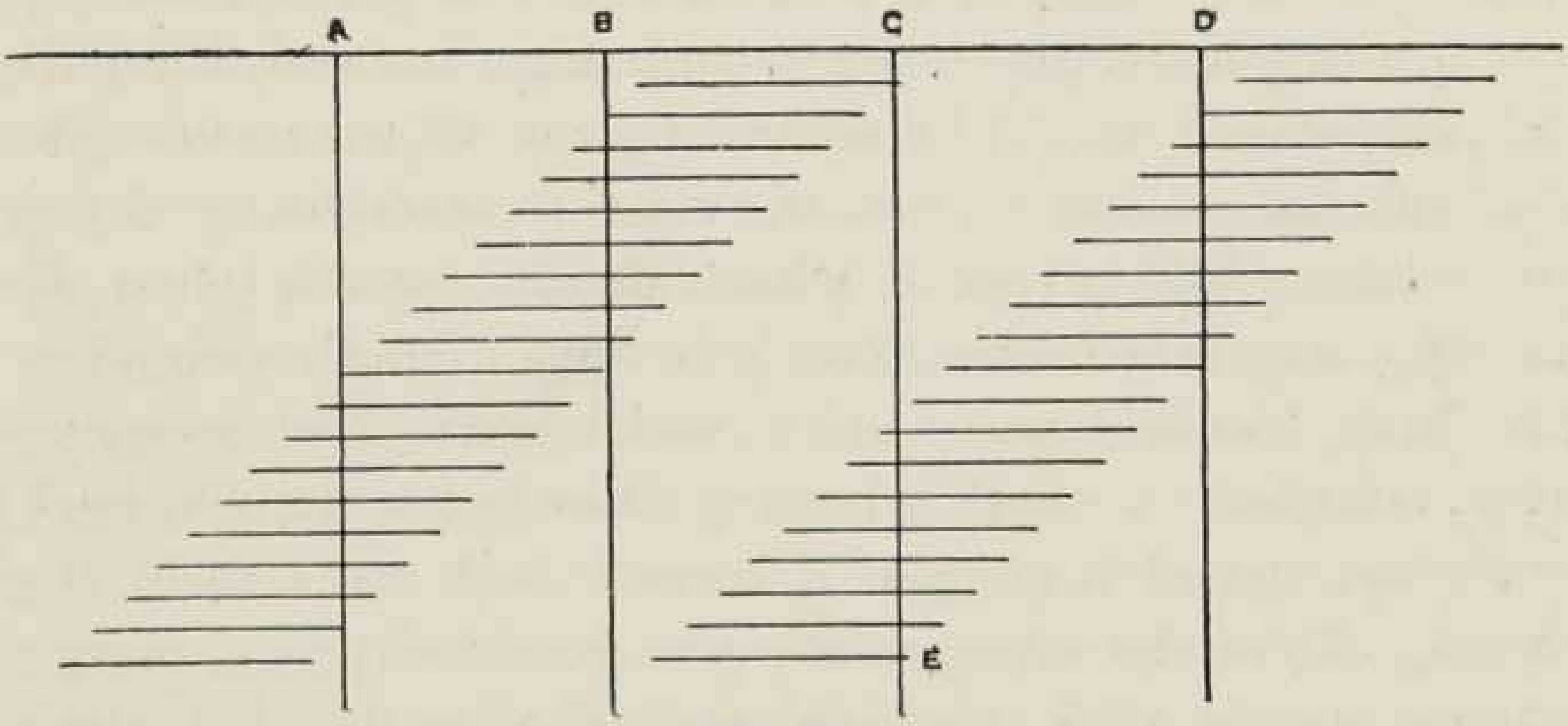

FIG. 49.

contact named practically acts as a backward drag upon its free end. This is quite clear upon a little reflection, because the rollers B, revolving at a superior speed to C, naturally tend to draw all the fibres forward at the increased velocity, while the more slowly moving rollers tend to prevent this accelerated forward movement. Thus there is a draft exercised on the fibres embedded in the mass, by which they are straightened and caused to lie in the line of direction of the pull exercised on them. If this description has been followed, it will be seen that the contention is, that the fibres are in three conditions during their passage through the rollers—gripped at one end by the rollers of inferior and free from contact with those of superior velocity ; free from the contact of both ; or gripped at the other end by the rollers of superior but free from contact with those of inferior velocity. In the gradual change of position which they assume the influence of the rollers of superior velocity is one tending to draw them forward, and that of the rollers of inferior velocity one tending to prevent them moving at a more rapid rate than the surface speed of the rollers. Thus the fibre is constantly being submitted to a strain in opposite directions, and the proportionate influence of each upon it will depend solely on the ratio of its total length within the sphere of the respective pairs of rollers. It is important to remember that unless this alternate draft upon each end of the fibre occurred there could be no straightening of it, and it is this fact which renders the correct setting of the rollers a matter of importance. It will be noticed that in no period of its passage through the rollers, however close their setting may be, is the fibre actually in contact with two rollers at one time. If it was, the superior draft of one pair would immediately pull it into two pieces, which is a thing specially to be guarded against. The action, which has thus been explained, is that by which the fibres are drawn into parallel order, but it also results in an attenuation of the sliver, as will now be shown.

(186) It has been explained that the four rollers indicated by A, B, C, and D rotate at gradually accelerating speeds, and it has also been shown that one effect of the drag thus exercised is to pull the fibres apart from each other. This can readily be tested, and the action observed by anyone who will get a small piece of carded sliver, and hold it with the left hand, while, at a distance of say two inches, gripping it with the right and then gradually withdrawing the latter from the left hand. The actual sliding of the fibres over each other can be seen, and the resistance which is felt to the movement of the hand is solely that occasioned by the frictional contact or adhesion of the fibres with each other. True, it is not a large resistance in the aggregate, but proportionately to the strength and size of the fibres it is considerable. But an examination of the sliver, after

this manual drawing has been made for some time, will show that its area has become contracted, if not throughout, at least in parts. In other words, it has been attenuated or drawn. If the process was continued sufficiently long, the sliver would rupture and be drawn into two parts. Now, if the two elements of a stationary and movable grip be exchanged for those of two revolving grips, we have, in the instance given, the true analogue of drawing. It is only necessary to arrange that the cotton shall be delivered by one of the nipping parts at a slower velocity than it is taken up by the other, to produce exactly the same kind of attenuation, but the degree, of course, varies in exact proportion with the difference in velocity. If the latter is made large enough the rupture of the sliver can be obtained, but by regulating the proportionate velocities properly any desired degree of attenuation can be obtained. It has thus been shown that a two-fold but connected action takes place in a drawing machine, and that, although the attenuation of the sliver is the main object, it is inevitably accompanied by the disposition of the fibres parallelly and longitudinally within it.

(187) It has been already indicated that a number of carded or combed slivers are fed to the drawing frame simultaneously. The number varies, but an average is six, and they are commonly spoken of as so many "ends" put up to the machine. They are first taken, as shown in Fig. 46, through the guide plate F, which is formed with a number of holes or guides, and thus acts as a separating plate. After passing through F, the sliver is taken over the end of a short, unevenly-balanced lever G, which can oscillate freely on a knife-edge bearing. The end over which the sliver passes is hollowed out and highly polished, being named, from its shape, a spoon lever. The superior weight of the inner end of the lever causes the spoon to be ordinarily raised, and the tension of the sliver as it passes to some extent counteracts this tendency, and presses the spoon down. By means of an eccentric, fixed upon a shaft suitably driven, a rod receives a reciprocal movement, and communicates it by a bell crank, rocking shaft K, and levers L, to a square bar

fixed in the upper end of the latter. On the shaft H a bell-crank lever is fixed, which engages with a snug on the stop rod, on which a longitudinal pull is exerted by means of a helical spring. As the strap guide is fixed on the stop rod, the movement of it in either direction respectively pushes the driving belt on or off the fast pulley.

(188) The object of this arrangement is to prevent the formation of what is technically, but erroneously, called "single." This is the passage into the drawing rollers of one or two ends less than the number put up, and arises from the breakage or failure of an end as it is taken from the can. The object of putting up so many ends will be discussed at a later point, but it may be stated that it is absolutely necessary that the combined sliver shall consist of all of those put up, as otherwise unevenness will occur. If, therefore, an end fails or breaks, the pressure on the spoon end of its respective lever G is removed, and the weighted end falls and comes into the path of the bar fixed in the levers L. Thus, when the latter endeavour to make their forward reciprocation they are unable to do so, and the rocking lever is thus oscillated so as to release the detent stop on the stop rod. The helical spring at once throws the belt on to the loose pulley and stops the machine. It may happen that after the sliver has emerged from the front roller it will break before it passes into the calender rolls Q. To stop the machine in this event a spoon lever O, of the same character as G, is used, which, when released, engages with a short lever P oscillated from the shaft H. The action is the same as in the former case. After passing the calender rolls, which it does in the shape of a loose rope, being collected by the trumpet guide shown, the sliver in some cases is passed through a coiler head, by which it is delivered into cans. In order to prevent damage to the cotton by overfilling of the cans, it is the practice to fit underneath the coiler head a loose plate, which can be pressed up, and which brings into action a stop lever having the same effect as the oscillation of any of the spoon levers.

(189) Before passing on to consider a few points in connection with the working of the machine, it should be stated that above the rollers are placed flannel-covered surfaces, the object of which is to collect the short fibres which are thrown off from the cotton in the form of "fly." These, unless carefully and systematically removed, gather into lumps or "slubs," and pass forward with the sliver into the cans. Whenever this happens, a thick place will be found in the subsequent yarn, which it is then difficult to remove. By placing above the rollers the flannel surface named, the fly is taken up by the rougher surface from the rollers, and these "clearers," as they are called, can be easily and regularly cleansed. The clearers are of one of three types, viz., (1) a round roller, resting in the space between the two rollers, so as to engage with two of them, and free to rotate; (2) a flat flannel-covered board, lying on the top of all four rollers; or (3) an endless flannel band, constantly traversed, one side of it pressing on the rollers, and capable of being freed from the collected fly by an oscillating comb. The last named is the best form of clearer, and is known as "Ermen's revolving clearer." The clearers should be at once removed if their surfaces get roughened, as otherwise there will be a great risk of licking and roller laps.

(190) The policy underlying the combination of several slivers at the drawing frame is practically that referred to in connection with the scutching machine. It is well established, although the effect is often exaggerated, that a good deal of advantage is derived from the passage of several slivers at one time. It is by no means an incontrovertible fact that the inequalities of a sliver forming one of a series will fall in the convenient manner often imagined. It is generally believed that the thick place in one sliver will be presented at the same time as the thin one in its fellow, but this is not demonstrated, and is many times contrary to fact. But it is true that if six or seven slivers are put up together it will probably happen that the thick places in some of them will be counteracted by the thin places in the others. Further, the gradual parallelisa

tion of the fibres as they are passed through the rollers induces a more even thickness of sliver, especially when the drawn slivers are themselves combined and passed through the machine once or twice. The mere attenuation of the sliver, if it does nothing else, reduces any existing irregularity, and when repeated two or three times practically corrects it. Thus if in one of six slivers put up, which should contain 9,000 fibres in their cross section, there was only 8,000, the total number of fibres in the six slivers would be 53,000 only instead of 54,000. When the combined sliver is reduced six times by a draft of 6, instead of containing 9,000 fibres it will only contain 8,826. It will be seen how rapidly the deficiency is reduced, and, if the attentuation is continued at a second head, as it always is, it practically disappears. But the most valuable features in this process of doubling are the reduction, by successive drafts, of the fibres to parallel order, and the gradual approximation of the sliver to a perfectly even condition, so that each foot contains more nearly the same number of fibres in its cross section, mainly in consequence of the parallelising operation. Doubling possesses many features of interest, but the observations of the author have confirmed the view that its chief merit lies in the establishment of parallel order in the fibres included in the finished sliver. It is true that the gradual reduction of the thickness of the slivers also tends to lessen or remove any inequalities, as just shown, but the real secret of an even *drawn* sliver is the production of an even *carded* one. This, in turn, implies care in the formation of a lap, and so the genesis of a perfect drawing is removed to the earliest process within a mill. Every sliver possesses its distinctive defects—if any exist—at different points in its length, and these do not all pass into the rollers at the same point, so that the continuous attenuation is likely to be of advantage. Whatever may be the explanation of it, the fact remains that when doubling is resorted to the finished sliver is much better than when it is not. It is usual to pass the slivers through three heads, and it is a very common thing to put up six slivers to each head. In this case the aggregate doubling received by a sliver is $6 \times 6 \times 6 = 216$. The question of the effect of the draft of the rollers and doubling the slivers will be dealt with a little later.

(191) Among the more important detailed points which, in the manipulation of a drawing frame, require attention, that of the condition of the rollers is most important. The lower rollers, being made of steel or iron, and fluted, are, of course, much more durable than the covering of the upper ones. It is necessary to see that the flutes of the rollers are kept clean and smooth, and that the points are not too sharp. Any roughness, however slight, speedily results in licking, and the greatest care must be taken to avoid this. The upper rollers being covered, a series of points arise of more or less importance. In the first place the cloth with which they are covered requires to be selected carefully to suit the class of roller which it has to cover. If a solid roller is used, a lighter cloth is permissible than when a loose boss or shell roller of the same length of boss is employed, and in like manner the shortening of the boss of a roller has an effect upon the weight of flannel used. The reason of this is that a loose boss roller requires a heavier weight applied than the solid roller, and the pressure upon its surface being so much greater necessitates a better bed for the leather. It does not really matter whether this careful grading of the weight of the flannel is made or not, provided that the thickness of the cloth used is ample for the pressure put upon the roller, as in most cases it will be. The point really aimed at is to provide a bed sufficiently firm to accommodate itself to the weight applied, so that while enabling the necessary pressure to be put on the roller there is no danger of crushing the fibres which are being drawn. Even with the most perfect bed there is always a danger of this crushing action, which is most objectionable and injurious. The tendency is for weights to increase, but the student will do well to bear in mind that no increased drawing power is worth having if it endangers the fibres in their passage. The cloth being selected of a proper

thickness, should be carefully formed into a sheath, and fastened on the roller boss. The greatest care must be taken to see that it is evenly stretched over the whole surface, and that there is no thick place where the two ends are joined. If this is not done, cutting of the fibres will take place at every revolution. The roller, in fact, must be as nearly cylindrical as possible, and the same remark applies to the leather covering, which must be equally carefully prepared. The skin-grinding machine of Messrs. Dronsfield Bros., Limited, is especially valuable in this respect, as it ensures the absolute evenness in thickness of the skins. After the leather sheath is prepared and put upon the roller, it is a very good practice to subject the latter to a rolling pressure, so as to make it quite cylindrical. No care is too great with the leather-covered rollers, if good work is required, and the smoothness of their surface must be absolute. Any roughness induces licking of the fibres, and means waste, the amount of which in a drawing frame ought to be very trivial. Any roller which is not running true, or the leather of which has become fluted, should be at once overhauled and be re-covered, if that is found to be the fault, or straightened, if the roller itself is strained. The question of whether a loose boss or solid roller is the best is one which possesses some interest.

(192) There can be little doubt that in England, at least, there is a liking for the loose boss roller, and something may be said on this point. The weight of a roller has a certain influence upon the drawing power, and we shall see that in many of the spinning frames it is the custom to make the top rollers of some of the lines self-weighted. In a recently-introduced form of drawing roller, both the top and bottom lines are fluted, and made of steel, and the top rollers are, therefore, of greater weight than the usual form. It is found that these fluted rollers can be employed without weights, this arising partially from the fact that the flutes intermesh and partly from their greater weight. If the construction of a loose boss roller be considered, it will be seen that the friction existing is that of its

inner surface against the outer surface of the arbor. This friction is still further reduced by the efficient lubrication of a roller of this type, so that the shell can revolve with ease. This fact has a two-fold bearing. It renders the rotation of the top roller easier, and at the same time it increases the necessity for weighting. An ordinary solid roller has to overcome the friction of the hooks on its arbor as well as the friction set up in its bearings. Both of these are absent in the loose boss, being replaced by the friction between the shell and arbor, which is much less than that of the hooks and rollers. The loose boss shell will therefore rotate more freely than a solid roll, and this fact renders it a little more difficult to obtain the nip required to obtain the draft. Thus the loose boss needs weighting, with due regard to the facts that it is more readily driven and is lighter than the solid roller, but this can be very easily arranged. With a loose boss roller one danger is practically removed. We refer to the abrasion of the fibres which occurs if there is any retardation of the rotation of the top rollers. For these reasons, although in some respects the solid roller is meritorious, the balance of advantage appears to the author to lie with the loose boss type, and by their use the wear of the leather is increased. On the other hand, it ought to be said that some spinners contend that a much better draft can be got with a solid than a loose boss roller, and that lighter weights can be used. With reference to the latter point it should be pointed out that the aggregate weight of roller and weights does not greatly differ in either case, and, with regard to the former, experience generally leads to the opposite conclusion. Further, it might be pointed out when double bossed top rollers are employed it is of less importance to have the diameters of each boss, when covered, exactly the same size with loose boss than with solid rollers. Each shell in the former case revolves independently, while in the latter the surfaces of the bosses necessarily revolve at one speed, and if the surface speed is not the same there will be a certain amount of rubbing, which is detrimental. The lubrication of all the rollers is of importance, and should be specially looked after. Care should be taken to prevent oil getting on to the leathers, and the periodical cleaning of the rollers is an absolute necessity.

(193) The arrangement of the cans behind the frame is worth a little consideration. The usual practice is, as has been said, to place behind the machine a number of cans—five to eight—for each delivery at the first head. Subsequently a certain number of those produced at the first drawing head are fed to the second head, and the same practice is pursued at the third. Now, it is obviously a faulty procedure to feed a number of full cans simultaneously, because at each head these would all run empty at once, and the machines be stopped until the attendant had pieced up the ends throughout the series. To avoid this it is better to feed them in sections, one section being full, the next section three-quarters full, the next half full, and the next quarter full. In this way the piecing can be effected with a minimum of stoppage.

(194) The question whether the resultant sliver from the drawing frame is thinner or lighter than that from the carding or combing machine which is fed to it depends for its answer entirely upon the number of ends put up and the total draft of the rollers. Suppose, for instance, that six ends are put up to a drawing head, the draft of which is six, it is obvious that there would be no reduction in the weight of the sliver delivered compared with that of any *single* sliver put up. It is, of course, true that every one of the latter has been reduced to one-sixth its original weight, but the combination of the six produces the full weight in the drawn sliver. If, therefore, it is desired to know what the weight of a drawn sliver will be, all that it is necessary to do is to multiply the weight of each by the total draft and divide by the number of ends put up. In order to establish a uniform method of calculation, it is customary to speak of a sliver as of such a number of hank, and this is arrived at as described in paragraph 162 in connection with carding. Thus, supposing the carded sliver is ·16 hank six ends are

put up, and the total draft of the draw box is 5, then the resultant drawn sliver will be $\frac{\cdot 16 \times 5}{6} = \cdot 133$. In this way the calculation can be made throughout, and, as will be shown at a much later stage in this book, the proper system is to plan the drafts from the opener to the spinning frame with strict relation to one another. The total draft of a frame is got by multiplying together the drafts—*i.e.*, the ratio of the velocities—of each pair. Thus, if the roller C (Fig. 48) travels at $1\frac{1}{4}$ time the velocity of D, the roller B $1\frac{3}{4}$ time as quick as C, and A 3 times as quick as B, then the total draft would be $1\frac{1}{4} \times 1\frac{3}{4} \times 3 = 6\frac{9}{16}$. Having determined what the drafts shall be, it is easy to make the necessary wheel changes required, and in doing so the velocity of the front roller is the determining factor. It is, for the reasons previously detailed, the practice to put in th larger portion of the draft between the front and third line of rollers. It is, therefore, only usually necessary to alter the relations between the velocities of the front and back rollers, unless this change is excessive, because, as will be seen at 2 and 3 in Fig. 48, the relations between the velocities of C, B, and D are practically fixed, and are affected by any change in the relative velocities of A and D. The necessary wheel change is therefore ordinarily made at E, that being a pinion which can be easily altered. Now the draft of the machine is the ratio existing between the surface velocity of the front roller and that of the back roller. The ordinary rule for this purpose is as follows.

(195) Multiply all the driven wheels and the diameter of the front roller together for a dividend, then all the drivers and the diameter of back roller together for a divisor, and the quotient will be the draft required.

(196) This rule is really the reverse of the true way of putting the case, but produces the same result. The value of a wheel train is usually calculated in mechanics by multiplying all the drivers and dividing that product by one obtained by multiplying all the driven wheels. If the quotient so obtained is

multiplied by the velocity of the first driver, the velocity of the last member of the train is obtained. Thus, in the case shown in Fig. 48, the wheel train consists of the wheels E, F, G, H, and its value is $\frac{E \times G}{F \times H}$ Now let us assume that the front roller is $1\frac{1}{8}$in. diameter, and the back roller 1in., and the velocity of the front roller 220 revolutions. Let also E have 30 teeth, F 90 teeth, G 42 teeth, and H 60 teeth. Then, according to the formula, the velocity of the back roller will be $\frac{30 \times 42}{90 \times 60} \times 220 = 51\frac{1}{3}$. The draft therefore is, according to this computation, $\frac{220}{51\frac{1}{3}} = 4{\cdot}3$ nearly. If the front and back rollers were the same diameter, this would represent the draft, but as they are 9 to 8, the draft is $4{\cdot}3 \times \frac{9}{8} = 4{\cdot}8$. If the draft be worked out by the rule detailed above, it will be found to be as follows : $\frac{90 \times 60 \times 9}{30 \times 42 \times 8} = 4{\cdot}8$, which is identical. Another method, and one that is the best, is to ascertain the surface velocities of the front and back rollers, and divide that of the former by that of the latter. The velocities can be arrived at either by calculating them in the manner described, and multiplying each by the respective circumferences, or by counting them. If, in the case named, the velocities are 220 of the front roller, the circumference of which is 3·5343in., and $51\frac{1}{3}$in. of the back roller, which has a circumference of 3·1416, then the relative surface velocities of each respectively are 777·546 and 161·268. Dividing the former by the latter we get 4·8, as before. It does not therefore matter which of the three methods is adopted, the result obtained is identical, but the latter is the simpler way. The drafts of the lines B and C are calculated in a similar manner as described in connection with the front line, the wheel trains being shorter, and as in each case the centre wheel only acts as a carrier, the factor needed in the calculation being for C line $\frac{L}{K}$ and B line $\frac{L}{N}$

(197) The calender rollers are driven by the carrier wheel T from a pinion on the front roller arbor, and revolve at a somewhat quicker surface speed than the front roller. This must be allowed for in arranging for the total draft. The coiler calculations need not now be dealt with, as they were fully gone into in connection with the carding engine. The length of sliver that the drawing frame will pass can easily be arrived at if the draft be known. Let it be assumed that the draft is 6, and that the front roller is $1\frac{1}{4}$in. diameter and revolving 300 times per minute, the back roller being $1\frac{1}{8}$in. diameter. To give a draft of 6, the velocity of the back roller must be 55·5. At this speed it will take in 196in. per minute of each sliver, while the front roller will deliver 1178in. of the drawn sliver. It follows, that if six ends be put up, the length of sliver taken up and delivered is practically the same. It was pointed out that the change is made in the drafts by means of the pinion G. If it is desired to change the hank drawing delivered, it is very easy to calculate the number of teeth in the new pinion. Thus, if a ·15 hank drawing is produced by a pinion of 36 teeth, a ·20 hank drawing would require a pinion $\frac{15}{20} \times 36 = 27$. This can also be arrived at by calculating from the weight of six yards of the drawing which is being made with any definite change wheel and that desired to be made. The rule is, that the coarser the drawing produced the larger the change wheel required, and *vice versa.* The hank of the final drawing made can be obtained, if the hank carding is known, by multiplying the latter by the drafts at each head and dividing by the number of ends up at each head. Thus, assuming the drafts in the three heads to be 4, 6, and 6, and six ends of ·15 hank carding to be fed at first, and six to each of the other two heads, the matter stands thus: Drafts $4 \times 6 \times 6 = 144 \times {\cdot}15 = 21{\cdot}6 \div 6 \times 6 \times 6 = 216 = {\cdot}10$ hank.

CHAPTER VI.

SLUBBING AND ROVING.

(198) In the scheme of operations which was given in paragraph 61, Chapter II., those of slubbing and roving are defined as drawing and twisting processes. They form practically the first stage in the formation of the twisted thread to which the name of "yarn" is given. As produced on the drawing frame the sliver is, as was shown, seldom much thinner than that obtained from the carding engine. It differs mainly in the important fact of the parallel order of the fibres within it, which is absolutely essential to the proper effecting of the twisting operation. The drawn fibre could be twisted into a yarn or thread, but its diameter would be too great for practical use. It is therefore essential to still further attenuate or draw the sliver, and this is usually done in three stages, of which the first is "slubbing." In the slubbing frame the sliver is drawn to the utmost extent which is permissible without damage to its strength, and is, as it emerges from the drawing rollers, given a slight twist. The twist given is only sufficient to impart a certain cohesion and strength to the yarn which will enable it to withstand the draft in the next of the series of machines. As the attenuation of the thread is continued until just before the final twist is put into it, it is highly desirable that up to this point it shall not be so "hardly" twisted—*i.e.*, have so many turns in each inch—as to present any obstacle in the way of the drawing action of the rollers. Accordingly it is the practice to put into the thread in each of the machines successively a definite amount of twist, but the amount put in in each case is not great. The final product of this stage is known by the generic name of "roving."

(199) Each of the machines of the series is practically the same in mechanical details, differing only in the size and strength of the parts. The slubbing frame is fed from the slivers in the drawing cans, and during the time the material is passing through the machine it is wound on to wooden tubes, being formed into a spool or "bobbin" with a cylindrical centre portion and truncated conical ends. The bobbins so produced are fed to the intermediate frame, being for the purpose fitted with round rods or "skewers" pointed at each end. By means of the skewers the bobbins are sustained in a nearly vertical position in a light frame known as a "creel," which is placed above the body of the machine. The creel consists of a number of light longitudinal rails which have fixed in them at regular intervals small porcelain cups or steps in which the points of the skewers fit loosely, so that when the thread is drawn off the bobbins the latter can easily revolve. It may be perhaps as well to explain at this point that any frame which is used for the purpose of holding the bobbins or spools from which a machine is fed is known as a "creel." The bobbins produced on the intermediate frame are smaller in size than those on the slubbing frame, and in consequence they can be placed nearer to each other in the creel in the roving frame. The same length of frame will therefore contain more bobbins. A creel may be one, two, or three in height, according to the number of rows of bobbins it holds. As at each operation the coarsely twisted thread produced is reduced in thickness, the bobbins on which it is wound are made less in size, and the pitch of the spindles is reduced.

(200) As the material passes from the cans or creel it is taken through the drawing rollers, which are in construction and mode of operation similar to those used in the drawing frame. There are ordinarily three lines employed; the top rollers for the back lines are of cast iron, and are made so much heavier than those for the front lines that they are not otherwise weighted. The rollers revolve in bearings of a similar character, and are fixed to the roller beam in a similar manner

to those used in the drawing frames. Clearers are fitted above and also below the rollers; a revolving clearer being sustained in bearings formed in a spring fastened to the roller beam, the spring being sufficiently strong to ensure the constant contact of the clearer with the rollers. The spindles are borne by two rails, one having bearings formed which act as "footsteps" for the spindle and the other rail carrying an upper bearing or "bolster." The spindles are in two lines, placed one behind the other, and are disposed rather peculiarly, their centres being arranged thus : ▪˙ ▪˙ ▪ . It will be noticed that those in the back line are not placed exactly midway between the others, but more to the left, and for this reason it is customary to describe the "gauge" of the spindles—that is, the distance from centre to centre—as being so many spindles in so many inches; as, for instance, 4 in $17\frac{1}{2}$in., 6 in $19\frac{1}{2}$in., and so on. The object of this peculiar arrangement is to enable more spindles to be fitted into any given length of machine, and to give easy access to the back line.

(201) The spindle A Fig. 50 is made from steel carefully ground, is reduced in diameter at the lower end to form a foot, and at the upper end is made with a taper spigot, fitting into the flyer B. The top end is slotted across, so that a pin driven across a hole bored through the central boss C, fits the slot and drives the flyer. The spindle only projects into the socket for a portion of its length, and the upper orifice of the boss is carefully rounded and smoothed. Near the top a hole C^1 is bored, which is also well rounded and smoothed, and through which the sliver or slubbing is threaded during spinning. The flyer has, as shown, two downwardly projecting arms B^1 B^2 connected to the boss by means of a bridge or coupling, piece. One of these arms carries two snugs or projections D D^1 acting as bearings for a pressure finger or "presser" E. This is a round rod hooked at its upper end, and bent to a right angle at its lower end. The presser is dropped into a socket, formed in D, and, being also sustained by D^1, is capable of oscillating freely. The inner end of the horizontal limb of the presser E

is flattened out and formed with a guide eye, and is of such a length from the vertical limb that it always lies about the centre of the empty bobbin F. The sliver or roving is passed through the boss C, out at the hole C^1, through the tubular

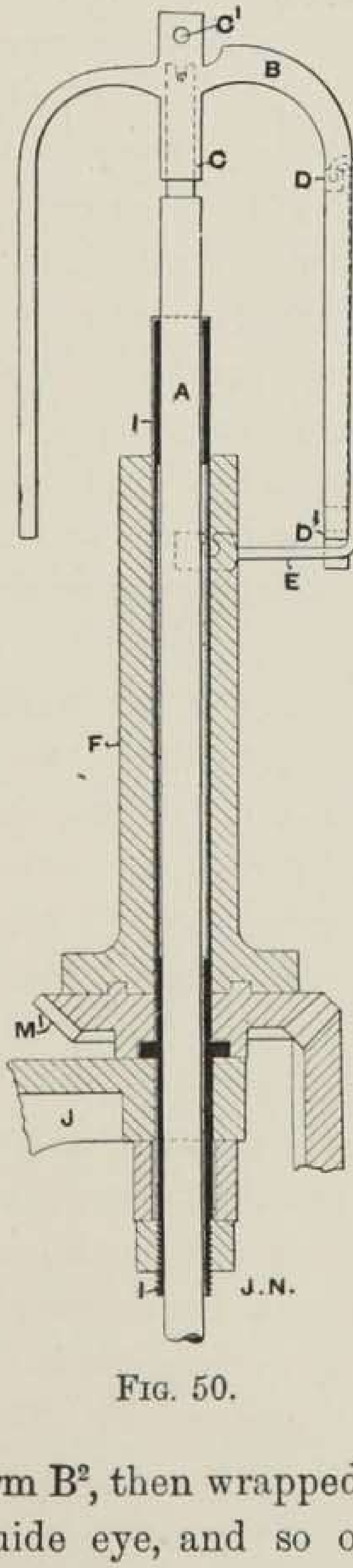

FIG. 50.

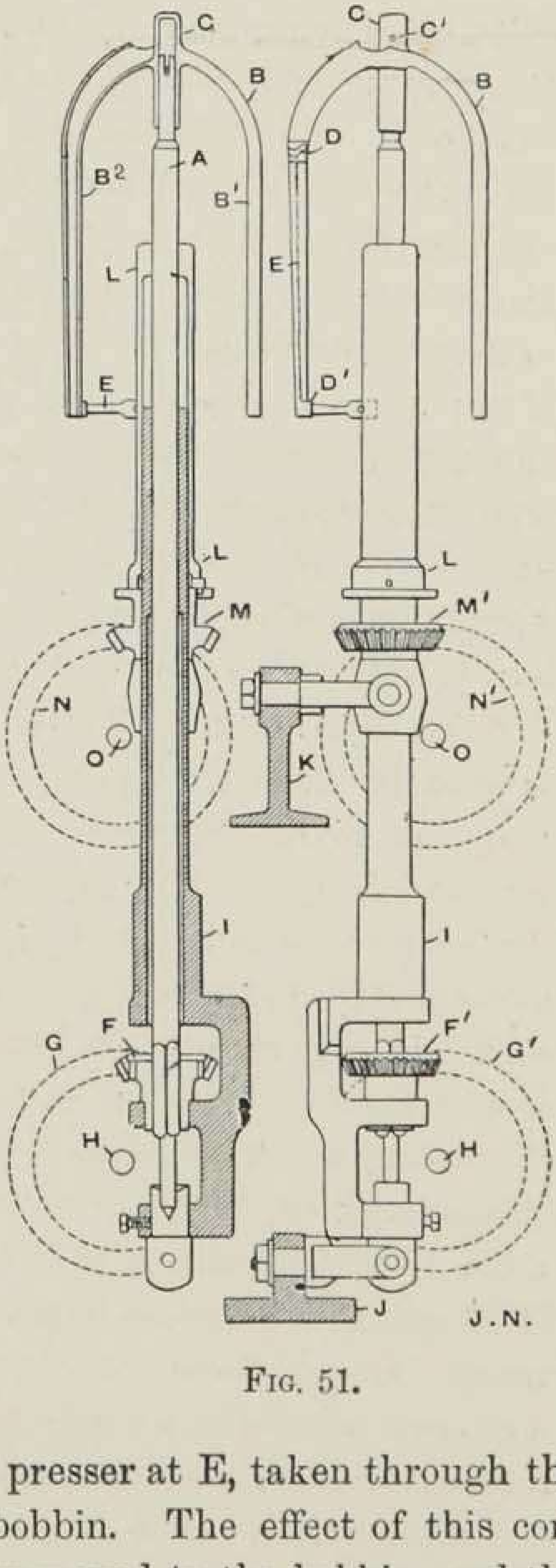

FIG. 51.

arm B^2, then wrapped round the presser at E, taken through the guide eye, and so on to the bobbin. The effect of this construction is that the roving is conveyed to the bobbin, and the centripetal force generated by the rotati on of the flyer establishes a tendency in the presser arm to move towards the centre of the spindle, and thus exercise a certain pressure on the roving being wound. If only one presser is employed, the arm carrying it is made tubular, and the balance of the flyer is restored by making the other arm solid. If a double presser is used—which is now very seldom done—both arms are made tubular. In either case the flyer is very well finished, being made of close-grained material and highly polished. Unless this is the case, "fly" rapidly accumulates, and forms "slubs," which may possibly pass forward with the roving, and form a thick place in it.

(202) The spindle is, as shown, borne by a footstep and bolster, and in order to give it steadiness it is usual to make the latter a tube, which according to length is spoken of as a "short" or "long" collar. The latter is shown in Fig. 50 at I, and extends upwards from the bearing to a point within the flyer. The advantage of this arrangement is the freedom from vibration arising from the support within the flyer. The collar is shelled out, so as only to be in contact with the spindle at the bottom and top, thus giving the maximum of support with the minimum of friction. Another method of mounting the spindle is shown in Fig. 51. The spindle A is carried in a long tube I, extending downwards until it forms a footstep for the spindle toe. The tube is attached to the rails J K by means of swivel joints, so that it practically forms a sort of cradle, and allows the spindle to adjust itself in case any uneven balance exists in the spindle. The latter is thus permitted to find its own centre of gravity, gyration being thus prevented and the friction on the bearings much reduced. There are many advantages in this construction over any other, and both the velocity and wear of the spindles and bearings are favourably affected.

(203) The spindles are positively driven by means of a bevel wheel F, fixed on the foot of each and fastened to the spindle by a set screw or, as in Fig. 51, formed with a square hole, into which a similarly shaped part of the spindle fits. The wheel on the spindle engages with a larger wheel G, fixed on a

shaft H, extending longitudinally of the frame. As there are two lines of spindles, two shafts H are used, one driven from the other, each line of spindles being driven by wheels of the same character. The wheels G G^1 are skew bevels, and the pinions F F^1 gear with them on their opposite sides respectively. As the shafts H H are driven one from the other they necessarily revolve in opposite directions, and the effect of this method of gearing the wheels is that the spindles are driven uniformly in one direction. The bobbins are driven by means of skew bevel pinions M and wheels N in the same way. The pinions M are borne in the bolster rail, and have a flange formed on their upper surfaces which sustains the bobbins L. The bobbins are provided with notches in their lower ends, which engage with projections or snugs on the flanges of the pinions M, so that the bobbin is positively driven. The rail K, bobbin wheel M, and bobbin are given a vertical traverse for a certain distance in each direction. This traverse is known as the "lift," and during its continuance the bobbin slides upon the spindle or collar, as the case may be. The extent of the traverse is from 5in. or 6in. in a roving frame to 10in. or 12in. in a slubbing frame. As the flyer eye continues to revolve in one plane during the lift of the bobbin, the spindle rail J being stationary, the roving is wound on the bobbin in coils which vary in pitch according to the velocity of the vertical movement of the bobbin. The spindles and bobbins are, it will be seen, driven independently, and may therefore be rotated at different velocities, the sliver being in the meantime delivered at a uniform and regular rate. The parts thus described form what may be called the essentials of the machine, and a description of their action can now be given, in the course of which one or two points of interest and importance will be treated.

(204) It was shown in Chapter I. that whenever fibrous material is twisted it is necessary to hold one or both ends while the twist is being introduced. In the roving frame the yarn is held at one end by being wrapped on the bobbin, and

at the other by the rollers. It is necessary to observe that the grip exercised is in the two cases of an entirely distinct character. The bobbin grip is one exercised by a rapidly revolving body which rotates at a velocity slightly greater or less than that of the flyer. On the other hand, the delivery of the yarn by the rollers is made at a much slower rate than the rotation of the bobbin or flyer, so that between the latter and the roller a certain number of twists or turns are put in the yarn. The number of these depends upon the ratio of the revolutions made by the flyer and the number of inches of sliver delivered by the rollers in any given time. If, for instance, the flyer makes 20 revolutions in the same time as the rollers deliver 5in. of sliver, there will be four turns put into every inch of the latter. This delivery may be intermittent or constant, but the effect is not varied so long as the ratio of the velocities of the two parts remains unaltered. It is the practice in all spinning machines, however, except in special cases, to deliver the sliver at a steady and continuous rate, and thus both the delivery and twisting are regularly conducted. All twists therefore are obtained at a uniform rate, and are defined, as indicated, as so many turns per inch. Thus, the chief features of a machine of this character are a steady, continuous delivery of a sliver which is drawn by the rollers, an equally uniform rate of twisting it, and the winding of the twisted strand, at a regular speed, on to the bobbin. The last two of these three points include the chief mechanical problem of machines of this class, the proper understanding of which is most important alike to the spinner and mechanic.

(205) From the illustrations in Figs. 50 and 51 it will be seen that the bobbin and spindle, although independently driven, rotate round a common axis. It follows that upon the relation existing between the velocity of the flyer eye in its rotation and that of the surface of the bobbin will depend whether any yarn or roving will be wrapped on the latter. The rollers deliver, as was shown, a definite length of sliver or slubbing, which must be disposed of by being wound on the bobbin. There are three

ways in which this can be done: (1) The flyer eye may revolve and the bobbin be stationary, so far as rotary movement is concerned; in which case, if the necessary vertical traverse is given to it, the material would be wound on its surface in coils; (2) the flyer eye may rotate at a speed so much superior to the bobbin that the roving will be wound on the surface of the latter; this is what happens when there is a "flyer lead;" (3) the bobbin may be revolved at a velocity so much in excess of that of the flyer that it will take up the roving and wind it upon the surface. This is the condition of things during a "bobbin lead." The first of these three conditions only holds good when one or two layers of yarn are to be laid, because if the bobbin remains stationary it is clear that the rapidly-increasing surface upon which the material is wound will stretch and ultimately rupture it. By so arranging the bobbin, however, that it can be sufficiently retarded by friction, this difficulty can be overcome, and this solution has been applied in the case of throstle spinning. In the roving frame, however, it is absolutely essential that the true relation of the velocities of the parts should be preserved, and a positive driving of the bobbin is therefore necessary.

(206) A few words may be expended in explaining the principle underlying the second and third methods of winding the rovings on the bobbins, and for this purpose the four diagrams given in Fig. 52 will be useful. In each of these the circle A represents the spindle, B the surface of the bobbin, and C the path of the flyer. The yarn passes from the flyer eye at D on to the bobbin at E, as shown in the figure marked 1. Now, if the two surfaces B and C rotate at a constantly uniform speed, the relation of the positions of D and E remains the same, and therefore no roving can pass from one point to the other. If, however, the flyer moves in its orbit at a superior speed to the surface of the bobbin, then, as shown in the diagram No. 2, the point D having gained the distance from E to F during any given number of revolutions over the point E, it follows that on the surface of the bobbin B yarn will be wound for that distance.

This is indicated by the thick line extending from E to F. This gain, if continued, will cause the roving to be wound on the whole of the peripheral surface of the bobbin, and the velocity at which the winding will take place depends upon the diameter of the bobbin B, upon its velocity, and upon the length of roving delivered by the rollers. This is the effect when the flyer leads. Now, if it be assumed that during any definite number of revolutions the point E on the bobbin has moved so much faster than the point D, representing the flyer eye in the third diagram, then the same result is produced by this excess of speed as shown in diagram 4, but in the opposite way to the former instance. In this case of a "bobbin lead," also, the amount of this excess of movement is limited by the three

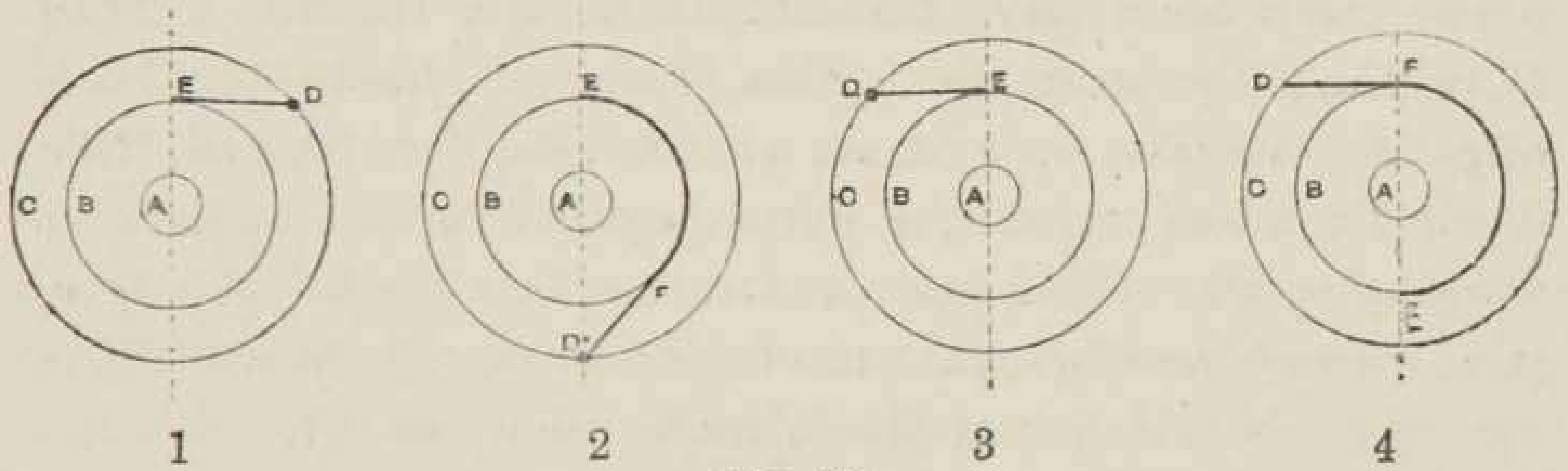

FIG. 52.

factors previously named. The explanation thus given holds absolutely so long as the diameter of the bobbin remains constant, but as soon as this is departed from the conditions are at once changed. Suppose, for instance, that the circumference of the front roller and of the bobbin alike is one inch. Then, so long as the velocity of the bobbin is the same as that of the rollers, it will take up all the material delivered by the latter. If, now, it be assumed that the velocity of the bobbin and rollers and the circumference of the latter remain constant, while the circumference of the bobbin be increased to 1½in., it will follow that for every inch of roving delivered by the rollers 1½in. can be taken up by the bobbin. As the roving is gripped by the rollers, this quantity cannot be obtained, and if such conditions arose the roving would be ruptured. It is therefore absolutely necessary to provide some means whereby the velocity of the bobbin can be reduced as its diameter increases, so that its surface speed shall coincide exactly with that of the rollers.

(207) It is the practice at the present day to adopt the bobbin lead, and there are several reasons to commend this course. It will be shown hereafter that the bobbins and flyers are driven by two trains of wheels. Of these, the train driving the spindles contains the fewest members, and is directly connected with the driving shaft. Thus there is more danger of delay in the commencement of the rotation of the bobbins than there is in that of the spindles. When a frame is started, therefore, the spindles begin to revolve a little quicker than the bobbins, and the flyers tend to slightly stretch the roving before the bobbins have assumed their true relative velocity. If, on the other hand, the bobbin leads, the tardy commencement of its rotation only causes a little slack place to exist, which is rapidly taken up as the parts begin to revolve at their full working speed. In addition to this fact there is another, which is, in view of the wear and tear of the frames, not unimportant—viz., that the velocity of the wheels, when the flyer leads, is much greater than when the bobbin leads, and accelerates as the latter fills with roving, which it does with every lift of the bobbin-rail. If the bobbin has to lag behind the flyer, as is the case with the latter leading, it is easy to see that the retardation must be greater when the bobbin is empty than when it is full, for it is clear that there is a smaller surface on which the roving is wound in the former case. As the bobbin fills therefore, its surface velocity must be increased, in order that the relative position of the point where the yarn leaves the flyer and that where it passes on to the bobbin, shall be preserved. Let it be assumed again that the bobbin and rollers are the same circumference, then the bobbin must lag behind the flyer one revolution for every revolution of the roller. If, however, the circumference of the bobbin is increased to double that of the roller, then it is clear that its periphery with the same amount of retardation would not be covered, but that such a drag would

be put on the roving as to stretch and break it. Thus half the retardation is sufficient, and the bobbin must be quickened in order to attain that end. The reverse of this is the practice when the bobbin leads. In that case the bobbin requires to run at a velocity so much in excess of the flyer as will enable it to take up the roving delivered by the rollers. Now it will be at once apparent that the smaller the surface on which the roving is wound, the greater the number of revolutions needed to take it up as delivered by the rollers. Thus a gradual diminution of the speed of the bobbins takes place as they are filled. The action is not easy to describe, but may be briefly put thus. With the flyer leading, the roving is *wrapped* on a surface which is moving at a relatively slower pace than the flyer-eye. With the bobbin leading, the roving is *drawn* on to a surface travelling a relatively quicker pace than the flyer eye. Therefore, the larger the diameter on which the roving is wrapped—given a uniform delivery—the greater its velocity when the flyer leads, and the less when the bobbin leads. Now, it should be noticed especially that the increase in speed takes place, with the flyer leading, as the bobbins become heavier, and therefore more difficult to drive; while with the bobbin leading the highest velocity is attained when the bobbins are lightest. From the point of view of the spinner this is a matter of some importance, as it diminishes the strain on some of the parts very considerably.

(208) Before proceeding further it is necessary to describe in detail the mechanism employed to drive the various parts, and in order to do this the diagram given in Fig. 53 can be referred to. The driving shaft A has on its outer end a pair of pulleys, fast and loose, by which the machine is driven from the counter shaft. The shaft A extends within the framing of the machine, and has fixed upon it the wheels B and O. From the wheel B the shaft C is driven by means of the carrier wheel shown and pinion B^1. On C is fixed the upper cone E and the pinion C^1. The latter gears with the wheel D on the front roller shaft, by which means the front roller D^1 is driven, and from it the

second and third lines, as shown. The spindles are driven by the wheel O, communicating motion by a carrier wheel to O^1, fixed on the end of one of the spindle driving shafts, the second spindle shaft being driven from the first, as was described, by a pair of spur wheels fixed upon each respectively. The bevel wheels W W^1 communicate the rotation of the shafts to the spindles. The bobbins K are driven by the bevel wheels M M^1 by means of a train of wheels N K^1. The carrier wheel between N and K^1, K^1 itself being fixed on one of the bobbin driving shafts, is sustained in a swing frame—shortly called the "swing"—which is centred upon the shaft A. The "swing" is, in the best machines, made double, so as to give a good bearing to the arbors of the wheels, and is secured to a box or frame, which extends along the frame, and within which the bobbin driving shafts and the wheels fixed on them are sustained in suitable bearings. The bobbin rails and box are attached to vertical racks or pokers V, which are suitably guided, and to which an alternate reciprocal motion is given by the rotation of pinions V^1, obtained in a manner to be afterwards described. Thus the bobbin rails receive a vertical motion up and down for a distance which is regulated by the period of rotation of V^1 in either direction. The swing being fastened to the bobbin rail is caused to oscillate on its centre, and the wheel K^1 and its carrier are made to roll round the wheel N. In this way the necessary constant driving of the bobbin K is obtained, while at the same time it can receive the requisite vertical traverse to effect the operation of winding. The wheel N, known as the "bobbin wheel," is compounded with a wheel I^1, forming part of the differential or equating motion, a full treatment of which will be made presently. I^1 is driven by means of the intermediate carrier wheels J J^1, from the pinion I, which is fastened on and revolves with the driving shaft. The carriers J J^1 are borne in studs fixed in the arms of the plate or stud wheel L, which rotates on a sleeve surrounding the shaft A, and which is driven by a pinion L^1 fastened to a shaft H. On the end of H is a pinion G, driven by a carrier from a wheel G^1 fixed on the axis of the lower cone E^1, which receives its motion from the upper cone E by a strap F. On the shaft H is also a bevel pinion R engaging with a wheel R^1, fastened on the head of a vertical shaft, on the lower end of which a pinion S is secured, which can be engaged by either of the wheels S^1 S^2—called "striking wheels"—when they are thrust into gear with it. The pinions S^1 S^2 are fixed on a shaft which has a long pinion T fastened on it, T engaging with a pinion T^1 on a short shaft borne by the framework. This shaft is in front of the spindle shaft from the point of view in Fig. 53, and should not be confused with it. A pinion U keyed on it engages with a wheel U^1, fastened on a horizontal "lifter" shaft, on which the pinions V^1 are secured. Thus the latter receive rotation in a direction which is dependent entirely on the engagement of either S^1 or S^2 with the pinion S. The traverse of the strap F on the cones and the alternate engagement of S^1 and S^2 with S are both controlled from the motion Q, to which special reference will be hereafter made.

(209) The general description thus given will enable the operation of the various parts to be understood. Assuming the speed of the driving or "jack" shaft A to be 300 revolutions per minute, the velocity of the spindles is obtained by multiplying together the driving wheels and dividing the product by that of the driven wheels multiplied together. The dimensions about to be given are all taken from a frame in actual work, which was producing a roving for a special purpose. They will, however, enable the relative influence of the various parts to be followed with ease, and will also show the mode of calculating the velocity of the various parts. We will first, therefore, ascertain the relative velocity of the spindles and rollers, so as to determine the twist put into the roving. The spindles are driven by the wheel O, with 60 teeth, driving, by means of a carrier wheel, O^1 which has 50 teeth. O^1 is on one end of a shaft having on the other end the bevel pinion W, with 50 teeth, gearing with the spindle wheel W^1, with 22 teeth. The

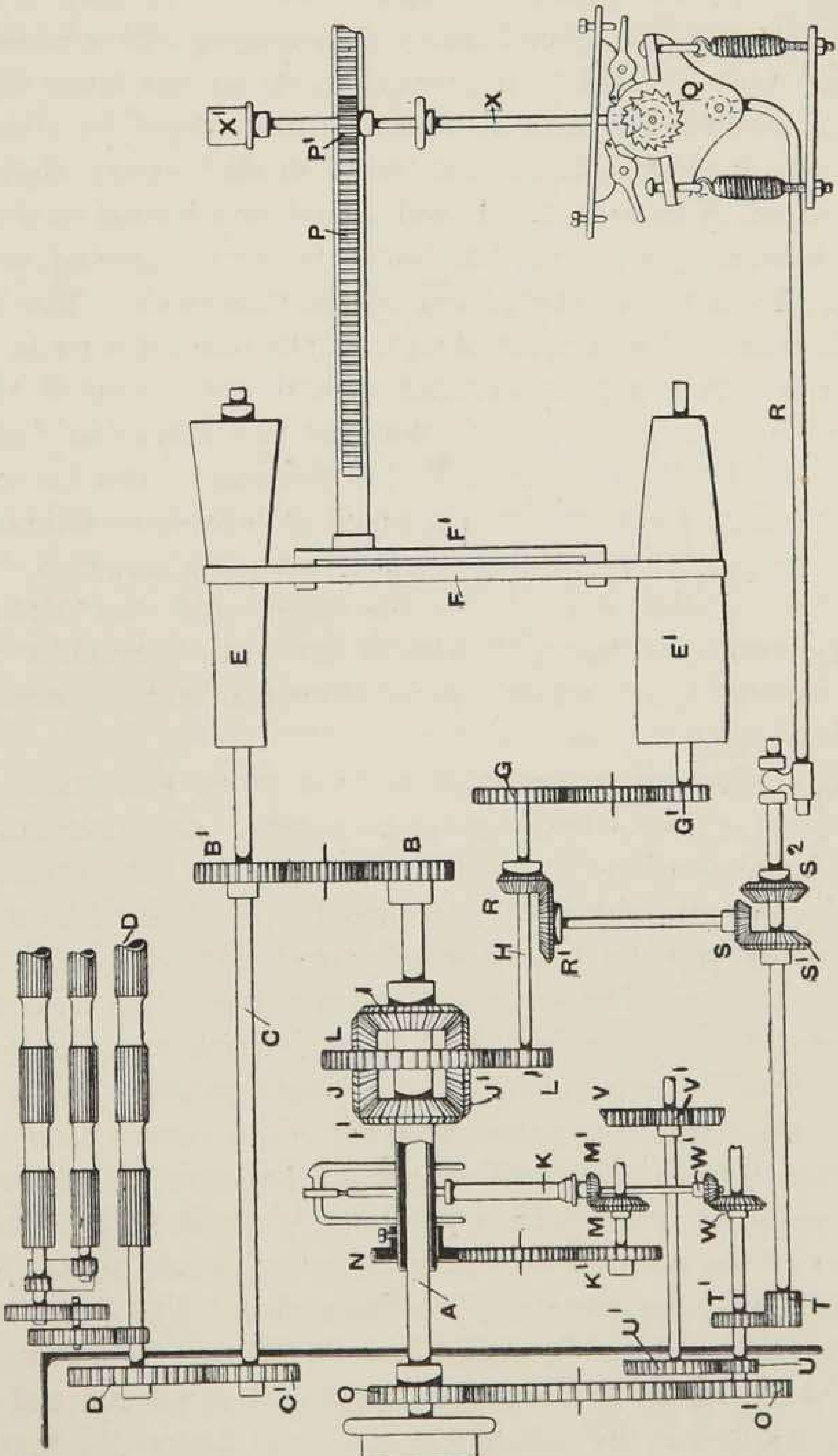

Fig. 53.

velocity of the spindles is therefore $\frac{60 \times 50}{50 \times 22} \times 300 = 818$. The front roller is driven from the jack shaft A by a pinion B, known as the "twist" wheel. By changing this wheel the relation of the velocities of spindles and rollers is entirely changed, and, as will be afterwards shown, every motion in the frame is controlled by this wheel. B has 28 teeth, and drives, by the intervention of a carrier, the wheel B^1 fixed on the top cone shaft C. B^1 has 32 teeth, and on the outer end of the shaft C is a wheel C^1 with 34 teeth, which meshes with the wheel D on the front roller shaft having 120 teeth. The velocity of the front roller is therefore $\frac{28 \times 34}{32 \times 120} \times 300 = 74$. The front roller being $1\frac{1}{8}$in. diameter, it will deliver 261·2 inches of yarn per minute. The twist is therefore $\frac{818}{261 \cdot 2} = 3 \cdot 13$ per inch. The second and third lines of rollers are driven by means of a pinion with 20 teeth gearing into a crown wheel of 110 teeth, compounded with a pinion having 35 teeth, which gears with a wheel of 57 teeth on the back roller. Thus the speed of the back roller is $\frac{20 \times 35}{110 \times 57} \times 74 = 8 \cdot 26$, and that of the centre line is the same, the driving being arranged for this purpose. The back roller is the same diameter as the front roller, and the draft is therefore $\frac{74}{8 \cdot 26} = 8 \cdot 97$, which is somewhat in excess of the usual draft, and, as will have been noticed, is put in entirely between the centre and front rollers.

(210) We now come to deal with the driving of the bobbins, and on the assumption that the bobbin is leading, we have to deal with a case in which it shall travel so much in excess of the velocity of the flyer as to take up in every minute the 251·5in. of yarn delivered by the rollers. The upper cone shaft C rotates at $\frac{28}{32} \times 300 = 262 \cdot 5$ revolutions per minute, and drives the upper cone E at that velocity. Assuming that the

strap was on equal diameters of each cone the lower cone E^1 would be rotated at the same velocity. In that case the pinion G^1, which is on the lower cone shaft and has 15 teeth, will drive the wheel G with 75 teeth at $\frac{15}{75} \times 262 \cdot 5 = 52 \cdot 5$ revolutions. G is fastened on the shaft H, on which is also the pinion L^1 with 20 teeth engaging with the "sun" or "stud" wheel L, having 125 teeth. L therefore is revolved $\frac{20}{125} \times 52 \cdot 25 = 8 \cdot 4$ times per minute. The wheel L forms part of the "differential" or "equating" motion, which requires a special explanation before proceeding further. This motion is sometimes called the "Jack in the box," and is perhaps more widely known by that name than by any other.

(211) The differential motion belongs to that species of motions which are known in mechanics as epicyclic trains, and which consist of two wheels geared together by carriers, borne by an arm which revolves on a common centre with the driving wheel during the rotation of the driving and driven wheels. In this special case the wheel I fixed on the "jack" shaft drives by the intervention of carrier wheels J J^1 the wheel I^1 loose upon the same shaft, and compounded with the wheel N which is either cast in one piece with it or fastened on its boss. It is now customary to provide a tube surrounding the "jack" shaft on which the wheels L and I^1 N revolve. By shelling out the tube and providing special means of lubrication the friction on the shaft is much reduced. The carrier wheels J J^1 are borne by studs fixed in the arms of the wheel L, and are free to revolve thereon. Thus they have a rotatory motion upon their axes, and are simultaneously carried round the orbit of the wheel L as it is revolved. The motion of these parts produces a very remarkable result in practice, and as it is often only imperfectly understood a full explanation is given. If the pinions J J^1 were mounted on centres which were stationary, the rotation of the wheel I would cause I^1 to revolve at the same speed in the contrary direction.

If now the wheel L is revolved in the same direction as I, and at an equal velocity, the whole of the wheels will be locked, and I^1 be carried round at the same speed as I. If, however, the wheel L rotates at a slower speed than I, but still in the same direction, then for every revolution of L the wheel I^1 will lose two revolutions as compared with I. Thus in practice a curious result is produced. When the velocity of L is half that of I, and its direction of rotation the same, the motion of I^1 entirely ceases. As the velocity of L still further decreases the velocity of I^1 increases, but its *direction* of rotation is reversed. Thus what happens is, that if the velocity of L is either more or less than half that of I, its direction of rotation being the same, the velocity of I^1 is increased, but the direction of its motion is altered—that is to say, the central point is a zero, and there is a gradual acceleration until either of the poles—as they may be called—are reached. Thus, if L revolves in the same direction as I, and makes more than half the number of revolutions of I, then the wheel I^1 will move in the same direction as I, at a constantly accelerating velocity, as the speed of L and I approximate to one another. If, on the other hand, L rotates at less than half the speed of I, then there will be a constantly accelerated velocity as the speed of L is decreased, but the direction of the rotation of I^1 will be reversed. It may be convenient to give the formula ordinarily employed to calculate the value of this class of wheel train. It is $n = 2a - m$, where $n =$ the number of revolutions of the last wheel I^1, $m =$ the number of revolutions of the first wheel I, and $a =$ the number of revolutions of the stud wheel L. Thus, if $m = 300$ and $a = 150$, then $n = 2(150) - 300 = 0$. If $m = 300$ and $a = 100$, then $n = 2(100) - 300 = -100$, indicating that I^1 is revolving 100 times per minute in the opposite direction to I. If $m = 300$ and $a = 200$, then $n = 2(200) - 300 = 100$, or in other words, I^1 and I are revolving in the same direction at that speed. Now, if the wheel L revolves in the opposite direction to I, quite a different state of things arises, for the formula then becomes $n = -2a - m$, the quantity a having, by the reversal of the movement of L, become a minus quantity. Then the equations become as follows, when (1) the wheel L is stationary, (2) when it revolves at half the speed of I, and (3) when it revolves at the same speed as I, but all in the opposite direction : (1) $n = -2(0) - 300 = -300$; (2) $n = -2(150) - 300 = -600$; (3) $n = -2(300) - 300 = -900$. In other words, the velocity of the wheel I^1 steadily increases with the increase in the speed of L, but the direction of its motion is in all cases the reverse of that of I. This fact has an important bearing upon the working of the motion, because it enables an equal velocity of the wheel I^1 to be got with a slower speed of the wheel L. Further, when the bobbin leads, it is possible to commence the operation with a comparatively moderate speed of the wheel L, and to still further reduce it as the bobbin fills and requires a smaller circumferential speed. Thus we arrive at the conclusion that when the flyer leads it is better to run the wheel L in the same direction as I, and gradually accelerate the velocity of I^1, while with the bobbin leading it is necessary to rotate the wheel L in the opposite direction to I, and gradually diminish the velocity of I^1. From the point of view of wear and tear, there is no comparison in the merits of the two systems.

(212) Without pausing to consider the way in which the wheel L has its rotation diminished, we will take up the calculation where it was dropped in paragraph 210, merely premising that the wheel L is rotated in the opposite direction to the jack shaft, and consequently to I. We saw that L was revolved 8·4 times per minute, therefore according to the formula $n = -2a - m$ we get the velocity of I^1 as $-2\ (8{\cdot}4) - 300 = 316{\cdot}8$; that is, I^1 is revolving in the opposite direction to I at a speed of 316·8 revolutions. The wheel N has 60 teeth, and drives by the intervention of a carrier the wheel K^1, which has 50 teeth. On the same shaft as K^1 is the bobbin wheel M with 50 teeth, which drives the bobbin by means of the pinion M^1 with 22 teeth. Thus the velocity of the bobbin is $\frac{60 \times 50}{50 \times 22} \times 316{\cdot}8 = 864$, which is 46 revolutions in excess of that of the spindles.

(213) An examination can now be made of the effect of the cones upon the motion of the "stud" or "sun" wheel L, and in doing so it will be necessary to explain why the cones are hyperbolic in outline. Their object is, as has been stated, to effect a reduction in the velocity of the wheel L, and owing to the fact that the surface which is finally operated on—that of the bobbin—is gradually increased, the reduction in the velocity of the wheel L must be also uniformly and gradually made. Of the two cones, E is the driving and E^1 the driven one, and the motion is communicated from one to the other by means of the belt F. In order to accelerate or diminish the velocity of E^1—that of E being constant—the belt F is traversed along the cones from one end to the other. The diameters of the large and small ends of E and E^1 are respectively 7in. and $3\frac{1}{2}$in., and they are placed with their large and small ends opposite one another. Thus, if the strap is on the large end of E and the small end of E^1, the latter will be driven at double the speed of the former. When these conditions are reversed the velocity of E^1 is only half that of E. By this arrangement the belt is kept in even tension. If the speed of the shaft C is 262·5, and the belt F is on the large end of E, then E^1 will revolve at $\frac{7}{3 \cdot 5} \times 262 \cdot 5 = 525$ times per minute. If, now, the belt be at the other end of the cones, E^1 will revolve $\frac{3 \cdot 5}{7} \times 262 \cdot 5 =$ 131·25 times per minute. Thus by traversing the strap from the first-named position to the last, there would be a diminution of the speed of E^1 from 525 to 131·25 revolutions per minute. Now it is not enough that this diminution of 393 revolutions must take place during the total traverse of the strap from one end to the other, but it must also be an equal diminution for each inch of movement made by it. If the cones have a straight profile—that is, if they are right cones—this regular diminution will not occur, but, on the contrary, the loss of speed varies throughout the whole of the traverse of the strap. This is a well-established fact, and the reason of it may be profitably explained.

(214) In Fig. 54 a representation of the frustra of two right cones is given and it is assumed that they are of the diameters just given and 36in. long, the length being represented by the letter X. The two sides being produced will meet, and the length between the end of the cone and the point at which this junction is effected is called Y. The complete length from base to apex will therefore be X and Y, and the distance Y will depend upon the diameters of each end of the cone. It can be ascertained by the following formula assuming y to be the diameter of the small end and z that of the large one $Y = \frac{y}{z}(X + Y)$.

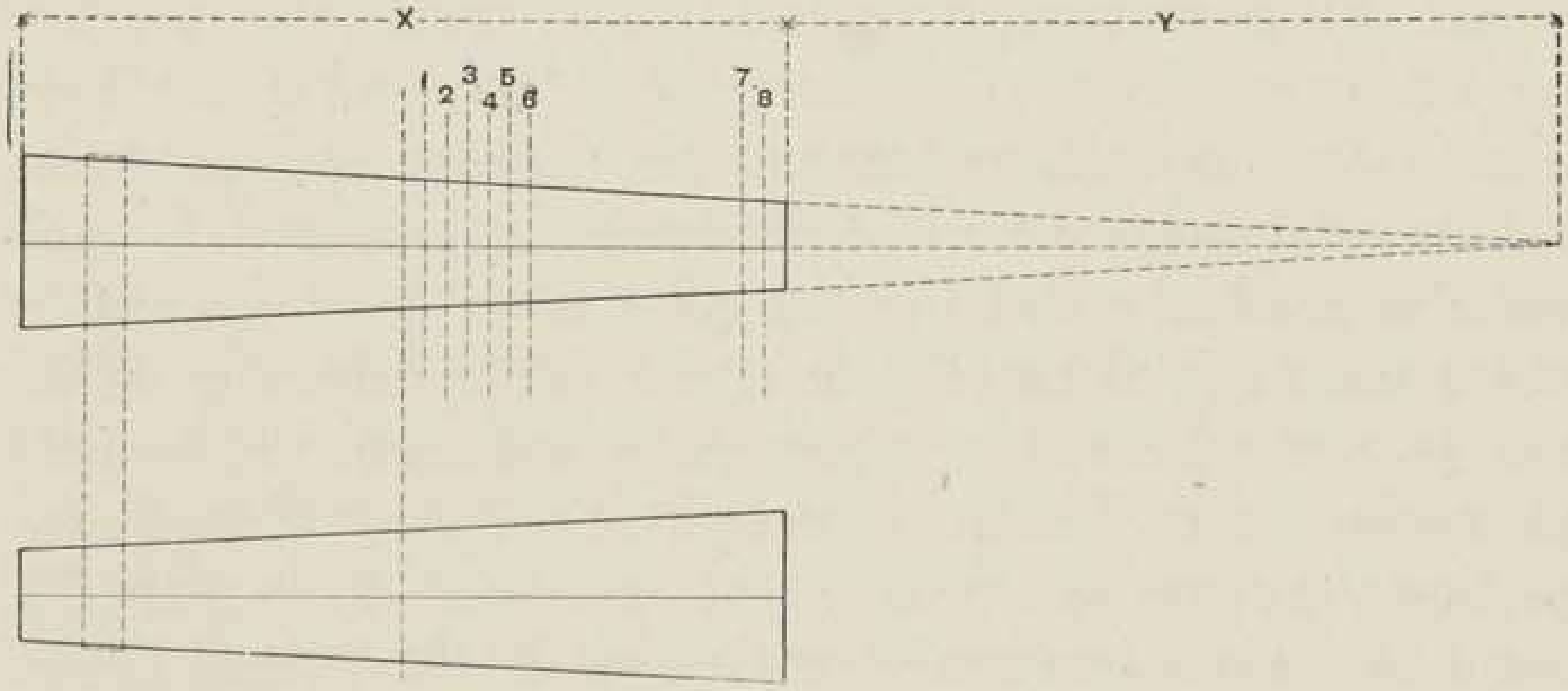

Fig. 54.

This works out as follows :—$Y = \frac{3\frac{1}{2}}{7}(36 + Y)$ whence $Y = 36$. Thus the whole length X Y is 72in. When the belt is at a point, midway between the two ends, it will be passed round a diameter of $5\frac{1}{4}$in. This is obvious, but it can be calculated from the formula just given. The distance of the belt from the apex of the cone is $Y + \frac{1}{2}X = 54$, and if x = the diameter of the cone at the central point, then $Xx = (Y + \frac{1}{2}X)y$. Putting this in figures we get $36x = (36 + \frac{1}{2}36)3\frac{1}{2} = 5\frac{1}{4}$. Now if the strap be assumed to be moved along the cone at intervals, so as to assume the positions shown by the dotted lines 1, 2, 3, 4, 5, 6, each traverse being 1in., by the formula given the diameters of the cones at these points respectively can be easily calculated. They are for the upper cone 5·15, 5·05, 4·95, 4·85, 4·75, and

4·65in. The combined diameters of the cones, at their centres, being $10\frac{1}{2}$in., it is only necessary to subtract the diameters just given from that size to obtain the respective diameters of the lower cone at the points named. These are 5·35, 5·45, 5·55, 5·65, 5·75, and 5·85.

(215) So long as the belt is in the position in the centre of the cones, the velocities of the two are equal, but as it assumes the positions marked 1 to 6, the velocity of the lower cone is for each of the positions as follows: 252·68, 243·23, 234·12, 225·33, 216·84, and 208·65. In other words, the traverse of the strap one inch in each case implies that the velocity of the lower cone is reduced 9·82, 9·45, 9·11, 8·79, 8·49, and 8·19 revolutions respectively. If now the strap be moved from the point 7 to 8, which are assumed to be respectively two and one inches from the ends of the cone, the reduction is still less, being only 5·13 for that traverse. Thus, instead of the traverse of the strap producing a regular and proportionate difference in the velocity of the driven cone, a variable one, which is not permissible, is produced. It is, therefore, necessary so to proportion the cones that every equal movement of the strap will ensure the same increase or diminution in the velocity of the driven cone.

(216) In proceeding to draw the outline of a cone to fulfil the conditions laid down, the following course may be followed. First, determine the extreme range of variation wanted, and the length of cone which is permitted by the construction of the machine. Having determined this, the procedure is as follows. If the cones are of the proportions shown in Fig. 54, the extreme range of variation is, if the driving cone revolves 300 times per minute, 600 and 150 revolutions, or a difference of 450 revolutions. The cone being 36 inches long, every time the belt is moved one inch, an increase or a reduction of speed occurs of 12·5 revolutions. Draw a straight line, and after measuring off the length of the cone, divide it into 36 parts. Through each of these points draw a line at right angles to the centre line. Cut off the first line representing the small or large end of the cone on each side of the centre line a distance equal to half its

diameter, viz. : $1\frac{3}{4}$ or $3\frac{1}{2}$ inches. If the process is started at the small end of the driven cone, the number of revolutions required when the strap has been moved an inch is $600 - 12{\cdot}5 = 587{\cdot}5$. The diameter required for this can be obtained in the following way. Let a and b be the values respectively of the diameters of the driving and driven cones, and x and y the speeds. Then $a \times x = b \times y$. In the case just supposed this works out as follows : $a \times 300 = b(600 - 12{\cdot}5)$, whence $a = b\frac{587{\cdot}5}{300}$ and (I.) $a = b \times 1{\cdot}95$. As $a + b = 10{\cdot}5$, therefore (II.) $a = 10{\cdot}5 - b$. Placing the values (I.) and (II.) together, we get $1{\cdot}95b = 10{\cdot}5 - b$ or $2{\cdot}95b = 10{\cdot}5$; therefore $b = \frac{10{\cdot}5}{2{\cdot}95} = 3{\cdot}56$ nearly. In the same way the values are found for each inch of lateral traverse of the strap, and they can be marked off on the verticals. By drawing a line through the points of intersection thus obtained, the profile of the cones can be described, and by deducting the diameters as calculated from the added diameters of the two cones, the shape of the concave cone can be marked off in the same way.

(217) The strap F receives its longitudinal traverse along the cones by means of the forward movement of the toothed rack P, which is actuated by the rotation of the pinion P^1. The pitch of the teeth of the rack is $\frac{5}{16}$in., and the pinion has 45 teeth. One complete rotation of the latter, therefore, will move the rack $14\frac{1}{16}$in. It was shown in par. 213 that the extreme variation in the number of revolutions of the lower cone is 393, or, if the cone is 36in. long, 10·9 for each inch of strap traverse. Thus, one revolution of the pinion P^1 will reduce the velocity of the lower cone 153 revolutions. The rotation of the pinion P^1 is obtained by means of the pull of a cord or chain passing round the pulley X^1 on the shaft X. The latter cannot, however, revolve freely, being held by the detent catches of the motion Q, of which a description will now be given. This motion is called sometimes the "box of tricks," but a much better name is the "building motion." It has a

two-fold function. It regulates the movement of the belt along the cones and it throws into gear alternately the wheels S^1 S^2 with the pinion S. By the first of these actions it regulates the velocity of the bobbin, and by the second the duration of its lift. It may be here explained that in the early period of the history of this machine it was customary to wind the roving on bobbins with flanges at each end. It was found, however, that the roving in being drawn off adhered to the flanges and was thus stretched and broken. It has therefore become the practice to shorten the lift of the bobbin after every layer is wound, and to wind the roving on to plain cylindrical wooden tubes without aids. Unless the lift was shortened the roving would be easily unravelled or fall off at the ends, but by the adoption of the system of shortening the traverse, the double conical bobbin is built, which can be handled with impunity.

(218) The illustrations in Figs. 55 and 56 represent respectively a front and back view of the building motion, which is in every respect like the one shown in Fig. 53 except that weights are substituted for the springs, and the rod R is differently coupled. Two cradles A and B are centred on the pins A^1 and B^1. The upper cradle A has attached to it at each side double hooks C C^1, which pass through holes in the lower cradle, and have weights attached to them. In the lower cradle B a pin E^1 is fixed, which engages with a slot in the lever E, centred on the pin F, and jointed to the rod R, coupled to the striking wheel. On the pin A^1 a ratchet or "rack" wheel N is fixed, with which two catches G G^1 can alternately engage. These catches are coupled by a spring, and are of different shape, so as to engage with the teeth of the rack wheel at each side of its centre. On the same pin as the rack wheel the bevel pinion J is fastened, this gearing with a similar one J^1 on the upright shaft X. Two detent levers L L^1 are pivoted to the frame, and have their inner ends connected by a helical spring M, which passes round the centre B^1. These levers, from their action, are sometimes called "pigeons' wings," and their inner extremities engage with shoulders I I^1, formed

in the lower cradle B. The bobbin rail has attached to it a double slide Q, which is slotted so that the pin O can move along it. On this pin one end of the "diminishing" rod S is centred, the rod passing through bearings formed in the cradle A. A toothed rack is formed on the underside of the rod S, with which a wheel T, fixed on the pin A^1 engages.

(219) The action of these parts is as follows: The hanger Q rises and falls with the bobbin rail, and consequently communi-

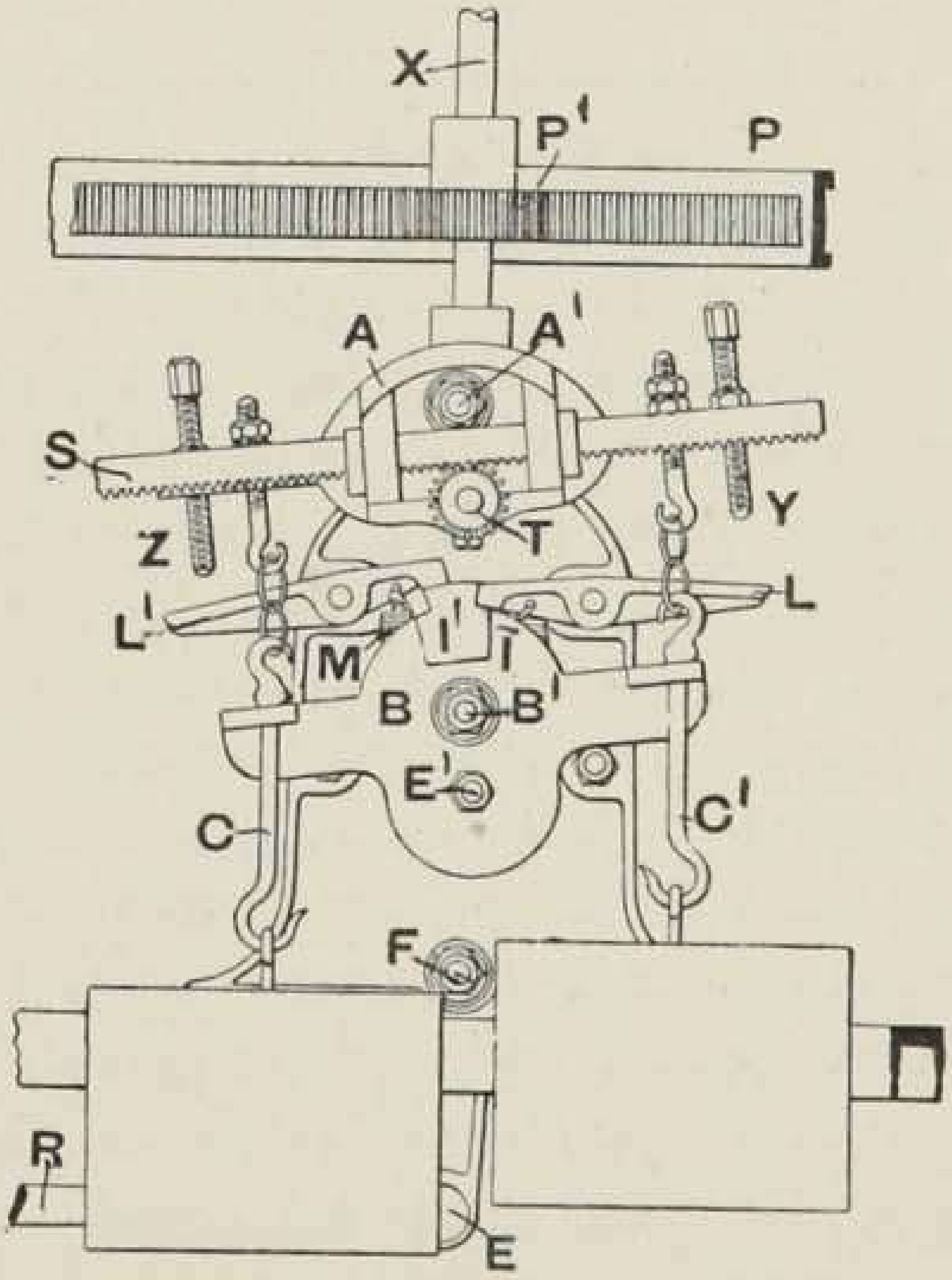

FIG. 55.

cates an oscillatory motion to the cradle A. The slide Q is properly set when a line drawn through its centre passes through the centre of the pin A^1 when the bobbins are at the central point of their lift. The rod S could then be moved horizontally without producing any effect on the cradle A. The levers L L^1 are then engaged with the shoulders I I^1. If the bobbin rail now descends the cradle A is oscillated on its axis, and as a consequence the hook C^1 is raised while C is lowered. There is a shoulder or boss on the latter which prevents it falling too low, but causes the weight to come upon the arm of the cradle B, and so exercise a pressure on the latter. As the oscillatory movement of the cradle A is continued the weight of C^1 is entirely removed from B, and the point of contact of L^1 and I^1 becomes a fulcrum by which the motion of A is temporarily arrested. This is practically an anchor action, and when springs are used bears much more resemblance to it than in this case. The effect is that the point where the weight C^1 is ordinarily applied is quite free, while there is a proportionately heavier thrust on B. As A continues to oscillate the screw Z begins to press on the outer end of L^1, and finally causes it to oscillate so as to free it from contact with the shoulder I^1. The cradle B makes a sudden movement, which partakes both of a rotary and vertical character. The result is that the pin E^1 strikes the slot in the lever E and the latter turns upon the pin F. A blow is thus given to the detent catch G, releasing the rack wheel, which at once turns. As, however, G and G^1 are coupled by a spring, the lateral movement of one is accompanied by a similar movement of the other. Thus the rack wheel can only move half a tooth for each of the oscillations of the cradle in either direction. The partial rotary movement so made is communicated to the pinion P^1 by the gearing described. The oscillation of the lever E or of the cradle in Fig. 53, communicates a longitudinal motion to the rod R, and causes it to throw the wheel S^2 into gear with S, thus reversing the motion of the lifter pinion. The rotation of the rack wheel is also accompanied by that of the pinion T engaging with the rack on the underside of the bar S. The latter is thus drawn inwards, and the relative position of the pin O and the centre of the cradle A is altered, with the result that at the next lift of the bobbins the escapement motion is actuated a little earlier. Thus the duration of the lift is constantly shortened, and as a result each layer occupies a little less vertical space than its predecessor.

(220) Let it now be assumed that the strap is on the small end of E^1, the velocity of the shaft H will be 105, and of the

wheel L 16·8. From this we deduce the speed of the bobbins as 909·27, or 91·27 in excess of that of the flyer. Now, if the bobbin be supposed to be $1\frac{1}{8}$ diameter, it will, for every revolution, take up 3·53in. of yarn. In other words, it will, during the 91·27 revolutions in excess take up 322in. of yarn. It was shown in paragraph 209 that the rollers delivered in a minute 251·5in.; therefore the velocity of the feed cone is too great, and the strap must be moved towards the large end

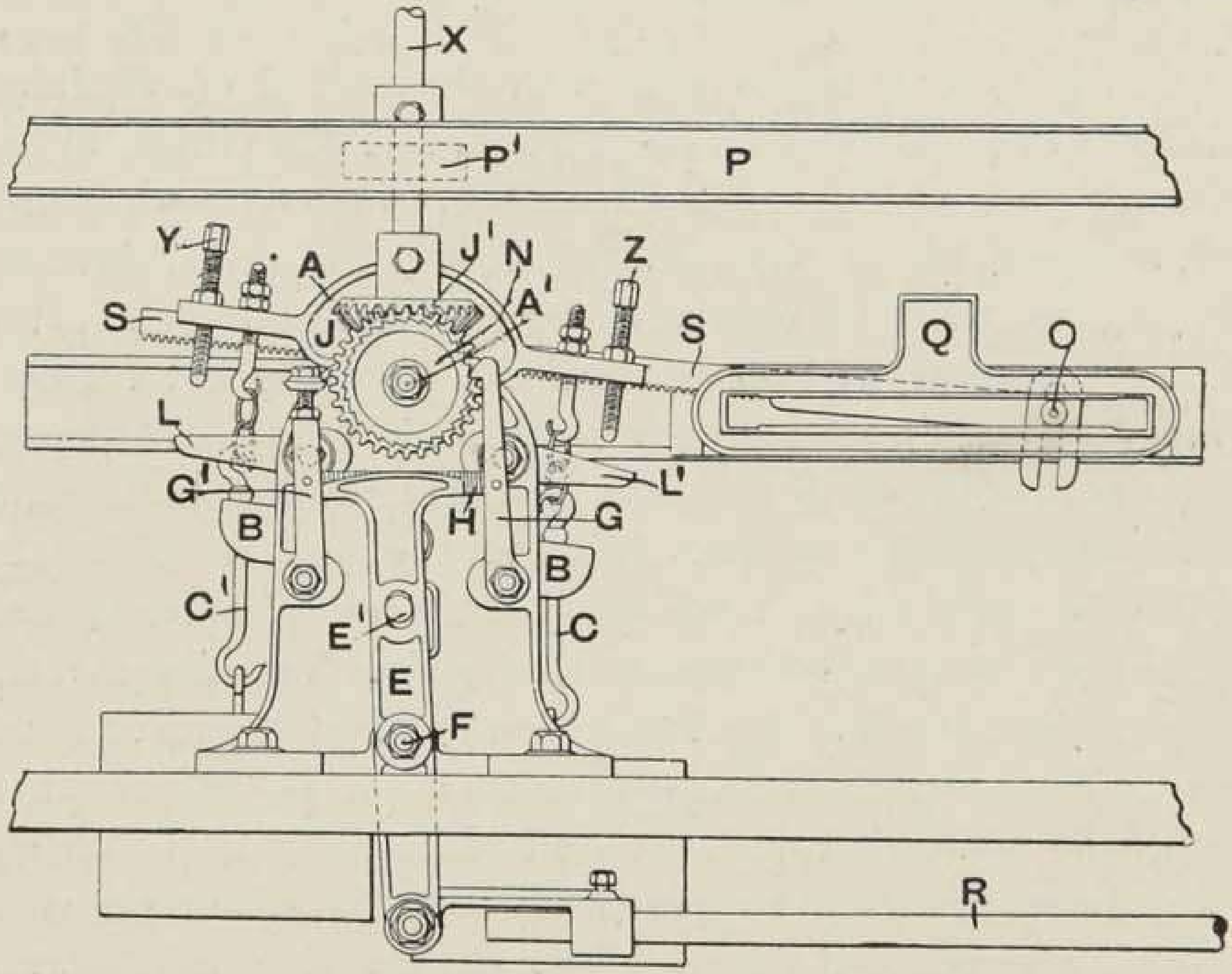

FIG. 56.

of E^1 in commencing the set. The bobbin requires reducing to a velocity of 889·3 revolutions, or 71·3 revolutions in excess of that of the flyer. By means of the modes of calculating previously detailed we find that the strap must be at a distance of 10·9in. from the smaller end of the cone E^1, when the velocity of the latter will be 406·25 revolutions, at which speed the bobbins will revolve 889·3 times, which is what is required. Suppose at the end of a set the bobbin is $2\frac{3}{4}$ diameter, at each revolution it will take up 8·5394in. of yarn. Thus to take up the 251·3in. of yarn delivered by the rollers it must revolve 29·31 in excess of the flyers, or 847·36. This means a reduction of the velocity of the cone E^1 to 167·2 revolutions, and the traverse of the strap 22in., or in other words, nearly to its large end. As will be afterwards shown, the effect of such an extended traverse of the strap can be much increased by an alteration in the wheels by which the bobbins are driven, but this demonstration will show the general principle.

(221) We now come to deal with the method of obtaining this traverse. The rack P is $\frac{5}{16}$ pitch, and the pinion P^1 has the same pitch and 45 teeth. Therefore, as shown in paragraph 217, one rotation of the pinion P^1 moves the rack P inwards $14\frac{1}{16}$in., so that to obtain a total traverse of 22in. the pinion P^1 must make 1·56 revolutions. Now the bevel wheels J and J^1 (Fig. 53), having each 25 teeth, it follows that every time the rack wheel N makes a complete revolution the shaft X and pinion P^1 do so also. Thus as the rack wheel has 32 teeth and moves a half tooth every lift, a complete revolution means the winding of 64 layers on the bobbin. Thus to attain the full diameter of $2\frac{3}{4}$in. $64 \times 1{\cdot}56$ layers must be wound, or 99·84 in all. The successive series of coils are not laid over each other, but as the roving is round, each alternate layer falls into the spaces between each of the previously laid coils, so that only half the diameter is added at each layer. As the difference between the diameters of the full and empty bobbins is $1\frac{5}{8}$in., the diameter of the roving is approximately $\dfrac{1{\cdot}625}{\frac{1}{2}\,(99{\cdot}84)} = {\cdot}032.$

(222) On the shaft H is a bevel wheel R with 22 teeth, driving a wheel R^1 with 51 teeth. R^1 is on the same shaft as the striking wheel S, which has 16 teeth, and gears with the wheels S^1 S^2 with 51 teeth. On the same shaft as S^1 is the pinion T with 14 teeth, driving T^1 with 70. T^1 is on the same arbor as U, which has 16 teeth, and gears with U^1 with 80 teeth. U^1 is fixed on the lifter shaft, on which at intervals are pinions V^1 gearing with the racks V. The pitch of the teeth of the rack

V and pinion V^1 is $\frac{5}{8}$in., and V^1 has 16 teeth. Now on the assumption that the cone E^1 is making 406·25 revolutions, and the shaft H 81·25 revolutions per minute, then the pinion V^1 will make $\frac{22 \times 16 \times 14 \times 16}{51 \times 51 \times 70 \times 80} \times 81{\cdot}25 = {\cdot}44$ revolutions in the same time. At this velocity the bobbin rail will be raised 2·64in. per minute, and to complete the full lift of 7in. the pinion V^1 will require to make $1\frac{1}{6}$ revolution, and will take 2·65 minutes to do so. In that time the rollers will deliver 665in. of roving, which is the length of the first layer.

