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SILK, Manufacture of. In England, where silk is not produced in any quantities to be employed by the manufacturer, he must commence his operations upon the raw silk, with no other preparation than that of being wound off into skeins or hanks from the balls, or cocoons, which the silk-worms form.

In this state the silk is imported from those countries where it is produced, as Italy, Flanders, Spain, Portugal, Turkey, the East Indies, and China. A thread of this raw silk, drawn from the skein, is found to be composed of an assemblage of several of the fine fibres or threads produced by the worms; the fibres being united together by a natural gum, which is in the silk, and which is soluble in the hot water in which the cocoons are immersed when the silk is wound off.

To prepare this raw silk for use, it is wound from the skeins upon bobbins; the compound thread is then twisted, to unite the constituent fibres more firmly than they can be by the gum alone; and afterwards, being wound again upon fresh bobbins, two or three threads are twisted together to produce a stronger thread, fit for the weaver, who warps and finally weaves the silk into various articles of ornaments or utility, by processes very similar to the weaving of cotton or linen, but more delicately conducted.

In the countries where the silk is produced, the manufacture may be more properly said to commence with the operation of winding or reeling off the threads into skeins from the cocoons, or balls, in which the worms envelope themselves. These balls become an article of trade, as soon as the insect within them is killed by exposing them to heat, either of the sun, or in an oven, or by the steam of boiling water; and, in general, the breeders of silk-worms sell them, in this state, to persons who make a business of the operation of winding. In Piedmont, where capital silk is produced, it is conducted, as follows, by the aid of the silk reel represented in *Plate Silk Manufacture, fig. 1.*

The balls are thrown into hot water, contained in a copper basin or boiler, A, which is about eighteen inches in length and six deep, set in brick-work, so as to admit a small charcoal fire beneath it; or if a fire of wood is intended to be made, the fire-place must have a small flue or chimney of iron plate to carry off the smoke. At the side of the boiler is placed the reel, which is very simple. B-B marks the wood-framing which sustains its parts: these are, the reel D,

upon which the silk is wound; the layer *a*, which directs the thread upon it; and the wheel-work *b c*, which gives motion to the layer. The reel, D, is nothing more than a wooden spindle, turned by a handle at the end; and within the frame, at each end, it has four arms mortised into it, to support the four battens or rails on which the silk is wound. The rails are parallel to the axis, and at such a distance, that they will form a proper-sized skein by the winding of the silk upon them, (it is usually a yard for each revolution.) One of each of the four arms is made to fold in the middle of its length with hinges, so as to cause the rail, which these two arms support, to fall in or approach the centre, and thus diminish the size of the reel, and admit the skeins of silk to be taken off at the end of the reel when the winding is finished.

Upon the end of the wooden spindle of the reel, and within the frame B, is a wheel of twenty-two teeth, to give motion to another wheel, *c*, which has about twice the number of teeth, and is fixed upon the end of an inclined axis, *c b*; this, at the opposite end, carries a wheel, *b*, of twenty-two teeth, which gives motion to an horizontal cog-wheel of thirty-five teeth. This wheel turns upon a pivot fixed in the frame, and has a pin fixed in it, at a distance from the centre, to form an excentric pin or crank, and give a backward and forward motion to the slight wooden rail or layer *a*, which guides the threads upon the reel: for this purpose, the threads are passed through wire-loops or eyes, *a*, fixed into the layer, and the end thereof opposite the wheel and crank, *b*, is supported in a mortise or opening made in the frame, B, so that the revolution of the crank will cause the layer to move, and carry the threads alternately towards the right or left. There is likewise an iron bar, *e*, fixed over the centre of the boiler at *e*, and pierced with two holes, through which the threads pass to guide them.

To describe the operation of reeling, it should be understood, that if the thread of each ball or cocoon was reeled separately, it would be totally unfit for the purposes of the manufacturer; in the reeling, therefore, the ends or threads of several cocoons are joined, and reeled together out of warm water, which softens their natural gum, and makes the fibres stick together, so as to form one strong smooth thread; and as often as the thread of any single cocoon breaks or comes to an end, its place is supplied by a new one, so that by continually keeping up the same number, the united thread may be wound to any length. The single threads of the newly added cocoons are not joined by any tie, but simply laid on the compound thread, to which they will adhere by their gum; and their ends are so fine, as not to occasion the least perceptible unevenness in the place on which they are laid.

