MACHINES

AND

PROCESSES OF MANUFACTURE.

THE perfection of machine process which has been reached in the production of a single yard of cotton cloth is one of the best illustrations of the attainment possible to patient study and indefatigable experiment. Baines, the Lancashire historian of cotton manufacture, already quoted, who wrote in 1835, after rehearsing the train of processes, cannot forbear exclaiming: "It is by iron fingers, teeth, and wheels, moving with exhaustless energy and devouring speed, that the cotton is opened, cleaned, spread, carded, drawn, rove, spun, wound, warped, dressed, and woven. The various machines are proportioned to each other in regard to their capability of work, and they are so placed in the mill as to allow the material to be carried from stage to stage with the least possible loss of time; all are moving at once—the operations chasing each other; and all derive their motion from the mighty engine, which, firmly seated in the lower part of the building, toils through the day with the strength of perhaps a hundred horses. Men, in the mean while, have merely to attend on this wonderful series of mechanism, to supply it with work, to oil its joints, and to check its slight and infrequent irregularities; each workman performing, or rather superintending, as much work as could have been done by *two or three hundred men sixty years ago.*"

Yet all this perfection of machine process is only the attainment of many years, half a century at least, and of the worn-out lives of a legion of workers. Brains and hands, working hopelessly in too many instances, were two or three decades in labor before the spinning-frame was evolved, and it is to-day even in doubt to whom the original credit of that great invention belongs. From Crompton's mule to the improved mule of Roberts, fifty years intervened. The Scotch loom of the clergyman Cartwright was invented in 1785, and though it was the original suggestion of all power-weaving processes, the inventor would hardly recognize his idea in the improved machine of the present day. While the principles involved were all suggested in the first constructions, time has wonderfully developed their perfection and magnified both the extent and the quality of their results, so that, what with an enlarged experience and advanced practical science, the model mill of the present must indeed be pretty near the culminating point of excellence in location, structure, labor organization, and mechanical equipment.

To explain satisfactorily, for the comprehension of the general and unpractical reader, the elaborate operation through which a yard of cotton cloth is produced, would be impossible by means of ordinary letterpress, a patient inspection of processes from stage to stage, and story to story, in the mill, being the only mode of imparting a knowledge that involves so much beauty of theory and ingenuity of application. The following bare and superficial suggestion of the processes of manufacture may not, however, be without its value to the reader.

Among the more recently erected mills of Fall River there are probably three or four—possibly a larger number—superior in organization of labor and machine process to any in the world. As the most recent constructions, they not only possess the very latest practical features of perfection in all details of equipment, but are the best efforts of the wisest brains of a community of experts. The general production of the Fall River mills is print cloth, and when we state the probable and generally conceded fact that a yard of print cloth costs to produce in that city less than the same yard costs to produce in any other manufacturing district in the United States, the inference is obvious as to the relative capability of production.

In print-cloth *parlance* the standard of extras—as the marketable first quality goods are termed—is a piece or cut 28 inches in width and 45¼ yards in length, having 64 threads per inch running lengthwise, and 64 threads running crosswise, the cloth—that is, the goods have a standard fineness of 64 threads, or 64 by 64. The longitudinal threads are called the warp and the transverse threads the weft.

In the production of a yard of cotton the first stage regards the preparation of the raw material for the machining into threads. Every mill has its cotton house, conveniently located as is possible, fire-proof so far as ordinary care will secure that qualification, and dry. In a few of the later Fall River structures, where the location has permitted, the basement, but partially sunk, is used for storage of the raw material. The average stock carried by a mill is one thousand bales. Two thirds of the cotton worked up in Fall River is purchased directly for account of the mills, in the South. The grade runs from good ordinary to low middlings. Gulf and bottom-land cottons are much preferred, although it is brought to the city from every part of the producing region. No day passes that a Fall River mill treasurer has not an opportunity to purchase stock, and that quotations from every cotton centre in the country are not presented by the local brokers.