(223) On the same spindle as the rack wheel is a pinion T, which has 20 teeth $\frac{3}{16}$in. pitch, and gears into the rack on the underside of the diminishing rod, which is, of course, the same pitch. Thus one revolution of the rack wheel moves the diminishing rod S inwards $3\frac{3}{4}$in., and during the period of the full movement of the rack P the diminishing rod will be moved in 5·85in. Thus the pin O will be moved towards the cradle A (Fig. 55), and if the lift of the bobbins remained constant, the velocity of the oscillation of A would be increased; but this increased velocity leads to the release of the detent catches G G^1 respectively at an earlier moment, so that the reversal of the lift is made a little earlier every time it is completed. Thus the striking wheels S^1 S^2 are thrown into gear at an earlier period respectively, and the lifter pinion has its direction reversed at a proportionately early moment. The extent of the traverse is therefore shortened after each layer is wound, and the bobbin is thus formed into the double conical shape to which reference has been made. There is no definite ratio between the length of the lift and that of each layer, and the only object of the decrease in lift is that of forming a bobbin which can be easily handled, and which will not ravel off at the ends.

(224) The explanation so given is intended not so much to give an absolute instance of the operation of a machine of this character as to illustrate the principle upon which it works, and to define the connection between the whole of the parts. It

has been shown that the spindles, rollers, bobbins, and cones alike derive the whole of their motion from the jack shaft, and that of these the only parts which constantly maintain the same relation during the twisting of a set of bobbins are the spindles and rollers. They rotate at a definite and regular rate, so that it is possible to easily calculate their effect. When it is desired to change the hank of the roving it is necessary that the velocity of the rollers shall be increased or diminished. If the wheel B be changed for one larger or smaller, the rollers will revolve at a slower or quicker rate accordingly, and the twist can thus be altered. The alteration of the twist wheel B not only affects the rollers but also the velocity of the bobbins and the speed of the lift, for it will have been seen that the whole of these motions are driven from B. Thus if a larger wheel is substituted at B, giving a quicker velocity to the rollers, the roving delivered will have less twist, and will be coarser. Now any one who has carefully read the foregoing explanation must see that a coarser roving will increase the diameter of the bobbin at a quicker rate, and thus necessitate a more rapid diminution of its velocity. Accordingly the change in the wheel B causes the cones to run at a quicker speed, thus accelerating the lifter shaft, and consequently causing the change of the building motion to take place at an earlier moment. This in itself would bring about a quicker longitudinal traverse of the strap, but when the roving is made coarser it is the custom to change the rack wheel for one of fewer teeth, in order that the traverse of the rack P shall be made more rapidly. When the change is to a finer roving a larger rack wheel is used. The strike pinion S can also be changed if desired, as can also L^1, and where there is an increase of any great extent this is probably the best course. Ordinarily, however, the changes necessary can be effected by the substitution of the wheel B, the rack wheel, and the change pinion in the roller train, by others of the necessary size. It is, of course, necessary to alter the draft to suit the roving made.

(225) In the differential motion, constructed as described, it is necessary to use bevel wheels to transmit the motion of

the driving pinion to the bobbin wheel. It is also requisite for the wheels to revolve in the opposite direction to the shaft, and when they are borne directly by the shaft this gives rise to a good deal of friction. Accordingly, it has been thought desirable to design differential motions, by which the same effect is obtained without the evils ordinarily attaching to the motion. In one motion—Curtis and Rhodes'—the object has been to avoid the use of bevel wheels altogether and use spur wheels only. This motion is shown in Fig. 57, and consists essentially of a disc L, which carries studs, as shown at one part of

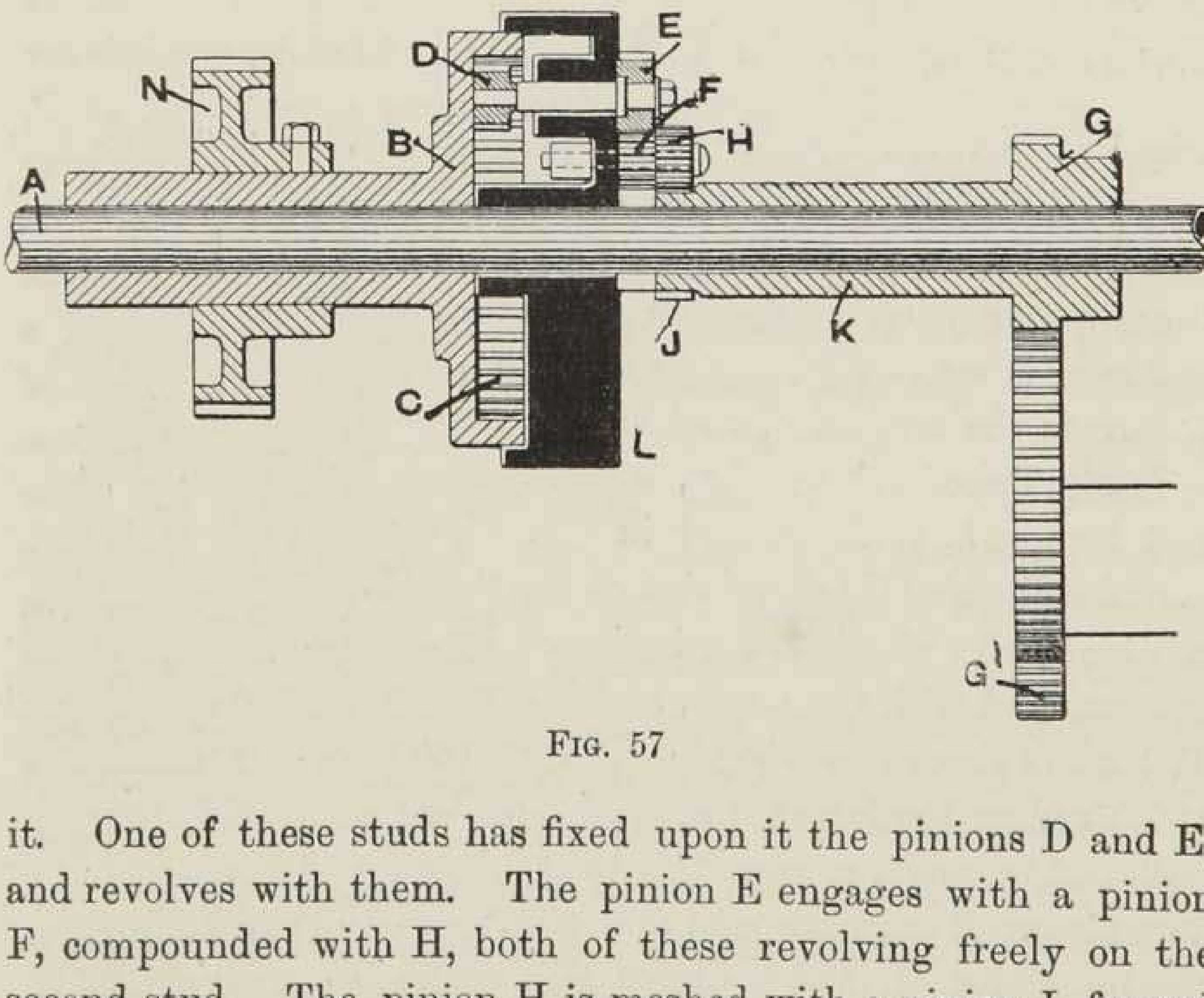

FIG. 57

it. One of these studs has fixed upon it the pinions D and E, and revolves with them. The pinion E engages with a pinion F, compounded with H, both of these revolving freely on the second stud. The pinion H is meshed with a pinion J, formed on the end of a long collar K, on the other end of which the wheel G is fastened. Thus, the rotation of G from the lower cone in like manner rotates the whole train of pinions from H to D. The latter is geared with an internal rack C, formed in the flange of a long bush B, rotating on the jack shaft A and having fastened on it the bobbin wheel N. The wheel G has

40 teeth; the pinion J, 24; H, 28; F, 25; E, 23; D, 14; and C, 90. The wheel G rotates at 316 revolutions when the belt is on the small end of the cone E^1 (Fig. 53), a special train of gearing being employed between E^1 and G. The disc L is fast on the shaft, and therefore revolves at 300 revolutions; or, in other words, the wheel G revolves at 16 revolutions in excess of L. Now, the pinion D is carried round with the disc, so that it will cause the internal wheel to gain on the disc, and the extent that it gains can be easily calculated by obtaining the value of the train from J to C, and multiplying it by the excess of revolutions made by the wheel G over the disc. This works out thus, $16 \times \frac{24}{28} \times \frac{25}{23} \times \frac{14}{90} = 2{\cdot}32$. That is, the internal wheel C revolves 302·32 times per minute, from which the speed of the bobbins can be easily calculated. It must be clearly understood that the speeds and sizes of wheels, although those actually used in some cases, are, so far as the present instance is concerned, purely arbitrary, and are simply used to illustrate the method of making the necessary calculations.

(226) Tweedale's motion, which is made by Messrs. Howard and Bullough, is illustrated in Fig. 58, and consists of a compound bell wheel C D revolving on the shaft A, the direction of the motion of the wheels being indicated by arrows. The wheel B is connected with the cones, and is compounded with the pinion E, both of these revolving freely upon the shaft. A double boss G is fixed on the latter, and carries a short transverse shaft on each end of which respectively the pinions F and H are fastened. The pinion E engages with and rotates F, thus giving motion to the pinion H, which drives the wheel D. There is one important point in this motion, which is, that all the wheels revolve in one direction and at a slower speed than the jack shaft, the speed being gradually diminished as the bobbins fill. The following formula will enable the effect of this motion to be easily calculated. Let m = revolutions of jack shaft; n = revolutions of pinion B; a = a constant number obtained as described, and v = speed of the bobbin wheel; then $v = m - a\,(m + n)$. The

constant number is obtained by multiplying the number of teeth in E and H and dividing by the number of teeth in F and D multiplied together. The pinion E having 18 teeth, H 16, F 30, and D 51, then the constant number is $\frac{18 \times 16}{30 \times 51} = \cdot 188$. The revolutions of the jack shaft being 300, and of B, say 260, then $v = 300 - \cdot 188\ (300 + 260) = 194 \cdot 7$. From this the velocity of the bobbins can be readily calculated. This motion is the simplest in construction of any which has had practical employment, and has many points of interest and value.

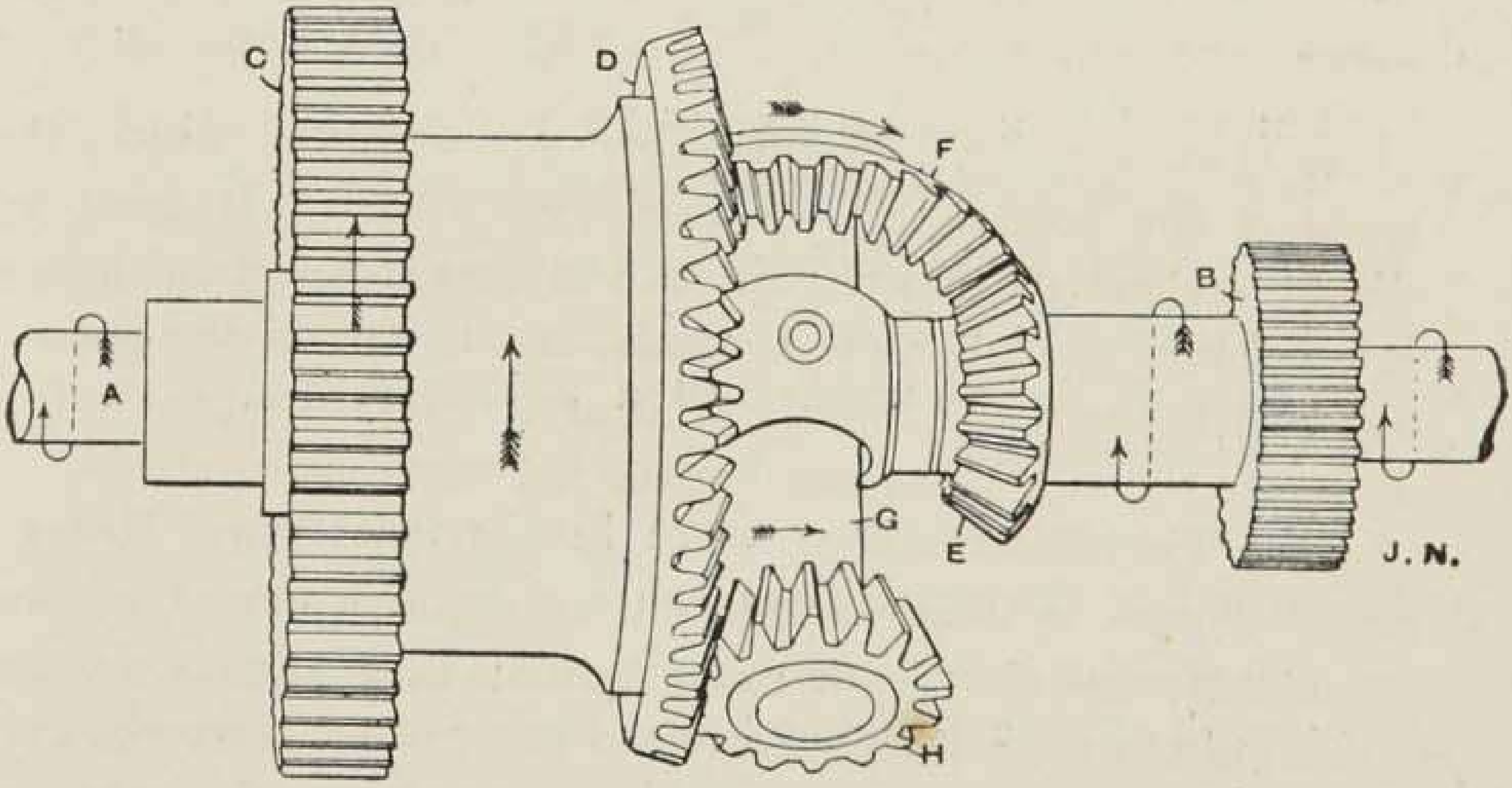

Fig. 58.

(227) The following are the rules for calculating the speeds and effects of the various parts. The rules are those which are in ordinary use, but to make them clear references are inserted to the letters in Fig. 53 :—

1. To find the velocity of the spindles—

Speed of jack shaft A × spur wheel O × pinion W divided by spur wheel O^1 × bevel pinion W^1.

2. To find the velocity of front roller—

Speed of jack shaft A × spur wheel B × spur wheel C^1 ÷ spur wheel B^1 × spur wheel D.

3. To find the length of roving delivered by the front roller per minute—

Speed of front roller × circumference of front roller.

4. To find the twist per inch—

Revolutions of spindles divided by length delivered per minute.

5. To find the draft of rollers—

Multiply all the driven wheels together and the product by the diameter of front roller in eighths of an inch, and divide the number obtained by the product of all the driving wheels multiplied together, multiplied by the diameter of the back roller in eighths of an inch.

6. To ascertain the correct change pinion to obtain a given draft—

Draft × wheel D × diameter (in eighths) of back roller ÷ crown wheel × back roller wheel × diameter of front roller.

7. To calculate turns per inch by the wheels—

Wheel D × wheel B^1 × wheel O on jack shaft × wheel W ÷ diameter of front roller (in eighths) × wheel C^1 × twist wheel B × wheel O^1 × pinion W^1 on spindle.

8. To calculate number of teeth in the twist wheel to be substituted when changing from one counts hank to another—

Twist wheel squared × hank roving spun ÷ hank required. The square root of quotient so obtained gives number of teeth required in twist wheel.

A second method of obtaining the same result is—

Hank made × present twist wheel ÷ hank required. The quotient of this + twist wheel ÷ 2 equals twist wheel required.

9. To calculate number of teeth in rack wheel when changing hank being made—

Hank required × present rack wheel ÷ hank being made. The quotient thus obtained + rack wheel ÷ 2 gives rack wheel required.

Another method is to square present rack wheel and multiply it by hank required, then divide this product by hank made. The square root of the quotient thus obtained gives the number of teeth required.

10. To ascertain what hank a roving is—

Constant dividend (see Table II.) ÷ weight of any number of yards.

Another form of this rule is—

Constant dividend ÷ given hank = weight of any length in grains.

In working out rules 6 and 7 a constant number can be used. This is obtained in the same way as detailed in the rules named, but leaving out the draft in rule 6 and the twist pinion B in rule 7. If the constant number be divided by draft required as in 6, or the turns per inch as in 7, the correct pinion in each case can be calculated. The ordinary method of finding the necessary turns per inch for slubbing and roving is as follows: Slubbing $\sqrt{\text{hank}}$ = turns per inch; intermediate $\sqrt{\text{hank}} \times 1{\cdot}1$ = turns per inch, and roving $\sqrt{\text{hank}} \times 1{\cdot}2$ = turns per inch. These are the usual twists, but different cottons require special treatment. In this connection refer to Tables III., IV.

TABLE I.

Measurement of cotton yarn (English) :—

1 thread on a wrap reel	=	$1\frac{1}{2}$ yards.	
80 threads	= 1 lea	= 120 yards.	
560 threads	= 7 leas	= 840 yards	= 1 Hank.

Weights used for cotton yarn (English) :—

24 grains	= 1dwt.		
$437\frac{1}{2}$ grains	= 18·225dwts.	= 1oz.	
7,000 grains	= 291·6̇dwts.	= 16oz.	= 1lb.

Note.—The counts of yarn are calculated by ascertaining the number of hanks in one pound weight. If one hank weighs one pound, the yarn is No. 1 count; or, if one lea of 120 yards weighs $\frac{1}{7}$th the weight of a pound (1,000 grains), it is No. 1 count. By ascertaining the accurate weight of a lea the counts can be easily calculated. The rule is, number of grains in $\frac{1}{7}$th of a pound ÷ weight in grains of one lea = counts. Thus, if one lea weighed 40 grains, the counts are $\frac{1000}{40} = 25$.

TABLE II.—Dividends.

The numbers in this table are arrived at by the following rule: Take 12 for a divisor, and divide as many hundreds as yards are weighed. This is based upon the fact that 10 yards are $\frac{1}{12}$th of a lea, and that 100 is a multiple of 10.

120	yards	=	1	lea	=	1,000	grains	dividend.
60	„	=	$\frac{1}{2}$	„	=	500	„	„
40	„	=	$\frac{1}{3}$	„	=	333·3	„	„
30	„	=	$\frac{1}{4}$	„	=	250	„	„
20	„	=	$\frac{1}{6}$	„	=	166·6	„	„
15	„	=	$\frac{1}{8}$	„	-	125	„	„
10	„	=	$\frac{1}{12}$	„	=	83·3	„	„
8	„	=	$\frac{1}{15}$	„	=	66·6	„	„
6	„	=	$\frac{1}{20}$	„	=	50	„	„
5	„	=	$\frac{1}{24}$	„	=	41·66	„	„
4	„	=	$\frac{1}{30}$	„	=	33·3	„	„
3	„	=	$\frac{1}{40}$	„	=	25	„	„
2	„	=	$\frac{1}{60}$	„	=	16·6	„	„
1	„	=	$\frac{1}{120}$	„	=	8·3	„	„

In using this table to find the counts the rule is to divide the dividends given above by the weight in grains of the respective number of yards taken. Thus, 20 yards weighing 80 grains is $\frac{166 \cdot 6}{80} = 2 \cdot 08$ counts.

TABLE III.

No. of Roving.	Grains per Yard.	Twists per Inch.		
		Slubbing.	Intermediate.	Roving.
·10	83·33	·316	·347	·379
·15	55·56	·387	·425	·461
·20	41·66	·44	·484	·528
·30	27·77	·548	·602	·657
·40	20·83	·63	·693	·756
·50	16·66	·707	·777	·848
·60	13·88	·778	·855	·933
·70	11·90	·89	·979	1·068
·80	10·41	·94	1·034	1·128
·90	9·25	·99	1·089	1·188
1·00	8·33	1·0	1·1	1·2
1·25	6·66	1·118	1·22	1·341
1·5	5·55	1·224	1·347	1·469
1·75	4·7	1·328	1·455	1·587
2·0	4·16	1·414	1·555	1·697
2·25	3·7	1·5	1·65	1·8
2·5	3·33	1·581	1·739	1·897
2·75	3·03	1·658	1·823	1·989
3·0	2·77	1·732	1·9	2·078
3·25	2·56	1·8	1·982	2·163
3·5	2·38	1·87	2·057	2·244
3·75	2·22	1·936	2·13	2·323
4·0	2·08	2·0	2·2	2·4
4·25	1·96	2·061	2·267	2·473
4·5	1·85	2·121	2·333	2·545
4·75	1·75	2·179	2·397	2·615
5·0	1·66	2·236	2·459	2·683
5·5	1·51	2·345	2·579	2·814
6·0	1·38	2·449	2·693	2·939
6·5	1·28	2·549	2·803	3·059
7·0	1·19	2·645	2·909	3·174
7·5	1·111	2·738	3·011	3·286
8·0	1·041	2·828	3·11	3·394
8·5	·980	2·915	3·2	3·498
9·0	·925	3·0	3·3	3·6

TABLE IV.

Hank Roving.	Square Root.	Coils per Inch.	Hank Roving.	Square Root.	Coils per Inch.
½	·707	6·57	4	2·000	18·6
¾	·866	8·05	4¼	2·061	19·165
1	1·000	9·3	4½	2·121	19·723
1¼	1·118	10·397	4¾	2·179	20·268
1½	1·224	11·389	5	2·236	20·793
1¾	1·322	12·302	5½	2·345	21·81
2	1·414	13·152	6	2·449	22·78
2¼	1·5	13·95	6½	2·549	23·710
2½	1·581	14·704	7	2·645	24·605
2¾	1·658	15·422	7½	2·738	25·468
3	1·732	16·107	8	2·828	26·304
3¼	1·802	16·765	8½	2·954	27·113
3½	1·87	17·391	9	3·000	27·9
3¾	1·936	18·203			

(228) The detailed examination into the roving frame just made is intended to enable the principles upon which it works to be understood, and a reference can now be made to one or two practical matters of detail which will be of service to the student. As after the slubbing has been formed it partakes more or less of the nature of a thread, it is found that its passage through the rollers leads to the formation of grooves or hollows in the leather covering of the top roller. This is obviated by the use of a traverse motion by which the thread is guided from end to end of the roller boss in each direction alternately. In this movement there are one or two points of interest, especially when double or treble bossed rollers are employed. If the rovings make their sideward movement simultaneously there is a period when one of them is well within the range of action of the weights, while the other is so near the centre of the roller as to be less acted upon. The problem is purely one of leverage, and if it be calculated out

by the ordinary rule of mechanics it will be found that the pressure on one of the slivers is greater than that on the other by a ratio of 2 : 1. It has been made abundantly clear that the drawing power of rollers depends largely upon the pressure which is induced by weighting, and if the effect of the latter is at any period so unequal it is certain to have an effect upon the roving being produced. Unless the draft exercised upon the sliver or slubbing is constant the tendency towards thick and thin places in the resultant roving is much increased, and anything which detracts from the uniformity of the action of the rollers is necessarily hurtful. Towards the production of this uniform action many things contribute, among which the two elements of effective lubrication and equal pressure upon the slivers are perhaps the most important. The ordinary traverse motion does not fulfil the latter condition for the reason stated. There are several traverse motions designed with a view of minimising the wear of the rollers by giving a differential traverse, but they retain the principle of moving all the threads in the same direction simultaneously. Whatever objections therefore exist in the case of the ordinary type of rollers, have equal force in the case of the differential traverse motions so far as the variation in weight is concerned. By adopting a double traverse rail with guides on each, so that the guide for one boss is on one rail and that for the other on the second rail, the difficulty can be overcome by moving the rails in opposite directions at the same time. The effect of this procedure is to place the slivers passing under each boss in the same position relatively to the points where the weight is applied throughout the whole of the traverse. An equality of pressure is thus established, and the best possible condition for good drawing exists. In this connection it is important to remember the remarks in paragraph 192, which are of equal importance in a slubbing or roving frame.

(229) The establishment of a correct surface velocity for the bobbin has been shown to be of great importance, and unless this is preserved uniformly even roving is impossible. It is sometimes

found that there is a draft between the top of the spindle and the front roller. Whenever this condition exists the roving is in constant danger of being stretched or "ratched," with the result that thin places are found in it when wound, which in turn produce inequalities in the yarn. Care should be taken and vigilance continually observed with reference to this matter, as otherwise good work is impossible. The condition of the wheel trains driving the bobbins and spindles should be carefully looked to, as otherwise back lash may exist, which results in an earlier start of the flyers relatively to the bobbins. This arises from the greater length of the train which drives the the latter, back lash or wear having a greater effect in consequence. If the acceleration of the revolution of the flyer is excessive the roving will be stretched at first, with the usual consequences. Another small point relates to the taper of the bobbins. This can be regulated within certain limits by setting the screws Y Z in the cradle A (Fig. 55) so that the levers L L^1 are tripped at an earlier moment. If the required change cannot be got by this, it may be necessary to alter the wheel T, by which means the traverse of the rod S can be made at a quicker rate. The coils of roving should be properly laid, neither too far away nor too near, because it must be remembered that the gradual shortening of the lift varies the pitch of the coils. What is wanted is that the largest possible number of coils shall be laid, so as to get the greatest length of roving on each bobbin which is possible. In this connection Table IV. may be referred to. If the bobbin rail traverses either too fast or too slow, the coils will be badly laid, and the surface of the bobbin will be rough and uneven instead of fairly smooth. To remedy this defect the builder wheel S (Fig. 53) should be altered so as to give the necessary acceleration or retardation to the lifter shaft.

(230) There are a large number of small points of more or less importance in working a frame of this sort. The strap should be carefully looked to, and kept sufficiently tight on the cones to avoid slippage. If the strap slips there will be either

slack or uneven winding, both being evils to be avoided. So many of the motions of the machine depend for their success upon the proper driving of the bottom cone, and the maintenance of a uniform velocity of it and the parts connected by it, that it is of the utmost importance that the strap is kept in absolutely perfect working condition. Vigilance should be observed to see that the minder does not move the strap along the cone by hand, as otherwise the variation in the roving so produced will be detrimental to the yarn spun. The object of all the carefully designed and constructed mechanism which has been described is to render the action of the machine automatic, and any interference with its operation is therefore to be carefully guarded against. The cones and strap should be kept clear from dirt and grease, the risk of slippage being thus increased. There are, of course, several points in the earlier processes which have an influence on the regularity of the roving, but these have been referred to in their own place. The bobbins in the creels should be free from contact with each other, and all undue friction which would in any way retard their free rotation must be avoided. It is not advisable to keep the rovings in the creels too long, as they are more or less affected by atmospheric changes. In making the necessary wheel changes, practice will enable allowances to be made for several small matters which cannot be strictly defined, but which all have an influence upon the successful operation of the machine. For instance, the oscillatory movement of the swing carriage has an influence upon the driving of the bobbins, as the carrier wheel rolls round the bobbin wheel it of necessity loses and gains alternately. All these points are comprehensively summed up in the word slippage, the allowance for which covers most of the loss in transmission, which is inevitable. It is perhaps necessary to say in conclusion that, in making any changes, care should be taken to see that they are accurately carried out, as otherwise there will be some defect in the roving which will be difficult to trace to its source. It often happens that a defect in the finished yarn has its origin in one of the earliest processes, and the obscurity of the cause leads to a considerable amount of trouble before it is finally traced. In a machine which depends so largely as the roving machine upon the accurate adjustment of its mechanism, no care can be considered too great to attain this result. It is true that the setting points ordinarily used are few in number and the changes easily calculated, but a slight error in these may be of great consequence subsequently. It is often the practice to double the slubbing and intermediate in feeding it to the next machine. The justification for this is, of course, that the resultant roving is rendered more even than it would otherwise be. If this practice is pursued it is essential to see that the tension on both threads is equal, as otherwise there will be a tendency for one to be wound round the other in the action of twisting. Another point which it is desirable to mention is, that although twist is introduced into the slubbing or roving, it is not preserved in its passage through the drawing rollers of the succeeding machines, but is, in each case, when the roving leaves the bite of the front roller, practically removed. It is therefore quite accurate to calculate the twists in each case as if an untwisted strand were being dealt with.

CHAPTER VII.

THE THEORY OF SPINNING.

(231) We have now reached the terminal stage in the formation of yarn, viz., that in which the sufficiently attenuated strand of cotton receives its twist. The method of carrying this process into effect is uniformly the same, although the mechanism employed, is different. It is not, however, the operation of twisting itself which gives rise to the variation in the character of the mechanism, but the necessity for winding the twisted strand or yarn into a cop, spool, or on to a bobbin, as the case may be. Twisting is effected by giving the roving a rotary movement on its axis at a velocity which bears a definite relation to the length delivered by the feed rollers. This was explained in paragraph 204 in the last chapter, and need not be recapitulated at this point. All twisting machines, therefore, consist essentially of means whereby the delivery of the material to be twisted is accomplished at a definite rate, while it is turned or twined by the rotation of a spindle or other similar part. The further attenuation of the roving or strand, and its formation into a spool or cop, are additions which are rendered necessary by manipulative considerations and are accessory to the principal object of this process. In proceeding to deal with spinning, therefore, we shall, in the first place, endeavour to discover what the principles are upon which it proceeds, before describing the various means and methods adopted to effect it.

(232) The cotton thread, like all those which are produced by modern methods, consists of a series of fibres laid successively, and which can be twisted round the axis of the thread or round one another, but are not possessed of any felting or milling properties. That is, the fibres being pliable and having been reduced approximately to the same length and laid serially, as described, can only be incorporated into a thread by the action

of twisting, and not by any other pressure, which interlocks fibres of different construction. From this factor it follows that it is necessary to provide throughout the whole length of a cotton thread successively fibres so arranged as to be present in equal numbers at every point. To illustrate this, let a reference be made to the three diagrams given in Fig. 59, marked, respectively, A, B, and C. In A the fibres are assumed to be laid in successive lengths, the ends of which adjoin each other without overlapping. The effect is that, assuming the fibres shown to be multiplied, when they are twisted they would form a number of short strands or cords entirely unconnected one with another. In the second diagram, B, the successive layers are overlapped, and no break is therefore left in their continuity, but the overlap is slight and there will exist only a partial coherence between the successive sets of fibres. Further, the thread will be affected so far as its diameter is concerned, which is a matter of some importance, to which reference will be hereafter made. Now let it be assumed that the fibres are laid as shown at C, where each alternate set overlaps its predecessor and successor to the same extent. It is clear that when a strand so formed is compressed and twisted the chance of any rupture of the yarn is largely avoided, and that a much stronger yarn will result. Roughly speaking, the three diagrams given accurately illustrate what it is desirable to aim at, and avoid, in preparing cotton for spinning. If it be assumed that at any point in C there is the same number of fibres, which were each of the same diameter, it is clear that a yarn twisted up from a sliver so constructed would be practically even. Of course, this is a large assumption, but it is the true statement of the conditions necessary to obtain the perfect thread. At any rate it enables the nature of the problem to be understood.

(233) This method of laying the fibres is what is aimed at by combing. There an arbitrary selection of fibres of a certain length is made, and they are so laid in the resultant sliver and are joined to one another in such a way that practically the order shown at C in Fig. 59 is established. It is clear that in

the succeeding drawing processes the effect upon each set of fibres will be practically uniform, and that there will be—if the drawing is properly conducted—no creation of places of variable thickness in the twisted yarn. It is far otherwise with a sliver constructed as shown at B. There the fibres do not fall within the influence of the drawing rollers in the same regular manner as do those shown at C. There are periods when the fibres are being strongly drawn, and other periods when they are only partially subjected to the draft. As was pointed out in Chapter V., the fibres in drawing are slid over one another by the action of the rollers. If, therefore, the overlap is slight, or all the fibres are not equally drawn, weak—that is, thin—places develop in the yarn with all the ill effects consequent thereon. It does not follow that, even when established, the

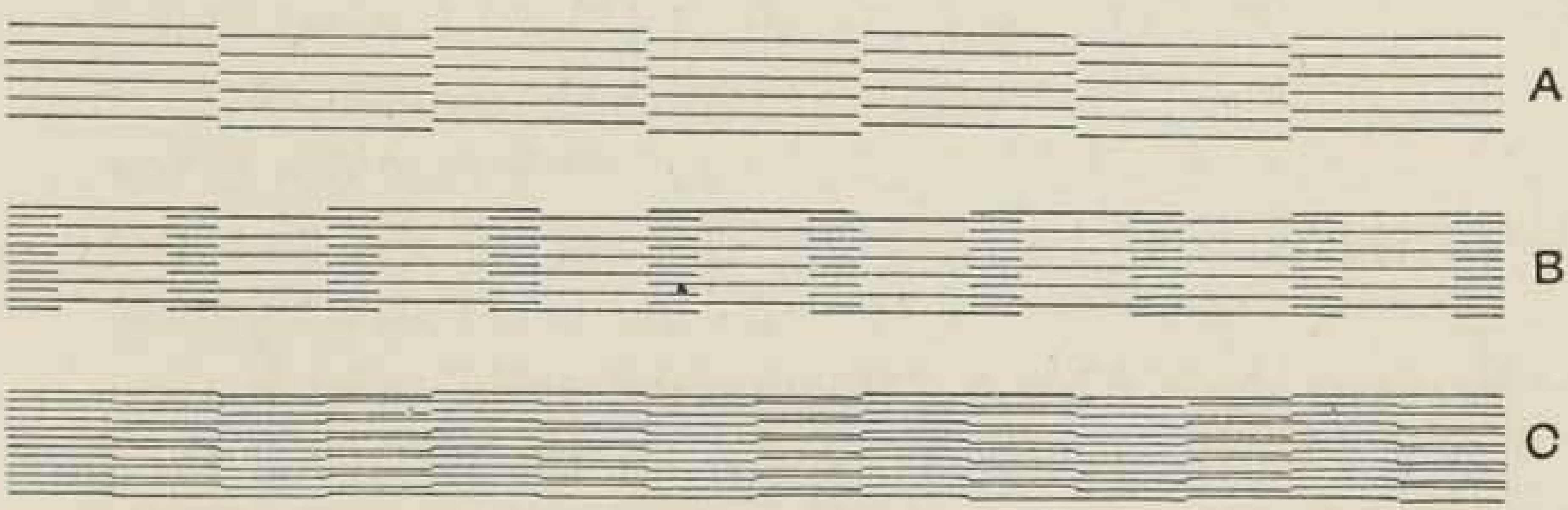

FIG. 59.

proper order is maintained throughout the various stages, but if anything approaching an even draft exists there is not so great a chance of any irregularity occurring. It is, however, obvious that if the fibres are so laid that their adhesion is considerably weakened, they can be more easily drawn into the position represented in diagram A in Fig. 59. Thus, if the sliver is constructed like B, it is much more liable to the danger thus indicated than when it is laid as at C, and this is a factor of the highest importance. The construction of such a sliver in any case where a selection of the fibres does not occur is very difficult, and it is doubtful when carded slivers are used whether it is ever attained.

(234) There are, therefore, a number of considerations of more or less value which it is necessary to remember in selecting a cotton for spinning, and a few remarks may be made on some of the features of the earlier stages. It is necessary to go over some of the ground already covered, and to amplify somewhat a few of the points made. It was shown in Chapter IV. that the fibres when delivered from the carding engine were laid in a tangled or crossed condition, and in Chapter V. that the draft exercised upon them in the drawing frame gradually laid them in parallel order. It does not need pointing out that the fibres which possess the greatest length are brought earlier within the range of influence of the drawing rollers, and remain longer under it. Thus they are subjected to a greater draft, and are consequently laid longitudinally in the yarn earlier than the fibres which are shorter. In consequence, the latter tend to move towards the outside of the sliver, and are thus placed in a position in which they can be twisted round the core of longer fibres as soon as the first twist is introduced. But owing to their imperfect development and consequent shorter length, they do not fully twist in, and the result is a hairy or oozy appearance on the surface of the yarn. The extent to which this exists varies with the cotton employed, but it is present in all yarns to a greater or less degree. This is one of the points requiring attention in making up a mixing. In all the preparatory processes it is necessary to proceed upon the assumption that a definite length of fibre is being treated. That is, of course, an arbitrary assumption, but it is necessary, as otherwise there cannot be any successful commercial work. The result is that to a large extent the fibres are broken, until in the yarn, as finally produced, there is much more uniformity in length than existed in the cotton to begin with. It may, however, be fairly laid down as a dictum—subject, of course, to all the limitations necessarily attaching to the knowledge existing—that in an ordinary yarn not specially prepared by combing, the sequence of the successive series of fibres is more or less like diagram B, and only partially

approximates to diagram C. This is one of the reasons for uneven yarn, because each of the spaces between the termination of the fibres in B is a source of weakness and unevenness.

(235) As has been said more than once, the object of the spinner is to produce the nearest approach to a perfectly cylindrical thread of equal diameter throughout its length, and containing at any point the same number of fibres in its cross section as at any other point. This is a task of enormous difficulty, and is one which it is doubtful will ever be solved. There are so many considerations which influence the result that even the most unceasing vigilance will barely suffice to accomplish it. It has been shown that the utmost efforts are made to obtain an evenly weighted sliver from the earliest stage, but it is obvious that these efforts can only at best be partially successful. Even when cotton is combed and a selection is made of the fibres, it is only a choice of length and not one of diameter. Now it is known that the fibres even of the best variety of cotton differ considerably in diameter, so that it is only necessary for a clump or group of the larger or smaller diameters to be formed to make a sensible variation in the diameter of the resultant yarn. Thus, assume that in the varieties of cotton used the fibres vary in diameter from $\frac{1}{1320}$in. to $\frac{1}{1260}$in. Suppose that at two points a foot apart in a strand containing 40 fibres in its cross section throughout its entire length the fibres were all of the largest and smallest diameters named respectively. In that case the strand would have a thickness at one point of $\frac{1}{33}$in., and at the other of $\frac{2}{63}$in., a difference of $\frac{1}{693}$in. The result would be that when twisted up, instead of being cylindrical, the yarn would be uneven in diameter. Of course this is only an example, but serves to illustrate the principle. Further, although the measurement of the thread when twisted will be diminished from its untwisted size, the relative variation is likely to be greater owing to the increased difficulty in twisting the thicker fibres. If a number of fibres, say like rhea or ramie, each possessing the same diameter, were laid alongside one another and twisted, it would be pos-

sible to produce a cylindrical thread equal to the length of the fibres, which is considerable, although the spinning properties of ramie are not good; but when it is necessary to deal with a material which exists in short lengths only, and which must be practically treated in mass and not in detail, the difficulties are largely increased.

(236) It has been shown how greatly the diameters of fibres of the same growth vary. Now, even where the disposition, shown at C, in Fig. 59, exists, it does not follow that the yarn will be of the same thickness, because it may happen that a lot of fibres of the larger diameter may fall together and *vice versâ*. Thus, in spite of the compression existing in the calender and drawing rollers, nothing but a change of disposition of the fibres would remedy this fault. This is only a minor point, but the measurements made by careful observers show that even with fine cottons it exists. The selection of the cotton, so far as the length of the fibres is concerned is, it has been shown, successfully accomplished, but it is a much more difficult task to select them relatively to diameter, even if it were desirable. If some procedure could be adopted by which the fibres could be mixed, so that an equal proportion of those of large and small diameters could be given in each part of the sliver, the problem would be solved, but this is well nigh impossible, and the only solution of it appears to be the provision of a staple naturally even in length and diameter, and its treatment so as to lay it in the sliver in the manner indicated.

(237) Another matter, which depends very largely upon the evenness of the diameter of the thread, is the strength of the yarn. All things being equal, the strongest thread has the greatest number of fibres in its cross section. Strength is, of course, a relative term. The strength of 100's yarn spun from Sea Island cotton is less than that of 30's spun from Orleans, but relatively to its diameter it is greater. Therefore in speaking of the strength of yarn it must be clearly understood that this refers to that quality in true relation to others. It follows, therefore, that the strength of a single thread of yarn

will vary with the number of fibres in its cross section, and if these vary considerably there will be corresponding differences in the strength of the yarn. This is easily ascertainable if single threads are tested; but as it is the custom to test 80 threads at one time, it is the average strength which is ascertained and which influences the record. The point which it is desired to make is that the existence of uneven places in the yarn detracts from its strength, and on this account they should be avoided. There is an element of strength in the fibres which is sometimes lost sight of, and that is the resistance to rupture which is caused by the friction of contiguous fibres upon each other. This has been admirably treated by Dr. F. H. Bowman in "The Structure of the Cotton Fibre," and is a similar action to that which was remarked on in connection with drawing in Chapter V.

(238) There arises from the various circumstances which have thus been detailed an unevenness in the yarn which has an influence upon the operation of twisting. It is obvious that if 300 fibres are to be twisted in any strand of yarn that they will be turned with more difficulty than 200 fibres of the same diameter. It is probably true that the extreme variation in the number of fibres in the cross sections of any yarn do not reach so high a percentage as the assumed case just given, but a much less percentage is ample to produce the same effect. Thus it is found that the tendency of twist is to run into the thin places existing first, and afterwards to affect the thicker parts of the strand. The observations of the author—which have not, however, been sufficiently extensive to warrant a dogmatic statement—tend to prove that the presence of thick places in the yarn is coincident with the existence of thicker fibres, but this is a point which is by no means settled. That even in the best yarns, made in the most careful manner by combing and repeated doublings, great variation exists is certain, and this matter can be determined in two ways, namely, by comparing the weight of several leas of the same yarn, or by microscopic measurement. The former

is the most convenient method, but is of necessity much less exact than the latter. The student may be referred to Dr. Bowman's book for a number of tests of the weight of leas, which will illustrate this point. In an interesting paper, communicated to the Manchester Microscopical Society by Mr. E. H. Turner, the following measurement of mule yarns were given :—

Description of Cotton.	Counts.	Average Diameter. In $\frac{1}{1000}$ths of an Inch.	Average Diameter. Decimal of an Inch.	Largest and Smallest Diameter in $\frac{1}{1000}$ths of an Inch. Highest.	Largest and Smallest Diameter. Lowest.	Largest and Smallest Diameter. Percentage of Lowest to Highest.	Maximum Variation. Maximum Variation $\frac{1}{1000}$ths in.	Maximum Variation. Percentage to Average Diameter.
Egyptian	24	48	·0096	65	30	46	35	73
American	36	42·5	·0085	55	30	55	25	59
"	46	30·6	·0061	40	20	50	20	65
"	56	26·5	·0053	40	15	37·5	25	93·5
Egyptian	60	25	·0050	40	10	25	30	120
"	70	23	·0046	40	11	27·5	29	126
"	76	23	·0046	31	17	55	14	61
"	80	23·75	·00475	36	15	41·5	21	88·5
"	86	19·2	·00385	25	14	56	11	56·5
"	100	18·4	·003675	26	12	46	14	76
"	110	18·2	·003625	28	12	42·75	16	88
"	120	17·7	·00354	25	10	40	15	85
Sea Island	140	13·4	·00267	20	9	45	11	82

These results are very remarkable, but it is evident that the 70's, 76's and 80's yarn, are by no means the correct counts, as otherwise the diameters would not vary as they do; as, instead of the latter being the thickest, it should be the thinnest of the three. Making all allowance for the defects in the yarn, however, the results confirm the common experience. The table is only given in order to show the variations existing in the same spinnings, and does not by any means deal with all the points requiring elucidation. With these may be compared the results given by Dr. Bowman, on p. 149 of his work, when dealing with the twist per inch in two folds 60's yarn spun from Egyptian cotton. Here the variation in the twists per inch is shown to be 12 per cent, which is quite sufficient to account for a considerable difference in the diameters, especially when it is stated that Mr. Turner's measurements were made with yarn wound on slips one inch wide so that the variations would be easily observed.

(239) It was mentioned in Chapter II. that cotton fibres are naturally possessed of good spinning qualities—that is, they are possessed of a natural twist which induces that intertwining one with another which is so necessary in spinning. There is, however, a fact, which in this connection is not always kept in view—viz., that the twists in the natural fibre are neither regular in pitch nor are they always in the same direction. It is not uncommon to see a fibre with twists of widely different characteristics in various parts of it, while in some grades the convolutions, spirals, or twists are extremely irregular. These facts somewhat detract from the absolute reliance sometimes placed upon this natural twist, although in the main it is a feature not to be lost sight of. There is, however, one point which is affected to some extent by this convolute formation. It is customary when twisting rovings up into yarn, which is to be employed for warp or "twist," to rotate the spindles from right to left—that is, give them a "right-handed" twist—the reverse being the practice when "weft" yarn is spun. It has often been supposed that this difference in procedure had an effect upon the finished

yarn, by reason of the untwisting of the natural twist in spinning "weft" yarns, the direction of rotation being in that case opposite to that existing naturally. Weft yarn presents a more hairy or "oozy" condition than twist, and an explanation which has been offered is that the untwisting of the fibre led to it being thrown out from the surface of the yarn. There does not appear to be any justification for this theory, especially if it be true that the fibres possess twist in both directions. The more open appearance of weft yarn is rather to be attributed, in the author's opinion, to the smaller twist put into it in spinning, and to the fact that the fibres employed in the manufacture of weft are generally of a softer nature than those used for twist. It is desirable always to keep in mind the purpose for which cotton is to be used, and to manipulate it throughout the whole series of processes, so that it will eventually be in the best condition for spinning the class of yarn for which it is employed.

(240) The strength of the yarn is affected by the twist introduced into it in a two-fold way. The cohesion of the fibres and the consequent resistance to rupture of the sliver is much increased, while in one system of spinning the thin places are hardened so that more strain is thrown upon the thick ones in drawing. Two principal factors have an influence upon the strength of a thread—the parallel disposition of the fibres, their arrangement in equal numbers throughout the whole length of the yarn, their diameter and the twist given to the thread. It has been found that only a percentage of the sum of the strength of all the fibres in any yarn is utilised. The exact amount of this has not been determined, but does not exceed in any case 40 per cent. The pull exercised upon a thread is ordinarily in the direction of its length, and the loss in its strength as compared with the sum of the individual strength of the fibres composing it, is partially the result of the divergence of the fibres from straight lines, which is the result of twisting them. Unless the whole of the fibres composing a thread are equally twisted—that is, unless throughout the yarn there is a spiral

disposition of the fibres—if, in other words, the fibres laid on the outside of the yarn receive more twist than the inner ones, they must be proportionately less able to resist a longitudinal strain than those forming the centre or core. Thus the existence of twist is at once a source of weaknesss and of strength. The yarn is weakened by the divergence from the parallel longitudinal disposition of the fibres, and is strengthened by the additional cohesion thus obtained. Of these two the latter factor has the most powerful influence, and, in consequence, weft and hosiery yarns, which are more slackly twisted than warp yarn, are, even when of the same counts, relatively weaker. Although the strength of a yarn may be practically ascertained by the test of one lea, it is quite clear that within that length there will be considerable variations, and that, as the strength of a chain is practically that of its weakest link, the existence of thinner and weaker places in a strand of yarn limits its power of use in the same ratio.

(241) Having thus dealt with the question of the structure of the cotton thread generally, without any consideration of the way in which the twisting is conducted, we are thus naturally brought to deal with the different methods of twisting. Of these, as was intimated in Chapter I., there are two, the intermittent and continuous. The earliest method was, as was shown, of necessity the intermittent, if the phrase be employed to indicate the fact that the operation was conducted with successive lengths of material. Relatively to the amount of material prepared the operation was a continuous one, and the difficulty was rather one of preparing the material for spinning fast enough than of twisting it. As soon as the preparation could be made continuously, spinning also became a similar operation. At the present day there are two methods adopted, which are indicated in the classification in Chapter II., viz., mule and ring spinning. The third mode named—flyer spinning—is now practically extinct, except for special ranges of counts, but has some points of special interest. Its rationale was described in paragraph 205 in the last chapter, and need not now be dealt

with. Between mule and ring spinning there is a wide difference existing in the mode of procedure and the result upon the yarn. In the former the yarn is twisted in successive lengths of from 60 to 66 inches each, while in the latter it is continuously spun. At first sight there does not appear to be much in this, but without going into a number of points bearing upon each operation, there is a wide distinction. As the roving is delivered from the rollers in the mule it is conveyed to a nearly upright spindle, which gradually recedes, during the time twisting is going on, from the roller beam. The velocity at which the spindle recedes from the rollers is such that a draft is exercised upon the yarn as it is being twisted. There is a distinct difference in the effect of this draft and that of the rollers. In the latter case the fibres are in a sense compressed or bound by the nip of the roller, which to a certain extent prevents them from assuming a different disposition in the cross section of the sliver. That is, the fibres are not so free to move from the centre of the sliver to the outside, although where they vary in length considerably this action unmistakably takes place. But when the roving is finally freed from the bite of the rollers, when it is stretched between two points, then the longer fibres having more cohesion, and offering proportionately great resistance to the draft exercised, gradually approach the centre of the yarn as the attenuation of each length takes place. The shorter fibres consequently move outwards, and are placed on the outside of the yarn, where by the rotation of the latter upon its axis they are wrapped round the inner core. The latter is also twisted, but by reason of the superior length of the fibres composing it, is not so easily ruptured as its outer covering of short fibres. The ends of the latter project from the thread at all points, thus giving it the distinctive hairy or oozy appearance named.

(242) The effect thus described has no correspondent in the second of the two methods of spinning. In mule spinning the successive treatment of definite lengths of yarn in the manner described is followed by the winding of each length as a separate

operation before the subsequent length is twisted and drawn. In ring spinning the only draft which is put upon the roving is that exercised by the rollers, and immediately it leaves the latter the roving is twisted up and wound on to the bobbin. All these operations are continuous and without break. There is therefore no possible chance of any further attenuation of the roving after passing the rollers, and the drawing of the fibres into the order which occurs in the mule is absent in this case. Whatever the disposition of the fibres may be in the roving after the final roller draft, remains the disposition in the twisted yarn plus the effect of the twist itself, which is considerable. It is quite easy to understand that under such different conditions the structure of the thread will vary considerably, and that the effect of the final draft upon a defined length of yarn will be greater than the draft of rollers applied to the same length continuously. In the first-named case the older forms of spinning, when conducted by hand, are approached, while in the latter the more modern method of continuous drawing is relied upon. The importance of this factor is made manifest when it is remembered that twist is being put into the yarn simultaneously with the additional draft in one case, and subsequently to the final draft in the other. This has an important bearing on the subject. In continuous spinning operations the moment the roving leaves the rollers it receives twist, so that whatever may be the disposition of the fibres, it is at once fixed. Thus, if the shorter and longer fibres are intermingled throughout the cross section, they are twisted up together and are formed into a thread at once. If, moreover, there exists any variation in the thickness of the roving as it leaves the rollers, the twist fixes itself first in the thinner places, but is not so soon put into those which are thicker. In paragraph 238 this point was illustrated, and it is obvious that the twist will be much more readily introduced into the thinner than into the thicker parts of the roving. The velocity at which, in continuous spinning, the roving is delivered, and the speed at which it is wound is so great, that before any adjustment of the twist in various parts of the yarn can take place, it is attached to and fixed on the spool or bobbin. This is not the case with intermittent or mule yarn. Here each successive length receives the twist as it emerges from the rollers, and, as in the preceding case, it runs at once into the thinner places. This increases the cohesion of the fibres; in other words, it causes them to resist the draft put upon them, and as a result the latter exerts more power upon the thicker untwisted places in which, despite their larger diameter, the cohesion of the fibres is less. Thus the thicker places are drawn out, and as they decrease in size the twist gradually runs into them. There is, further, a slight pause of the spindles at the termination of their recession from the rollers, which is generally a little in advance of the cessation of their rotation, so that, during this period, the twist can gradually pass into every part of the length of yarn and thus become equal throughout. Two distinct features thus characterise the intermittent system of spinning, namely, the draft upon the thread after leaving the rollers, and the subsequent equalisation of the twist. Both of these are, by the necessities of the case, absent in yarn spun continuously, and in consequence the structure of the resultant yarn is much affected.

(243) The essential properties of a good yarn are elasticity, evenness, strength, and colour of the thread. The former quality is very important. If a strand of yarn is strained until it approaches the point of rupture it is very clear that its strength will be materially diminished. Even if the draft exercised falls short of this point, as it always does when spinning is properly conducted, the method and period of winding has an effect upon the yarn. It is obvious that if yarn is kept in tension while being twisted, and is thereupon wound so that the tension is maintained subsequently, it has no chance to recover its elastic strength. The amount of this property which it retains is made to depend solely upon the question of the treatment accorded to the fibres in the preparatory stages. If they have been overstrained the defects consequent thereon will be fixed, but if reasonable care

is exercised in this respect, a yarn possessing a fair amount of elasticity can be produced even by continuous spinning. In the intermittent process, however, after the full tenuity of the yarn is obtained and the twist introduced, the spindles are rotated a little in the reverse direction prior to the commencement of winding, and the strain upon the length of yarn is considerably reduced. Further, during the operation of winding, the spindles again gradually approach the rollers, so that the yarn is slowly relieved from tension. Every condition which can favourably influence the preservation of the elastic strength of the yarn is present in the intermittent system of spinning. Among these must not be forgotten the tendency towards the formation of a core of longer fibres, to which reference has already been made. The hardness imparted by extra twist naturally decreases the elasticity of the yarn, and, as will be shown, it is customary to give continuously twisted threads—at any rate when formed on the ring frame—a harder twist than mule yarn. Care should be taken not to confound the strength and elasticity of yarn, as these are absolutely distinct characteristics, although each affects the other. We have already dealt with the evenness and strength of the yarn and their causes, and need not again treat this part of the subject. With regard to the colour of the yarn, this depends largely upon the twist imparted to it, as was mentioned in paragraph 68, Chapter III. There is, as was there shown, a difference in colour between yarns spun from the same cotton, the degree of which depends upon the amount of twist put in. This effect arises from the incidence of the light upon the fibres, as they lie upon the surface of the yarn. This naturally varies with the angle at which the fibres are disposed, which in turn is determined by the pitch and direction of the spirals. The latter depends upon the number of turns per inch, as can be clearly understood.

(244) It is not pretended that the foregoing explanation exhausts the subject of the structure of the cotton thread, but it is sufficient to enable the chief features in connection with it to

be comprehended. It must also be understood that the remarks made with reference to continuous spinning are more especially directed towards ring spinning, and are not so true of throstle or flyer yarn. There is the difference between ring and flyer yarn which exists between yarn spun by means which ensures an absolute regularity of twist and those where the regular motion is absent. The winding of flyer yarn also differs from that of ring yarn, by the fact that in the former case the bobbin is frictionally retarded, while in the latter it is positively driven. In the flyer frame the yarn is wrapped on a bobbin the motion of which is retarded as described, while in the ring frame it is drawn on to a bobbin positively driven. It is quite clear that the conditions existing in the first case are more favourable to the production of an elastic yarn than those in the latter. It is also true that flyer yarn, probably owing to the method of putting in the twist, is very even and cylindrical, but the slow velocity of the spindles has at present put this method of production out of the field. It is, perhaps, necessary to caution the student against the supposition that ring yarn is necessarily deficient in the qualities named. This is not so, as it possesses considerable strength and elasticity, but these properties are necessarily comparatively greater in some classes of yarn than in others. All that has been attempted to show is that the method of constructing the thread by the intermittent process is more favourable to the creation of a perfect thread than the continuous system. Looking at the matter from the commercial point of view, the relative values of the various properties of yarn, of course, assume a different aspect, and on this matter something will be said at the conclusion of the consideration of the two systems of spinning.

CHAPTER VIII.

MULE SPINNING.

(245) Having explained the theory and some of the reasons for the adoption of the special construction of the thread, and having intimated the differences naturally arising in it according to the method of producing it, we can now profitably proceed to describe the special mechanism employed and its manipulation. As the intermittent system has, on the whole, the largest employment, and as the machine employed in effecting it is the more complex and interesting, it will be perhaps the better course to deal with it first. The machine used is known as the "mule"—the origin of the name being given in Chapter I.—and on account of its practically automatic action, the "self-acting mule" or "self-actor." It has been previously indicated that the various operations of twisting and winding, which together form the complete cycle which is understood by the term spinning, are in this machine performed separately. It will be better therefore to describe the elementary or essential parts of the machine before proceeding to show how it is operated in detail. To enable the description to be understood the diagrammatic illustration given in Fig. 60 is used. In this the roving bobbins R are shown fixed in the creel, and the roving is passed through three lines of rollers E, by which it is drawn and emitted from the front pair. From thence it is taken directly to the spindle S to which it is attached, and on which it is wound in the form of a spool or "cop" C of the shape shown. The spindle S is borne by two rails, one carrying a footstep and the other an upper bearing or "bolster." It will be noticed that the spindle is not absolutely vertical in position, but is slightly diverged from a perpendicular line. The amount of angularity varies with the class of work being done to

an extent which will be defined a little later. Between the bolster and footstep the spindle has fixed upon it a small grooved pulley V^1 called a "warve" or "whirl" which has an endless band V passed round it. V is also taken round a cylindrical roller T^2, revolving with a shaft T, and called the "tin roller." The tin roller is so named because it is constructed of short cylindrical lengths made from tinned iron sheets which are coupled together by a specially arranged coupling shaft. The spindles and tin roller are borne in a frame or "carriage" O, which is carried by transverse bearers, at the ends of which are journals for the axes of disc rollers O^1. The latter are formed on their peripheries with square grooves, which fit on to narrow iron bars or "slips" U secured to the floor of the room. Thus, if a traction is applied to the carriage it can readily be moved to or from the rollers E in a horizontal direction. It will be noticed that the roving passes under a wire N fixed in the sickle shaped bar shown, which oscillates on the centre shaft or pivot B, and which is known as the "faller wire," or shortly, the "faller." The object of this is to guide the yarn on to the spindle in suitable coils during the operation of winding. The yarn also passes above the wire M—known as the "counter faller"—fastened in the arm or bar shown, this being oscillated on the centre B^1.

(246) Yarn is produced by this mechanism as follows: When twisting is beginning, the carriage O, with the parts which it bears, is brought to a point near the rollers E. As the latter begin to deliver the roving the carriage simultaneously commences to recede from the rollers, and the spindles S begin to revolve. Thus there are three things taking place: The roving is being drawn and delivered; it is, as it is delivered, twisted; and it is kept in a stretched condition by reason of the recession of the carriage. The latter moves away from the rollers—or makes its "outward run" or "stretch"—for a distance of 63 or 64 inches, during the whole of which period the triple operation named is going on. When the carriage reaches the end of its stretch—that is, when it has made its utmost reces-

sion from the rollers—it is stopped, and is held for a brief period at that point. While so held, the spindles are sometimes rotated for a short time, so that a little additional twist is put into the length of yarn. It is perhaps necessary to say here, that although the singular number is occasionally used in speaking of the various parts, mules contain a large number of spindles, sometimes as many as 1,500, so that the processes described are equally applicable to all of these. After the completion of the twisting the motion of the spindles is arrested and at once reversed, so that a few coils of yarn which are wrapped

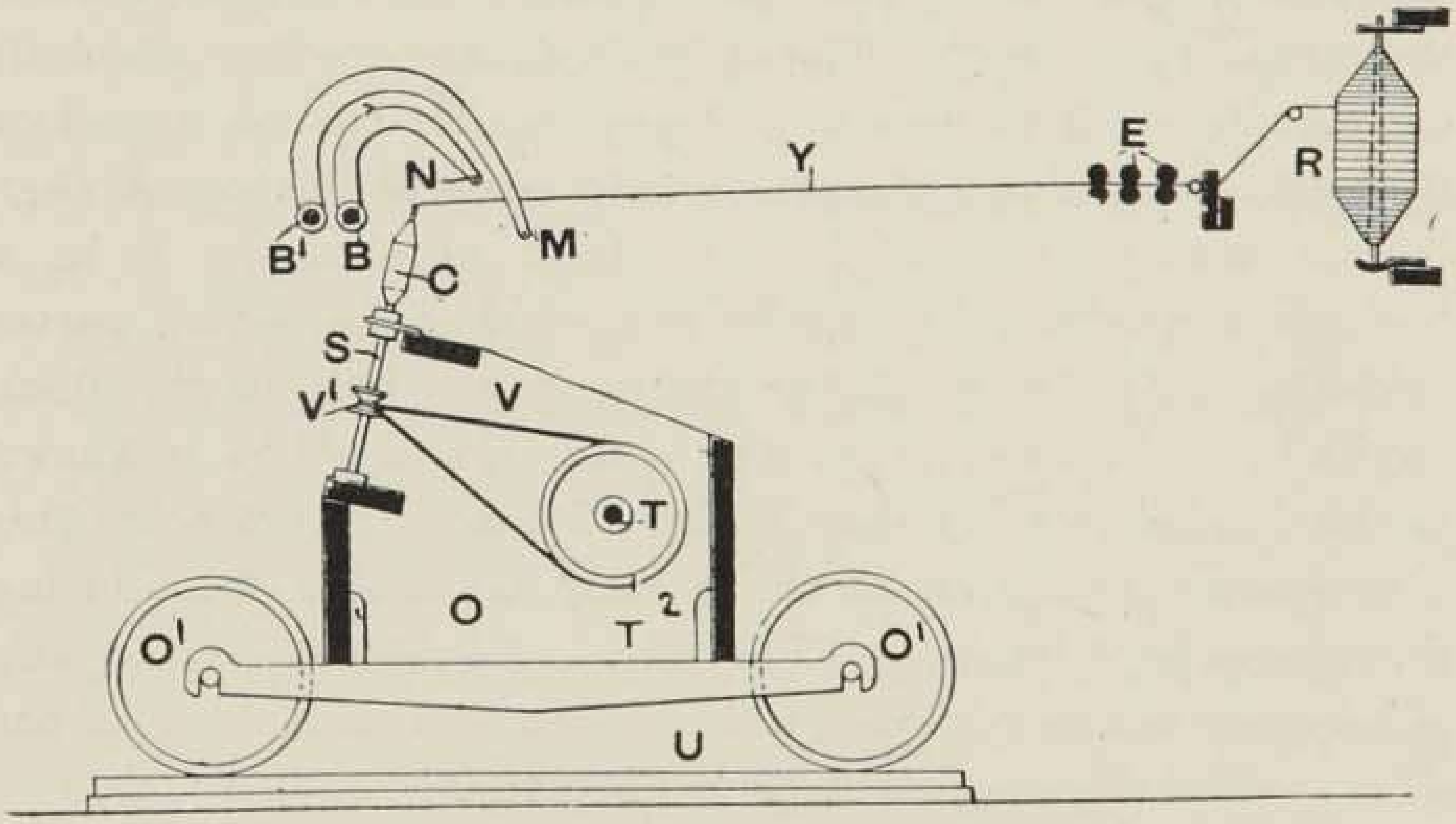

Fig. 60.

on each spindle between its point and the nose of the cop C are uncoiled. As this takes place the faller N descends and the counter faller M ascends, so as at once to maintain approximately the tension of the stretch of yarn and to guide the latter on to the cop. This operation of reversal of the spindles is technically known as "backing-off." Immediately it is completed the drawing in of the carriage begins, and the spindles are revolved in their normal direction, so as to wind the yarn on to the cop as it is released by the inward run. As this takes place the faller N rises, and the yarn is thus guided on to the cop in ascending coils. When the inward run is complete the whole of the winding operations cease, the faller and counter faller wires assume their normal position clear of the yarn, and the parts are again adjusted to begin the work of drawing and twisting.

(247) The brief description just given enables a classification of the various stages to be given. They are, 1st, twisting and drawing; 2nd, arrestation; 3rd, backing-off; 4th, winding; and 5th, re-engagement. The operations of the various parts during each of these periods will be dealt with in detail as they arise, but for a full treatment of this portion of the subject the student is referred to the author's work on "Modern Cotton Spinning Machinery." The difficulty which arises when an attempt is made to master and comprehend the movement of the various parts at different periods arises from the fact that

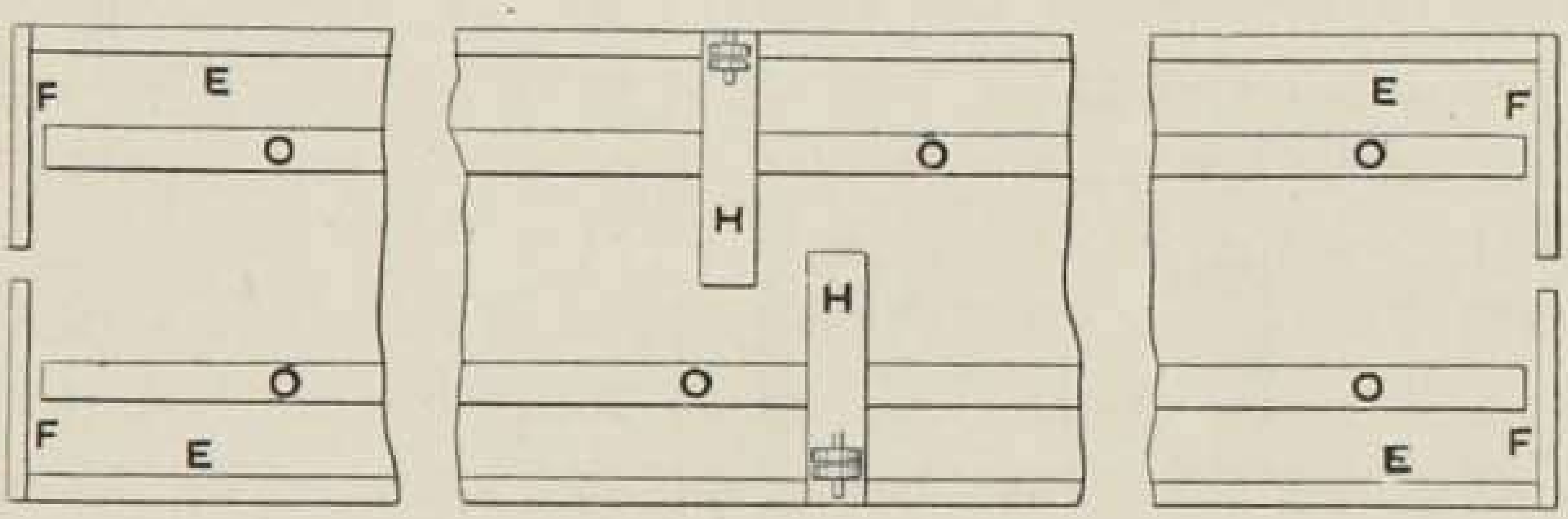

Fig. 61.

at one time a certain portion of the mechanism is performing one function and at another quite a different one, both the direction and velocity of its movement being changed. In order to save space and trouble the whole of the mechanism which forms the operative portion is contained in a central frame, called the headstock, from which diverge to the right and left the two carriages, roller beams, and bearing pieces. This arrangement is shown diagrammatically in Fig. 61, which is a representation of two mules set in the positions which they occupy in the mill. H in each case represents the headstock, which is a double longitudinal frame securely tied together by transverse beams or rails. The carriages O extend at right angles to the right and left, and in each case the carriage is shorter on the right hand side of the headstock. The roller beams marked E also extend the whole length of the mule, and are borne at suitable intervals by light frames or spring pieces, and at the ends by frames F as shown. The number of spindles in a mule varies with the work it has to do, the gauge—that is, the distance from centre to centre—being less with the fineness of the yarn produced. Weft cops, being smaller in size than those used for warp purposes, are spun upon smaller spindles, and the gauge of the spindles is less. Mules are made with gauges varying from $1\frac{1}{8}$in. to $1\frac{3}{4}$in. There is an advantage in the disposition of each pair of mules in the manner shown, which is that as the minder works between the headstock he is able to attend to each alternately. The bulk of the piecing of broken ends is done during the early part of each stretch, so that it is possible to be piecing the ends which may be broken on one machine while the other carriage is running up. This relative movement is always maintained if possible, and greatly facilitates the conduct of the work.

(248) There are usually three lines of rollers in a mule, the lower line being fluted, the upper front line sometimes loose boss, the back top rollers being self-weighted. The practice in this respect varies, some people preferring to weight all the three lines by stirrup and weight, while others only fit the front line in this manner. The loose boss roller is unsuitable for mules of a fine pitch. The rollers are of course in two sets in each machine, one on each side of the headstock, but the two front lines are coupled by a short shaft extending across the headstock. This shaft is fitted with a clutch, the engagement or disengagement of which gives motion to or stops the rollers. The period of the engagement of the clutch is regulated in a manner to be afterwards described. The carriage of the mule is a strong frame, built partially of wood, the longitudinal beams being of that material. These are secured to each other by transverse cast-iron stays, or "muntins," which also act as bearings for the tin roller shafts. It is also advisable, especially in long mules, to provide diagonal

stays. Each of the carriages in a mule is firmly secured to a strong iron frame, which is known as the "square." The square carries the driving mechanism for the tin roller and also a great part of that connected with the fallers. The rollers in each carriage are coupled by a shaft extending across the square, on which is fixed the pulley by which they are driven. The spindle is made of steel, is from 13½in. to 18in. long, and of a diameter varying from ⅜in. to ⅛in. For that part of its length between the footstep and bolster it is of the same diameter, and on this part—called the haft—the warve is secured. Above the bolster the "blade" of the spindle is made taper, and on this the spool or cop of cotton is wound. The spindles are, as has been indicated, not carried vertically but angularly in their bearings, the degree of angularity depending on the material to be spun. The rule generally pursued is to give the point of the spindle a forward inclination from a vertical line drawn from the centre of the footstep of about ¼in. for each inch of its length. Thus a 16in. spindle would have 4in. of inclination. It is, however, the practice to vary this according to the counts of yarn being spun, coarse counts being spun on spindles having less inclination, the amount of which is increased as the yarns spun become finer. The average, however, is as stated. The purpose of this inclination is to permit of the ready passage of the yarn over the point of the spindle, for it is evident that the angle formed by the yarn when the carriage is out, and it is held between the spindle point and the rollers, will be more acute than when the carriage is in. It is, therefore, necessary to give the spindle such an angular disposition as will enable the yarn to pass readily over the point at all parts of the carriage traverse without undue strain or any slip. The spindles are driven by bands in the manner previously named.

(249) This very general review of the essential portions of a mule is sufficient to enable a clear idea to be obtained of the mechanism, and a detailed description can now be given. In doing so, it may be stated at the outset, that it is intended to deal with the various motions, less from the mechanical than

from the spinning point of view, and although it will be necessary to treat largely the mechanical construction, it will be done with a view of elucidating the actual operation of the machine. Referring then to Figs. 62, 63, and 64, which are representations of the method of driving the mule of Messrs. Platt Brothers and Co., Limited, the machine is driven from a counter-shaft by means of a belt, which passes over a pulley A, fixed on a shaft C, known as the "rim shaft." The pulley A is 16in. diameter and is 5in. wide. Alongside the pulley A, which is fast on the shaft, is a loose pulley B of the same diameter, but 5¼in. wide. The strap is only

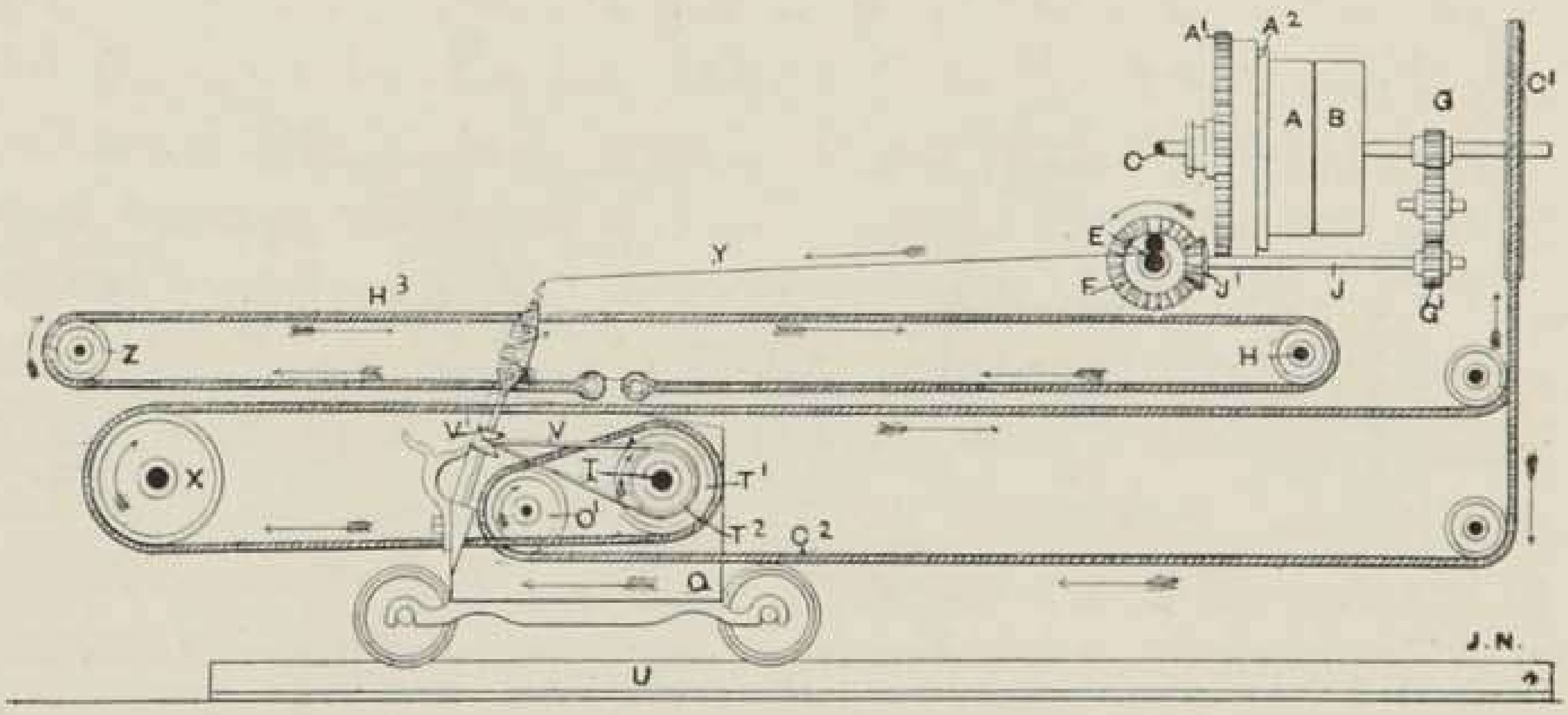

Fig. 62.

partially put upon the fast pulley, a certain portion of it, sufficient to drive the loose pulley, being always on the latter. The fast pulley is provided at one side with a part of a cone A^2, engaging with a similarly shaped, but female cone on the wheel A^1. This is called the "backing-off friction," and is utilised as afterwards described. The spindles are driven, as shown in Fig. 62, from the pulley C^1, which, although there shown as a single grooved pulley is generally made with two and sometimes with three grooves. The pulley C^1 is called the "rim pulley," or shortly, the "rim." The course of the endless band or rope C^2 is clearly indicated, and it will be seen that it passes over a pulley T^1 on the tin roller shaft T in such a way that the latter is effectively driven. The course of the rope is, naturally, doubled or triplicated, when a double or treble grooved rim is used, but to show the course of the rope, under these circumstances, would complicate the drawings and render them obscure. The rollers are driven from the pinion G, fixed on the rim shaft. By means of a carrier wheel, G drives the pinion G^1, fastened on the side shaft

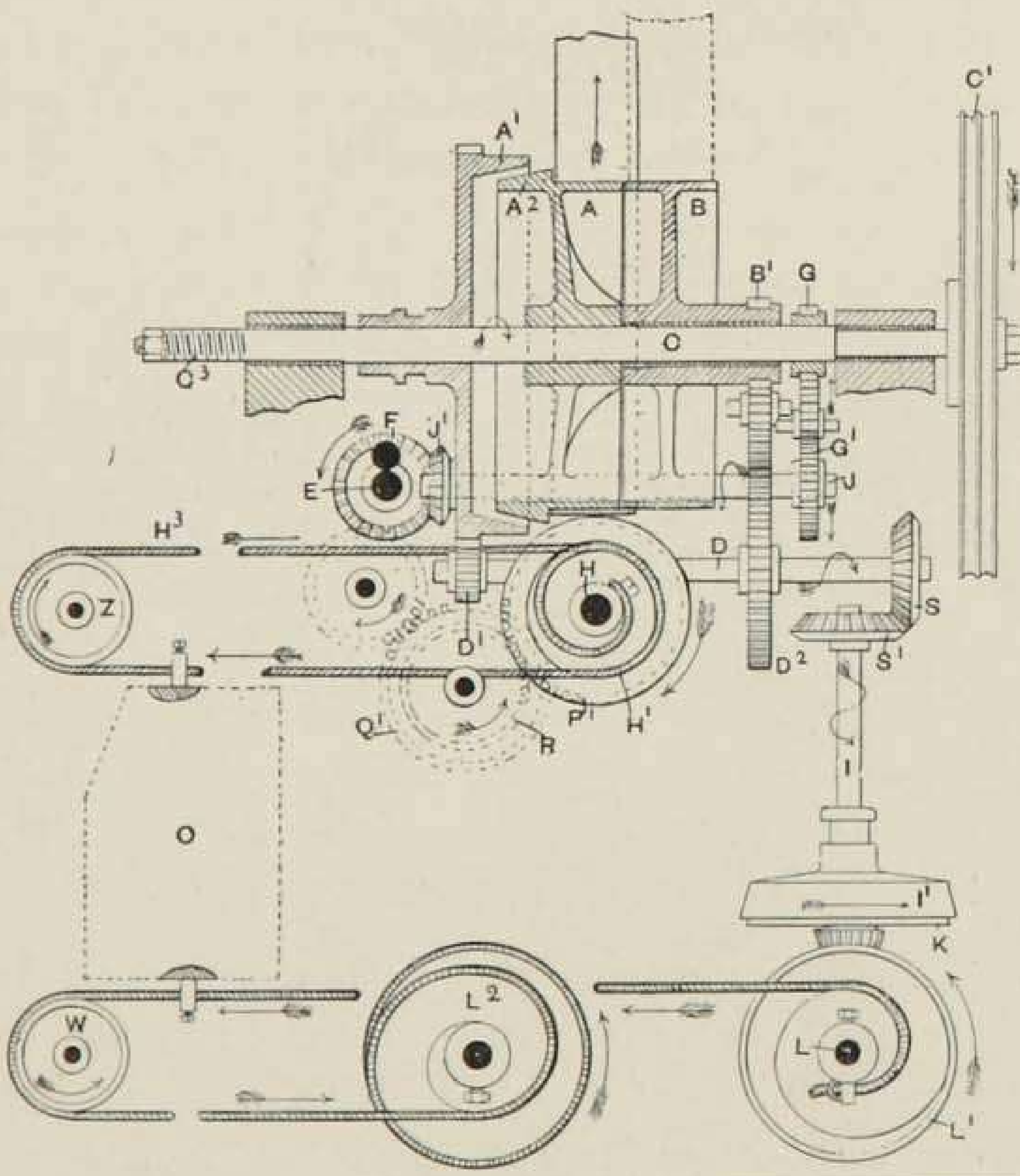

Fig. 63.

J, on the other end of which is a bevel pinion J^1, engaging with a bevel wheel F on the roller shaft E. In order to give a clear idea of the operation of most of these parts, it is intended to show the effect of the various trains of wheels, but it must be clearly understood that, in doing so, the number of teeth given are not actual, but only such as will illustrate the subject. So long as the principle is demonstrated the actual size of the wheels employed is immaterial, and fictitious dimensions can be employed with equal effect to actual ones. Let it therefore be assumed that the rim pulley C^1 is 22in., the pulley T^1 on the tin roller shaft T 12in., the tin roller T^2 6in., and the warve V^1 on the spindle $\frac{3}{4}$in. diameter respectively. Let it also be assumed that the rim shaft is running at 600 revo-

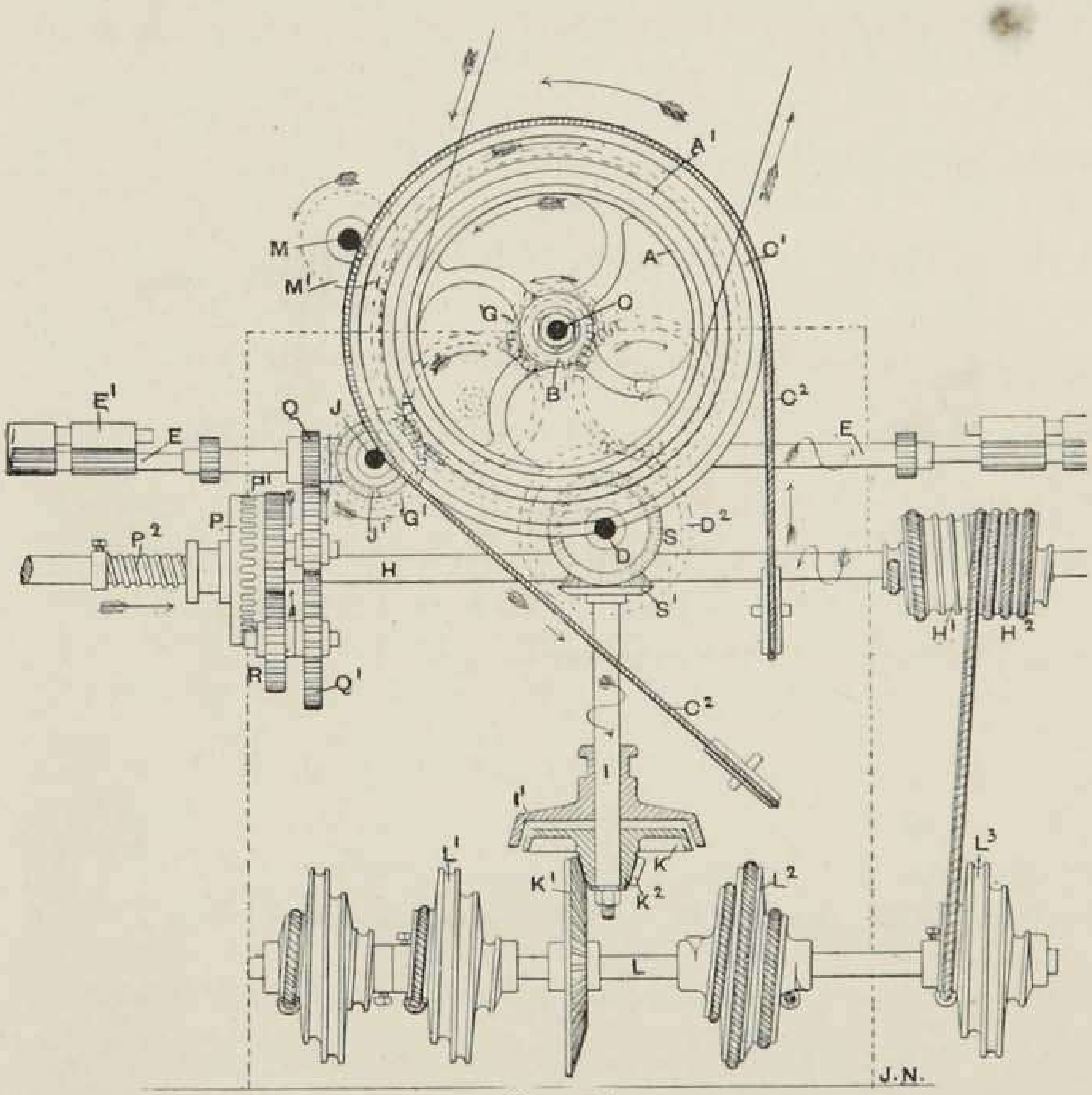

FIG. 64.

lutions per minute. Then the velocity of the spindles would be $\frac{22 \times 6}{12 \times \frac{3}{4}} \times 600 = 8{,}800$. In like manner, if the pinion G be assumed to have 18 teeth, the wheel G^1 39, the pinion J^1 19, and the front roller clutch wheel F 40, then the speed of the latter would be $\frac{18 \times 19}{39 \times 40} \times 600 = 131 \cdot 5$ revolutions per minute. Now, if the front roller be assumed to be 1in. diameter, it will deliver 413·2in. of yarn. The twist is therefore $\frac{8800}{413 \cdot 2} = 21 \cdot 5$ turns per inch, which is practically equal to that required for 32's twist. The back shaft is driven by the train of wheels shown in Fig. 64, of which Q is fixed on the roller shaft and is assumed to have 21 teeth. It drives, by the intervention of a carrier wheel, the wheel Q^1, which is fixed on a short shaft, on which is also a pinion R, called the "gain wheel," gearing with a wheel P^1, which forms part of a clutch on the back shaft H. The half clutch P is ordinarily pressed into gear with the wheel P^1 by the spring P^2, which is, however, sufficiently weak to yield if any obstruction is presented to the rotation of the shaft H. Q^1 is supposed to have 50 teeth, R 23, and P^1 56. The velocity of the back shaft is therefore $\frac{21 \times 23}{50 \times 56} \times 131 \cdot 5 = 22 \cdot 6$. On the back shaft H are scrolls H^1, which are assumed to be 6in. diameter. 22·6 revolutions of the scrolls will therefore give a traverse to the rope of $6 \times 3 \cdot 1416 \times 22 \cdot 6 = 426$in. The rope H^3 passing round the scrolls is attached to the carriage O and is taken round a carrier pulley Z, fixed to the headstock at the outer end of it. Thus, if the rope is moved, the carriage is also traversed at the same velocity. In the case supposed the carriage is traversed at the rate of 426in. per minute. It would therefore take for a full stretch of 64in. 9 seconds, and in this time the rollers would deliver $\frac{9}{60} \times 413 \cdot 2 = 62$in. of yarn nearly. The carriage thus gains upon the roller delivery 2in. in each stretch and draws the yarn out as described. The effect of this "gain" of the carriage is to elongate or subject the roving to a further draft, and thus decrease the inequalities in diameter. As was described in the last chapter, twist runs into the thinner places in the roving, and thus hardens them. It follows therefore that this supplementary drawing action elongates the untwisted—*i.e.*, the thicker—places, and aids in the production of an even thread. The amount of gain which is permissible depends entirely upon the quality and staple of the cotton which is being treated. Very short stapled cotton will not permit of the introduction of any draft subsequent to the roller draft, while long stapled cotton allows it to be introduced to a considerable extent. The practice in the former case often is to allow the rollers to deliver yarn at a quicker speed than the rate of traverse of the carriage, the rollers thus gaining on the carriage. This is principally the case when very coarse counts are being spun from short stapled cotton. The total draft depends entirely upon the quality of the cotton, and in arranging it, it must be properly divided between the rollers and carriage.

(250) No special description need be given of the method of obtaining the differential velocity of the three lines of rollers in order to put in the draft. This is similar in principle and practically in detail to that in the roving frame. In setting the rollers, however, some care should be exercised, as the draft in the mule is considerable, as will be seen when the question of drafts comes to be dealt with. This subject will be reverted to in a short time. It will be better at this point to give the various rules for working out the speeds and drafts, in so far as they relate to the operation of the parts described up to the present point. Practically, the different portions of the mechanism with which we have dealt, comprise the whole of those necessary for spinning, the remaining operations being connected with winding, and having no relation to spinning. The ordinary rules employed are as follows :—

To find the draft required in the rollers when the gain of the carriage, the counts to be spun, and the hank roving are known—

Subtract the amount of gain from the total length of stretch. Thus, if gain is 2in., and length of stretch 64, net length of yarn delivered is 62in.

$$\frac{\text{Counts required} \times \text{length delivered}}{\text{Full length of stretch} \times \text{hank roving}} = \text{draft.}$$

To find the draft required in the rollers when the carriage does not gain—

$$\frac{\text{Crown wheel} \times \text{back roller wheel} \times \text{diameter of front rollers (in eighths).}}{\text{Front roller wheel} \times \text{change pinion} \times \text{diameter of back roller (in eighths).}}$$

A constant number can be got by making the above calculation, and omitting the change wheel.

To calculate number of teeth in change pinion, to obtain any given draft—

$$\frac{\text{Crown wheel} \times \text{back roller wheel} \times \text{diameter of front roller (in eighths).}}{\text{Front roller wheel} \times \text{draft required} \times \text{diameter of back roller (in eighths).}}$$

To find the counts being spun when carriage gains—

$$\frac{\text{Hank roving} \times \text{total draft} \times \text{total stretch.}}{\text{Length delivered by rollers.}}$$

To find change pinion required to spin any counts when present counts are known—

$$\frac{\text{Present counts} \times \text{present change pinions.}}{\text{Counts required.}}$$

To find back roller wheel for any draft—

$$\frac{\text{Front roller wheel} \times \text{change pinion} \times \text{diameter of back roller} \times \text{draft required.}}{\text{Crown wheel} \times \text{diameter of front roller.}}$$

To find the correct wheel on middle roller—

First determine the ratio of draft which exists between the back roller and the middle roller. Say this is as $y : x$, representing the relative velocity of the middle and back rollers. Then—

$$\frac{\text{Back roller wheel} \times \text{diameter of middle roller} \times x.}{\text{Diameter of back roller} \times y.}$$

To find the number of turns per inch in the yarn, velocity of spindles and rollers being known—

$$\frac{\text{Number of revolutions of spindles.}}{\text{Revolution of front roller} \times \text{circumference of front roller.}}$$

To find the required size of rim pulley, to obtain any counts when present counts are known, without altering front roller speed—

$$\frac{\text{Diameter present rim pulley squared} \times \text{counts required.}}{\text{Counts spun.}}$$

The square root of quotient = diameter of pulley required.