The woman who conducts the reeling is seated before the basin A, and employs a boy or girl to turn the handle of the reel; a fire is lighted beneath the basin A; and when the water becomes nearly boiling hot, she throws into the basin two or three handfuls of cocoons, and leaves them some minutes, to soften that natural gum with which the silk is impregnated; then she stirs up or brushes the cocoons with a wisk of birch or of rice-straw, about six inches long, cut stumpy, like a worn-out broom; the loose threads of the cocoons stick to the wisk, and are drawn out: she then disengages these threads from the wisk, and by drawing the ends through her fingers, cleans them from that loose silk which always surrounds the cocoon, till they come off entirely clean: this operation is called *la battue*: and when the threads are quite clean, she passes four or more of them, if she intends to wind fine silk, through each of the holes in the thin

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iron bar *e*, which is placed horizontally over the centre of the basin *A*; afterwards she twists the two compound threads (which consist of four cocoons each) twenty or twenty-five times round each other, that the four ends in each thread may the better join together by crossing each other, and that the thread of the silk may be round, which otherwise would be flat.

The threads, after passing through the holes in the iron bar *e*, and being twisted together, are passed through the eyes of the loops, *a*, of the layer, and thence being conducted to the reel, are made fast to one of its rails. The child who turns the reel, gives it the most rapid movement possible, and thus draws off the threads from the cocoons in the basin *A*. The slow traversing motion of the layer prevents the threads lying over each other upon the reel, until it has made so many revolutions in the air as to dry the gum of the silk so far, that the threads will not adhere together. After the reel is covered for about the breadth of three inches, by the gradual progression of the layer, it returns and directs a second course of threads over the first laid, and so on until the required length for the skeins is obtained. The machine winds two skeins at one time. As it is essential to the production of good silk, that the thread should have lost part of its heat and gumminess before it touches the bars of the reel, the Piedmontese are by law obliged to have a distance of thirty-eight French inches between the guides, *a*, and the centre of the reel; and the layer must also, under a penalty, be moved by cog-wheels instead of an endless cord, which is sometimes used in Italy, and which, if suffered to grow slack, will cause the layer to stop and not lay the threads distinctly, and that part of the skein will be glued together, whereas the cog-wheels cannot fail.

When the skeins are quite dry the reel is removed from the frame, and by the folding of two of its arms the skeins are taken off. A tie is made with some of the refuse silk on that part of each skein where it bore upon the bars of the reel, and another tie on the opposite part of the skein; after which it is doubled into a hank, and usually tied round near each extremity, when it is laid by for use or sale.

This operation appears very simple, but to produce a good thread requires much attention. The reeler must not wait until the thread of a cocoon is entirely exhausted before she joins on another, because the threads near the end have not above a quarter of their full thickness. The cocoons produce a very unequal length; some may be met with which yield 1200 ells, whilst others will scarcely afford 200 ells. In general, the production of a cocoon may be estimated from 500 to 600 ells in length. As often as the cocoons she winds are exhausted, or break, or only diminish, she joins fresh ones to keep up the requisite number, or the proportion; because, as the cocoons wind off, and the thread becomes finer, she must join two cocoons half wound to replace a new one. Thus she can wind three new ones and two half wound, and the silk will be equal to that produced from four to five cocoons. When she would join a fresh thread she must lay one end on her finger, throw it lightly on the other threads which are winding, and the gum will join it immediately, and it will continue to go up with the rest. She must not wind off her cocoons to the last, because when they are near at an end the hulk of the worm joins in with the other threads, and makes the silk foul and gouty. The silk may be wound of any size from one cocoon to 100, but it is difficult to wind more than thirty in a thread.