The first introduction of the raw cotton to its new life is its conveyance to the mixing-room, where the bagging and hoops that it put on in the Southern cotton-press are removed. An average quantity of twenty-five tons is

assorted ready for the subsequent operation of cleaning. Here we have our initial glance at the white mass, and can imagine, or attempt to, the myriad myriads of fibres in that fleecy pile. Taking a tiny lock between finger and thumb and pulling the staple, what a delicate filmy nothing is the cotton fibre! It would beggar fancy, could we estimate the infinity of fibres in that mountain of twenty-five tons, reflecting that one week's work of the six towering stories demands that all the fibres of three such mountains shall be cleansed, dusted, straightened and laid out side by side, roved and twisted, and finally elongated into miles on miles of thread of warp and weft, to be interlaced and woven into 250,000 yards of cloth.

Manufacturing conventionalism has originated many expressions strange to well-disciplined terminology, and one of these is the word *bing*. The *bing* is the heap of cotton after it is mixed.

In all well-ordered factories it is considered of large importance to constitute the bing of fair proportions of all the bales. The wool from each bale is evenly spread in a layer upon a perfectly clean floor, so that when the whole number of bales are opened a section cut through from top to bottom will include a contribution from the whole stock. As the cotton in one bale may, notwithstanding the most careful discrimination, be superior or inferior in part or whole, this procedure is obviously important to assure uniformity of the character of yarn, which is a prime quality. No small skill or judgment is exercised in the mixing operation, in order to improve a weak stapled quality and make it work into good yarn. Cottons differing at all considerably in their length of staple and form of fibre lack the elements of strength and tenuity, and the careful manufacturer regards this difficulty with the utmost jealousy, often using fingers and sometimes the microscope to determine characteristics of his raw material. It is said that cotton-brokers—and why not mixers—in exceptional instances, can detect the original locality and year of a bale of cotton, blindfolded, by the simple pull of staple and feel of fibre in their fingers.

Having been mixed, the first introduction of the fleecy bing to its new life is at the eight-inch orifice of a tin or sheet-iron tube. A man sitting at the mouth of the tube does nothing the live-long day but throw armful after armful of cotton into it, a strong inhalation drawing it through as fast as it is served. Urged swiftly along its dark passage, the cotton is precipitated upon and into a revolving cylinder, having an inner bottom wall of fine screen-work and an internal mechanism of moving arms. During its revolution it is beaten and whipped violently by the active arms, the consequent agitation together with a strong air-current forced into the cylinder, separating the usual constituents of dust, sand, and other foreign matter, and driving it through

the screen, to which the main body clings till thrown from an extended apron in fleecy masses on the floor.

There now remains a proportion of seeds, nubs, and leaves yet to be expelled. This is the office of a train of pickers, from each of which, as it moves along, the cotton issues cleaner and cleaner. The pickers first receive the cotton between revolving fluted rolls, from which it is torn into minute fragments by the swiftly operating blades of what is termed the beater, the object being to loosen the hard-packed filaments of the pressed bale, and still farther disintegrate the foreign material. Conveniently situated at this point is an aperture through which enters a powerful draught, which seizes the light fibres as they are torn by the flat blades of the beater, and lodges them on the face of a revolving screen, at the same time expelling the more palpable dirt and leaves from the machine. Carried on the exterior of the screen, the cotton is next introduced to another set of rollers, beaters, and screens, until, free from all its plantation and press-room vices, it emerges in a coil of broad laps of proper weight and uniform thickness, ready to be subjected to the operation of the carding-machines.