Or, $\frac{\text{Counts required} \times \text{diameter present rim pulley}}{\text{Present counts.}} = a.$

Then $\frac{a + \text{present size of pulley}}{2} = \text{diameter pulley required.}$

It is much preferable to change the twist wheel rather than the rim pulley except in extreme cases of variation. To do this if the size of the twist wheel is substituted for the rim pulley in the last rule given the size of the twist wheel can be ascertained when changing counts.

To find the amount of gain in the carriage—

There are three ways of doing this. The first is indicated in the last paragraph, this giving the total gain. By dividing this by the roller delivery the gain per inch is given. Thus, in the case supposed the gain is $\frac{2}{62} = \cdot 032$ per inch. The next method is as follows—

$$\frac{\text{Number of inches carriage travels.}}{\text{Number of inches of roving delivered by front roller.}}$$

The third method is (refer to Fig. 64)—

$$\frac{\text{Wheel Q} \times \text{pinion R} \times \text{diameter of scroll H.}}{\text{Wheel Q}^1 \times \text{wheel P}^1.}$$

The quotient in either case will be the roller delivery plus the gain, and will be the distance travelled by the carriage during the delivery of one inch by the rollers.

(251) The rules thus given are those which relate to the spinning or twisting mechanism, and a brief description of what happens during this period, together with a few detailed remarks about the care required, may not be out of place. The strap being on the fast pulley A, which is free to revolve and entirely out of contact with the friction clutch A^1, the rim pulley C^1 is rapidly rotated. By means of the rim band this movement is communicated to the spindles, which are revolving at their normal velocity. During the same period the rollers are delivering roving, which is being twisted as it emerges. The two faller wires are out of contact with the yarn, and the carriage O is traversed as described by reason of the forward movement of the drawing out band. During all this period the work of spinning and drawing is going steadily on, and continues to do so until the carriage arrives at the end of its outward stretch. As will afterwards be specially described, when very fine yarns are spun the rollers cease to deliver roving a little before the carriage terminates its traverse, and an extra draft is given to it. This operation is called "jacking." It is also the practice for twisting to be continued after the carriage

has arrived at the end of its stretch, this being known as "twisting at the head." The determination of the amount of each of these operations is made by the peculiar setting of the mechanism, which will be dealt with presently. The condition of the various bands used in connection with twisting is an important matter. It has become the very praiseworthy practice of machinists to make all the rope pulleys used as large as possible, the rim, carrier, and tin roller pulleys being alike made of large diameter. In this way the operation of twisting is improved, and the life of the rope increased. All change wheels are also made of as large a diameter as possible; the reason of this being that if they have only a small number of teeth, one tooth more or less makes a large proportionate difference in the velocity of the part driven, and thus renders the exact variation which is required difficult to obtain. Thus, if the regulation of the roller speed depended upon the changing of the pinion J^1, which has been assumed to have 19 teeth, it is obvious that a change of one tooth would have an effect upon the velocity of the rollers much greater than would happen if J^1 had 50 teeth. It is customary to change the wheel G^1 when it is desired to accelerate or diminish the rate of delivery of the rollers. The tin roller bearings require to be kept constantly lubricated, and it is most important to attend to the tension of the spindle bands. These, if too tight, so speedily add to the power required to drive the machine, that it is highly important they should be of absolutely the correct tension. If the pull of the bands is excessive, an increase of friction on the bearings immediately follows, while if they are too slack, slipping occurs, and the correct twist is not introduced. The tension of all the bands in a mule is more or less affected by atmospheric conditions, and this is a point which ought not to be forgotten. The lubrication of mule spindles is a difficult matter, and requires careful attention. Unless they are properly looked to, friction arises, and loss of power ensues. The oil has a tendency to rise up the spindle and be flung off by centrifugal action. Not only is there a loss arising from this cause, but there is a danger of oil getting on the cops. There are one or two patented devices in the way of shields which overcome this difficulty to a large extent, and which are meritorious in that respect. The setting of the rollers has been previously referred to, and it may be here said that, as in the drawing-frame, the diameter of the rollers used depends to a large extent upon the length of staple treated. Thus, Indian cotton can be best drawn by rollers $\frac{7}{8}$in. diameter, while most other varieties can be drawn by a front roller 1in. diameter. In setting the rollers, a space should be left between the back and middle lines of from $\frac{1}{4}$in. to $\frac{3}{16}$in. greater than the average length of staple, and between the front and middle lines a space of from $\frac{1}{16}$in. to $\frac{1}{8}$in. The reason for this procedure is obvious. The roller draft in the mule is large, taking place usually entirely between the front and middle lines, but is only used for the purpose of attenuation, and not for paralleli-sing purposes. Thus the absolute work required can be easily carried out with the rollers set as described. The covering of the rollers should be carefully looked to, and the leather sheaths kept in as nearly a perfect condition as possible. All the remarks which were made in dealing with this point in drawing should be carefully borne in mind, and unless they are, the evils produced in the drawing will be reproduced at this point. The leather should never be permitted to become too dry, as, if so, slip occurs, and the yarn will be too coarse. This matter is one of the most important details in connection with a mule, and uneven yarn is largely the result of inattention to this point. Lubrication should, therefore, be strictly looked to, so as to ensure the preservation of a uniform surface velocity between the top and bottom lines. The bottom rollers should be kept cylindrical, and, if strained, must be at once attended to. If traverse motions are fitted, they must be kept clean, as otherwise they are liable to set up such a friction on the roving as to stretch it considerably. It is easy to see that this is an attenuation not provided for in any system of drafts, and one which will only be perceptible when wrapping the yarn. The remarks made about cleanliness in the traverse guides and motion apply equally to all the parts of the mule. The creel pegs and their bearings should be arranged in such a manner and kept in such a condition that the bobbins can easily and freely revolve. Cleanliness in this part is essential, and any collection of fly or dust must be avoided. Attention to a number of little points is, in brief, essential if the best work is to be produced, and although a good workman will look after these himself, they should also be borne in mind by those in authority.

(252) The points thus detailed have especial reference to the operation of spinning or twisting. As soon as the carriage arrives at, or near, the end of its stretch, or outward run, it is necessary to stop it, so as to permit of the readjustment of the parts for performing the operation of winding. It becomes, therefore, requisite to provide means whereby the motion of the rollers, spindles, and carriage can be stopped, and this is accomplished in the following manner. The driving strap is transferred to the loose pulley, so that when the roller motion is driven from the rim shaft, as shown in the preceding figures, the rollers and back shaft would be stopped. It is the practice, however, to afford facilities for the detachment of the clutches actuating the rollers and back shaft independently of each other and of the strap guide. Accordingly, on the roller shaft a toothed clutch is fitted, one-half being formed on the wheel F and the other half sliding on a feather key on the shaft. By means of a ring groove the necessary lateral motion of the sliding half-clutch is obtained, a claw fitting in the groove. This claw is at the end of a lever which is actuated as presently described. The back shaft clutch P P^1 is also connected and disconnected by means of a claw ended lever. It only remains to be seen how these various levers are actuated. This is mainly the work of a shaft M, shown in Fig. 65 with its connections, which is known as the "cam shaft," owing to the fact that it carries several cams, by means of which the necessary levers are actuated. It is becoming the fashion to do without the cam shaft, and to rely, for the necessary changes, on levers suitably

arranged and actuated. That all the requisite changes can be made without the aid of the cam shaft is true, but on the whole, the latter is a convenient method of effecting them; and, at any rate, in principle, is not dissimilar to the other arrangements named. The principle underlying them all is to produce the requisite movement of the various parts by means of leverage, so as to cause the transferral of the strap and the detachment or attachment of the clutches at the proper moment. In some cases the cam shaft is employed as an aid to other mechanism, which is thus relieved from a good deal of strain. Whatever may be the manner of its application, the object is the same in every case. Hinged to one side of the headstock framing is a lever T, known as the "long lever." This is actuated in the example shown by two brackets S S^1, which are affixed to the carriage, and which, when the latter runs out or in, come in contact with the two bowls R R^1, placed on studs fixed in the lever. In some makes of mule the lever T is straight, and has affixed to it at each end brackets with angular faces which project above the top of the lever, so as to come into contact with the faller rods. The effect is the same, as the lever T is in either case depressed alternately at each end, as the engagement with the bowls R or brackets takes place. After each alternate movement the long lever is locked by the lever Q, which is constantly pressed against it by the spring O. When this movement occurs, a lever U^1, coupled to T by the rod U, is rocked so that (as shown in a detached view in Fig. 65, at the left hand corner) one end of it is oscillated towards or from the cam shaft M. The cam V, against which the lever T^1 abuts, is formed with two raised surfaces, V^1 V^2, one being part of an outer ring, and the other part of an inner ring. So long as the lever T^1 is pressing on either of the raised parts of the cam V, the half-friction clutch W is kept out of contact with the other half X. As the latter has a toothed annulus formed on it, which engages with the teeth in the friction clutch A^1, it is constantly revolving, because, as will be shown presently, A^1 is also in constant rotation. When the lever U^1 is oscillated, however, its end is removed from the high part of the cam surface with which it is engaged, and is brought into the lower space of the other ring or surface. The coiled spring V^3 is thus able to push the clutch W into gear with X, and the cam shaft is revolved. As the end of the lever U^1 is, however, held up to the face of one of the cam courses, and as the raised part in each is opposite that in the other—that is, at the other side of the cam shaft centre—the cam shaft can only make half a revolution before its motion is arrested by the detachment of the clutch W X. In one form of cam shaft, where it is placed alongside the framing and below the long lever, the detachment is obtained

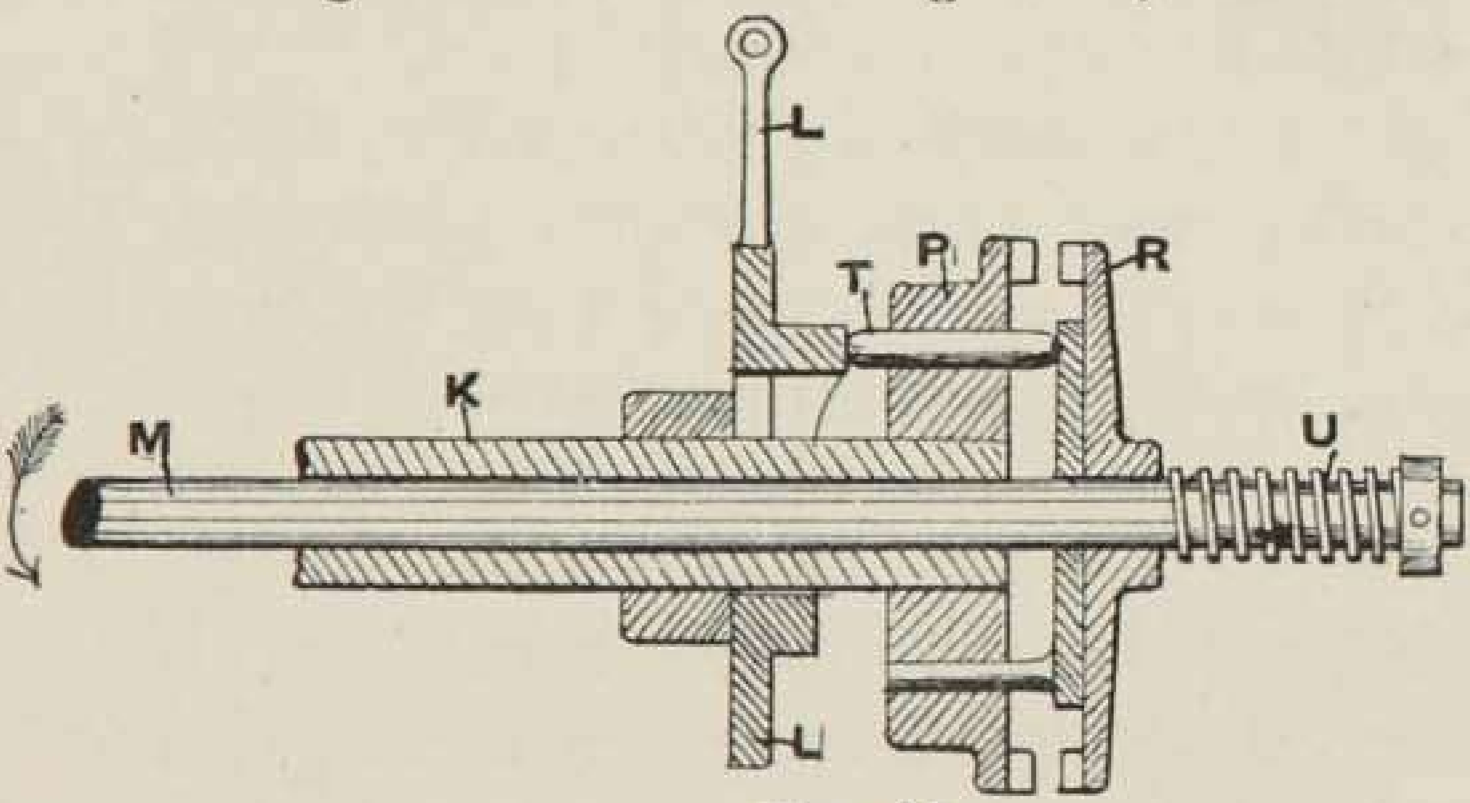

FIG. 66.

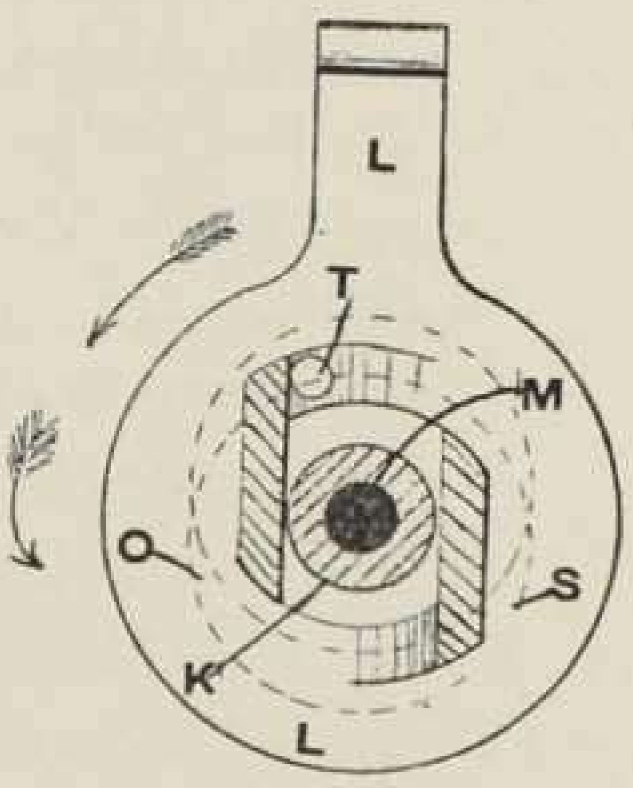

FIG. 67.

by means of a pendant plate L (Figs. 66 and 67) surrounding the shaft M, on which revolves a tubular cam shaft K. The plate L is jointed to the long lever, and is formed with a slot in it to permit of its rise and fall. It is constructed with two cam courses, O and S, against which the pin T is kept constantly pressed by reason of the pressure of the spring U acting through the half clutch R. The action is precisely that of the preceding case. When the cam plate L is lifted, the pin T moves on to the lower part of the adjoining cam course, and the clutch P R is engaged. The cam shaft makes its half revolution, and the clutch is again detached.

(253) The effect of this movement is threefold. Referring again to Fig. 65, there are three cams on the cam shaft. One

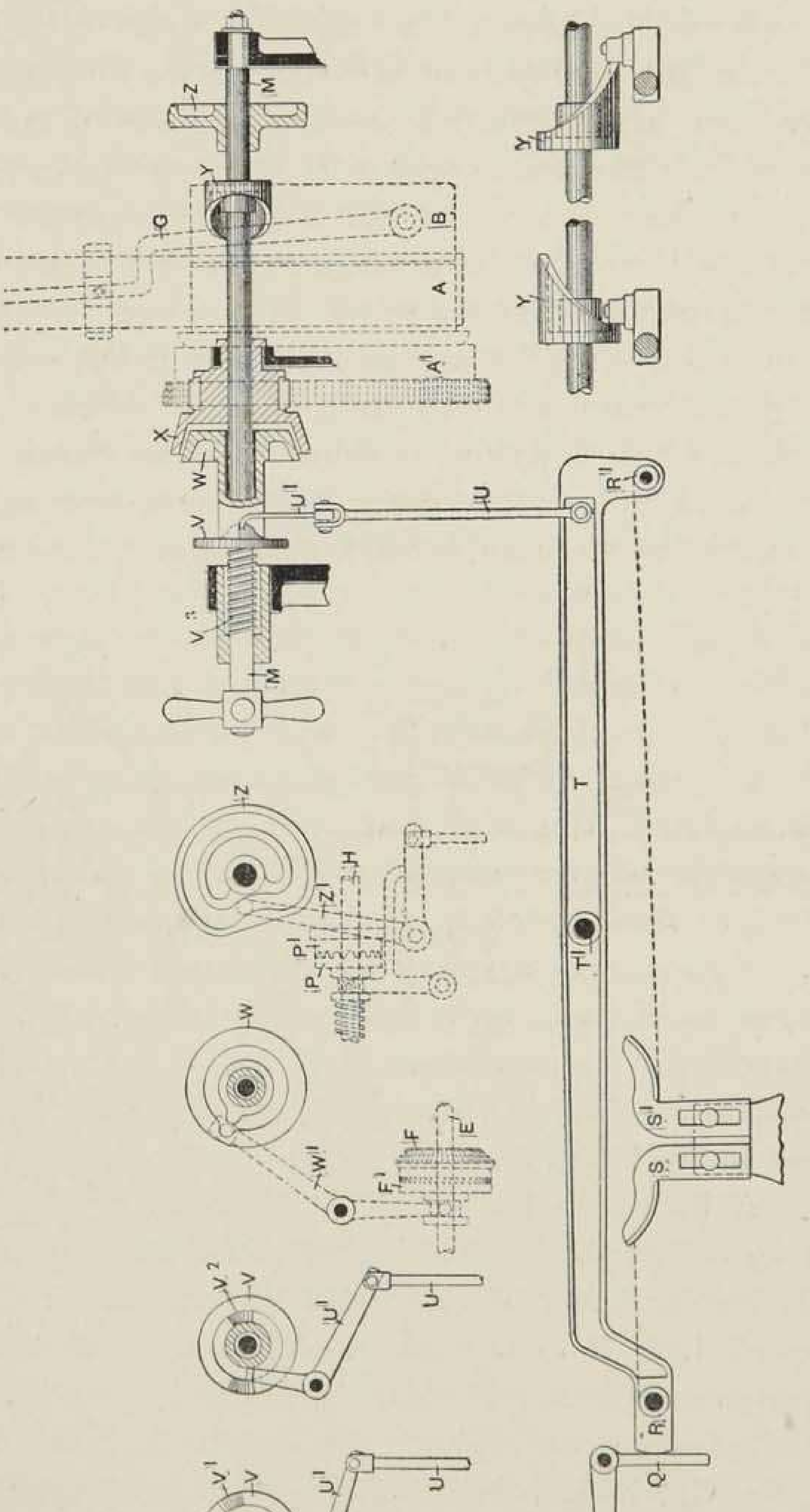

Fig. 65.

of them Z operates the back shaft clutch P P^1 by means of the lever Z^1, as shown in the detached view. The clutch, as was previously named, is usually kept in gear by a coiled spring H^2, threaded on the shaft H, and the half rotation of the cam Z presses the clutch open. Thus the back shaft is stopped and the carriage is brought to rest. A second cam course formed in the half clutch W actuates by means of a rocking lever W^1 the roller clutch F^1, which is also shown in a separate view. A third cam Y engages with a pin in the strap guide lever, which is pivoted at its lower end, and the rotation of Y—as separately illustrated—causes the strap lever G to be moved. The position of the bowl on the strap guide lever when the strap is on the loose and fast pulley is shown separately in the detached view at the lower right hand corner. In some cases the movement of the strap lever G is made by means of a separate motion, known as the "strap relieving motion," on which a few words may be said. Before dealing with this part of the subject, however, a brief description of the method of moving the strap in the mule illustrated may be dealt with. The strap guide is fixed as indicated at the upper end of the lever G, which is free to oscillate. By means of a spring attachment a second hinged lever is constantly drawn towards the strap guide lever. The second lever is fixed upon a short shaft, and has an arm on it which receives a pull from a second spring. The cam Y engages with a pin in the latter, and the spring constantly keeps them engaged. A horizontal hinged lever H, shown in Fig. 68, is attached to the headstock framing, and is drawn upwards by means of a spring P, so that a shoulder H^1 formed on it engages with a catch L fixed to the frame. Thus, when the catch is engaged any oscillation of the strap guide is impossible. The worm C^3 formed on the end of the rim shaft gears with a worm wheel G, which, being compounded with a spur wheel G^1, rotates, by means of the wheel J, a small crank arm K, the pin in the outer end of which is caused during its rotation to press on the end of the horizontal arm H. When this happens the latter is depressed, and the catch L is disengaged.

The strap guide lever is thus unlocked, and the springs attached to it are free to draw it over so as to move the strap from the fast to the loose pulley when freed by the cam. The period at which this detachment can take place is easily regulated by means of the gearing named, and it is obvious that by duly proportioning the various levers the extent of the movement can be accurately regulated. It is also clear that the roller and back shaft clutches may be disengaged, while the strap, owing to the engagement of the catch with the horizontal lever, is held on the fast pulley. The cam shaft having made its half revolution the strap guide lever would, of course, be free, but could not make its traverse until the catch was released. Thus, drawing out would have ceased, the rollers would not be delivering yarn, while the spindles would be revolving for a period controlled by the detachment of the catch and lever. "Twisting at the head" can thus be effected, and its extent is entirely dependent on the difference between the time when the cam shaft moves and the catch is released. The spur wheel on the crank arbor is practically the twist wheel when this arrangement is fitted, because its diameter determines the period of termination of the spindle rotation, but the change is more conveniently made by altering the pinion G^1 driving it. Where twisting at the head does not take place, and this contrivance is not fitted, the necessary change can be made by controlling the roller speed, which is effected by changing the pinion. For the reasons given it is desirable to make these wheels as large as possible, and thus enable slight variations to be effected. It may perhaps be stated that the cam shaft is technically said to "make the changes" when it rotates in the manner described.

(254) Before describing the operation of a strap relieving motion, it is necessary to deal with the method of operating the friction cone A^1, shown in Figs. 62 and 63. As will be seen in those illustrations, A^1 has a ring groove formed on its boss, by means of a lever engaging with which it can be moved along the rim shaft towards or away from the pulley A. Without stopping at present to enquire how this is done, it may be

stated that the friction cone is always revolving, being driven (as shown in Fig. 63) by the train of wheels B^1 on the boss of the loose pulley, D^2 on the side shaft D, and pinion D^1, also on that shaft, and engaging with wheel A^1. The loose pulley is always revolving, owing to the overlap of the strap previously referred to, or, in some cases, is separately driven by a grooved pulley fixed on D. In either case, the friction cone A^1 is always revolving. B^1 having 23 teeth and D^2 55, the velocity of the side shaft D is $\frac{23}{55} \times 600 = 251$. D^1 having 14 teeth and A^1 112 teeth, the speed of A^1 is $\frac{14}{112} \times 251 = 31{\cdot}37$ revolutions—that is, when the strap is transferred from the fast to the loose pulley, as indicated by the dotted lines in Fig. 63, and the engagement of A and A^1 takes place, A is revolved, as is the rim shaft C, at a speed of 31·37 revolutions. The spindles are therefore revolved at a velocity of $\frac{22 \times 6}{12 \times \frac{3}{4}} \times 31{\cdot}37 = 460$. Their direction of motion is, however, reversed, and is utilised for a purpose to be shortly described. The point it is desired to make is, that the engagement of the friction clutch A^1 with A, when the rim shaft is running at its normal velocity, entails the expenditure of a good deal of power to arrest the motion of the rim shaft and spindles prior to the direction of that motion being reversed. So great is that power that many spinners prefer to begin to transfer the strap from the fast to the loose pulley at a time a few inches before the carriage reaches the end of its outward run. It is also a common practice to fix on the end of the shaft D a grooved rope pulley, which is driven by a separate band from the counter shaft, thus relieving the gearing driving the backing-off friction considerably. The premature transferral of the strap involves the diminution of the velocity of the spindles, and also necessitates the abolition of the strap lever cam Y, as the work of moving the strap in either direction is performed by the pull of springs which are brought into action by the release of catches or detents by means of levers. The result of such a transfer of the strap is to reduce the friction named to a considerable extent as the momentum of the carriage gradually decreases, as can easily be understood. Thus, when it arrives at the end of the stretch the power required to arrest the movement of the spindles and reverse its direction is much less than it otherwise would be. The construction of strap relieving motions is very simple, consisting of a hinged lever, which is coupled to a connecting-rod, which, in turn, is jointed to the strap lever. The first-named lever is arranged to have one end of it so disposed as to come into contact with a stud fixed on the carriage. The stud is capable of adjustment, and should be set so that it will have depressed the hinged lever sufficiently to move the strap, and cause it to be leaving the fast pulley when the carriage finally arrives in its outermost position, and is locked. Means of adjustment are provided at various points in the series of levers, so as to give them a greater or less range of action. The chief merit of a motion of this character is the saving of wear caused by the reduced friction of the parts. It also, when applied, undoubtedly relieves the cam of much of its work. It also enables the minder to have a better control of the mule, which, owing to the fact that the strap fork is not moved by the cam, but by springs, is more easily stopped at any point. On the other hand, there is the undoubted fact that the amount of twist is reduced during the time that the carriage is gradually coming to rest. The strap being ordinarily traversed by this motion when the carriage is from 7in. to 9in. from its outermost point, the velocity of the spindles is of necessity reduced. It is true that the velocity of the rollers is also reduced, but the effect of the reduction in the latter case is not so great as is the loss of speed in the spindles themselves. If the relieving motion is used, this factor should not be lost sight of. More important than this, however, is the fact that, when it is employed, "twisting at the head" is impossible. It is doubtful whether this alone does not outweigh all the advantages obtained from a relieving motion.

When the final twist is put in with the carriage out, the yarn has been drawn by the gain of the carriage, and is in the best condition for receiving twist. Therefore, the practice of twisting at the head—although not permissible with some classes of cotton—possesses real advantages which cannot be overlooked. For these reasons, although the relieving motion undoubtedly has advantages, it possesses other disadvantages, which should be borne in mind. Its profitable employment or otherwise depends upon circumstances, and can be best determined by every spinner for himself. It will probably be found most advantageous when the coarser counts are being spun, especially when short stapled cotton is used. Before passing on to consider the next branch of the subject, it may be stated that a duplex system of driving has found extensive employment. In this case there are two fast and two loose pulleys on the rim shaft, two straps of less width than those ordinarily used being also employed. There is thus a less range of movement required in the strap guide, and consequently less power required to move the straps, while the bite of the two straps upon the pulleys is increased. On the other hand, there is the difficulty which arises when it is necessary to keep two straps uniformly of one tension. This factor is a most powerful one, and all kinds of schemes have been devised to overcome it. Straps have been specially constructed from the same hide in order to get a similar strength and structure, but the trouble of unequal tension is only partly overcome. From this cause there is a loss of power, which has an important bearing on this matter from the commercial point of view. It is also alleged that the starting of the mule is made too rapidly, thus giving too great a shock. There is, however, the fact that the strap is moved more quickly, and in beginning to "back off" this is a matter of some advantage.

(255) The cessation of the whole of the motion of the parts having been accomplished it is now necessary to obtain the backward movement of the spindles which has been referred to, this being known as "backing off." The reason of this pro-

cedure is as follows: A cop is built or wound on to the spindle in gradually ascending coils which, as will be hereafter fully explained, are at first laid only upon a certain part of the length of the spindle, and are subsequently wound on the further portion of it so as to cover the greater part of the blade. As the yarn passes over the point of the spindle it is coiled round

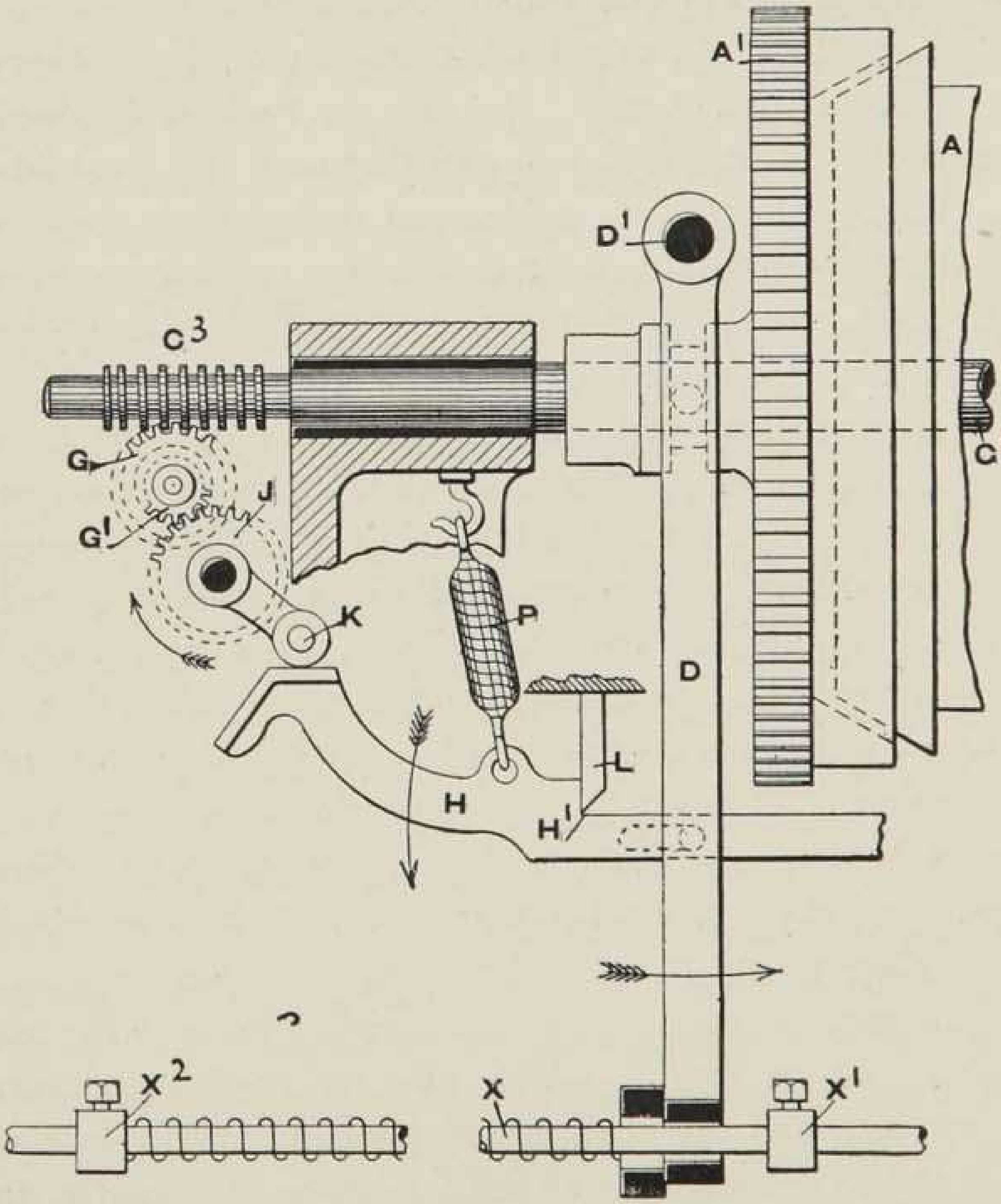

Fig. 68.

it in coarsely-pitched spirals until it finally reaches the nose of the cop, whatever may be the position of the latter. As it is necessary to commence winding at a point a little below the upper end of the cop, the yarn must be depressed from the line it forms between the rollers and spindle during spinning to a line drawn from a little below the nose of the cop to the rollers.

It is clear that if the yarn remained coiled on the spindle blade between its point and the nose of the cop it could not be forced down in the manner described. Thus it is essential that between the moment when the movement of the various parts ceases and winding begins, the length of yarn which, as described, is on the spindle blade, must be released. Backing-off is effected by the engagement of the friction clutch A^1 with the pulley A when the strap is on the loose pulley B. In order to make this movement clear, reference can be made to the diagrammatic illustration given in Fig. 69 (p. 273). The contact between the two parts of the clutch is established by means of a movement given to a vertical lever D, which is fixed, as shown in Fig. 68, on a short arbor placed above the groove in the boss of A^1. On the same arbor, which is free to oscillate, is a claw lever engaging with the ring groove, so that the oscillation of D in either direction engages or detaches the clutch A^1. The lower end of D is arranged so that it passes over a rod X, which is guided by suitable brackets attached to the longitudinal framework of the headstock. On the rod X are two stop hoops X^1 X^2, and between X^2 and the end of the lever D a spiral spring is threaded on the rod, Fig. 68. The backing-off lever D has a pin fixed in it which engages in a slot formed in the horizontal catch lever controlling the movement of the strap. It is essential that the transferral of the strap to the loose pulley shall be nearly simultaneous with the backing-off, but it is equally essential that the latter operation shall not possibly precede the former. In order to give the requisite power to push over the lever, the spring on X is put into compression a little before the strap is moved. This is effected by means of the lever V, which is hinged on the carriage O, and has a constant pull exercised on it by the spring V^1, so that it presents its open mouth to the end of one arm of the lever L pivoted on a stud attached to the headstock. The upper end of L is jointed to the backing-off rod X. When the carriage runs out the bowl at the end of the horizontal arm on L engages with the angular portion of the mouth of V, and the lever L is thus oscillated so as to compress the spring on X. As soon, therefore, as the horizontal strap catch lever is released, as described in paragraph 253, the spring, which has previously pushed over the backing-off lever D as far as it can move, continues the forward motion, and so brings the backing-off friction A^1 into contact with A^2. It is important to note that the backing-off lever must be actuated so as to gradually establish the contact between the backing-off friction cones. Two objects are served by this. In the first place, the friction is considerably reduced, and the heat arising from it is to a great extent avoided. It should, however, be stated that, owing to the large diameter of the backing-off friction which is now adopted, the power exerted is better applied and the spindles are gradually but rapidly brought to rest prior to their reversal. This is the second object aimed at. As soon as backing-off commences and the yarn wrapped between the nose of the cop and the point of the spindle is being released it becomes necessary to take up this portion of it so as to preserve the tension existing in each length. If this object is not attained the twist in the yarn would cause it to run into little kinks or loops, known technically as "snarls." The manner by which this is effected will now be described, reference being made to Fig. 70.

(256) The thread is guided by means of a wire N fixed in the ends of sickle-shaped arms, which are fixed, at intervals, on a longitudinal rod, which can be freely oscillated. As described in paragraph 245, this wire is known briefly as the "faller." The arms are, from their shape, spoken of as "sickles," and the rod as the "faller rod." There is also a second set of sickles which sustain the "counter faller" wire M; the former being fixed on the "counter faller" rod. It is, perhaps, necessary to say that the winding and counter fallers extend along the whole length of the carriage. It will be noticed that the counter faller presses against the underside of the yarn so as to divert it from the direct line between the rollers and the cop. The winding and counter faller rods are set quite parallel with the centre of the tin rollers, and when the carriage is at its innermost point the same parallel relation should exist between them and the

rollers. It was stated in the last chapter that the object of the counter faller wire was to take up the yarn as it is delivered from the spindle during the process of backing-off. The maintenance of the required pressure to sustain the whole of the threads in the manner described, entails the freedom of oscillation of the counter faller rod and also necessitates the balancing of the counter fallers so that they will easily yield when anything above the normal pressure is put upon them. The action of the counter faller is in brief a negative one, and is practically that of a compensating motion. The object of the winding faller, on the other hand, is to press down the yarn to the required point for the commencement of winding, and subsequently to guide it in such a way as to enable it to be wound on the cop. It becomes therefore essential that the motion of the winding faller shall be rigidly controlled, and for that reason it is attached to suitable mechanism. There is, however, a co-relation between the two fallers, and it is necessary to use such means as preserves this. On the counter faller rod a curved sector is fastened, which has attached to and passing over it a chain E. This is fixed at its lower end to a weighted lever J, which is hinged to the under side of the carriage O at J^1. The weight of J is sufficient, when the counter faller rod is free, to oscillate it, but ordinarily the weight of J is taken by a second chain I, which is attached to J at a point nearer its centre J^1. I is fixed to a hook attached to a bracket fastened on the winding faller shaft. This bracket is formed with a stop resting on the counter faller rod, and is normally pulled in that direction by a spring not shown in the drawing. The result is that the extent of the upward movement of the winding faller is regulated. As backing-off proceeds the winding faller slowly descends, and the chain I is thus by the oscillation of the bracket gradually slackened until a point is reached when the lever J is free to exercise a pull on the chain E, and thus cause the counter faller to press on the underside of the threads. The regulation of the weight of the lever J is very important, and it is arranged to be readily weighted by small balance weights. The state of equilibrium established depends entirely upon the yarn being spun, and must be carefully regulated for that purpose. For fine or delicate yarns the counterpoise must, of course, be more exact than when stronger yarns are being spun, and a little practice will speedily enable the correct results to be attained. It is easily possible to adjust the balance so that a few threads in extra tension will depress the counter faller, and this is one of the small points which requires constant attention.

(257) We now come to deal with the method of actuating the winding faller, and this brings us to the consideration of a very

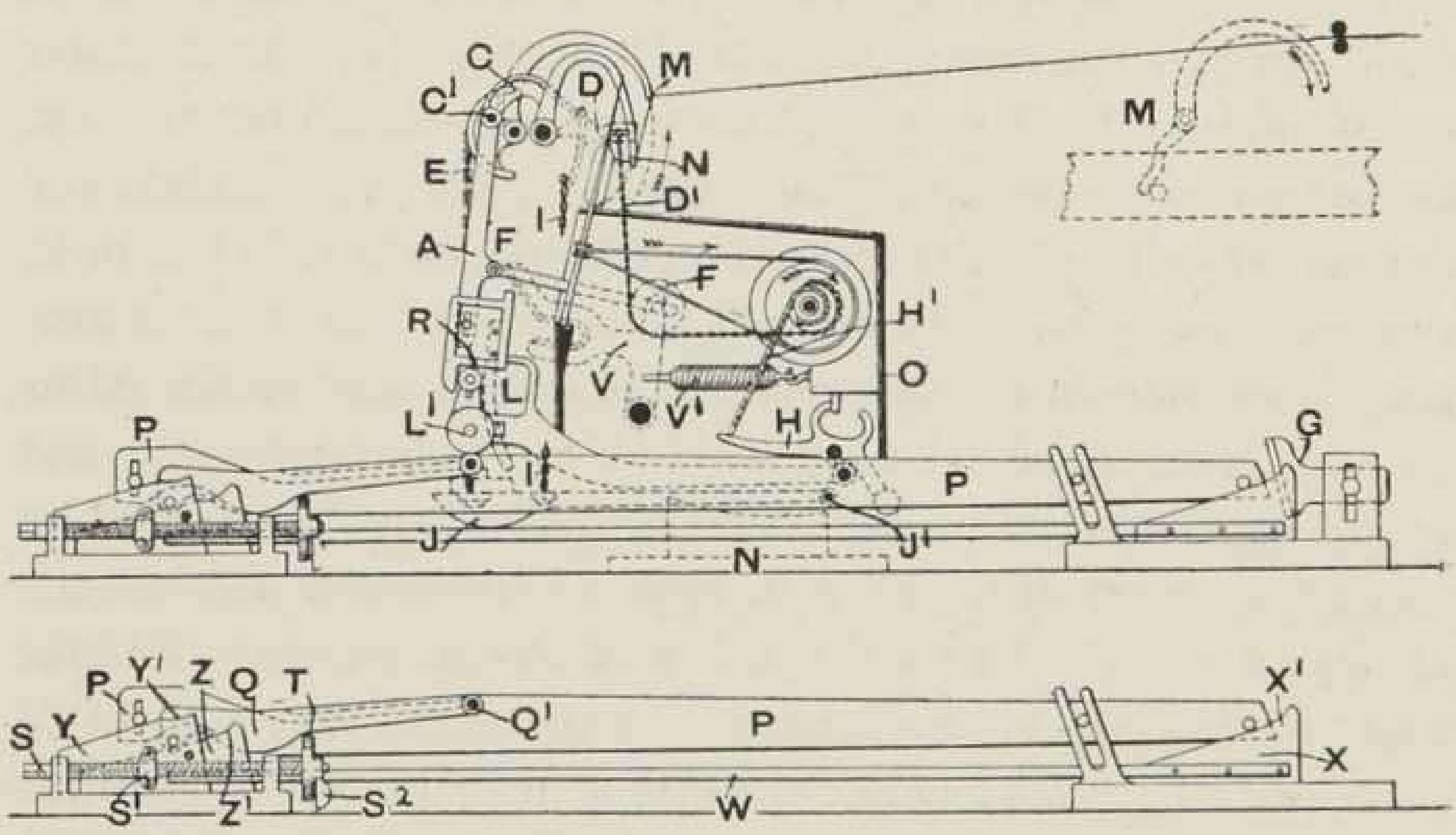

Fig. 70.

important portion of the whole operation. The winding faller rod has pivoted to it an arm D, which is curved at one end so as to pass over the counter faller rod, and thus forms a sector C, which is jointed at C^1 to the "locking" lever A—or "boot-leg," as it is sometimes called. A chain D^1 is fastened to the outer end of D and passes over the pulley F, borne by the lever V, being attached to a snail or scroll mounted in the tin roller shaft. The snail is geared by means of a ratchet clutch in such a manner that it is only revolved when the tin roller is reversed during backing off. The effect of this arrangement is that the moment the tin roller shaft begins to run backward, the chain is wound on the snail, and thus draws down the backing off finger D. This raises the locking lever A, and at the same time necessarily depresses the winding faller. As soon as the latter reaches the point which it should occupy at the commencement of winding, the shoulder R is pulled over the bowl carried at the end of the lever L, called the "trail" lever, which is hinged to the carriage, as shown. In some cases a small slide or bracket is used instead of the trail lever, but the effect is the same. L carries a small bowl L^1, which rests on the top of a longitudinal rail P, along which it is traversed by the movement of the carriage. As soon as the engagement of R and the bowl in L takes place, the "locking" lever and winding faller are said to be "locked," and the commencement of winding is possible. It should be noticed that during the time the locking lever is being raised the counter faller balance weight is being released, so that, simultaneously with the descent of the winding faller, the counter faller is raised by the action of the lever J. In many mules this is all the mechanism which is provided, but in the special arrangement which is illustrated in Fig. 70, there is provision made for an adjustment of the position of the faller wires. It can be readily understood that the number of revolutions to be made in a backward direction by the spindles during backing off will vary with the position which the winding faller must assume at the beginning of winding. Further, backing off commences a little in advance of the full depression of the faller, so that there is a short length of yarn unwound before the faller presses on it. The relation which this prematurely released yarn bears to the whole is greatest near the termination of the cop, and gradually increases as the cop is built. For these reasons it is necessary to expedite the movement of the faller so as to cause its engagement with the yarn at the earliest moment. At the commencement of a cop the distance traversed by the winding faller is greater than at its termination, and it is locked at an earlier moment. The amount of lagging in the winding faller which is permissible when a cop is being commenced is absolutely detrimental when it approaches its conclusion, because the ratio of this retardation to the total traverse is much greater in the latter case. It is, therefore, absolutely necessary to draw the winding faller down at an earlier moment and at a quicker velocity. In order to effect this, a lever H is pivoted to the carriage, and can freely oscillate on a stud fixed to it, but has its range of motion controlled by a claw, the two horns of which engage with a stop fastened to the carriage. The vertical arm of this lever carries a bowl which engages with the top of a bracket N, which is gradually pushed under it, as afterwards described. The horizontal arm has attached to it a rope or chain H^1, which gradually winds on to the snail the backing-off chain. Thus the latter is gradually tightened, and from being quite slack at the commencement of a set of cops, is drawn into complete tension at the termination. In this way the required expedition and acceleration of the descent of the faller are obtained.

(258) As soon as the faller is locked, the period of backing-off is at an end, and the parts want adjusting for winding, but it should be stated that the carriage is locked while at its outermost point, and must be released prior to the beginning of its inward run during winding. In order to illustrate this, the diagram in Fig. 69 may again be referred to. It may here be explained that this diagram is constructed on the assumption that the mule is opened out, one of the sides of the headstock being shown at one side of the shaft I, and the other at the other. Actually they are parallel to each other, the locking lever A being right opposite the locking lever S at the other side of the square. The relative positions of the various parts is shown diagramatically at the right hand top corner. On the carriage O, then, is a bracket or catch O^1, with which the end of the horizontal arm of the bell crank lever S can engage. The latter is jointed to the horizontal rod R, which is coupled to a second lever U^1, also free to oscillate. U^1 is attached by the connecting rod U with the lever W, and the latter is connected

to the horizontal arm of Z^1 by the rod M. Thus a connection is set up between the cam Z, which controls the back shaft clutch P and the "holding-out catch-rod" R. When the carriage is running out, and has nearly arrived at the termination of its outward run, the movement of the rod X, obtained in the manner described in paragraph 255, causes the lever Y to be oscillated on its pivot. There is a short arm Y^1 formed on Y, which is pushed under the end of W^1 of the lever W, and acts as a support for it and the top cone I^1. W^1 is forked, and has pins fixed in the fork which project into the ring groove in the half clutch I^1, thus controlling and sustaining it. When the carriage arrives at the end of its outward run, the cam Z makes a change and detaches the clutch P on the back shaft H. Previously to that period the rod R is free, so that the catch on S easily rises and falls over the pin in O^1, thus locking the carriage securely. It will be seen that at the moment of locking three things happen: the carriage is locked, the friction clutch I^1 is locked so that it cannot fall into gear with K, and the backing-off friction is being pushed over by the spring on X, as previously described. The carriage can be locked at the end of any stretch by the pedal lever fixed to the floor.

(259) We have now reached the fourth period—that of winding, in which the nicest mechanical problems existing in the mule are found. At the moment when backing-off is finished, the parts are in the following position: The strap is on the loose pulley; the backing-off clutch is in gear; the spindles are revolving in a backward direction; the winding faller is locked in a position a little below the nose of the cop; the counter faller is held just out of contact with the threads, but is released as soon as the carriage moves in; the roller and back shaft clutches are disengaged, and the upper half of the friction clutch I^1 K is out of gear with the lower, but is revolving with the shaft on which it slides. It is, therefore, necessary, in order to commence winding, for the following things to be done: the backing-off clutch must be disengaged, the carriage must be

unlocked, the friction clutch I^1 K engaged so as to give motion to the bands which draw in the carriage, the counter faller released, and the spindles revolved at a velocity sufficient to take up the length of yarn as it is freed by the run in of the carriage. We will take these different steps in the order named, and in doing so deal with several problems arising.

(260) It should be noted that when the whole of the yarn has been unwound from the spindles and taken up by the faller the function of the backing-off clutch is finished and it may be detached. As the backing-off chain draws down the backing-off finger D it can freely move, but as soon as the locking lever is

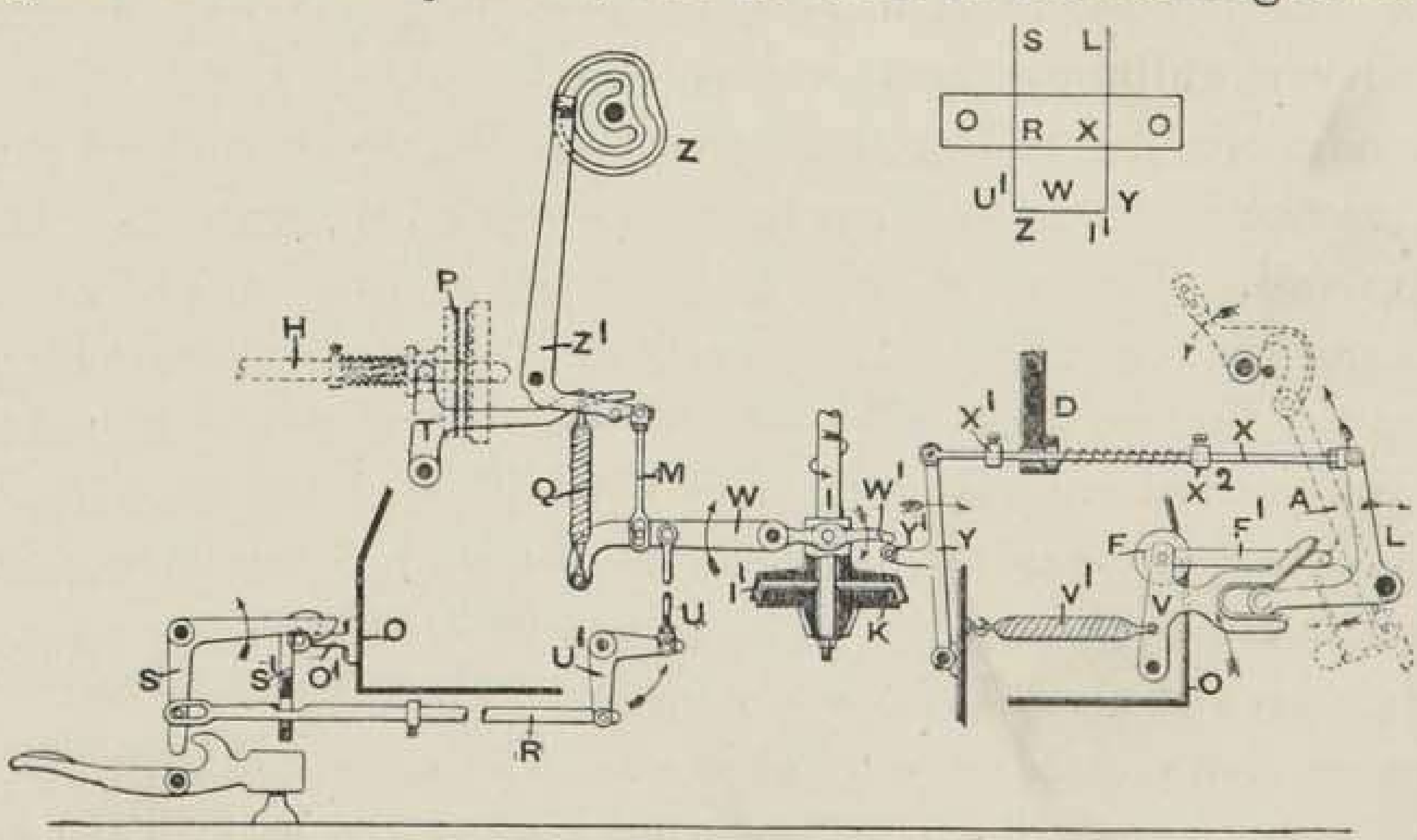

FIG. 69.

ready for locking the continued movement of the backing-off finger ceases, and the chain draws in the upper end of the lever V, and by means of the connecting link F^1, also pulls in the lever A and thus locks it. This same movement withdraws the mouth of the lever V from the end of the lever L, and when the sudden inward motion of the locking lever is made, the pressure of the lower jaw of V causes the lever L to be moved in the direction of the arrow. The result is the disengagement of the backing-off clutch by reason of the pressure of the stop X^1 against the lever D; the motion of the rod X being aided by the extension of the spiral spring threaded on it. The movement of the rod X oscillates the lever Y and takes away the supporting arm

Y^1 from under the end W^1 of the lever W. In this way the clutch I^1 can fall into contact with the lower clutch K. The fall of the end W^1 of the lever W is aided by the pull of a spring Q, which is attached to the arm of the backing-off clutch lever T, which rests on a stop fixed in the horizontal arm of the lever Z^1. In order to permit of this movement of the lever W on its centre there is a slot in one end of the connecting rod M, which is sufficient to allow of this motion without affecting that of Z^1. By means of the connecting rod U, lever U^1, and holding-out catch rod R, the motion of W is communicated to the holding-out catch S, and thus unlocks the carriage. It is obvious that the backing-off friction and the holding-out catch must be nearly simultaneously released, and that they must be quite free before the taking-in friction engages, as otherwise there would be breakage. Thus there are many points of adjustment provided. The stops X^1 X^2 can be set as required, the connecting rod M, coupling Z^1 and W, can be also adjusted, and the holding-out rod is also arranged to be regulated. The effect is that immediately after the release of the carriage and the detachment of the backing-off clutch, the taking-in clutch I^1 K is engaged, and the carriage begins to run in.

(261) The shaft I (Figs. 63, 64, and 69), on which is mounted the friction clutch I^1, is driven from the side shaft D by means of the bevel wheels S S^1. The lower part of the half clutch K is formed as a pinion K^2, which engages with the wheel K^1 fixed on the shaft L, called the "scroll shaft." On the latter are several scrolls L^1, which vary in diameter from 9in. in the largest to 3in. in the smallest portion. To these scrolls are fastened ropes or bands, attached to the carriage, so as to draw it in when the shaft L is suitably revolved, which it is when the "taking-in" clutch I^1 K is in gear. Assuming the wheels S S^1 to have 28 and 31 teeth respectively, and the pinion on K to have 20 teeth, while K^1 has 80, then the speed of the shaft D being 251 revolutions (paragraph 254) L revolves $\frac{28}{31} \times \frac{20}{80} \times 251 = 56{\cdot}6$ revolutions. Thus it will communi-

cate to the drawing-in bands when they are on the largest diameter a speed of 1,600in. per minute, and when on the smallest diameter a velocity of 532in. per minute. The carriage is, of course, started at its slowest speed and also finishes at about the same velocity, attaining its highest rate of traverse at about the middle of its course. It is thus brought evenly and easily to rest. The curve of the scrolls is carefully formed, in order that the acceleration and diminution of the carriage speed may be obtained without any jerkiness or irregularity, it being important that these should be avoided. There is fixed on the scroll shaft an extra scroll L^2, which is set at an angle of 180° to the others, and which, being fitted with an extra band, which is naturally diametrically opposite that of the remaining "scroll bands," is wound on when they are unwound and *vice versâ*. The object of this "check band" is to exercise a drag and avoid over-running of the carriage, which it can be easily understood may readily occur owing to the high and varying velocity of the carriage traverse. The scroll shaft only extends across the headstock, and the pull exerted by it is consequently confined to a limited space. It is therefore the custom to fit an extra scroll L^3, which is connected by a band to a scroll H^3 on the back shaft H, on which it is wound, as the latter is revolving to draw out the carriage. When the scroll shaft is rotated—at which time the back shaft is free—the latter, which extends behind the carriage for its whole length, having scrolls at intervals, is converted into a taking-in shaft, and powerfully aids in drawing in the carriage. The end frames of the carriages are drawn in by a band which is attached to them, as shown in Fig. 71. It will be noticed that these bands have means of adjustment. These are provided in order to enable the carriage to be "squared," as it is called—that is, drawn into such a position that the centre line through the points of the spindles is parallel with the rollers. As this is a most important matter, it is proposed to spend a few words on it. The bands being made of cotton, are, of course, liable to stretch, and if one of them elongates more than the others, it will follow that the carriage will have a varying pull exercised on it at different points. The effect of this is, that when it is being drawn its great weight causes it to deflect from a truly straight line, and the result is that the yarn is neither so evenly drawn or so evenly wound as it ought to be, the tension on the different ends not being the same. It is absolutely necessary for good work that this departure from perfect alignment should be obviated, and it is essential that minders and overlookers should keep a sharp eye on this defect. The check bands require considerable adjustment to make them work smoothly, so that the carriage, when it comes against the back stops, will come up gently, and not with a bang. There is, towards the end of the inward run, owing to the greater pull of the

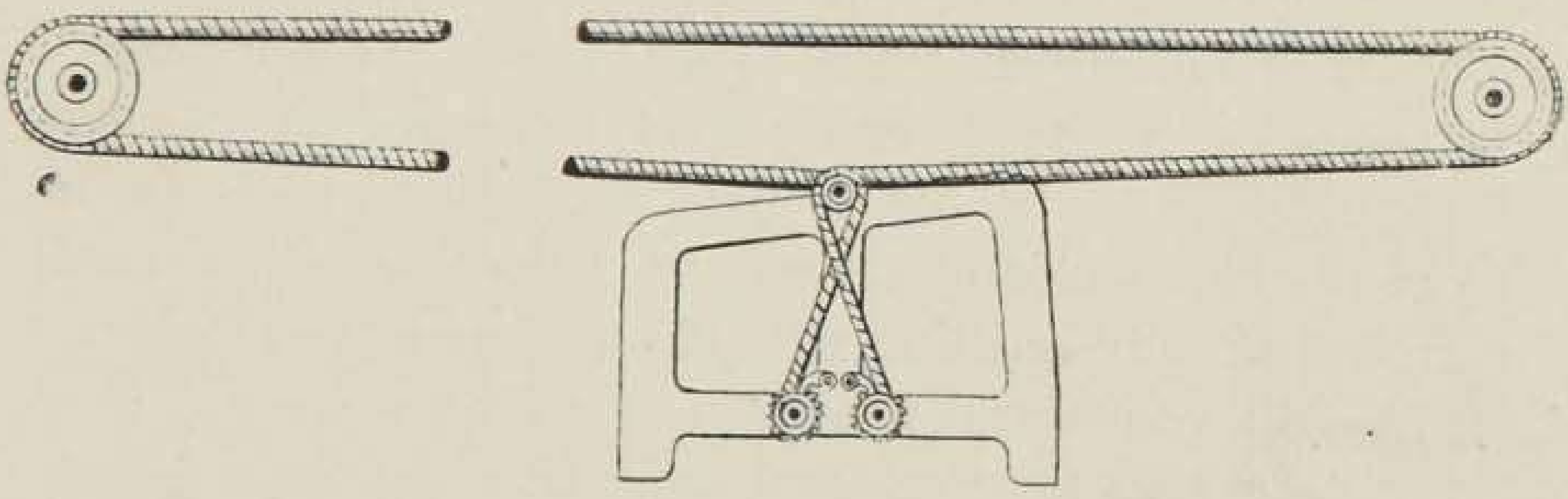

FIG. 71.

winding chain, more resistance to the inward movement of the carriage, and this tends to stretch the check bands. There are two principal faults arising from an imperfect adjustment of the check band. The carriage either comes against the back stops violently, or pauses a little before doing so. The result is that in the first case the threads will be snarled or broken, in the second case winding takes place at such a tension that the ends are broken. This matter of the stretching of the scroll bands is a most material one if good work is wanted, as it will be shown hereafter how very important it is to have the tension on every thread equal, which cannot happen if the carriage is out of alignment. The length of mules is now so great that difficulty is sometimes experienced, and the longer the mule the greater the trouble. An increase in the diameter of the end bands shown in Fig. 71 would probably be attended with good results in the case of very long mules.

(262) We now come to deal with the problems underlying winding. It has been shown that the carriage is drawn in at a variable speed, and that in so doing it releases the yarn held in tension between the spindle point and the rollers. This it is necessary to wind on the spindles, and in order to make quite clear the nature of the problem thus stated, the construction of the cop must be understood. For this purpose a reference to Figs. 72 and 73 may be made. The cop is shown as a cylindrical body or spool, formed with conical ends of different tapers. The part indicated by the letters B, G, J, E, is nearly, if not quite, cylindrical; while to the bottom and top of these are cones A, B, E, F, and G, H, I, J respectively. The cop is wound into this shape by winding upon the spindle successive ascending layers of yarn. At first the yarn is only traversed along a short part of the spindle in closely pitched coils, the whole of the first stretch being wound within a vertical space of about an inch. The next length of yarn is wound upon that previously laid, and the initial point at which winding begins is gradually raised. It has been previously pointed out that the winding faller when locked in position ready to begin the guidance of the yarn on to the cop is a little below the "nose," or uppermost point of the latter. As soon as winding begins,

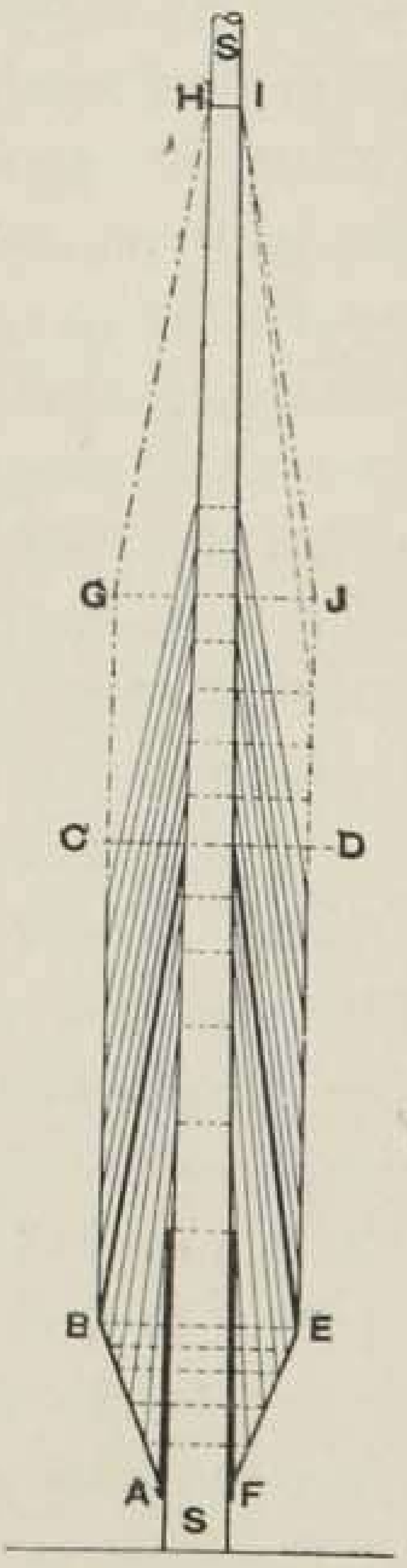

Fig. 72.

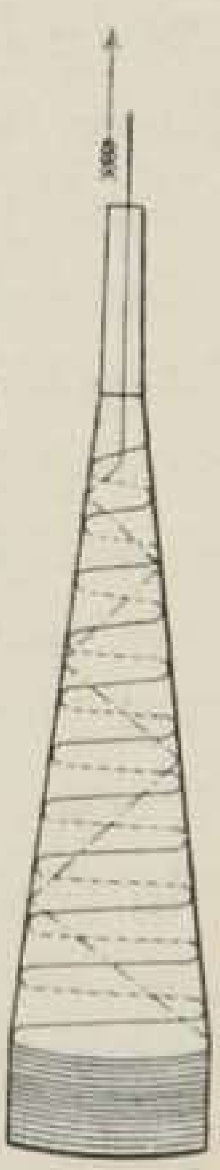
Fig. 73.

the first movement of the faller is rapidly downwards, so as to lay the yarn upon the nose of the cop in widely pitched spirals, as illustrated by the coarsely broken and rapidly descending lines shown in Fig. 73. As soon as the winding faller reaches the base of the top cone for the time being, it begins to rise at a more gradual rate, and so allows the yarn to be wound in the finely pitched spirals also shown in the same figure. The full length of each stretch of yarn is wound by the time the winding faller reaches the uppermost point at the nose of the cop. After the first layer or two have been wound, the initial position of the faller wire is gradually raised, and its traverse slowly increased until at last that portion of the full cop, as shown by the letters A, B, C, D, E, F, is formed. This is known as the "cop bottom," and some idea of the actual method of altering its shape is shown by the angular lines. After the cop bottom is fully formed, the traverse of the faller wire is gradually shortened until the angle of the nose C, H, I, J, is a little more acute than that of the cone B, C, D, E. The length of the traverse of the winding faller is called the "chase" of the cop or faller. There are thus two things required in connection with the traverse of the winding faller. Its initial point must be raised, and the extent of its traverse varied.

(263) The manner in which these two objects are attained is as follows. Referring again to Fig. 70 it will be seen that the bowl L^1 in the trail lever or slide rests upon the upper edge of the rail P, which is known as the copping rail, and is drawn over it by the carriage in its movement. As the latter travels, during its traverse along the slips, in the same plane, it follows that if the profile of P is arranged to be angularly disposed relatively to the edge of the slips, there will be a certain amount of vertical movement of the bowl L^1 and its slide L. As during the inward run of the carriage the boot leg or locking lever A rests on the upper edge of the slide L, it follows that any motion of the latter is communicated to the former. The locking lever A being jointed by means of the sector C to the winding faller shaft, the vertical motion of A is necessarily communicated to

the latter, which is, in consequence, oscillated in its bearings. The winding faller sickles being fastened on the shaft B, any oscillation of the latter necessarily affects the former. Thus, when the locking lever A is raised by the action of the backing-off chain as described in paragraph 257 the winding faller is lowered into winding position. After it is locked, the vertical motion of the lever A in either direction is communicated to the winding faller, but the direction of the latter is in every case the contrary to that of the locking lever. That is to say, the ascent of A implies the descent of N, and *vice versâ.* All that is therefore requisite to obtain the necessary guidance of the yarn as described in the last paragraph is, that the profile, or upper edge of P, shall be so shaped that, as the bowl L^1 runs along it, it shall first rapidly ascend, and then slowly descend.

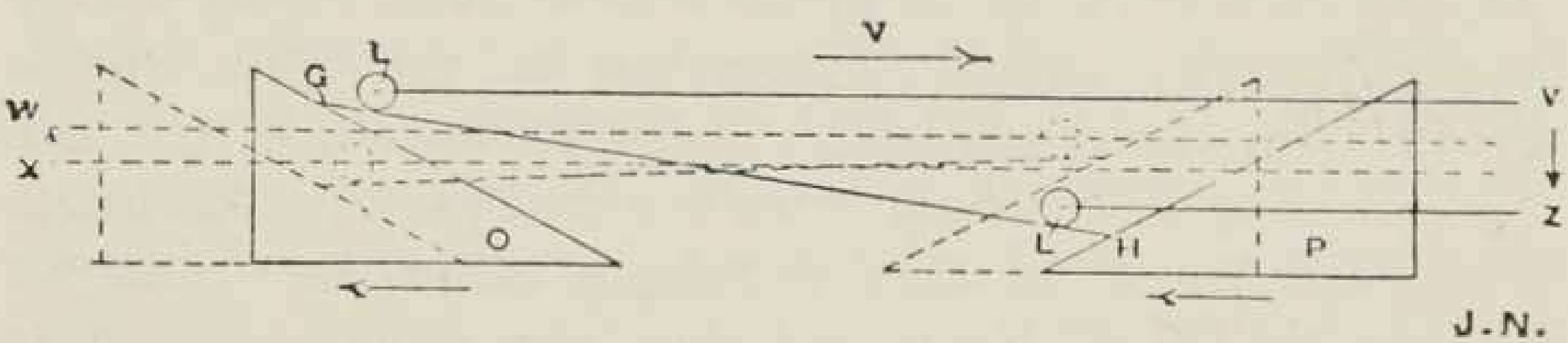

Fig. 74.

This point is illustrated in Fig. 74. Assuming the bar P to be in this case represented by the line G H, which rests at each end upon the surface of the triangular blocks O and P, it will be seen that as the runner L travels in the direction of the arrow V from G to H, it will descend the distance indicated by the letters Y Z. If, on the other hand, the triangular blocks O P be supposed to be moved into the positions shown by the dotted lines, then a similar traverse of the roller L along the bar, which has also altered its position, would result in the lifting of L to the extent shown by the letters W X. Now, if the bowl L controlled, as previously described, the locking lever A, it would naturally follow that the latter would be elevated or depressed, and that the winding faller would also be affected. The proportion which the traverse of the winding faller bears to the extent of the elevation of the locking lever depends upon the ratio which the distance N from the centre of the shaft B of the joint C^1 where the locking lever and the sector C are coupled bears to the distance from the winding faller to the centre. If, for instance, the first-named distance was four inches, and the last-named eight inches, then an elevation of the locking lever one inch would depress the winding faller two inches, and *vice versâ.* By duly proportioning the various parts, it is easy to design a copping rail which will give the required variation during building.

(264) Before finally leaving this point of the action of the winding faller, it will be well to explain the theory of the regulation of its position. For this purpose a reference to Fig. 75 can be made. In this figure the copping rail is shown by the line Q P, the locking lever by the line A, the sector by C, and the winding faller by N. It will, of course, be understood that the winding faller, sickle, and sector are represented by the straight line C N, and that they are supposed to oscillate about the centre B. Now if it be assumed that the winding faller is locked when a little below the nose of the cop, it will be in the position shown at the left hand side of the drawing. The yarn is then passing to the cop round the faller N at the point shown. By the time the locking lever has reached the point Q^1, the faller N is depressed until the yarn is passing on to the base of the cop. From this point onward the faller rises as the locking lever traverses the rail P, until, when it arrives at the position shown at the right hand of Fig. 75, the faller is opposite the nose of the cop. It is quite obvious that owing to the dimensions and shape of the two portions of the rail Q and P, the upward traverse of the winding faller N will be much slower than its downward traverse. It is also clear that the number of coils laid in each case will partly depend upon the relative velocity of the spindles during each portion of the traverse. Of course the longer the distance from the initial point to Q^1 the greater length of time required to bring the faller N down to the base of the cop, and this is a factor which has some bearing upon winding, more especially when some of

the finer counts of yarn are being spun. It will be easily understood that, as the yarn is drawn in the doubling frame from a cop which rests on a skewer and rolls round on it, when it is being unwound from the portion where the finely pitched upward coils are laid it will travel more slowly than when the coarsely pitched downward coils are drawn off. In that case the cop tends to overrun, and thus renders the yarn liable to breakage. This fault can be remedied by lessening the angularity of the front incline Q, which it is obvious will cause a slower traverse of the winding faller Usually about four to five coils are wound during the descent of the winding faller, and if this number is increased to seven or eight the overrunning in the doubling frame creel is

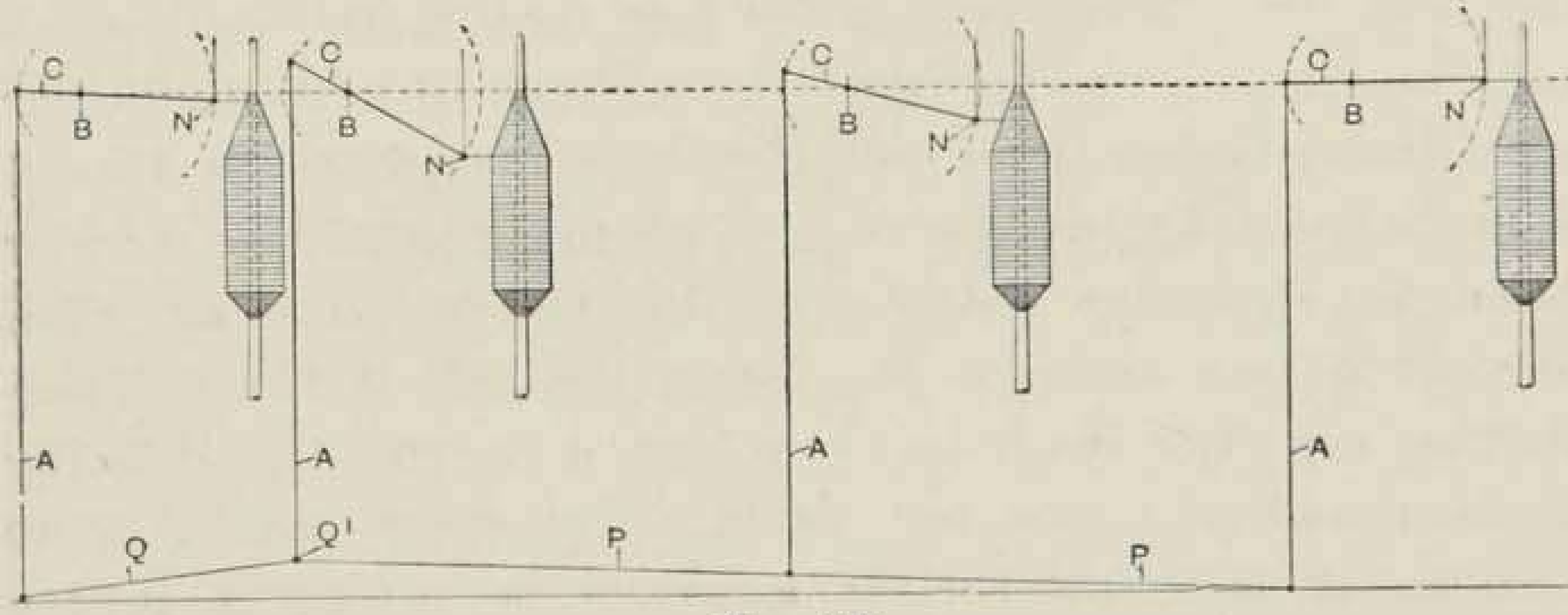

FIG. 75.

avoided. There is another method of dealing with this matter which will be referred to when considering the problem of winding. It is obvious that the relative position of the winding and counter fallers will have an influence upon the yarn. For instance, the angle formed by the yarn when it passes over the counter faller to the winding faller when the latter is in the second position shown in Fig. 75, must of necessity be greater than it is when it is in the position illustrated at the right hand of that drawing. In the one case, it is more acute than it is at the other, owing to two factors. There is the increased acuteness of the angle formed by the relative position of the winding faller and the nip of the front rollers when the carriage is out, as compared with the angle formed when the carriage is in. The variation in the angle at which the thread is bent, however, remains, and forms a consideration which cannot be neglected. The yarn always passes round the winding faller at a sharp angle, and the drag thus induced is not without influence upon it. The second factor which affects this portion of the subject is found in the variation in the paths of the faller and counter fallers. The former travels round a smaller circle than the latter, and its traverse relatively to a vertical line drawn through the centre B, shows a greater inward and outward movement than that of the counter faller. This variation is, of course, also affected by the extent of the depression of the faller at various points, as it is clear that the further the winding faller travels, the greater will be its distance from the circle described by the counter faller. There is also the fact that in the commencement of winding, the counter faller will rise to a much higher point than at other times, and the angle formed by the thread is made more acute. The extent of the rise of the counter faller is naturally determined by the amount of yarn released during backing off. Thus, throughout the building of the cop the yarn is bent at a constantly differing angle round the counter faller. In other words, there will be at different periods considerable variations in the strain put upon it between the counter and winding fallers. This point has a bearing upon the weighting of the balance lever which controls the counter faller, and involves the consideration, that if this is too great, the strain upon the yarn may be caused to vary considerably during a stretch, and throughout building, with a necessarily detrimental effect upon it. Another feature in connection with this part of the subject is the character of the surface upon which the yarn is spun. If it has to be wound upon a hard surface like a steel spindle, it is quite evident that the strain on it will be greater than when wound on to the cushion-like surface of the cotton when the cop is partially filled. Although a small matter, this has some bearing on the character of the winding and the diameter of the yarn.

(265) As, however, the initial position of the winding faller must be changed during the building of the cop, it is necessary and desirable to provide means by which the inclination of the copping rail can be continually varied. For this reason the ends of the rail P (Fig. 70) are sustained by means of pins, which project from each side, and on which small runners or bowls are placed. These rest upon plates Y and X, which are duplicated, and are coupled together by the rod W. The plates Y X are carried by slides fixed to the floor, so that they can readily move in and out when desired. On one side of the "copping plate" Y is an ear S^1, which forms a nut into which the "shaper" or "builder" screw S is fitted. S is borne so that it only has rotary but no longitudinal motion, and on its inner end has fixed a hanging pawl S^2, which engages with a "shaping" or "building" wheel fixed on S. The pawl is controlled from the quadrant, which makes its stroke as afterwards described. The profile of the back copping plate X is formed with a quick curve at its higher end, while Y has a flatter curved surface at its highest point. When a set of cops is being started, the rail P is pushed back as far as it will go, and, consequently, the bowls at its inner end rest on the higher part of the plates X. Thus, when the plates Y X are moved by the rotation of the screw S, the effect is that the inner end of P rapidly falls, and that the fall of the slide L during its inward traverse is proportionately increased. This procedure gces on until the cop bottom is formed, when the full traverse of the winding faller has been reached, after which time the rail P begins to more nearly approach the horizontal, and the extent of the traverse of the winding faller to be proportionately limited. It has been found that in the period before the beginning of winding and the attainment of the full diameter of a cop, it is necessary to have a little more accurate regulation of the actual position of the winding faller prior to locking. It is, therefore, necessary to attach at Q^1, to the copping rail P, an additional or loose copping rail Q, the outer end of which rests on a third plate Z. By the accurate shaping of the plate Z an

absolutely correct setting of the faller can be made. The loose copping rail is a valuable adjunct to the movement, as it ensures a truly shaped cop, while permitting of easy adjustment. The plate Z is, of course, also traversed simultaneously with Y X. When the loose copping rail is not applied, the faller will occasionally be locked at a point 1in. or $1\frac{1}{2}$in. below the nose of the cop, and when this happens, there is always the danger of broken ends. If the profile of the copping plate Z be examined, it will be seen to be very similar to that of the back plates X. The result is, that a similar rapid downward movement of the loose copping rail Q takes place, as was noticed in connection with the action of X. This, it will be seen, is the necessary movement to compensate for the rapid increase in the "chase" of the cop, as shown in Fig. 72. It is obvious that as the total length of each layer increases at the rate shown in the illustration referred to, it is necessary to give a longer traverse to the winding faller in an upward, and a quicker traverse in a downward, direction. Both these objects are attained by the adjustment of the copping rails, which is produced by the peculiar shape of the plates X Z. As shown in Fig. 70, the rail P at its outer end is fitted with a setting screw, by means of which its vertical position can be adjusted at will. There is also an adjusting screw, by means of which the longitudinal traverse outwards of the copping plates can be regulated. After a consideration of the problem of winding, a few words will be said about the ordinary defect of copping motions and the best way to remedy them.

(266) As was shown in paragraph 248, the cop is built upon the taper blade of the spindle, which varies in diameter from $\frac{5}{16}$in. to $\frac{1}{8}$in. At first, and more especially when a short paper tube is employed, the yarn is wound on a practically cylindrical surface, so that every revolution takes up about the same quantity. Thus, if this be $\frac{5}{16}$in. diameter, or ·98 circumference, every revolution will take up the latter length of yarn. Thus, to wind on 63in. 64·3 revolutions of the spindle are wanted. Every layer of yarn increases, as shown in Fig. 72, the diameter

of the cop until the full size is reached, so that if it be assumed that the cop is finally 1in. diameter, every revolution of the spindle will take up 3·1416 in. of yarn, and only 20·5 revolutions of the spindle are required to take up the full length of yarn. But, as was made obvious when the method of building the cop was dealt with, the yarn is not always being wound either on the smaller or larger of the diameters named, but is during each stretch wound on a variable diameter. Thus, when the cop bottom is formed, the next layer is wound on the surface B C (Fig. 72), and is consequently taken up at a continually varying velocity. Now, if the carriage had a uniform speed, and the tin roller also received a similar rotation during the period of winding, it would follow that the yarn would either be taken up at the point B too quickly or too slowly at the point C. In the first case it would be strained and broken, and in the latter case would be wound too slackly on the spindle. Either of these difficulties are detrimental to the production of a perfect cop, and must be avoided. It is a natural consequence of these factors that there must be means provided by which the velocity of the spindle is accelerated as the yarn is wound on the constantly decreasing circumference of the cone. Until the cop bottom is finished this acceleration is calculable and easily provided for, but after that period an entirely new set of conditions arise. If it be assumed that the correct initial and terminal velocities of the spindle which are needed to wind the yarn on the spindle blade have been obtained when the cop bottom is finally formed, every rise of the initial point of winding brings into play a new set of conditions. The spindle S (Fig. 72) is, as shown, tapered, and the result is that the yarn is being wound at the nose on a perpetually decreasing diameter. Suppose, for instance, that at the termination of the cop bottom the yarn is wound at the nose on the spindle, which at this point has a diameter of $\frac{5}{16}$in. In this case its circumference would be ·9817, and to take up the last 5in. of yarn it would require to rotate 5·09 times. Now, let it be assumed that the winding is being conducted higher up the spindle, and that the diameter of the spindle at the nose is $\frac{1}{8}$in. In this case the circumference of the spindle will only be ·3927, and to wind 5in. of yarn will require 12·72 revolutions. It is quite obvious that the same terminal velocity of the spindles being maintained in each case, if the yarn is wound with sufficient tension on the larger diameter of the blade, it will be slackly wound on the smaller diameter. In other words, a "spongy nose" will be formed. As yarn is always wound off a cop by drawing it upwards, as shown in Fig. 72, any such condition of the cop nose results in a number of coils being drawn off simultaneously in an entangled condition. In this case the cop is said to be "halched," and a good deal of waste is produced when the unwinding takes place. From the foregoing remarks it will be seen that there are two things required in winding. First, an increase in the variation of the velocity of the spindles as the full diameter of the cop is approached; and second, an acceleration of the terminal velocity as the cop nose is wound on a higher point on the spindle.

(267) It was shown in paragraph 259 that when backing-off is concluded the strap is on the loose pulley, and that, therefore, the spindles receive no motion from the rim band. It is, however, necessary, in order to wind the yarn, to rotate the spindles in the same direction as that in which they revolve during spinning. This object is attained by special mechanism which revolves the tin roller shaft the required number of times, by means of the pull exercised on a chain passing round a drum geared with the tin roller shaft. The precise method of gearing this mechanism and the mode of operating it will be specially explained hereafter, but in the meantime the principle of its construction can be easily dealt with. For this purpose a reference may be made to the diagrams given in Fig. 76, which approximately represent the action of this mechanism. Let it be assumed that the three series of circles B to G, H^1 to N^1, and O^1 to T^1 represent the winding drum to which the chain is attached, and that while it can be moved horizontally in the direction of the arrows shown it is quite free to rotate on

its centres. Attached to the drum is a band or chain which at the other end is fixed to some convenient part—in actual practice, a nut which can be traversed along a slide. Let it first be supposed that the point A is a stationary one, having no motion whatever, and that the winding drum is moved equal distances—B, C, D, E, F, and G—in a horizontal plane. It is obvious, and is shown clearly in the upper series of circles, that every such movement of the drum will cause a portion of the chain to unwind from it, and, as a consequence, will rotate the drum as shown by the curved arrows. The result is, that when the drum finally arrives at its last position, G, the chain is entirely unwound from it, and has thus caused it to rotate a little over two revolutions. This is very clearly shown by the series of small diagrams given below the circles, where the amount which the chain is wrapped on it, at each position, is indicated by the diagonal lines. In each of these diagrams the centre of the drum is indicated by a vertical line, and its diameter by the space between the two dotted vertical lines. Thus, in each of the positions, it will be seen that the chain is gradually uncoiled, but it can also be noticed that as each horizontal movement is assumed to be equal, the same length of chain is unwound in consequence of each, and the rotation of the drum would be uniform. Now let a reference be made to the lower set of diagrams. In this case the point of attachment of the chain, at its free end, is supposed to be a nut which can slide out from the centre I, and which is carried by an arm, H I, to which, simultaneously with the movement of the drum horizontally, a forward oscillating motion in the direction of the arrow is given. In order to illustrate the point more fully, the travel of the arm, H I, is divided into six equal parts, each of which is assumed to be traversed during the period occupied by the motion of the drum from one position to the next. In the lower set of diagrams the nut is at a point only a little removed from the centre. It will be noticed that as the arm H I approaches the horizontal, the traverse of the nut, although equal in a circular direction, becomes smaller horizontally.

This is clearly illustrated by the dotted vertical lines which are drawn from each of the six positions of the nut, and which cut the horizontal line given. The result is, that while the drum is travelling the same distance as in the upper diagram, the chain is *delivered to it* to the extent indicated by the distance W X between the first and last of the vertical dotted lines. The result is that when the drum reaches its sixth position—N^1 or T^1—the chain, instead of being drawn from it to the full extent, as illustrated in the first series of diagrams referred to, remains wrapped on it for a portion of its circumference, as clearly shown. In other words, the drum has made fewer rotations. But this is not the only difference. If the small diagrams illustrating the wrapping of the chain on the drum in the diagrams B to G and O^1 to T^1 be compared, it will be seen that the chain, instead of being unwound to an equal extent as in the former case, is unwound in the latter unequally during each stage. A comparison of the terminal points of the line indicating the position of the end of the chain when on the drum will show this very clearly, and this is the salient feature to which attention should be specially directed. A close inspection should be made of these drawings, as it enables the precise action which occurs in winding to be fully comprehended. Now, if the point at which the nut is placed on the arm be assumed to be moved outwards until it occupies the position shown by the outer curve H N, then a still greater variation arises. Again, the extent of each forward movement of the nut is assumed to be equal, as is also each made by the drum, and, as in the former case, lines indicating the chain are drawn to the drums from the various points, H to N. The chain, instead of being unwound entirely as indicated at G, or to the extent shown at T^1, is now only unwound as indicated on the last of the circles, N^1, in the centre set of diagrams. It has, in fact, been *delivered* to the drum to the extent indicated by the space U V between the first and last of the vertical dotted lines drawn from each of the six assumed positions of the nut, H to N. In addition to this, if the

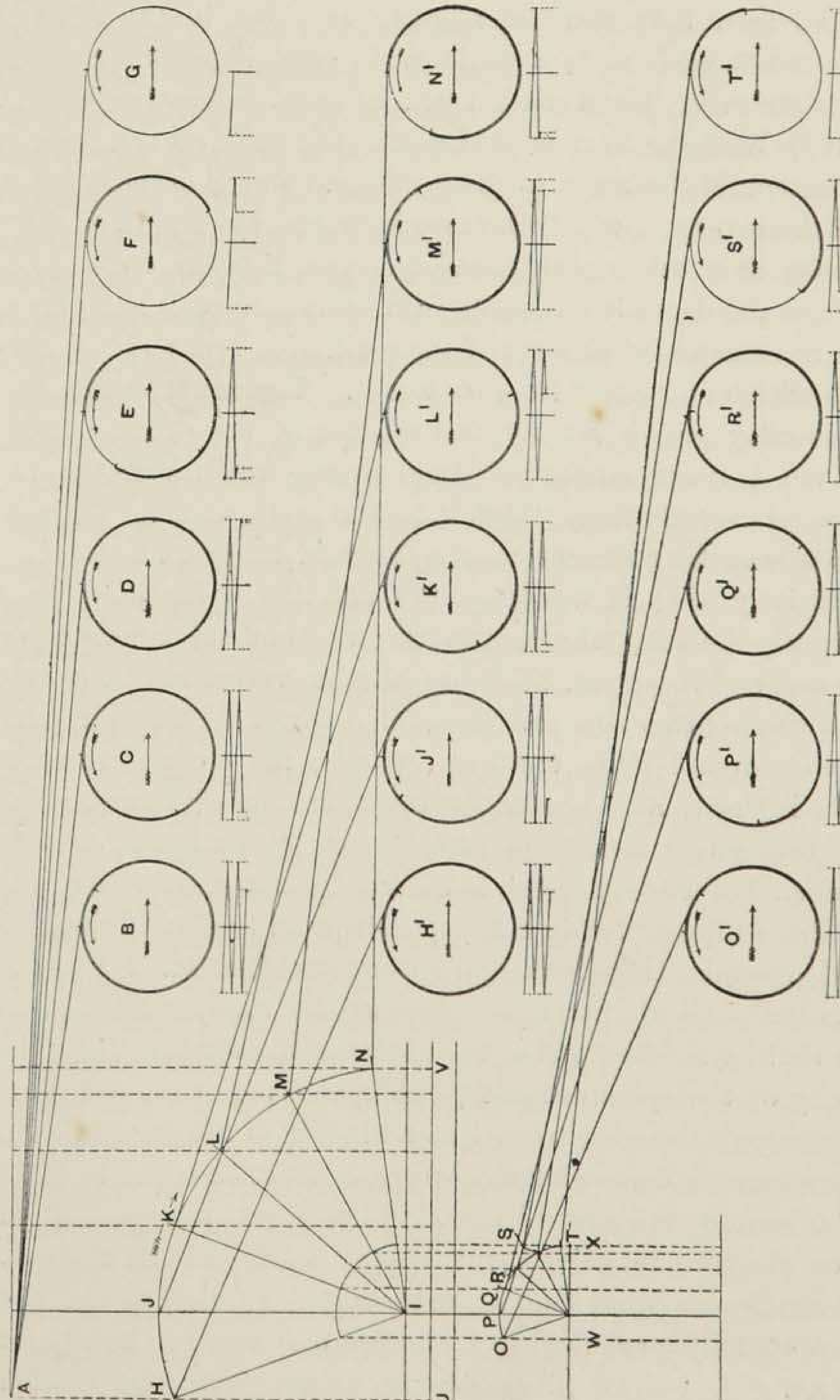

FIG. 76.