The nicety of the operation, and that part in which lies the greatest difficulty, is to wind an even thread, because as the cocoon winds off the end is finer, and other cocoons must be joined on to keep up the same size. This difficulty

of keeping the silk always even is so great, that (excepting a thread of two cocoons, which is called fuch) they do not lay a silk of three, four, or six cocoons; but a silk of three to four, four to five, or six to seven cocoons. In a coarser silk it cannot be calculated even so nearly as to four cocoons more or less; they say, for example, from 12 to 15, from 15 to 20, and so on.

During the operation of winding, the woman must always have a bowl of cold water by her, to dip her fingers in, and to sprinkle frequently upon the iron bar *e*, that the heat of the basin may not burn the threads, also to cool her fingers every time she dips them in the hot water, and to pour into the basin when necessary, that is, when the water begins to boil. The water must be just in a proper degree of heat; for when it is too hot, the thread is dead, and has no body; and when too cold, the ends which form the thread do not join well, and form a harsh silk. The heat of the water from which the cocoons are wound, causes that adhesion of the fibres which compose the silk: a thread can with difficulty be wound off when cold water is employed; but in this manner the adhesion is very slight, and the thread breaks with a slight force, or the least moisture will separate the fibres; but the silk wound from hot water cannot be separated except by hot water.

The old cocoons require the water to be very hot: if the threads break very frequently, it may be concluded that the water is too cold; or, on the other hand, if the silk comes off entangled, and in the state of wool, the water is too hot. When the first parcel of cocoons is finished, the basin, *A*, is cleaned, taking out all the striped worms, as well as the cocoons, on which there remains a little silk: these are thrown into a basket, into which the loose silk that comes off in making the battue is likewise put as waste silk, to be carded and spun into threads. The water in the basin must be changed four times a day for coarse silk, and twice only for good cocoons of fine silk: if the water is not changed, the silk will not be so bright and glossy, because the worms contained in the cocoons foul it very considerably. The reeler must endeavour to wind as much as possible with clear water, for if there are too many worms in it, the silk will be covered with a kind of dust, which afterwards attracts moths, which destroys the silk.

From the gummy or viscid material which silk gives out to water when the cocoons are infused in it, Chappe found that he was able to blow up the water into bubbles, or small balloons, far more permanent than those of soap and water, and offering all the colours of the rainbow. So close, indeed, is the texture of these silky bladders, that even the most subtle gas does not penetrate them. Chappe filled many of them, the diameter of each not exceeding three inches, with hydrogen gas, and found several of them continued in a state of suspension, in an apartment, for considerably more than twenty-four hours. It is not all silk, however, that is sufficiently glutinous for this purpose; that which is of a very deep yellow will not answer the same purpose. This silk, from its colour, is supposed to be produced by the worm in a peculiar disease, yet this is a state by no means uncommon.

All kind of silk which is simply drawn from the cocoons by the reeling, is called raw silk, but is denominated fine or coarse according to the number of fibres of which the thread is composed. In general, the raw silk requires dyeing; to prepare for which the thread is very slightly twisted, to render it strong, and more able to bear the action of the hot liquor, without separating the fibres or furring up. Silk-yarn, which is employed by the weavers for the woof or weft of the stuffs which they fabricate, is composed of