The office of the carding engines—generally two, a breaker and finisher—is to still farther separate the filaments and to complete the work of the pickers, and to turn out the cotton, straightened in parallel direction of staple and fibre, in an ultimately continuous strand. If we look in our Webster Unabridged at the common word *sliver*, which from time immemorial is associated with the wounded fingers of childhood, many of us will be able to catch the meaning of a term that the agent of a Fall River mill uses with an entire correctness of original phraseology and application that must be conceded, but a disregard for the pronunciation of the outside world which is at least startling. The *sli-ver* of the cotton-manufacturer's terminology is a provincial English word, and expresses the condition of cotton in a straight strand or ribbon; and it is the business of the carding-room to perform the operation upon the raw material which shall entitle it to this appellation.

Uncurled from the roll of laps by a movement so slow as to be imperceptible to the eye, within the grasp of fluted iron rolls, the cotton is now exposed to the revolving surface of a large cylinder, as thickly studded with minute, exquisitely fine, and hook-pointed teeth as the drum of a music-box. Caught by this legion of tentacles—and it seems impossible for a single particle, however insignificant, to elude them—every fibre is torn individually from every other fibre, and from all foreign substances. The bunch or seed that may have escaped the picker, essays in vain a farther intimacy with the cotton. It can not hide itself away among the interstices of the teeth, but, left on the surface, is at once caught up in a series of "top slats," also armed

with tentacles, which cover the upper periphery of the machine. Opposite to the side of the carding cylinder, at which the cotton lap attaches to it, is another cylinder, some 16 to 18 inches in diameter, called the doffer, whose office is to receive the carded, straightened body of dismembered filaments and roll it out in a fleecy sheet, combing delicately but decidedly the fibrous constituents into a uniform direction.

The extreme tenuity of the sheet as it falls from the doffer may be inferred from the fact that it is only a hundredth part the thickness of the lap which entered the main cylinder.

This thin sheet, as it proceeds from each doffer, is made to pass through an elliptical orifice, and is thus formed into the *sli-ver* or strand, about an inch broad and perhaps one eighth of an inch thick. The cards are worked in gangs, twelve or thirteen of them together, usually placed in a row, and each deposits its charge upon an endless belt, which traverses their united frontage, gathering up the combined production, and finally delivers it to the curious and clever process of the railway head.

The duty of this machine is to transform the bulky mass of fibre coming from the thirteen cards into a small, even, and manageable strand. The railway head is a series of rolls, kept in proper relative contiguity by weighting, to which converge, by means of the belt above referred to, the ribands of cotton from the rank of cards. The stream of ribands, ten inches broad and an inch thick apparently, enters the rolls, and, coming out so thin as to almost resemble cloth of the same width, is swept into a trumpet, delicately poised on springs and having an elliptical aperture hardly one eighth by half an inch in dimensions. Through this small aperture passes the entire product of thirteen cards. The function of the trumpet is double, it being not only to govern the confluence of these distinct streams of machine fibre and reduce them to an approximate stage of their subsequent proportion, but also to correct any errors of weight due to an occasional default of its principles. To the observer's eye it has a generally swaying motion; a downward deflection indicating overweight in the coincident delivery, and an upward the opposite. As soon as it discovers a discrepancy, however, it automatically increases or slackens the speed of the delivery roll, and thus regulates the excess or deficiency.

From the mouth of the trumpet the strand of sli-ver is coiled in a cylindrical case, standing ready to receive it. In the average Fall River mill there are twelve of these gangs or sections of cards, six of which treat the cotton which goes into the warp, and the same number that for the weft. In England, previous to the invention of the railway head, which was originated at the cotton factories in Matteawan, N. Y., each card delivered into its individual

can, and an independent process was requisite to unite the products in one strand.

We have now arrived at the first form of the thread. We have the cotton clean, the fibres straight and parallel, but the thread is much too large, and altogether lacks strength, being nothing more than a spongy continuity, held together by the mere coherence of its staple. To reduce it to a suitable size and impart the needed degree of strength, are problems next claiming our attention, the solution of which calls for two processes of drawing, three of speeding, and finally the function of the mule, or yarn finishing proper.