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diagrams illustrating the winding of the chain be examined, it will be seen that there is a great variation in the amount unwound at each motion of the drum, and if actual measurements are made, this variation will be found to be considerable.

(268) We have thus arrived at the fact that, as the point of attachment of the chain to the oscillating arm is moved further from the centre on which the arm is hinged, the length of chain unwound from the drum is decreased—that is to say, the number of times the drum is rotated is diminished in exact accordance with the forward movement of the oscillating arm and the relative position of the nut from its centre. Therefore the spindles will, if they are driven by the rotation of the drum, be also revolved a fewer number of times during the traverse of the drum horizontally from the first to the last position. Now it can be seen by reference to the diagram in Fig. 72 that this is precisely what is wanted. The traverse of the carriage is uniformly the same throughout the whole of the construction of a cop, and it follows, therefore, that no variation of the rate of unwinding can take place from that cause. When the yarn is being wound upon the bare spindle, the circumference of which is small and practically equal, the spindle must make more revolutions to wind on each stretch than it would need to do when the circumference is enlarged. For that reason the conditions represented in the upper diagram in Fig. 76 approximately resemble those actually required at this point. But as the cop is built and winding takes place upon a conical surface, it is clear that for the first part of the ascent of the winding faller the velocity of the spindles must be comparatively slow, and must increase towards the termination of winding as the yarn is being wrapped on the decreasing diameter. It must be borne in mind that as soon as the bowl L^1 (Fig. 70) has passed the point Q^1 on the copping rail, its subsequent descent is gradual and uniform. This implies a similar motion in the winding faller, so that the yarn is steadily presented to a smaller diameter of the cop for winding. If, therefore, it has to be wound with even tension on all parts of the cone—or, in other words, if the spindle must

take up the same length of yarn for every equal movement of the carriage horizontally the velocity of the spindles must be increased in due proportion to the decrease in the diameter of the cop. But it is obvious that, as was shown in the last paragraph, the increasing difference in the diameter of the cop increases the variation required in the velocity of the spindles as winding proceeds. If, therefore, an examination be made of the lower and middle diagram in Fig. 76, it will be seen how this is accomplished. Referring first to the lower one, which is illustrative of the condition of things shortly after the commencement of building, it will be noticed that for each of the movements of the drum horizontally from O^1 to T^1 there is nearly the same length of chain unwound, but that there is a little more taken off after the arm has passed the position indicated by Q, the amount of chain unwound from the drum gradually increasing with each subsequent equal movement horizontally. Now this is precisely what is wanted. For some distance the diameter of the cop is nearly equal, and the difference between its largest and smallest diameter is not great. Although there is some variation, it requires only a slight additional acceleration of the terminal rotation of the drum to enable it to take up properly the length of yarn delivered to it. But when the full diameter of the cop is reached, then the conditions shown in the middle diagram in Fig. 76 are reached. During the earlier stages of winding, the velocity of the spindles requires to be comparatively little, and, in consequence, the quantity of chain unwound must be proportionately decreased. The horizontal movement of the chain is, as will be seen, comparatively great when it is out near the end of the arm, and thus the length of chain taken off the drum is less during the earlier portion of the horizontal movement of the latter than it is when the nut is nearer the centre. As in the latter case, however, the terminal speed of the drum is greater than its initial velocity, owing to the diminished horizontal movement of the nut and the consequent increased pull on the chain. Thus, there is a general similarity between the two cases, but owing to the smaller forward motion of the nut there is more chain unwound in the one than in the other. This point is made clearer if the points indicating the end of the chain on each of the circles representing the drum be observed. By comparing these with the number of times the chain is wound on the drum, the extent to which it is drawn off can be easily seen. In winding fine yarns the diminished pitch of the downward coils can be obtained and a greater length of yarn wound on the nose by giving to the spindles an accelerated motion at the beginning of the inward run. This is obtained by regulating the velocity of the quadrant so that a greater pull is put on the chain at the beginning of winding, thus causing a quicker velocity of the spindles, while it assumes, after the nose is wound, its ordinary rate of forward movement, and thus winds the yarn effectively throughout.

(269) This description enables a clear understanding of the nature of the means adopted to overcome the problem of winding to be understood, and if it has been followed it will be seen that there are two things which are essential in this operation. The first of these is the elevation of the faller wire at a gradual and uniform rate after it has been depressed to the base of the cop; and the second is the regulation of the velocity of the spindle during the period of winding, so that the yarn shall be taken up by the spindle at the same rate that it is freed by the inward traverse of the carriage. These two separate treatments are closely related to each other, and each is equally important in the formation of a true cop. If the elevation of the winding faller proceeds at a speed which is too great or too small, the yarn is guided on to a diameter which is either too large or too small for the number of revolutions which the spindles are making. If, on the other hand, the requisite acceleration of the spindles does not take place at the proper period, the spindles will either not take up the yarn as it is freed, or will stretch or break it. There is thus an absolute interdependence of each of these two functions of the mechanism, and it therefore becomes necessary to maintain a true relation between their movements. When the gradual outward traverse

of the nut, which is made during the time the cop bottom has been formed, has been completed, the relative initial and terminal velocities of the spindle remain fixed, so that any further acceleration of the spindle must be obtained by other means. This supplementary acceleration is requisite, as shown in paragraph 265, on account of the diminishing diameter of the spindle blade, and the consequent inability of the spindle to take up exactly the same length of yarn at the nose throughout the whole of the building, as previously explained. A glance at Fig. 72 will show that the maximum diameter of the cop remains practically the same during the whole of the building after it has been once reached. It will also be noticed that the length of the conical surface upon which the yarn is wound remains practically the same, so that if the diameter of the spindle blade was thereafter uniform, the establishment of the true conditions for successful winding at this point would be all that is necessary. As, however, this is not the case, but the spindle blade decreases in diameter, it follows that a new set of conditions arises, which, however, does not affect the operation, except at the point where the yarn is being wound at the nose. It therefore becomes necessary, as was said, to communicate to the spindle, as the yarn approaches the nose, a greater velocity, and the amount of the acceleration at this point must increase in exact proportion to the diminution of the diameter of the spindle. There are two ways of doing this. One is to deflect the chain attached to the drum from a straight line while it is in tension, and the other is to gradually shorten it by taking it up. In the first method the chain is either pressed or pulled down as the arm H I approaches the horizontal, so as to be suddenly shortened. For instance, if it be assumed that the line from A to F in Fig. 76 represents the chain in tension, and the drum F be supposed to be stationary, it is clear that if the chain be pressed down between those two points so as to be deflected from a straight line, the drum F would, if free to rotate, revolve for a distance commensurate to the deflection of the chain. It is easily understood that the deflection of the chain is practically equivalent to shortening it, so that in addition to the rotation of F, caused by the ordinary pull on the chain, it would receive an additional amount because of the extra pull put on it by the deflection of the chain. If, on the other hand, the chain is shortened, then the effect upon a truly cylindrical surface, such as that shown in Fig. 76, would be practically nothing. All that would happen would be, that the chain would be earlier unwound from the drum. If, however, in lieu of a cylindrical surface on which the chain is wound, a spiral surface, such as that found in a scroll, is used, then the shortening of the chain has an important consequence. For instance, if the largest and smallest diameters of the scroll were 6in. and 3in. respectively, their circumferences would be 18·84in. and 9·42in. respectively. Thus, to cause the drum to rotate once, lengths of chain equal to the circumference must be unwound. In other words, if 18·84in. of chain is unwound from the large part of the scroll, so producing one revolution, the same length taken from the small diameter of the scroll would cause the drum to revolve twice. Thus there is not only the acceleration caused by the increased pull upon the chain referred to in the last paragraph, but also that caused by the unwinding of the chain from a surface of less length. Shortening or taking up the chain when used in conjunction with a scroll is, therefore, very effective as a means of getting a high terminal velocity, from the fact that it is taken off a smaller circumference as the shortening proceeds, and that the pull of the chain itself draws it from a circumference which is continually increasing. If a scroll were used with a fixed point of attachment of the nut there would be a terminal acceleration, but when it is employed in conjunction with a greater pull on the chain as the nut moves forward, and the gradual removal of the chain from the larger diameter as the chain is shortened, the acceleration is considerably increased. It is, of course, necessary to give a proper and special velocity to the winding arm in its forward movement to compensate for the diminishing diameter of the scroll, because it is essential that the conditions illustrated in Fig. 76 should be as nearly as possible approximated to.

(270) Having thus fully explained the principles upon which the operation of winding rests, we can now proceed to deal with the actual mechanism employed for the purpose. This is shown in Fig. 77. The winding chain or band C is attached, at one end, to the scroll X^1, and at the other is attached to a small barrel E. The latter is carried by a slide A, which is fitted to the face of the oscillating arm or "quadrant" M, and has fastened to it a nut threaded upon the screw P. It is clear that if the latter is revolved in either direction the nut will be correspondingly traversed along the arm M. At the lower end of A, a pulley D is carried, which serves to act as a guide for the "winding chain" C. The arm M has formed on it a quadrant rack M^1, with which a pinion Z engages, Z receiving its rotation from the back shaft H, as the carriage moves, by means of the band shown. Thus the motion of the arm M in either direction is entirely controlled by that of the carriage O. On the lower end of the screw P a bevel pinion is fixed, gearing with a similar pinion on the arbor or spindle on which the grooved pulley P^1 is fastened. On the scroll shaft X, which is carried by suitable bearings, a wheel X^2 is fixed, gearing with a pinion V^2 on the tin roller shaft T. The pinion V^2 is in one piece with a disc V loose upon the shaft T, so that any rotation of the disc has direct driving power on the shaft. The disc V has fixed on it at one point a pin on which a small catch or "click" V^1 is hinged. The "click-catch" is formed with a forked end, against one side of which the end of a bent "click-spring" W^1 ordinarily presses W^1 is formed so as to surround and clip the boss of the disc V, and the pressure of its free end is ordinarily employed to hold the "click-catch" out of gear with the "click-wheel" T^1. When, however, a slight oscillation of the "click-spring" in the direction of the arrow occurs it causes it to engage with the wheel T^1, and so rotates it. T^1 being fixed on the tin roller shaft T, the latter is also rotated, and so communicates motion

to the spindle. The action of these parts is as follows: As the carriage O is drawn in, the quadrant arm M begins to move forward, and a pull is at once exercised on the winding chain. A rotatory movement is at once given to X^1, and the disc is moved a little forward, thus engaging the click catch with the wheel. The subsequent pull upon the chain continues to rotate the scroll X^1 and wheel X^2, and consequently the tin roller shaft T. The spindles are thus revolved, and by the arrangements previously described, run at such a velocity as just to take up the yarn as it is released. The arrangement just described is the ordinary one, but the method of engaging the click-catch is somewhat defective. It will have been seen that only when the disc V is being rotated in the manner described is the click-catch in gear. As soon as the completion of winding takes place, the spring W^1 acts upon the catch, and takes it out of gear. The tin roller shaft can then be rotated entirely independently of the winding scroll X^1, from which the chain is withdrawn during the forward movement of the quadrant arm M. It may happen that when backing off is complete, the nose of the click-catch may at one time be in close contact with the face of the tooth in the click-wheel with which it must next engage, or it may be only just over the point of the preceding tooth. In the first case, the rotation of the tin roller would take place immediately the scroll X^1 began to move, and in the other it would not begin until the catch had time to fully engage with the next tooth. In the mean time the traverse of the carriage would release a little of the yarn, and in hard twisted yarns the result is the production of "snarls" which are drawn on to the cop. In order to avoid this difficulty a lever W is placed on the tin roller shaft, and the spring W^1 fits on the boss of this lever. If therefore the latter is oscillated, it causes the spring to press the click-catch into gear, and this movement is obtained by means of a stop R^1 on the holding out rod R. When the latter is released it causes the oscillation of W, as shown by the dotted lines, and thus ensures the engagement of the click-catch. As soon as winding is finished, and the holding-out rod assumes its normal position in consequence of the movement of the cam, the weight of the tail end of W causes it to again assume a perpendicular position, and so disengage the click-catch. It is obvious that the stop R^1 can be easily set so as to cause the full engagement of the click-catch prior to the commencement of winding, so that there is an equal celerity in commencing winding at every stretch. The arrangement just described varies from the preceding one in the fact that the click-catch is put in by an actual movement prior to the commencement of the run in of the carriage, while in the older method it was put in consequence of that movement.

(271) There are two additional points to consider in relation to this part of the subject. The first is the manner of rotating the screw P, and the second the method of obtaining the required terminal velocity of the spindles. The small pulley P^1 (in Fig. 77) is, as shown, traversed by an endless cord or band Q, which is taken over small carrier pulleys, and a large carrier fixed, as shown, and also over two pulleys S S^1 sustained in bearings attached to the carriage. If the whole of these pulleys are free to revolve, the motion of the carriage in either direction has no effect upon the cord Q, but if any one of these are held, then the ccrd is locked and will receive motion. The pulley S has affixed to it a winged wiper or detent, which is formed with three teeth with straight faces. If, therefore, a catch is presented in the path of these teeth during their rotation, and the pulley S prevented from rotating, the cord Q will receive a longitudinal motion which will be communicated to the pulley P^1. In order to effect this, a lever Y, with a downwardly projecting arm Y^2, is hinged to the carriage O, and is sustained by a chain Y^1, one end of which is attached to an arm U, on the faller shaft B, and the other to an arm U^1 on the counter faller shaft B^1. The position of these arms is, of course, controlled by the oscillation of the faller shafts, as previously described. It is clear that if the two arms be depressed sufficiently, the downward arm Y^2 on the lever Y will engage with the

winged detent on S. And it is equally obvious that the engagement or non-engagement of the detent depends solely upon the relative position of the arms U U^1. It was shown in paragraph 268 that the outward movement of the nut only takes place during the time the cop bottom is being formed. After every layer of yarn has been wound, the nut remains in the same position until the next layer has been begun. The alteration in the diameter of the cop, consequent upon the winding of the last layer, increases the speed at which the yarn is taken up, and consequently puts it in considerable tension. The degree at which the diameter increases varies, of course, with the yarn being produced, coarse yarns necessarily giving a more rapid increase. The result is, however, that the initial velocity of the spindles becomes too great after a certain thickness of yarn has been laid, and establishes the tension spoken of. In consequence of the manner in which the counter faller is balanced, it yields to this tension, and thus slackens the chain Y. The result is that the arm Y^2 falls into contact with the catch on S, and prevents the pulley from turning. Thus the cord Q is held between S and S^1, and is traversed. The pulley P^1, at the foot of the arm M, is rotated, and in consequence the screw P is turned by means of the bevel wheels shown. The bevel wheel on the spindle of the pulley P^1 is held by a brake spring P^2, which clips its boss and prevents it from rotating with the forward motion of the quadrant, causing the pinion on the screw to roll round it. When the cord Q is moved, as described, it overcomes the resistance of the clip, and rotates the pulley and bevel wheel. When the winding faller is depressed at the commencement of a set of cops its position is lower than at subsequent periods, and consequently it requires a greater elevation of the counter faller to disengage the catch Y^2 than at later stages. In either case the effect is the same. The advance of the nut from the centre gives it a little greater movement horizontally, and so decreases during the early portion of the carriage traverse the velocity of the spindles. The tension on the yarn is thus released; the counter faller rises, and

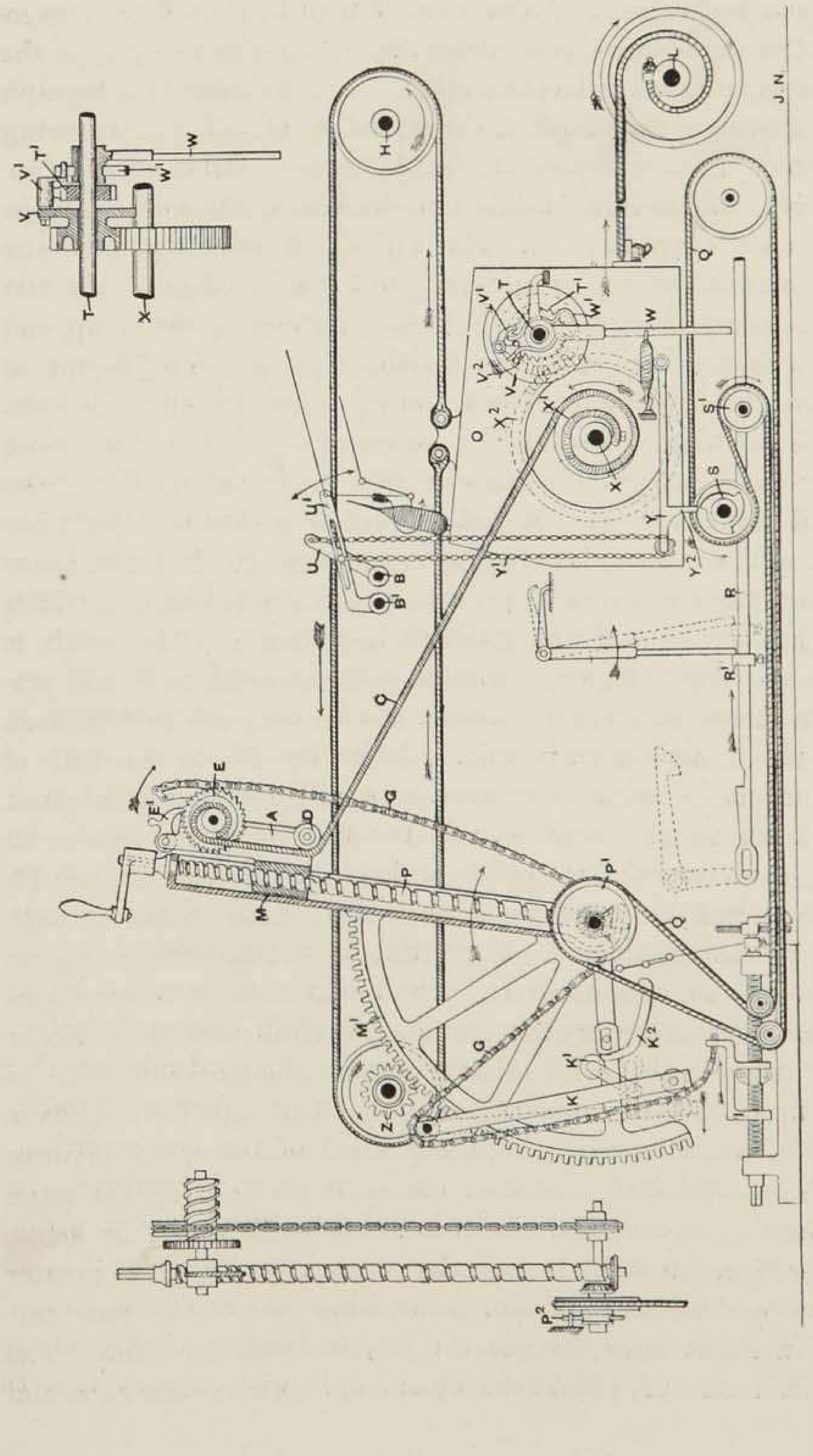


FIG. 77.

draws the catch Y^2 out of contact with S, thus causing a cessation of the traverse of the nut. When the locking point of the winding faller has been raised to that necessary when the cop bottom has finished, the elevation of the arm U is sufficient to prevent any further engagement of the catch Y^2 with S. This it will be seen is simultaneous with the arrival of the nut at its outermost point. From the fact that this motion is intended to regulate the velocity of the spindles during winding it is called the "governing" motion, or, on account of the use of a band or strap to give rotation to the screw, a "strapping" motion. Although on the whole this motion is an effective one it is not without fault, and it is often found that the traverse of the nut is not quick enough to preserve the correct tension. It will have been observed that the motion of the nut takes place when the winding is actually in operation, and that the tension must be put upon the yarn before governing takes place. It has been accordingly attempted by various devices to obtain the required motion of the nut during the time that the quadrant is making its backward stroke, and two of these are described in the author's work "Modern Cotton Spinning Machinery," to which the student is referred. In either case the regulation is made from the fallers, and the relative elevation of these regulates the period during which the nut is traversed. It is essential that the yarn shall neither be stretched too tightly or be too slackly wound, and this is a point which requires care and watchfulness on the part of the minder. It is questionable whether any automatic motion will ever entirely be an efficient substitute for this vigilance, and a good minder is able to keep his yarn in very even tension throughout a set of cops, by occasionally regulating the position of the nut by means of the handle shown. It is, of course, much to be preferred if an efficient automatic motion can be substituted for a manual operation, but there is generally some difficulty about this, and it is troublesome to obtain. The skill of the minder is, in mule spinning at least, of great value, and will probably always remain so. If Fig. 77 be observed, it will be seen that the screw P has a rapidly decreasing pitch. Thus, one revolution of the screw, when the nut is near the centre, will move it more rapidly outwards, and this enables the relatively rapid increase in the diameter of the cop at this point to be compensated for, the regulation of the initial velocity being thus accurately accomplished.

(272) It is now requisite to deal with the method of actuating the chain to obtain the desired terminal acceleration. This is done in most cases by a device known as a "nose peg," which is a pin or stud fixed in an arm fastened to the upper end of the quadrant. As the nut is gradually moved outwards, the nose peg begins to press upon the chain, and depresses it more and more as it is brought in a higher line. At first, while the cop bottom is being formed and is in its early stages, the pressure of the nose peg is slight, but as the building proceeds it gradually increases. It is worth while noticing, however, that with the plain nose peg, the chain, after the nut has arrived at its outermost point, and the cop bottom is finished, is always deflected to the same extent, so that unless the terminal velocity of the spindles is too great at first, it is too little at the termination of building. Accordingly, it is sometimes the practice to fit an automatic arrangement by which the peg is gradually traversed away from the quadrant arm, and thus presses upon the chain with increasing force, communicating to it a greater deflection each time the quadrant moves. In many respects this arrangement has been satisfactory in actual practice, and has found extensive use. Another method of obtaining the same result is Dobson and Hardman's, in which, instead of pushing the chain down, it is pulled out of a straight line by means of a second chain which is being continually shortened. The author has, in the work previously named, given full particulars of this movement, but it may be stated that the regulation of the amount of deflection given to the chain is obtained fr m the faller, a procedure which possesses many merits. The vertical point at which winding occurs being continually raised causes, as was seen, the terminal winding of the yarn on a con-

tinually decreasing diameter. It is in consequence necessary to regulate the velocity in accordance with these factors, and in taking the faller mechanism as a base from which to carry out the operation the method is noteworthy and meritorious. One good point in this procedure is that an alteration in the deflection of the chain only takes place when the elevation of the faller really necessitates it, which is a matter of some importance. The arrangement shown in Fig. 77 is based upon the idea of shortening the chain, and is controlled from the shaper screw, which may be said to be the other extremity of the mechanism of which the winding faller is the last member. The ratchet wheel E is actuated by a pawl E^1, receiving a pull from the chain G which is guided, as shown, until it is attached to the bracket I, moved inwards by the shaper screw. In its course the chain is passed over a hinged or pendulum bracket K, a short arm in which K^1 comes into contact with a finger or bracket K^2 on the quadrant during the backward movement of the latter. The extent to which the pendulum K is pushed back by this action depends entirely upon the extent to which its lower end is drawn forward by the travel of the bracket I, which varies as winding proceeds. The pull upon the chain G, which is thus induced, actuates the pawl E^1, and thus rotates the ratchet wheel E, causing the chain C to be wound on the barrel. The amount of the movement of E is very slight until the cop bottom is completed, when it begins to increase. The result of the winding of the chain G on the barrel is that it is gradually wound off the large diameter of the scroll, so that there is the combined effect of the slower horizontal movement of the nut and the unwinding of the chain from a smaller diameter. The actual position which these parts occupy, at the beginning and end of a set, is shown in Figs. 78 and 79.

(273) In commencing to build a set of cops it is the practice to attach the first few layers to the spindle by means of a starchy mixture. This practice is supposed to strengthen the cop bottom, and to enable it to be more readily placed upon a skewer when it has to be wound. The initial position of the

nut in the quadrant depends upon whether the cop is formed on the bare spindle or upon a paper tube. If the latter, it is not wound down so far as it is when winding begins on the spindle. In commencing a set of cops the copping plates are wound back to the stops, adjusted as described, and the nut is wound down to its initial position. The extent to which the copping plates are drawn back and their setting

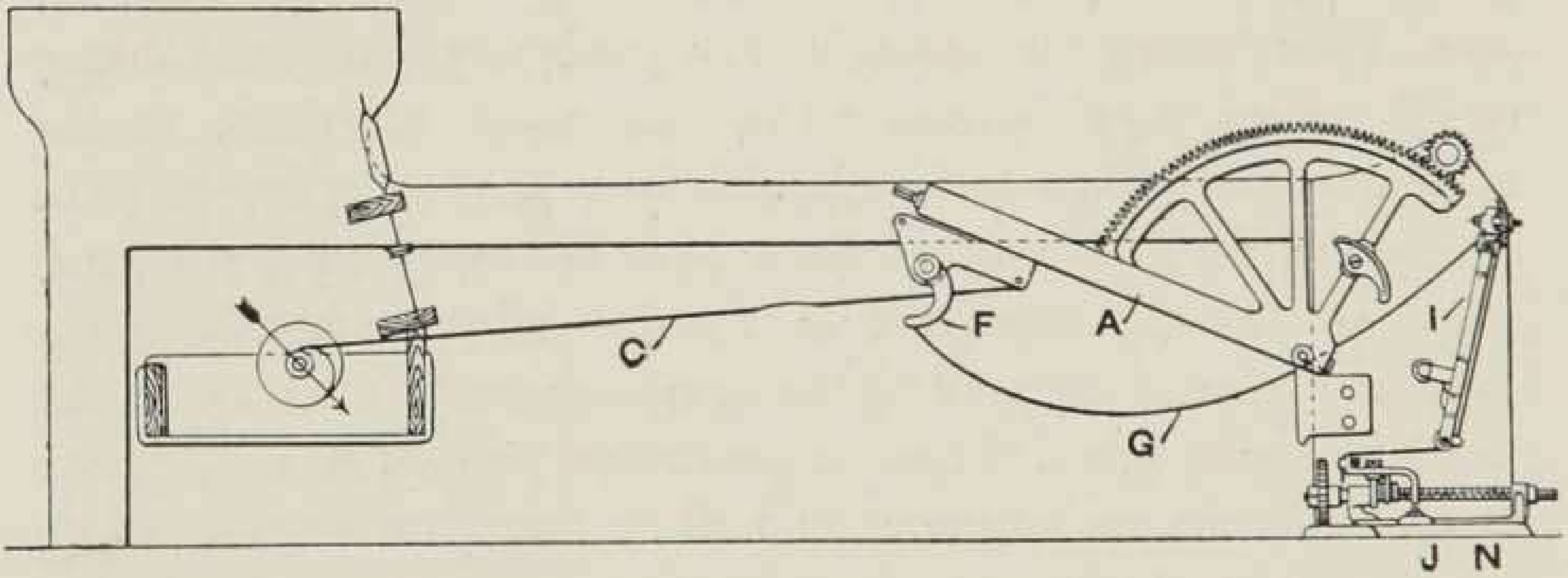


FIG. 78.

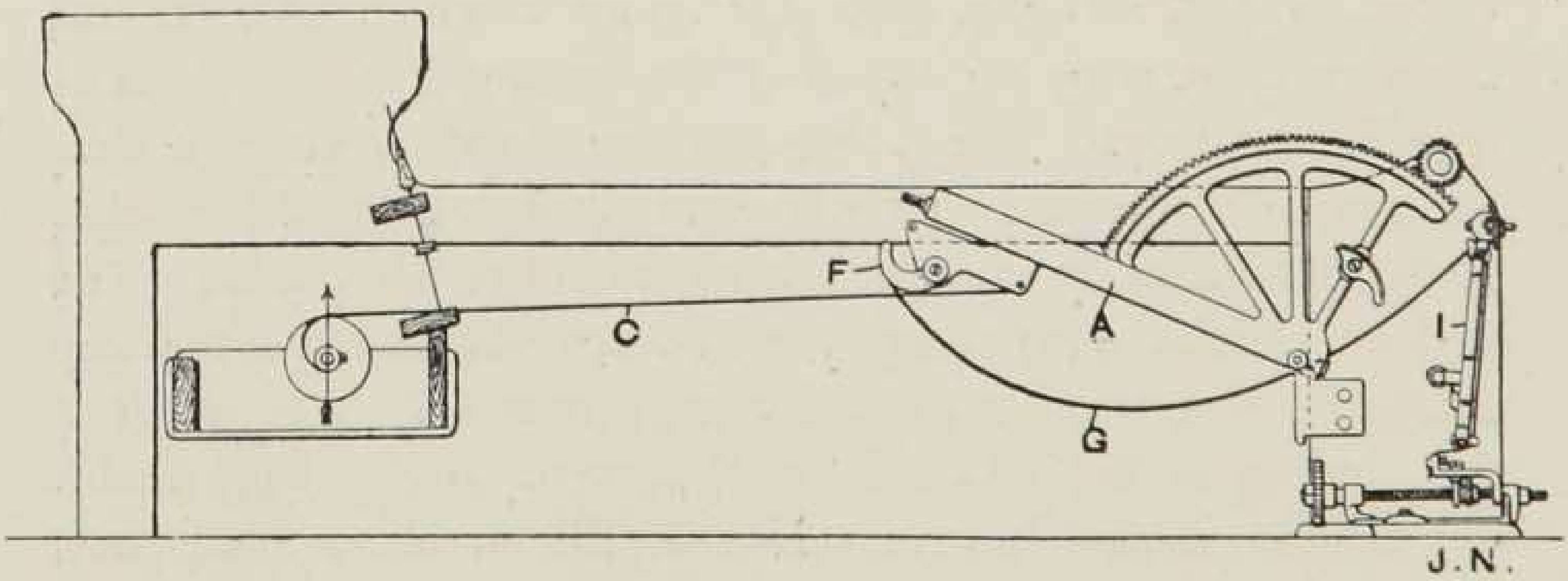


FIG. 79.

is determined by the fact whether a short or long cop bottom is wanted. Some spinners prefer the former, alleging that they can be better made, especially when starching takes place. In this case the bottom cone is made short, and the lengthening of the chase takes place with a very slow elevation of the locking point. The regulation of this is effected as afterwards described, but it is worth noting that by skilful manipulation of the shaper or copping mechanism cops of any shape can be easily obtained.

(274) The proper building of a cop is seen, from the foregoing explanations, to depend upon two operations, viz., the elevation and traverse of the faller and the differential rotation of the spindles. These two factors have a close connection and each has an influence upon the other. It is quite clear that the inaccurate adjustment of either of the two portions of the building mechanism would entirely destroy the normal relation of one to the other, and it is this absolute interdependence which renders this part of the operation of a mule of high importance. It will, therefore, be profitable to consider some of the defects usually found in cops, and explain the causes which produce them. If the explanation given in paragraph 265 has been followed, it will be seen that during every run-in of the carriage a uniform length of yarn is wound on the spindle. If the traverse of the winding faller is not correctly adjusted, or if the velocity of the spindles is not differentiated properly, then some of the yarn will be wound upon a part of the cop which is not the right one. In this case the cop will be wrongly built, and, unless great care is taken, the readjustment is likely to lead to mischief in other directions. Cops are often badly shaped—that is, instead of maintaining the cylindrical shape in the body, which is the characteristic of a true cop, they vary in thickness at different points. In other cases the nose of a cop will be spongy and soft, so that when the yarn is being unwound it unravels, and thus causes a great deal of waste. Occasionally, cops will vary in weight, one from another, although they may be produced on the same mule. Now, all these defects arise from causes which are ascertainable, although, in some cases, a long search is required before the cause can be found. It is always necessary to ascertain the part of the cop in which the defect exists, because, by so doing, a guide is given to the parts which require adjustment or alteration. For instance, if it was found that the cop suddenly became thicker at a point about midway of its length, this would enable the observer to determine the place where the defect arose. It would be evident to him that for some reason or other the gradual elevation of

the initial position of the faller during winding was not, at this particular point, taking place at the proper velocity. Suppose, on the other hand, that the cop became gradually thinner as building proceeded, then it would be easily inferred that the elevation of the faller was taking place too rapidly, and that, instead of the cone being properly formed, the first coil of each stretch was being laid upon a portion of cop where the diameter was too small. If the cop thickened, as building proceeded, the cause could be ascertained, by the same reasoning, to be the too tardy elevation of the winding faller and the consequent winding of the earliest coils on a diameter of excessive size. In this way, by exercising a little thought, much time and labour will be saved, and there will be a chance of the actual defect being cured in the most effective manner.

(275) It will be better to deal with the defects in cops as they are produced, by treating first, those which are due to the improper setting of the carriage or driving mechanism; second, those which can be attributed to the wrong shaping or manipulation of the copping rail; and third, those arising from imperfect winding. In the first instance named the faults which are created are mainly those of imperfect drawing. If a carriage is not perfectly squared—that is, if the centre line of the spindles is not parallel to the rollers—then, during the outward run, some of the threads will be subjected to a greater draft than others, and will be, when spun, thinner, and of course lighter. The tension upon the drawing out bands is so great that it is only natural that they will stretch. The result is that one part of the carriage is drawn out quicker than the other, and the draft put upon the yarn is proportionately increased. Thus on the same mule there will be cops produced which vary in weight considerably. It is, in practice, necessary, especially with long mules, to make some allowance for the inevitable vibration caused when dealing with so large a body as the carriage, but the amount necessary is not great, and will not practically affect the general principle. If the rollers are not carefully attended to, and the lubrication of the top rollers

properly effected, the drawing will be imperfect, and the result will be variable threads. There is another consequence of the imperfect squaring of the carriage, which rather comes under the third division, but which can be conveniently dealt with here. If the tension is not even, the spinner, in attending to the governing of the quadrant nut, will be almost certain to regulate the winding by the tightest threads, with the result that snarls will—especially with hard twisted yarn—be liable to form in the ends which are slackest. When soft twisted yarn, such as hosiery or weft yarn is wanted, the extra tension induced by a badly squared carriage is very prejudicial, and is apt to produce uneven yarn, which in the first case named is most undesirable. It is, of course, not intended to be implied that the bands are always stretching and requiring adjustment, only that this is a point which requires periodical attention and care. Sometimes it happens in very long mules that the scrolls on the back shaft will work loose, and that the carriage is thrown out of the square. This is not a frequent occurrence, but if it takes place the scrolls should be set and re-fastened on the back shaft.

(276) Coming now to deal with the question of bad copping caused by the incorrectness of the shaping mechanism, it is necessary to point out one or two features in the latter which bear upon the subject. The copping plates are formed as shown in Fig. 70, with curved portions at their upper ends. These are indicated by the letters Y^1 Z^1 and X^1. When the copping rail P is in position for commencing a set of cops, the studs fixed in each of its ends rest on these curved portions of the plates, and the first result of the inward traverse of the latter is to rapidly alter the position of the profile of the copping rail. It will be noticed that the curve X^1 is much steeper than Y^1, the result being that the back end of the rail P falls more quickly than the front, and the traverse of the faller is in consequence rapidly lengthened. This action is intended, as was shown, to form the bottom cone properly, and it will be an obvious corollary to this fact that the special formation or setting of the plates will enable

a shorter or longer cone to be formed. This can be done in one or two ways. If the back plate X be moved towards the plates Y Z by an alteration in the point of attachment of the rod W the studs will rest on a higher part of the curve X^1, and will thus fall more rapidly as X is pushed back. In ordinary cases the same effect can be produced by winding back all the plates. It is quite clear that the length of the cop bottom can be varied at will by the simple adjustment of the parts in such a way that, when the inward motion of the plates takes place, the back of the copping rail P will fall more rapidly forward than the front. It is extremely desirable that the position of the rail shall not be such as to cause the yarn to be wound below the lower coils of the bottom cone. If this occurs the yarn is liable to be broken either when being unwound in warping or when in the shuttle. We have referred to the variation in the diameters of cops which is sometimes found, and have indicated its cause, which is that the elevation of the point of locking takes place too early or too late. In other words, the descent of the copping rail is, at the particular point where the defect occurs, not properly accomplished. If the cop is thickened, then the elevation of the locking point is made too slowly, and the copping plates require adjustment to permit the rail to fall. In the case of a thin cop the opposite of this procedure is necessary. These points are so obvious, if the principles of copping are understood, that it would be hardly worth while spending time in explanation, were it not that the matter is one of some importance and occasional perplexity. What is desired to do is to endeavour to make clear the reasons which regulate the adjustments rather than give a specific for every imaginable case. The yarn should, if the rail is truely formed, produce a cop the upper cone of which is straight and neither convex nor concave, and unless this is the case the rail should be straightened. It is a common practice, when these defects are found and are attributed to the formation of the copping plates or rails, to file or plane the plates or rail, and there are cases in which this is the only procedure which will remedy the evil. It is desirable, however, to give a warning against undue interference with the shape of the copping plates or rails, as, unless the alteration is skilfully made, evils worse than those it is intended to cure will be produced. In addition to this it may happen that the variation thus produced will so affect the working of the machine as to render it difficult for any one who is not familiar with the alterations made to put on the required ratchet or "shaper" wheel S. This point may be illustrated thus. Suppose the shaper or copping plate Y was shaped so that its edge was at an angle from the vertical of 45°, then the rail P would fall at a definite rate. Let this angle be now altered to one of 20°, it is obvious that for each inch of inward traverse of the plate the end of the rail would fall proportionately quicker. If, therefore, it is desired to maintain a uniform rate of descent, it follows that the velocity of the inward movement of the copping plates must be decreased or increased according to the amount of angularity in the plates. In other words, the speed at which the screw is rotated must be varied, and if its pitch remains the same, this implies the adoption of a shaper or builder wheel S of greater or smaller size. The evils which arise from worn or loose pins need not be dilated on, as these are well known to be very great in machines of all classes, and when the accuracy and delicacy of the settings of this part of the mechanism are remembered, it is not too much to say that this feature is of prime importance.

(277) We have now to deal with the defects which arise from imperfect winding. These may be caused in the cop bottom by the governing of the traverse of the quadrant nut being imperfectly performed, and this is a point which requires careful attention. The initial point of the quadrant traverse is a matter to which some care should be devoted, and there can be no empirical rule given to guide the student. In most cases the quadrant arm should be, as shown in Fig. 77, set well behind the vertical line through its centre at the commencement of winding, and a common practice is for the quadrant to be set

quite vertically when the bowl L^1 is at the point Q^1 (Fig. 70), and the full diameter of the cop has been reached. It is not, however, possible to say that in all cases such an adjustment will succeed, and the best practice is to leave the setting to be determined by careful observation, coupled with experience. The exact delivery of chain to the carriage by the quadrant during its forward stroke cannot be other than a variable quantity, and the amount of variation necessarily depends on the whole circumstances of the case. The setting of the scrolls on the scroll and back shafts is also a matter which affects winding, because the quadrant is driven by a band from the back shaft, and its forward motion should be in unison with that of the carriage. If this is not so, and if any antagonism of the two parts exists, it is impossible for winding to be effected properly. The regulation of the nosing motion is a matter of the greatest importance, as has been previously pointed out, and should have constant attention paid to it. We have now touched upon most of the points which affect the formation of the cop, and without giving dogmatic and inflexible rules for adjusting the various parts, have indicated sufficiently the points which require special attention. It is altogether undesirable, in dealing with a subject of this kind, to do more than point out the direction in which the efforts of the student should be made; but a careful study of the explanations given will enable most ordinary defects to be grappled with. It may, however, be said that the following procedure can be followed in adjusting the various parts. The carriage being out and locked, an inspection can be made of the position of the scrolls to see that all the bands are in the proper position. If the scrolls want adjusting, in order that the proper speed of winding shall be obtained, this should be done, and the scrolls fixed. Next, examine the backing-off, and ascertain that the chain is just tight enough to draw down the faller to its proper position, and no further, and that immediately the faller is down the click-catch gears. Next, adjust the quadrant in the manner described, after which the squaring of the carriage can be carried out.

Care should be taken to see that no slip is taking place in the rim band, as, although this is an unusual occurrence, it does sometimes happen, and is difficult to discover. All the rollers must be kept very clean, and any imperfect ends ought to be broken, if seen, and not allowed to run on to the cop. These are a few of a large number of points which should be looked to, and it is this multiplication of detail which makes the mule a comparatively difficult machine to tend.

(278) In paragraph 250 the various rules used for calculating the effect of the parts actuating the rollers and carriage were given, and we can now give those which relate to the various portions of the mechanism subsequently described.

To find the correct twist wheel to put in any defined number of turns per inch—

$$\frac{\text{Number of inches in a stretch} \times \text{turns per inch.}}{\text{Number of revolutions of spindles for each revolution of rim pulley.}}$$

To calculate number of teeth required in twist wheel in altering counts—

$$\frac{\text{Present twist wheel squared} \times \text{counts required}}{\text{Counts being spun.}} = x.$$

$$\sqrt{x} = \text{twist wheel required.}$$

NOTE.—It may be found more convenient to have a twist wheel which makes two complete revolutions, in which case the number of teeth in present wheel would require multiplying by 2, and the number equalling $\sqrt{x}$ divided by 2.

To find the builder or shaper wheel required to spin any counts when counts being spun are known—

$$\frac{\text{Present wheel squared} \times \text{counts required}}{\text{Present counts spun.}} = x.$$

$$\sqrt{x} = \text{wheel required.}$$

NOTE.—The above rule should be read in the light of the last paragraph, especially those remarks which are made regarding the alteration of the profile of the shaper plates.

To find turns per inch during the outward run of carriage, by means of the wheels (refer to Figs. 63 and 64), when relative number of turns of spindles to rim shaft is known—

$$(1)\quad \frac{\text{Pinion G} \times \text{pinion J}^1 \times \text{wheel Q} \times \text{pinion R}}{\text{Wheel G}^1 \times \text{wheel F} \times \text{wheel Q}^1 \times \text{wheel P}^1} = x.$$

$$(2)\quad \frac{\text{Relative turns per minute of spindle to rim}}{x \times \text{circumference of scrolls H}^1} = \text{turns per inch.}$$

The method of arriving at the number of turns per inch which should be in yarn is, for the different varieties, as follows—

Hosiery yarn	$\sqrt{\text{counts}} \times 2{\cdot}50.$
Yarn for doubling	$\sqrt{\text{counts}} \times 2{\cdot}75.$
Weft (medium numbers)	$\sqrt{\text{counts}} \times 3{\cdot}25.$
Weft (fine numbers)	$\sqrt{\text{counts}} \times 3{\cdot}183.$
Twist (medium numbers)	$\sqrt{\text{counts}} \times 3{\cdot}75.$
Twist (fine numbers)	$\sqrt{\text{counts}} \times 3{\cdot}606.$
Twist (extra hard and ring)	$\sqrt{\text{counts}} \times 4.$

Although the numbers given form the usual multipliers employed in arriving at this result, it must not be understood that the amount of twist is inflexible. It may happen that a change of cotton, or many other causes, will enable the method of calculating the twist to be judiciously modified, and it is only possible, therefore, to give the above as a general rule for the purpose.

(279) Having now fully dealt with the question of winding and its accompanying problems, it only remains to describe the method by which the various parts are restored to the necessary position for recommencing the operation. As the carriage approaches the roller beam, the various parts are operated as follows :—The spindles are being revolved at a gradually accelerating speed by means of the winding chain; the carriage is being drawn up by means of the scrolls on the scroll and back shafts; the winding faller is locked and is gradually approaching the nose of the cop; the counter faller is sustaining the threads; the strap is on the loose pulley; and the rollers are disengaged. The whole of these portions of the mechanism want adjusting so that they shall occupy the places

and perform the functions which were detailed as belonging to the first period of action. In doing this, the cam shaft plays a great part where it is used, or the changes may be made by other means, such as a series of levers, which are set in motion by stops or fingers on the carriage. In the case of the mule illustrated, the bracket S^1 (Fig. 65) engages with the bowl R^1 on the long lever, and so oscillates the latter. This leads to the cam shaft making a half revolution in a similar way to that described. The half rotation of the cam Z detaches the taking in friction clutch I^1 K, and at the same time, by reason of the connection between the lever Z^1 and the back shaft clutch lever T, engages the back shaft clutch P P^1 (see Fig. 69). The roller clutch is engaged by the cam W and the strap is transferred by the cam Y from the loose to the fast pulley. The horizontal catch lever, which is connected with the strap guide lever, is pushed forward and is engaged with the detent catch, thus firmly fixing the strap lever in driving position. At the completion of the half revolution of the cam shaft, the friction clutch W X is disengaged, and the cam shaft stops. The carriage is drawn by the scroll bands up against the back stops, and it is very desirable that it should be drawn up gently and without a hard blow. This has been previously touched upon, and depends upon the adjustment of the scroll and check bands. If the carriage is not parallel to the roller beam, it is very likely to thump against the back stops, and this is a matter to be avoided. When the carriage runs up to the beam the counter faller is relieved by means of a pendant arm which engages with a releasing bracket in the manner diagrammatically shown in Fig. 70, and the lever J is also released by means of a stop. The effect of this to take the strain from the yarn before delivery by the rollers recommences. The lower end of the locking lever A in like manner comes in contact with one of the back stops, and the shoulder R is pushed off the bowl L^1 in the trail lever. The weight of the locking lever causes it to fall until its movement is checked by the stop bracket engaging with the counter faller shaft, the winding faller being in the meantime entirely removed out of contact with the yarn. It is obvious that the guiding action of the faller must be fixed, so far as its period is concerned, by the height at which the cop is being built, and it must terminate at such a point that sufficient yarn is left to coil on the spindles between the nose of the cop and the point of the spindles. As this length of yarn varies throughout the formation of a cop, and is greatest at the commencement of building, it follows that the detachment is required at a little later period as building proceeds. For this reason the face of the stop bracket G (Fig. 70) is made curved, and is so shaped that the exact moment when the faller is unlocked is strictly regulated by the position of the winding faller at the termination of each stretch. The descent of the copping rail P has an influence upon this special operation. The whole of the parts are thus restored to their initial position and spinning recommences.

(280) It will have been noticed that the quadrant arm M is at the termination of winding in its most forward position, and that the winding chain is drawn off the scroll or drum. It has also been shown that the forward motion of the quadrant is obtained from the back shaft by means of a band driven by the latter. As the back shaft therefore rotates in the opposite direction in drawing out the carriage, it by means of the pinion M^1 restores the quadrant arm to its original position. During this time, the tin roller is rotating, but no motion is given to the scroll X. It is accordingly necessary to provide some means by which, during the outward run, the latter will be rotated so as to take up the winding chain preparatory for the recommencement of winding. This is found in the employment of a band S (Fig. 80), which is kept in tension by means of a weighted lever U hinged to a bracket fixed on the floor. S passes over the pulleys fixed on the carriage, and the tension is sufficient to cause it to rotate X, and thus wind the chain on to the winding scroll. In this way the parts are in the necessary position to recommence winding. There is another motion which is sometimes fitted to a mule about which some people speak in high terms.

This is called a hastening motion, and consists in an arrangement by which the transfer of the strap to the fast pulley is accomplished prior to the completion of the inward run of the carriage. It will be easily understood that as at the completion of winding the spindles are revolving in their normal direction, the actual transference of the work of driving them to the rim band is merely an acceleration. The question is whether this action should take place a little before the actual termination of the inward run. Where nosing motions of an inefficient character are used there is an advantage in this course, but otherwise the only gain from its employment is found in the more rapid commencement of the outward motion of the carriage. If used it requires constant attention, or the carriage will not "light in" so easily, and the slow motion thus produced will

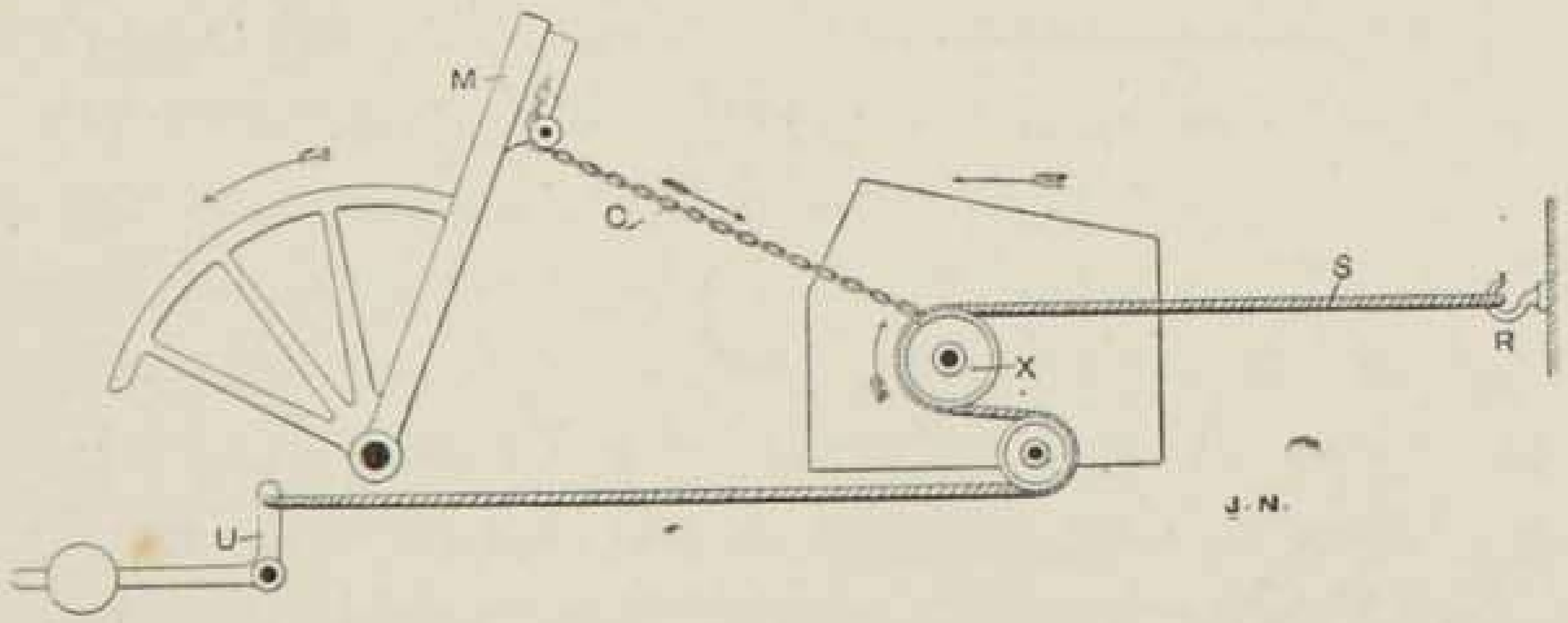


Fig. 80.

probably be more detrimental to good winding than the acceleration of the spindles in the manner described will be beneficial to the general operation.

(281) Instead of employing a clutch like P P[1] on the back shaft, as described in paragraph 249, it is in some makes of mule the practice to drive the back shaft by a train of wheels from the roller shaft, and to mount these in a lever having an oscillatory movement round the roller as a centre. This lever M, which is shown in Fig. 81, is known as the Mendoza lever, and is oscillated by suitable means from the long lever. The wheel Q is fixed on the roller shaft, and drives through the intervention of a carrier wheel the wheel Q[1], compounded with which is the pinion R. R in turn drives the

wheel P on the back shaft H. The communication of the motion from the roller to the back shaft only takes place when the pinion R engages with the wheel P. The exact period when this occurs is, as will be understood, the same as that when the back shaft clutch is engaged—that is, immediately upon the carriage finishing its inward run. During the periods of backing off and winding, the lever M is raised so that the pinion R is out of gear with the wheel P. It often happens, therefore, that as the back shaft immediately commences to revolve and draw

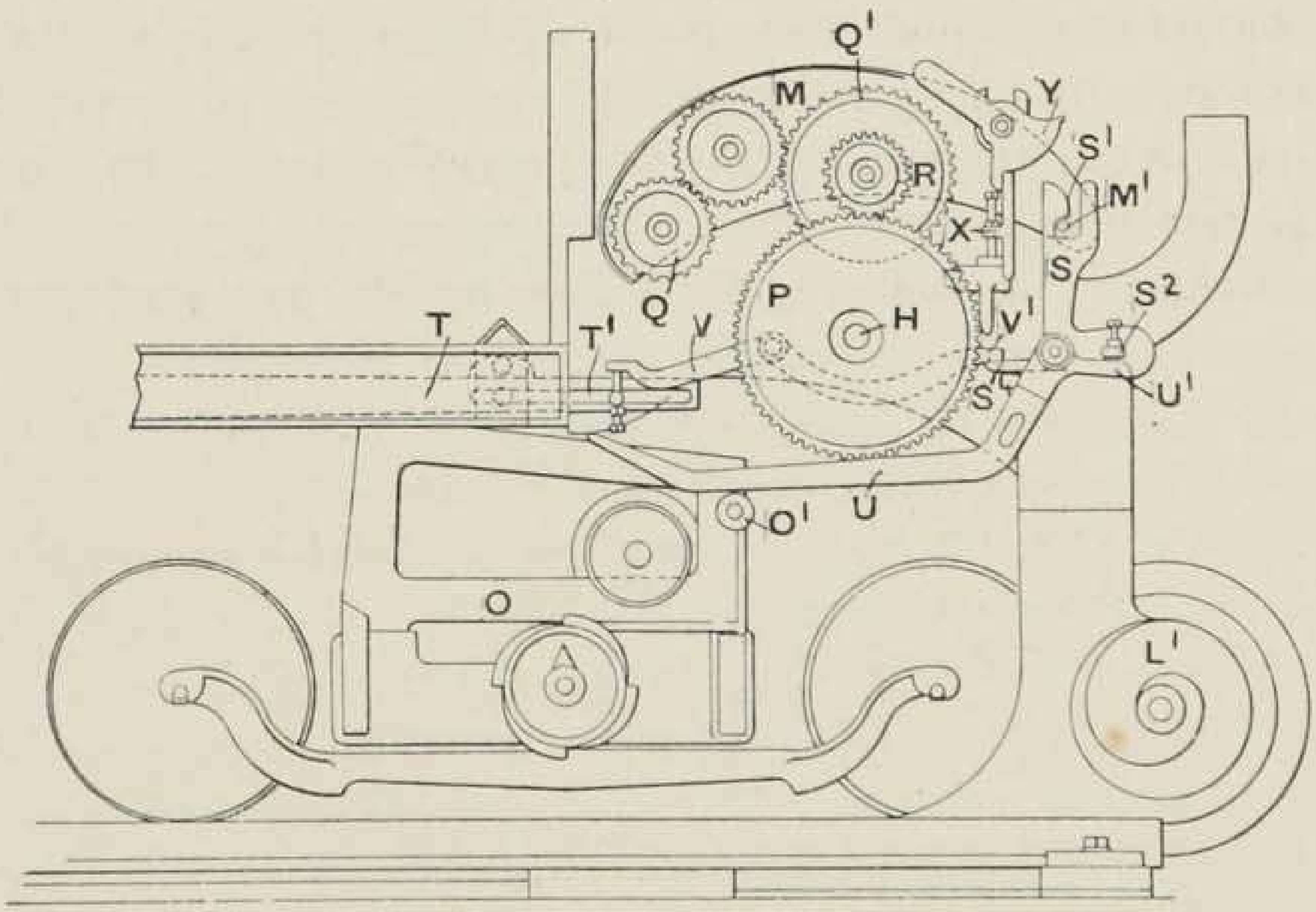


Fig. 81.

out the carriage, a considerable strain is put upon the wheels P R, which sometimes jump out of gear in consequence. In engaging again, there is a danger of broken teeth, and this is one of the parts of a mule where there is considerable danger of damage. It is not an unusual thing to see the pinion R dance in and out of gear with P until the momentum of the carriage is overcome, and this is one of the chief objections to the Mendoza lever. There is always a difficulty in engaging a revolving and a stationary wheel, and it very often results in breakage, especially if the power to be transmitted through the stationary wheel is considerable. It is true that the weight of the Mendoza lever and its attached parts is considerable, but that does not prevent this slip or failure to engage taking place. It is accordingly desirable to make some provision for ensuring that the moment the Mendoza lever falls and the pinion R engages with the wheel P it shall be locked and prevented from rising. In the arrangement made by Messrs. John Hetherington and Sons (Limited) this trouble is avoided. Fixed in the Mendoza lever M is a pin M^1 which is long enough to take into an open mouthed slot S^1 in a counter-balanced lever S. S is hinged to the framing, and, when left entirely free, its horizontal arm being heavier than the vertical causes it to overbalance the latter. The result is that a shoulder formed in the slot S^1 at the point shown falls over the pin and firmly secures the lever M. As the carriage O runs in, a bowl O^1 fixed on it engages with the angular portion of the lever U and raises it, thus freeing the lever S from the sustaining effect of the tail end U^1 of the lever U. It will be noticed that a small ear S^2 on S has a screw fitted the point of which bears on U^1. So long, therefore, as the lever U can freely move on its centre the lever S is held in position to allow the free passage of the pin M^1 into the slot S^1; but when it is raised as described, the lever S is allowed to oscillate and thus lock the Mendoza. A glance at the illustration will show that it is not until the bowl O^1 passes from the angular to the straight part of U that the absolute locking of S^1 and M^1 can take place, and this is simultaneous, or practically so, with the engagement of the pinion R with the wheel P, which, as explained, occurs as the strap is transferred to the fast pulley. After the carriage has made a small portion of its outward run the lever U is released by the bowl O^1, and the locking lever S is thus oscillated so as to free the pin M^1. By this time the carriage has gained its full momentum, and the chances of disengagement of P and R are very slight. It occasionally happens that in cleaning the minder will run out the mule a little and then change the cam without freeing the lever U. The result is that both the back shaft and taking-in shaft are in gear, and the two sets of bands are pulling against each other, and there is in this case a great danger of serious straining of the carriage. Breakages thus occur, and to avoid these there is attached to the long lever T an arm T^1 engaging with a relieving lever V, the tail V^1 of which presses upon a small projecting piece S^4 formed on the lever S. Any elevation of the inward end of the long lever T—which is what takes place under the circumstances named—is followed by the arbitrary release of the pin M^1 and S^1. Thus the chance of a breakage is practically avoided. With a contrivance of this character many of the evils usually existing with this type of gear are entirely removed. The Mendoza is raised by means of a lever X operated from the cam shaft, and can be locked in position by the small catch Y, which holds it up. This is very useful at times, when it is desired to clean or make adjustments of the parts. Although the Mendoza lever is perhaps more widely employed by makers than the clutch, the latter is on the whole less liable to induce breakages, and can be more certainly and smoothly put into gear. In another make of mule a very similar catch is employed to prevent the engagement of the taking-in friction, even after the cam has been changed, and in this way breakage is avoided.

(282) The machine which has hitherto been dealt with is designed for the purpose of spinning medium counts, and when the finer counts are to be spun it is necessary to provide special means for the manipulation of the material. The finer the counts the greater number of twists contained in the yarn, and, as a consequence,, the shortening effect, which takes place in each length of yarn by reason of the twisting, is proportionately increased. As the yarn is of smaller diameter, it is less fitted to sustain the extra strain thus put upon it, and if delivered and twisted in the same manner as a coarser yarn, it would be broken. In addition to this, there is another factor which has to be reckoned with. Yarns of medium counts are subjected to a draft, by means of the gain of the carriage, the amount of which is proportionate to the counts spun. The longer the staple of the cotton the greater the draft which the yarn will

stand. It follows, therefore, that the finer yarns being spun from the longer staples, a better draft can be given to each thread. It is very desirable that yarns of this class shall be as even in diameter as the best skill can make them, and the draft to which they are subjected, after some of the twist is put in, is well calculated to draw out the thick places. It is customary, in spinning fine yarns, to put in, during the outward run of the carriage until it arrives nearly at its termination, very little twist, and the amount of this is just sufficient to enable the thin places to be strengthened sufficiently to resist the final draft. When the carriage approaches within a few inches of its extreme outermost point, the rollers cease to deliver yarn while the carriage continues its outward run. There is thus an additional and final draft exercised which has some influence in evening the yarn. The full twist is put in when the carriage arrives at the end of its stretch, and a shortening of each length of yarn takes place. The extent to which this takes place is dependent solely upon the number of turns per inch put into the thread. The tension of the yarn, which is induced by the operation of "jacking" just described, entirely precludes the possibility of any further stretching of each length. If the tension is maintained during the final period of twisting rupture is inevitable, and a large percentage of breakages will occur. It is customary, therefore, to relieve the yarn either by shortening the length held between the spindles and rollers or by delivering a small length as twisting takes place. The first method involves the movement of the carriage towards the roller beam for a short distance. The weight of the carriage renders the regulation of the extent of this movement difficult to obtain, and this course has therefore ceased to be followed. The usual practice is to give the rollers a slight forward motion, so that they deliver a little yarn, sufficient to relieve the tension without affecting the twist in the yarn. This "roller delivery" has entirely superseded the "receding" motion, and can, as will be shown, be very easily effected.

(283) Referring now to Fig. 82, which is a plan view of the

mule in the Manchester Technical School, it will be seen that in all essential features it is similar to the machine previously described. It may, however, be pointed out that the winding barrel X is in this case cylindrical, and the terminal acceleration of the spindles therefore depends upon the action of the nosing motion. In this machine the method adopted is, as has been mentioned, to draw the chain out of the straight line to an increasing extent by means of a second chain, which is shortened as required, the actuation of the mechanism for this purpose being regulated by the position of the locking lever. The mule, as shown, is adapted for spinning the finer medium and fine counts. The "jacking" motion is controlled from the side shaft J, which has fixed on it, in addition to the wheel J^1, the smaller bevel pinion J^2. This engages with a larger wheel, which is geared, by means of a catch and ratchet clutch arrangement, to the wheel Q^2 driven by the wheel Q on the roller shaft, and forming one of the train of wheels driving the back shaft H. So long as the motion is derived from the wheel Q, the velocity of Q^2 being then higher than when driven from J^2, the catch driving Q^2 slips over the ratchet teeth in the latter. When the friction clutch F Q is disengaged, then the wheel J^2 obtains command of Q^2, and drives it and the back shaft at a slow velocity until the Mendoza lever, in which the wheels driving Q^1 are carried, is raised, and the back shaft thus ceases to rotate. The amount of this extra "jacking" stretch is dependent upon the timing of the motions controlling the disengagement of the rollers and back shaft, which in this case can be varied as desired. During the period that the shaft J is running, which coincides with that of the rim shaft, the supplementary shaft K is also rotated, being driven by a pinion on J, which gears with a carrier also engaged with a pinion on K. The shaft K has on its outer end a worm, which meshes with a worm wheel K^1 fastened on a short shaft. This is provided with a clutch box N, similar in construction to that in Q^2, one half of N being loose upon the shaft and compounded with a pinion N^1; N^1 drives a pinion

N^2, fastened on the roller shaft E. When the roller shaft E is driven by the clutch F Q the velocity of the wheels N^1 N^2 is such that the pawl in N slips over the teeth in the ratchet, but when F Q is disengaged, then the clutch box N takes command and drives the roller shaft E at a slow speed. Although this movement of the rollers accompanies the slow motion of the back shaft it lasts for a longer time, and only ceases when the strap is taken off the fast pulley A. Thus it is possible, by timing these motions and providing suitable wheels, to enable the rollers to deliver any desired length of yarn, which is equivalent to the recession of the carriage. For this purpose the worm wheel K^1 can be changed and the pinion or gain wheel which gears with Q^1. The wheel G^1 can also be substituted by any other, when it is desired to change the twist by altering the roller delivery. The relative velocities of the rollers is obtained by means of the wheel train F^1 F^2 Z Z^1, of which Z is the change pinion. It will be noticed that the middle and back lines of rollers are driven one from the other at the same velocity by the intervention of the wheel Y, the draft being entirely put in between the front and middle lines. A change can also be made by substituting one size of rim pulley for another. On the back shaft H is a pinion R, which drives by the intervention of a carrier wheel the wheel R^1, which, although not so shown, is provided with a catch box similar to N, and by its means drives the shaft E as the carriage is moving in. This motion is that which gives a "roller delivery during winding," and its object is to ensure the delivery of a little yarn as the inward run of the carriage is made. It is found that the winding of the yarn is more effectively performed in this way, and that better twisting is obtained in spinning fine yarns by reason of the short length of unspun yarn thus delivered. The action of this motion is obviously similar to that of N, and the catch in the box on R^1 does not obtain command of E until the back shaft H rotates during drawing up. The full length of yarn wound is of course lessened by the amount delivered, whatever that may be. It is only necessary further to point out that this machine is driven by a belt on A during spinning, but that the backing-off and taking-in mechanism is driven by a rope separately driven from the countershaft and gearing with the grooved pulley D^3. The actuation of the strap fork after the completion of the twisting is the work of a small crank arm driven from the worm on the end of the rim shaft, as in the case of the mule previously described. The points of adjustment in this mule are very numerous, and enable a wide range

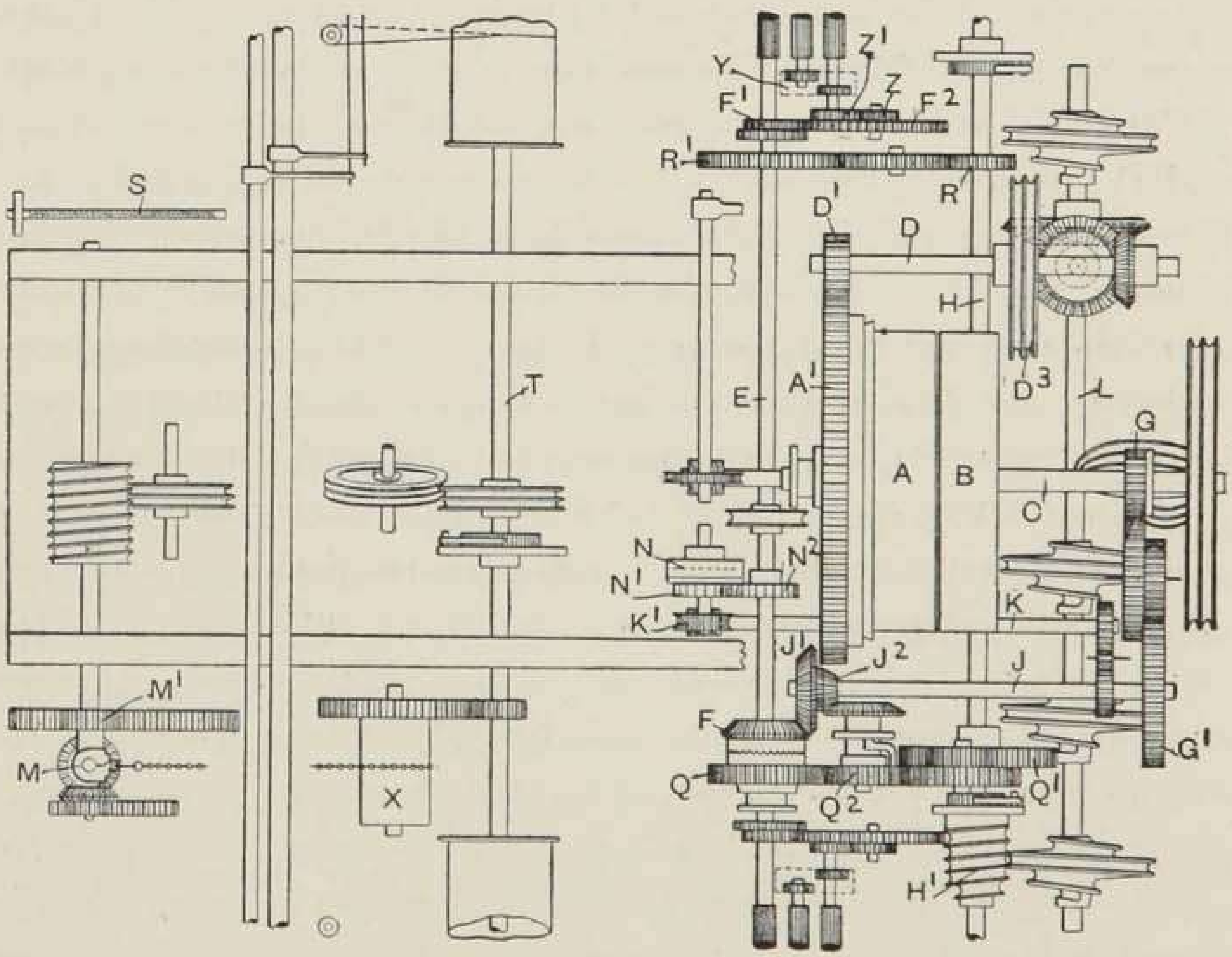


Fig. 82.

of counts to be spun. In all fine mules special provision is made for the relief of the fallers at the conclusion of winding, and this is a matter of some importance.

(284) The description thus given of the mule and its mode of operation has necessarily been a very lengthy one; but, if studied, will enable a clear idea to be got of the operation generally. There is one point which deserves some notice, and that is the question of the power required to drive the machine

This is considerable, but is variable throughout the cycle of movements which together make up mule spinning. As is natural, the greatest power is taken when the spindles are revolving at their highest velocity during the period of spinning, the friction of the spindles during this portion of the operation being greatest. In Oesterrich's "Wollen-Industrie" a record appeared of a number of tests made with one of Rieter's brake dynamometers, by which the power required is approximately settled. The mule which was tested contained 600 spindles, $1\frac{1}{2}$in. gauge, and was spinning 20's yarn. The rim shaft, when spinning, made 578 revolutions per minute, and the spindles 7,450. The outward run of the carriage occupied 8·6 seconds, and the recorded diagram showed a pressure on the lever at the beginning of 235 kilogrammes. During the first three seconds the inertia of the carriage and other parts actuated is overcome and the pressure falls to 115 kilogrammes, at which it remains until the stretch is completed. Backing-off lasts 2·2 seconds, and the power required falls to 10 kilogrammes. Winding began at the end of 10·8 seconds, and lasted 2·6 seconds. The power absorbed rose during 1·7 second from 10 to 50 kilogrammes pressure on the lever, but fell during the next ·9 second to zero, which it reached at the termination of the cycle of movements. The mean pressure during the trial was stated to be 101 kilogrammes, and by using the formula $x = \frac{P \times n}{t \times 75}$ the horse power absorbed is obtained. In this formula P = mean pressure; n = number of revolutions of dynamometer pulley indicated on counter; and t = duration of trial in seconds. Applying this to the case in question, the formula is worked out as $\frac{101 \times 66{\cdot}5}{13{\cdot}4 \times 75} = 6{\cdot}68$, which gives the total horse power registered, but deducting the power absorbed by the dynamometer itself, the net horse power required is found to be 6·59. This gives the power required for 100 spindles as 1·098 H.P., which approximates very closely to that generally assigned to the mule. There is a singular lack of reliable data as to the power absorbed during the whole cycle of movements of a mule, and this test, although obviously made with a slow speed of carriage traverse, is valuable as throwing some light on the amount required at various periods. Thus the mean pressure during the period of spinning is 134 kilos., but reaches 235. The rise of pressure during winding is obviously affected by the increase in the velocity of the carriage about the middle of the outward run, which is the moment when the greatest weight is being moved at the highest speed. Thus a good deal of light is thrown upon the conditions of working, and it is to be hoped that some further experiments will enable the point to be still further cleared up.

(285) The actual twist which is put into the yarn is never equal to the full calculated twist, the variation arising from the slip of the bands and similar causes. It is obvious that the bands will slip more at one time than at another, atmospheric variations and several other causes contributing to this result. The question as to what is the right amount to allow for the slip of bands is one which is largely settled by personal experience, which is not always accurately recorded. It will vary, however, from three to eight per cent, and the latter figure is often nearer the mark than the former. It is requisite, therefore, in making any calculations to remember this fact, as it has an important bearing upon the subject. There is a little difference in the twist put into yarn when being spun on a cop either partially or fully built, this arising mainly from the better grip which the yarn has in the one case than in the other. This is not an important point, but it has a little bearing on the subject, and causes a slight variation in the weight of a lea. In doffing a mule, after a set of cops is finished, the following procedure is adopted :—The mule is stopped during backing-off and the counter faller is depressed and fastened down at a point below the cop by a special catch. The cops are then raised a little by placing the thumb below them so as to free them ready for removal. The winding quadrant and shaper screws are then turned by hand so as to bring the quadrant nut

and shaper plates back to their initial position. A turn or two of yarn is then wound on the spindle below the bottom of the cop so as to hold it sufficiently to enable it to be broken when the cops are finally removed, which is the next operation. Thus there is a connection remaining between the spindles and rollers. If paper tubes are used they must be fitted on the spindles immediately the cops are doffed, and in that case the quadrant nut should be wound back a few turns to compensate for the increased diameter. From 6 to 10 turns will be found sufficient. The counter faller is released, the carriage then run up to the rollers and spinning begun. After a few stretches have been wound and the cop bottom formed, the starch may be applied if necessary. The size or starch used for this purpose is made from potato flour or farina, principally with a little tallow and soft soap mixed with it. It is boiled for about half an hour, and is taken to the mule in buckets or cans. A good plan has been adopted by which, instead of handling a large bulk of starch, it is boiled at some convenient point and pumped up to the mule rooms by a special pump, being discharged over a trough or tray, into which the surplus starch can fall and be again used up.

CHAPTER IX.

RING SPINNING.

(286) The machine which replaced the old spinning wheel was founded upon it, and accordingly both Wyatt's and Arkwright's machine was constructed with a flyer revolving round a common centre with a bobbin. The only rival to the mule for many years was the flyer or throstle frame, and in many respects it was the most perfect spinning machine ever used, so far, at any rate, as the character of the product was concerned. The throstle consists of an arrangement of rollers by which the roving is delivered, and of twisting mechanism. The latter is similar in principle to the roving spindle, but differs in constructive details. The spindle is borne by a footstep and bolster, and the bobbin is placed loosely upon it. On the upper end of the spindle a flyer, with two downwardly projecting arms formed with curls at their extremities, is fitted by means of a screwed nipple. The flyer eyes revolve with the spindle round the bobbin, and the yarn is, after leaving the rollers, passed through the curl or eye of the flyer on to the bobbin. The latter rests upon the rail in which the bolsters are fixed, and is formed with a comparatively broad flange, which is recessed on its under side. The bobbin has also an upper flange, and upon the cylindrical barrel between the two the yarn is wound—this space being the "lift" of the bobbin. Below the bobbin, and between it and the rail, flannel washers are placed, the object of which is to so far retard the rotation of the bobbin as to cause it to lag behind the flyer, and thus wind on the yarn. There are two things to notice in connection with this operation. The first is that the flyer always maintains a definite and uniform velocity, which thus establishes a constant relation between it

and the rollers. The second is that the bobbin is drawn round the axis of the spindle by the pull of the yarn, and is held back sufficiently to ensure that it will take up the same length of yarn which is delivered by the rollers. The moment the tension on the yarn increases beyond the normal amount the bobbin is moved, and thus a constant relative velocity of the bobbin and flyer is established. The conditions of spinning thus established are marked by two characteristics. They are eminently fitted to produce a very evenly twisted thread, and are equally likely to result in a strong elastic yarn being obtained. It is well established that flyer or throstle yarn is the most even, cylindrical, and regularly twisted which has yet been produced, and there is little doubt that two factors contribute to this. These are first, the fact that the twisting is effected by the rotation of an eye which travels in the same orbit at a uniform velocity; and, in the second place, the moderate velocity at which the operation is conducted. The first point does not require demonstration, and is only made in order that some little light may be thrown upon the conditions prevailing in the modern method which is substituted for flyer spinning. The second consideration is more important, and there is little doubt that a comparatively slow delivery of the roving and a positive steady turning of it on its axis is much more likely to produce an ideal thread than any system where these two factors are absent. Whatever be the explanation, the fact remains, that no yarn has ever been produced which, for evenness, strength, and elasticity, compares with flyer yarn. As the process is now comparatively obsolete it is not necessary to expend many words on it, but it is worth while emphasising that it is eminently suited for the production of a high quality of yarn, although confined, mainly, to the coarser counts.

(287) The system to which the name of ring spinning is given is in its elements very simple, and it will be most convenient to give a brief description of the machinery employed prior to considering the problems involved. For this purpose a reference to Figs. 83 and 84, which are, respectively, transverse and

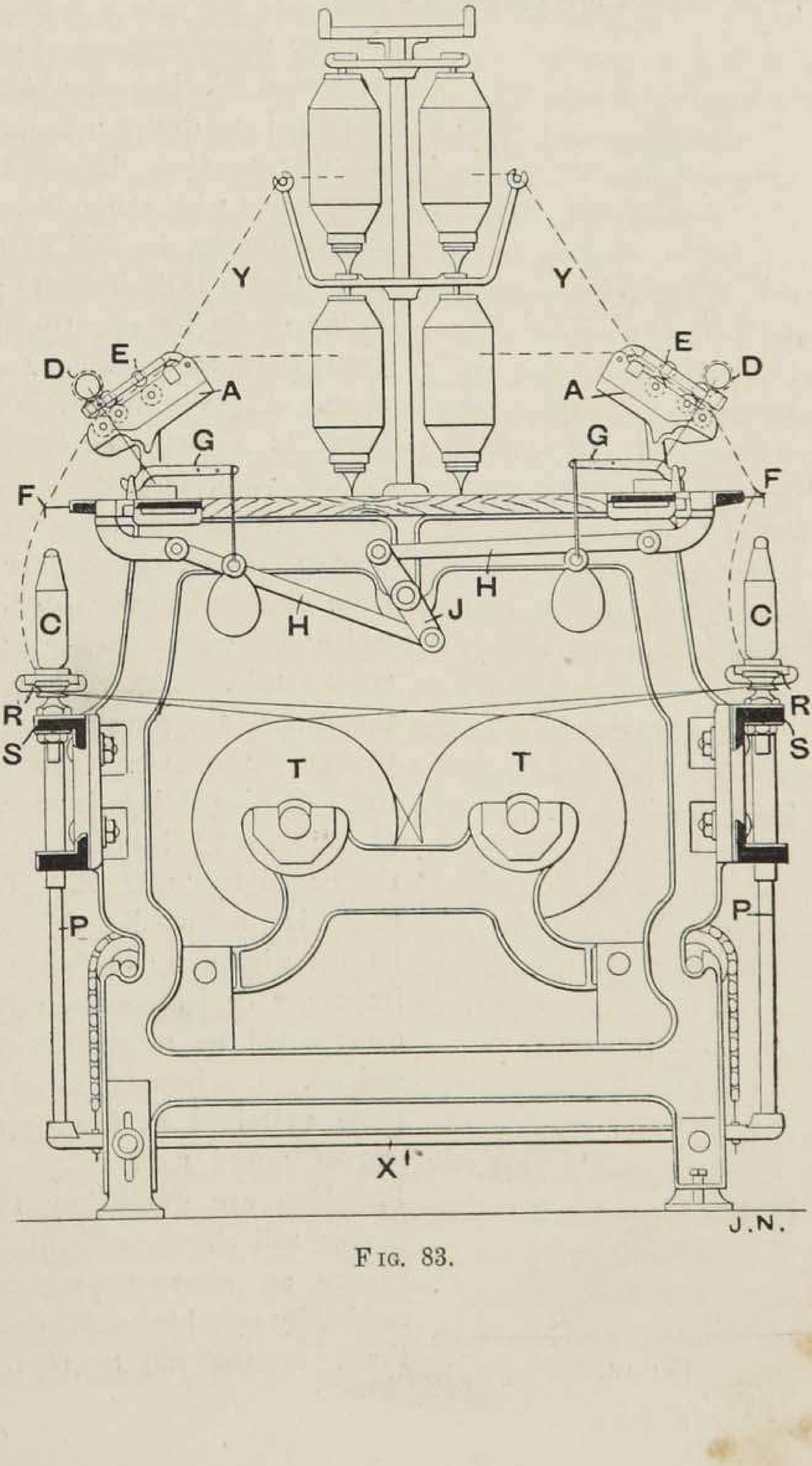


FIG. 83.

partial sectional views of a ring frame, may be made. The roving bobbins are placed in a creel, and the yarn Y is guided, in the manner shown, to the rollers E E^1, through which it is passed and drawn in a similar manner to that described in connection with the mule. It may, however, be said at this point that it is desirable to put in the drafts for slightly finer yarns than are intended to be spun. As twist is introduced there is a little contraction of the yarn, and it is desirable to avoid thin and uneven places, to deliver a little greater length than that which is calculated by the strict rule. After leaving the rollers the yarn is taken through the wire eyes F fixed in hinged boards known as "thread boards," and thence to the ring R. The ring is a small cylinder formed with a lip or flange at its upper or both ends, being constructed as afterwards described. It is borne in a rail or plate sustained at the upper end of round rods or pokers P, which are guided by the double rail shown, and which receive an alternate vertical motion by suitable mechanism. Fixed in the rail S^1 is the

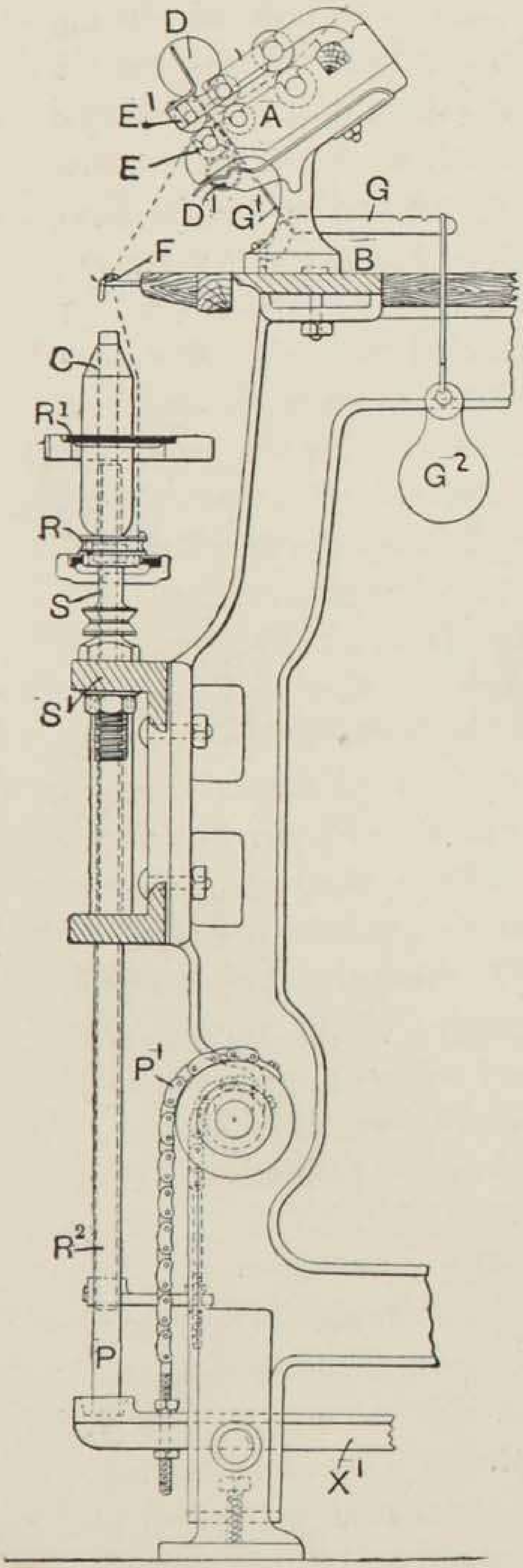


FIG. 84.

spindle S, which is accurately adjusted and fastened in the exact centre of the ring. Thus, the conditions of the operation are not dissimilar in principle to the operation of roving, but are different, in the fact, that, instead of the bobbin being given an alternate reciprocal vertical movement, while the flyer eye remains stationary, it is fixed, so far as its vertical position is concerned, and the part corresponding to the flyer eye receives a motion of that character. The above is a general description of the mechanism, which may now be treated in detail. The rollers are sustained in roller stands A, which are fastened to a longitudinal beam B and are, as usual, in two lines E E^1. They are weighted by means of stirrups G^1, levers G, and weights G^2. It is customary to form the roller stands A so that a line through the centres of the rollers is angularly disposed to the horizontal. The reason for this procedure will be explained presently. A revolving clearer D is placed above the top rollers, so as to take up the fly from the two lines, and an underclearer D^1, is sustained below the bottom front rollers. The thread boards are connected by levers H to a central rocking lever J which can be oscillated by means of a handle on the end of the shaft on which it is fixed. Thus, the thread boards can be simultaneously turned up when required for doffing.

(288) The mechanism described up to this point is that which is concerned with the delivery and guiding of the yarn to the spindles S. The latter are now entirely self-contained—that is, they can be fixed in position at one operation—and, as presently shown, carry wooden spools or bobbins upon which the cop C is wound. They are driven by bands from the tin rollers T. The ring R is fastened in a light rail, preferably of wrought iron, which is given a reciprocal traverse up and down. The ring is usually of the shape shown in Fig. 85, but a better form is that shown in Fig. 86, which is Coulthard's double ring, and which is fastened to the ring rail by means of a special fastener. Ordinarily, the ring is formed with a cylindrical portion at its lower end, fitting a hole in the rail to which it is firmly secured. On the ring a small clip, made of special wire, is sprung,

being of such a size that it can freely rotate round the ring, but cannot come off easily. This "traveller," as it is called, is the means by which the twist is put into the yarn, but has a twofold object, of which something will be said hereafter. The yarn is passed through the traveller on its way from the eye F to the bobbin. The pokers P rest, as shown, on the ends of a crossbar X^1, which is coupled by the chain P^1 (Fig. 84), to small grooved pulleys fixed up on a shaft running longitudinally of the machine. Reference may now be made to Fig. 87, which is an end view of the machine, showing the method of driving. Driven from the main shaft of the machine by the train of

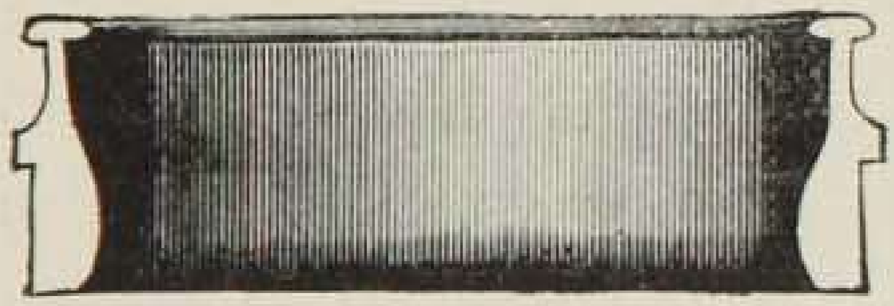


Fig. 85.