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two or more threads of the raw silk, slightly twisted in a machine; and the thread employed by the stocking weaver is of the same quality, but composed of a greater number of threads, according to the thickness desired. Organzine silk is composed of two, three, or four threads of raw silk twisted, and so combined as to obtain the greatest strength: for this purpose, each thread of raw silk is twisted separately upon itself by a mill: the twist is given in a right-handed direction, and extremely tight. By a second operation of twisting, two of these threads are combined together, the twist being given in a contrary direction, and not above half as tight: this forms a thread similar to a rope. This description of silk, used for the warp of stuffs, is of the utmost importance to the manufacturer, for none of the principal articles can be fabricated without it. The Italians, from whom we formerly imported the silk in the state of organzine, for a long time kept the art of throwing it a profound secret. It was introduced into this country by the enterprise and skill of Messrs. Thomas and John Lombe, the latter having, at the risk of his life, and with wonderful ingenuity, taken a plan of one of these complicated machines in the king of Sardinia's dominions, from which, on his return, they established a similar set of mills in the town of Derby. (See DERBY.) In consideration of the great hazard and expence attending the undertaking, a patent was granted to Sir Thomas Lombe in 1718, for securing to him the privilege of working organzine for the term of fourteen years; but the construction of buildings and engines, and the instruction of the workmen, took up so much time, that the fourteen years were nearly expired before he could derive any advantage from it; in consequence of which, he petitioned parliament, in 1731, to grant him a further term: but parliament, considering it an object of national importance, granted him the sum of 14,000*l.* on condition that he should allow a perfect model of the machinery to be taken, and deposited in the Tower of London for public inspection. Similar mills were, in course of time, erected in different parts of the country; but owing to the difficulties that were experienced in procuring raw Italian silk of the proper size for organzine (the exportation of which was prohibited by the Italians), and to the mills having subsequently found employment for other purposes, the quantities worked into organzine, for many years, bore scarcely any proportion to the imports from Italy; it has however been since revived and improved, in consequence of which it is now carried on to a very considerable extent, as well in other parts of England as at Derby.

The process which the silk undergoes to bring it into this state, consists of six different operations. 1. The silk is wound from the skein upon bobbins in the winding machines. 2. It is then sorted into different qualities. 3. It is spun or twisted on a mill in the single thread, the twist being in the direction of from right to left, and very tight. 4. Two or more threads thus spun are doubled or drawn together through the fingers of a woman, who at the same time cleans them, by taking out the slubs which may have been left in the silk by the negligence of the foreign reeler. 5. It is then thrown by a mill, that is, the two threads are twisted together, either slack or hard, as the manufacture may require; but the twist is in an opposite direction to the first twist, and it is wound at the same time in skeins upon a reel. 6. The skeins are sorted according to their different degrees of fineness, and then the process is complete.

The first operation which the raw silk undergoes is winding, that is, drawing it off from the skeins in which it is imported, and winding it upon wooden bobbins, in which

state it can go to the other machines. The winding-frame is shewn at *fig. 2.* of the plate, or rather a part of it, which will wind six threads at once, and by increasing the length it may be made to receive any number. Each of the skeins is extended upon a slight reel *AA*, called a swift; it is composed of four small rods, fixed into an axis, and small bands of string are stretched between the arms to receive the skein, but at the same time the bands admit of sliding to a greater or less distance from the centre, so as to increase the effective diameter of the reel, according to the size of the skein, because the skeins, which come from different countries, vary in size, being generally an exact yard, or other similar measure, of the country where the silks are produced. The swifts are supported upon wire pivots, upon which they turn freely when the silk is drawn off from them; but in order to cause the thread to draw with a gentle force, a looped piece of string, or wire, is hung upon the axis within the reel, and a small leaden weight, *c*, being attached to it, will cause a sufficient friction. *B, B,* are the bobbins which draw off the threads; they are received in the frame, and are turned by means of a wheel beneath each, the bobbin having a small roller upon the end of it, which bears by its weight upon the circumference of the wheel, and the bobbin is thereby put in motion to draw off the silk from the swift. *D* is the layer, a small light rod of wood, which has a wire-eye fixed into it, opposite to each bobbin, so as to conduct the thread thereupon; and as the layer moves constantly backwards and forwards, the thread is regularly spread upon the length of the bobbin. The motion of the layer is produced by a crank fixed upon the end of a cross-spindle, *E*, which is turned by means of a pair of bevelled wheels from the end of the horizontal axle, upon which the wheels for turning all the bobbins are fixed.

These winding-machines are usually situated in the top building of the mill, the frames being made of great length, and also double, to contain a row of bobbins and swifts at the back as well as in front. Two of these double frames are put in motion by cog-wheels from the vertical shaft, *F*, which ascends from the lower apartments of the mill, where the twisting-machines are placed. The winding-machines require a constant attendance of children to mend the ends or threads which are broken; or when they are exhausted, they replace them by putting new skeins upon the swifts. When the bobbins are filled they are taken away, by only lifting them up out of their frame, and fresh ones are put in their places.