Twist is the element which adds strength to sli-ver, by compactly twining about each other the cotton fibres. In the drawing-frames no twist is imparted; in the speeders, or roving-frames, only so much as will afford enough strength to uncoil itself for each succeeding process; but in the mule all the twist is furnished that a perfect and enduring thread demands. From each consecutive stage of the process of manufacture we are now considering, the strand gradually emerges smaller and smaller, nearer and nearer approaching the yarn, which is our objective.

The process of drawing is conducted by machines involving the same principle as the railway head, and not unlike it in general design, having rollers and funnel preserving the same relations to each other. In the first process three separate strands, the product of the railway head, are drawn down by the action of fluted rolls, and then united through a trumpet or funnel in one strand. The second process is an exact copy of its precedent, the same number of strands emerging from the first train of drawing-rolls being subjected to a second operation of union. The effect of this machining has been not only to reduce the relative bulk of the sli-ver, but to perfect the straightening of filaments, and by associating ribands of sli-ver to strengthen the whole.

The strand is now ready for the action of the speeders. These are three in number, namely, the slubber, intermediate, and jack. The processes of these machines are all similar, the work being simply a series of stages. As in the drawing-frames, the grooved rolls are still essential features, reducing gradually the volume of the strand. But, as twist is first here introduced, an entirely new feature is now for the first time found, in the presence of the spindle.

From the cans containing the product of the drawing-frames, the sli-ver is first subjected to the train of rolls, and then passes automatically on its way till seized by a bifurcated attachment of a revolving spindle, of which there are generally thirty to each slubber or coarse-roving frame. The spindle likewise carries a wooden bobbin or spool, the flyer, as the bifurcated attachment is called, setting over it on the spindle. The strand, in the grasp of one of

the arms of the flyer, is swung round and round by its revolution, and thus compelled to assume a regular degree of twist, while, directed by the other arm, it is wound about the convenient bobbin in layers of coil.

The rolls through which the strand is fed, and the spindle which carries both flyer and bobbin, have each their regular and certain speed of revolution, but, while the flyer revolves with the spindle, the bobbin has its independent motion and different in speed from that of the flyer. This variance of velocities is necessary, since, if both revolved with the same speed, the small periphery of the bobbin could not take up the full measure of roving, as the strand is called after twisting, fed to it by the extended arm of the flyer. To meet this exigency has required no especial skill in mechanical movements, but a second difficulty presented itself, much more serious. This discovered itself in the increasing surface of the bobbin, its volume enlarging with every additional coil of roving, while the stream itself was not at any time accelerated or slackened. The result was that the bobbin must have what may be termed a speed varying from itself, a velocity of rotation in inverse ratio to its increase of periphery. The solution of this problem, for a time baffling the inventive powers of many excellent machinists, was at last achieved by Mr. Henry Houldsworth, of Manchester, England, who devised an equational motion, by which every exigency was allowed for. It may well be called the differential calculus applied to mechanism; a more beautiful device certainly is not known in the whole range of cotton machinery.

The slubber, or coarse-rover, is followed by the intermediate. This machine has just half the number of bobbins of its predecessor, two bobbins in the former delivering strands to one in the latter frame. The same process is pursued with the jack or fly-frame, which is the last of the train of roving-machines.

The bobbins of the fly-frame represent the finished product of the carding-room. All the stages of the manufacture so far described are under the direction of one man, who employs about sixty operatives to perform his work in all its branches.

From the processes of the three speeders, the sli-ver, or, under its new appellation, *roving*, receives just so much twist, and no more, as is essential to enable it to unwind, without impairing its uniformity. Having still to undergo a process of elongation and consequent attenuation, a proportionately increasing union of filaments is obviously demanded.

The finishing and spinning stage of the cotton thread is now reached. The machine by which these final operations are performed is termed a mule. The name of a hybrid animal was probably given to the machine at its birth, because it had two distinct functions—to subject the cotton strand to its

extreme tension, and thus draw it down to the constituency of thread, and to exert upon it the maximum torsion required to give it a permanent twist, and thus, by the perfect implication of its filaments, to assure its strength.