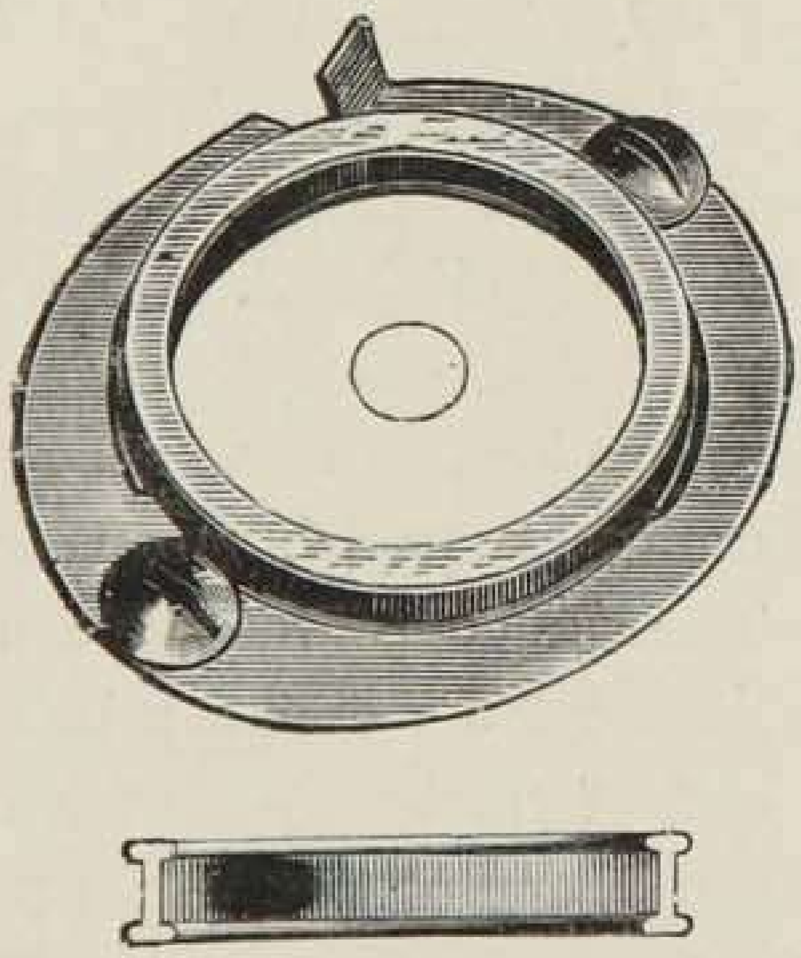


Fig. 86.

wheels indicated, is the shaft Z, having on its lower end a worm K meshing with a worm wheel L. On the axis of the latter is a heart-shaped cam M, eccentrically mounted, against which is constantly pressing a bowl in the lever N. The latter carries a small barrel at its outer end, receiving by means of the rotation of the worm O, gearing with the wheel Q on its axis, a rotary motion when O is rotated. This happens when a pawl, suitably placed, is caused to rotate the wheel U geared to the wheel O^1 on the axis of the spindle on which the worm O is fixed. Thus, when the arm N is pressed down by the cam M, the chain W is unwound from the barrel P^1, which is thus caused to rotate, along with the shaft on which it is fixed. Another arrangement, which is often preferred, is that shown in Fig. 88, which is a perspective view of a ring frame. In this case the pokers P are raised by the action of levers L, which are affixed to rocking shafts, and are coupled by the quadrants

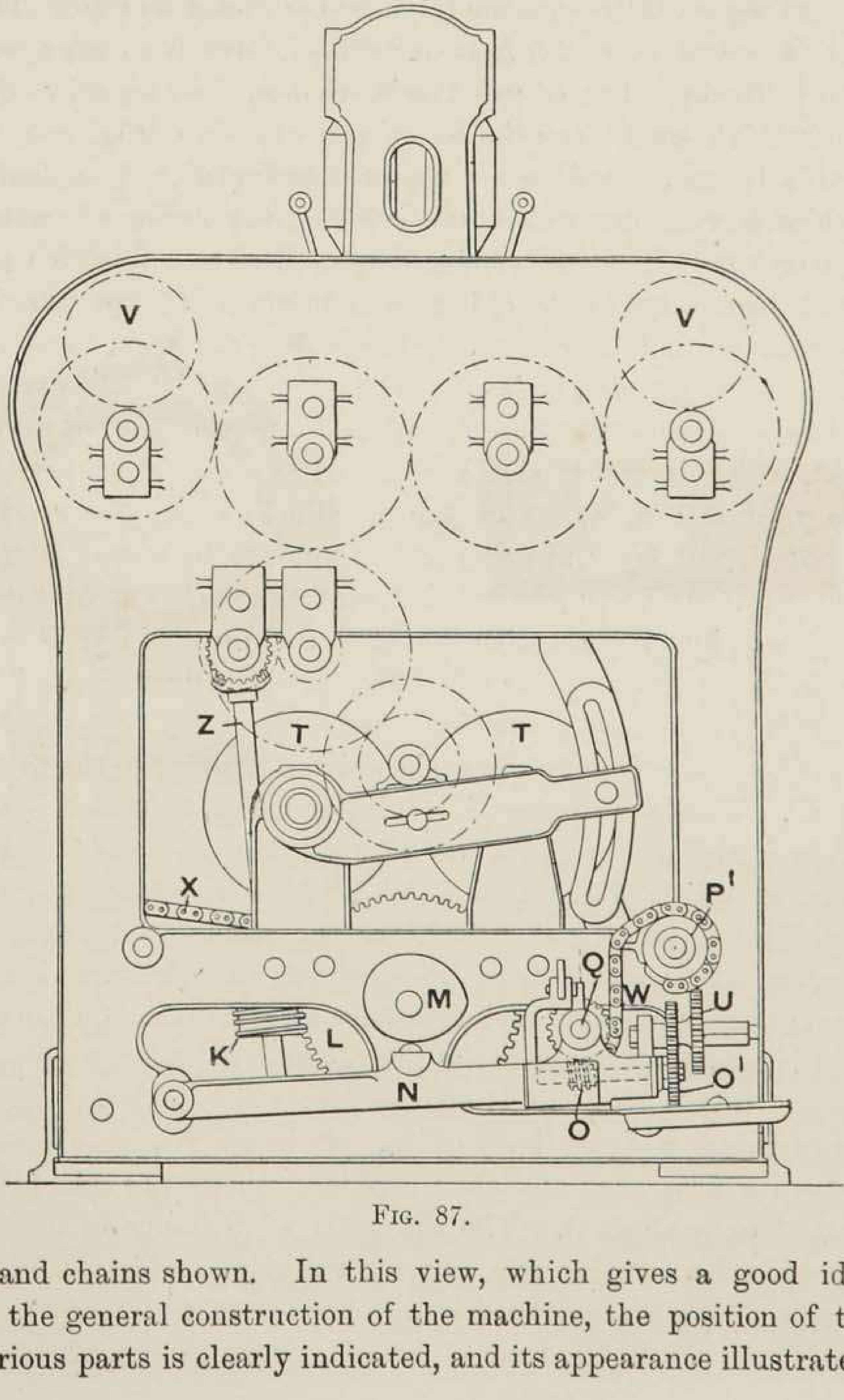


Fig. 87.

Q and chains shown. In this view, which gives a good idea of the general construction of the machine, the position of the various parts is clearly indicated, and its appearance illustrated.

(289) The action of this mechanism is as follows:—When a cop or spool is commenced the ring rail is at its lowest position, as shown in both Figs. 83 and 84, and two or three coils of yarn which are passed through the traveller are wound on the spindle below the bottom of the bobbin. These have been wound on prior to the operation of "doffing"—that is, the removal of the full bobbins—and when the latter operation is carried out the yarn is broken, but does not require piecing up. The empty bobbins having been put on the spindles, the frame is started, and the rotation of the bobbins causes them to wrap the yarn round them, very soon breaking the connection with the spindle. The traveller is thus caused, by the pull of the yarn, to travel round the ring, and twist begins to be introduced into the roving. At the same time the lever N makes its first reciprocal movement, which is one of slow ascent and of more rapid descent. The yarn is thus coiled on the spindle in a manner shortly described, and layer after layer continues to be wound in the same way. In the meantime the ratchet wheel U is actuated by coming into contact with the pawl, and the chain W is thus gradually taken up by the wheel O, rotated as described. The result is that the shaft on which is the chain pulley P^1 is slightly rotated, so as to take up the chain which is coupled to the cross-bar X^1. Thus the ring rail is gradually raised, so that it has a higher initial point at each traverse, and finally a spool C of the shape shown in Fig. 84 is formed. It is necessary to note that the length of each "lift"—as the reciprocal traverse of the ring rail is called—remains constant throughout, and that the character of the reciprocations also remains the same. That is to say, throughout the process of building, the upward traverse of the ring rail is comparatively slow and the downward traverse comparatively quick. It is sought, in this way, to form a firm nose, and thus enable unwinding to take place without entanglement. The operation of building in a ring frame is not a complex one, but the velocity at which it takes place is, of course, regulated by the fineness of the yarn which is being spun. In the train of wheels, shown in Fig. 87, there

is ample adjustment for many changes. The velocity of the traverse or lift of the ring rail can be varied by an alteration of the size of the pinion driving the train of wheels shown, but this involves a similar change in the velocity of the front roller wheels V. By varying the shape of the heart or cam M the relative velocity or extent of the upward and downward lift of the ring rail can be changed as desired.

(290) We now come to deal with the question of the relative adjustments of the rollers. As shown, the axes of the rollers

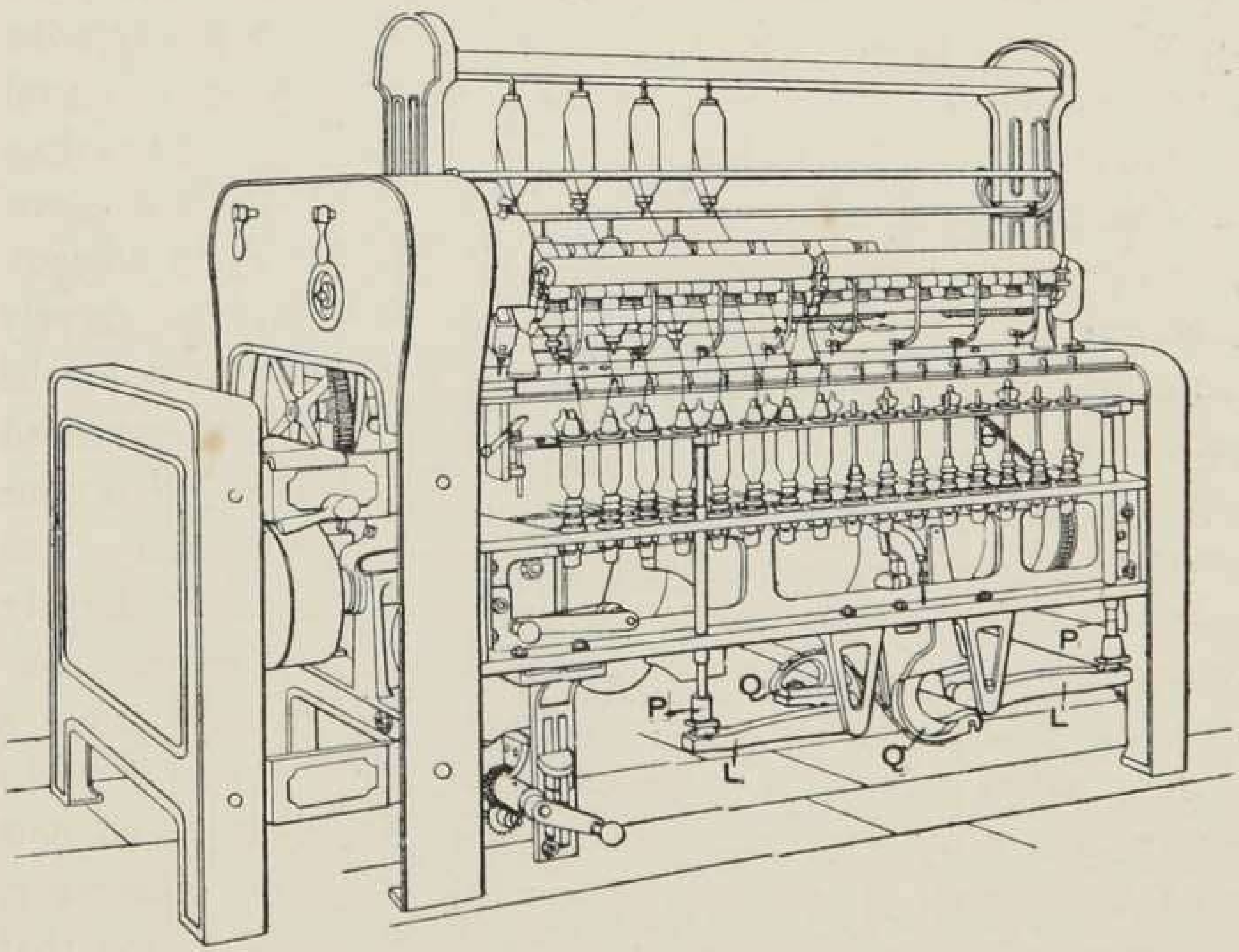


FIG. 88.

are not in a horizontal plane, but are angularly disposed. The reason for this procedure is as follows: As the yarn emerges from the bite of the front rollers, it is essential that it shall receive the twist at once, as the velocity at which the spindles run and the tension put into the yarn, owing to its work in pulling round the traveller, alike tend to break the ends. It is obvious that if the yarn had to press against a part of the circumference of the front roller the twist would not readily pass the point of contact. It is thus necessary to provide an adjustment which enables the twist to run right up to the nip of the rollers, and this necessity becomes greater when softer twisted yarns are spun. The practice is, therefore, to vary the amount of inclination according to the character of the work, and the range of variation being from 5 to 35 degrees. Weft yarns require the greater inclination on account of the smaller number of turns put into them. Not only, however, is it necessary to set the rollers angularly, but the nip of the front roller must in some cases be as nearly as possible arranged so as to allow the yarn to pass to the traveller in a straight line from the rollers. If it were bent to an acute angle round the wire eye F, for instance, it would be detrimental to the best work, and accordingly there is a growing tendency to approximate the line to a straight one. Before leaving this point it may be stated that the most common angles adopted are about 35° for weft and 25° to 30° for twist yarns. This is one of the most important features in a ring frame, and upon it largely depends the success or non-success of the machine.

(291) The ring is made almost universally now of mild steel, and is constructed without a weld; being, after it is turned to shape, case hardened, so as to present a very hard surface on which the traveller can travel. The absolute cylindricality of the rings is essential, and users of them should see that they are free from defects of any kind. The traveller is a ∩-shaped clip which, as was said, can be sprung into place on the ring, but, when in position, is quite free from any binding contact. Something will be said, at a later point, about the necessary grading of the weight of the travellers used for the various counts; but, in the meantime, it is necessary to deal with the character of the spindles used. Without going into the history of the subject, which has been amply treated by the author in the book previously referred to, it may be said that the first type of spindle was similar to the mule spindle, and was sustained by a footstep and bearing possessing considerable weight. It was not long before the vibration set up by the increased

speed at which they were run led to the construction of spindles with a bearing well within the bobbin, so that the position of the bolster was practically raised to a higher point on the spindle. To Mr. Sawyer belongs the honour of first applying this principle successfully; but although the spindle bearing his name was very successful, it was not in existence long before it was superseded by the Rabbeth spindle, which was introduced into this country by Messrs. Howard and Bullough. The Rabbeth spindle is illustrated in Fig. 89, being marked A. It possessed the chief feature of the Sawyer by having its upper bearing within the bobbin, but this very decided advantage was accompanied by another—viz., the fact that the whole of the bearings of the spindle were self-contained, only one setting being required. Referring to the illustration, the spindle B is carried in a bolster H, which is bored so as to form a footstep F at its lower end and an upper bearing at C. At the latter point it is fitted with a nickel tube which is cut with a very coarsely pitched spiral groove by which the oil, contained in the reservoir formed by the space shelled out in the body of the bolster, is raised. The bolster, at the lower end, has a flange formed on it, below which is a screwed shank on which is fitted a nut. The shank is passed through the spindle rail S^1, as it is called, which is pierced by holes a little larger than the shank of the spindle, thus allowing for adjustment. Fitting tightly upon the spindle at a point a little above the upper bearing is a cast-iron sleeve E, formed, at its lower end, with a warve round which the driving band passes. On the lower end of the sleeve, just above the warve, is a cup D, which receives the lower end of the bobbin A. It is not, however, good practice to allow the bobbin to fit the cup, and it should be so constructed that it will only fit the spindle tightly at its upper end. The sleeve is prevented from rising by a device consisting of a hooked wire G, which can be arranged to swivel, or which, as in the example shown, is fastened in a small hinged frame which can be oscillated as required, to allow of the sleeve and spindle being lifted out when required to oil. The great merit of the Rabbeth spindle lay in the fact that it contained sufficient oil to last, without renewal, for many months, and it had a very large employment in a short time. It was, however, found that although a largely accelerated velocity was possible with it that the bobbins did not run as steadily as could be desired, for which reason it was, after a time, abandoned in favour of another form, to which the name of the "top" or "elastic" spindle was given.

(292) The elastic type is founded on the principle that any rapidly revolving body, which is in slightly uneven balance, will tend to assume such a position that its axis is out of the perpendicular, and will continue to rotate steadily in that position. This tendency is observable in humming tops, as everybody is aware, and it is the application of the principle to spindles which forms the basis of the "top" or "elastic" type. It is not permissible, nor, for reasons shortly to be given, would it be desirable, that the variation from the vertical position shall be too great, and means are taken to limit the movement of the spindle. For all the practical purposes of spinning, however, the freedom of the spindle to assume its true centre of gravity is absolute. One of these forms—the Whitin spindle—is shown in B, Fig. 89. In this type the spindle A is sustained by a bolster of the ordinary type, but rotates entirely in an inner sleeve C, which is turned at D to a diameter about $\frac{1}{500}$in. less than the inner diameter of the bolster at that point. The lower end F of the sleeve is turned with a cup or recess passing over a nipple formed in the bolster, and the upper end of this recess fits on a small pad of cork placed on the top of the nipple. There is a certain space left for the movement of the sleeve C in all directions at its foot, and this, combined with the freedom at the point D, allows the sleeve C to assume any position required by the want of balance in the bobbin. The oil is introduced into the cup E, and is contained in the recess shown, being raised in a similar manner as in the Rabbeth. The sediment contained in it can be deposited at the point G. Another form of elastic spindle is that shown at C in Fig. 89, this being the invention of Mr. John Dodd. In this case an inner sleeve D is

fitted, which is prevented from rotating by a rectangular nipple C formed at its lower end. The sleeve is made of such a size that it practically oscillates on its upper end when the exigencies of the case necessitate it, and it will be noticed that there is an increase in the size of the spindle up to and above the top bearing, by which, with a slight increase in weight, great strength and increased steadiness is obtained. A small ring B is fitted which prevents the rise of the oil to a point above the top of

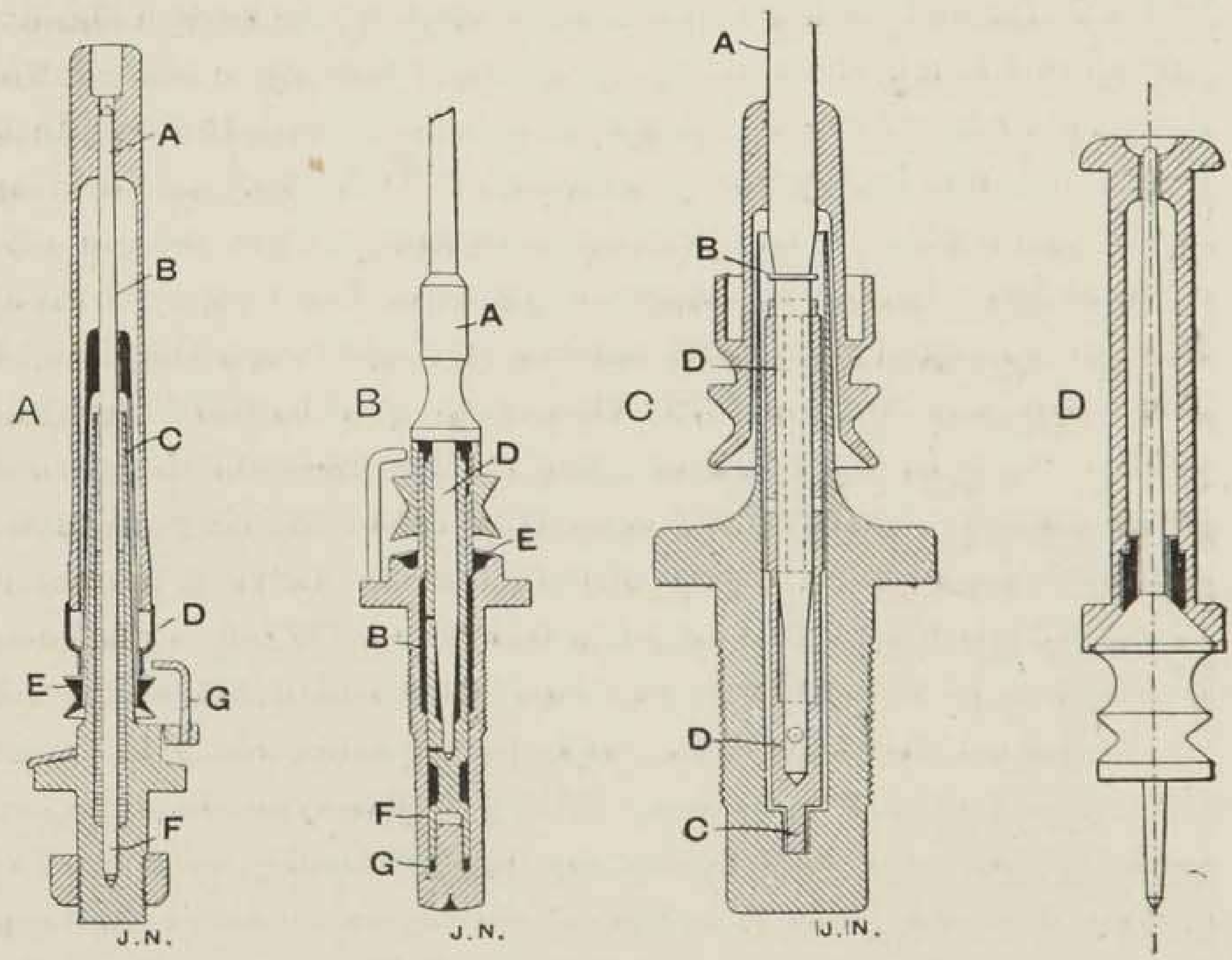


Fig. 89.

the bolster and causes it to flow back into the reservoir. The spindle is driven, like the Rabbeth, by a short sleeve formed with a cup for the reception of the bottom of the bobbin. There are a large number of spindles in the market varying from those described in small details but not in any essential principle. In some forms the bottom of the bolster is open and is covered by a withdrawable cap, so that the removal of the dirty oil and its substitution by fresh lubricant can be easily effected. In one form made by Messrs. Dobson and Barlow, a cork cushion surrounds the bolster at its upper end, thus supplying the necessary yielding when required. One of the most recent developments which has received the test of actual practice is that shown at D in Fig. 89. This is the device of Mr. Thomas Wrigley, and is chiefly notable for the method of driving the bobbin. Only the spindle and bobbin is here shown, because the spindle can be fitted to any form of bolster as desired. On the spindle is fixed a warve, the upper portion of which is formed with a conical surface. On this rests a bobbin, turned out to a corresponding cone at the underside of its lower flange. Except for the contact thus established the bobbin is free, and is not in any way jammed on the spindle. The driving is wholly effected by the frictional contact of the bobbin and cone, and the bobbin is, instead of being of the shape shown at A, double flanged with a cylindrical barrel between the flanges. The lift of the ring rail is, in this case, equal to the lift of the bobbin—that is, the space between its flanges—and the yarn is therefore wound throughout each traverse of the ring rail upon a surface of the same, instead of upon one of a varying, diameter. It is found that the driving of this type of bobbin is perfectly effected, and there are one or two features about it which will be dealt with in due course. It is perhaps necessary to say in closing this brief description of the various types of spindles, that they are all very accurately constructed. By means of special machine tools the greatest nicety is obtained in their manufacture, and they form one of the best instances of the admirable results of the systems of construction which have been adopted in recent years.

(293) We have now to consider the relations of the ring and spindle to each other. It is absolutely necessary that these two parts shall be concentric, and for this purpose means of adjustment are provided both for the ring and the spindle. In setting, it depends whether the fixed or elastic type of spindle be used, whether the ring is set to the spindle or *vice versâ.* It is a common practice to fix the spindle and set the ring to it when an ordinary Rabbeth spindle is used; but it is much

preferable to reverse this procedure, and set the spindle to the ring when the elastic or top type is employed. It is quite clear that, owing to the fact that an elastic spindle may vary from the perpendicular, there may be moments during the lift of the ring rail, when the concentricity of the two parts is destroyed, but owing to the limitation of the motion of the spindle previously referred to, the amount of variation is not great. The relation which the sizes of the bobbins and rings bear to one another is a matter also of some importance. It is well established now by practice that the best results are obtained in spinning certain counts with a ring of a definite diameter. Thus counts of about Nos. 28 to 32's can be well spun with a $1\frac{5}{8}$in. ring, and it is important that the size of the full and empty bobbins are carefully adjusted to suit this. The reason of this will be explained immediately, but in the meantime it is well to record the fact. It is especially desirable to remember this when dealing with the finer numbers, but it always has a considerable bearing upon the case. In the instance given above a bobbin of $\frac{3}{4}$in. diameter when empty and $1\frac{1}{2}$in. when full will give good results. Generally speaking, a difference of $\frac{1}{8}$in. in the respective diameters of the ring and full bobbin will give sufficient clearance for practical working, but less than this amount should never be given. The setting of the building motion should, therefore, be such that as soon as the full size is reached the gradual elevation of the ring rail which takes place will be sufficient to build the spool of a cylindrical form. Care should be taken to see that all bobbins are free from defects, and that the spindles and rings are kept clean, and, as will be shown, it is a matter of great importance to maintain perfect cleanliness.

(294) Enough has now been said to enable the principle of the ring frame to be dealt with, and for this purpose a reference to Fig. 90 may be made. In this figure A represents the spindle, B the empty bobbin, C the full bobbin, and D the circumference of the ring. It will be noticed that, assuming the yarn to be passing through the traveller at the point E, it is taken

to the surface of the full and empty bobbins in a line disposed tangentially, in each case, to the circumference of the ring. The traction thus exercised upon the traveller causes it to rotate round the ring at a velocity which depends upon that of the spindle and the diameter of the latter. For the present it is only necessary to note that this is the manner in which the traveller receives its motion, and that the yarn, in passing from the rollers to the bobbin, is bent round at a sharp angle—practically, at a right angle—to the vertical line occupied by it as it travels from the rollers. It is quite obvious that in the length between the traveller and the bobbin a considerable tension will exist, and that as all that is taking place is the direct passage of the yarn on to the bobbin there cannot be any turning of the yarn upon its axis, which is necessary to put in twist. The latter is put in by means of the rotation of the traveller at a defined relative velocity during the delivery by the rollers of a definite length of yarn. In short, the traveller performs the same function as the flyer eye in the throstle or the presser eye in the roving frame. It is, however, necessary to note that the motion of the traveller, instead of being obtained from its connection with the spindle, is one which is only derived from the spindle. In ring spinning the primary rotation is that of the spindle, that of the traveller being purely secondary and derived. The effect, however, is that being caused to rotate round the ring it gives a rotating movement to the thread, and twists it. It is a corollary from this that the velocity of the spindles determines that of the traveller, which, in turn, fixes the twist introduced into the yarn. The traveller, therefore, plays an important part in the economy of the ring frame, and it is highly necessary to understand its precise action. In addition to the effect which it has upon the twisting of the yarn, it also has the function of causing the winding of the yarn upon the bobbin. In order to enable it to do this its weight is arranged so that it will lag behind the periphery of the spindle sufficiently to enable the length of yarn delivered by the rollers to be wrapped on the bobbin. There is thus a two-fold action going on, in consequence of the rotation of the traveller, and, as there is much misapprehension existing as to its precise action, it will be as well to enquire into its operation in each case.

(295) Referring to Fig. 90, it will be seen that the traveller receives a pull in two different ways when the yarn passes from it on to the full bobbin C and the empty bobbin B. In the latter case the pull is more directly towards the centre, and is not, therefore, so well suited to draw the traveller round the ring D. To make this point clear, let it be assumed that the yarn was drawn round the ring before going to the bobbin; it

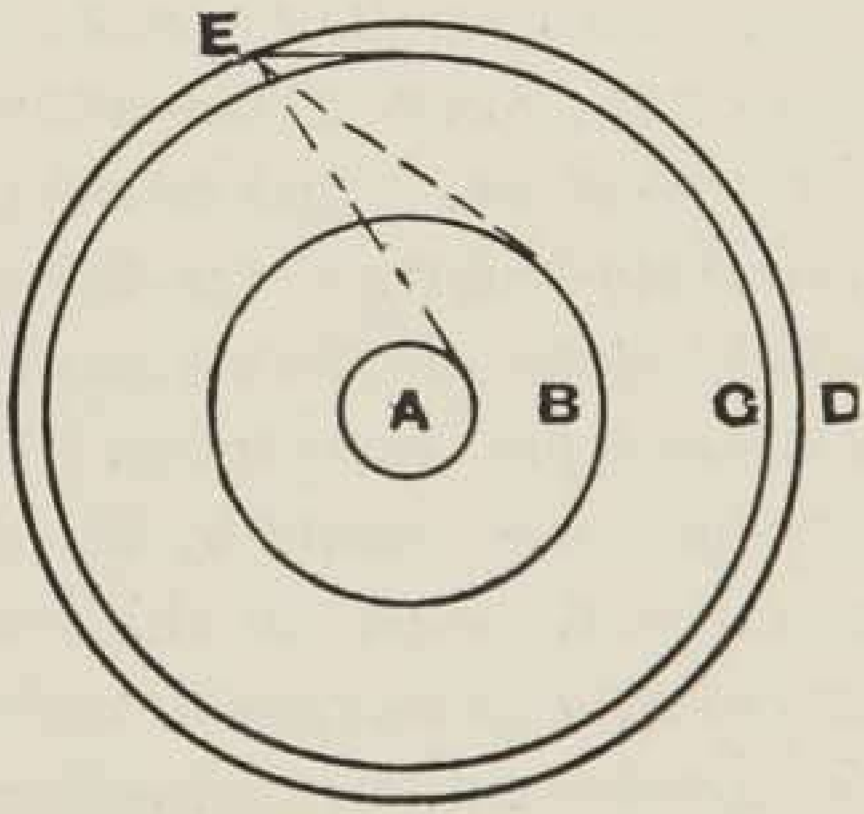


Fig. 90.

can at once be seen that the tractive force exerted would be such as to cause the traveller to rotate at the speed at which the yarn moves. The nearer the yarn approaches a radial line, the less the tractive force which is applied becomes, and, consequently, the slower relatively the rotation of the traveller. This is one source of loss, but there is another of equal importance. The power exerted is applied from the periphery of the bobbin at every point, and consequently is varying throughout the lift of the ring rail. Thus, the yarn when held at the base of the cone formed during building, is—if the full bobbin be $1\frac{3}{8}$in. diameter—being carried round through a space of 4·31in. at each revolution. When it is held on the surface of the bare bobbin, which is $\frac{3}{4}$in. diameter, it only travels at the rate of 2·35in. at each revolution. It is thus clear that, if no retardation of the traveller took place, it would travel during each revolution of the spindle a distance equal in each case to that stated. The effect of this upon the twist is easily seen. Suppose that 100 revolutions of the spindles are made in each case, and the rollers deliver 5in. of yarn, the effect would be that the traveller in one case would travel 431in., and in the other only 235in. The circumference of the ring being 5·1, this means that the traveller makes 84·5 and 46 revolutions respectively. There would thus be introduced into the yarn 16·9 and 9·2 turns per inch respectively at each of these periods, which is a considerable variation. This instance illustrates the principle, and shows the effect of the varying diameter of the bobbin; but the reader should be warned against supposing that this degree of variation actually occurs. It will be shown presently that there are a number of elements entering into the problem of more or less importance and complexity. There is, beyond doubt, a considerable influence exerted by this factor alone, but it is partially overcome by others, to which reference will be made. The fact remains, however, that the smaller the diameter of the bobbin the slower the speed of the traveller.

(296) This variable size of the bobbin has another effect beside that on the question of twist. It was shown in dealing with the roving frame that an increased diameter of the surface upon which the yarn is wound necessitates a reduction of its velocity. This is obtained in the roving frame by a reduction of the velocity of the bobbin, which there rotates independently of the flyer eye. It is obvious that this solution of the difficulty is not possible with the ring frame, because the flyer eye, or its equivalent—the traveller—only receives its motion as a consequence of the rotation of the bobbin with the spindle. In one sense there is a resemblance between the roving and ring frames to the extent that each has a bobbin lead, but the resemblance in this respect only deepens the contrast actually existing. This point may be briefly put as follows: The bobbin in the

roving frame draws the roving on to it by reason of the excess of its speed over that of the flyer, both of these factors being determined by suitable mechanism. The bobbin in the ring frame winds the yarn on to its surface because of its excess of speed over the traveller; but the rotation of the bobbin is constant, while that of the traveller is slower only on account of its retardation from various causes. The amount of lagging is determined by a set of conditions to which fuller attention will be presently given. The problem of winding in the ring frame is also like and unlike that of the mule. Here also there is the difficulty of winding on a surface of variable diameter, and taking up a given length of yarn. But the likeness does not extend further, because the spindle in this case rotates at a uniform velocity, and the roving is being constantly delivered to the bobbin. Thus it is clear that other means must be found to enable the yarn to be wound throughout building at an even tension. Reverting to the illustration given in the last paragraph, where the diameters of the full and empty bobbins were $1\frac{3}{8}$in. and $\frac{3}{4}$in. and their circumference 4·31in. and 2·35in. each, it will be seen that when the yarn is being wound on the smaller circumference it will require more revolutions to take up any given length of yarn delivered by the rollers than when it is being wound on the larger diameter. But we have shown that the velocity of these two points is uniformly the same, so that they cannot take up more than the lengths named at each revolution. To ensure proper winding, therefore, there must be some compensating arrangement, and this is found in the variable motion of the traveller previously referred to. It was observed that it was not likely that there would be between the highest and lowest velocity of the traveller the variation calculated in the manner given. The matter which really determines the amount of lagging of the traveller is the tension upon the yarn between it and the spindle combined with the direction of the pull exercised on it. The action which takes place is affected by these two factors in different degrees at different times, but they are always the determining factors.

If the spindle is revolving at 1,000 revolutions a minute during the time the rollers are delivering 50 inches of yarn, the first result is that the yarn receives 20 turns per inch. But the tension put upon it during the rotation of the spindle drags the traveller after it, at a velocity depending entirely upon the maintenance of this tension. Suppose that the tension is relieved by a slightly increased delivery of yarn, the effect would be that the traveller would lag until a tension was again established sufficient to overcome its resistance and drag it round the ring. Thus, the pull upon the traveller is entirely determined by its weight, the speed of the surface of the bobbin, and the delivery of yarn by the rollers. It can thus be seen that the weight of the traveller must be graded so that it will lag behind the bobbin at all times to maintain a uniform tension sufficient to cause the bobbin to take up the same length of yarn as that delivered by the rollers, less the shortening consequent upon twisting. It follows, therefore, from this, that, as the bobbin will only take up, when the yarn is being wound on the nose, 2·35in. of yarn, while it will take up 4·31in. when it is being wound on the full bobbin, there must be a variation in the speed of the traveller of a like amount. This is presuming that the ring rail remains opposite each of these points for the same length of time, but, as a matter of fact, this does not take place. Owing to the shape of the builder cam or heart, there is a great variation in the speed of the lift at various points, and this has an influence upon the problem. The smaller diameter of the bobbin would necessitate more rotations of the spindle to wind the same length, and as it cannot get this, the tension on the yarn becomes relaxed, the pull on the traveller consequently relieved, and the latter falls behind the bobbin a little more, on account of the decreased tension. The converse of this is the case when the yarn is being wound on the larger diameter, the traveller being then drawn a little further forward. Thus, supposing the front roller to be 1in. diameter to revolve 100 times per minute, and the full and empty bobbins to be of the sizes given, then the following will be the result. In every minute 314·16in. of yarn would be delivered by the front roller. Now, the circumference of the empty bobbin being 2·35in., the traveller would have to lag behind the bobbin 314·16 ÷ 2·35 or 133·7 turns. When the yarn is being wound on the full bobbin, with a circumference of 4·31, then the lagging is 314·16 ÷ 4·31 or 73 turns, nearly. Assuming the spindle speed to be 9,000 revolutions, then the relative velocity of the traveller, at each of these points, is 8,866·3 and 8,927 revolutions respectively. In other words, the twist would be, in each case, 28 and 28·4 respectively. This more nearly approximates to the actual condition of things than the calculation previously deduced from the speed, but neither of them are actually exact. The above gives an accurate theoretical explanation of the action of the traveller, both in its effect upon the twist and upon winding, and it is, in the main, correct, when applied to practice. There are, however, one or two considerations which require taking into account, and which very materially modify the conclusions thus arrived at. It is quite true that if the variable speed of the traveller, to which reference has been made, takes place, there will be a considerable difference in the twist of the yarn, but it can also be seen that the greatest amount of twist should, according to this reckoning, be found in the yarn at the base of the cop and the least in that at the nose. Between these two points there should be, according to this theory, a gradual increase or decrease of twist according to the direction of the lift of the ring rail and, acting on this assumption, calculations, such as that given, have been made by which the exact variation between the maximum and minimum is obtained. The observations of the author, during the past few months, have led him to reject this theory in its entirety, and a few w rds may be expended to make the matter clear.

(297) So far the demonstration has proceeded upon the hypothesis that the only forces which affect the traveller are the pull of the yarn being wound and the weight of the traveller

itself. It does not, however, require much thought to see that these are the converse of and antagonistic to each other, and that each has other effects than those just stated. The tendency for every rapidly revolving body is to fly outwards from the centre, which it will do unless it is controlled. Now it is quite clear that a traveller, although a comparatively light body, is yet by reason of its high velocity necessarily impelled to move from the centre round which it revolves. Its motion in this direction is, however, limited in two ways, viz., by the ring and by the pull of the yarn upon it. It is quite clear from the construction of the parts that a very slight outward movement would bring one end of the traveller into contact with the inner surface of the ring, and thus retard its motion. On the other hand, the pull exercised upon it by the yarn draws the traveller away from the ring, and thus prevents this friction taking place. There are, therefore, two forces which play an important part, each of which is the complement of the other. It is when they are balanced that the most steady rotation of the traveller is obtained; but the description of the action of the bobbin recently given shows that there cannot be any preservation of this balance throughout the lift of the ring rail. When the centrifugal force exerted by the traveller is exactly met and held in check by the tangential pull of the yarn, then the traveller will revolve round the ring without any appreciable friction. It is obvious that this set of conditions can only exist at one point, and that when it is necessary for the traveller to fall back in order to wind on the yarn, as is the case when the ring rail is opposite the nose of the spool, this balance, if it previously existed, is destroyed. There must be therefore periods when each of these forces is in the ascendant, and when that is the case there will be entirely different results obtained. When the pull of the yarn, owing to the large diameter of the bobbin, is at its maximum, then the traveller will, as was shown, rotate at its highest speed. In this case its momentum is necessarily increased, and it will tend to overrun the yarn and fly out. When it makes a slight outward movement it comes into contact with the ring, and the speed of its rotation is immediately checked. But so long as the surface speed of the bobbin is large, the drag on the traveller is sufficient to re-establish its velocity and momentum. The effect is that throughout the building of a bobbin there is a constant series of alternate accelerations and retardations of the velocity of the traveller, according as the centrifugal or tangential tractional forces are in the ascendant. It is therefore easily ascertainable by careful observation that instead of there being the maximum twist put in at the base of the cop and the minimum at the nose, the amount varies throughout the whole of the lift of the ring rail. It is customary, as stated, to base all calculations of the loss of twist upon the difference in the maximum and minimum circumferences of the bobbin, as if no other factor entered into the calculation. For the reasons stated, the author is of opinion that this is an erroneous assumption, and his attention was first called to the subject by an observation made to him by a gentleman of long experience in ring spinning. This was to the effect that although there was a good deal of talk about loss of twist at one point, it was very difficult to find. Observation has led the author to come to the same opinion, with the modification that throughout the whole length of a ring cop there is a variation of twist occurring, and that it does not merely happen at one point in each lift. The rapidity with which each lift is made is sufficient to prevent the traveller from entirely losing its momentum when it is opposite the nose of the cop, although it will naturally tend to do so, and on this account the difference in twist arising from the variation in circumference is not so great as a calculation would show it to be. That there is a difference is certain, but the conditions under which the operation is conducted are such that it is impossible to localise the place where it occurs. The action of the traveller is an extremely complex one, and depends on several conditions, which may be summed up as follows: The velocity of the spindle, the velocity of that portion of the surface of the bobbin on which winding is taking place, the weight of the traveller, which affects its centrifugal action and the amount of its retardation, and finally, the direction of the pull of the yarn towards the bobbin. If the remarks previously made were not considered, it would be seen that there are several opposing elements existing, and that it is extremely difficult to establish a balance between them. Although great care is taken in grading the weight of the traveller so that the most regular action takes place, it is impossible under the conditions of practical work to obtain an equilibrium of forces. Even if it were perfectly established, a small change in the tightness of the driving bands, the speed of the engine, and many other causes would lead to its destruction. Thus it is deduced that throughout the practical operation of the machine there is a continual variation in the effect of the traveller which is faithfully reproduced in the yarn. So far as the author is concerned, it appears that the difference in twist exists alike in the yarn wound at the base and at the apex of the ordinary cone, and actual countings of twists have shown this assumption to be correct.

(298) Reference was made a short time since to a method of winding ring yarn on a cylindrical surface, which was shown in Fig. 89, at D. Now, in this case, it will be seen that throughout each lift the circumference upon which the yarn is wound is approximately equal. It follows, therefore, that the strength of the tangential pull upon the traveller will remain the same from the beginning to the end of each lift. Under these circumstances it might be expected to find a greater evenness in the twisting of the yarn than in that spun in the ordinary manner. Careful tests, made by independent observers, show that, as gauged by the strength of the yarn, this is undoubtedly the case, and this is, perhaps, as good a rough test as can be applied. But even with this system there is evidence of the alternate preponderance of the centrifugal and frictional forces referred to, and it appears to be inseparable from any system of ring spinning. The subject is one of great interest, and opens a field for the observer

which ought not to be neglected, and regarding which it is probable that some important facts may be brought to light. There is one advantage in this method of building a ring bobbin, which may at this stage be referred to. A greater length of yarn is wound on each bobbin, and in unwinding, a higher speed can be obtained, owing to the fact that for a considerable period the yarn is being drawn from a circumference of the same size, instead of being unwound from a surface varying considerably within a comparatively short length. On the whole, however, the characteristics of ring spun yarn are preserved, and there is no reason to doubt that although one of the elements which tend to vary the twist is removed, the rest remain and exert their due influence.

(299) It is now necessary to say a few words on a subject of extensive interest, which has received a large amount of attention without, however, having been very successfully dealt with hitherto. We refer to the question of spinning, as in the mule, on the bare spindle. The importance of this may be understood when it is stated that a large quantity of yarn is exported in the cop; that a still larger quantity is sent from spinning mills to the weaving factories in that form, and that weft cops are used as they are produced in the shuttles of looms to an enormous extent. If, therefore, it is necessary to wind the yarns on bobbins in the spinning frame, this implies the carriage of the bobbins to and from the place to which the yarn is sent, which, in addition to an increase in the cost of carriage, is also subject to the disadvantage of the loss of large numbers of the bobbins. Further, when weft is so spun, the length put on each spool is somewhat decreased, this involving more frequent renewals in the loom. For these reasons—which are, of course, of greater cogency when the yarn is used in establishments apart from those in which it is spun—the spinning of ring yarn is somewhat handicapped, but, as will be shown hereafter, there are a number of advantages which must be set against the disadvantages. At the same time a solution of the problem of spinning on the

bare spindle would be of enormous advantage to spinners, and it is not therefore surprising that many strenuous efforts have been made to accomplish it. The chief difficulty has been found in the direction of the pull of the yarn when it is being wound on the spindle at the nose of the cop. Referring to Fig. 90, it will be seen that at this point the direction of the yarn from the ring to the spindle is almost a radial line, and that in consequence very little traction is at this point exercised on the traveller. Now although it is quite true that the momentum of the traveller must not be neglected, it is not sufficient to maintain the balance of forces to which attention has been directed. In addition to this, the angle at which the yarn is bent is much more acute, and therefore the strain on the yarn at this point is greater. Weft yarn is more commonly spun on the bare spindle, and as this is more softly twisted than warp yarn, it follows that this excess of strain is thrown upon yarn in which the cohesion of the fibres is less than in other varieties. Thus all the elements of the case are against the successful accomplishment of the operation, and it is found that it is precisely at the point where it might be looked for that failure takes place. The defect of most of the machines constructed for this purpose has been the difficulty experienced in restarting the machine, when it has stopped with the ring rail opposite the nose of the cop, without an excessive number of breakages of the ends. A few particulars of the various devices adopted in the endeavour to overcome this trouble will not therefore be without interest. One of the earliest methods used was to give the ring rail such a velocity of traverse as to cause it to move much quicker as it left the nose of the cop than it did during its ascent. This plan was only partially successful, and in the most important feature it was practically a failure. After this attempt the only approximately successful efforts have proceeded upon the principle of diverting the course of the yarn from a straight line. The traveller was so constructed that it had two loops or hooks, and the yarn passed under the first of these, which was in a position corresponding to the ordinary traveller, thus having the twist put in in the usual manner. The second loop or eye was arranged to lie close up to the spindle, so that as the latter revolved it set up such a pull on the outer end of the traveller as to cause it to move rapidly round the ring. The traveller, in fact, was a lever with its fulcrum on the spindle, and the application of the force of the yarn was sufficient to cause its outer end to move rapidly in a circular direction. The fulcrum or inner end of the traveller is, of course, always changing its position, being retarded in the usual manner, and so effecting the winding. Although machines thus constructed have been fairly successful, they have not been completely so, but they constitute a very considerable advance on anything previously devised. The mastery of this problem may be accomplished in time, but it is surrounded with difficulties, and is accompanied by many features of mechanical intricacy.

(300) There is another matter to which reference may be made at this point. A reference to Fig. 84 will show that, between the wire eye F and the ring R, there is at times a considerable distance, especially when the building of the cop is just commencing. The result is, that even when the ring is at its highest point, in each lift, there is a certain length of yarn which is being carried round at a high speed by the rotation of the traveller. In its passage through the air it naturally encounters a considerable resistance, and this combined with the centrifugal force set up causes it to fly outwards, so as to assume the shape shown in Fig. 83. This is called, technically, "ballooning," and it is not without some advantages. As, however, the distance from centre to centre of the spindles is limited, if there is too large a balloon the "ends" of yarn lash, become entangled, and break. Means are therefore adopted to check this tendency, and restrain the distance which the yarn can fly out. These consist of the placing of guards on each side of the spindle, so that the ends are limited in their outward movement. Devices of this character are in this country called anti-ballooners, and in America separators. In the arrangement

shown in Fig. 84 a second rail R^1 is employed, which is formed with holes surrounding the bobbins of such a size as to permit of the formation of a certain size of balloon. This procedure is found to be advantageous, as it is proved by practice that if the yarn is not unduly restrained it greatly aids the traveller in its rotation, and that, in consequence, a lighter traveller can be used than is otherwise possible. The balloon rail R^1 is mounted on the ends of pokers R^2, which receive movement from the same shaft as the ring rail, but have a reciprocal traverse much more limited in extent. Thus, the balloon rail rises with the ring rail, and its motion is arranged to give, as nearly as possible, the best results. Although this device has undoubtedly many merits there is one feature in connection with it which ought to be mentioned. There is of necessity a certain retarding influence in the friction of the yarn against the separator or guard, which is not without its influence upon the twist, because the greater the length of yarn between the thread guide F and the ring rail R, the greater the tendency to balloon, and the consequent frictional contact of the yarn and separator. Before leaving this subject it is necessary to say that there is a well-defined influence exerted alike by the guide F and the position of the balloon guard, or separator. If the angle formed by the yarn on passing through the wire eye is too great, the twist cannot pass up to the bite of the rollers, and is practically put in in two stages. If the separator is too low, relatively, to the length of yarn, between the wire eye and the ring, instead of checking the balloon at its larger diameter it does so below that point, and consequently the yarn presses over the the top of the separator, with the necessary consequences.

(301) There are, therefore, a well defined set of conditions which affect the proper carrying out of spinning on the ring frame, and they may be summarised thus : A proper inclining of the roller stand, a definite ratio between the diameter of the ring and size of bobbin, a traveller of correct weight, and an effective separating appliance. The second and third of these are the most important, and although the principles on which they

are founded have been fully explained, there are several considerations which still require noticing. With reference to the relative size of the bobbin and the ring this is important, because of the direction of the traction on the traveller, which, if varying to any great extent, has an important bearing on the character of the product. This is especially noticeable when spinning the finer yarns, and as there is, especially in America, a determined effort being made to spin the finer counts on the ring frame, the subject is of importance. Thus, in spinning 100's yarn at a spindle speed of 10,000 revolutions per minute, the ring used was $1\frac{5}{8}$in. diameter, and the bobbin $1\frac{1}{16}$in., leaving only a difference of $\frac{9}{16}$in. Allowing for the clearance of $\frac{1}{8}$in. between the ring and full bobbin, this reduces the difference in the space to $\frac{7}{16}$in., or, in other words, only $\frac{7}{32}$in. of yarn is wound on the bobbin. The diameter of the bobbin when full is, therefore, $1\frac{1}{2}$in., and a little examination will show how small is the difference in the velocity of the ring at the two points. At a velocity of 10,000 revolutions, the traveller would—neglecting its drag—move through 33,379in. when the bobbin was empty, and 47,124in. when it was full. If this be compared with the calculation given in paragraph 296, it will be seen that the loss of speed, and consequently of twist, is proportionately much less between the full and empty bobbin than it was in the case there supposed. Further, the necessary difference in the retardation of the traveller to wind on the yarn is considerably reduced, owing to the smaller variation in the diameter of the full and empty bobbins. It is evident that this is the true condition when dealing with fine yarns, which possess much less absolute strength than do the coarser counts. A variation, which in the former case was permissible, would be in the other fatal, and this is a fact which must not be lost sight of. There is, therefore, a close connection existing between the size of the bobbin and that of the ring, and it will be easily understood after this explanation upon what principle the sizes are adopted, but in order to make the matter clear, a full sized diagram is given in Fig. 91, illustrative of this point. If the direction of the yarn in its passage from the traveller to the full and empty bobbin be compared with Fig. 90, it will be seen that the variation in the angle formed by it in the former case is slight when compared with the latter figure. Usually, counts from 10's to 26's are spun with a ring $1\frac{3}{4}$in. diameter, and from 28's to 40's on one of $1\frac{1}{2}$in., or $1\frac{5}{8}$in. diameter.

(302) We now come to deal with the second of the two special points named—the weight of the traveller. The traveller is, as may be easily imagined, probably the most important instrument in ring spinning, and performs a variety of functions.

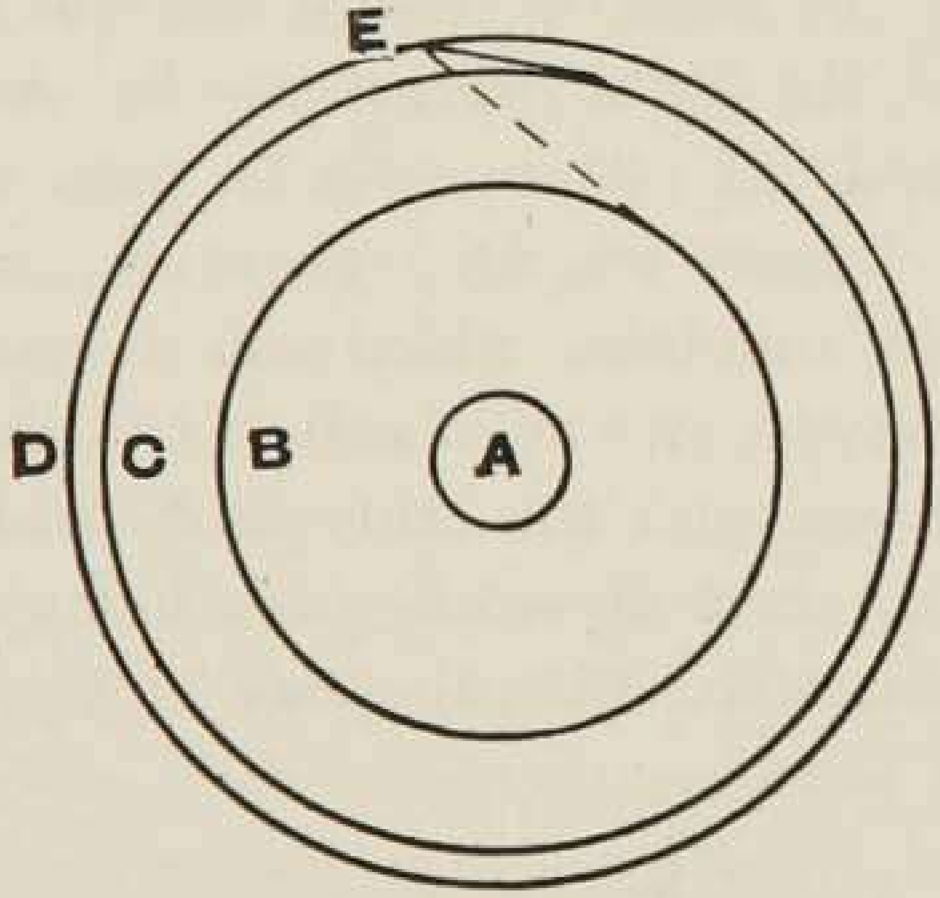


Fig. 91.

Not only does it guide the yarn from the ring to the bobbin, but, as has been shown, it is the means by which it is twisted. Equally as important as these functions is that of regulating the tension so as to lead to effective winding. Not only is its weight of importance in that respect but its form also, and this latter feature furnishes grounds for careful study. If a traveller which is too heavy is adopted it is evident that not only will the tractive force necessary to rotate it be excessive, but the traveller will not accommodate itself so readily to the variable pull exercised. When it acquires its full speed its momentum will be so great that it is likely to overrun, and thus wind imperfectly. On the other hand its weight would prevent it from acquiring the full speed, and the result would be that an excessive tension would exist. A traveller which is too light would be so easily moved that its retardation would be very imperfectly obtained, and the result would be that the winding would be only partially effected, so as to produce a soft bobbin. It is impossible to give any empirical rule by which the weight of the traveller can be arrived at, as many considerations enter into the calculation. The temperature of the spinning room, the velocity of the spindles, and the amount of fly which collects have each an effect upon the traveller. In consequence it is necessary for the attendant or overlooker to carefully grade the traveller in accordance with the observed conditions, and a little practice speedily enables the right weight to be determined. The travellers are made of certain sizes of wire, so that a given number have a definite weight. They are accordingly designated by certain numbers, which can be referred to when necessary. There are two standards of weight, one being that adopted in Scotland and the other that used in the United States. A few common sizes are given herewith, but it must be distinctly understood that they are only given as a guide and not as fixed sizes.

SIZES OF TRAVELLERS AND RINGS.

MESSRS. HOWARD AND BULLOUGH'S FRAMES.

Counts being Spun.	Diameter of Ring in inches,	Counts of Travellers. U.S. standard.
10	$1\frac{3}{4}$	7 or 6
16	$1\frac{3}{4}$	4 or 3
20	$1\frac{3}{4}$	2 or 1
24	$1\frac{3}{4}$	1/0 or 2/0
28	$1\frac{1}{2}$	2/0 or 3/0
30	$1\frac{1}{2}$	3/0 or 4/0
32	$1\frac{1}{2}$	4/0 or 5/0
34	$1\frac{1}{2}$	5/0 or 6/0
36	$1\frac{1}{2}$	6/0 or 7/0
38	$1\frac{1}{2}$	7/0 or 8/0
40	$1\frac{1}{2}$	8/0 or 9/0

MESSRS. BROOKS AND DOXEY'S FRAMES.

Counts being Spun.		Diameter of Ring in inches.		Counts of Travellers. U.S. standard.
0 to 4	......	$2\frac{1}{2}$ to 3	......	—
4 to 10	......	2 to $2\frac{1}{4}$	......	—
10	......	2	......	6
14	......	$1\frac{3}{4}$ or 2	......	4
18	......	$1\frac{3}{4}$	......	2
22	......	$1\frac{3}{4}$	......	1
26	......	$1\frac{5}{8}$	......	3/0
30	......	$1\frac{5}{8}$	......	4/0
32	......	$1\frac{5}{8}$	......	5/0
36	......	$1\frac{1}{2}$	......	7/0
40	......	$1\frac{1}{2}$	......	9/0

The following figures relate to special American practice for hard twisted yarns $\sqrt{\text{counts}} \times 4{\cdot}7$ with a spindle speed of 9,000 :—

Counts.		Traveller.	Counts.		Traveller.
3	......	40	18	......	4
4	......	34	20	......	2 or 1
4·7	......	28	22	......	1/0
5·5	......	24	25	......	3/0
12	......	9	30	......	6/0
14	......	8	35	......	10/0
16	......	6	40	......	22/0

The accumulations of fly about the traveller must be carefully watched, and it is the practice to fit to the ring rail a clearer or cleaner, which is simply an upwardly projecting piece of metal which catches the fly on the traveller in its rotation and removes it. The clearer should be set so that it approaches the traveller, when the latter is pushed outwards as far as it will go, within the space of a piece of writing paper. It is highly important to keep the traveller free from fly, as any accumulation of it speedily adds to the friction on the ring. In doubling it is necessary to lubricate the ring well. For this purpose a special grease is used which adheres to the surface of the ring very tenaciously.

(303) The spindles are driven, as shown in Fig. 87, by means of two tin rollers. It was formerly customary, and is still largely the practice, to drive one tin roller from the other by

passing the spindle bands from the driven roller over it. That is to say, the bands driving the spindles on the left hand side of the frame are those which are driven from the right hand tin roller, and *vice versâ.* It is obvious that by a method of this kind there must be necessarily some uncertainty as to the actual velocity of the driven roller, and it has therefore been arranged that each of the tin rollers is driven by means of an endless cord or band, similar to a rim band. In this way the speed of the tin rollers can be ascertained and relied upon, and much more even work can be produced on each frame. Allied to this factor is the question of the construction of the bands, and the first remark which it is necessary to make is that it does not pay to use spindle bands made of inferior material. When it is considered that the band is bent round a half circle of three-eighths inch radius from 8,000 to 10,000 times per minute, it will be seen that it is subjected to a strain which, unless great care is taken, will prove fatal. It is, therefore, the truest economy to have them made of good cotton, carefully prepared and twisted. In putting them on, care should be taken that the joins are as free from lumps as possible, and that the tension on the bands is even throughout. It is preferable to stretch them a little before putting on, which can easily be done by giving them a smart pull while held in some convenient way. Opinions vary as to whether the bands should be put on when the machine is running, or when it is stopped; but, on the whole, the latter is probably the best course. The condition in which the bands are kept is an important factor, and this requires steady and constant attention.

(304) We have now touched upon all the points which practically affect the working of the ring frame, and the rules by which the various calculations are made in it can now be given.

To find the number of revolutions of the spindles—

Ascertain the velocity of the tin roller, then

$$\frac{\text{Revolutions of tin roller} \times \text{its diameter.}}{\text{Diameter of spindle warve.}}$$

To ascertain the twist in turns per inch—

$$\frac{\text{Diameter of tin roller} \times \text{carrier or arm wheel} \times \text{front roller wheel.}}{\text{Wheel on tin roller} \times \text{twist pinion} \times \text{circumference of front roller} \times \text{diameter of warve.}}$$

To find change pinion for twist—

$$\frac{\text{Constant number}}{\text{Turns per inch}} = \text{change pinion.}$$

The constant number is found by the method given in the preceding rule, omitting the twist change pinion. From the result thus obtained deduct five per cent as an allowance for winding on.

In conclusion it may be said that in the ring frame, as in the mule, absolute cleanliness is essential to complete success. It would be going over much of the ground previously traversed in connection with the mule to deal with a number of points of more or less importance, and it may just be said briefly that the conditions of the spindles, rollers, and bobbins are as important in one case as in the other. Constant vigilance is required, and in a well organised mill the cleaning of the machines will be a regular and not a spasmodic operation. Not only is this the best course for efficient work, but it is distinctly the most economical, and this should be borne in mind.

CHAPTER X.

THE MANUFACTURE OF THREAD.

(305) Yarn, whether spun on the mule or ring frame, is used mainly for three purposes, weaving, knitting, or thread. With that used for the first purpose we have not to do beyond the stage of reeling, and the same remark applies to hosiery yarns. Very large quantities of both qualities are shipped abroad, and in this case the yarn is made into hanks and formed into bundles for convenience of carriage and the saving of cost. For this purpose there is a special class of machines made, which are part of the outfit of any mill in which yarns are prepared for export. The first of these machines is intended to wind the yarn into hanks of any determined or defined length. In this country, as previously stated, a hank is usually 840 yards long, and is wound in coils or layers, each of which is $1\frac{1}{2}$ yard or 54 inches long. These are produced on a machine called a "reel," and its construction depends upon whether it winds the yarn from cops or bobbins. A "cop" and "bobbin" reel are widely different in appearance, but in each the operating instrument is a light frame called a "swift" or "fly." This consists of a central axis or barrel made either of light iron tube, or of tin cylinders, and having mounted upon it several arms on the ends of which are fixed longitudinal wooden laths or rails, the outer surface of each of which is equidistant from the centre of the shaft. The arms are either formed in pairs with a central boss, or are part of a light iron spider, that being the course when a "drop motion" is used. The latter is an arrangement by means of which two of the staves can be dropped so as to release or free the hank and facilitate its removal. This

object in an ordinary reel is effected by oscillating the arms on the barrel, which is effected by drawing the various staves so that they lie closely together. In either case a "fly" is formed, on which coils of yarn of the required length can be easily wound. The fly or swift revolves in suitable bearings at each end, and is driven by hand or power in the case of a cop reel, or by power mainly if bobbin reels are used. The yarn is drawn from the bobbin on which it is spun and is wound on to the fly, being in the process guided by means of a "guide rail" which is actuated by suitable mechanism. The cops to be reeled are mounted on skewers, which are fixed in small holes in longitudinal rails, and the yarn is taken to the fly through a guide rail, as described. In consequence of the method of winding the bobbins formed on ring frames, and the extra twist put into the yarn, it is necessary to subject the latter in reeling to a considerable tension, in order that they will wind properly. For this purpose a special wire guide is used, which is so constructed as to draw out the snarls as the yarn passes.

(306) The form in which the yarn is wound on the fly depends upon the purpose to which it is to be put. It may be either formed into seven "leas" or small hanks of 120 yards each in length; "crossed" wound—that is, laid by the rapid reciprocal traverse of the guide rail in a crossed condition; or "skeined," in which case it is wound into hanks of a defined length and weight. Cross winding is resorted to when the hank is to be dyed, the yarn being left in such an open condition that it not only receives the dye better, but is more easily unwound without entanglement. If the hank is to be formed with seven leas, the guide rail is actuated as shown in Fig. 92. The rail K is fitted with an arm in which is fixed a pin H engaging constantly with the face of the stepped rack R. A spring is attached to K, so as constantly to draw it towards R, so that when any one of the seven steps comes opposite the pin, the rail can make a movement so as to bring the pin into contact with the face of the rack R. The latter forms the head of a vertical bar G guided in suitable bearings attached to the frame,

and having at its lower end a second rack F with a corresponding number of teeth to steps in the upper rack. On the barrel B of the swift is a worm W, gearing with a worm wheel D, on the axis of which a tooth E is fixed so as to engage with the rack F. Thus every revolution of D is followed by the raising of the rack G to the extent of one of the teeth in F, which is

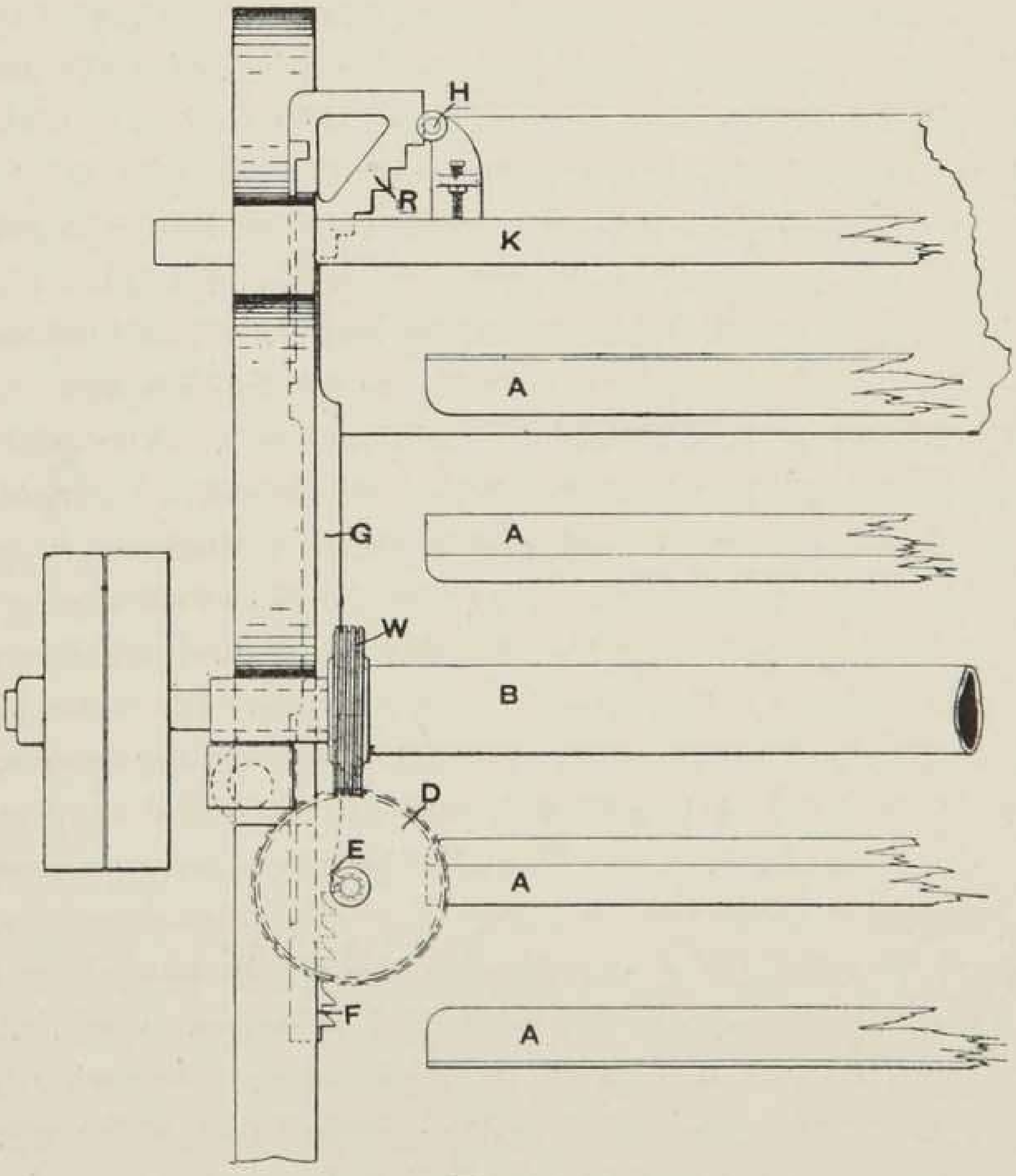


FIG. 92.

sufficient to lift the next step in R high enough to enable the pin H to fall into it. The guide rail F is moved to that extent, and the yarn is thus laid on another part of the rails A, a small space being left between each lea. It is therefore obvious that the length of yarn wound on the swift, during the period occupied between one lift of G and the next, will be regulated by the velocity of the swift barrel B and the size of the worm wheel D. Thus, if D has 80 teeth, the barrel and swift require to make 80 revolutions before the pin E raises the rack F one tooth. The swift being $1\frac{1}{2}$ yard circumference, it follows that 80 times that length, or 120 yards, is wound in each lea. To cross reel yarn, the pin H is removed, and the rail K coupled to a small disc crank rotated from the barrel B, so that K receives the necessary rapid reciprocal motion. In skeining, a plate is fixed to the head R of the rack G in such a way that it projects beyond the steps in the rack. The pin H presses against the plate, so that the hank is wound in a regularly spiral manner. By arranging the driving of the rack F, any length of a hank or "skein" can be wound. It is customary, when skeins are required, to substitute for the coarse rack F a finely pitched rack with which a pinion gears. The pinion is driven by a train of wheels, which in turn receive their motion from the worm on the barrel, and, by simply changing a pinion forming one of the train, the rack can be raised at any desired speed. Skeining is usually resorted to with doubled yarns. Whatever system of reeling is adopted, when the rack F has been raised sufficiently high to wind on the proper length, the stop rod of the reel is released, and by means of a spring is traversed so as to stop the machine by transferring the strap from the fast to the loose pulley.

(307) The weight of a swift with the hanks wound on it is considerable, and requires a good deal of power to lift it. As the hanks require "doffing," it is necessary to provide some means by which they can be easily removed from the swift. If this operation is manually performed, it is effected by collecting all the hanks at one end of the machine, and lifting the swift with one hand while with the other the hanks are removed. There are two objections to this course. The first is, that the operatives, being generally women, the strain caused by the weight, especially of doubled yarns, is excessive; and the second is, that there is a great danger of greasing the yarn. It is, therefore, customary to fit to the machines what are called

doffing motions, which are mainly of three forms, the "wheel," the "gate," and the "bridge" motions. Of these, the last named is the simplest mechanically, consisting merely of a small slotted bracket of sufficient length to bridge a gap formed in the end frame of the machine. The hanks are drawn up to the end of the fly as in ordinary practice, and are partially placed in the gap. By means of a smart push the bridge piece is forced over with the fly, so that it rests on its pivot in a bearing constructed to receive it at the other side of the gap. The hanks can thus be readily removed and the fly pulled back to its place. It should be said that the bridge bracket is in a vertical position both during reeling and doffing, and rests upon pivots formed in each end, respectively, during this period. To avoid greasing, the end of the fly is borne in a sleeve arranged to lubricate it perfectly, and, at the same time, to avoid the escape of the oil. The nipple of the sleeve is cylindrical, and fits in the slot formed in the bridge bracket. The chief advantage of doffing motions is, of course, the ease with which the hanks are removed, but there is also much less danger of their being oiled.

(308) The hanks after being doffed are, if for export, formed into bundles; these are either 5lb. or 10lb. weight each, and are formed in a press which contains, within a strong frame, powerful gearing by which a table is pressed upwards. Attached to the side frames are wrought iron plates, five or six in number, separated from each other sufficiently to permit the passage of string. To one of the sets of plates other bars are hinged, which pass across the top of the space between the two sets, and are locked by levers jointed to the second set. The hanks are placed in the box thus formed, the covering plates are drawn down and locked, and the machine is started. The table thus ascends and presses the bundle considerably. When it reaches a determined point the machine is automatically stopped, the bundle is tied up, after which, the pressure is relieved, the box thrown open, and the bundle removed.

(309) We now come to deal with the "doubling" of yarn,

which is the name given to the process by which two or more strands or "ends" of yarn are twisted together. There are many purposes for which doubled yarn is used. Sometimes the warp threads used in weaving are doubled, and in many of the better classes of cloth this is the custom. Doubled yarn is used for the manufacture of lace, crotchet and knitting cotton, embroidery yarns, and sewing thread. The yarn used for crochet and knitting purposes is carefully made and free from knots, and lace yarn is generally "gassed" with the same object. Sewing thread is almost invariably doubled by two operations, being in most cases composed of six or nine separate ends twisted up into one, being known as "six" or "nine" cord. The practice is in manufacturing it to twist together first two or three strands of yarn, and subsequently to twist a similar number of the threads so produced into the finished thread. There are several ways in which yarn can be arranged for doubling. The cops can be fixed on skewers threaded into them, and placed in the creel of the doubling machine, from which they are drawn in the ordinary way. This is a practice which has largely fallen into disuse except for the very finest counts of yarn, two ends of which are doubled together for lace purposes, and for warps for fine mixed cotton and worsted goods. It is now the usual practice to wind the yarn to be doubled on to bobbins produced in a machine known as a doubling winding machine. This is a drum winding machine—that is, the bobbins on to which the yarn is wound are rotated by surface contact with a series of drums fixed upon a shaft suitably driven. The bobbins are formed with a cylindrical barrel, at each end of which is a broad flange. The distance between the two flanges is the lift of the bobbin, and the yarn is guided by the traverse of a guide rail between these two points in each direction alternately. The object of using a machine of this character is to avoid the production of "single" and "corkscrewed" thread. "Single" is a name which, although technically understood, is inaccurate as a description of the true character of the defective thread. It has arisen from the fact that when two ends are twisted together the failure of one of them is likely to result in the winding on to the doubling bobbin of one end only. This is only true when the ends are twisted together in the same direction to that in which they are spun, but, as a matter of fact, doubling is always conducted by twisting up the ends in the opposite direction. Thus, if two ends were being doubled, the only result of the failure of either of them would be that the other would be untwisted, and would, by the tension put upon it, be speedily broken. When more than two ends are being twisted, this effect does not take place, as the breakage of one does not prevent the other two or more from being twisted together. In this case there will be a certain length in which the number of ends in the thread will be less than the normal number. "Corkscrewed" yarn is caused by the uneven tension of the threads being twisted, and is very likely to occur when they are drawn from a surface varying in diameter like that of a cop. This was referred to paragraph 264, in Chapter VIII., and the overrunning of cops is a fruitful cause of this defect. When such a state of uneven tension exists, one end, being slacker, is wrapped round the other in coils which are not regular in pitch, but are irregular and slackly formed. This tendency is utilised in the production of fancy yarns, which are employed for various classes of dress goods, but when it is desired to obtain a perfectly even thread, such as must be used for sewing machines, or for any other purpose where it has to be passed through needles, such as hosiery or lace, it is fatal in its effect.

(310) For these reasons, therefore, the use of a doubling winding machine is desirable. Such a machine is shown in transverse section in Fig. 93, and consists of one or two lines of drums A—usually one—fixed upon shafts suitably driven by a belt. Against the face of this drum the barrel of the bobbin B is pressed, the latter being held on a spindle or mandril borne in a forked cradle C. The necessary pressure on the bobbin is exerted by means of weights J, which are coupled by chains to the tail end

of C. Also hinged to the cradle C is a frame E, which is forked at its outer end, and formed with bearings in which rest the pivots of a small box free to oscillate. The box is provided with guides for several light wires, with eyes or curls G at their upper extremities, through which the yarn passes on its way to the bobbin. The wires are usually sustained by the tension of the yarn during winding, but are heavy enough to fall quickly as soon as an end either breaks or fails. When this happens, the lower end F of the wire comes into contact with one of the wings of a revolving wiper H, and the pressure thus exerted on the wire causes it to oscillate the box. A catch I which holds down the frame E is thus released, and the weight J is thus free to act on the cradle C and its attached parts. The pull so set up causes the bobbin B to be drawn slightly away from the drum on to a brake surface D, so as to arrest its motion at once. A further movement of the cradle C can be made so as to draw it away from the drum, and thus entirely free it, enabling the piecing of the broken end to be done with ease. The position of the parts during winding is shown on the left hand side of Fig. 93, and when an end is ready for piecing, on the right hand side of the same figure. The yarn is wound from the cops, which are borne in brackets fixed to a central shaft O. If bobbins are being wound a special creel is constructed to receive them. Each of the ends is taken through a slit in a thin metal plate, and then over a flannel-covered rail Y, the angular position of which can be adjusted to give more or less tension. By the time the yarn has passed this point, if the flannel rail has been properly covered and set, the tension on the ends will be equalised. After passing the detector wire eye the yarn is taken over a light roller X, and thence through the guide eye W, fastened on a rail Z, to which the necessary reciprocal traverse is given. The box T is used for the reception of the wound bobbins, and the rollers X are carried by brackets fastened to the underside of T, T itself being borne by brackets from the frames of the machine, the same brackets acting as guides for the traverse rail Z. The latter is actuated by suitable mechanism from the driving shaft, and the traverse should be so arranged as to be a little shorter than the full lift of the bobbin. Doubling winding machines of this construction will wind yarn at speeds up to 7,300in. per minute, but for ordinary working purposes 5,000in. is a good speed. If this

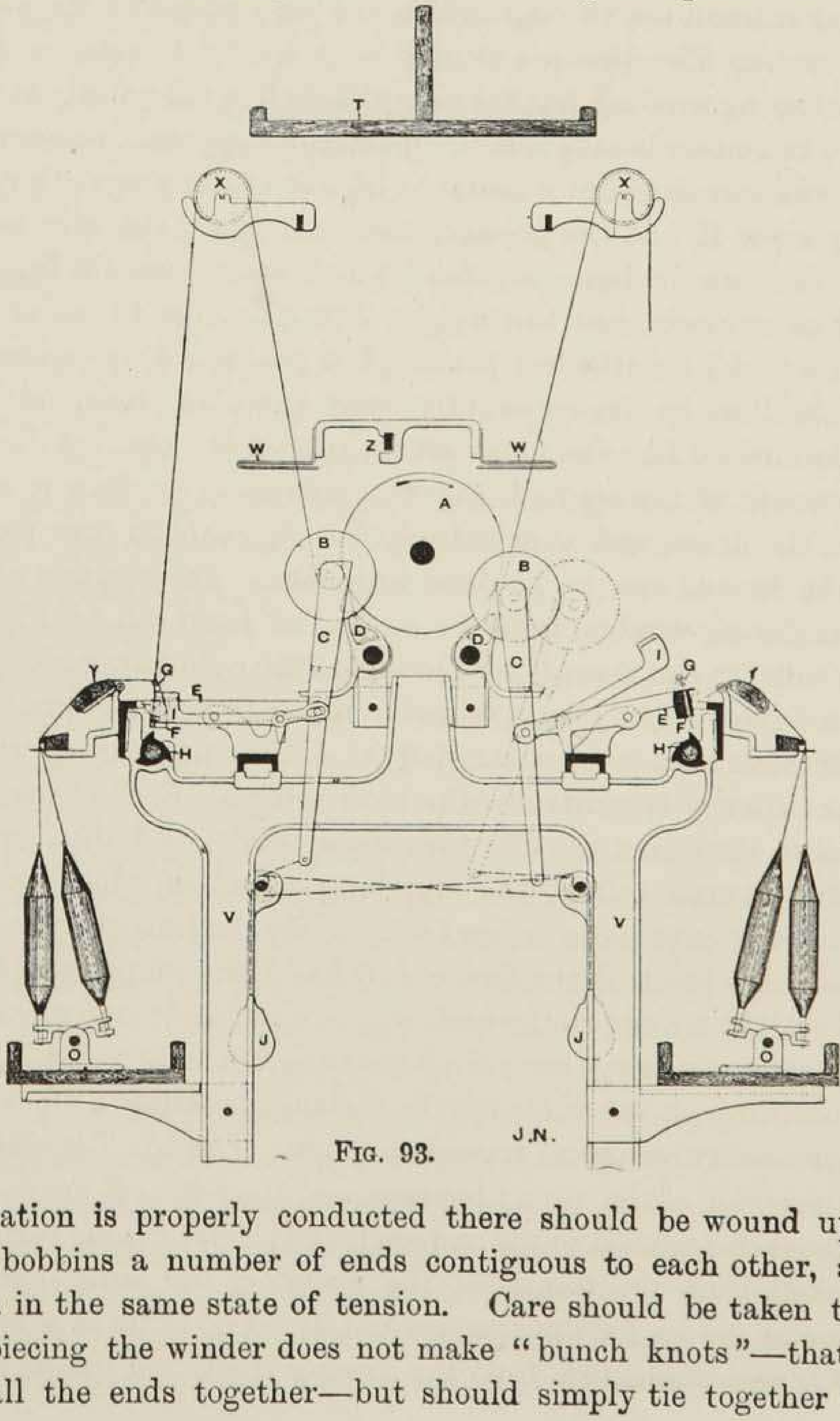


FIG. 93.

operation is properly conducted there should be wound upon the bobbins a number of ends contiguous to each other, and each in the same state of tension. Care should be taken that in piecing the winder does not make "bunch knots"—that is, tie all the ends together—but should simply tie together the broken ends of each strand singly. Unless this is done the subsequent twisting will be very ineffectively performed, and the thread will be full of lumps, which are very objectionable. If the machine is well looked to, and care is taken in its operation, there will be a great improvement in the resultant thread with a very slight increase in the cost.

(311) Instead of using a machine in which double-flanged bobbins must be employed, it is largely the custom to wind cylindrical spools on wooden or paper tubes without flanges. In order to do this, it is necessary to increase the velocity of the guide wire traverse relatively to the speed of the bobbin, so that the yarn, instead of being laid in finely pitched spirals, is wound in coils, which rapidly cross the surface of the bobbin. It is, therefore, requisite to alter the mechanism actuating the guide rail, so that the latter will receive the rapid reciprocation necessary. In doing this there is a mechanical effect produced which is somewhat of a difficulty. The guide rail should be given such a movement as will practically ensure uniformity of speed throughout. In order to obtain the required velocity of traverse, a cam or cam course of suitable shape is ordinarily employed. It has, however, the defect that at the points which represent the end of the stroke in each case the reversal of the movement of the guide rail is not made quickly enough. However little the time occupied, it is sufficient to cause a slight dwell during the change, and the yarn is held at the ends of the bobbins a little too long. This results in a bobbin being made with the ends slightly raised, which is very objectionable. All forms of cams employed are, from their shape, liable to this defect, and a slight wear at the point speedily increases it. A motion recently introduced by Mr. Joseph Stubbs, deserves in this connection a special mention. It is an ingenious combination of a cam and crank, by which the reduction in the velocity of the traverse rail—which is coupled to the crank pin—as the crank approaches its dead centre is compensated for by the motion of the cam, which gradually accelerates it at that point. By this arrangement there is practically a uniform speed through-

out the whole period of the traverse of the rail obtained, and no dwell is either visible or can be traced in the character of the bobbin produced. This is a more important point than it appears at first sight, because, unless the yarn is taken away rapidly from the ends of the bobbin it is very liable to unravel when it is being handled. As the object of this method of winding is to form bobbins or spools which can be handled with the utmost freedom, it is obvious that any defect such as that named will be fatal to true efficiency. Machines of this character are now extensively employed, and their use is extending. When bobbins are formed in this way they can be transported without difficulty, and the reduction in the cost of carriage is very great.

(312) The actual operation of doubling is carried out on a machine similar in general construction to the ring frame, or in a modification of the mule, known as a twiner. Of these, the first named is most largely used, and the twiner is chiefly confined to the production of doubled yarn for warps. The twiner differs from the mule in the fact that the spindles are sustained in a stationary frame, being rotated at a definite speed by a rim band. The faller motion is, in principle, identical with that of the mule, but the necessary lift of the locking lever is obtained by giving a sliding movement to the copping rail instead of letting it remain stationary. This entails, of course, a different method of constructing the rail, which is much shorter than that used in the mule, and there is also a different mode of unlocking, but the principle of the operation is the same. The rollers are entirely done away with, and their place is taken by a creel, in which the cops are mounted in such a way that the yarn can be readily unwound from them while being held in sufficient tension to permit of the insertion of the twist. This creel is fixed on a slide which receives a to and fro motion from the spindles, the construction of this portion of the machine being completely reversed. The drawing out shaft is driven by a train of wheels from the tin roller shaft, no draft being needed in the operation of twist-

ing so that it is only necessary to deliver the yarn at the proper tension during the revolution of the spindles at a speed which is sufficient to supply the quantity required. When the period of winding comes the yarn is firmly gripped by a sliding nipper, so that it can be formed into a cop free from snarls. Winding is conducted, in all respects, as it is in the mule, the motions being practically identical. Twiners are used almost exclusively for twisting two-fold yarns, but the wheel trains are so arranged that they are capable of giving a great variation in the effect produced. The spindles revolve from 7,500 to 9,000 revolutions per minute, and an allowance of about $2\frac{1}{2}$ per cent for the slip of bands is necessary in calculating the twist. It is not requisite to give the rules for the various motions in the twiner, but the following will give the number of turns per inch.

$$\frac{\text{Revolutions of spindles per minute}}{\text{Length in inches of movement of slide.}}$$

Each of these can be ascertained by making the calculations of the effects of the various trains of gearing in the machine. In calculating the necessary twist wheel to make any desired change, recourse must be had to the square root, as in the case of the mule. It may however be said, finally, that the size of the rim pulley has no effect upon the twist, which is entirely controlled by the rate of movement of the slide, which, in turn, is driven from the tin roller shaft. In most of its essential features the twiner is like the mule, and the methods of calculating the turns per inch, speed of spindles, etc., are similar to those given for that machine.

(313) The difference existing between the ring doubling and spinning frames is principally one of size. The gauge of the spindles, the diameter of the ring, the shape of the traveller, the size of the spindles, and the arrangement of the drawing rollers constitute the chief differences existing. Taking these in order, the gauge of the spindles varies from $2\frac{1}{2}$in. to 4in., and the diameter of the rings from $1\frac{1}{2}$in. to 3in. The traveller, instead of being constructed so as to clip the upper bead of the ring, is made of such a shape that it passes over both the upper

and lower beads, and is consequently much heavier than the spinning travellers. The spindles are made generally larger and heavier, and the top of the sleeve is provided with two projections, one on each side of the spindle, which take into recesses formed on the under side of the lower flange of the bobbin, which is thus absolutely and positively driven. Similar arrangements are made to ensure the steadiness of running of the spindle, but the necessity for limiting the movement of the sleeve is greater than is the case with spinning spindles. Another point which is allied to this is the character and length of the lift. There are two ways of arranging this. The first is similar to the one described in the last chapter, which is used when the doubled yarn is to be wound into a cop or spool. The second method is to give the ring rail a traverse equal to the lift of the bobbin, thus winding the yarn in parallel layers throughout. The latter is the most usual procedure. With reference to the drawing rollers, the chief characteristic is the fact that there is only one pair, both being covered with brass and the upper roller being heavy enough to establish a good nip. As the doubling frame is not required to draw the twisted yarn, but only to deliver it, all that is necessary is to provide means by which it will be emitted from the rollers at a regular and defined speed. The function of this machine is, therefore, that of twisting only, and no draft need be calculated. Once the relation of the roller delivery and the spindle speed is established for any number of twists that is all that is required. The rollers are arranged differently in the two existing systems, the English and Scotch. In the former they are fixed in front of a shallow water trough which has, running along its entire length, a glass rod immersed in the water. The yarn can be passed under the rod when wet doubling is required, or taken directly to the rollers when the yarn is doubled in a dry state. In the Scotch system the rollers are carried in arms fixed upon a rocking shaft, which can be oscillated, as required, by means of suitable gearing. In this way the yarn, which is wrapped round the top roller, can be made to absorb the required amount of moisture by simply lowering the bottom roller into a water trough placed for the purpose. The rollers can be raised as required, for cleaning purposes.

(314) The flyer doubling frame is still used to some extent for special classes of work, and everything which was said of the employment of the flyer for spinning is equally applicable in this case. For a really well twisted thread, in which cylindricality and regularity are requisite, the flyer has not been excelled, but its use is mainly confined to the coarser counts. The amount of twist put into thread varies largely with the class of thread being produced, but there is no rule to which all firms adhere. The same counts of yarn are twisted with widely varying numbers of turns per inch by different people even when intended for similar work. In manufacturing sewing thread, as has been said, the best practice is to "cable" the yarn—that is, twist up two ends together, and then twist three of the doubled threads so produced into one. It is found by that by this practice a more even and stronger thread is produced, and it is practically universal in this specific branch of the business. Thread so produced is called "six cord," and the counts or numbers given to it depend entirely on those of the yarn used from which it is made. Thus, 30's six-fold or cord means that six ends of 30's yarn have been twisted up together, producing the thread in question, which is, really, 5's counts.

(315) The doubled yarn having been produced, its further treatment is determined by the purpose for which it is intended. If for lace purposes it is cleared and gassed. The first operation consists in passing the yarn through a slit or nick which is wide enough to permit it to pass, but which, when a knot or lump is presented, prevents its passage. The winding in this case is effected by a frictionally driven bobbin, which either has its rotation arrested, or if the yarn is not strong enough for that, breaks it. In either case, whether the yarn is broken or the knots arrested, the effect is the same. The attention of the winder is called to it, and the lumpy place can be cut out

and removed. As an aid to this process a small appliance known as Balfe's piecing machine is very useful. It consists of two small spindles which are slit in such a way that the thread can readily be placed in them. When a knot comes up to the slit in the clearer, the winder lifts off the bobbin from the creel spindle, and also that on which the thread is being wound, and takes them to the piecing machine, which is conveniently situated for the purpose. A short length of yarn—about 12in. long—with the knot in it, is attached to the two spindles, being firmly held by a spring clip in the very centre of the spindle, the slits permitting of this adjustment. One of the spindles is then rotated by means of a hand wheel, so as to untwist the thread, and the knot is then cut out. The threads are then *pieced*, not tied, by twisting two strands in one of the portions of the several threads together with one strand in the other portion, and *vice versâ* if the thread is three-fold. If more than three strands are in the thread, a correspondingly varied piecing is effected. When the ends are thus attached the rotation of the spindle is reversed until the whole of the twist is again restored to the thread, when the bobbins are replaced in their position in the machine. Clearing, if properly effected, greatly improves lace yarns, and is indeed absolutely necessary. When thread is intended for lace purposes it is generally dry doubled and "gassed." In the latter case it is passed several times through a gas flame at a high speed, so as to burn off the filaments or "ooze" on its surface and leave it bare. In gassing it is essential that the tension on the yarn shall not be too great and that the gas flame shall be steady. In most cases Bunsen burners or their equivalents are used, and the bobbin on which the thread is wound, after gassing, is driven by frictional contact with a drum fixed on a longitudinal shaft suitably driven. The gassing frame is simple in its elements, and does not require special explanation.