The mule is the most ingenious and complex machine used in cotton manufacturing. If it possesses no isolated feature as curious as Houldsworth's exquisitely clever application of equational mechanism to the speed of the bobbin, in the antecedent process, it is the combination of numberless adroit achievements and ingenious devices, contributed by as many inventive hands almost as its whole has parts. No man can claim as his own invention the machine as it now is, the growth of many brains and product of many inventions.

Twenty years ago the hand mule was not infrequently met in American factories—a machine which could not perform its work without manual assistance in its regular and necessary changes. The self-acting mule of to-day operates of and through itself, and embodies the poetry of manufacturing. Six or eight hundred spindles, and sometimes even a thousand, set in a carriage, moving backward and forward automatically, hum busily around at a speed of 6000 revolutions in a minute. On these spindles is built the cop, or conical ball of thread spun by the two-fold operation.

Like the drawers and speeders, a mule has its essential train of rolls. The roller-beam may be imagined occupying the background of the machine. The bobbins, bearing the accumulations of the last speeder's work, are set in a creel back of the roller-beam, and their strand ends inserted between the rolls. In the foreground of the machine, perhaps five feet from the rolls, and parallel with them, are the spindles, in regular alignment, close ranked together. This rank of spindles, actuated by the will of the tender, travels forward to the roller-beam and backward to its own position, its carriage, not obvious to the view, running upon three or more ground rails. The spindles are first run up to the roller-beam to receive the ends of the bobbin strands. These attached, the farther operation is thus described by Dr. Ure: "When the spinning operations begin, the rollers deliver the equally attenuated rovings as the carriage comes out, moving at first with a speed somewhat greater than the surface motion of the front rollers. The spindles meanwhile revolve with moderate velocity, in order to communicate but a moderate degree of twist. When the carriage has advanced through about five sixths of its path, the rollers cease to turn or to deliver thread. The carriage thenceforth moves at a very slow pace, while the speed of the spindles is increased to a certain pitch, at which it continues till the carriage arrives at the end of its course. The spindles go on revolving till they give such an additional twist to the thread as may be desired, the degree of twist being

greater for warp than for weft. The spindles then stop, and the whole machine becomes for a moment insulated from the driving-shaft of the factory. Now the delicate task of the spinner begins. First of all he causes the spindles to make a few revolutions backward. In this way he takes off the slant coils from their upper ends, to prepare for distributing the fifty-four or fifty-six inches of yarn just spun properly on their middle part. He, using the *faller-wire* with his left hand, gives it such a depression as to bear down all the threads before it to a level with the bottom of the cop, or conical coil, of yarn formed, or to be formed, round the spindles. Under the control of an experienced eye, his right hand at the same time slowly turns the handle of a pulley in communication with the spindles, so as to give them a forward rotation, and his knee pushes the carriage before it at the precise rate requisite to supply yarn as the spindles wind it on. As the carriage approaches to its primary position, near to the roller-beam, he allows the faller-wire to rise slowly to its natural elevation, whereby the threads coil once more slantingly up to the tip of the spindle, and are thus ready to coöperate in the twisting and extension of another stretch of the mule."

Dr. Ure's description gives a correct idea of the general operation of the mule as it was in England in 1865. Improvements made since the issue of the volume from which quotation is made, and due to American ingenuity, have, however, still farther developed the self-acting nature of the machine, till it is now indeed, in all respects, automatic. In the perfected mule of American production—which, made by Hawes, Marvel & Davol, of Fall River, and other manufacturers of spinning machinery, is now generally purchased for the equipment of mills—instead of the one faller-wire indicated by Ure, there are two, the upper, or faller proper, which leads the thread and forms the cop, and the lower, or counter-faller, which stiffens the thread and assists the operation of its companion. These wires, supported by curved arms or hooks, placed at intervals along the rank of spindles, are extended parallel with the spindles at a distance of about three eighths of an inch. The hooks, actuated by a weight, incline downward when the carriage is nearly run out, thus dropping the wire to the base of the spindle and pressing down the thread. When the carriage retires, the hooks rise again, elevating the wires and relieving the cops. The wires can be controlled by hand, but this is unnecessary, and when their action is wholly automatic the cops are better than those produced by the most experienced spinners. In this respect the improvement is a very valuable one, while there is the still farther important advantage gained by the automatic process, that the spinner, relieved of his constant care of the faller-wires, has only to watch the general operation