(316) Having produced the thread, it is necessary to make it up for the market. There are two methods of doing this, thread being sold either in its ordinary or "soft" condition, or polished.

In preparing the latter class of thread, 360 bobbins are placed in a creel and are wound on to a beam, which is similar in construction to those used for receiving the warp in weaving, the ends being wound side by side. A "chain" of ends is made, which consists of the 360 threads loosely gathered together, and in this form the material is bleached or dyed, as the case may be. After dyeing, it is wound by means of a special arrangement, which ensures the proper tension of the threads on to a beam similar to the one described. This is placed in bearings formed in the frame of the polishing machine, and the threads are drawn off the beam and passed through a box in which a mixture of pure size or starch is placed, which is taken up by the thread. Immediately it has passed this point it is subjected to the action of brushes which are revolving at a high velocity, the frictional contact of the bristles giving it a very high polish. The thread is then dried, and finally wound on three rollers, each of which is divided in the centre so that 60 threads are laid in each division. These rollers are used to feed the yarn to a winding machine, which winds the thread on to specially shaped wooden spools, each of which has about 1¼lb. of the polished thread laid upon it. Soft or unpolished thread is not, of course, passed through the polishing machine, but is, after being dried, beamed in the manner described. There is another system by which the thread is polished in the hank, but it has the objection that the length of thread treated is comparatively small, and that on this account there are more knots required in the same length of yarn. The wages cost entailed is also lighter in the system named.

(317) Sewing thread is sold principally in the form of small wooden reels or bobbins, which are made with a cylindrical barrel and end flanges bevelled on their inner side. Thus the distance between the flanges is less at their roots than at their peripheries, so that the thread has to be laid on a continually lengthening surface. This operation is called spooling, and it is conducted on a machine of great ingenuity, invented by the late Mr. William Weild, and at present made by Messrs. Wm.

Ayrton and Co. The machine is usually made with six or eight heads—that is, that number of reels are wound at one time. It is, therefore, necessary to actuate the mechanism of all of the heads separately, but simultaneously, and the necessary regulation is obtained from a headstock placed at one end of the machine. The empty spools are held in troughs, the lower orifice of which is directly opposite the different heads, and in the latter are two spindles with conical ends which grip the holes in the centre of the bobbins. After a bobbin is finished and removed, these spindles open, and an empty bobbin falls from the trough into a plate which is automatically raised so as to place it between the two spindles. These immediately close and begin to rotate the bobbin. As the ends of the threads which are drawn from the spools are held in a suitable position, the beginning of the rotary motion of the bobbin causes them to be wound on to the latter. In its passage from the spool on which it is wound the thread is taken through a tension clip, by which the required amount of tension is put upon it, and is then passed over a groove formed in a thin steel guide. This is mounted on a shaft which can rock on its centres, but which has also a longitudinal reciprocal movement The under edge of the steel guide is cut in such a way that it corresponds to the pitch of the spirals formed by the threads as they are wound, the reason of this being that the guides rest upon the thread during winding. It is obvious that the rate of the longitudinal movement of the guide must be identical with the pitch of the spirals, as otherwise there would be a rubbing action which would be very injurious to the thread. The guide rods are, therefore, actuated from a finely pitched screw, to which a definite speed of rotation is given which can be regulated as desired by suitable gearing. With this, two half-nuts correspondingly thread, and on different sides of the centre, engage alternately, so that the guide rod is given the necessary reciprocal movement. By an ingenious arrangement the exact time when they are alternately geared with the screw is regulated so as to give the requisite lengthening of the traverse of the guide to compensate for the increasing distance between the flanges as the bobbin fills. When the required number of layers of thread have been wound—which can be regulated as desired—the shaft, on which is a driving wheel engaging with a pinion on one of the spindles in each head, is stopped, so that winding ceases. A knife descends and cuts a nick in one of the flanges of the bobbin, immediately after which, the thread is drawn down into this nick and across a knife edge, thus severing its connection. The guide which pulls the thread into the nick and cuts it off, leaves it in such a position that it is gripped by the new bobbin and immediately begins to wind on the latter as soon as it is rotated. As soon as this operation is completed the spindles open automatically and release the reel, after which, a new reel is fed and the operation again begins. By means of the various machines described a large quantity of thread can be prepared for the market in a week: 120lbs. weight of 30's three-cord can be polished in ten hours, and soft thread can be turned out at the rate of 5,670lbs. in a week of 56 hours. An eight-headed spooling machine will produce spools or reels, each containing 200yds. of thread, at the rate of 26 gross per day of 10½ hours.

(318) Cotton thread which is employed for crotchet and mending purposes is often wound into a barrel-shaped spool called a "ball." The balls are formed on a mandril, which is mounted on an oscillating frame, and which is placed between the forks of a flyer. This has eyes at the ends of its arms, and by passing the thread through one of these and rotating the flyer, the thread can be wound on the mandril. By oscillating the mandril in each direction alternately for any defined distance, the thread is wrapped on it in coarse spirals until at last a "ball" is formed. The length of thread wound is not usually great, and the operation of balling is generally a manual operation, although there are one or two machines which are approximately automatic. Compared with spooling, "balling" is a very small trade, and does not require any further explanation.

CHAPTER XI.

WASTE SPINNING.

(319) In the series of processes which have thus been described there is necessarily a large quantity of waste produced. The amount varies naturally with the quality of the cotton and the skill of the workpeople, but it is always large. Over the whole series of operations the amount varies from 12 to 20 per cent, but some of this is the dust and similar impurities deposited in scutching and opening. While there is always a certain part of the waste made in the two stages named which consists of fibres of more or less value, on the whole, the usable waste—if the phrase may be employed—is principally that which is made in the carding engine and subsequent processes. Waste is defined as being "hard" or "soft," the former including all cotton into which twist has been put, and the latter, untwisted or partially twisted material. These are the broad distinctions made, and are sufficient for practical purposes. At present the trade in yarns spun from waste is principally a Continental one, and in England it is the exception to produce this class of yarn. The reason for this is probably that to spin it requires a special plant, which is different in many cases from that usually found in the spinning-mill. It is, however, an undoubted fact that waste spinning is an operation which repays the trouble entailed, and a brief treatment of the method usually pursued is likely to prove interesting.

(320) Much of the waste which it is possible to spin into yarn is of a greasy nature, and this partially facilitates and partially retards the performance of the operation. It is obviously the first thing to do, when dealing with hard waste, to restore the material into its fleecy condition and detach the fibres from

each other. For this purpose it is obvious that the machines employed to deal with cotton in its ordinary open condition are absolutely useless, and that the treatment given to it must be quite different. Accordingly waste is first treated in the Oldham willow, which has already been referred to. The willow is constructed with a drum or cylinder, having its surface covered with spikes or teeth. It is surrounded for the greater part of its circumference with a grid also fitted with projections on its inner side. By the rotation of the cylinder, the twisted cotton is rapidly broken up, as it is called, and reduced to a soft fleecy mass. The form of machine employed varies a little in its details. In one type, which is constructed for dealing with hard waste, more especially in the form of cop bottoms, there are several cylinders used one after the other, each provided with round taper teeth, revolving at a rapid rate. The cylinder shafts are made long enough to project beyond each side of the machine, so as to receive the necessary pair of driving pulleys. This construction is adopted in order to enable the cylinders to be reversed after the teeth have become bent out of their true position, which sometimes happens. When they become too much inclined, the reversal of the cylinder is necessary, in order that they will be fully effective. Machines on this principle are made with three, four, or six cylinders, and the hardest waste is speedily reduced into a condition resembling raw cotton. The length of staple obtained depends largely upon the character of the cotton broken up, and it must, of course, be understood that the fibres have lost part of their strength by their repeated manipulation. Still, an excellent product can be obtained from clean hard waste, and it is worth noting that for this class it is found that a treatment by six cylinders gives the best result. Soft waste—such as that made in the processes of scutching, carding, and drawing—obviously does not need the same severe treatment as that described, only requiring to be dealt with so as to remove any dirt or other extraneous matter which may be mixed with it. Two courses may be pursued with the waste opened in the willow or breaker.

It may be passed through a scutching machine, or it may be fed to a breaker carding engine. In the former case, a modification in the details of the machine is necessary, in order to allow of the effective treatment of the material. An extra picker or breaker cylinder is provided, and the cotton is fed by means of a lattice apron, it being, of course, essential that this operation is conducted with care, so as to produce a good and even lap. A pedal motion being fitted, the latter object is naturally considerably aided. To all machines for cleaning and opening waste it is advisable to apply fans to carry away the dust, of which there is a considerable quantity.

(321) When the opened or broken-up cotton is thus obtained, it is carded, and in this operation we meet with a distinct departure from the methods previously described in connection with the carding of cotton. It was shown in Chapter IV. that the cotton was fed to the carding engine ordinarily in the form of a single lap, the regularity and evenness of which was obtained by the mode of producing it on the scutching machines. In proceeding to card waste, a different course is followed. If the cotton has been formed into a lap on the scutching machine, two of these are placed on a lattice apron fitted to the end of the machine, so that a certain amount of doubling takes place at this point. For reasons which will be detailed later, it is desirable to obtain an even weight in the sliver at the earliest possible time. If the cotton is in the open or loose condition, the practice is to weigh a certain portion and spread it upon the feed lattice, thus pursuing a similar course to that which is followed in carding wool. In many respects, the manipulation of cotton waste resembles that of wool, and it is found that, like the latter material, the carding is better performed if the waste is a little greasy. When the material is too dry, it is therefore the custom to use a little oil to increase its working qualities. The object aimed at in feeding the breaker card is to get a regular and uniform supply delivered to the action of the machine. So far as the construction of the latter is concerned, that described in paragraph

113, Chapter IV., is closely followed, except that the number of worker and clearer rollers is greater. There are also in some cases extra or "fancy" rollers fitted, these being practically similar in construction to the workers, by which the cotton is raised from the surface of the cylinder, and is more effectively delivered to the doffer than it otherwise would be. The material is doffed from the cylinder in the usual way, and the web taken from the doffer is variously treated. There are three ways of dealing with it, but the object in each case is the same, and a few words may be expended in explaining it. As there is not any very effective separation possible of the various grades of waste produced, it is at once obvious that there will be a great variation in the component parts of the opened mass, so far as quality and length of staple is concerned. This is especially the case when waste spinning is conducted as a special business, and the raw material is bought from dealers in it, or from several mills. To produce really satisfactory results, it is therefore of the highest importance that the mixture of the various elements in the broken waste shall be as intimately made as possible. When a six-cylinder breaking machine, such as was described, is used, this object is to a large extent attained, but it is absolutely necessary not to neglect it, and no precautions are too great to ensure its full attainment. It is therefore the practice so to deal with the web, as taken off the breaker carding engine, as to ensure the fibres within it receiving this intimate mixture, and the three principal methods of doing this will now be described.

(322) The first plan of which notice need be taken is to form the web into a sliver, and coil it into a can in the same way as if cotton were being carded. If this course is pursued, it is necessary to take special precautions to prevent the sliver being broken, as it is very liable to rupture owing to the short staple and the weakness of the cotton fibres within it. It is obvious that if a fibre has been twisted on its axis as described, the separation of it from its fellows in the necessarily severe manner described must weaken it, and there is every reason to suppose

that the effect of its natural convolutions is largely destroyed. After slivers have been obtained, however, they are drawn from the cans, and passed through a machine known as a Derby Doubler. This machine, although at one time extensively employed in the preparation of cotton for spinning, has not hitherto been described, because the methods of spinning used at the present day in this country have largely rendered it obsolete. A number of cans are placed so that the slivers can be readily drawn from them and traversed along a polished plate alongside each other, after which they are combined and passed through a pair of compression rollers, and are afterwards rolled into a lap of about 25in. wide. The lap is made by these means very solid, and is usually about 15lb. to 20lb. in weight. As the various slivers are possibly composed of different qualities of fibre, a combination is thus obtained, which, when treated by the finishing carding engine, results in their intimate mixture. The second method of dealing with the web is to wind it upon a large drum constructed of wood, and of such a size that a bulky web is obtained. When the required thickness is thus wound, the web is taken off the drum by being cut across at one point, the sheet thus produced being fed to the finishing carding engine. As there are several layers in this sheet—which resembles wadding—it is evident that when it is treated by the teeth of the licker-in, the fibres will be laid upon the cylinder promiscuously, and will be intimately mixed. The third plan pursued is to use what is known as Blamire's feed. This consists of an apron or lattice fitted immediately behind the doffer upon which the web is deposited, and which in turn delivers it to a transverse lattice, running at right angles to the first one. The delivery is made by rollers, and is made in such a way that the fleece or web is laid all over the surface of the second lattice in folds. As this formation takes place the second lattice slowly traverses and delivers the web to a lap roll, by which it is rolled up into a lap of the requisite width. It is important to note that the direction of the fibres on the first lattice and in the lap is necessarily different, they being disposed at right angles to their former direction when in the lap. This, although at first sight a defect, is not really so, as the fibres are laid in every direction within the delivered web, and further, this peculiar arrangement, when the lap is afterwards carded, greatly aids the proper mixture, the importance of which has been described. When the laps are formed, they are fed to the finishing carding machine, and, as in the first mode of dealing with the material which was described, two laps are placed on the lattice, so that they are doubled and presented simultaneously to the action of the licker-in.

(323) Whatever form the cotton is given it is carded a second time on a machine which is of similar construction to the one used for breaking, so far as the carding part of the machine is concerned. The object of the second or finishing carding is to complete the blending of the fibres, so as to obtain a better and more uniform thread than is otherwise possible. As the web leaves the doffer it is dealt with by a device known as a "condenser." This is an arrangement by which the web is cut or divided into narrow strips which are rolled up into the form of a round strand. The number of divisions made depends upon circumstances, but the range is from about 40 to 120. There are two chief forms of condenser, the Bolette steel tape and Saxon or leather tape. In each case the operating instrument is a narrow tape which, in combination with rollers consisting of alternate rings and grooves, divides the web into a number of separate filaments or ends. The exact number produced depends, of course, upon requirements, but this can be arranged as desired. Opinions differ as to the merits of the two systems of division; but, in late years, the steel tape condenser has met with great favour. It is desirable, in using the machines, that the dividing mechanism is kept in good order, as it is requisite to get a clean, sharp division of the web and thus avoid any unevenness in the roving produced. After the slivers —as they may be called—leave the dividing tapes they are

passed between broad bands of leather, very smooth on their surface, and stretched over rollers to which a rotative motion is given. The leather bands are being constantly traversed, so that the strips of carded material placed between them would be carried forward and delivered at the point where the leathers pass round their respective rollers. The surface velocity of each band must, therefore, be identical, and it is highly desirable that the bands shall be quite free from any unevenness or roughness. In additional to the longitudinal motion, the bands are given a transverse reciprocal movement in opposite directions by means of eccentrics fixed on an upright shaft driven from the cylinder shaft. Thus the strips are rubbed up between the leathers, and are formed into a roving which, while acquiring large amount of cohesion, has no twist, in the proper sense of the word. The pressure exercised upon it is sufficient for all practical purposes and is considerable, so that the roving, when it emerges, has strength enough to enable it to be wound on to specially constructed bobbins, and to be unwound from them with equal facility. The name of the apparatus is, therefore, evidently derived from the method of treating the material, the strips formed from the web being literally condensed by the action of the "rubbing leathers." The bobbins upon which the rovings are wound are light barrels of metal or wood, with light flanges at each end, and mounted so that they can be readily and freely rotated. From twenty to thirty ends are ordinarily wound on each bobbin, which thus is capable of containing a considerable length of material. It is sometimes the practice to provide each of the finishing cards with two sets of rubbers, this entailing two rollers for removing the web from the doffer. It is, on the whole, preferable if this arrangement be used, to spin the bobbins produced on the upper and lower condenser separately, as it is difficult to get the doffing quite equal in each case. The whole of the arrangements of the condenser require care and watchfulness, and the leathers used should neither be too rough or too dry. It is also necessary to keep them clean, as any adhesiveness would speedily result in a defective roving. The operation of carding waste, generally speaking, is not a difficult one to effect, but it naturally possesses several points of difference to the carding of raw cotton.

(324) Having obtained the rovings in the shape named—viz., on bobbins from 24 to 30 inches long—it is necessary to spin them. The twisting of waste varies from that of ordinary cotton, mainly because the character of the material has been so changed that it will not permit of any draft being put into it until it is partially twisted. It is this fact which necessitates the great care to which we have referred as being essential in the preparation of the roving. There is no chance of rectifying by means of a draft exercised on a combined sliver any unevenness which may be found in it, and it becomes the more requisite therefore to obtain from the finishing carding machine a web as even in weight and thickness over its whole area as it is possible to make. The intimate mixture of the fibres to which reference has been made has this object, and the formation of laps or the weighing of the cotton fed to the carding engines are directed towards the same end. Whatever unevenness exists in the roving when formed will be found in the twisted thread with such reductions as follow upon the operation of spinning. This factor affects the construction of the spinning machine, because it is necessary to provide means by which, subsequently to the introduction of twist, a little draft can be exercised. Waste spinning is therefore generally conducted on a mule of a construction which, in its main features, resembles that employed for spinning woollen threads. It deals with the thread in an entirely different way to that in which ordinary yarn is formed, and the characteristics of the thread correspondingly vary. It was shown that the twisting of cotton yarn, although completed in some cases after the draft had ceased, was, to a large extent, put in simultaneously with the reduction of the roving by the rollers. Further, the draft of the carriage takes place at the same time as the twisting, and thus the attenuation and spinning

of the material are effected during one period of the cycle of movements. In addition to this, there is the fact previously named, that the attempt to produce an even and cylindrical roving from waste is very difficult, and cannot, by the manner in which it is carried out, be expected to give perfect results. Still, in spite of all these factors, a thread is produced which is remarkably level, but the counts which can be spun are naturally limited. In some cases an attempt is made to get a little draft by means of rollers, but, on the whole, the best results are obtained by the employment of mules in which this element is absent. Accordingly only one line of rollers is used, and it is principally in the arrangement of the parts affecting these that the difference between a waste spinning and ordinary mule is found. The condenser bobbins are placed in a creel, and the various ends are taken from them and guided to the rollers. These are made $1\frac{1}{4}$in. diameter, and the top rollers are self-weighted. The rollers may be made with two bottom lines, on which the top rollers rest, the roving being passed between the rollers, and being thus nipped twice. The cops are formed in the usual way, the turns per inch depending upon the same conditions as those ordinarily existing. At first the carriage runs out at its highest speed, and the rollers deliver the roving at the same or a little quicker speed than the travel of the carriage. The exact amount of the excess of roller speed depends, of course, upon the strength of the roving, which is determined by the character of the mixing made. When the carriage has made a certain portion of its outward run the rollers are disengaged and the delivery of the roving entirely ceases, but the traverse of the carriage continues at a slower velocity. In this way the twisted yarn is drawn, and for the reasons explained in Chapter VII., this results in a certain reduction of the thick places owing to the hardening of the thinner ones. This, it will be noticed, is a somewhat similar procedure to that adopted with fine yarns, being a species of "jacking," but it differs from it because it is the only draft which is exercised on the yarn throughout. There is a wheel provided on which figures are stamped, and by setting a finger to the required figure the detachment of the rollers takes place at the right moment. A draft of a few inches is given, and instead of calculating this, and making elaborate wheel changes, the adjustment of the setting finger is all that is needed. If required, a drawback motion can be fitted. As the cops spun are naturally large the gauge of the spindles is great, varying from $1\frac{3}{4}$in. to $2\frac{1}{2}$in., and from 300 to 500 spindles are usually fitted in one mule. Productions vary naturally with the counts being spun, but $7\frac{1}{2}$lb. per spindle per week of 56 hours is a common production when producing No. 4's yarn. The strength of waste yarn depends upon two factors—the quality of cotton used in the waste from which it is spun, and the twist introduced—but is in some cases considerable. As was said, it is possible to spin waste yarn from condenser bobbins on continuous flyer or ring spinning machines, but generally speaking, the method described is that adopted.

(325) Although soft waste may be dealt with by a set of machines such as those described, it is a common practice to use it up in the mill in which it is spun by mixing it—judiciously, of course—with the cotton as it is passing through. For some classes of yarns a mixture of two-thirds soft waste and one-third cotton can be advantageously used, and it must not be forgotten that waste in this condition consists of fibres which have not been twisted, and are not, therefore, so liable to damage in opening them. Of course the drafts of the rollers must be arranged to suit this special mixing, and the resultant yarn is sure to be weaker than one spun from cotton solely, but by careful arrangement the whole of the soft waste can be easily utilised in the ordinary work of the mill. A certain loss is inevitable, however great the precautions taken, but the utilisation of the waste in the best manner is a most important thing in the economy of a mill. It is recommended by some persons that soft waste of all kinds should be made a mixing of by themselves, and spun in the ordinary manner, but this is an

objectionable and expensive course. It is much preferable to use this class of material along with cop bottom waste, and spin it by the series of machines previously described. On the Continent Vigogne and Barchant yarns, which are the specific names given to waste spun material, are produced on machines of this character, and as the principal seat of the manufacture is found in Germany and Italy it may be taken for granted that the system described is the best and most economical.

CHAPTER XII.

THE CONSTRUCTION OF MILLS.

(326) The various operations described are those which are usually carried on in spinning mills, and the full explanation given needs only to be supplemented by a consideration of the methods of constructing and arranging a mill for any specific counts. There is one subject which requires special treatment prior to dealing with the constructive details, and which has been repeatedly named. This is the arrangement of the drafts in the various machines. It is evidently of the highest importance that in the management of a mill due regard should be paid to the proper drafting of the machines, even though the range of counts and the production of the machines should be limited by their special construction. This is a duty which falls rather into the province of administrative than constructive work, but is one of the most vital matters in the actual operation of a mill. There are several circumstances which have a bearing upon it, and not the least of these is the number of the machines of various kinds provided. It is obvious that this factor will affect the problem very materially, but within limits it is possible to vary the numbers of the machines used in the different stages, and still obtain a satisfactory scheme of drafts.

(327) Among the chief elements which affect this question is that of the class of cotton used. It is clear that a scheme of drafts which is suitable for a long stapled cotton like Egyptian is utterly unsuitable for a short stapled variety, such as Surat. It follows that at no stage in spinning the latter can there be any approach to the long drafts which are quite per-

missible—nay, necessary—in spinning the longer stapled cottons. When arranging a scheme of drafts therefore the character of the material employed must be taken into consideration, and, as will be shown, leads to a good deal of variation. Another point which exercises a great influence on the question is the number of machines which are employed. As was pointed out in paragraphs 61 and 62, the sliver is treated in two, three, or four roving machines, according to the quality of the cotton employed. It is obvious that in accordance with the number of stages which are employed, the reduction of the sliver must take place differently in each case. Another factor which has an influence upon the subject is whether the slubbings are doubled,—that is, two of them fed simultaneously—in the intermediate, roving, and spinning machines. When this is the case a more severe draft can be given in the machines than is exercised when a single roving is used. Then again the class of yarn which is being produced must be considered. For instance, hosiery yarn, which must be as level as it is possible to make it, in addition to being pliable and soft, requires careful and special preparation in the earlier stages. Any excessive draft speedily has an effect upon the roving, inducing uneven places in it, and, as this special yarn receives only a small amount of twist, the draft in the mule has not so great an effect upon it as is the case with other varieties. Finally it may be said that, without absolute uniformity being preserved at each stage of the whole set of drawing processes, it is better that the reduction should be gradual and continuous. All these various matters and many others have an influence upon this subject. In considering the remarks and instances which follow, a special warning must be given that it is not intended in giving a set of drafts for any counts to infer that these are fixed, and will work out successfully in every case and under all circumstances, but only that having been employed they form a guide which may be useful. Nothing is more fatal to any proper treatment of this subject than to accept as inflexible, arrangements which work well under given conditions, but which if the conditions are varied, even slightly, will not do so. The reader must, therefore, understand that the different schemes of drafts given are merely illustrative and not fixed rules.

(328) It will be convenient to commence with a system of drafts for the lower counts, and subsequently deal with those which are finer. One of the most important points to be considered in dealing with this subject is the weight of the scutcher lap which is fed to the carding engine. This should not be too heavy, as, if it is, the draft in the carding engine, or those in the succeeding machines, must be materially increased. For counts from 10's to 20's, a lap of from 11 to 12 ounces per yard is heavy enough, and as the yarn to be spun becomes finer, the lap is necessarily lighter, although the difference in the weight is not proportionate to the increasing fineness of the yarn. Another matter requiring special care is the draft in the carding engine. There is no rule observed in this case, and, judging by results, a draft of 85 and one of 105 give equally satisfactory results. Generally speaking, however, the shorter the staple of the cotton the less the draft in the carding engine. Having made these preliminary remarks, a few instances may be given of typical drafts. In spinning the lower counts, say up to 20's, short stapled American and Indian, or a mixture of these cottons are used, and the drafts are regulated accordingly. Assuming that an 11oz. lap of Indian cotton is used, and that such speeds are adopted in the card as to produce a sliver of 60 grains weight per yard, a draft of about 85 will be found sufficient. A 60 grains sliver is ·139 hank, and assuming that the usual procedure was followed of putting up six ends at each passage through the drawing frame—two passages being thought sufficient in some cases for such coarse work—and a draft of 6 being arranged for in each head, the hank roving is the same. Thus, to reduce this to a slubbing of ·625 hank, a draft of 4·5 is wanted in that machine. In some cases it is preferred to give a little less draft in the drawing frame, so as to get a heavier sliver for presentation to the slubbing frame, the draft in which is increased, but with a

cotton so short in the staple as some classes of Indian, it would probably be better to keep the draft as low as possible both in the drawing and slubbing frames. This can be done by getting a finer carded sliver, but the weights given will be found to work fairly well. Having got a slubbing of the hank named, a draft of 2·8 will give a roving of 1·75. Drafts of 5·7 or 6·85 will be needed to spin 10's or 12's yarn respectively. These drafts are all arranged for single roving. If the slubbing was doubled at the roving frame, the draft in that machine would necessarily be double that stated, or, in other words, it would be 5·6. If American cotton is used, then the drafts in the drawing frame can be arranged to increase the weight of the sliver, or a heavier sliver can be employed, in which case the draft in the roving frame would be increased, as would be also that in the spinning machine. In spinning Indian cotton into 16's yarn, and using three roving frames beginning with a carded sliver of ·144 hank, and passing it through three heads of drawing in which the number of ends and the drafts are equal, then the following are a good set of drafts. Slubbing 3·5, intermediate 2, roving 2·75, spinning machine 5·8. Now this scheme has the fault that the drafts in the drawing machine are too great, and in the three passages an increase in the weight of the sliver may very advantageously be made. If the draft at this stage be reduced, and that at the slubbing and intermediate arranged to compensate for it, an improvement would result. In spinning the same counts, leaving out the intermediate machine, the sliver can be reduced in weight in the drawing machine, and the draft in the slubbing frame increased, leaving that of the roving frame about the same, but increasing that of the spinning. In producing counts from 20's to 24's, a little lighter finished scutcher lap is used, and a draft of about 90 in the card will be sufficient. In this class of yarn, whatever may be the carded sliver produced, it is good practice to obtain the same weight of drawn sliver. Assuming this to be done by making the draft and number of ends put up at each head to be equal, and that the slubbing should be

·625 hank, a drawn sliver of ·16 hank will give good results. If the material used be Indian cotton, this weight may be slightly increased, and if American is employed it may be a little decreased. If, however, this is the sliver used, a draft of 3·9 in the slubber, of 2 in the intermediate, and of 2·4 to 2·8 in the roving machine, will enable a draft of 8·3 to 8·6 in the spinning machine to produce 20's or 24's yarn.

(329) Twist yarn, as was stated, can be spun either on the ring frame or mule, but there is not in the main much difference in the preparatory stages. As stated when dealing with the ring frame, it is necessary to rather increase the draft in that machine to compensate for the shortening action which takes place, but this is a matter affecting the final draft, and not those in the preparatory stages. In preparing twist yarn, say 22's or 24's, and beginning with a carded sliver ·15 hank, the common draft of 6 in each of the drawings and doubling of 6 ends will give a similar hank drawing. Now let the drafts in the three rovings be respectively 4, 4, and 5—the intermediate and roving frames being fed by double slubbings—then a roving will be produced of 3 hank, which being used single in the mule or ring frame, can be spun—in the first case with a draft of 8, and in the latter with a draft of 8·2, which will give a yarn of 24's. It is possible to vary these drafts by using a slightly heavier carded sliver, increasing the drafts in the roving frames, and decreasing that in spinning, but this is a matter which must be left to the discretion of the spinner. Now let it be supposed that the yarn so made has been produced from laps made at the opener, which have been passed through two scutchers, three being fed to each. The doublings given to the cotton under this system would be $3 \times 3 \times 6 \times 6 \times 6 \times 2 \times 2 = 7,776$. In spinning counts coarser than 20's the drafts do not greatly vary if an intermediate slubbing frame is used, but a heavier sliver is employed. Say that 16's yarn is being spun, then the drafts in the drawing head can be well arranged to reduce the sliver to the necessary extent as it passes the first head, preserving its weight in the subsequent passages. A final drawn

sliver of ·155 to ·165 will give good results in the subsequent processes. If only two machines be used for producing the roving, then the draft in the roving frame must be largely in excess of that in the slubbing frame. The latter can be about 4·5, while the former may be as high as 5·8. A draft in spinning of about 7·5 will give the desired counts of yarn. If, on the other hand, an intermediate frame is added, then the weight of the sliver must be increased, and the draft in the slubbing frame can be reduced materially, that in the intermediate be a little higher, and that in the roving frame somewhat less than that stated above. Suppose, for instance, that we commence with a carded sliver of ·14, and double six at each of the drawing heads, but give drafts of 6·4, 6·2, and 6 respectively, then the drawn sliver will be ·154. Now, if only two machines are being used to further prepare the sliver for spinning, then a draft of, say, 4·7 given in the slubbing will give ·72 slubbing. Double this in the roving frame creel, and give a draft of 5·8 in that machine, then a roving will be produced which will be 2·09 hank. To spin this into 16's yarn from a single roving requires a draft of 7·7. Now, if the same procedure be followed, with the exception of introducing an intermediate frame, then the sliver can be made as heavy as ·12 hank when it leaves the drawing frame, and the drafts must be arranged accordingly. Thus, giving drafts of 3·6, 4, and 5·1 in the three machines respectively, and using double, slubbing, and intermediate, will give a 2·24 hank roving, which, with a draft of 7·14 in the mule with single roving, will give the necessary yarn.

(330) In arranging the drafts for 20's hosiery yarn, the carded sliver should be from ·15 to ·18 hank, and a good result is got by putting up six ends to each head of the drawing frame, and giving a draft of 6, by which a similar weight of drawn sliver is got. The following are good drafts in the rollers of the drawbox for most classes of cotton:—From back to third roller, 1·25; from third to second roller, 1·48; and from second to front roller, 3·222. The total draft is, therefore,

$1{\cdot}25 \times 1{\cdot}48 \times 3{\cdot}222 = 5{\cdot}96$, or, practically, 6. The cotton from which hosiery yarn is spun being of the softer varieties, the distances of the rollers apart can be regulated as indicated in Chapter VI. Assuming that the sliver from the drawing frame is ·15, the following is a good scheme of drafts throughout. In the slubbing frame the draft is 5, and the hank slubbing produces $5 \times {\cdot}15 = {\cdot}75$. For the best work it is preferable and necessary to double the slubbing and roving at each subsequent stage, as this conduces largely to the regularity which is essential. Whenever two ends are put up and drawn together, it is equivalent to doubling the weight of the slivers put up, and thus, in the present case, the slubbing would practically be, when presented to the intermediate frame, ${\cdot}75 \div 2 = {\cdot}375$ hank. The draft in the intermediate frame being 5·865, the hank roving produced is ${\cdot}375 \times 5{\cdot}865 = 2{\cdot}2$. The intermediate slubbing being doubled, and the draft in the roving frame being 5·2, the hand roving produced is $\frac{2{\cdot}2}{2} \times 5{\cdot}2 = 5{\cdot}72$. When placed in the mule creel two ends are doubled, and the rollers in the mule having a draft of 7, the yarn produced is $\frac{5{\cdot}72}{2} \times 7 = 20{\cdot}02$. If the hank sliver produced in the drawing frame be, say ·17 hank, then the draft in the intermediate and roving frames could be reduced, but that in the mule ought to be kept constant. In spinning hosiery yarns, a speed of about 7,000 revolutions is a good one for the spindles. Weft yarns for medium counts, say 36's to 40's, are spun much in the same way as hosiery yarns. Taking a weft yarn of, say 36's counts spun from average American cotton, the drafts could be averaged thus. Let a carded sliver of ·16 hank be obtained, it is desirable to have a triple passage through the drawing frame, putting up six ends to each head and giving a draft at each passage of 6. The drawn sliver would therefore have the same weight. The drafts in the roving frames are determined by the question whether a single or double roving is to be used in the intermediate and roving frames and mules, or any of them, but it is a very common practice to put up double rovings throughout. In that case the drafts could be arranged as follows :—

Slubbing, one end up, draft 4·5, gives $\cdot 16 \times 4{\cdot}5 = {\cdot}72$ hank.

Intermediate, two ends up, draft 4·8, gives $\frac{{\cdot}72}{2} \times 4{\cdot}8 = 1{\cdot}72$ hank.

Roving, two ends up, draft 6·25 gives $\frac{1{\cdot}72}{2} \times 6{\cdot}25 = 5{\cdot}33$ hank.

Mule, two ends up, draft 13·5 gives $\frac{5{\cdot}33}{2} \times 13{\cdot}5 = 36{\cdot}0$ hank.

There are one or two remarks which may be made on this. The drafts given will work out very well, but it is the practice in some cases to give a greater draft in the mule, using not more than a 5-hank roving for this yarn. In that case the drafts in the intermediate and roving frames require reducing, and that in the mule increasing. Drafts of 4·6, 6, and 14·5 in these machines respectively will give the desired result. Now, let it be assumed that only one end is put up to the mule, or that the yarn is spun from single rovings, then the hank roving could be reduced to, say 4·5, and the draft in the mule 8. It is therefore possible within certain limits to alter the drafts very considerably, and yet get good results. For instance, the following are the drafts which are actually used in spinning 40's weft from a ·18-carded sliver in a mill in which the drawing frames are too few in number. It is therefore essential to compensate for this at a later stage.

Drawing, 1st head, six ends up, draft 4·01, gives sliver ·12 hank.
 „ 2nd head, six ends up, draft 6·02, gives sliver ·12 hank.
 „ 3rd head, six ends up, draft 6·02, gives sliver ·12 hank.
Slubbing, 1 end up, draft 5·3, gives sliver ·636 hank.
Intermediate, 2 ends up, draft 5·2, gives sliver 1·64 hank.
Roving, 2 ends up, draft 6·21, gives sliver 5 hank.

The drafts just given show an important variation from those previously given, and may be compared with the following, which are also actual instances, with single rovings throughout. For 32's yarn, a draft in slubbing frame of 3·8, with a ·16 sliver of 2·8 in the intermediate, of 2·6 and of 7·3 in the spinning machine will be sufficient : 40's yarn can be spun from a similar sliver, with drafts of 4·7, 2·5, 2·53, and 8·4 in the slubbing, intermediate, roving, and spinning machines, respectively. 50's yarn can be produced with drafts in the same machines of 5·4, 2·3, 2·5, and 10; but these drafts can be very advantageously changed by using a finer sliver and reducing the draft in the slubbing machine; say a ·17 sliver and a 5·1 draft. If the slubbings and rovings are doubled the drafts in the intermediate and roving frame must be proportionately increased, as has been previously shown. All the above are drafts for American cotton.

(331) Fine yarns can be best spun when the slivers are combed, but the higher medium counts are often spun without a combing machine. In spinning yarn of 45's to 50's counts, using a good staple and double rovings, with a draft in the slubbing frame of 4·5, a drawn sliver of ·194 hank may be used, which will make the slubbing ·875 hank. Doubling the slubbing and intermediate in the creel, then drafts of 6·3 and 6·6 will give a 9 hank roving, which spun with a draft of 10 (with double roving) will give 45's, or of 11·2 will give 50's yarn. It is not necessary to give, in full detail, all the drafts for the various counts, so far as the drawing is concerned, but it may be stated that a sliver of from ·19 to ·21 hank may be used for counts from 60's to 150's, getting finer as the yarn is also made finer. It may also be noted that the draft must not, in the finer numbers, be always understood, when applied to the mule, as meaning the total, but only the roller draft, the difference required to produce the yarn being that given by the extra stretch referred to previously in dealing with the mule. After this explanation the drafts for various counts may now be given tabularly, these only relating to the slubbing, roving, jack-frames, and mule, double rovings being presumed in each case. The hank given with the mule is, of course, the counts of yarn spun, as will be easily understood. It will be noticed in reviewing these drafts that there is a considerable change in procedure taking place as the counts are varied, and that even when the same numbers are being spun there is a good deal of variation possible in the drafts.

PARTICULARS OF DRAFTS.

Machine.	1 Hank.	1 Draft.	2 Hank.	2 Draft.	3 Hank.	3 Draft.	4 Hank.	4 Draft.	5 Hank.	5 Draft.	6 Hank.	6 Draft.	Remarks.
Slubbing	1·125	...	1·25	...	1·375	...	1·0	4·6	1·5	...	1·5	...	Egyptian Cotton.
Intermediate.	3·25	5·75	3·5	5·6	4·0	5·8	2·2	4·2	4·25	5·6	5·0	6 7	
Roving	11·0	6·8	12 0	6 9	14·0	7·0	5·54	5·0	15 0	7·1	17·0	6·8	
Jack	...	...	...	..	...	...	16·0	5·75	...	...	...	...	
Mule	60's	10 9	70's	11·7	80's	11·4	80's	10·0	90's	12·0	100's	11·8	

Machine.	7 Hank.	7 Draft.	8 Hank.	8 Draft.	9 Hank.	9 Draft.	10 Hank.	10 Draft.	11 Hank.	11 Draft.	Remarks.
Slubbing	1·0	4 8	1 25	...	1·125	...	1·375	...	2·5	...	
Intermediate.	2·2	4·4	2·25	3·6	2·5	4 4	3 0	4·36	6 0	4·8	No. 7 with Egyptian Cotton.
Roving	6·0	5 5	6·25	5·55	6·5	5·2	7·5	5·0	16·0	5·3	No. 8 with Short Sea Islands.
Jack	18·0	6·0	21·0	6·72	22·0	6·7	28·0	7·4	48·0	6 0	Nos. 9 and 10 Sea Islands.
Mule	100's	11 1	120's	11·2	140's	12·0	160's	11·0	250's	9 25	

The drafts given in Nos. 7, 9, 10, and 11, are extracted from "Progress in Cotton Carding," by the late F. A. Leigh, of Boston, U.S.A.

Although the drafts given can, of course, not be taken as actually applicable to all cases in which the same counts are being spun, they are founded upon actual practice, and will serve as a guide for the formulation of a complete set when any given counts are being spun. The ground is thus cleared for a consideration of the number of machines of each class needed in any mill which is intended to spin a given range of counts.

(332) We are now able to calculate the necessary number of machines and their size in order to produce any given kind of yarn, and will take a mill producing 32's twist only and containing 60,000 spindles. A good average production for this class of yarn is one pound per spindle per week, although this is sometimes exceeded. Such a mill will, therefore, produce 60,000lb. of yarn per week, and this weight of cotton must, consequently, be supplied by each set of machines. Assuming that it is spun from a four-hank roving, the production of which is 10·62lb. per spindle per week, with a front roller speed of 119, 5,650 roving spindles are required. The hank of the intermediate roving used being 1·75, which enables a production of 31lb. per spindle to be obtained with a front roller speed of 132, the number of intermediate spindles required is 1,936. This is produced from a slubbing of ·625 hank, which can be produced at a rate of 89·26lb. per week with a roller speed of 161. This implies the use of 672 slubbing spindles. Now, these spindles have to be supplied by the drawing frames, which will deliver a varying quantity of sliver, depending upon its weight and the diameter and velocity of the front roller. Assuming this to be produced from a drawn sliver of ·16 hank, or 52 grains to the yard, and the front roller to run at 340 revolutions, then the production of each drawing head will be in 56½ hours, with a front roller 1¼in. diameter, 1,057lb. Thus, to supply 60,000lb. of cotton, 56 deliveries would be required, which could be got by using eight machines of seven deliveries each. If revolving flat carding engines are employed, and it be assumed that they

produce 850lb. of finished sliver per week, then 70 will be wanted. The necessary opening and scutching machinery required would be three finishing scutchers, three intermediate scutchers, and two combined openers and lap machines. Thus we arrive at the needs of a mill of this description to be as follows:—

2 or 3 combined opening and lap machines.
3 breaker scutching machines.
3 finishing scutching machines.
70 revolving flat carding engines.
8 drawing frames with seven deliveries each.
672 slubbing spindles.
1,936 intermediate spindles.
5,650 roving spindles.
60,000 mule spindles.

It only remains, therefore, to fix the size of the slubbing and roving frames and mules to arrive at the arrangement of the machines in the mill. If it was not thought advisable to have so many deliveries in the drawing frames the number could be increased say to 11 frames of five deliveries each, which, with a slightly accelerated speed of front roller, would provide all the drawing power required. As the mill building would probably be arranged to get in mules as long as possible, this is the determining feature in designing it, and would to some extent control the length of the roving frames. Assume the mules to have 1,044 spindles, and to be $1\frac{3}{8}$ guage, then the spinning rooms would have to be 125ft. wide plus the space required for alleys or passages at each end. Assuming these to be 3ft. each, this gives a total width of mill of 131ft. within walls; and if four spinning rooms are used, then there would be 14 mules in each room, and a length of 172ft. would provide for these. Thus the lower floor would be 172ft. by about 128ft., because, as will be shown hereafter, the width of the rooms gradually narrows as the basement is reached. In a room of this size, therefore, the whole of the carding, drawing, and roving machines have to be fitted. The carding engines are sometimes provided for in modern mills of a large size by the erection of a shed adjoining and forming part of the lower room; and the blowing room is also separately arranged. It must, of course, be understood that these dimensions are only approximate, although in the main accurate. It is useless following the calculation and fixing the size of the machines, because this can only be done when the whole circumstances of the case are known. In Fig. 94, however, the card room of a mill containing 86,494 spindles is shown in plan, which will give an idea of the method of arrangement. It will suffice therefore to demonstrate the method of calculating the number of spindles required, but it may perhaps be stated that for spinning counts of this character the roving frames would be made with 8 spindles in 20in. or 20½in. space, with bobbins of 7in. or 8in. lift. The intermediate frames could be conveniently made about 6 spindles in 19in., with bobbins of about 9in. lift, and the slubbing frames with 4 spindles in 19in. or 20in., and a bobbin 10in. to 11in. lift. The drawing frames are made of various guages from 15in. to 20in., but a convenient guage for frames of the character required is 18in., and as many as 8 deliveries can be got from each head of these machines. In arranging the blowing rooms it is now customary to separate them from the main building by the rope race, and to have a mixing room on an upper floor, from whence, by pneumatic means, the cotton can be conveyed to the first opening machine in the manner previously illustrated. The latter is arranged so that its lap end adjoins the feed end of the breaker scutcher, which in turn is succeeded by a finisher scutcher in an approximately similar position. The laps do not therefore require much handling, and the expenditure of labour is thus reduced.

(333) The instance just given will enable the general principles upon which mills are planned to be understood, and in order to give a little better guide than the purely illustrative case stated, a few actual instances will be given. Of these, one is the Standard Spinning Company's Mill, of which plan and full details will be found in the author's "Modern Cotton Spinning Machinery." The mill is designed to spin from

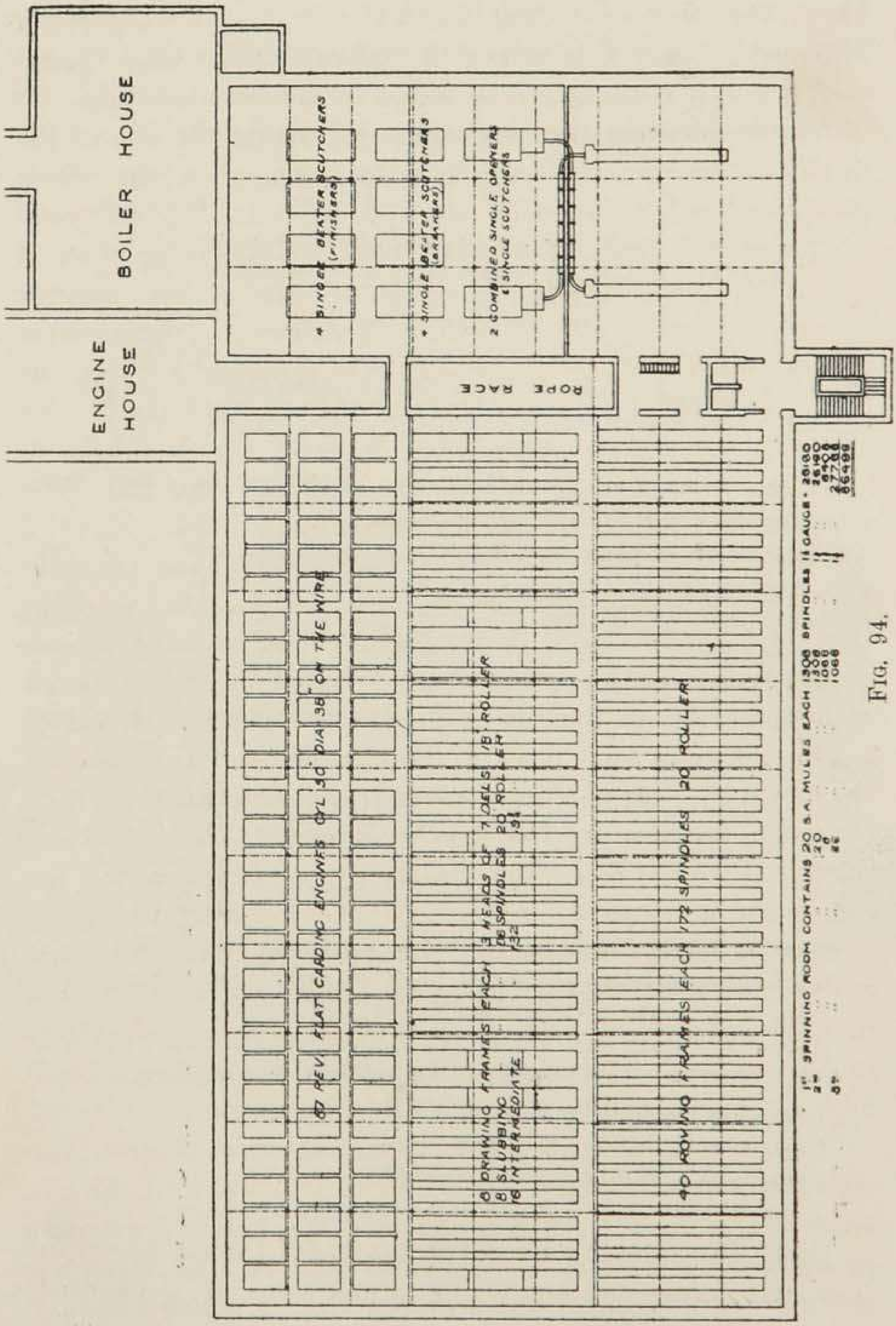

BOILER HOUSE
ENGINE HOUSE
ROPE RACE
4 SINGLE BEATER SCUTCHERS (FINISHERS)
4 SINGLE BEATER SCUTCHERS (BREAKERS)
2 COMBINED SINGLE OPENERS & SINGLE SCUTCHERS
REV. FLAT CARDING ENGINES CYL 50" DIA 38" ON THE WIRE
DRAWING FRAMES EACH 3 HEADS OF 7 DELS
SLUBBING SPINDLES 20 ROLLER
INTERMEDIATE
ROVING FRAMES EACH 172 SPINDLES 20 ROLLER
SPINNING ROOM CONTAINS 20 S.A. MULES EACH 1308 SPINDLES 11 GAUGE

Fig. 94.

American cotton, 40's to 50's twist and 50's to 70's weft. There are the followiug machines employed .—

22 weft mules, $1\frac{1}{8}$in. guage each, 1,260 spindles	=27,720
22 weft mules, $1\frac{1}{8}$in. guage each, 1,272 spindles	=27,984
Total...............	55,704
22 twist mules, $1\frac{3}{8}$in. guage each, 1,038 spindles	=22,836
22 twist mules, $1\frac{3}{8}$in. guage each, 1,044 spindles	=22,968
Total...............	45,804

52 roving frames, 8 spindles in $20\frac{1}{2}$in., 7in. lift, 168 spindles in each = 8,736
18 intermediate frames, 6 spindles in $19\frac{1}{2}$in., 10in. lift, 132 spindles in each = 2,376
12 slubbing frames, 4 spindles in 19in., 10in. lift, 90 spindles in each = 1,080
9 drawing frames, 4 heads, 7 deliveries each = 252
128 revolving flat carding machines, 50in. cylinder, 38in. wire.
6 finishing scutchers, fed from 4 laps.
6 breaker scutchers, fed from 3 laps.
4 opening machines, with lap attachment.
4 porcupine feed tables in mixing room.

The following are the details of the machinery in the plan given in Fig. 94 :—

40 mules, each 1,308 spindles, $1\frac{1}{8}$in. guage	=52,320
32 mules, each 1,066 spindles, $1\frac{3}{8}$in. gauge	=34,174
Total...............	86,494

40 roving frames, 8 spindles in 20in., each 172 spindles = 6,880.
16 intermediate frames, 6 spindles in $19\frac{3}{4}$in., each 132 spindles = 2,112.
8 slubbing frames, 4 spindles in 20in., each 86 spindles = 688.
8 drawing frames, each 3 heads of 7 deliveries = 168.
67 revolving flat carding engines, 50in. cylinder, 38in. on wire.
4 single beater finishing scutchers.
4 single beater breaker scutchers.
2 combined openers and single scutchers.
1 bale breaker.

(334) The following are the particulars of the machinery in a modern spinning mill devoted to the production of good yarns for sewing cottons, the mules being arranged for spinning medium fine counts :—

74 mules, 1,016 spindles each, 1⅜in. gauge.
60 roving frames, 182 spindles each, 8 spindles in 18in., 7in. lift.
30 intermediate frames, 126 spindles each, 6 spindles in 19½in., 10in. lift.
14 slubbing frames, 84 spindles each, 4 spindles in 16in., 10in. lift.
6 drawing frames, 4 heads, 6 deliveries each.
1 drawing frame, 3 heads, 6 deliveries each.
3 drawing frames, { 2 heads, 7 deliveries each.
1 head, 6 deliveries each. }
140 combing machines, 8 heads each.
20 ribbon lap machines.
20 sliver lap machines.
140 revolving flat carding machines, cylinders 50in. diam., 44¼in. wide.
6 finisher scutching machines.
6 combined opening, scutching, and lap machines.
1 bale breaker, used as a mixer.

As there is a considerable variation existing in designing mills for countries in which spindles are not run at so high a speed as in England, nor the productions so great, a few details of the spinning department of a mill fitted in Portugal by Messrs. John Hetherington and Sons, Limited, will be of interest. In these works weaving and bleaching are also carried on, but as these lie outside the scope of this book, nothing is said of that class of machinery. It will be noticed that a large variety of yarn is made, which renders it necessary to make special provision for it.

4 mules, each 404 spindles, 1½ in. gauge, for hosiery yarns.
2 mules, each 780 spindles, 1½in. gauge, for reeled weft.
8 ring frames, each 408 spindles, 2¾in. gauge, for twist yarn.
4 ring frames, each 428 spindles, 2⅝in. gauge, for twist yarn.
4 mules, each 1,040 spindles, 1⅛in. gauge, for weft.
22 ring frames, each 500 spindles, 2¼in. gauge, for weft.
18 ring frames, each 428 spindles, 2⅝in. gauge, for twist.
3 ring frames, each 408 spindles, 2¾in. gauge, for twist.
} Weaving.
3 ring frames, each 428 spindles, 2⅝in. gauge, for reeled yarn.
33 roving frames, each 164 spindles, 8 spindles in 20in., 7in. lift.
24 intermediate frames, each 124 spindles, 6 spindles in 19¾in., 10in. lift.
17 slubbing frames, each 82 spindles, 4 spindles in 20in., 10in. lift.
18 drawing frames, each 3 heads, and 6 coilers to each head.
140 revolving flat carding engines, 50in. cylinder, 38in. wide.

3 finisher scutchers for 40in. laps.
3 breaker scutchers for 40in. laps.
2 single Crighton openers and lap machine.
1 bale breaker.

In addition there are—

14 forty-hank double reeling machines.
15 cop reels.
2 bundling presses.

The following particulars of the equipment of a recently erected ring spinning mill will be of interest:—

21 ring spinning frames, 2⅝in. guage, 5in. lift, each, 372 spindles = 7,812.
32 ring spinning frames, 2⅝in. guage, 376 spindles = 12,032.
34 ring spinning frames, 2⅝in. guage, 380 spindles = 12,920.
31 roving frames, 8 spindles in 20½in. each, 180 spindles = 5,580.
12 intermediate frames, 6 spindles in 19½in. each, 140 spindles = 1,680.
7 slubbing frames, 4 spindles in 17½in. each, 98 spindles = 686.
4 drawing frames, 3 heads, 8 deliveries }
9 drawing frames, 1 head, 8 deliveries } = deliveries 104.
56 revolving flat cards.
3 finisher scutchers.
3 breaker scutchers.
2 openers.

(335) In order to enable the necessary calculations to be made, a few particulars of productions of various machines are given. Scutching machines may be taken as being able to produce 20,000lbs. weight of laps per week, and opening machines up to 30,000lbs. weight. Carding engines of the revolving flat type will produce 800lbs. to 1,000lbs. per week, and roller and clearer machines from 600lbs. to 700lbs. It is not desirable to overload carding engines, and 850lbs. per week may be taken as a base in calculating the number of revolving flat carding engines wanted. Combing machines will produce from 30lbs. to 75lbs. per day, according to the quality of yarn. The production of drawing frames depends upon the number of deliveries and the speed and diameter of the front roller. It can easily be obtained by calculating the number of yards delivered by the front roller in a week, and then multiplying that product by the weight of the sliver in grains per yard. If 10 per cent be allowed for stoppages, a fair margin is given. With reference

PRODUCTIONS OF MACHINES FOR ROVING AND SPINNING FOR VARIOUS COUNTS PER WEEK OF FIFTY-SIX HOURS.

Slubbing Spindle Speed, 700 Revs.		Intermediate Spindle Speed, 800 Revs.		Roving Spindles, 1,000 Revs.		Jack Frame Spindles, 1,400 Revs.		Mule.				Ring Frame.	
								Twist.		Weft.			
Hank.	Lb. per Spindle.	Hank.	Lb. per Spindle.	Hank.	Lb. per Spindle.	Hank.	Lb. per Spindle.	Counts.	Lb. per Spindle.	Counts.	Lb. per Spindle.	Counts.	Lb. per Spindle.
·35	195	·8	79	1·75	40·0	7	7·25	6	4·5	28	1·4	10	6
·4	154	·9	68	2·0	33·0	8	6	8	3·5	29	1·3	12	4·5
·5	115	1·0	60	2·5	23·0	9	5·25	10	2·75	34	·96	16	3
·6	92	1·1	54	3·0	17·0	10	4·5	12	2·4	36	·88	18	2·75
·7	83	1·2	49	3·5	13·5	12	3·5	16	2·0	38	·8	20	2·5
·9	62	1·3	44	4·0	11·0	14	2·5	20	1·75	40	·75	24	2
1·0	56	1·4	39	5·0	7·75	16	2	24	1·5	46	·66	28	1·625
1·25	38	1·5	36	5·5	6·8	18	1·8	28	1·2			32	1·25
		1·6	33	6·0	6·0	20	1·5	30	1·1			36	1·0
						25	1	32	1·0			40	·875
								34	·9				
								36	·85				
								40	·75				
								50	·56				
								55	·47				
								60	·4				
								70	·32				
								80	·21				

to the remainder of the machines, the table on p. 405 gives a number of average productions, but it must be understood that these can be varied according to the circumstances of the case. They are all derived from data collected by the author, and are given only as a guide, and not as fixed productions. The speeds of the various parts can be altered at will, thus affecting the production.

(336) Having thus dealt with the system of drafts and the production of the various machines, we are now able to consider the question of the construction of mills. This is a subject of much importance, but is also one permitting of much diversity of opinion. Briefly put, the design of a mill depends largely upon the materials which can be utilised for its erection, and these naturally are affected by the situation. In Lancashire the prevailing material is brick, and owing to the comparative dearness of timber, it is only sparingly used. In America, on the contrary, timber is more extensively employed, and the result is that in each country a special type of mill has been evolved. In other parts of the world the character of the building materials are widely diverse, timber, rubble, or even poorer qualities being necessarily used. It is obvious that with such a diversity, the work of designing and erecting must be largely affected. There are several other things which have an influence upon the problem. Atmospheric conditions, temperature, light and heat, all affect the subject, and it is obvious that the absolute necessity for light which exists where machines for manipulating cotton are employed must be fully considered in the erection of a mill. The necessity for ample ventilation, sufficient heating, humidity, and protection from fire are amongst the factors which must be steadily borne in mind. The great skill of the English operatives and the power of obtaining as many as are wanted for spinning mills have led to a gradual enlargement of the length of the mules, until they are now made as long as possible. The difficulty of maintaining the stiffness of the mule carriage, so that it will not vibrate at the ends to too large an extent, has practically settled the width of

the modern English mill. Mules of about 125ft. long are now commonly adopted, and the result is that the width of the room is ordinarily from about 128 to 132ft. in a mill of this character. The length of each room depends upon the number of mules

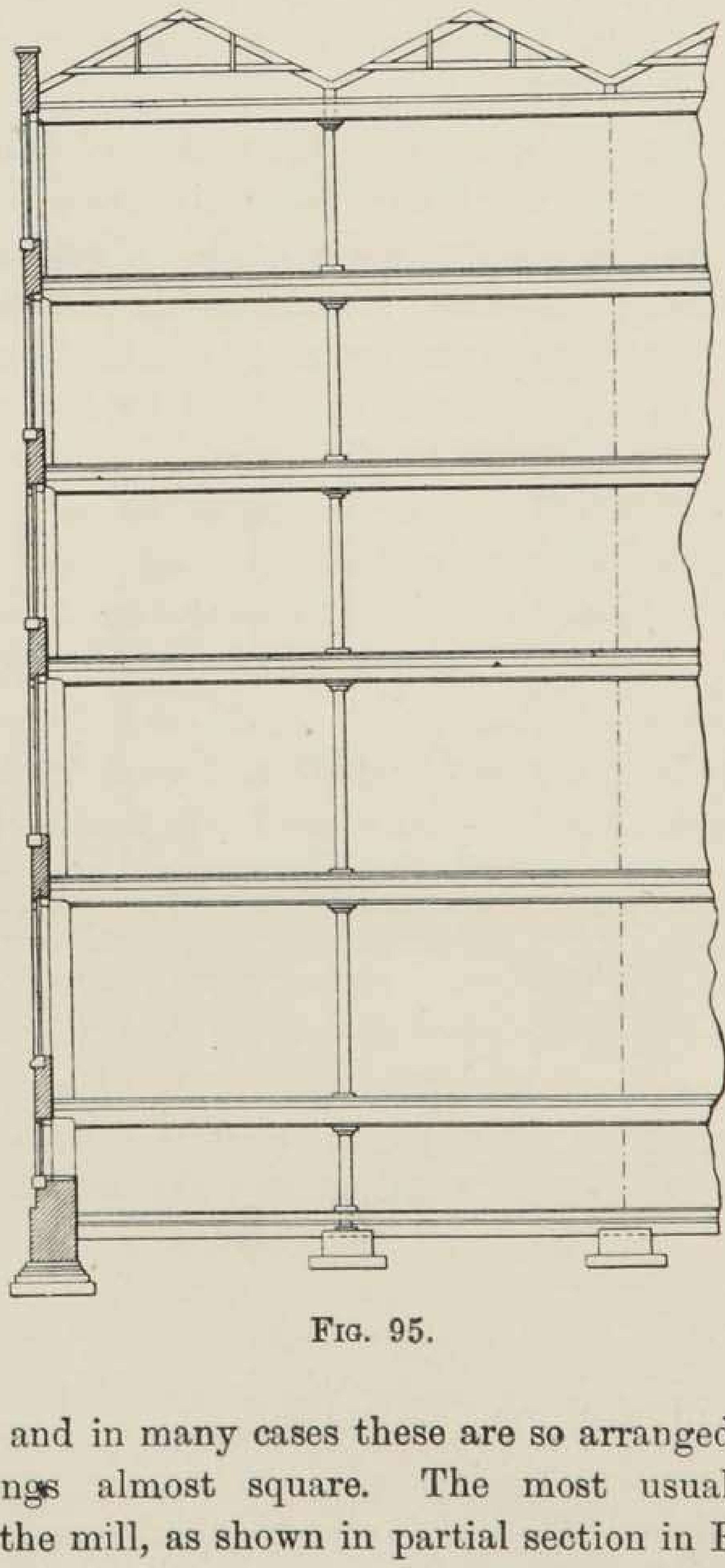


FIG. 95.

fitted in it, and in many cases these are so arranged as to make the buildings almost square. The most usual procedure is to build the mill, as shown in partial section in Fig. 95, with four or five floors and a storage cellar. This illustration, and

Figs. 96 and 97 are copied from a paper by Mr. John R. Freeman, in the Journal of the Association of Engineering Societies. The cellar or basement is made about 6ft. to 7ft. high, and is either provided with a concrete floor or is paved with brick or stone

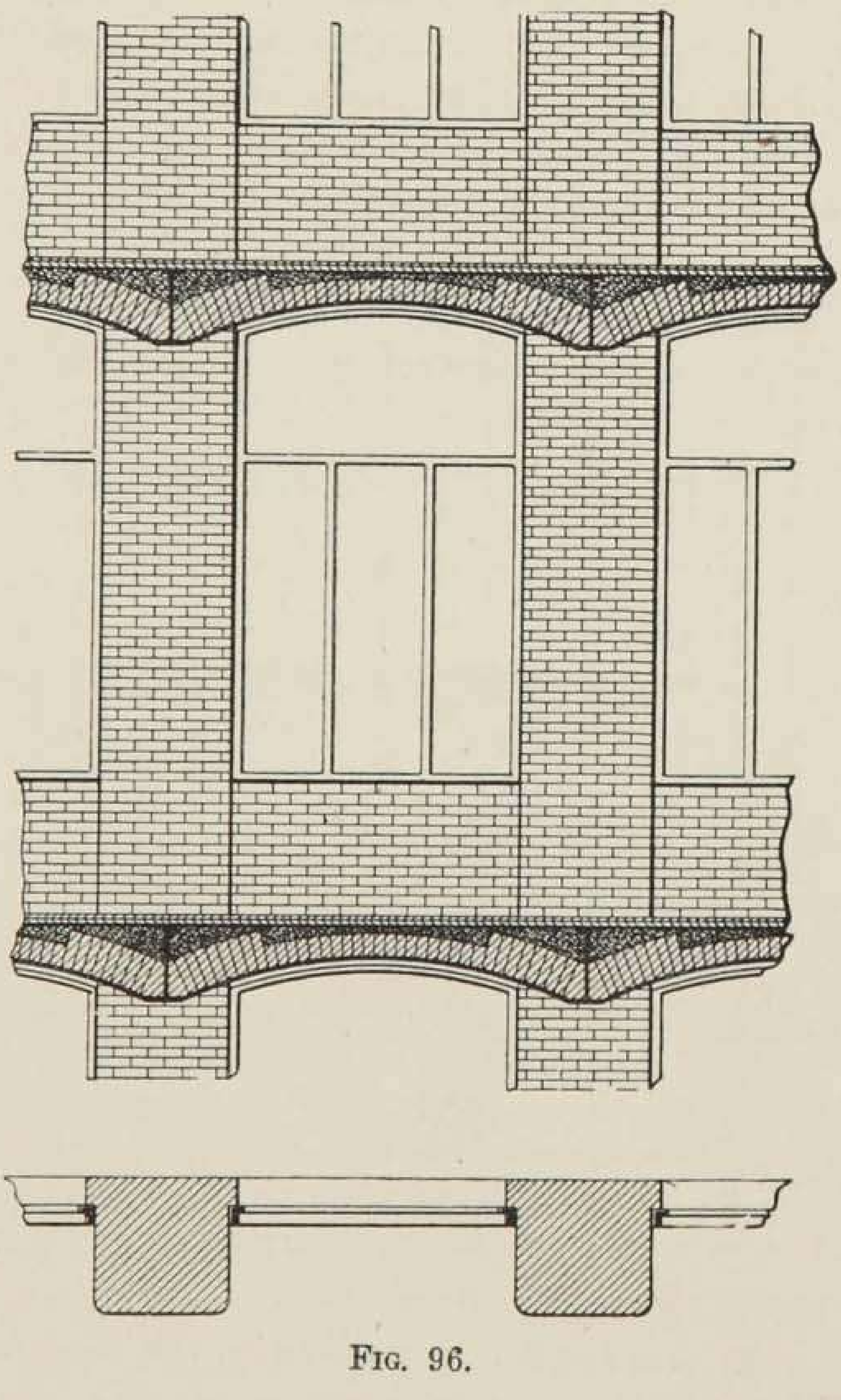


Fig. 96.

set in a suitable bed. The ground floor is in most cases the card room, and contains the whole of the carding, drawing, and roving machines. Each of the rooms above are used as spinning rooms, and the mules are made to extend across the full width. The card room is usually about 15ft. and each of the spinning rooms about 13ft. high. The floors are supported by means of transverse rolled iron, or better, steel girders, which are in turn sustained by cast-iron pillars, from 8in. to 5½in. diameter, the pillars getting smaller in the upper rooms. The pillars are arranged so as to occupy equal distances from each other, and longitudinally are so pitched that they fall into the alleys between the mules and not into the mule-gate. As the span thus given is large, it is necessary to obtain the required

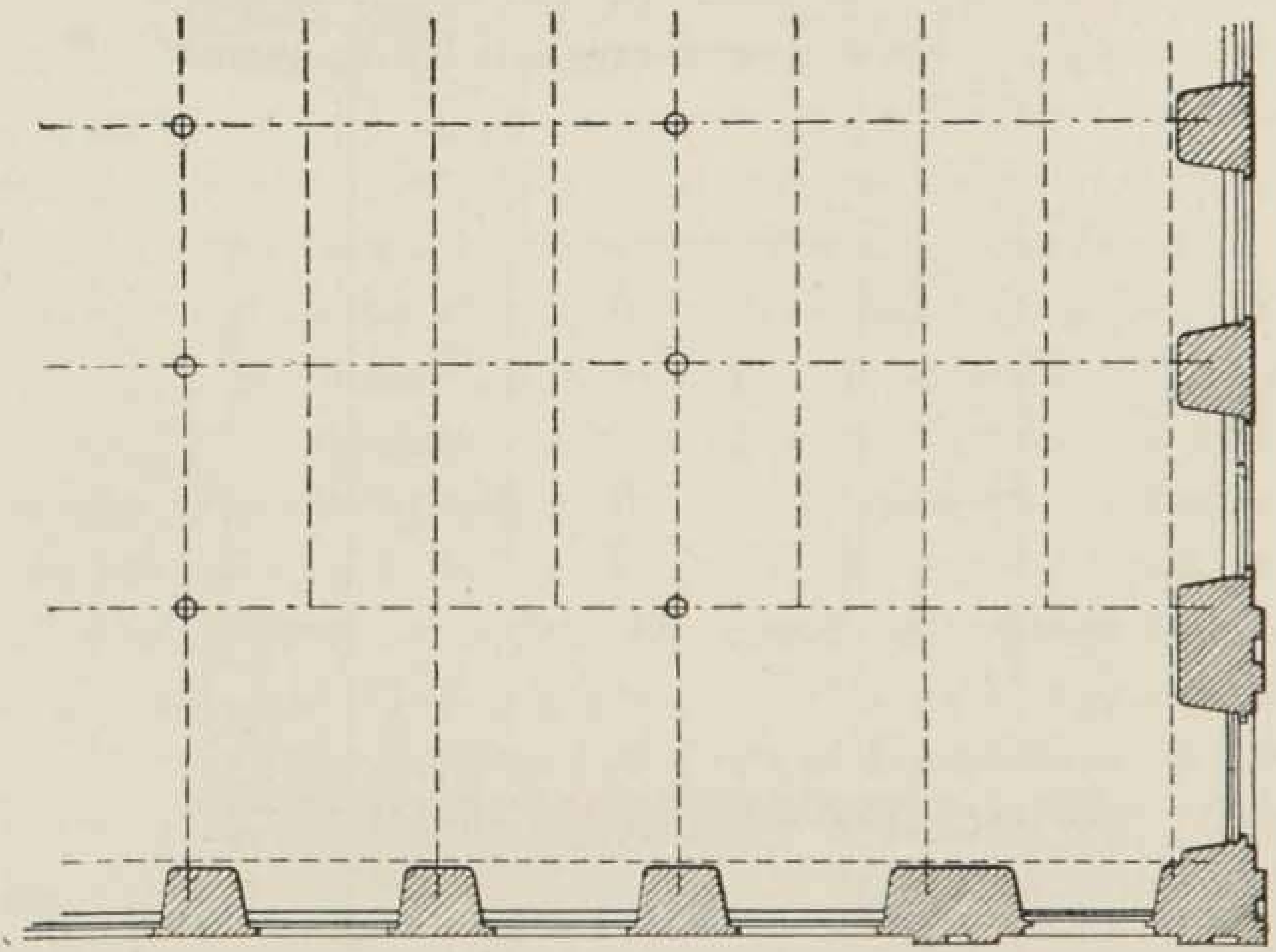


FIG. 97.

strength by a system of stringers or cross-beams supported by the heavy transverse beams. This is indicated in the plan given in Fig. 97. Brick arches are sprung from the beams so as to form the floor of each room, and the space above is filled with a thin layer of concrete, about 6in. in thickness, coming up to the top of the ⌶ girders, on which the wooden flooring is fixed. This is very clearly shown in Figs. 96 and 97, which are elevation and plan of two arrangements of windows of a typical English mill. The window is made 7ft. 6in. wide, and is carried up to within 12in. or 15in. of the ceiling of the room. Between each pair of windows a brick pier, 3ft. wide by 3ft. 2in. thick, is formed, into which the sash is fitted. Thus there is a large extent of glass and very little brickwork, so that the lighting is very effective and the light can reach well across the room. In a climate of the character of that of England this is a point of great importance, as the prevalence of grey skies makes it a problem of some difficulty. Ventilation is obtained where necessary by making the upper windows to swing, or by fitting hopper casements in the window frames. In some of the more modern mills the card rooms are fitted with some form of air propeller fixed in the window openings, and provided with self-closing doors which prevent any back draught. The greatest defect in the ventilating arrangements of a modern mill is found in the means provided for the inlet of air. Sooner or later it will be the practice to admit warmed humid air in a definite volume and provide suitable means of extraction. The thickness of the outer walls of the mill gradually decreases with each room, there being a difference of about 20in. between the wall of the upper and ground floors. It is thus rendered possible to fit in mules containing a few more spindles in the upper as compared with those fixed in the lower rooms.

(337) The method of construction thus detailed involves, as will be seen, the use of a large quantity of iron, and, in a strict sense, no mill thus constructed can be deemed to be fireproof. In any case where sufficient heat can be generated the use of unprotected iron is dangerous, but it is rarely that in a cotton mill any such volume of heat can be created. It has, however, in one or two cases, been the practice to cover up the iron by a coating of plaster or cement, so as to protect it. In the United States the practice is rather to make a building of a slow burning than of fireproof construction, and where timber is plentiful this is a course possessing some advantages. The floor in this case is formed of two thicknesses of boarding, with a layer of plaster about $\frac{3}{4}$in. thick between them, rendering the floor very

difficult to penetrate by fire. In that country the system of many-storeyed buildings is as prevalent as it is in England, but in tropical countries the practice is rather the other way. Where land is cheap and the temperature high, the practice of building factories on one level is pursued, and this is a matter which must depend solely upon the character of the surroundings. Any engineer or architect, with a knowledge of local circumstances, can speedily adapt his design to them. Among the many appliances which are employed to overcome or obviate the danger of fire, the "sprinkler," as it is called, is probably the most useful. This consists of a small appliance or "head," screwed into a water pipe, forming one of a series extending all over the mill. In England it is the practice to keep these pipes filled with water supplied from a tank at a suitable level, but in countries where there are severe frosts, they are filled with air under pressure. In the latter case, the orifices of the sprinkler heads are turned upwards. The sprinkler consists of a small tube, the orifice of which is closed by a valve sustained in its place by means of levers or supports, which in turn are fixed in position by fusible cement. When the temperature of the room rises above 170° F.—usually—the cement fuses, and the pressure of water forces away the valve, thus causing a spray of water to be discharged for many feet. The peculiarity of the sprinkler is that it is local in its action, and will check a fire at the point where it arises before it has had time to spread. Of the various types made, the Grinnell has had the widest use, and having been recently improved, is very effective. The sprinkler heads must be arranged at a distance of 10 feet in each direction from each other, and in places where there is great risk of the transmission of fire—as, for instance, a belt race—at much shorter distances. An alarm gong is fitted, which is actuated by the smallest fall in pressure, and, being placed without the mill, gives a speedy alarm. In all modern mills it is the custom to provide water pipes running through the mill, to which hose pipes can be attached, and which are in connection with powerful force pumps. In addition to these precautions, the provision of *filled* water buckets, placed in convenient positions, is a very wise procedure.

(338) Another question which has an influence upon spinning is that of humidity. The natural humidity of the atmosphere in Lancashire is considerable, reaching 90 per cent, and in most cases very little trouble arises from this cause. In the dry weather which occasionally prevails, however, considerable differences arise in the character and weight of the yarn produced. Moist weather enables the drawing to be better effected, and the drier the weather the more difficult it is to preserve the weights of the slivers and rovings. This is a matter which more affects spinners in other countries, as it renders it more difficult to maintain even weights, and also increases the amount of clearer waste which is caused by licking. A variation amounting to 20 per cent in the finished yarn has been recorded in the United States, which is a very serious matter. This difficulty is partially overcome by the employment of humidifiers, or "atomizers," as they are called, which consist of apparatus by which the air is charged with moisture, and injected into the room. The crudest method is to provide means by which jets of steam are injected into the room, but a much better plan is to saturate the air as it enters, either by means of steam jets or water sprays. The amount of humidity required varies with circumstances, but from 70 to 80 per cent is a good amount. Allied to this subject is that of heating the mills. This is best done now by means of steam pipes made of wrought-iron, through which high-pressure steam is forced. The higher temperature of the steam enables a much larger radiation to take place than is possible with low pressures, and the pipes used are correspondingly smaller. Temperatures of 98° F. are often reached in English fine-spinning mills, but in the author's opinion they are quite unnecessary if proper attention be paid to humidification.

(339) The motive power required to actuate a mill is derived in many ways. In some cases, notably abroad, it is obtained by means of water power, turbines being used for the purpose.

The City of Holyoke, in the State of Massachusetts is a notable example of the profitable use of water. In this case the Connecticut River, the fall of which at this point is considerable, was dammed, and the water turned into three canals on different levels, which were cut across the land on which the city stands. From these canals the turbines driving the mills built on their banks derive their water, and as there is a steady and unvarying fall in all seasons the driving is of a very light character. There is in this case plenty of fall, so that the trouble of back water is entirely obviated. The same lavish and profitable use of water occurs in some of the Continental states, notably Switzerland, the large and perennially flowing streams of which provide a constant and ample source of power. By far the greater part of the spinning mills in existence, however, are driven by means of steam engines. A steam engine is, as it is well known, an instrument by which the heat derived from the combustion of the fuel can be utilised and converted into work. It is neither wise nor necessary to deal with the subject of steam engines at length, because to do it justice requires a separate treatise. It will, however, be possible to give such a treatment as will state in a simple manner the essential facts, leaving the student desirous of going further into the subject to seek information in works specially devoted to it.

(340) It may be said that the desiderata in a steam engine for mill purposes are (1) steadiness of driving arising from a uniformity of the velocity; (2) an economical consumption of steam; and (3) simplicity of design combined with the necessary strength. As the yarn, during the period of spinning, is very sensitive to variations in the speed of the machinery, which, even when of limited extent, tend to breakage or unevenness of the yarn, it follows that a uniform velocity is of high importance. The economic forces always at work render it necessary so to employ the steam that the least weight which is capable of developing the required power shall be needed. Bearing these facts in mind, it has become the practice to construct engines so

that all losses of steam are avoided until every possible pound of work has been taken out of it. Up to quite recent date the engines employed for driving have been of the compound horizontal type, either arranged with the cylinders side by side,or as "tandems," with the cylinders one behind the other. The pressures for use in compound engines have gradually risen from 60lbs. to the square inch to 120lbs., which is now believed to give the best results. Few compound engines are now working at a pressure of less than 80lbs. The steam engine is, as has been said, a heat engine, the efficiency of a perfect heat engine, being calculated from Carnot's formula $\frac{T - T^1}{T}$ where T = absolute maximum temperature of the steam or other gas in the engine, and T^1 the absolute minimum temperature, which is that of the steam as it leaves the engine. This formula is never absolutely true for a steam engine, where not more than half the available work is often obtained. The additional efficiency of a compound, as compared with a simple—one cylindered—engine is caused by the lessened condensation which takes place in the cylinder. When steam is expanded in the act of doing work in an engine it gives up its heat, and in doing so tends to condense. If the amount of work done in one vessel is excessive—that is, if there is too great a fall in the pressure and temperature—the condensation becomes so great as to cause serious loss. The advantage of dividing the work between two cylinders is, therefore, that the range of pressure in each is reduced, and the loss reduced to a minimum. Not only so, but the stresses created at the beginning of the stroke are also reduced, and there is more chance of obtaining a uniformity of rotation of the crank shaft. When the pressure of the steam is raised to a high point, say from 150lbs. to 180lbs, a division of the work between three cylinders is found to give the best economic results, for the reasons just stated. Without attempting to deal at all fully with the subject, it may be said that compound engines properly proportioned give the best results with the pressure of 120lbs, and triple-expansion engines from 150lbs. to 200lbs. Quadruple-expansion engines are being made for mill work at the present time, but the data available is not yet sufficient to show how far they are advantageous. The cost of raising steam to 200lbs. pressure is little greater than it is to raise it to 100lbs., while the heat units are greater in number. This is all which in a book of this kind it is necessary to say on the theory of the various types, but a little time may be spent on a few constructive details.

(341) It has been said that the ordinary method of constructing compound engines is with the cylinders either side by side or tandem, one behind the other. In constructing triple-expansion engines three plans are followed. The engines may be made either as a pair of tandems, as shown in Fig. 98 (which illustrates the position of the cylinders), as a tandem engine side by side with a simple engine, or, when vertical, with the three cylinders side by side and inverted. All three of these plans have been adopted by engineers, and each form appears to give satisfaction. The inverted vertical cylinder engine has the advantage that the floor space occupied is smaller than that needed for other types. When the double tandem type is employed, as in Fig. 98, there are two low-pressure cylinders fitted, the combined area of which is carefully calculated. In any case it is always endeavoured to so arrange the cylinder areas and their combination as to get as nearly as possible the same load upon the cranks. This principle is, however, often departed from, although it is a perfectly sound one. With reference to the question of the relative areas of the cylinders, these vary considerably in different cases, but an

approximation to correct results is possible. The ratio of the areas is obtained by multiplying the area of the low-pressure cylinder by the length of the engine stroke, and dividing the product by the product of the area of the high-pressure cylinder and its piston stroke. The ratio naturally varies according to the range of the temperatures permissible, it being desired to get an equal amount of work out of each cylinder. A few examples from actual practice with various types of engines are given on p. 417. It must be noted in considering the figures given in the table that the coal consumption in each case

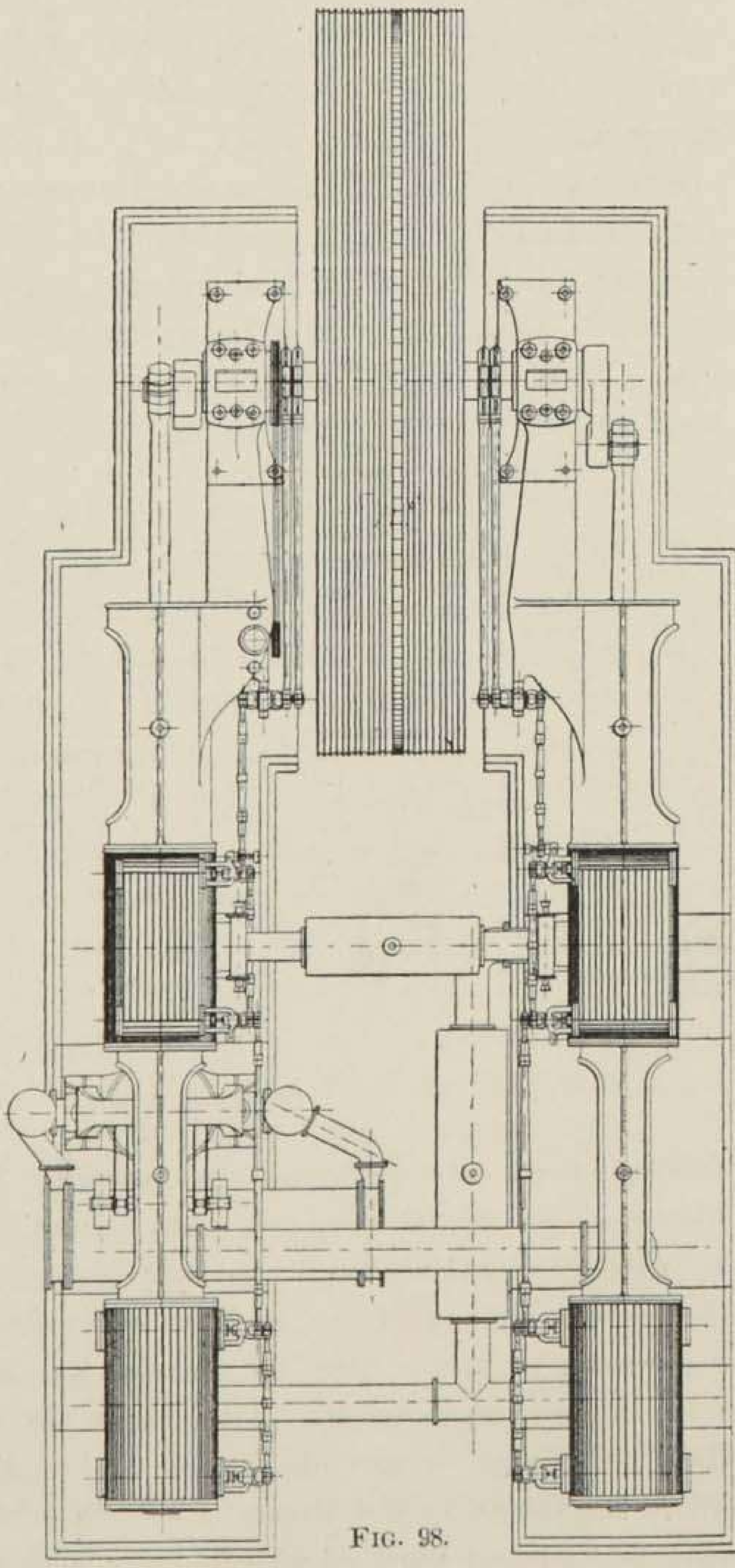


Fig. 98.

Type of Engine.	Cylinder Diam. H.P. inches.		L.P. inches.		Piston. Stroke in feet.	Speed in ft. per min.	Ratio of cylinder areas.		Boiler pressure in lbs.	I.H.P. developed.	Coal consumed per I.H.P. per hour. Lbs.
Compound.											
Side by side..	24		44		5	550	1 : 3·36		105	611	1·93
Dbl. tandem..	21		42		6	432	1 : 4		100	914	2·00
do. ..	20		40		5	565	1 : 4		93	962	2·10
do. ..	24		48		6	420	1 : 4		90	1·125	1·75
Sing. tandem.	30		50		6	678	1 : 2·77		80	1·250	2·85
Side by side..	26		48		6	600	1 : 3·39		70	521	2·21
Triple expan.	H.P.	Inter.	L.P.				H.P. to Inter.	Inter. to L.P.			
Horizontal 4 cylinders..	18	29	e'ch 34		6	492	1 : 2·6	1 : 2·7	163	771	1·87
Vertical 3 cylinders....	16	26	42		4½	630	1 : 2·6	1 : 2·4	160	741	1·72
Quad. Expan.	HP	1st Int.	2nd Int.	LP			H.P. to 1st Int.	1st Int. to 2nd.			
Vertical 4 cylinders	18	26	37	34	4½	720	1 : 2·08	1 : 2·01	200		
							2nd Int. to L.P.				
							1 : 2·14				

includes that used for heating the mill, which is equal to a deduction of about 12½ per cent in the weight used, thus reducing that employed for the engine to about 1½lbs. in the triple, and from 1¾lbs. to 2lbs. in the compound engine. It is always desirable to provide between the high and low pressure cylinder of a compound engine a "receiver"—that is, a vessel of sufficient capacity to receive the exhaust steam from the high pressure cylinder. This may either be done by making the exhaust pipes of sufficient area, or by con structing a separate vessel. When the cranks of a compound engine are set at right angles to each other, as in a side by side engine, it is desirable to have a receiver with a capacity sufficiently large to equal the cubic capacity of the low-pressure cylinder. The object is to provide such a reserve of steam that no loss of initial pressure shall take place in the low-pressure cylinder, where it ought to be nearly equal to the terminal pressure in the high-pressure cylinder. In a compound engine the latter should be from 8lbs. to 12lbs. In many instances engines have given bad results owing to inattention to this point. In some of the most recent examples both the high pressure cylinder and the receiver are jacketed—that is, are cased so that a space is left between the outer and inner shells. If jackets are fitted they should be filled with steam directly from the boiler, otherwise the temperature in the spaces will be lower than that of the enclosed steam, and condensation—the prevention of which is aimed at—will take place. It is always desirable not to have too long a range of pipes between the boiler and the engine, and these should be well protected by some kind of composition which prevents the radiation of heat. In addition to this, means should be taken to drain the water of condensation, and, if the length of connecting piping is great, expansion joints should be fitted. No greater velocity than 2,500 feet per minute should be given to the steam in the main steam pipe. If a throttle or equilibrium valve is used, it should not only be of sufficient area to avoid all wire drawing of the steam, but be placed as near as possible to the valve chest. If these two points are neglected, there will be found to be a considerable fall in the initial pressure on the piston when compared with that in the boiler. The parts of a steam engine should be so proportioned that the pressure per square inch on the crank pin is not more than 800lbs., a lower pressure being preferable; on the cross head slides, with good lubrication 400lbs., and on the main bearings about the same amount as the crank pin, 400lbs. or 500lbs. being in each better than the higher amount. The area of the exhaust pipes should be great enough to limit the speed of the steam to about 4,500ft. per minute. The best velocity of the piston is from 500 to 600 feet per minute for mill engines. The weight of steam used per horse power per hour in condensing compound engines averages, if well constructed, about 16lbs. Triple-expansion engines can be made to consume no more than 13lbs., but a little more is often taken, 14lbs. being, however, an excessive amount. The result is that, if all the conditions are equal, much less coal is required for each horse power developed in a triple-expansion than in a compound engine. Taking into account all the steam required in a mill, it is found that a well-constructed compound engine, working at 100lbs. steam pressure will, in this country, take about 2lbs. of coal per horse power per hour. The quantity may be a little more or a little less, according to circumstances, but that named is considered a fair average. Triple-expansion engines, under similar conditions, have a consumption of 1·5lbs. and under. For the purpose of raising steam, about 17lbs. of water per indicated horse power per hour is required when compound engines are used, and an average of about 14lbs., with triple-expansion engines. The amount in each case may be about a pound more or less. There are doubtless a number of other facts which may be stated, but it is necessary to exclude all those which really belong to the province of the constructor, and as several points will be dealt with in treating of the use of the indicator, only one or two more need be dealt with at this point. The weight of water required with an ordinary jet condenser is from 25 to 30 times the weight of steam used, but it is obvious that the quantity will depend on the heat of the water when injected. This should never exceed 100° F. In most cases the water, after being used for condensing, is passed into a reservoir for storage, and is before its reception cooled by exposure to the air. It depends upon several factors what the area of the reservoir should be, but it may be taken as a safe rule that if the water is intended to be repeatedly used, it is better to have a large shallow reservoir than a small deep one. If an ample supply of fresh cold water is at hand, a low temperature is easily attainable, otherwise, the provision of a large cooling area is imperative. It is a general practice to provide a reservoir with a capacity equal to that of the whole volume of water injected into the condenser during a day's work, but it is obvious that there are many circumstances which will affect this matter. There is a considerable loss by evaporation under any circumstances, the amount varying according to atmospheric conditions. It has been estimated by Mr. Hurst that in England from $\frac{1}{4}$ to $\frac{1}{8}$ inch per day is lost by evaporation due to the heat of the sun in the summer, and from $\frac{1}{12}$ to $\frac{1}{16}$ inch per day in the winter. Assuming that this quantity is approximately correct, it will be easy to estimate the quantity of water required to make up for the loss thus caused. There are two or three other points which will be touched upon at a later stage, but enough has now been said to enable an accurate idea to be formed of many of the working conditions.