of the mule, preserve the continuity of threads, and repair those that are broken.

Looking at the spinning process, in which sometimes a thousand spindles are twisting, stretching, and winding up a thousand threads, the mule of mechanism seems much more like a sentient organization than the mule of nature.

In the average Fall River mill, 40,000 of these spindles run back and forth, in industrious locomotion, all day long, as busy as the ant of fabled story.

The same machine can be adapted for the production of warp or weft, the former being coarser and requiring more twist. The weft on leaving the mule is ready for the loom, the warp still requiring some preparatory attention before it is in condition. The thread in both cases, however, is all right, as the stage of manufacturing ended with the spinning process.

Our yard of print cloth, it will be remembered, is 28 inches broad, having 64 threads to the inch, and consequently 1792 threads of warp must be used to constitute its whole width. It is obvious that the yarn-beam, which is to furnish the material for the loom's consumption, must, therefore, hold 1790 threads, the weft forming the two outside threads. The operation of transferring the thread from the cops to this beam is not direct, there being intermediate stages worthy our notice.

In the first place, the warp cops are wound on spools, 6 inches long and 4 inches in diameter. These spools, 358 in number, are then arranged in a creel or stand, and subjected to the warping-machine, an ingenious contrivance credited to the eccentric Jacob Perkins, inventor of the steam-gun, which detaches their threads and winds them, each distinctly, the whole number preserving an exactly parallel alignment, on its beam. Five of these beams thus freighted are then taken to the slasher, or dressing-machine, where they are all wound on to the main yard-beam for the loom. During its passage through the slasher, the yarn is stretched and ironed, and also measured into sections of forty-five and one quarter yards, the points being indicated by a red, blue, or yellow dye, where the weaver is to take off a cut. The Fall River mills weekly consume 50,000 lbs. of potato starch in dressing their yarns.

The yarn-beam, 34 inches in length, has now wound upon it 1790 parallel coils, each something more than 15,000 feet, and together forming a body of warp, as the thread is now termed, 18 inches in diameter.

The weft-thread requires no dressing, or even manipulation, after the finishing stage in the mule, being at once taken, cop by cop, and placed in the shuttle to do its duty as an individual thread in the weaving process.

If we reflect that the function of a shuttle in a loom is the same as that of a needle in a woman's fingers, it is obvious that the warp must be made to assume some shape different from a web of 1790 threads, stretched upon a perfectly even plane. In the process of darning, the sempstress's intelligent and habile fingers direct the needle over and under the threads of the fabric she works upon. The shuttle has to darn, but has no sentient intelligence to direct its point, and is obliged to run its course to and fro in the loom, whether it passes a thread or not. This being the case, it is necessary to arrange the warp threads so that the shuttle, carrying its thread of weft, will pass over one and under the next, and *vice versâ* across the web. To effect this, recourse is had to the harness.

The harness, or heddle, as it is called in England, was a necessary fixture of the original hand-loom, and, until some more clever and convenient device shall supplant it, will remain a fixture of the power-loom so long as men weave cloth. Possessing neither mechanical beauty nor the least degree of ordinary inventive ingenuity, its place is permanent and its function indispensable.

The harness is a web of varnished hempen twines, running perpendicularly and quite close together, enclosed in a framework just heavy and strong enough to give it permanent shape. In forming the web, each couple of twines by a system of knotting is furnished with an eyelet, or small loop, so that the harness has a row of eyelets crossing its entire length. The pair of harness are separately suspended by pulleys from an arched beam of iron which rises over the loom—one a little lower than the other, so that the ranks of eyelets will be on a different level—and passing down into the loom, are secured to the machinery of a set of treadles, by which they receive such upward and downward play as the work demands.

Before placing the yarn-beam in its position on the back of the loom it is necessary to pass its threads through the two harnesses that are required in the production of plain cloth. This is done in the web-drawer, which separates the 1790 ends of thread, and puts half of them through the eyes of one harness, and half through the eyes of the other. The beam is now set in its place and the harnesses suspended from their iron archway. The next operation is to take the ends of each pair of threads, held by the loops of the harnesses, and insert them in the dents of the reed, a light framework of wood, after passing through which they are finally secured to the cloth-beam, which is situated on the front of the loom, relatively opposite to the yarn-beam. If the reader has been able to follow this description of the arrangement of the warp, he will see that after passing the loops of the harnesses it is divided into two webs, or banks of web, the threads of which have an upward and down-

ward play through the harnesses, actuated by their treadle connection. The space thus opening and constantly changing for the race of the shuttle, and with each motion offering a thread alternately above and below its plane, is termed *shed.* With every play of the shuttle crosswise, its coadjutor, the reed, vibrates backward, *beating up*, or forcing the threads of weft to close together, and then, resuming its position, gives place for the return of the busy worker. This is, roughly and superficially sketched, the process of the loom, utterly prosaic and destitute of the fine mechanical achievement and the poetry of motion discovered in the spinning stage, yet a veritable realization in its operation of the cognate process pursued by human fingers.

The foregoing summary of the different stages of manufacture, though without the assistance of illustrative cuts to make its details clear to the unpractised contemplation, will still impart a general idea of the operation through which the raw material from the Southern cotton-press is spun and woven into 64 by 64 print cloth in the Northern mill.

How long a period is consumed in the passage of the raw material through the consecutive processes, is a question that may suggest itself to the curious mind. It is not so easy to answer this question in the regular operation of a mill, but assuming a new grade of cotton to be put into a mill, furnishing the entire preparation for the looms, it would require fully seven weeks to work up the whole bing, though within ten days a portion of it should have issued in the shape of cloth. The latter period may therefore be accepted as a fair length of time to go through all the processes, under good average working conditions.

The manufactured cloth is conventionally allowed to weigh seven yards to the pound of cotton consumed; that is, one yard weighs one seventh of a pound, or $2\frac{29}{100}$ ounces. This does not of course represent the entire weight of cotton as taken from the bale for the specific yard, there being an unavoidable waste in the various operations; and practically, calculating the proportional weights of hoops and bagging for which the mill has to pay, about three ounces gross weight in the bale is the equivalent of the yard of Fall River print cloth. The estimate is also somewhat affected by the grade of cotton used (some grades showing much less foreign matter and making less waste than others), and by the care taken to utilize the waste. The first figures given of the weight allowed ($2\frac{29}{100}$ ounces) to each yard indicate a waste of $\frac{79}{100}$ ounces in the gross amount. The value of this waste is realized by selling it, and by so much diminishes the gross amount, leaving a net waste relatively small. Manufacturers of print cloth, out of every gross pound of the grades commonly put in, expect to obtain from 5 to $5\frac{1}{2}$ or $5\frac{5}{8}$ yards of fabric.

The waste per gross pound is now estimated at about fifteen per cent in the New England mills. In 1831 it was perhaps twenty per cent.

The experience of the Fall River cotton manufacturers has led them to the conclusion that the most desirable size of a mill, for the manufacture of print cloths, is one of 30,000 spindles. In such a mill, the different parts balance each other to the best advantage; that is, if properly arranged, the looms will just take care of the preparation—the carding, spinning, dressing, etc.—with no surplus or deficiency. It is also about as large as a superintendent can handle easily, by keeping up the different ends, and having every thing run smoothly, without hitch or break.