(342) The power which is given off in the cylinder of a steam engine is ascertained by means of the indicator. This is a delicately made instrument consisting of two principal parts— a steam cylinder and a revolving drum. The cylinder is carefully bored, and has within it a piston which is made of such an accurate fit that, while preventing leakage of the steam, it can easily slide without undue friction. This is one of the points which requires special attention in taking indications, when care must be taken to prevent any grit or dust getting within the cylinder. Between the top of the piston and the cylinder cover a light spring accurately made and tested is placed and the piston when forced up has to rise against the pressure of the spring. The springs are carefully graduated so that the movement of the pencil point, which is derived from the piston, is controlled. This will be more fully discussed presently. The piston rod after passing through the cylinder cover is coupled by suitable links to a lever, in the free end of

which a pencil is fixed. The lever or levers employed are so proportioned that the free point moves through a greater distance than the piston, but it is so controlled by means of a parallel motion or other device that the pencil always moves in a truly vertical line. It is in the gear employed to give this directional control that the variation in the different instruments is chiefly found, although there are, of course, other differences. The whole of the pencil gear can be moved so as to bring the pencil into, or take it out of, contact with a paper barrel, which forms the second principal part of the instrument. This barrel is constructed as a very light metallic cylinder in true balance and sustained by a light steel pin fixed in an arm in such a way that it is quite free to rotate. It is provided with two clips to enable the paper which is wrapped round it to be easily gripped, and is of such a circumference that a length of paper sufficient to take diagrams of maximum size can be fitted. At the lower end of the cylinder a small drum is fitted, round which the driving cord is taken twice. Within this drum there is a coiled spring of sufficient strength to return the cylinder to its normal position after the release of the cord. The latter, which is taken to the drum by a guide pulley, is actuated from some reciprocal moving part of the engine, so that it receives an alternate movement in each direction. Fig. 99 is an illustration of the Tabor indicator, which has many merits. As the length of motion given to the cord by the part to which it is attached is much in excess of that required by the drum, a reducing gear of some kind, about which something will be said later, is employed to give the required diminution. The ordinary length of diagram for mill engines is 4 inches. The stroke of the barrel should always be arranged so that it never touches the stops. The springs are so arranged in strength that for every inch of movement of the pencil vertically a definite number of pounds pressure is indicated. Thus a 30 scale spring means that every inch in height on the diagram represents 30lbs. pressure. Thus the smaller the scale the

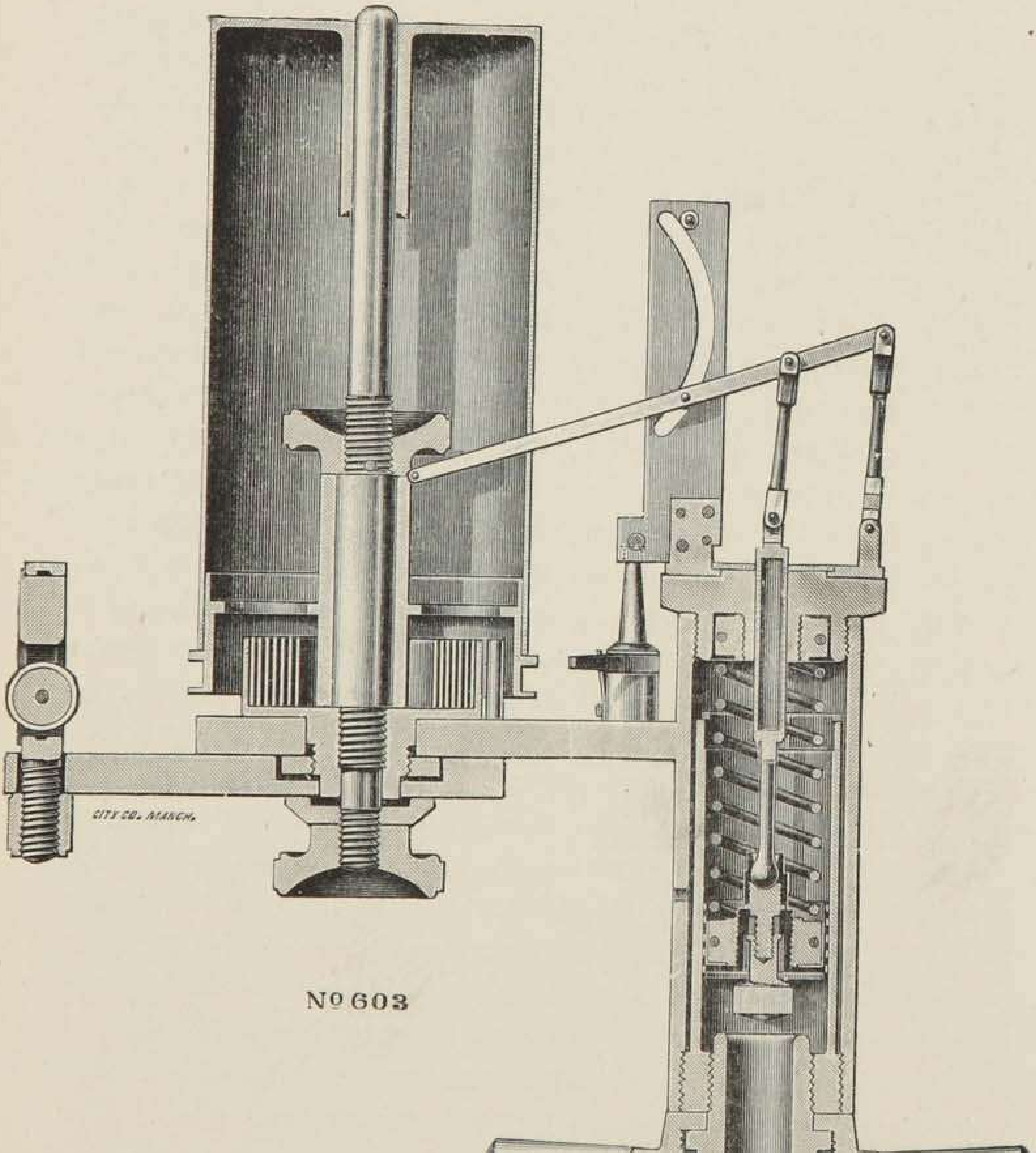


Fig. 99.

higher the pressure which can be represented on the diagram. In beginning to take an indication there are one or two things to remember. First, that it is better to fix the instrument as near its work as possible, and that whenever practicable tubes should be avoided. Second, that the motion of the drum should be steady; and, third, that the piston is quite free in its movement in the cylinder. After it has been ascertained that the stroke of the barrel is correct, the paper is placed upon it and the cord is coupled up. The steam can then be admitted to the cylinder without at first putting the pencil in contact with the paper, a few strokes serving to get everything into working order and warm the cylinder. The steam is then shut off and the pencil brought lightly in contact with the paper, on which it makes a line which indicates the atmospheric pressure, and called the atmospheric line. When the steam is again turned on, the pencil describes an irregular line on the paper in exact accordance with the change of pressures in the engine cylinder. It is desirable in taking an indication to keep the pencil in contact with the paper during several strokes, as it often happens that there is a difference in the figure produced in successive strokes, nor is it uncommon for several diagrams varying considerably in area to be so produced. When this happens the mean diagram is accepted as being sufficiently correct. The pencil should only be pressed lightly against the paper, as undue friction may disturb the accuracy of the figure, and a stop screw is provided to enable the adjustment to be maintained. Ample lubrication must be given to the piston and cylinder as well as the whole of the pencil gear, and the best quality of cylinder and watch oil should alone be employed for this purpose. If pipe connections have to be made so as to enable indications from each end of the cylinder to be taken, no unnecessary bends must occur, and the three way cock employed must not contract the area of the connection. It is much better, however, with cylinders of great length to use an indicator at each end of the cylinder, or at any rate at each end alternately. The holes in the cylinder must be in such a position as not to be covered by the piston either partially or wholly. After the diagram has been taken and the steam shut off, it is desirable to retrace the atmospheric line in order to see if any error has occurred. The operator should mark upon the card the date and hour when the diagram was taken, the end of the cylinder dealt with, the boiler pressure, and the speed of the engine. There are many other details which may be noted if desired. There are several means of reducing the motion derived from the reciprocating part from which the rotation of the drum is obtained, some of these being very ineffective. The most common one is to have a pendulous lever oscillated by a pin from the crosshead, to which, at a point sufficiently near its centre, the cord is attached. This is a crude and unreliable mode. It will be seen that instead of the cord receiving a motion similar to that of the piston it will lead off to the indicator at a continually varying angle, and derive its power by a different leverage at each part of the stroke. Another device is the "Lazy Tongs," as they are called, these being a series of levers so arranged as to act like a pentagraph, and rapidly reduce the length of the motion. A simple form of pentagraph can also be used, but if either of these devices are employed, care should be taken to lead the cord from them in a line parallel to the motion of the crosshead, and thence angularly to the indicator. A still better method of obtaining the motion for use in horizontal engines consists of an endless cord fixed to the pin of the cross-head and passed over two pulleys rotating on pins fixed at the ends of the slides. On the boss of one of these pulleys, the one nearest the cylinder preferably, a smaller grooved pulley is formed or fixed, over which the indicator cord is coiled, and is made of such a diameter that it will give the required length of motion to the indicator barrel. The indicator cord can be led off from this to the cylinder, and the required motion is given in a very perfect way.

(343) When it is obtained a diagram of a good character resembles that shown in Fig. 100. In this the atmospheric line is marked A L. The steam is admitted at the point B, and a rapid rise in pressure within the cylinder takes place until the point C is reached, making the line B C, called the "admission line." From thence to the point D the valve remains fully open —the line C D being the "steam line"—after which it begins to close and finally closes at E. From the point E to F the steam is doing its work by expansion—the line E F being the "expansion curve"—and at F the valve opens to allow the exhaust to take place. At G the exhaust valve is quite open, and from G to H, which is the "exhaust line," remains so. At the point H the piston is approaching the end of its stroke, and as at H the exhaust valve begins to close the steam is compressed until the admission point B is reached. Compression really begins at the point J, when the exhaust valve is nearly closed, and the line J B is the compression line. The diagram taken from the low-pressure cylinder, while resembling that from the high pressure, has the dissimilarity that a great part of it lies below the atmospheric line. This portion is caused by the creation of a vacuum by the condensation of the steam, and indicates the amount which the steam pressure is below that of the atmospheric. From the figure so described, many things can be deduced in addition to the extremely useful power of calculating the power evolved. For instance, the setting of the valves, and their method of closing, can be ascertained. Thus, in the diagram in Fig. 100, it is clear that the admission of steam is instantaneous, while its cut off is more gradual. In like manner the exhaust valve opens gradually. If any irregularities occur in any special portion of the diagram, it becomes at once clear that something is taking place which ought not. For instance, if the exhaust line G H is continued until the compression line J B is entirely done away with, it is obvious that there is no compression existing,

and that the clearance spaces which always exist at the end of a cylinder are emptied at every stroke. A two-fold waste occurs from this. The steam as it enters has to heat the spaces before it can expend itself in useful work, and the piston, instead of being cushioned and brought easily to rest prior to commencing to reverse, travels unchecked to the end of its stroke. The retention and compression of a portion of the steam leads to great economy. Further, the jar, occasioned by the sudden cessation and reversal of the piston travel, leads to wear of the bearings of the connecting rods, and gives rise to knocks during work. A reasonable degree of compression improves the work of the engine and is undoubtedly economical. In

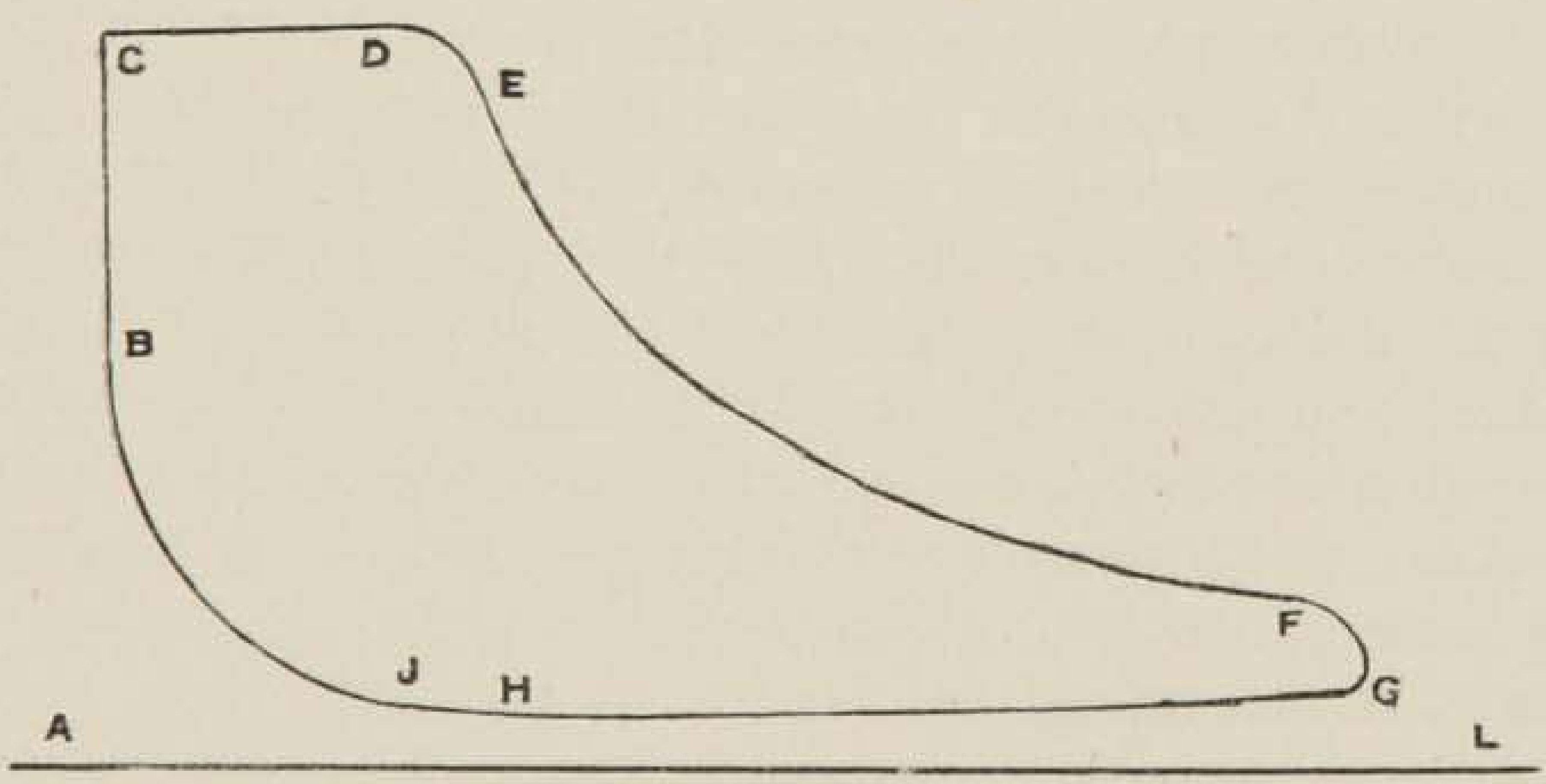


FIG. 100.

all low-pressure cylinders the need for terminal compression is very great, owing to the large areas otherwise emptied at each stroke. In no case should the steam be compressed above the initial pressure in the cylinder. Again, the line C D, which indicates the admission of the steam, should be horizontal throughout its length. If it is otherwise the valves are not acting properly and are wiredrawing the steam. The relative height of the point C to a point representing on the same scale the boiler pressure, indicates to what extent there is a loss of pressure from the boiler to the cylinder. If the admission line B C is not perpendicular, it shows that the opening of the valve is not prompt, and if the exhaust line G H is too high above the atmospheric line A L, it indicates either that the exhaust valve opens too late or that some obstruction is taking place to the free passage of the steam. The line of expansion E F should be regular, and in its most perfect form approaches a hyperbolic curve, which is the true curve for a perfect gas expanding regularly under the best conditions. Cylinder condensation will cause a divergence from this line, and it is not an uncommon thing to find during the period of expansion both condensation and re-evaporation. This can be easily recognised by a departure from the true expansion curve. Condensation implies a loss of work on the piston at the point at which it occurs, while the re-evaporation results in more pressure being applied when it occurs, thus increasing the work. These two points can be easily ascertained by an examination of the diagram and a comparison of it with the true expansion curve. By comparing the diagrams from each end of the cylinder, it can be seen whether the valves at each end are evenly set, which is very often not the case. It is now only necessary to show how the power evolved is calculated, the calculation of the clearance spaces at the end of a cylinder being to a large extent a purely engineering matter. In proceeding to calculate the power which a diagram shows, it is first necessary to erect upon the atmospheric line two perpendicular lines touching respectively the extreme ends of the diagram. In Fig. 100 these would touch at A and G respectively, and the length of the diagram would thus be shown on the atmospheric line. The space between these points may be divided into eleven spaces, the central nine being equal, and that at each end half the width, vertical lines being drawn from each point of division. By measuring the height of the diagram in the centre of each of these divisions, the mean pressure is obtained by multiplying the height in inches by the scale of the spring. Each of the figures thus obtained is the mean pressure within each division, and by adding all these results together and dividing by 10, the mean pressure of the whole of the diagram is obtained. Having got this, the horse-power exerted by either cylinder can be calculated as follows:—Let P = the mean effective pressure in lbs.; L the length of the stroke in feet; A the area of the

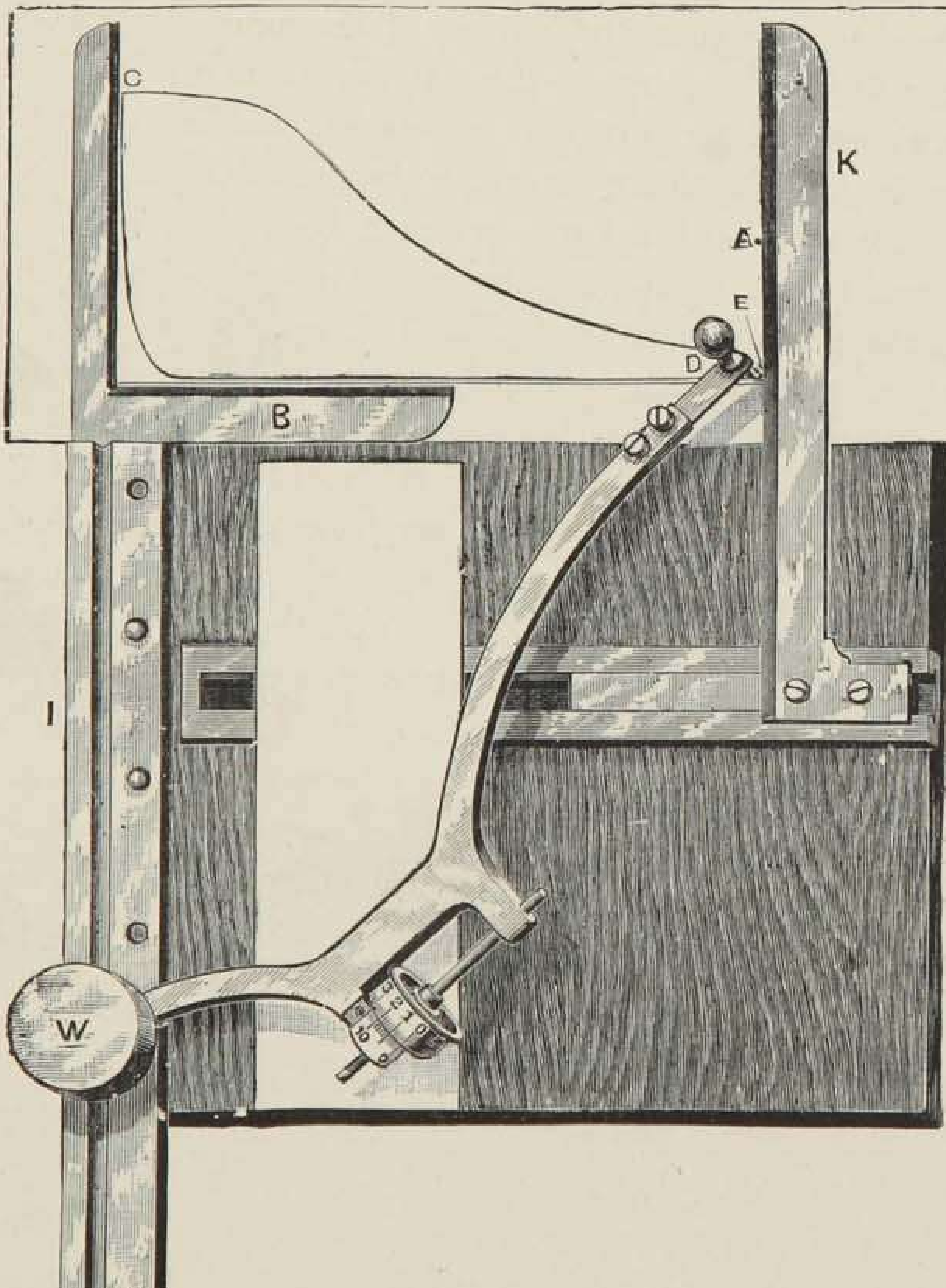


Fig. 101.

piston in square inches; and N the number of strokes per minute. Then $\frac{PLAN}{33,000}$ = indicated horse power (I.H.P.). A more accurate method is to employ an instrument known as Amsler's Planimeter, which is especially devised to facilitate the measurement of the areas of plane services. In like manner an instrument called Coffin's Averager may be employed, this being an improvement on the Planimeter. In each of these instruments the outline of the figure is traced by a pointer fixed in one arm of the instrument, and a small graduated wheel forming part of it is rotated, enabling a reading to be made. In the Coffin Averager the procedure is as follows: The indicator card is fixed on a flat board between the two clamps, and the pointer is then moved round towards the left from the point D, shown in Fig. 101, and is carefully drawn over the outline until D is again reached. Prior to the commencement of this operation the graduated wheel shown is set so that its zero mark and that on the vernier coincide. By the time the circuit of the figure has been made the wheel will have rotated a certain distance, and as soon as D is reached the pointer is pushed up vertically until the zero points again coincide. The point—say A—where this takes place is marked on the paper, and the instrument is then moved away. By the application of a special scale the distance from D to A, each point being marked by a slight indentation, is measured, the reading of the scale giving the mean pressure in lbs. per square inch. The reading on the wheel after the circuit of the figure is completed is the area in square inches of the diagram.

(344) The type of boiler which is most commonly employed in mill work in this country is that known as the Lancashire. This is a cylindrical vessel through which two or three internal cylindrical flues pass. As a rule, it is of large capacity, and under the circumstances of its employment is admirably adapted to produce steam at an economical rate. Preferences are shown in some parts of the world for some type of water tube boiler, but until quite recently the evaporative capacity of this has been inferior to the Lancashire With the increase of higher pressures it will, however, probably be found that some such form of boiler can be economically

employed, and as its construction slowly improves it will be of greater service yearly. The Lancashire boiler is at the present day working at 200lbs. pressure, so that it is capable of being serviceable at these high pressures. The shell of a Lancashire boiler is made of a number of parallel rings of iron or steel plates, the successive rings being fitted alternately within and without each other and riveted together. The plates are all planed on the edges, and are fastened together at their ends by means of short plates—called butt plates—covering the joint. These butt plates are secured to the plate on each side of the joint by rivets suitably pitched. The rings are riveted to those adjoining so as to complete the shell. It is not necessary to give a full description of the method of making a boiler, but it is desirable to give a few general details. The end plates are always in one piece, and sometimes flanged up to fit the shell, it being a common practice, however, to secure the plates to the shell by solid angle iron rings rivetted to it. The flues are built up of parallel rings, which should be welded at the ends of the plates, and it is customary and preferable to fit between each ring some form of an expansion joint. The end plates are stayed by means of gusset stays to the shell, and also by longitudinal stay bolts. If the boiler is made of steel, as is now usually the case, the steel must have a tenacity ranging between 26 and 30 tons per square inch, with an elongation of not more than 20 per cent in 10 inches. All holes should be drilled; those in the shell when the various plates are in position. All the blocks and stand pipes should be of steel and manhole covers of wrought iron or steel. The fittings must be of the best kind, and a dead weight safety valve is imperative. To go into further details will be trenching on the province of the boiler maker, but the student can easily ascertain the full details of construction. It has been found that under ordinary conditions a Lancashire boiler will evaporate from 8 to 10lbs. of water for each pound of coal consumed, the former amount being more often near the mark than the latter. The coal consumption is about 15lbs. per square foot of grate, using coal of the ordinary class employed in Lancashire. An evaporation of from 120 to 150 lbs. of water per square foot of grate is permissible. The evaporation of 30 lbs. of water per hour, when the water is at boiling point on entering a boiler in which a pressure of 70 lbs. is maintained, is considered to be equal to 1 H.P. The ratio of the heating and grate areas is an important one, and varies in accordance with the method of setting the boiler. The grate area should never be less than $\frac{1}{10}$th that of the heating surface. By ascertaining the consumption of steam in the engine it is easy to calculate the power of the boilers required. Generally it has been the practice to use a natural or unaided draught in mill boilers, but sometimes forced draught is employed by creating a pressure in the ashpit below the grate by closing it and using a blower of some type. Of course in this case an economy of fuel can take place. In setting a boiler it is desirable to avoid giving an undue area of flues below it, while at the same time giving an ample space to avoid any interference with the free flow of the gases. At the same time it is always desirable to let the gases travel at a slow velocity through the flues, which should be large enough to permit of easy access for repairs. In arranging the flues it should be remembered that the gases require to flow without hindrance, so that all obstructions should be avoided, from design or otherwise. As it is good practice to fix an economiser, or feed water heater, of the Green type behind the boilers for the purpose of heating the feed water prior to passing it into the boiler, it is necessary to make provision for fixing it. It is recommended that four pipes be fixed for each ton of coal consumed, or one pipe for each 3 I.H.P. The chimney used requires carefully proportioning. The length of the horizontal flues coupled to it have an influence upon its proportions, and these are affected by several other circumstances. Taking the consumption of air at 230 cubic feet per lb. of coal—which quantity may be exceeded or not according to circumstances—and assuming that 15 lbs. is burned per square root of grate area, then 3,450 cubic feet of air is required for that area. To this must be added the volume of gases evolved and passed away unconsumed. It should be remembered that provided a sufficient draught is caused, the slower the velocity of the current the better. The area of a chimney in its smallest point depends upon its height, and can be deduced from either of the following rules :—

$$\frac{2 \times 112 \times \text{cub. ft. water evaporated per hour}}{\sqrt{\text{height in feet.}}} = \text{area in sq. ins.}$$

$$\text{Area in sq. ft.} = \frac{1 \cdot 5 \times \text{area of firegrate.}}{\sqrt{\text{height of chimney in feet.}}}$$

The last rule is based on a consumption of 21 lbs. of coal per square foot of grate. There are many other circumstances affecting this matter, such as the length of the flues and the quantity of fuel burnt. The height of a chimney is variously stated, and no empirical rule can be given, but assuming it to be 30 yards high when 1,000 lbs. of coal per hour are used, 6 yards may be added for each additional 1,000 lbs. burnt. The higher it is built the greater the allowable consumption of coal per hour. The foundation for a chimney ought to be carefully chosen and prepared, and its thickness ample. The shaft must be tapered to the extent of 1 inch in each yard of height, and the lower portion should be lined with fire-brick. There is in many cases a good deal of incrustation formed in boilers which can be removed, and for which many specifics are sold. These are not equally suitable for all cases, and the following general hints will be serviceable. For carbonate of lime, add caustic soda in the proportion of 3 grains for each 4 of the lime contained ; for sulphate of lime, 4 grains of soda ash for each 5 grains in the water. If both sulphate and carbonate are found, the caustic soda will suffice to precipitate both. The soda should be mixed prior to forcing into the boiler. The student who desires fuller information on the subject of the appliances used in the production and employment of steam can be referred to the numerous text-books existing, as it has only been the aim of the author to give a general description of the various parts. Space will not permit a longer treatment of this portion of the subject, although it is very tempting. What has been attempted to do is to give such general information as is likely to be useful in daily practice.

(345) Having thus dealt with the various points relating to the production of power, we now come to consider the question of its transmission. There are three ways of doing this, by toothed wheel, belt, or rope gearing, in which order they will be treated. On the crank shaft of the engine is fastened a wheel or pulley which forms the first in the train of gearing transmitting the power. This wheel is, in the first class of transmitting machinery, toothed, and gears into a pinion on a shaft called the second motion shaft, from which the rest of the mill is driven. This is usually done by fixing on the end of the second motion shaft a bevel wheel gearing with a similar wheel on an upright shaft passing upwards through all the floors of the mill, and driving, in each room, by means of similar wheels, a line shaft transmitting the power to the machines in that room. The chief fault of this method of transmission lies in the enormous weight of the upright shaft, which it is necessary to sustain by one bearing or footstep placed at its foot. Owing to the great pressure on the step and the difficulty of lubrication considerable wear takes place, which naturally alters the vertical position of the shaft. As bevel wheels only work well when their pitch lines touch each other during the rotation of the wheel, their teeth being designed with this object, it follows that the destruction of this, the true position, gives rise to a noisy and ineffective drive. It has been found, however, that by a carefully designed footstep the wear can be reduced to a minimum. The pressure upon the bearing should not be greater than 600 to 800lbs. per square inch, and the footstep should be constructed so as to form a chamber, which can be filled with oil. By fitting within this chamber a number of—say four—washers one above the other, which are free to revolve, and are always immersed in oil, the

grinding friction is practically nil. The upper washer should be phosphor bronze, or some other equally good bearing metal, the next one steel, and so on. Bearings of this character within the author's personal knowledge have worked for many years without any serious wear developing. Further, care should be taken in arranging the upright shaft and the line shafts driven from it to see that they are thoroughly supported by ample bearings, which should be capable of adjustment in the event of wear. It is highly important that the wheels should be kept in their true working position, and that they should neither be too little or too much in gear. During recent years there has been a tendency towards a change in the mode of constructing wheel teeth. The total length of spur wheel teeth has commonly been ·75 of the pitch, ·35 of this having been above the pitch line. This has left a long tooth with much of it disengaged when working perfectly, but often grinding when wear has occurred. Mr. Michael Longridge, however, has demonstrated that a shorter tooth is much to be preferred for all main driving wheels, and recommends a tooth not longer than ·35 of the pitch. Two examples of the form of tooth recommended by him are given in Figs. 102 and 103, and many engineers have adopted it with considerable success. With regard to the employment of what are known as double helical teeth, so far as the author's observations go, they lead him to the opinion that their use is undesirable, it being very difficult to get the true form by any of the ordinary processes of moulding. The power transmitted by wheels is in a direct ratio to the velocity of the pitch circle, which it is necessary to limit, to avoid the bursting strains created by centrifugal action. The horse-power of wheels can be obtained by multiplying together the square of the pitch in inches, the width of the teeth in inches, the diameter of the wheel in inches, and the number of revolutions per minute, and dividing by 33,000. Molesworth's rule is $0·6\ P^2\ V$, where $P =$ pitch and $V =$ the velocity. The rule given by Messrs. John Musgrave and Sons, Limited, of Bolton, is as follows: If $P =$ circumferential pitch in inches; B = breadth of tooth in inches; V = velocity of pitch line in feet per minute; then

$$H\,P = \frac{P^2 \times B \times V}{1000} \text{ for cast iron.}$$

$$= \frac{P^2 \times B \times V}{625} \text{ for cast steel.}$$

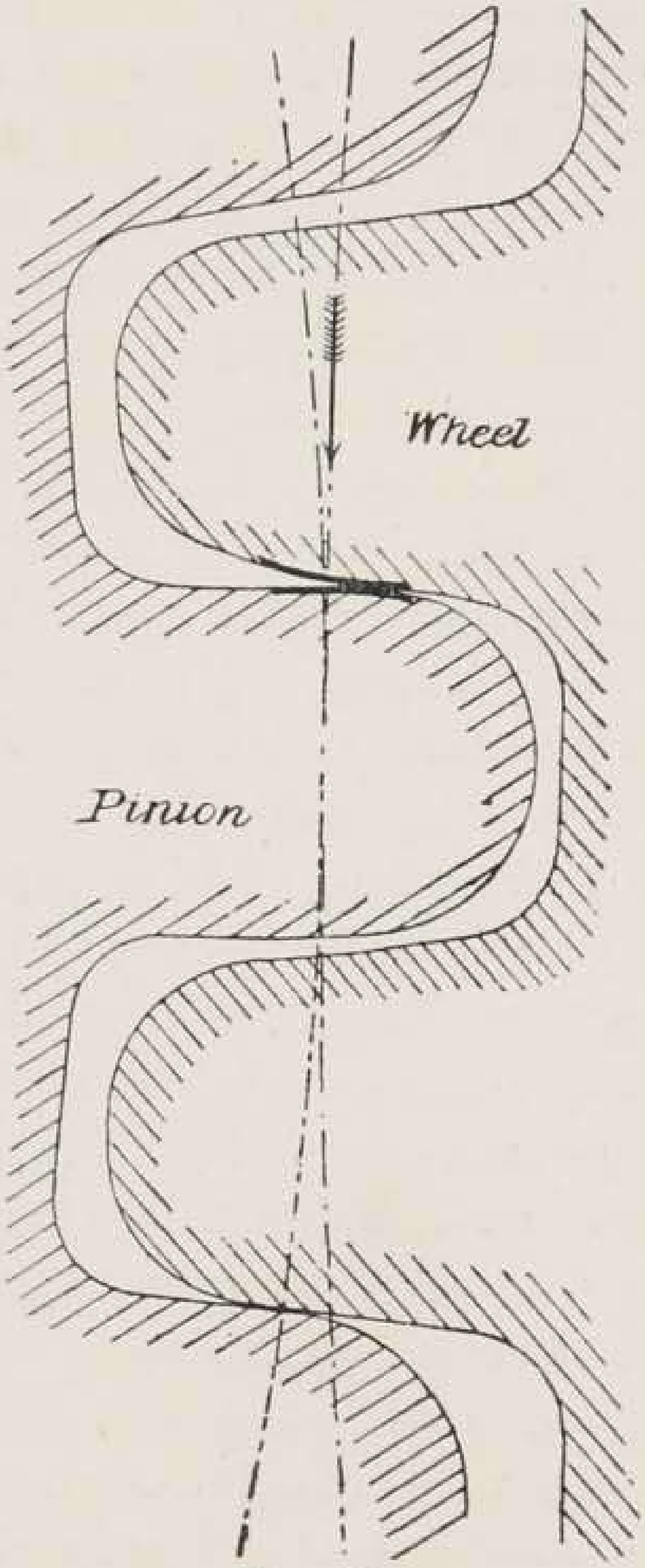


FIG. 102.

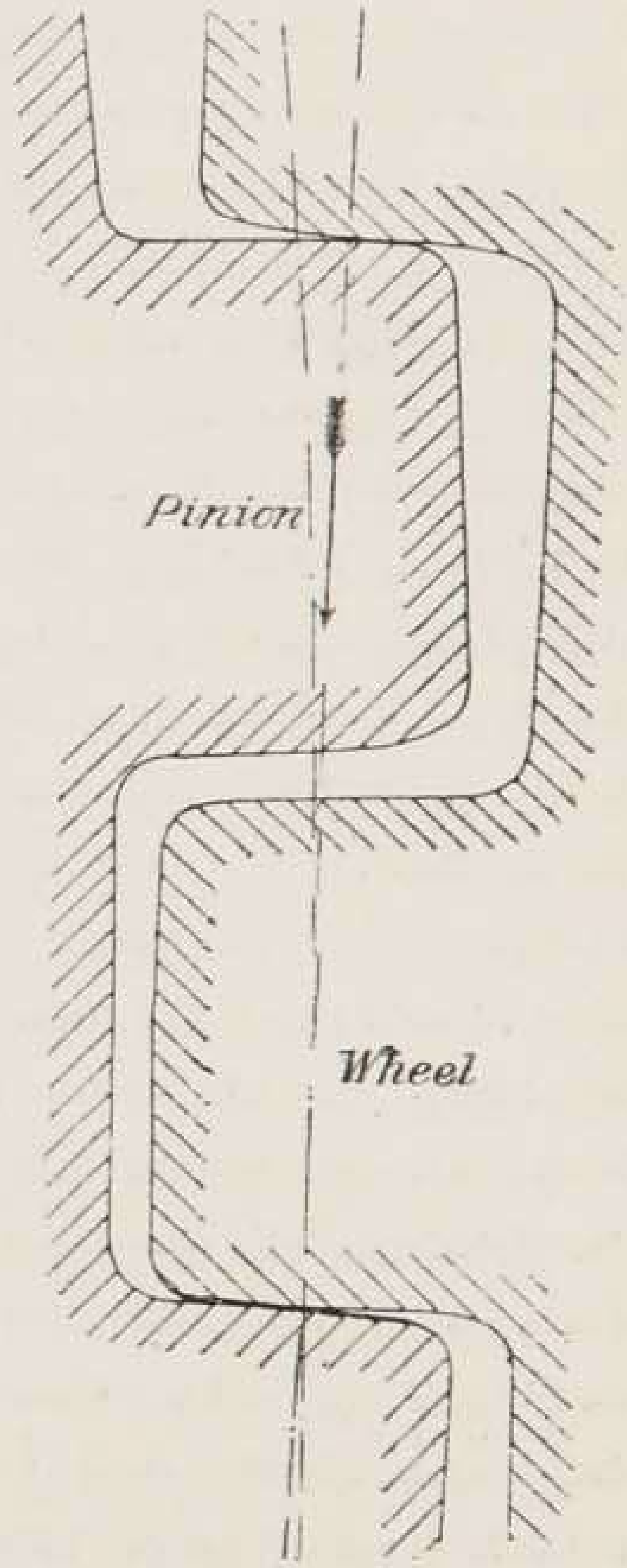


FIG. 103.

Hutton's rule is, where D = diameter to pitch line in feet, W = width of teeth in inches, P = pitch in inches, and N = number of revolutions per minute.

$$HP = \frac{P^2 \times W \times D \times N}{240}$$

Before leaving the question of toothed wheel driving, it may be said that it is not always the practice to take off the power within the mill by wheels. In some cases the power is transmitted from the second motion shaft by a belt or ropes. If such a plan is adopted, it requires to be carefully considered; as otherwise, a good deal of backlash will be set up in the wheels, which is very destructive of them.

(346) The second method of driving is by means of leather, cotton, or canvas belts, but although this has been widely adopted in the United States, it has never become popular in this country. In transmitting power by this method it is usual to place upon the crank shaft a large pulley prepared for the reception of one or more belts of considerable width, afterwards sub-dividing the transmission by smaller belts driving the main shaft in each room. As all belts have to be jointed, the strength which is available is that of the joint only. This is estimated to be from 250lbs. to 500lbs. per inch in width, according to the character of the joint, but in allowing for the working strains much less than this is taken. A cemented joint, which is the best, has recently been stated by Mr. Henry A. Mavor to be equal to 842lbs. per inch in width, but this is much higher than the average strength. The working strain of a good single leather belt can be taken at about 60lbs. for each inch of width, and that of a double belt about 60 per cent more. It is always preferable to make the underside of a belt the driving side, because the "sag" of the top side increases the arc of contact of the belt with the driven pulley. In making a joint by the ordinary methods, an overlap of about twice the width should be given up to 3 inches wide, from 6 to 8 inches, with belts from 3 to 8 inches wide, and $1\frac{1}{4}$ times the width, with belts wider than 8 inches. Rules for calculating the power vary a good deal in their results, giving powers varying as much as 4 to 1, but the following are accepted for single belting. V = velocity in feet per second; W = width in inches, then $H\ P = \frac{V \times W}{1100}$. Or, if

F = driving force, which can be obtained by the use of the following formula, where W = width and T the working strain :— $F = \frac{W \times T}{2}$, then $H P = \frac{V \times F}{33,000}$. A rule given by a large firm of belting manufacturers, which has at least the merit of simplicity is, 1 H.P. per inch of width at a speed of 1,000ft. per minute, and Messrs. Harper, of Aberdeen, give the following approximate powers for single belting per 100ft. of velocity :—

3, 4, 5, 6, 7, 8, 9, 10, 12, 15, 18 inches wide.
$\frac{3}{8}$, $\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, $\frac{7}{8}$, 1, $1\frac{1}{8}$, $1\frac{1}{4}$, $1\frac{1}{2}$, $1\frac{7}{8}$, $2\frac{1}{4}$, H.P.

For double belts the rule is to multiply by $1\frac{1}{2}$. Professor Unwin's rule is that a belt 1 inch wide, running 800 feet per minute, with an arc of contact of 180°, will give 1 horse power. Professor Thurston's rule is $W = \frac{7,000 \times H P}{S \times V}$ where S = surface of smaller pulley covered by belt. There are a large number of rules for this purpose, and the results obtained by their use vary as much as 6 to 1. Those given are, however, generally accepted as being most accurate. The diameters of the pulleys used have a great influence upon the power transmitted, as the relative arc of contact of the belt and pulley increases or diminishes the slip. The diameters of the driving and driven pulleys should never be in a greater ratio than 6 : 1, and the distances apart should be regulated according to the ratio. It is always preferable to give a little convexity to the surface of the pulleys used, as this keeps the belt in the centre of the pulley. The usual amount given varies, but $\frac{1}{4}$in. per foot of width gives satisfactory results in most cases; the amount per foot being slightly less in wide pulleys. In determining the velocity of heavy belts, regard should be paid to centrifugal force, which, after a velocity of 3,500ft. is reached, tends to reduce the power transmitted by the amount required to overcome it. In certain cases perforation of the periphery of a pulley improves the driving, but the same result is got from the employment of link belting. The latter form, however, has the disadvantage of being heavy, and so being subjected to a reduction of the power transmitted by centrifugal force at a lower velocity than ordinary belting. Leather belts require a good deal of care. If working in a dry atmosphere they may be treated on their outer surface with a dressing of castor oil, but no resin or any sticky material should be applied to them, especially to the working faces.

(347) The third form of gearing employed is transmission by ropes. In this mode there is fixed upon the crank shaft a large pulley with its periphery grooved for the reception of one or more ropes. In drives where the aggregate horse-power transmitted is large, there are a large number of grooves used, As many as 67 have been formed, 40 being common. It is customary to build up the pulleys for large powers in the manner common to all large sized driving wheels, the boss, arms, and rim being cast separately, thus avoiding the internal strains otherwise created. In common practice it is the rule not to build up rope pulleys until a diameter of 12 feet is exceeded, and the number of segments employed in larger wheels differ in exact accordance with the size of the wheel, although there is a divergence in the practice of even good makers. In determining the size of pulleys used it is taken as a general rule not to make any of them less in diameter than thirty times the diameter of the rope ; but there are many pulleys at work successfully in which the ratio is much smaller. The distance between the centres of the driving and driven pulleys should be as long as convenient. In English practice, where it is the custom to make each rope independent of all the others, it is desirable that the rope should, while maintained in a proper degree of tension, be free to "sag" between the pulleys. If possible the rule which is recognised as sound in belt driving should be observed, viz., to let the lower side be the driving side, the reason in each case being the increase in the arc of contact which follows. In arranging the position of the driving and driven pulleys, care must be taken that a line drawn through

the centres of the crank shaft and the highest driven shaft shall not be more than 45° above the horizontal. This is shown in Fig. 104, which is an actual example of a drive on a reduced scale. The full advantage of the downward pressure is thus obtained, and a moderate tension is sufficient, whereas, if a higher position is assumed the tension must be proportionately increased. In designing the groove, it is arranged that between the two sides an angle of 45° is enclosed, as

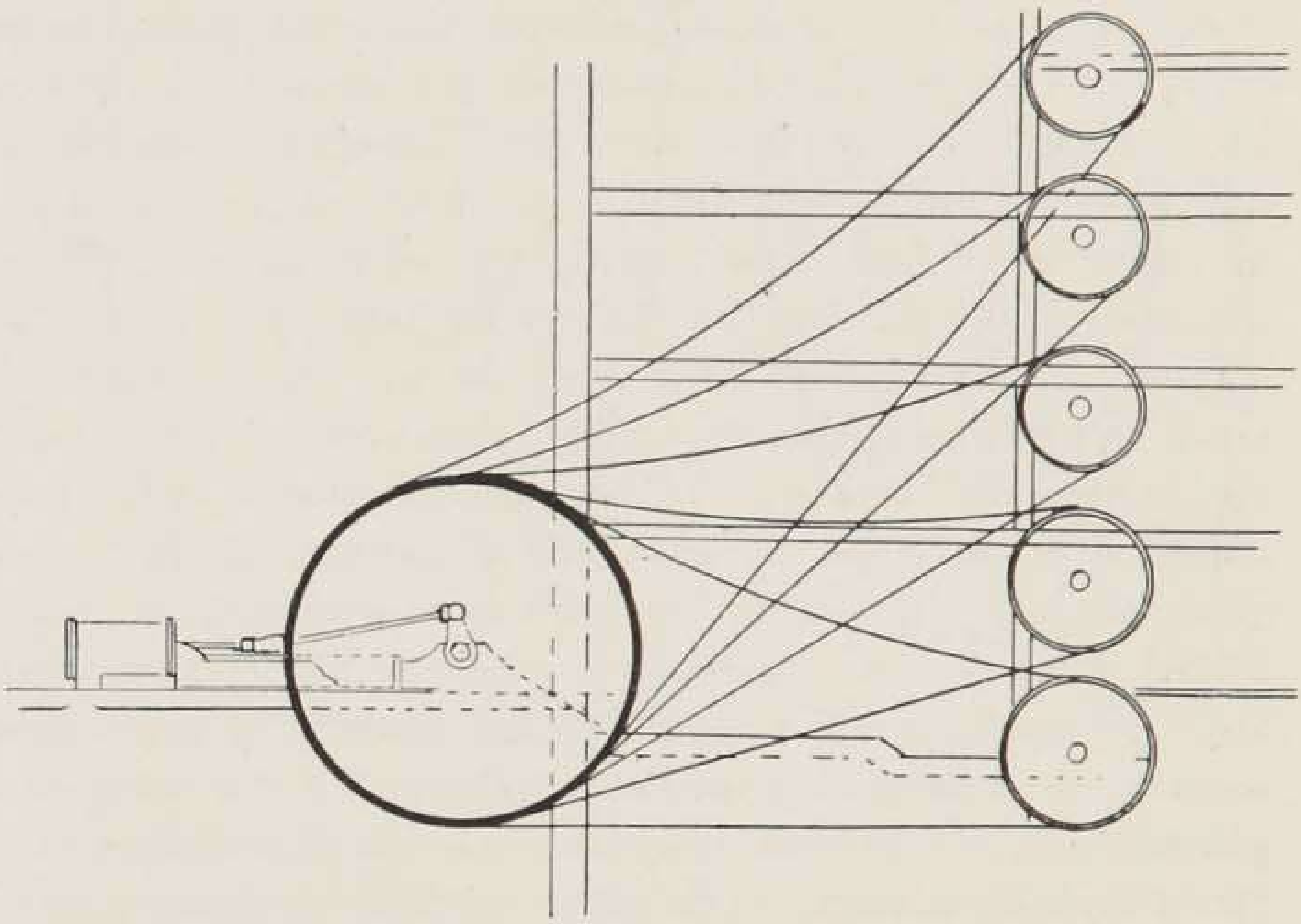


FIG. 104.

shown in Fig. 105. Some makers prefer an angle of 40° as being less liable to wedging. The depth of the groove is great enough to avoid all chance of the rope reaching the bottom, which is rounded to the curve the radius of which is marked R. Above the bearing portion of the groove its sides are also slightly inclined, so that the mouth of each groove is a little wider than at the commencement of the angular portion. It should, however, be noted that although the sizes about to be given are those in common practice, yet it is always better to fit the ropes carefully to the grooves, as unless the bearing takes place properly loss of power will result. Almost every maker's groove varies, and it is in consequence very difficult to fit the ropes. In one case the side of the groove presents a slight elevation about the point where the rope fits. The experience

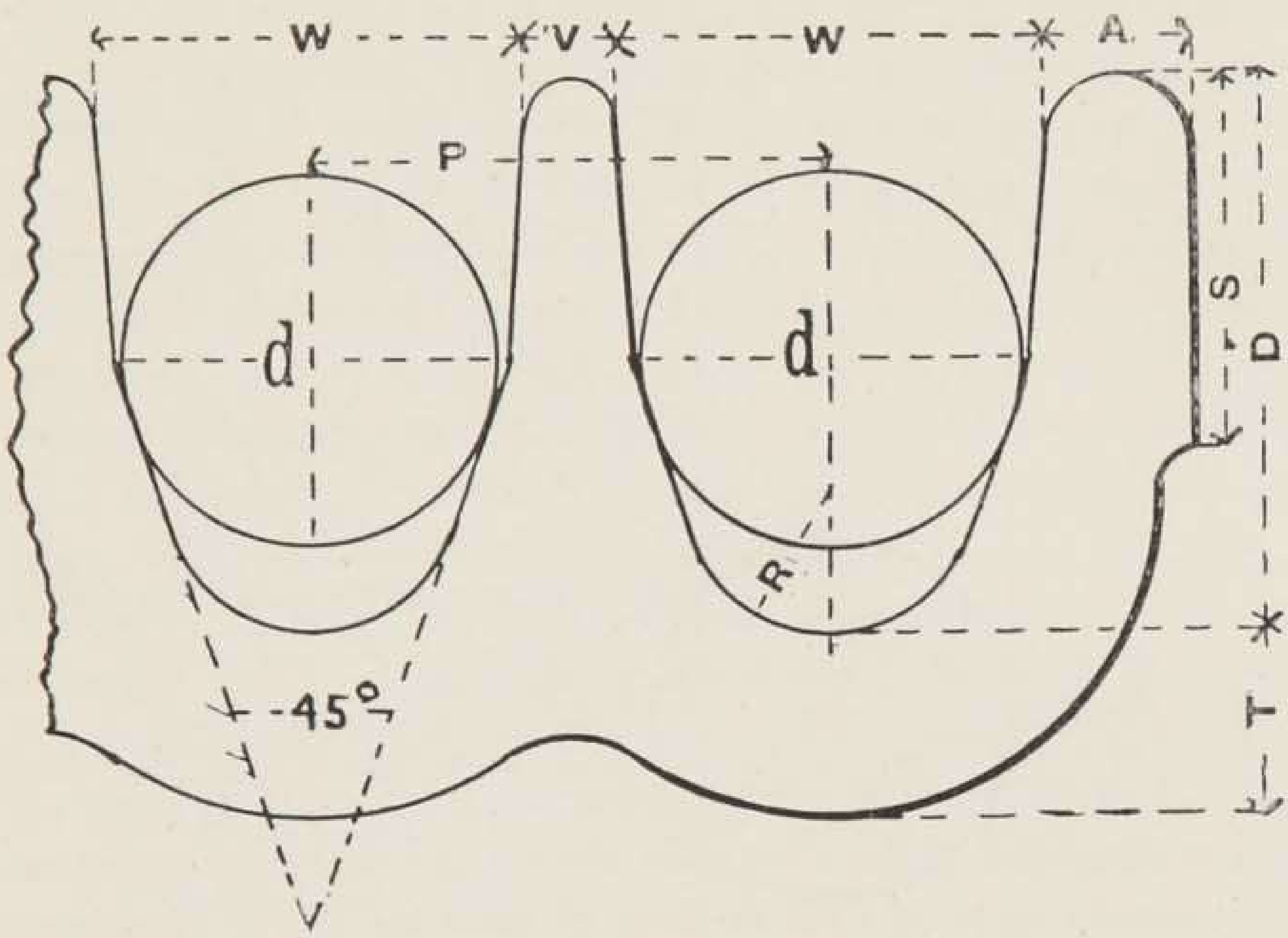


FIG. 105.

gained with scroll bands in driving mules shows that a slight concavity at the point named is not without some advantage. The following formula give the principal dimensions of the various parts of the groove. Let d = diameter of rope in inches; P = pitch of grooves; D = depth of grooves; R = radius of bottom of groove; W = width of mouth of groove; V = thickness of flange between inner grooves; A = thickness of outer flange; S = depth from tip of outer flange to shoulder; and T = thickness through bottom of grove.

Then $P = 1\frac{1}{4}\ d + \frac{1}{4}$in. or $+ \frac{5}{16}$in.
$D = 1\frac{1}{4}\ d + \frac{1}{8}$in. or $+ \frac{1}{4}$in.
$R = \frac{3}{8}\ d$; and $W = d + \frac{3}{16}$ or $+ \frac{5}{16}$.
$T = \frac{1}{2}\ d$; and $A = \frac{1}{3}\ d + \frac{1}{16}$.
$S = d$; and $V = \frac{1}{4}\ d$.

From these formulæ can be constructed the following table which will give sufficiently accurate data of the principal dimensions, the smaller sizes being taken.

Diameter of Rope = *d*. Inches.	P in.	D in.	R in	W in	T in.	A in.	V in.	S in.
1	$1\frac{1}{2}$	$1\frac{3}{8}$	$\frac{3}{8}$	$1\frac{3}{16}$	$\frac{1}{2}$	$\frac{7}{16}$	$\frac{5}{16}$	1
$1\frac{1}{4}$	$1\frac{13}{16}$	$1\frac{11}{16}$	$\frac{15}{32}$	$1\frac{7}{16}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	$1\frac{1}{4}$
$1\frac{3}{8}$	2	$1\frac{7}{8}$	$\frac{1}{2}$	$1\frac{9}{16}$	$\frac{11}{16}$	$\frac{9}{16}$	$\frac{7}{16}$	$1\frac{3}{8}$
$1\frac{1}{2}$	$2\frac{1}{8}$	2	$\frac{9}{16}$	$1\frac{11}{16}$	$\frac{3}{4}$	$\frac{9}{16}$	$\frac{7}{16}$	$1\frac{1}{2}$
$1\frac{5}{8}$	$2\frac{1}{4}$	$2\frac{1}{8}$	$\frac{5}{8}$	$1\frac{13}{16}$	$\frac{13}{16}$	$\frac{5}{8}$	$\frac{7}{16}$	$1\frac{5}{8}$
$1\frac{3}{4}$	$2\frac{1}{2}$	$2\frac{3}{8}$	$\frac{21}{32}$	2	$\frac{7}{8}$	$\frac{5}{8}$	$\frac{1}{2}$	$1\frac{3}{4}$
$1\frac{7}{8}$	$2\frac{5}{8}$	$2\frac{1}{2}$	$\frac{11}{16}$	$2\frac{3}{32}$	$\frac{15}{16}$	$\frac{11}{16}$	$\frac{17}{32}$	$1\frac{7}{8}$
2	$2\frac{3}{4}$	$2\frac{5}{8}$	$\frac{3}{4}$	$2\frac{3}{16}$	1	$\frac{3}{4}$	$\frac{9}{16}$	2

The character of the rope used is a matter of some importance. In the early days of this method of drawing it was customary to use hemp or Manilla ropes, but modern practice—in this country, at any rate—runs decidedly in favour of cotton ropes. Experience shows that well-made cotton ropes properly cared for will run for ten or twelve years without any difficulty. The "Lambeth" cotton rope, which is specially made with four strands, each of the four strands having a protecting envelope of tightly-twisted yarn, is a good example of what can be done in this respect. Mr. Kirkaldy, the well-known expert in the testing of materials, has made a large number of breaking tests of several classes of driving ropes made of manilla, hemp, and cotton with three and four strands. Strength is not the only quality required in a driving rope. It is quite as important that flexibility and resistance to extension should exist, the latter especially, as it is obvious that if a rope extends it will diminish in diameter, which, as will be shown, is fatal where each rope is independent. No class of rope possesses these qualities to so great an extent as cotton ropes, which are therefore to be preferred for that reason. Ropes, as every spinner knows, are sensible to the influence of atmospheric changes, and their tension is materially affected thereby. After a stoppage, such as occurs at the end of the week, the ropes will tighten themselves and recover some of the stretch. It is therefore clear that if the rope is possessed of this elastic quality it is much more advantageous in use. The power of recovery is highly important, and is not always to be found. The following are Mr. Kirkaldy's tests of Lambeth ropes :—

Circumference.	Weight per Fathom.	Ultimate Stress Exerted.	Stress per Fathom Weight.					
			500 lbs.	1000 lbs.	1500 lbs.	2000 lbs.	2500 lbs.	3000 lbs.
in.	lbs.	lbs.	Ext'sion. Per Cent.	Ext'sion. Per Cent.	Ext'sion. Per Cent.	Ext'sion. Per Cent.	Ext'sion. Per Cent.	Ext'sion. Per Cent.
4·86	3·93	9,722	5·36	9·02	12·68	15·06	—	—
5·51	5·05	12,639	7·46	12·22	15·64	18·62	20·92	—

It is to be noted that with the release of the stress the ropes showed no permanent set. Further, the working strain at no time approaches anything like the stress exerted in the test, so that the extension is not likely in actual work to require consideration. Messrs. Wm. Kenyon and Sons, of Dukinfield, make an excellent three strand rope, the distinguishing feature of which is that by a peculiar process of manufacture, they are able to get an even tension on every thread. In addition to this, every thread occupies throughout the whole length of the rope, the same position, so that the line of pull is constant, and wear simply exposes a new, but equally well laid surface. The breaking stress on a $1\frac{1}{4}$ inch rope of this make has been stated by Mr. Kirkaldy to be 12,017lbs.

(348) We now come to consider the power exerted by ropes. This is affected mainly by two considerations, viz., their speed and weight. It will be obvious that the higher the velocity attained the greater the strain on the rope, and that the lighter the rope, consistently with its power to receive a working strain, the less loss there is from centrifugal force. The strains upon a rope are, therefore, threefold, and arise from the power exerted, centrifugal force, and the loss arising from the resistance of the air and the bending and straightening of the ropes. It is obvious that the smaller the diameter of the rope the less the loss will be from each of these causes; first, because of the lesser surface presented to the air; and, second, because of the smaller diameter. This will, of necessity, affect any formula calculated on an equal allowance for all sizes. The action of centrifugal force is to induce a movement in the rope which causes it to have less grip or adhesion in the groove of the pulley, and is precisely the same action as that which induces "creep" in an ordinary driving belt. In endeavouring to estimate the amount of strain due to this cause, it is usual to ascertain the gross working strain of the rope. Thus, assuming, as has been done in one case, that the ultimate strain on a well made cotton rope is 9,000lbs. per square inch, the working strain is usually estimated at from 3 to $3\frac{1}{2}$ per cent of this. In the case of a rope 4·86 inches circumference or 1·5463 diameter, the area is 1·853, and the strain on this would be 16·677. A safe working strain for that rope would be 555lbs. It is necessary to allow for the loss previously named, 20%. The centrifugal force is in direct ratio to the square of the speed and is calculated as follows:—

$$\frac{\text{Speed in feet per second}^2 \times \text{weight of one foot of rope.}}{32.}$$

Having got these two allowances, which must be made from the total working strain on the rope, it becomes easy to calculate the horse power given off. Thus, if the rope be assumed to be $1\frac{1}{2}$in. diameter, with an area of 1·767, the breaking strain would be 15,903lbs., and the gross working strain is 530lbs. Deducting from that 20 per cent we get a strain of 424lbs. The centrifugal force at 4,500 feet per minute, if the weight of rope is 0·74lb. per foot, is $\frac{75^2 \times \cdot 74}{32}$ = 130. The mean effective working strain is, therefore, 294lb. The rule to calculate the power is then the same as the case of belts. V = velocity in feet per minute; S effective strain, then $\frac{V \times S}{33,000}$ = H.P. Applying this formula to the case supposed, we get $\frac{4,500 \times 294}{33,000} = 40 \cdot 1$. This calculation is only given to illustrate the method of arriving at the result, and it may be supplemented by assuming the acceleration of the velocity of the rope until its speed is 6,500. Then the centrifugal force is $\frac{108^2 \times \cdot 74}{32} = 269$, and the effective working strain is reduced to 155lbs. The power transmitted is, therefore, $\frac{6,500 \times 155}{33,000} = 30 \cdot 5$, so that there is a point at which the results obtained are less favourable in spite of the increased velocity than those at a lower speed. With a rope of the weight named the best velocity is from 4,300 to 5,100 feet per minute, at which the horse power transmitted is respectively 40·11 and 40·03.

The procedure just illustrated is undoubtedly the most correct way of ascertaining the horse power of ropes, but it will be noticed that it rests upon an assumed maximum working strain. The breaking stress given—9,000 lbs. per square inch—is a very high one, and it is hardly a safe thing to make a calculation on such a basis as that stated. There is a singular lack of data of the breaking stresses of cotton ropes, but such as there are do not establish so high an efficiency. The matter is one rather for an ascertained working strain than an assumed one, and the strength of the rope is mainly instrumental in the prevention of extension. It may be worked with advantage at a low tension. It is therefore clear that if calculations be made upon the assumption of the higher strength they may very easily be misleading. In the absence of precise information as to the ultimate strength of any rope which is used, it is desirable in calculating the number of ropes required for an installation to err on the side of caution. It is a matter of easy proof that few ropes are worked to the powers which are obtained from the figures which have been used in the calculations just made, and in the majority of cases the powers transmitted are a considerable percentage below these. It is well known that the various rules given to calculate the power of leather belts yield widely divergent results, and a similar thing occurs with ropes. For these reasons it is desirable that the calculation made shall give a reserve of power instead of being actually equal to the full power transmitted. For instance, the "Lambeth" rope is lighter than the majority of ropes used, the weights being as follows :—

Diameter in inches	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{5}{8}$	$1\frac{3}{4}$	$1\frac{7}{8}$	2
Weight per foot in lb..........	·27	·37	·45	·54	·62	·72	·79	·91	1·04
	ozs.	lb.oz	lb.oz	lb.oz	lb.oz	lb.oz	lb.oz	lb.oz	lb.oz
Weight per yard................	13	1 2	1 6	1 10	1 14	2 3	2 6	2 12	3 2

If the powers transmitted by this rope are calculated on the basis of the breaking strain of 9,000lbs per square inch and an effective strain of 300lbs, it will be found that an $1\frac{3}{4}$ inch rope at a speed of 5,000 feet will transmit 61·5 horse power. Experience shows this to be too great, and it is therefore necessary not to overstate the breaking strain. There is, however, in regard to this matter, one thing which may be said, namely, that under some circumstances ropes will give extraordinary powers. For instance, Messrs. Kenyon give an instance of a rope $1\frac{3}{4}$ inch diameter transmitting at 7,040 feet per minute 93 H.P. It must, of course, be under a very high working strain. After a good deal of investigation and comparison of actual examples the author has come to the conclusion that a working tension of 200 lbs. to the square inch gives the best results.

Speed per minute in feet.	Diameter of Ropes in Inches.								
	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{5}{8}$	$1\frac{3}{4}$	$1\frac{7}{8}$	2
	Horse Power Transmitted.								
2500	10·8	13·4	16·7	20·5	24·3	28·5	33·2	38·1	43·4
2600	11·1	13·9	17·2	20·8	25	29·4	34·1	39·4	44·7
2700	11·4	14·3	17·7	21·7	25·7	30·2	35·3	40·6	46
2800	11·8	14·7	18·2	22·3	26·4	31	36·2	41·7	47·3
2900	12·1	15·1	18·7	22·9	27·1	31·9	37·2	42·8	48·6
3000	12·3	15·4	19·1	23·4	27·8	32·6	38·1	43·8	49·5
3100	12·5	15·7	19·5	24	28·4	33·4	39	44·8	50·6
3200	12·9	16·1	19·9	24·5	29	34	39·9	45·8	52
3300	13·2	16·5	20·3	25	29·6	34·8	40·8	46·8	53·2
3400	13·4	16·7	20·6	25·5	30·1	35·4	41·6	47·7	54·3
3500	13·6	16·9	20·9	26	30·6	36·2	42·3	48·6	55·2
3600	13·9	17·1	21·2	26·4	31·1	36·5	43	49·5	56
3700	14·1	17·3	21·5	26·8	31·5	37·1	43·6	50·2	56·8
3800	14·2	17·5	21·7	27	31·9	37·5	44·2	50·8	57·6
3900	14·4	17·7	21·9	27·3	32·2	37·9	44·8	51·4	58·2
4000	14·5	17·8	22·1	27·5	32·6	38·4	45·3	51·9	58·9
4100	14·6	17·9	22·3	27·8	32·9	38·7	45·8	52·4	59·6
4200	14·7	18	22·5	28	33·1	39	46·3	52·8	60·3
4300	14·8	18	22·6	28·1	33·3	39·3	46·6	53·2	60·6
4400	14·9	18·1	22·7	28·2	33·4	39·6	46·8	53·5	60·9
4500	15	18·1	22·7	28·3	33·5	39·7	47	53·8	61·2
4600	15·1	18·1	22·7	28·4	33·6	39·7	47·2	54	61·4
4700	15·1	18·1	22·6	28·4	33·7	39·8	47·4	54·2	61·5
4800	15·1	18	22·6	28·5	33·7	39·8	47·5	54·2	61·5
4900	15	18	22·5	28·5	33·7	39·9	47·6	54·3	61·6
5000	15	17·9	22·4	28·4	33·6	39·8	47·5	54·3	61·5
5100	14·9	17·8	22·3	28·3	33·4	39·6	47·4	54	61·3
5200	14·8	17·6	22	28·2	33·2	39·3	47·2	53·8	61·1
5300	14·7	17·4	21·8	28·	33	39	47	53·6	60·9
5400	14·6	17·2	21·6	27·7	32·7	38·6	46·8	53·3	60·4
5500	14·5	17	21·3	27·3	32·3	38·2	46·1	52·8	59·8

From this must be deducted the loss from centrifugal force, which cannot be left out of the account, but the factor of safety, if 200lbs. per square inch, is sufficient to cover all other sources of loss. While it is possible that a higher tension can be used, the question of the life of the rope must be considered, and from this point of view experience has shown that a working tension of 200lbs. is entirely satisfactory. The table of powers developed, given on page 446, is founded upon this figure, and will be found to be reliable and in accordance with the best practice. It will permit of the development of powers somewhat in excess, if absolutely required. The remarks made a little earlier about the bending and air resistance should also be remembered.

There are a few more points to be dealt with before concluding this portion of the subject. It is of great importance that the splice should be properly made. Mr. Hart, the maker of the "Lambeth" rope, has favoured the author with the three illustrations given in Figs. 106, 107, and 108. In making rope slings, and for similar purposes, the splice shown in Fig. 106 is used. In making it the free ends of the rope are untwisted for a short distance, and are then interlaced in regular sequence several times. A splice of this nature inevitably leaves a small enlargement in the rope, which is quite inadmissible in rope driving. Even in the case of the rigging of ships or in lifting tackle, when it is desired to pass the rope through the blocks, a long splice like that shown in Fig. 107 is employed, and it practically leaves the rope of one thickness. Each end is unlaid for about 5ft. or 6ft., and the ends are then interlaid as in the preceding instance, with the difference that the splice is made in sections, and although a regular sequence is followed, the three or four strands are spliced in different places. The rope is thus kept of practically the same thickness throughout. One of the strands is unlaid for the required length about 4ft., keeping the turn in it, and the corresponding strand on the other hand having been similarly unlaid is placed in the vacant place, and the two are then tied. No. 2 strand is then dealt with, but not until No. 3 has been similarly treated to No. 1, but only about 18in. is required for No. 2. Nos. 2 and 4 are then laid up like Nos. 1 and 3, but in the opposite directions. The portion of the strands remaining unlaid are

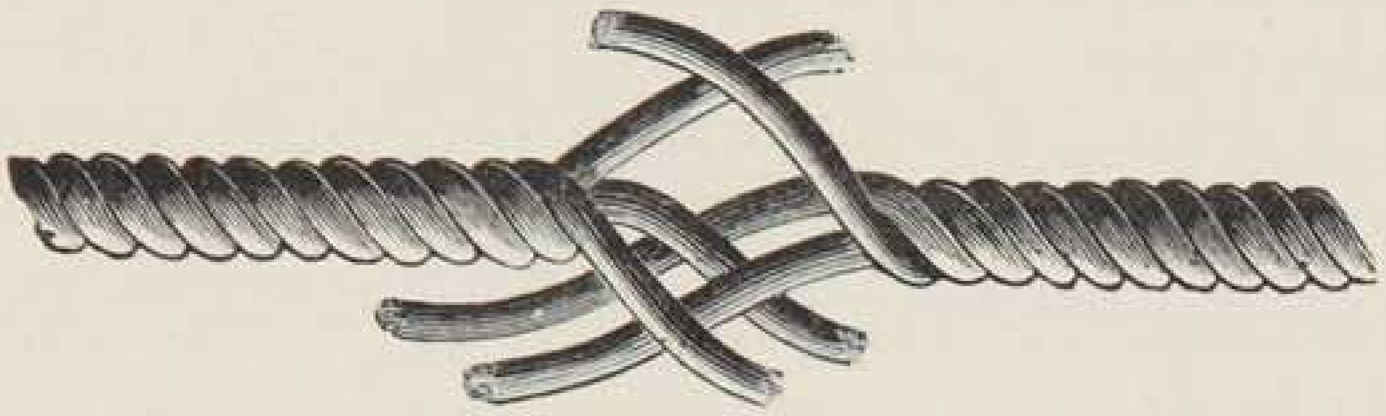


FIG. 106.

FIG. 107.

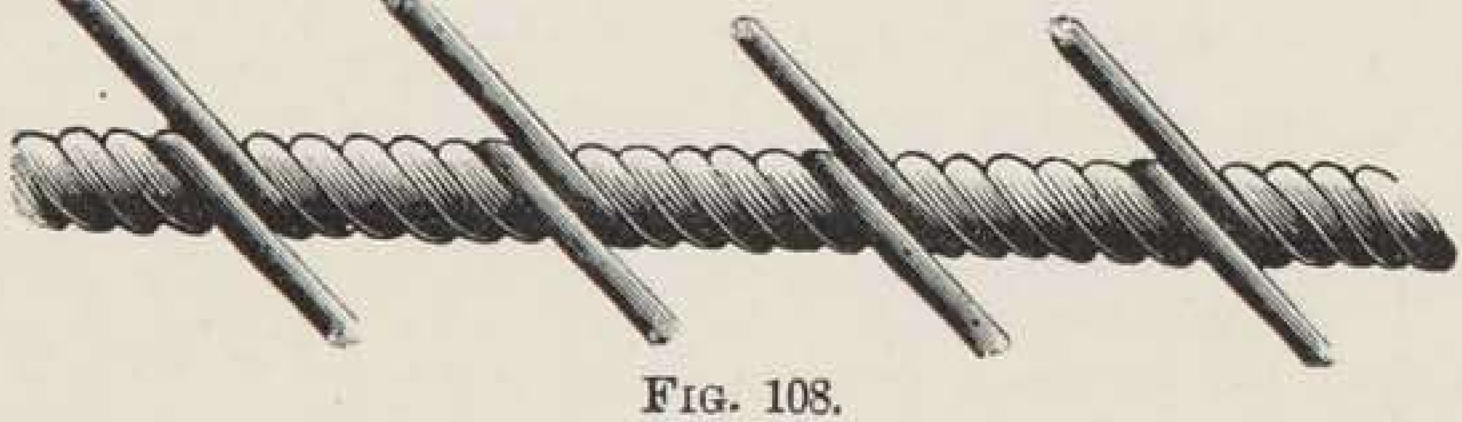


FIG. 108.

cut off to about a foot in length, and the friction bands are removed and tied up. Each end is then laid over twice by the aid of a marlin spike, and are then finished off by passing through the centre of the rope. The character of the splice for a four-strand rope is shown in Fig. 108. The operation is one which is difficult to describe, but which can easily be acquired by a little practice. The principle underlying the operation is the fact that, if two ropes working over pulleys of the same diameter, and with grooves similarly shaped, are of uneven diameter, they do not occupy the same vertical position in the grooves and are not therefore equally driven. The result is that more work is thrown upon the larger rope, and straining occurs, which speedily results in the deterioration of the rope. These remarks apply to English practice where, as has been said, each rope is worked independently. In the United States it is the practice to use only a single rope which is spirally wound over the driving and driven pulleys and kept in even tension by means of a tension pulley borne in a sliding carriage to which a suitable weight is applied, giving a tension equal to one-third of the tension on the working side. It is stated that the greatest efficiency of a two-inch Manilla rope—which is the size used—is obtained with a velocity of 4800ft. per minute. This mode of rope driving, although more generally in use in the United States than in this country, is, the author believes, of British origin, and is very similar to the mode of driving cranes long adopted here. It has the advantages that, as only one rope is used, variation of diameter is not likely, the tension can be maintained at an equal amount under all atmospheric changes, and there is no alternate wedging and release as the rope enters and leaves the grooves. On the other hand, only light ropes are so used, and if a breakage occurs an awkward and dangerous tangle takes place. All ropes should be carefully looked to and they should not be loaded with black lead and tallow, nor should this composition be afterwards used. It unduly adds to the weight and speedily deteriorates the rope. It is quite unnecessary, as a little application of a suitable wax is much better. Something has been said about the limits imposed on the velocity of wheels by the tendency towards bursting. That this is not an imaginary evil is demonstrated by two or three bad accidents from this cause. A peripheral velocity of about

5,000ft. per minute is permissible in a cast-iron flywheel of the usual construction. The number of revolutions which may be made by a wheel can therefore be obtained by dividing that velocity by the circumference of the wheel in feet. There are a number of minutiæ which may occur to the reader, which must necessarily be left untouched, but enough has been said to give the principal facts.

(349) The question as to which of the three methods of driving is the best is one which has exercised the minds of engineers for some time. There is not much doubt that the question is now practically decided. The friction of gearing, well designed and well constructed, is less than that of any other form of gear, belt gearing coming next, and rope last. That is to say, if the determination of the gearing to be applied in a mill rested solely upon this consideration all mills would be wheel-geared. There are, however, many other points to look at. The question of wear and tear, the difficulties and cost of repairs, consequent upon breakdowns, and the character of the drive alike have an influence upon the problem. A wheel drive is rigid, although it may be smooth running, and a breakdown in any part is expensive, and difficult to repair. Belt drives, although flexible, have the disadvantages arising from the cost of the belts used, and their great weight, besides the trouble of repairs. Rope gearing gives, owing to the flexibility of the rope, a drive which, while rigid enough for all practical purposes is yet sufficiently yielding to give a smooth, steady motion throughout. The shafts in each floor are driven separately, as shown in Fig, 104, and if a breakage occurs in one of the ropes it does not affect the rest. Owing to the mode of driving, a well is formed, which constitutes an effective division of the mill and scutching room, which in case of fire is valuable. The bearings of the counter shafts can be easily lubricated by circulation. It only now remains to say a few words on the subject of the shafting employed in a mill. This is usually in lines extending the full length of the room, and coupled about every 20ft. by

flanged couplings. The shaft is carried by suitable bearings which, wherever possible, are fastened to the vertical pillars in the room. The exact method of fixing is, however, not important, but the construction of the bearing is. For line shafts the length of the brass in which the shaft revolves should not be less than twice the diameter of the latter, and care should be taken—1st, that all the bearings are fixed and maintained in a true line with each other; and 2nd, that they are sufficiently lubricated. In fixing the wall boxes which sustain the extremities of each line, care should be taken that they are solidly built in, and in cases where the walls are of materials less stable than stone or brick, anchor plates secured in the wall at a lower level and long anchor bolts should be used. The importance of keeping shafts in line, and of maintaining throughout efficient lubrication, cannot be too strongly insisted on, and in these days of solid construction and ingenious engineering, there need be no difficulty in either case. The power which iron shafts will transmit can be got from the following rule. Multiply the cube of the diameter in inches by the number of revolutions per minute and divide by 120 for first motion shaft, 100 for second motion, and 80 for third motion. For shafting inside a mill the third divisor is the only one which need be considered. The distance apart of the bearings depends on the strength of the shaft, and can be obtained when pulleys are carried by multiplying the cube root of the square of the diameter by 4·8. This factor, however, is affected by the existence or non-existence of pulleys between the bearings which may be wider spaced when pulleys are not fixed. Wrought-iron pulleys are now often used to drive mules on account of their lighter weight. The scutching and blowing machines are always driven from counter shafts. It has become the practice, however, in driving the roving frames, to arrange a line shaft above their driving pulleys, and drive them direct by a quarter-twisted strap. In modern mills there is ample height for this purpose. Mules are, for obvious reasons, driven from counter shafts, and the use or otherwise of these must throughout the mill depend upon its design. The more direct the driving the better, as every belt is a cause of disturbance owing to stretching.

(350) The question of the power required to drive a mill is a matter of some importance, and one which has not been properly formulated. The powers which are usually given are as follows, but it must be obvious that these will differ considerably under different circumstances :—

Single opening machine, $2\frac{1}{2}$ h.p.
Double scutching machine, 1,400 revolutions of beater per minute, $4\frac{1}{2}$ h.p.
Revolving flat carding engine, $\frac{2}{3}$ to $\frac{3}{4}$ h.p.
Roller and clearer carding engine (single), $\frac{3}{4}$ h.p.
Roller and clearer carding engine (double), $1\frac{1}{2}$ h.p.
Drawing frames, per delivery, $\frac{1}{4}$ h.p.
Slubbing frames, 68 spindles, 600 revolutions, $1\frac{2}{3}$ h.p.
Intermediate frames, 74 spindles, 700 revolutions, $1\frac{1}{3}$ h.p.
Roving frames, 160 spindles, 1,000 revolutions, 2 h.p.
Mule spindles, 230 spindles, 9,000 revolutions, 1 h.p.
Ring spindles, 120 spindles, 7,000 revolutions, 1 h.p.

As a rule, it is considered that about 85 mule spindles, with the necessary preparation machinery, require one-horse power, the number of ring spindles being somewhat less. From some results of mills of equal size and of similar conditions 100 mule spindles, with preparation, spinning coarse and medium counts, take $1\frac{3}{8}$ H.P., while ring spindles take $2\frac{1}{4}$ H.P. for the same number. The power required, however, is only a part of the question, as the number of pounds of yarn produced per H.P. is much more important. In this respect, if ring yarn answers the purpose for which it is intended, there is little doubt that in counts up to 32's the ring has an advantage over the mule. In other respects there is some advantage, as the class of labour employed is remunerated at a cheaper rate.

APPENDIX.

(351) Since the first edition of this book was published, there have been one or two developments which require notice. It is with these that we have now to deal, and it is intended to add such matter, as, in the opinion of the author, is worthy of permanent record. The first point demanding attention is the practice with regard to the purchase of the raw material. On page 59 a table is given which, in the main, accurately states the usual classification of the principal kinds of cotton. It may, however, be remarked that between each grade there are sub-grades which are always taken into account in purchasing cotton. For instance, American is classified as fair, barely fair, strict middling fair, and so on with each grade. In New York these distinctions are adhered to. The full grades are those stated on page 59; the half grades have the prefix "strict"; the quarter grades, the prefix "barely," indicating the point midway between the half grade and the next full grade below; and "fully," meaning the point midway between the half grade and the next full grade below. When cotton is bought by the spinner in this country, it is purchased from a broker, samples being furnished to the seller at the time of purchase. The terms of purchase are 1½ per cent discount in ten days from date of purchase, with an allowance from the gross weight of 4 per cent for tares. That is, a bale of 400 lbs. would be regarded as one of 384 lbs. only. A good deal of cotton is now sold on what is known as "C. I. F." 6% terms. In this case the terms are fully set out in the statement below, which is extracted from Mr. A. B. Shepperson's "Cotton Facts."

Grade, Colour and Staple are specified as agreed upon Also whether the cotton is "Orleans," "Texas," "Gulf," "Memphis," or simply "Uplands."

Weights.—The invoice to be for American actual gross weight, less an allowance of six [6] per cent to cover bands and tare. The gross landing weight guaranteed to be within one per cent of gross invoice weight. Gross landing weight to be ascertained by weighing the cotton in Liverpool on arrival, before sampling (or if already sampled an allowance to be made for the samples drawn), due notice of weighing having been given in writing by the buyer to the seller. Any excess in weight of bands over 900lbs. for each 100 bales to be deducted from the "landing weight." Allowances to be made for missing bands and ship's pickings. Should weight of bagging exceed 4lbs. per 112lbs. the buyer shall have the right to claim for such excess at invoice price, but the claim must be made and properly substantiated within two months from the last day of landing.

Route of Shipment.—To be fully stated (as "by Rail and Steamer from Memphis to Liverpool, via any Atlantic port"), etc., etc., or as the case may be.

Date of Shipment.—To be specified as "during October," or "prompt shipment," or "immediate shipment," or "shipping or shipped," as stipulated. "Prompt" or "immediate" shipment means to be shipped not earlier than the date of the contract nor later than 14 days after. "Shipping or shipped" means the shipment shall be within 14 days either before or after the date of contract.

Declaration of Marks and Vessel's name, or particulars contained in through bill of lading, to be declared within four weeks of the date of bill of lading.

Marine Insurance.—To be provided by the seller, with a first-class company, covering particular average and five per cent in excess of invoice cost.

Samples.—When sold to equal an American drawn sample of the identical cotton, an allowance of $\frac{1}{32}$ of a penny per pound is made between it and the Liverpool re-drawn samples.

Arbitrations and Rejections.—No allowance to seller. Should arbitration be demanded by the buyer, the cotton shall be subject to mutual allowances except in the case of average shipment. Should any lot prove not in accordance with the contract the buyer to have the option of rejecting it.

Reimbursement is specified in Contract Drafts usually at 60 days' sight with shipping documents attached. Payment is usually made in exchange for shipping documents on or before arrival of vessel (at buyer's option).

(352) In some cases cotton is bought under contracts for future delivery, which have been made the medium of many of gambling transactions. These contracts may however be used in a legitimate manner, for there are many cases where a spinner, having sold his production, may desire to cover himself by purchasing cotton to cover the transaction. In this case cotton will be tendered at the due date in satisfaction of the contract, and it is not to transactions of this nature that any condemnatory terms can be applied. It is only when the contract is entered into without there being any intention of accepting cotton at any time in satisfaction of it, but merely to realise any profit which may accrue by reason of the higher selling price at the time of its completion, that the transaction becomes a harmful one. The following are the terms of the Liverpool Contract: It is for 47,200lbs. net weight in about 100 bales of cotton, of United States growth to be delivered from warehouse. The price is to be upon the basis of Middling, Liverpool classification; nothing below Low Middling to be delivered, and the additions or deductions to be settled by arbitration. The delivery is at the seller's option within the time specified, which is usually during two months, but the seller must intimate to the buyer his readiness to deliver,

and the buyer has a like option as to time, but must take the cotton within ten days after the date of the seller's declaration. The declaration must contain particulars of the marks of the bales, and the cotton must be ready for immediate delivery. If the cotton is purchased as a speculative venture, weekly settlements are made, and the differences are paid to the party requiring them. It is often the case that these differences will go through many hands before the contract is finally worked off; and a clearing-house system is in operation for this purpose. The following allowances are made in determining the net weight of cotton tendered :—2lbs. per bale for draft, actual weight of iron bands, 4lbs. for each 112lbs. for tare, the remainder being the net weight. Payment is to be made before delivery, and a transfer order is given, which gives the buyer the control of the cotton. A discount of $1\frac{1}{2}\%$ for cash is allowed. The Liverpool classification for Strict Low Middling to Middling is about half a grade lower than the New York classification, whilst for the grades below that named, it is a quarter to half a grade higher. The New York contract differs from the Liverpool one in a few particulars, more especially as to the grade which is tenderable. Any grade will be taken from Good Ordinary to Fair, but if the cotton is stained, nothing less than Low Middling. The price is based on Middling, and the necessary additions or deductions are settled by an Inspector appointed by the New York Cotton Exchange authorities. The option is for some specified month, and a deposit or margin can be demanded by either party to the contract up to $5 per bale. The sum deposited is lodged with a Trust Company until the settlement of the contract, but must be demanded within 24 hours of the transaction, when both parties must deposit an equal amount. It may be of interest to give the various weights used in different cotton growing countries, as prices are often quoted in these terms. These are given below and the equivalents in lbs. avoirdupois are appended.

Bengal 1 maund (82·28lbs.) = 40 seers (seer = 2·057lbs.)
Madras 1 candy (493·71lbs.) = 20 maunds (maund = 24·68lbs.) = 800 seers.
For convenience a candy is taken at 500lbs.
Bombay 1 candy (560lbs.) = 20 maunds = 80 seers.
Egypt 1 cantar = 98·046lbs.
Brazil 1 quintal = 101·186lbs.
China 1 picul = 133·33lbs. = 100 katties.

(353) According to the most recently published statistics, the acreage under cotton in the United States was for the season 1891-92, 19,018,460, and for the season 1892-93, 15,881,984. From this there has been produced a commercial crop, that is, one including all deliveries, whether grown in that season or not, amounting to 9,018,000 in 1891-92, and 6,717,000 in 1892-93. The average weight per bale is said to have been in the season 1892-93, 499·84lbs. The acreage in India for the season of 1892 was 14,928,000, and in the season 1893, 14,898,000. The production in 1891-92 was 2,959,211 bales, and for the season 1892-93, 2,770,000 bales. The Egyptian acreage in 1891-92 was 863,000, and in 1892-93, 950,000, the yield in the two years respectively being 625,000 and 684,000 bales. The Brazilian crop in 1891-92 was 310,000 bales, and in the season 1892-93, 438,000. The disposition of the American cotton crop for the season 1892-93 was as follows :—To Great Britain, 2,332,665 bales ; to France, 548,800 bales ; to the Continent of Europe, 1,521,425 bales ; the Northern States of America, 1,747,314 bales ; the Southern States, 733,701 bales. The Indian crop was disposed of as follows :—To the United Kingdom, 94,710 bales ; the Continent of Europe, 932,205 ; consumed in the Indian Mills, 1,100,000. The estimated number of spindles existing in the United Kingdom according to the latest statistics are 42,970,528 in Lancashire and the adjoining counties, and about 2,380,000 elsewhere. The number of spindles at work in India in 1892 was 3,402,000 ; in Japan 324,800 ; in the United States, Northern Mills, 13,250,000 ; Southern Mills, 1,950,000. These figures are the latest that are available at the time of writing.

VARIETIES OF COTTON AND CHARACTERISTICS.