Such a mill, according to the Fall River standard, should be built of stone or brick, 300 feet long, 72 feet wide, five stories high, with hip or flat roof, the latter more desirable on account of fire. It will have a capacity of 30,000 spindles and 800 looms, will employ 325 to 350 operatives, and use about 3500 bales of cotton in the production of 9,000,000 yards of print cloths per annum. A capital of $500,000 would probably be required to pay the cost of the mill and machinery (which are generally reckoned in the proportion of two fifths and three fifths), and allow a small margin for working capital. From four to ten acres is generally allowed for a mill site, varying according to the number of tenements put up for the operatives.

There are some twelve general departments in a mill of from 30,000 to 40,000 spindles, and employing from 350 to 450 persons. These are divided as follows: 8 pickers, 8 card-strippers and grinders, 4 drawing-tenders, 24 speeder-tenders, 30 other card-room hands, 32 spinners, 36 other hands in spinning-room, 28 spoolers, 6 warpers, 3 slashers, 11 web-drawers, 200 in the weaving department, and some forty on miscellaneous work. Each department is necessary to every other, and all act as forwarders of the general work. If one department, though never so small, becomes disarranged from any cause, the result is a disarrangement of all the other departments of the mill. Hence the necessity that the mill "when wound up," as it is called, should have all the departments balance each other in their production, and that the superintendent should be a man of skill and judgment, and of sufficient capacity to keep the whole machine well in hand.

Of course a very important factor in the perfect organization of a cotton factory is the arrangement of the different departments of machinery. The system pursued in Fall River disposes of the five stories allotted to manufacture, as follows: The first and second floors are used for weaving, the third for carding, and the fourth and fifth for spinning. The engine is placed in an ell, running from the centre of the rear of the mill and generally opposite to the tower, which furnishes the main ingress and egress on

the front. The main driving-wheel, from which proceed all the belts transmitting the power to the various departments, is entirely within the basement of the main structure, thus bringing the source of transmission in the closest possible relation to its work. This ell, usually three stories high, is occupied by the mixing-room and the picking-room, the latter on a level with the third story of the mill, so that the picking stage delivers its cotton on the same level to the carders, where it is divided, a part led off in one direction to form the warp and the remainder in the opposite direction to form the weft. After undergoing the various processes of the carding-room, the preparation, still preserving its newly assumed relations, passes up through elevators located at each end of the mill, to the stories occupied by the spinning machinery, whence the cops are lowered, when finished, to the weaving floor. In the factories of New England, at the period of Mr. Montgomery's visit and description, the second story was used for the carding, the third the spinning, and the fourth and attic the weaving and dressing.

The cotton is generally stored in a separate building, though in occasional new mills of six stories the ground floor is, by a very convenient and economical arrangement, devoted to this purpose.

The average wages for operatives of all ages are a trifle above those of Lowell and Lawrence, and while Fall River has to compete on short ten-hour time directly with the Rhode Island mills, not regulated as to hours of labor, the former makes a better showing in the remuneration accorded to its operatives.

The operatives employed in Fall River are mostly foreigners, but the American, French, and Irish elements are well disposed as a rule, and give little trouble except when led by the English (Lancashire) operatives, who, having come from the most discontented districts of England, have brought their peculiar ideas and the machinery of their home style of agitation along with them. This system is not relished by the other operatives, but so potent has been the influence of the active element that it has sometimes held the others in awe, and in times gone by has even been so powerful that if one of the trades-union men went into a mill and held up his hand, all the operatives at once, quitting their machines, left the mill, and went outside to find out why it was that they left their work. But it is hoped that the day of this style of terrorism and despotism has gone by, and that the compulsory system of school education, now in force in Massachusetts for factory children, will put them in a position to control their own motions, rights, and interests.