Variety of Cotton.	Sub-Variety of Cotton.	Mean Dimensions.		Yarn Produced.		Characteristics.
		Length. Inch.	Diameter Inch.	Counts.	Twist or Weft.	
Sea Island	Carolina	1·8	$\frac{1}{1575}$	up to 400s	T and W	Length, small diameter, regularity, silkiness.
	Florida	1·6	$\frac{1}{1570}$	up to 200s	do.	Do. do. do.
	Fijian	1·8		do	do.	Similar to preceding, weaker, more irregular, and more unripe fibres.
Egyptian	Peruvian	1·5	$\frac{1}{1480}$	up to 140s	do.	Inferior in chief qualities to preceding, light golden tint.
	Gallini	1·4	$\frac{1}{1480}$	up to 150s	do.	Strong, fine, light golden color, easy to spin.
	Brown	1·3	$\frac{1}{1350}$	up to 90s	do.	Strong, clean, easily spun, golden colour.
	White	1·25	$\frac{1}{1300}$	up to 70s	do.	Moderately strong, light golden, not so clean.
Peruvian	Rough	1·28	$\frac{1}{1280}$	do.	T	Light cream, harsh feel, wiry, clean, moderately strong, mixes well with wool.
	Smooth	1·28	$\frac{1}{1300}$	do.	W	Soft, smooth, flexible, easily spun.
Brazilian	Pernams	1·3	$\frac{1}{1270}$	up to 60s	T	Rather harsh and wiry, light golden.
	Maranhams	1·2		up to 50s	T and W	Dullgold, weaker than Pernams, rather harsh.
	Ceara	1·1	$\frac{1}{1300}$	do.	do.	Dull white colour, moderately strong, harsh and wiry.
	Paraiba	1·1	$\frac{1}{1270}$	do.	do.	Moderately strong, harsh and wiry.
	Maceio	1·1		do.	do.	Do. do. do.

American	Orleans	1·1	$\frac{1}{1320}$	up to 50s	T or W	Soft, moist, fairly strong, white to light cream colour, easy and economical to work.
	Texas	0·9	$\frac{1}{1310}$	do	do.	Similar to above generally, light gold colour.
	Upland	1·0		up to 42s	W	Like Orleans, soft, clean, excellent for weft.
	Mobile	1·0		up to 36s	do.	Not so clean as preceding, weaker in fibre.
Syrian	Smyrna	1·0	$\frac{1}{1300}$	up to 42s	T or W	Harsh, irregular twist in fibre, medium strength, dull white colour.
West Indian	West Indian	1·2 to 1·4		up to 40s	do.	Harsh, rather dry, moderate strength, varies in colour.
African		1·0	$\frac{1}{1200}$	up to 30s	T	Harsh but good colour, lacks cultivation.
Indian	Hinghunghat	1·0	$\frac{1}{1200}$	up to 36s	T	Strong, light golden tints, variation in diameter.
	Broach	0·8		up to 28s	T or W	Moderately strong, clean, golden tinted.
	Tinnivelly	0·8	$\frac{1}{1210}$	up to 26s	T	Strong, elastic, dull cream, fairly clean.
	Dharwar	0·7		up to 20s	T or W	Moderately strong, light gold, fibres variable and broken.
	Oomras	0·8	$\frac{1}{1180}$	do	do.	Strong, regular, cream colour, rather dirty.
	Dhollerah	0·7		do	W	Moderately strong, dull white, dirty.
	Madras or Westerns	0·7	$\frac{1}{1200}$	do	T	Strong, dark coloured, dirty, uneconomical.
	Coomptah	0·3		up to 15s	W	Weak, brown tint, dirty.
	Bengal	0·3	$\frac{1}{1180}$	do	T	Strong, harsh, golden tint, dirty.
	Scinde	0·4		up to 12s	T and W	Poor, fairly clean, dull white tint.

(354) The cotton gin was only mentioned in the earlier edition of this book, and a description of it has been suggested as likely to be useful. The early methods of freeing the cotton from seed were very primitive, and were afterwards displaced by a double roller machine. Subsequently to this, Eli Whitney introduced his saw gin, which has been successfully worked. Its chief feature is the employment of a number of saws in the form of a roller, which seize the cotton and draw it between the interstices of a grid suitably arranged so as to strip off the seed. The cotton is beaten off by a revolving brush. The action of this machine is harsh and severe, and results in a good deal of damage to the cotton. At the same time it is still extensively used in the United States, although the bending of the fibres nearly double in the process of ginning is very deleterious. If the saw gin is overfed it speedily breaks the cotton. As much as 500lbs. of American cotton has been taken off the machine per hour, but the result is very defective cotton. The machine which is probably in all respects the most satisfactory is the roller and double knife gin, an illustration of which, as made by Messrs. Platt, is given in Fig. 109. This machine consists of a hopper into which the cotton is fed. At the bottom of the hopper is the roller G covered with walrus leather, which has a rough surface so that it readily seizes the fibres. Against the face of this roller a fixed knife I is pressed, so that, as the roller revolves, it draws the fibres between its surface and this knife. In doing so the seed which adheres to the cotton is drawn to the point where the knife I presses against the roller G. While the seed is so held the two blades F^1 and F^2 strike it alternately, so pushing it away from the point where it is held. The seed is thus gently removed from the cotton without damage to the fibre, which is carried onward by the continued rotation of the roller G. In order to avoid any danger to the attendant a self feeder C actuated by a crank is fitted which always keeps the roller well supplied with cotton. The seed grid used is arranged so as to be movable, and thus considerably aids the

delivery of the seeds, which, when a stationary grid is used, tend to choke it. The choking of the gin is practically avoided, even when cotton containing a large quantity of seed is used. The advantage of a double knife machine is that the number of blows given per minute being more numerous, the machine can be driven at a slower speed without reducing its capacity, and, as a matter of fact, the output of a double knife machine is, at the speed of 600 revs. per min. of the crank shaft, greater than that of the single machine at 900 or 1000. The objects

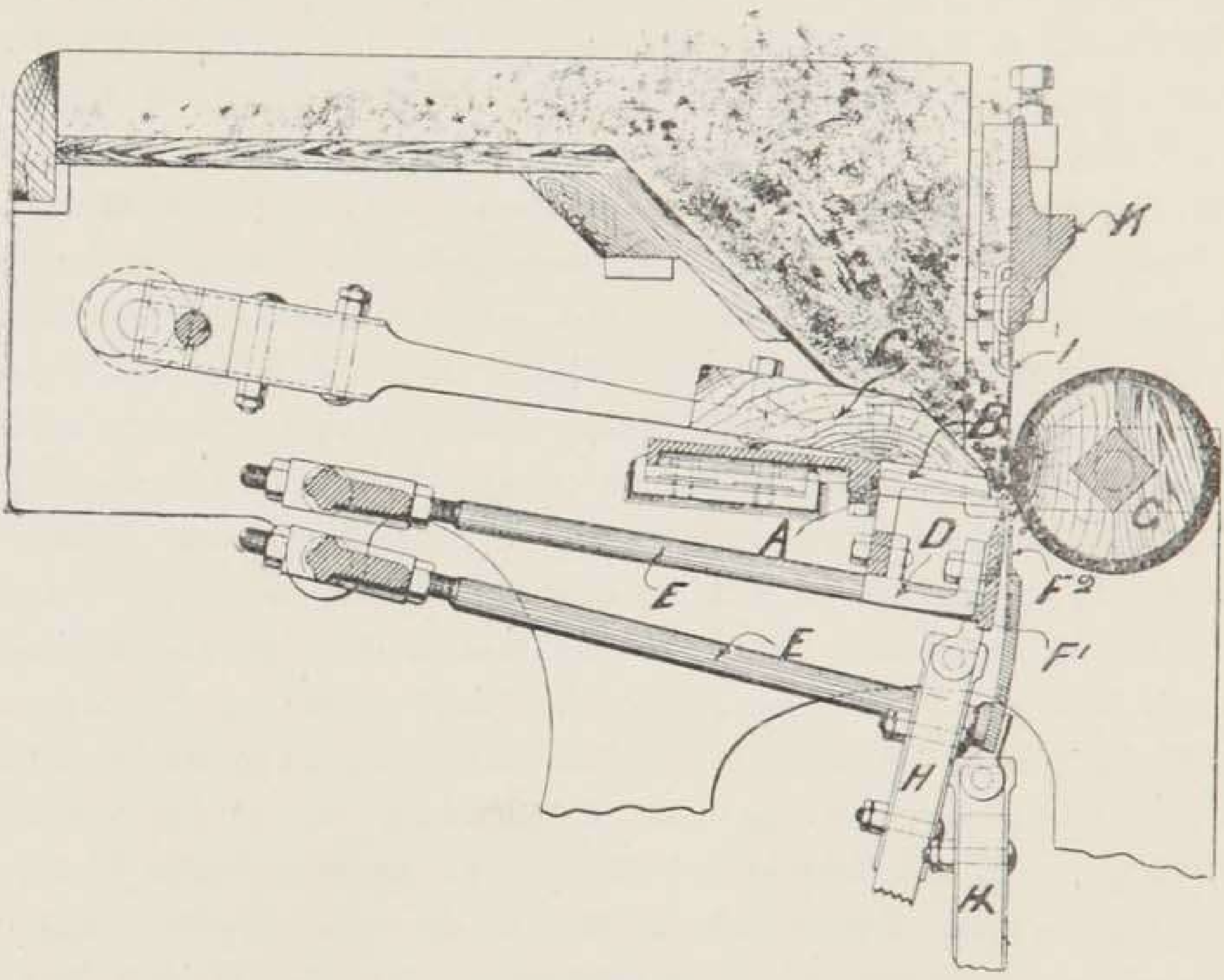


FIG. 109.

desired in ginning, viz., the removal of the seed without breaking or crushing the fibre or seed and without the production of nep, are well attained by this machine. Its production ranges from 25lbs. per hour of the inferior Indian cottons in which there is a maximum of seed to a minimum of cotton, to 45lbs. of the better qualities of Indian staples and proportionate yields of American. It is not desirable to overlcad a gin at any time, and this should be remembered.

(355) A new form of bale-breaking machine has been introduced by Messrs. John Hetherington and Sons, Limited. Instead of the ordinary three or four rollers running at different velocities they employ two travelling spiked aprons formed of transverse iron bars with hooked teeth. Each bar is fastened at each end to an endless link chain running over a front and back roller. The two aprons are placed one above the other, and both run in the same direction, but the lower one runs several times as fast as the other. The cotton is fed in the usual way by a lattice feed and feed rollers, and the draft which can be obtained is equal to that obtained under ordinary conditions. The pulling is effected first by the draft between the spiked lattice and the feed roller, and next by that caused by the unequal speeds of the two lattices. The cotton when it emerges is in an open fleecy condition and the lumps are of small size. As far as can be observed during work, the pulling into lumps is mainly effected between the chain and the feed roller, while, during the period the cotton is travelling between the aprons, it is still further reduced and opened. Another feature of recent date in the opening section is found in the introduction of the Automatic Feeder. This is an adaptation of a machine which has been long in use in the woollen trade, where it has been instrumental in abolishing the practice of weighing the wool. It was well known in that connection in this country, but its adoption as an instrument for feeding cotton is the work of the machinists of the United States. It may be said that all the various forms of this machine which are now made possess the same general characteristics, but that which is illustrated in Fig. 110 has some additional points of interest. As there illustrated it is made by Messrs. Howard and Bullough. It consists of a large hopper or receiver R, at the lower end of which is a travelling lattice apron A moving from left to right. At one side of the hopper, placed at an angle, is the apron B, which is formed of an endless canvas band, to which is secured transverse laths with spikes fixed in them. The cotton is fed into the hopper R, and the lattice A aids in bringing it up to the apron B, and within

the range of the pins, but as the hopper is usually kept well filled the cotton is in contact with a large area of B. At the upper corner of the hopper a revolving drum is placed, consisting of a cylinder smoothly turned on its periphery, and having a number of holes bored in transverse rows parallel to its axis. Through these the points of pins can project, these being fixed in slides which terminate in a frame surrounding an eccentric C mounted on the shaft. Thus as the drum revolves, the pins are alternately pushed out of and drawn in to the cylinder. As the function of the pins is to strip from the lattice B the surplus cotton, it may happen that some of it adheres to them. If this occurs

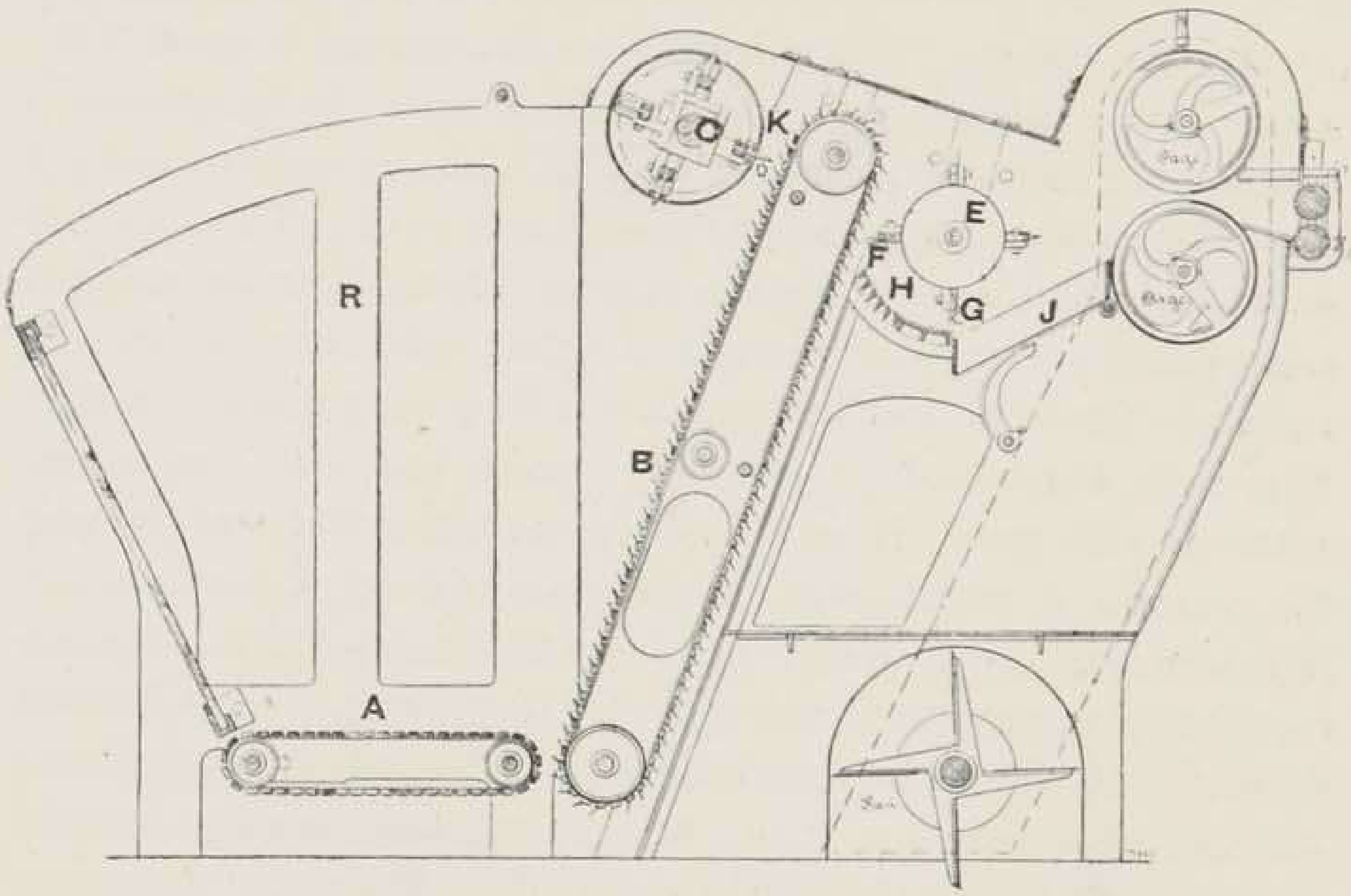


FIG. 110.

their withdrawal in the manner described strips them of this cotton, which falls back into the hopper. The relative distance of the centre of the drum and the lattice is capable of adjustment, so as to permit a greater or lesser quantity of cotton to pass. At the back of the apron B is a stripper E, which in this case is four-armed, the alternate arms being fitted with pins F and leather strips G. As its name indicates, this is employed to strip off the cotton from B and deliver it. In this specific instance the procedure is substantially that of scutching. The cotton is flung on to the grid H, thence over the longitudinal grid and dirt box J on to cages coupled to an exhaust fan in the usual way. After this it is passed through the calender rollers shown, by which it is compressed and delivered either on to a lattice apron or into an air trunk, as desired. In most cases the cotton when beaten off by the stripper is simply passed through a pair of rollers and is then delivered. The chief merit claimed for automatic feeders is the very important one that at the earliest possible stage in the manipulation of the material it is arranged for further treatment in the form of a fleece of even substance and weight per yard. It is, in fact, as an evener that the machine should find its principal function. Messrs. Taylor, Lang, and Co. employ instead of the stripper K a small spiked apron, which is so set that it gradually strips the cotton as it moves upward, the distance between B and the stripper apron gradually reducing. This is very effective. As a second object, that of opening or fleecing the cotton may be named. If necessary, this can be very effectually performed, and it is quite easy so to adjust or speed the various parts as to get the material into a practically fleecy condition when it emerges. It is, however, not always necessary that this should be done, and in the case of long stapled cottons it is sometimes better that it should not be so. Such fleecing as takes place, being in the nature of combing, does no damage to the cotton, and is much less calculated to do so than the treatment accorded to it in the ordinary process of scutching. It has been found in some cases that the fact of fleecing enables the cotton to be opened and scutched without the use of an intermediate scutcher, and this without any diminution in the evenness of the resultant laps. The earlier a fleece is formed the earlier and easier the dirt is removed, so that there is a distinct gain in this operation. It may, however, be pointed out that the establishment of a fleece which is of even substance in its entire length is of little value unless the distribution of the fleece in the width also takes place.

The object of the piano feed in the scutcher, for instance, is mainly to even the lap so far as its longitudinal substance is concerned. But a lap should, when finally produced, be even not only longitudinally but also transversely, and the same thickness should exist at the edges as in the middle. In short, there are two problems involved—one affecting the feeding of a definite weight and substance in a definite time, and the other the proper distribution of the cotton transversely when fed. In this respect, the arrangement of a hopper feed, with cages, as shown in Fig. 109, is likely to improve the result, because, with perfectly working fans, the lateral distribution of the cotton is improved. There is one feature in which the hopper feed is defective, and that is the difference in the delivery which arises when the hopper is well, or only partially, filled. The rate of passage of the cotton under these circumstances respectively is—despite the action of the beater—never absolutely even, and a variation in the thickness of the fleece delivered is found to take place. It is possible that the proposed application of the piano motion behind the point of delivery will do something to remedy this defect. However that may be it is certain that, except on the ground of the abolition of the labour of the spreaders, little is gained by the adoption of the automatic feed where the arrangements for the purpose have been well thought out previously. If, for instance, such an arrangement as that of Messrs. Platt Bros. and Co., Limited, illustrated in Fig. 111, is in working order, the whole requirements of the case are met. In this arrangement the cotton is fed to a porcupine beater by a lattice apron, the velocity of which is controlled by a piano regulator, and is thence discharged into a dust trunk, then passing over a travelling dirt lattice, being finally discharged into the opener. The arrangement of exhaust fans is such that in addition to being well fed so far as the weight per yard is concerned, the lateral distribution also takes place properly. The test of an evenly-formed lap is the maintenance of the weight over its whole area, so that a square foot cut from it at any part, either in the centre or at the sides, will be of the same weight. This is the thing to be aimed at in scutching; and experience shows that it is not unattainable. If a lap, when finally presented to a carding engine, is of uneven substance

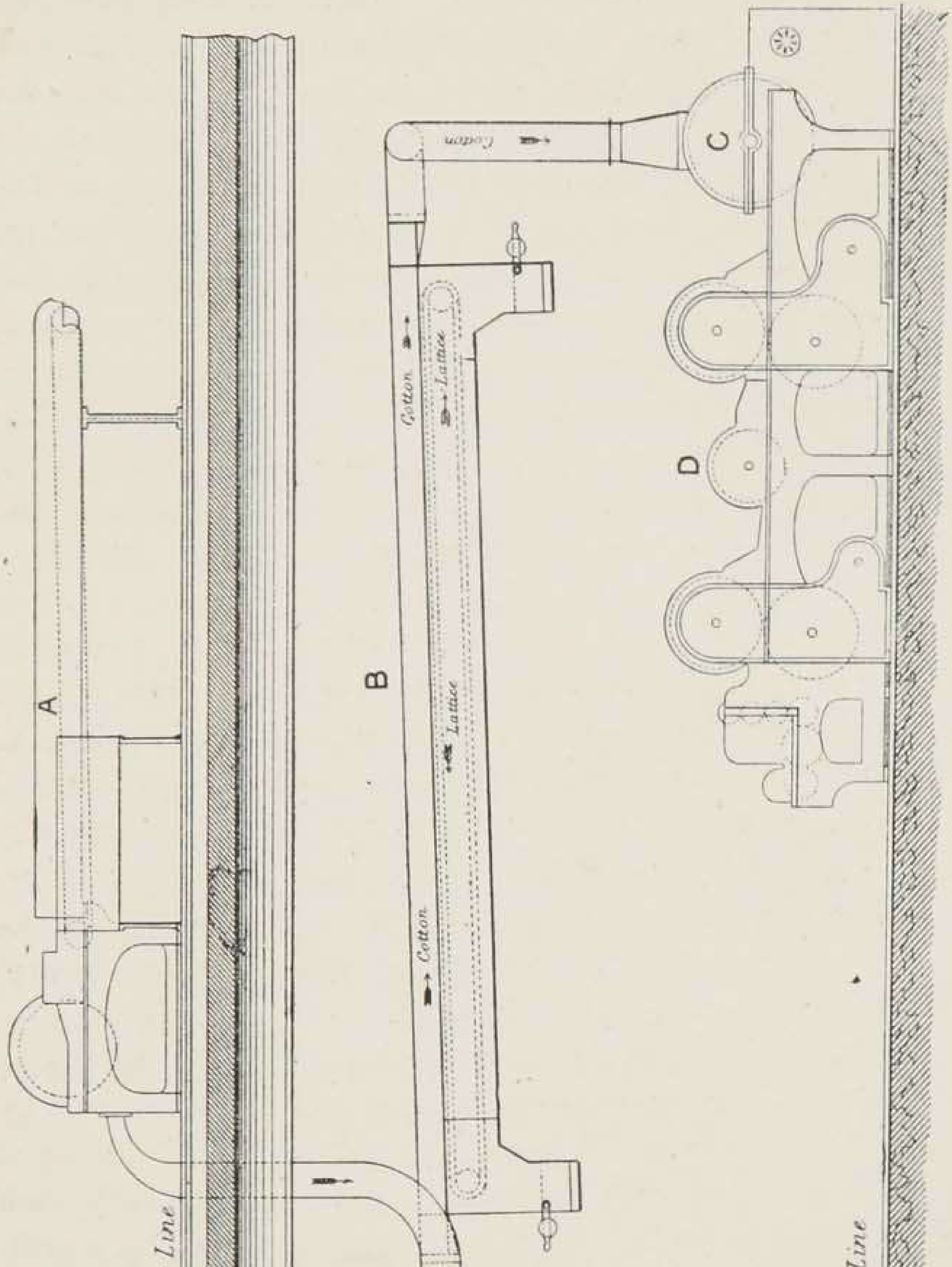


FIG. 111.

across its width, it will follow that, as the feed in that machine is constant, more fibres will be presented to the carding surface at one point in its width than at another. This is as fatal to the best work as inequalities in the weight of successive yards of lap. Now it is obvious, that in cases where laps of this character are produced the application of an automatic feeding machine can be of little service. Unfortunately, there are large numbers of cases where these conditions do not prevail, and in these the application of the machine may be attended with good results. It must never be forgotten that the appliances for evening the cotton are far in excess of any used in wool spinning, and that the characters of the two fibres are widely different. On the whole, it may be concluded that while under some circumstances the employment of a feeding machine is useful, it does not follow that it will be so under all circumstances. When applied, the cost of spreading is done away with, and a slight labour cost substituted, which is, of course, to the good. Since its introduction the machine has been largely adopted, and is finding, at the time of writing, a considerable sale.

Another matter which is worth referring to in connection with the scutching department is the treatment given to the waste caused in the opening and scutching machines and the fly from the carding engine, but more especially the former. In this country the whole of this waste is collected and specially treated. A description of a special plant, made by Messrs. Greenhalgh and Sons, will not be without interest. It is the practice to make a stack of the various kinds of waste collected at the stages named, laying the stack in such a way that a thorough mixture of the ingredients is made. From this stack, when completed, the waste cotton is taken in the usual manner by working down the face. It is fed to a willow, which consists of a cylinder provided with six rows of blunt spiked teeth, each row containing 12 teeth. This is partly surrounded by a grid, through the spaces in which the dirt can fall, and which is spaced so as to permit of this. The upper part of the machine has a cover, on the inside of which there is a row of spikes, also 12 in number, which are placed so that those on the cylinder pass between them. The cotton is placed in a self-tipping feeder, which is in the form of a long scoop, and, when this is tipped, is delivered within the range of action of the cylinder. This in its revolution flings the cotton against the cover, and beats it in such a manner that the dirt can fall freely. The cotton is kept in the willow for a sufficient length of time, and is ejected by a door at the upper part of the machine. The periods of opening this door and of tipping the feeder are controlled by a cam, which acts so that one operation succeeds the other; the ejection of the cotton being followed by the feeding of a fresh charge, or *vice versa.* The length of time elapsing between each discharge can be easily regulated, so that any amount of beating can be given. When discharged the cotton is thrown on to a travelling lattice, which, when several machines are in a range, serves them all, and is tipped into a bag or basket placed to receive it. The dirt falls below the machine, and is carried along with such fibre as it contains, and can be fed to a second willow, which is constructed to produce flocks. This willow has the rows of spikes diagonally arranged, one row having 12 and the next 11 spikes, and so on. Here the short fibre is ejected in the form of flocks, and the dirt is finally delivered by a conveyor either into carts, or into bins ready for delivery. This arrangement is very complete, and renders any manual work, beyond the stacking, unnecessary. It completely uses up the whole of the fibre, the finally ejected dirt being entirely free.

(356) As the detaching mechanism of the Heilmann combing machine, as ordinarily made, differs from that described, the following description of the construction and action of the ordinary mechanism will be serviceable. It should be read in conjunction with paragraphs 169 to 173 inclusive, but in some cases the reference letters are not the same. A cam O (Fig. 112) is fixed upon the cam shaft and is formed with a cam course. O is a bowl fastened at one end of a lever O^2 rocking upon a pivot borne by the framing, which is not shown in the drawing. The other end of the lever O^2 has hinged to it a

catch Q, which can be raised or lowered by means of a lever Q^2, a bowl carried by which engages with the cam Q^1, fixed in a position adjoining O. The catch, Q is constantly drawn down towards a "notched" wheel T, which is fastened on a spindle carried by the framing. It will be noticed that the notches in T are square, and that the end of the catch Q is correspondingly shaped. The reason for this construction is to enable a movement being given to the notched wheel with equal facility and without any danger of slipping in each direction. On the same spindle or arbor as the notched wheel is an internal disc wheel or annulus T^1, with which engages a pinion fastened on the end of the detaching roller S. Thus any motion which is given to the notched wheel is at once communicated to the detaching roller, and the extent to which the latter rotates in either

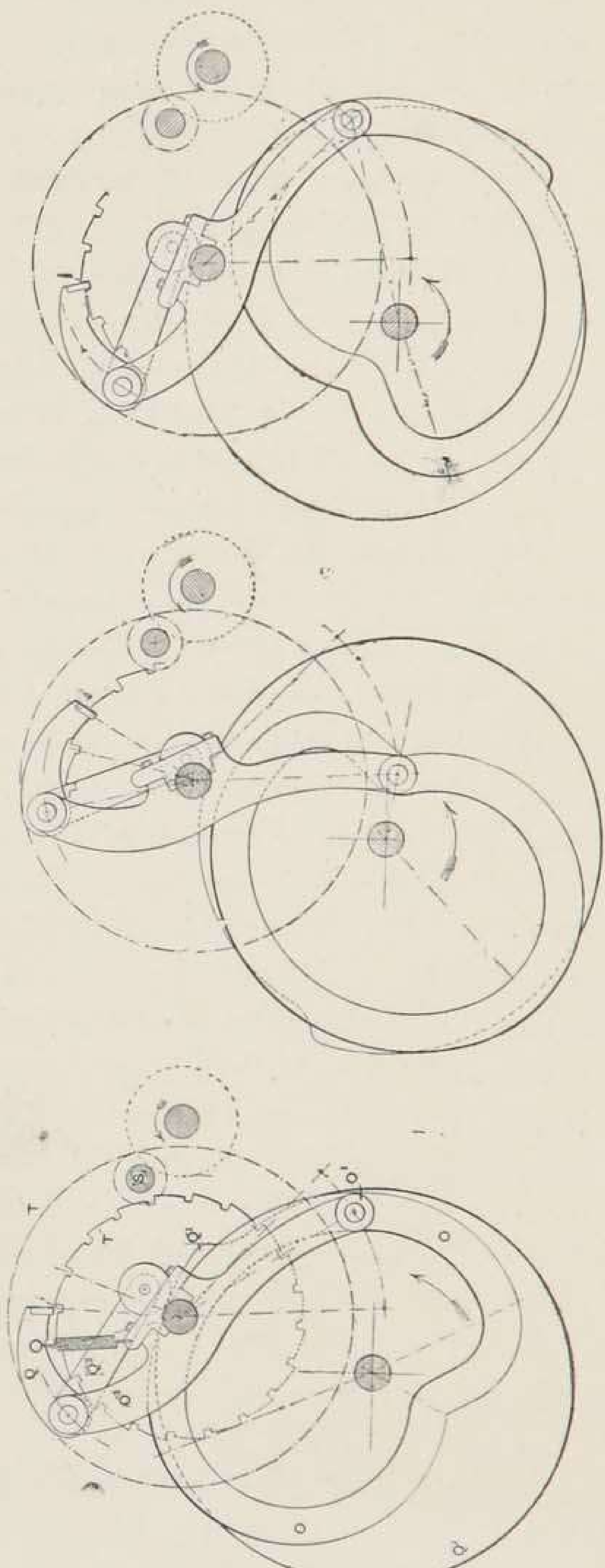


Fig. 112.

direction is regulated by the range of movement of the notched wheel and the proportionate relation of the number of teeth in the internal wheel and the pinion gearing into it. A glance at Fig. 112 will show that the course in the cam O is formed so that the lever O^2 is rocked upon its centre in each direction alternately during every revolution, but that the extent of the movement varies. Thus if the left-hand view in Fig. 112 be observed, it will be seen that the catch Q is disengaged, being held out of gear by the cam Q^1. As the bowl on O^2 begins to enter the curved part of the cam course in O, the catch Q is dropped into the notch marked 1, and the continued rotation of O is followed by a movement of the lever O^2, so as to cause the notched wheel T to take up the position indicated in the middle view. It will be seen that the notch 1 has moved forward, its position and that of the lever being very clearly shown in the drawing. The further rotation of O causes the lever O^2 to rock in the opposite direction, so that the notched wheel is drawn backward until the bowl in O^2 passes into the concentric part of the cam course, when further oscillation ceases. The distance travelled during the backward motion of the detaching roller is about $1\frac{3}{4}$in., which is a little less than one-third that of the complete forward motion. The total extent of the forward motion from one end of the motion of the catch to the other is about $4\frac{1}{8}$in. but this can of course be varied as desired by an alteration of the shape of the cam. It is now necessary to deal with the action of the top leather roller Q. This, it will be seen in Fig. 113, is in contact with the detaching roller, and is sustained by its arbors resting against the face of the block R. The latter is fixed on a lever called the "horse head,' which is centred on a pin R^1. Its tail end R^2 is oscillated by a cam Y, in which the bowl Y^1 engages. Y^1 is formed by a lever Y^2, which rocks on the same centre as the lever Y^3, coupled to the horse head by the connecting rod shown in the drawing. The effect is that as the face of the bracket R recedes from the centre of the detaching roller the distance between the centres of the comb cylinder N and Q in like manner is decreased, and the roller Q is able to fall so as to approach the cylinder N. The range of movement of R is regulated so that the roller Q can come in contact with the fluted segment N^2 at an earlier or later moment. At the same time this movement must not be

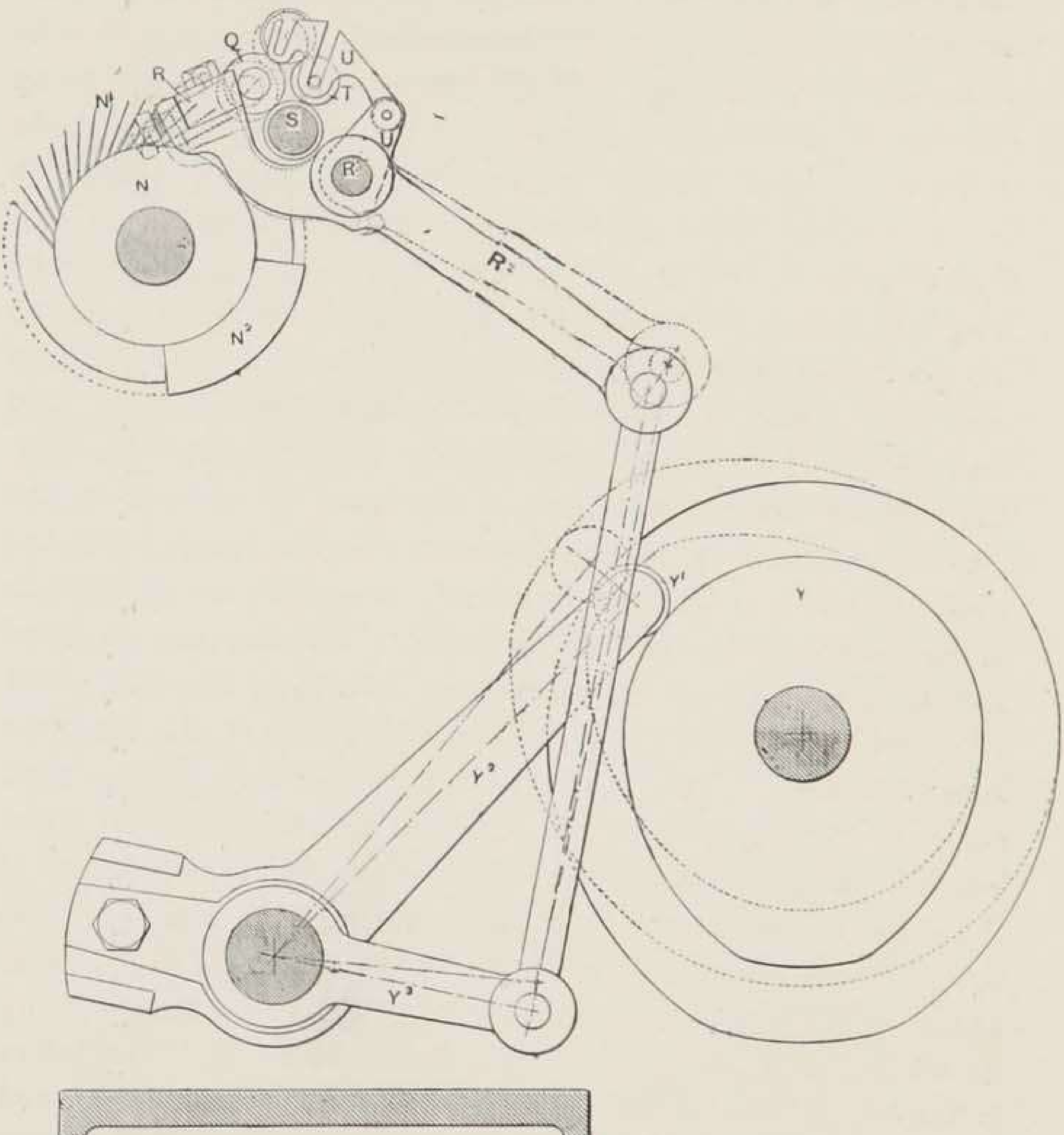


FIG. 113.

of such a character that the rollers S and Q fall out of contact. This adjustment can be made by means of the sliding block R, and by the coupling of the levers Y^2 and Y^3, which can be moved inwards or outwards by a screw and locked in position. The horse head lever is, of course, formed with two heads, so as to sustain the leather roller at each end. The effect of this mechanism is that the leather roller—always being in contact with the detaching roller—is alternately lowered into touch with, and removed from, the fluted segment. It is weighted by a stirrup and

FIG. 114.

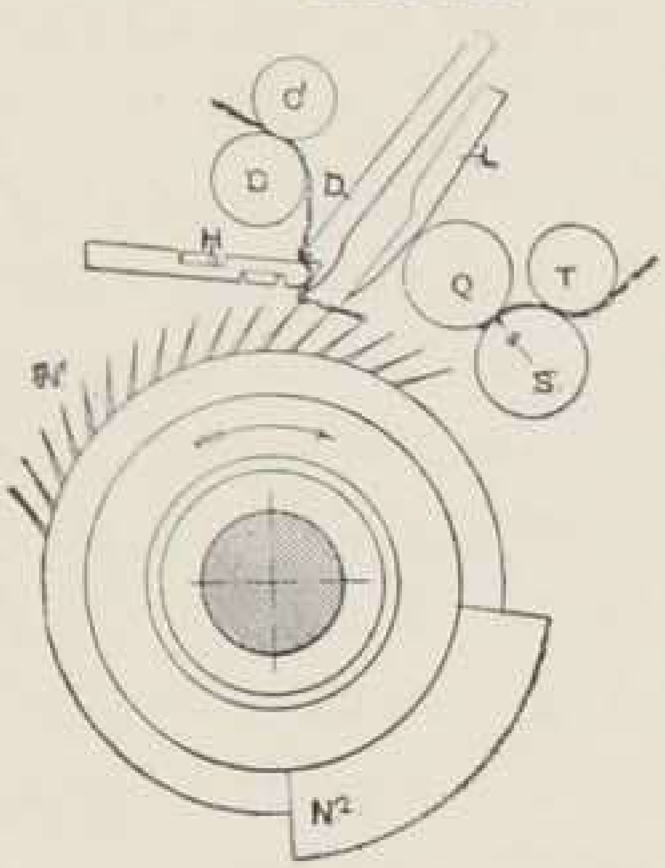
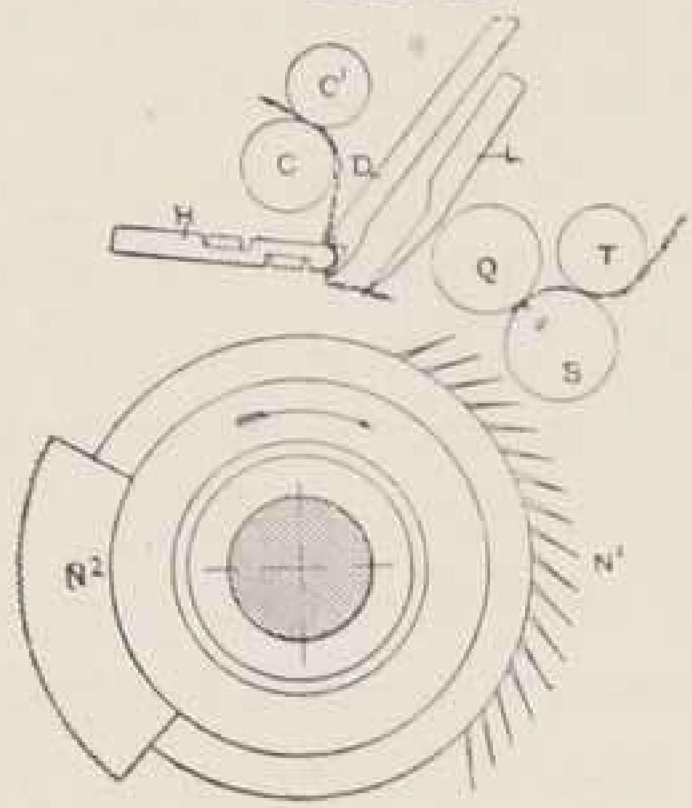


FIG. 115.



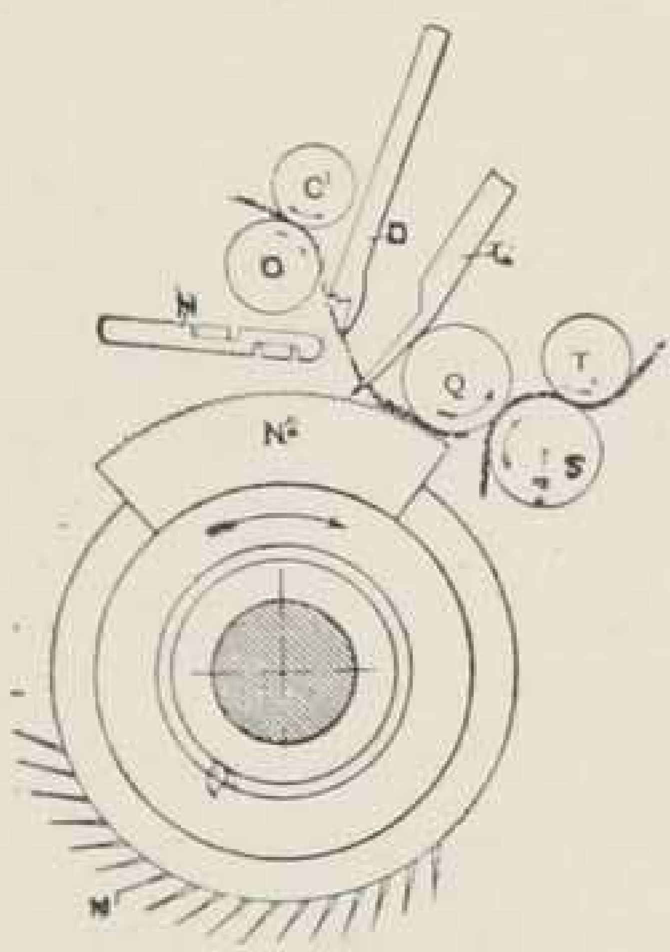


FIG. 116.

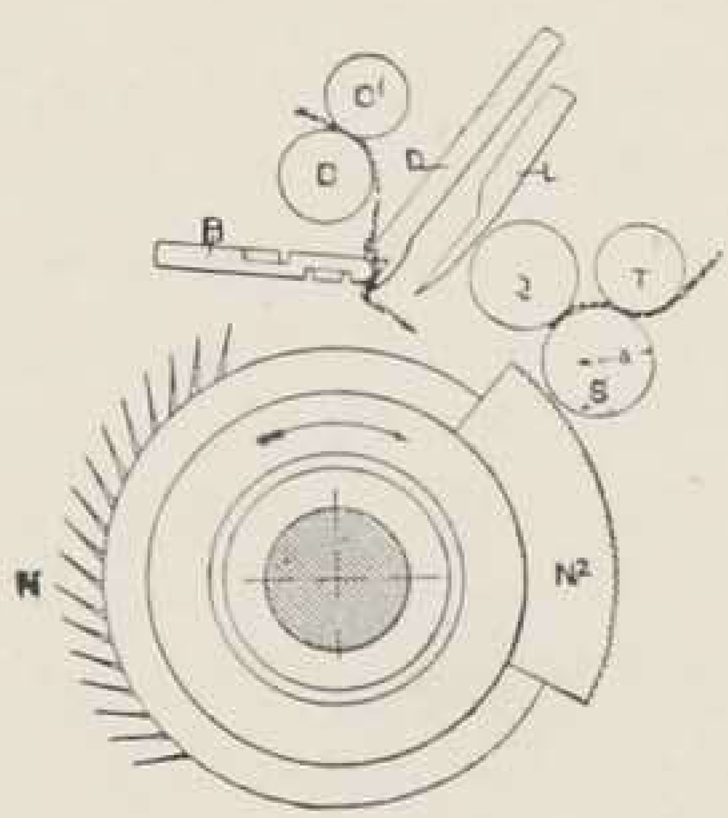


FIG. 117.

weight so that when it touches the segment it is caused to revolve with the latter and establishes a grip upon the cotton. Fixed upon the rod R^1, which acts as a pivot for the lever R^2, is a small bracket U, which carries a bracket U^1 having two slots formed in it, which act as bearings for the "pilling" roller T, and a flannel covered clearing roller. The roller T is covered with brass, and is finely fluted longitudinally. It is of considerable weight, and presses upon the detaching roller so as to compress the cotton as it passes. The precise action of the detaching mechanism can be dealt with and made a little more clear by the aid of the four diagrams given in Figs. 114 to 117. In the first of these, Fig. 114, the various parts are shown in their position during combing. The feed rollers C C^1 are stationary, and the lap is gripped by the nippers which have closed upon it. By the action of the cam, as previously described, the cushion plate has been forced down until the lap is laid in the path of the advancing comb needles, which enter and comb it. The top comb is raised so as to be out of the cotton, and the detaching roller is stationary with the top detaching or leather roller in its normal position. The circular comb needles enter the end of the lap very freely, and the gradually decreasing pitch of the successive rows causes them to remove all the fibres which are too short to be retained by the nippers as well as the neps which have been left in the cotton previously.

After the combs have passed, the ends of the fibres fall into the space left between the needles and the fluted segment, and the nipper begins to rise. At first the upward motion of the top nipper is accompanied by that of the cushion plate, the combined movement continuing until the screw in the upwardly projecting arm of the nipper cradle comes into contact with the bracket. When this occurs any further motion of the cushion plate ceases, and this is the position which is illustrated in Fig. 115. The top nipper D is just leaving the cushion plate H and the lap is being released. At the same time the top comb L is dropped into the end of the lap, just in advance of the portion which has been cleaned by the circular combs. As the fluted segment approaches the detaching rollers the roller S begins to make its backward movement, so as to bring the end of the combed sliver into a position to give the necessary overlap. The latter is needed in order that the fibres of cotton about to be removed shall be laid upon and joined to those which have previously been combed and detached. For this reason, therefore, the sliver, of which these form a part, is moved backward by the rotation of the detaching roller, which takes place during the period that the first portion of the oscillation of the notched wheel takes place, as described in the last number. At the same time the leather roller Q commences to roll round S, and does so until it comes in contact with the fluted segment. When this happens the position shown in Fig. 116 is assumed. The movement of the detaching roller S is indicated in the figures by the arrow which is marked *a*. A glance at the last figure named will show that the nipper is entirely open, in which case the cushion plate should be about $\frac{1}{4}$in. from the curve of the segment. The feed rollers receive their movement at this period and deliver the lap. The top comb is retained in the cotton, and the leather roller Q comes into contact with the fluted segment. The forward motion of the detaching roller must be sufficient to ensure a complete attachment of the tuft to the sliver, but must be limited so as to leave the end drawn from the lap protruding a short distance beyond the nip of the detaching and leather rollers. The usual overlap of the sliver is about $\frac{3}{4}$in. As soon as detachment and attachment are completed the leather roller is moved back to its normal position, and the end of the lap falls into the space between the segment and the comb. The top nipper descends and presses upon the cushion plate, the parts being then in the position shown in Fig. 117. The continued motion of the top nipper takes place, and the cushion plate is pushed down until it again assumes the position shown in Fig. 114, when combing recommences. The shape and setting of the cam actuating the top comb is such that the latter is raised out of the cotton as the circular combs enter the end of the lap and is dropped into it as soon as the combs have passed.

(357) In paragraph 192 a brief mention was made of a form of roller used for drawing frames which was being introduced. This is what is known as the "metallic" roller; a phrase adopted in order to establish a distinction between it and the

ordinary covered roller. Its main feature is shown in Fig. 118, which is an enlarged partial section of a pair of rollers made on this method. The upper and lower rollers are kept a definite distance apart by means of collars A A, which are fixed respectively at each end on the necks of the upper and lower rollers. These collars are hardened steel, and are ground to a definite size. The body of the rollers are fluted, as shown at B, and the flutes intermesh one with the other; but the point of one tooth is prevented from going to the bottom of its corresponding

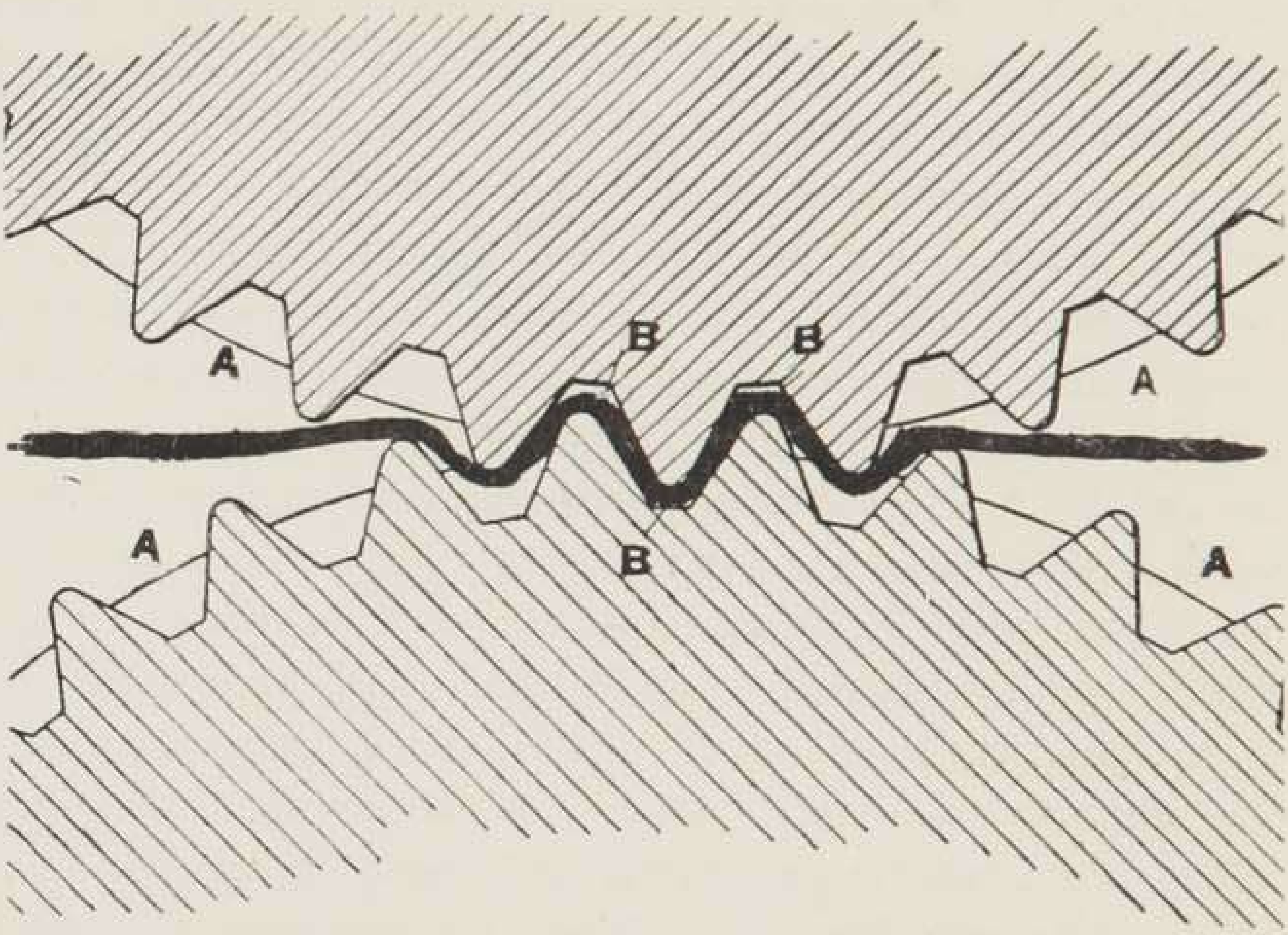


Fig. 118.

flute by the compulsory separation of the rollers. It will, of course, be understood that all the dimensions are greatly enlarged in Fig. 118. The sliver, which is forced through the roller, is shown by the thick black line, and is naturally caused to follow the formation of the teeth, and to be partially crimped, just as in a combing machine. The depth of contact of the teeth is ·044 inch, so that the crimping is slight. The bottom roller being driven naturally drives the upper roller, by means of the pressure exerted on it and the intervening sliver, as shown in the figure. The space between the teeth is ample for the sliver, and no crushing effect is produced. It is claimed for this type of roller that the draft is a positive one, and that there can be no damage to the fibre from such causes as slip or friction, which is often found with leather-covered rollers, especially when care is not taken to keep the top or covered roller in good condition. It is found that a reduction is wanted in the calculated draft when this type of metallic roller is used; and further, that instead of the calculated draft being in excess of the actual draft, the reverse is the case. The explanation of this is not far to seek. The ordinary leather-covered top roller is driven by the forward movement of the sliver, which in turn receives its motion from the rotation of the bottom roller. Thus there is, in the event of any inefficient lubrication or similar cause, a resistance to the free rotation of the top roller to overcome, which is in excess of the driving force of the moving sliver. For this reason it is often the practice to weight the top rollers of drawing frames considerably, especially if the material being drawn is harsh and wiry. The result is that the pressure on the fibre is considerable, and even then it is by no means easy to avoid slip. With the metallic roll such at condition as this cannot arise, because, owing to the absolute grip exercised upon the fibres drawing is certain. Further, the divergence of the sliver from the straight line which, as shown in Fig. 118, must occur, adds to the draft, and thus it is found that there is a greater actual draft than that calculated. Perhaps one of the most useful effects of this particular construction will be found in countries where the leather tends to become adhesive owing to the various atmospheric changes. In this country this cause does not often affect the result, but in some places it is an important matter. The draft of the metallic roll being positive and definite, and depending on a grip and not frictional contact, it is clear that there can be no adhesion. It is also found that there is no necessity to weight the top rollers so heavily, because, as it is only necessary to keep the collars in contact, only such weights as will do this are required. There is thus a decrease of friction. Upon the important matter of even drawing the data at the time of writing are not complete in this country; but the experience in America—whence this roller emanates—has been of longer duration, and it is freely stated that the drawn slivers are more even than those produced by the ordinary rollers, and that there is no weakening of the sliver. Reliable observers in the United States do not agree as to this invention, and a little more use in this country will doubtless establish its merits and demerits. It is a singular fact that corrugated rollers for drawing have been used for long periods in this country and abandoned, and it remains to be seen whether the slight alteration in the form of this roll will really make the difference hoped for. At present the matter may be looked upon not as settled but in process of settlement.

(358) Among the improvements which are worth noting are two of some importance in connection with the speed of roving frames. One of these is shown in Fig. 119, which is a representation of Ashton and Moorhouse's duplex cones for slubbing frames. On page 222, paragraph 230, this matter is referred to, and it was remarked that the strap required to be kept in good condition. Many practical difficulties have been found in this connection, and cone straps of special construction have been devised, to permit of the establishment of an even tension throughout their width. It is, at any rate, desirable that this condition of things should exist, and a considerable tension is put upon the belt to ensure it driving with certainty. Upon the fact of every movement of the belt being followed by the immediate change of velocity of the driven cone depends the correct winding of the roving. The difficulty of moving a belt laterally is proportionate to its width, and it is upon this principle that the arrangement illustrated is designed. It will be seen that there are two sets of cones used. Each of the upper and lower cones are, of course, respectively duplicates, and the cone shafts are extended so as to be long enough to receive both cones. The strap forks, which in this case are duplicated, are attached to an extended rack bar, and,

except for this necessary extension and duplication, the mechanism remains unaltered. The belts used are narrower than ordinary, being only 2 inches wide, and are not in such great tension as the wider belts ordinarily employed. The practical use of this invention has shown its utility, and it is found that the changes are made with greater certainty than when a single belt only is used. It is even of more importance

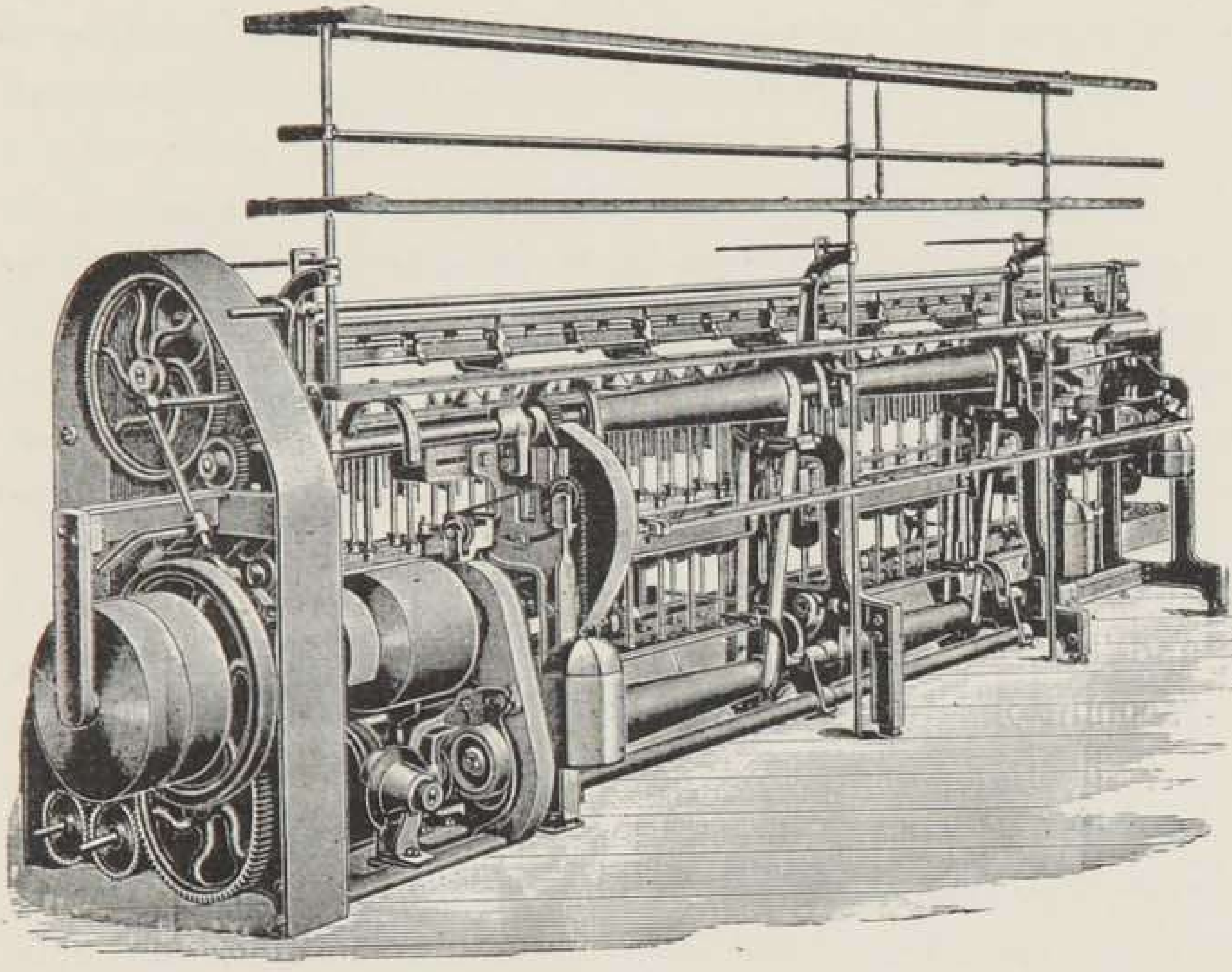


FIG. 119.

in this connection than in the mule, where the movement of the strap is of greater extent and its effect not so delicate.

In paragraph 228 a brief reference was made to the principles underlying the action of the traverse guides in roving frames, and it was remarked that when one traverse guide bar was used, receiving a reciprocal traverse of a definite length, there were times when the leverage exerted was such as to give a weight on one sliver twice as great as that on the other. The double traverse rails there referred to are the invention of

Mr. William Tatham, of Rochdale, who has granted a sole license to Messrs. Platt Bros. The principle involved is clearly set out in the paragraph named, and it is only necessary to give a little fuller description of the mechanism. In Figs. 120 and 121 the old and new form of traverse guide is shown. In the first case the guides are fixed on one rail, which is given an alternate traverse in each direction for a distance nearly equal to the length of the boss of the roller. It will be seen that one of the slivers will be at the nearest point to the centre of the roller which it reaches while the other is at the extreme end. As the weight is applied to the roller at its centre, it follows that under these conditions the sliver nearest to the weight will receive a pressure much in excess of that upon the other sliver. The exact amount of this excess is easily determinable, and it only requires a measurement to be made from the point of the application of the weight to the nearest position of the sliver. Adopting this as the unit, when the pressure is greatest, the relative pressure on the sliver can be easily ascertained. When the guides are in the position shown in Fig. 120, the pressure upon A is only half that upon B, and a load of 24lbs. applied to the centre of the roller would give a weight of 8lbs. on A and 16lbs. on B. In other words, the effective drawing force exerted on A is half that on B, and it is quite obvious that evenness of drawing would not be secured, it being necessary to overload B to get 8lbs. pressure on A. In the new construction shown in Fig. 121 the two guides used in connection with each roller are respectively attached to separate traverse bars. These move in opposite directions simultaneously, so that the slivers A and B move towards, and recede from, the centre of the roller during the same periods. The effect is that they are always evenly weighted throughout their movement, and that the variation arising from uneven drawing cannot occur. Further, a load of 16lbs. applied at the centre of the roller would always give 8lbs. on each sliver, and so ensure even drawing so far as equal weighting can do.

(359) The counts of yarn are ascertained by the employment

of what is known as a wrap reel. This consists of a light metallic swift revolving in bearings, attached to a wooden base, and rotated by a handle carrying on its tail a small bevel wheel forming one of an epicyclic train, similar to that employed in connection with the roving frame. The effect is that one revolution of the handle gives two turns to the swift. The swift, 54 inches circumference, is made wide enough to wind a skein from several cops if desired at the same time, which is

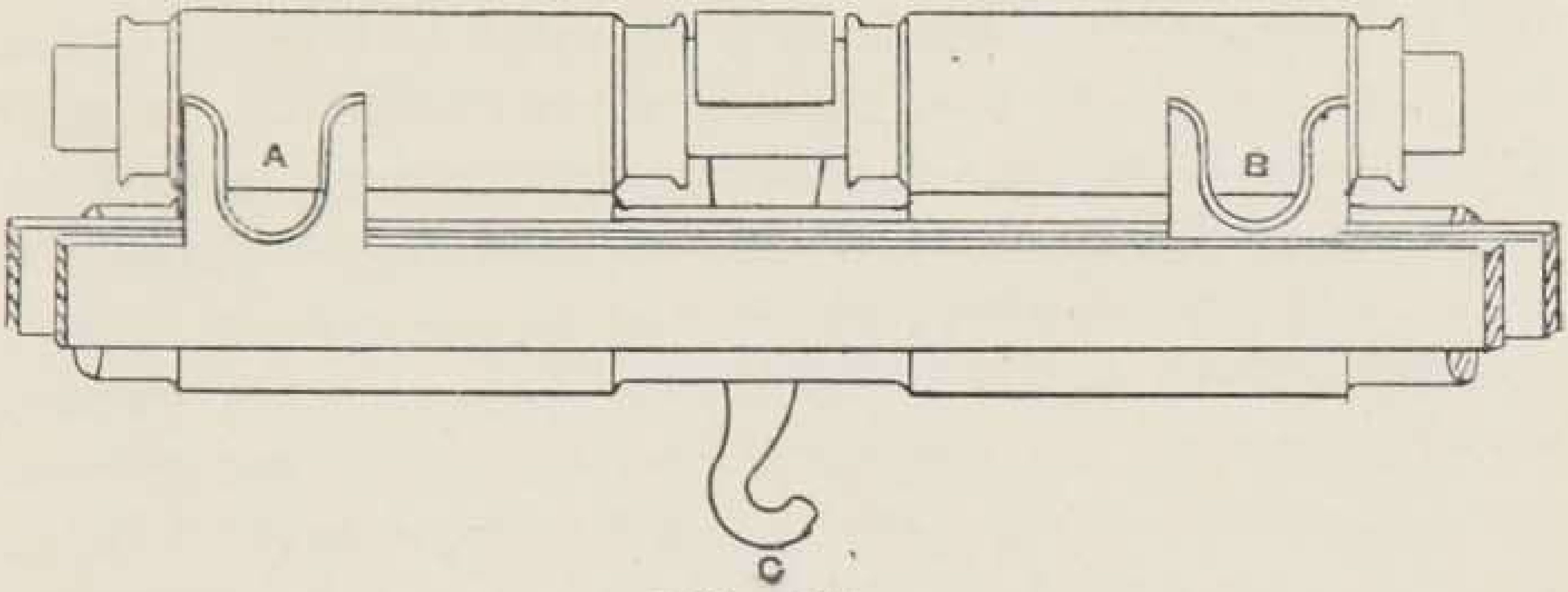


FIG. 120.

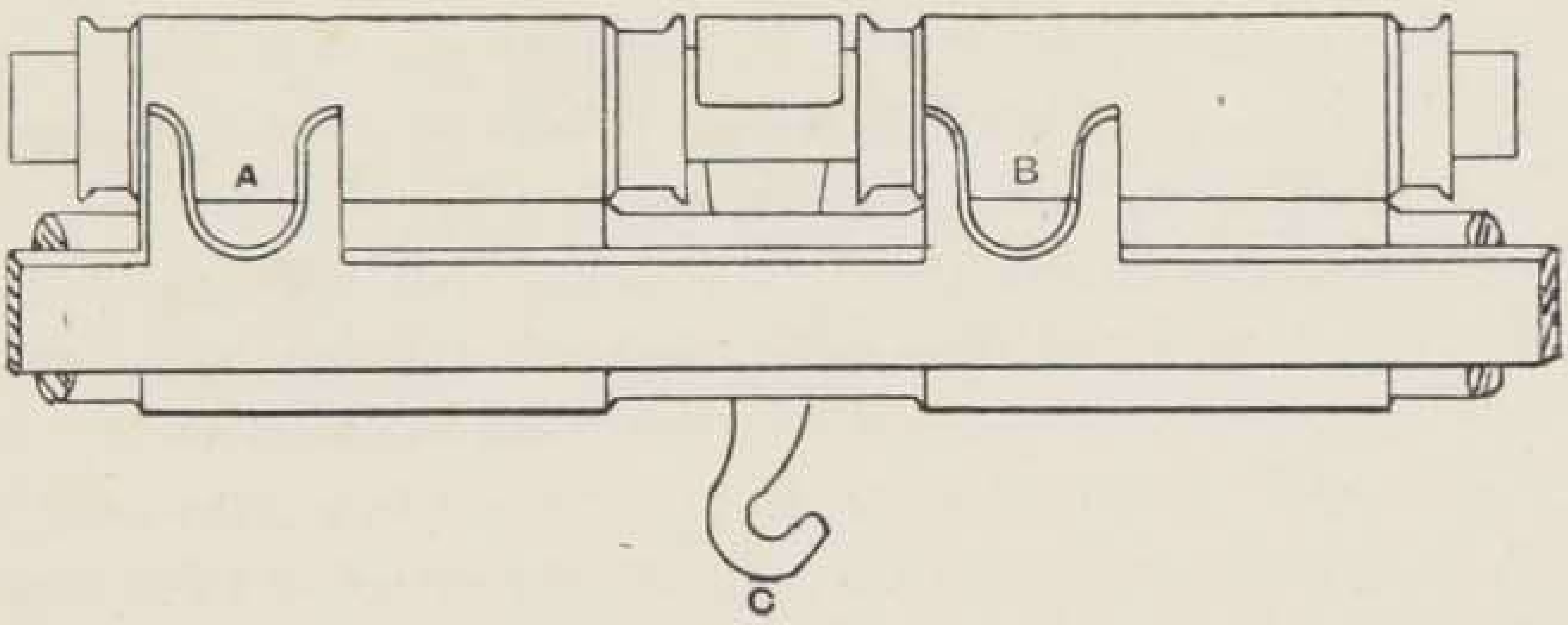


FIG. 121.

occasionally useful. Eighty revolutions of the swift winds 120 yards of yarn, and when this is concluded a bell is struck by a hammer, this calling attention to the fact that the full length is wound. By ascertaining the weight of one lea in grains the counts can be calculated, as described on page 217, by dividing 1,000 grains by the number of grains in each lea. To save the trouble of calculation, tables are published giving the weights of from one to seven leas of various counts of yarn, so that a reference is all that is necessary. The calculation, however, is such a simple one that it is not necessary to reproduce the table. If more than one lea is weighed the corresponding number of thousands must be used as a dividend and the weight of all the leas as divisor. After having got a lea it is sometimes necessary to test its strength. This is done by a machine called a yarn tester, which consists of a fixed hook and a hook attached to a slide controlled by a hand wheel and screw, the position of which causes a greater or lesser pull to be exerted on the yarn. The breaking strain is shown by a finger traversing the face of a circular dial plate. The breaking strain of the same counts varies under different conditions, and it is hardly possible to fix any standard strength. The conditions which affect this problem are so many and numerous that it is quite impossible to specify them all. The character of the cotton, its early treatment, the atmospheric conditions during spinning, the exact twist inserted, are only a few of the things which affect the strength. It is, therefore, customary in ordering yarn, where strength is needed to specify the amount which should exist. For instance, in a table issued by Messrs. George Draper and Sons, of Hopedale, Mass., U.S.A., the strength of 32's American ring warp yarn per lea is given as 54lbs. Dr. Bowman gives the strength of that counts spun from American cotton as 54·7lbs., although they were a little lighter than standard. Mr. James Hyde, in his well-known and admirable book, gives the strength of 32's yarn as follows: Ordinary, 45·6; fair, 46·4; good, 47·3; extra, 48·2; super-extra, 49·1. There is thus a considerable disparity in the figures, and, except as a mean of comparison, the tables given are not very serviceable. Generally the strengths given for American yarns are higher than those common in England, this being accounted for by the harder twist and the better mixture necessary, owing to the difficulties of spinning. The French counts of yarn are based upon the metrical system. The measures of length and weight employed are the metre = 39·37 inches, and the kilogram (kilo.) = 2·2047lbs The yarn which is called No. 1 count is that of which 1,000 metres weighs half a kilogram or 500 grammes, there being 1,000 grammes in a kilogram. The hank is divided into ten skeins (échevettes), each 100 metres long, the full 1,000 metres long being the hank (écheveau.) The circumference of the swift of the reel which is employed to form the hank is 1·425 metre — 56·122 inches — so that it takes seventy revolutions to wind one hank. The following rules will enable all the necessary calculations to be made.

$$\text{Counts} = \frac{\text{Length in metres}}{2 \text{ weight in grammes.}}$$

$$\text{English counts} = \text{French counts} \times 1{\cdot}18.$$

$$\text{French counts} = \frac{\text{English counts}}{1{\cdot}18}$$

(360) Yarn in England is, when produced, dealt with in several ways, as noted on page 359. In America, except for hosiery purposes, the trade in yarn is not great, as most of the great establishments in that country utilise their production in the manipulation of cloth. In England, on the contrary, there is a division between the two operations, although there are a large number of factories in which both the operations of spinning and weaving are carried on. Yarn is often sold through an intermediary, known as a yarn agent. He charges a commission of 1 per cent, with an extra ½ per cent if the account is guaranteed. In many instances yarn is sold by the direct representatives of the mill, and in Manchester 14 days' credit is given, with a discount of 2½ per cent at the end of that period, or an extra ½ per cent is given for prompt cash. There are, of course, many classes of yarns prepared for special purposes which are sold outside of Manchester. For instance, fine yarns are sold as warps, to mix with worsted yarns in Bradford dress goods. These are sold on monthly terms for all deliveries on and before the 25th day of each month, payment being made on the third Thursday in the following month. This means nearly two months' credit in some cases. In Glasgow, yarns are largely sold for thread purposes, and are subject to a maximum discount of 7½ per cent for payment

before the 20th of the month succeeding delivery. Cotton yarns for mixed linen goods are sold for payment less $2\frac{1}{2}$ per cent, on the 4th of every month, for deliveries made up to the 15th of the preceding month. In Nottingham, where yarns are sold for the purposes of lace and hosiery, all deliveries made up to the end of any month are paid for on the first Thursday of the second month following, that is, goods delivered up to the 31st December would be paid for on the first Thursday in February. Sometimes the agent buys his yarn and makes it up into bundles for the special market it is intended for, while in other cases this operation is performed at the mill. In most cases specific instructions are given as to the mode of making up. A bundle is usually made of 10lbs. net weight of yarn, and the number of hanks it contains depends upon the counts of yarn included. It is tied, as a rule, with four strings in its length, although occasionally five are used. If the hank is wound in leas, it is tied so as to keep each lea separate, and the hanks are laid in the bundles either straight or tied so as to form a figure of eight, being so ordered.

The details of a make-up can be varied, but are easily understood by a little study. This matter was raised by a question put in a recent examination, which is here repeated, with the answer. "Define exactly what is meant by the following particulars, given with an order for bundle yarn, taking them in the same order as given—10lbs. net, 40's, 36lbs. test, grandrelle, 20 hank halshed, 8, blue facing, back, no type stamp, black press twine, full length, say how many ends of knots would show at the end of the bundle?" Interpreted, this means that a bundle consisting of 10lbs. net of 40's yarn, each lea capable of sustaining 36lbs. weight, with hanks of full length is wanted. It must be made up so as to have blue facing paper on the face of the bundle, and back paper in the bundles, the twine being hemp and black. The hanks must be tied up in twenties in the form of the figure 8 with grandrelle yarn, and twenty knots would show at the end of the bundle. Yarns in the form of cops are also shipped to the Continent packed in casks, and are thus known as cask yarns. The counts sent in this form range in counts from 20's to 60's, all higher counts being sent packed in boxes. There is a growing trade in yarn wound on quick traverse winding machines into cheeses, as previously described; and ring yarn is now shipped in that form.

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APPENDIX.

GLOSSARY.

Bend. The surface used to sustain the rollers or flats in carding engines.

Changes. In a mule the alteration of the motion of the various parts at the end of the outward and inward runs.

Chase. The extent of the traverse of the winding faller wire.

Cop. The spool of yarn formed on a mule.

Counts. The number of hanks of yarn in one pound weight.

Creel. A frame in which feed bobbins are placed.

Doffer. In carding, the drum removing the fleece from the cylinder; the person removing the bobbins or cops from the spindles.

Doffing. The process of removing finished material from the machines.

Doubling. The combination of two or more laps, slivers, or threads; as a separate process, the twisting together of strands of yarn.

Draft. The amount of attenuation of a lap, sliver, or roving.

Draw. The longitudinal traverse of a mule carriage.

Droppings. The impurities removed from cotton during opening or scutching.

End. One strand of sliver, roving, or yarn.

Fillet. A narrow strip of card clothing.

Fly. The loose short fibres given off during the different operations.

Gauge. The distance from centre to centre of spindles or rollers.

Governing. The regulation of the traverse of the quadrant nut.

Gain. The excess of the surface speed of a mule carriage over that of the feed rollers.

Halching. The entanglement of the coils of yarn at the cop nose.

Hank. A length of 840 yards of yarn.

Keen. The amount of the angle of card teeth.

Lap. A rolled fleece of cotton.

Lea. One-seventh of a complete hank.

Lead. The excess of the revolution of a bobbin, flyer, or traveller over each other.

Licking.	The adhesion of cotton fibres to any surface.
Lift.	The extent of the traverse of a guide eye or bobbin.
Motes.	Fragments of broken seed or leaf.
Neps.	Small knots or tangles of fibres.
Nose.	The extreme upper point of a cop.
Ooze.	The projecting fibres from the surface of yarn.
Piecing.	The union of two ends of sliver, roving, or yarn.
Poker.	The vertical rod sustaining a bobbin or ring rail.
Roller Laps.	Coils of sliver, roving, or yarn wrapped on rollers after breakage.
Roving.	The attenuated and partially twisted sliver.
Selvedge.	The edge of a lap or sliver.
Shaper.	The mechanism by which the shape of a cop is determined.
Single.	A length of sliver, roving, or yarn, in which only one strand exists.
Skeining.	The process of winding yarn into hanks of definite lengths other than the normal.
Sliver.	The attenuated and collected fleece of cotton from the carding, combing, or drawing machine.
Slubbing.	The sliver after having passed through the first roving machine.
Slubs.	Thick pieces of cotton attached to or twisted into the yarn, caused by the accumulation of fly.
Snarls.	Small twisted loops of yarns.
Staple.	The length of individual fibres in any grade of cotton.
Stretch.	The longitudinal traverse of a mule carriage.
Stripping.	Removing the imbedded impurities from card clothing.
Strips.	The impurities removed from a card.
Twist.	The number of turns per inch in a thread or yarn ; yarn used for warps.
Warp.	Yarn used for the longitudinal threads in cloth.
Weft.	Yarn forming the transverse threads in cloth.
Yarn.	The fully twisted roving.

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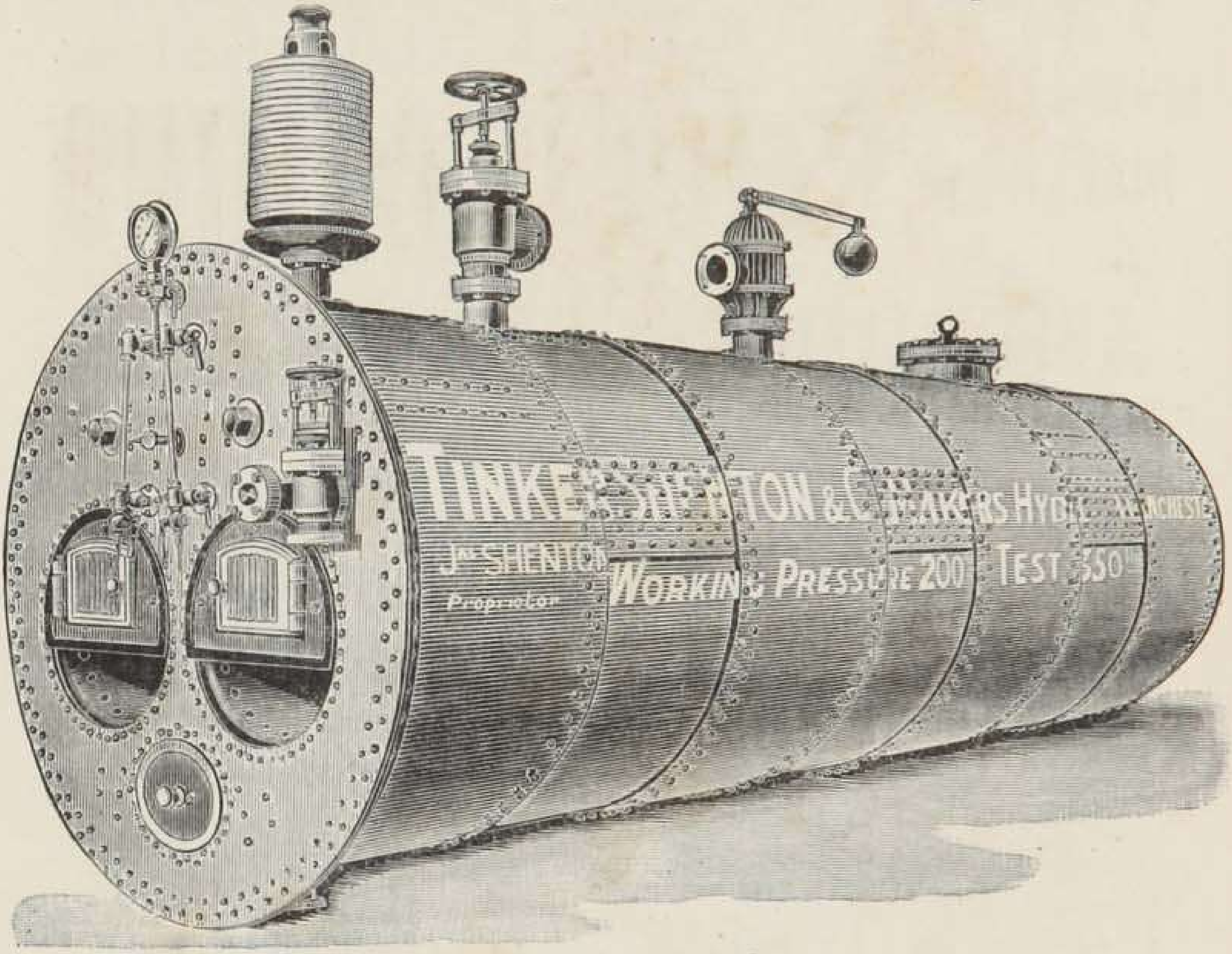

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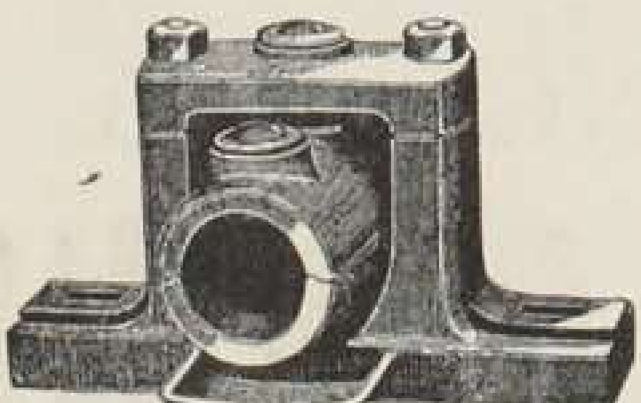

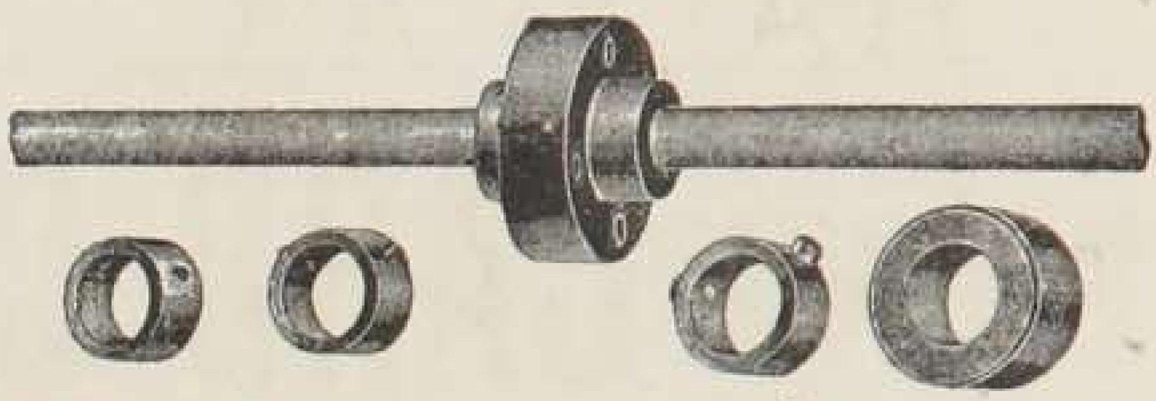

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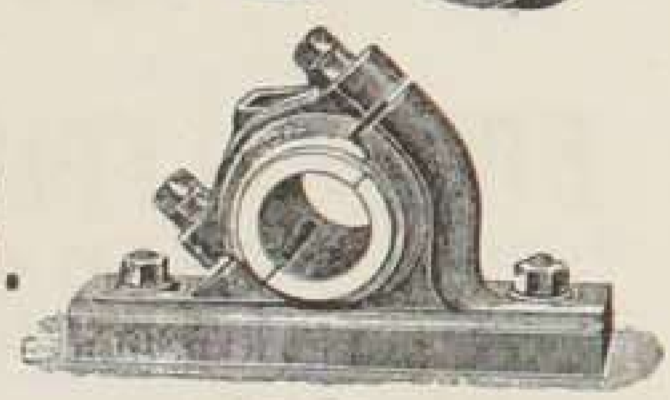
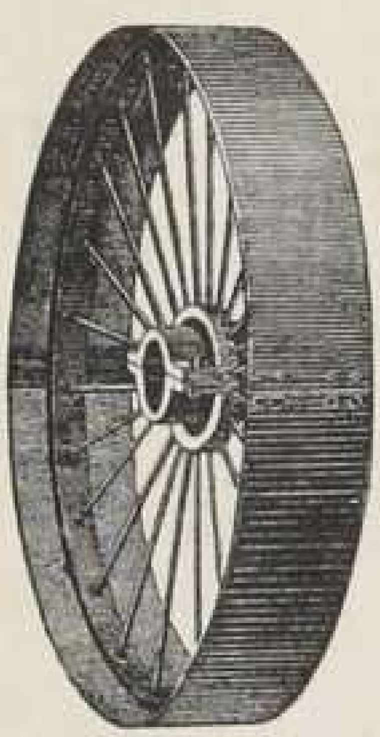
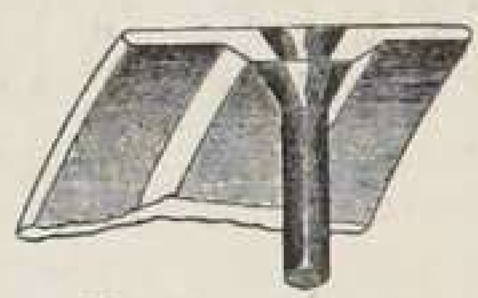




PATENT PULLEYS

Section of Rim and Arm showing method of secure connection.



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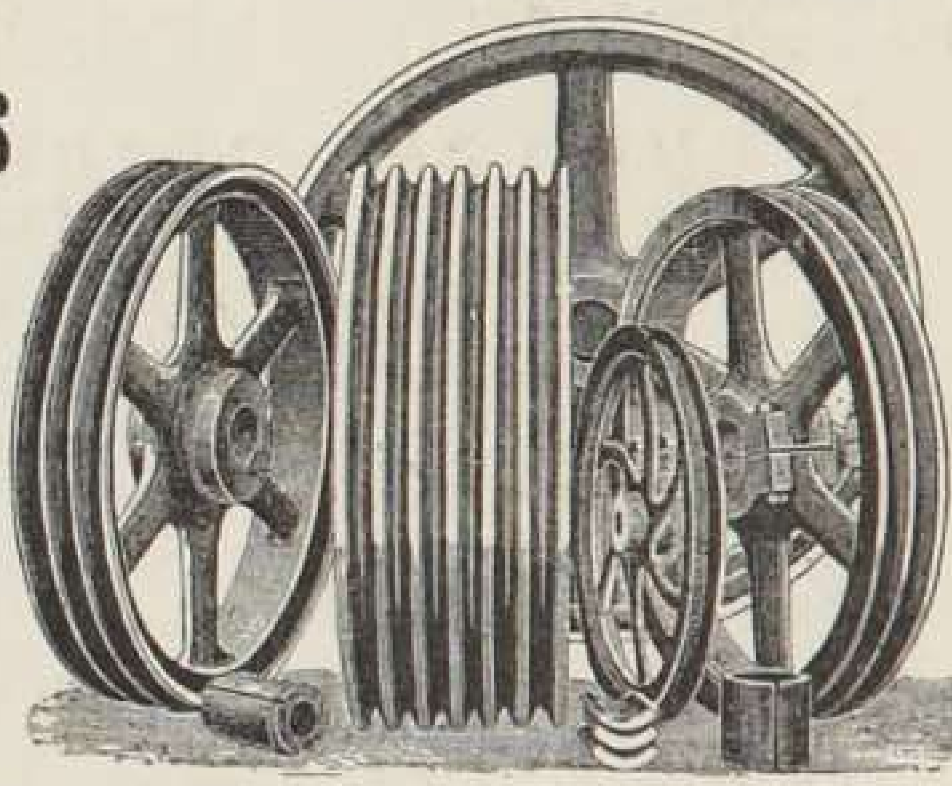
No Increase in Weight.



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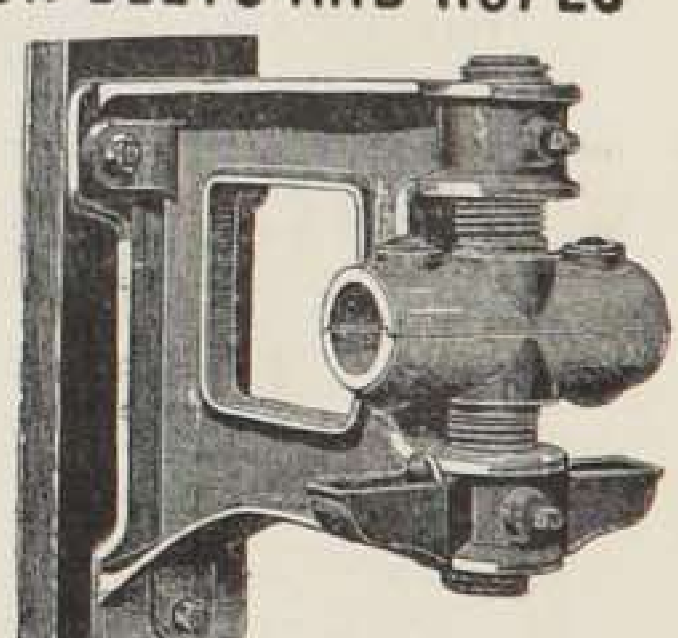

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