A patent has been lately taken out by Messrs. Gent and Clarke, for a new construction of the swifts for winding-machines: they are made with six single arms instead of four double ones; and the arms are small flat tubes, made to contain the stems of wire forks, which receive the skein instead of the bands of string in the common swifts. These forks admit of drawing out from the tubes until the swift is sufficiently enlarged to extend it; but as they extend the skein at six points instead of four, as in the common one, the motion is more regular. Instead of the weight which causes the friction, a spring is used to press upon the end pivot of the axis, and make the requisite resistance.

The twisting of the silk is always performed by a spindle and bobbin, with a flyer, but the construction of the machine which puts the spindle in motion is frequently varied. The limits of our plate do not admit a representation of the great machines, or throwing-mills, such as are used at Derby, and at almost all the other great silk-mills in England. In *fig. 3.* we have given a drawing of a small machine, which is similar in the parts which act upon the silk; and indeed many mills employ such machines constructed on a large scale.

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The one in our plate contains only thirteen spindles, and is intended to be turned by hand, a method which is too expensive for this country, but is common in the south of France, where many artificers purchase their silk in the raw state, and employ their wives or children to prepare it by these machines, which they call ovals, because the spindles *b, b*, are arranged in an oval frame, *G H*. *B* is the handle by which the motion is given; it is fixed on the end of a spindle, *R*, which carries a wheel, *D*, to give motion to a pinion upon the upper end of a vertical axle, *E*: this, at the lower end, has a drum or wheel *F*, to receive an endless strap or band, *a a*, which encompasses the oval frame *G*, and gives motion to all the spindles at once. The spindles *b, b*, are placed perpendicularly in the frame *G H*, their points resting in small holes in pieces of glass, which are let into the oval plank *G*; and the spindles are also received in collars affixed to an oval frame *H*, which is supported from the plank, *G*, by blocks of wood; *d* and *a* are small rollers, supported in the frame *G H*, in a similar manner to the spindles: their use is to confine the strap, *a*, to press against the rollers of the spindles with sufficient force to keep them all in motion.

The thread is taken up as fast as it is twisted by a reel, *K*, which is turned by a wheel, *b*, and a pinion, *i*, upon the end of the principal spindle, *R*. The threads are guided by passing through wire-eyes, fixed in an oval frame, *L*, which is supported in the frame of the machine by a single bar or rail, *l l*, and this has a regular traversing motion backwards and forwards, by means of a crank, or excentric pin, *k*, fixed in a small cog-wheel, which is turned by a pinion upon the vertical axis *E*; the opposite end of the rail, *l*, is supported upon a roller, to make it move easily. By this means the guides are in constant motion, and lay the threads regularly upon the reel *K*, when it turns round, and gathers up the silk upon it, as shewn in the figure.

One of the spindles is shewn at *r* without a bobbin, but all the others are represented as being mounted and in action. A bobbin, *e*, is fitted upon each spindle, by the hole through it being adapted to the conical form of the spindle, but in such manner, that the bobbin is at liberty to turn freely round upon the spindle: a piece of hard wood is stuck fast upon each spindle, just above the bobbin, and has a small pin entering into a hole in the top of the spindle, so as to oblige it to revolve with the spindle; this piece of wood has the wire-flyer, *b*, fixed to it: the flyer is formed into eyes at the two extremities; one is turned down, so as to stand opposite the middle of the bobbin *e*; and the other arm, *b*, is bent upwards, so that the eye is exactly over the centre of the spindle, and at a height of some inches above the top of the spindle. The thread from the bobbin, *e*, is passed through both the eyes of this wire, and must evidently receive a twist when the spindle is turned; and at the same time, by drawing up the thread through the upper eye, *b*, of the flyer, it will turn the bobbin round and unwind therefrom. The rate at which the thread is drawn off from the bobbin, compared with the number of revolutions which the flyers make in the same time, determines the twist to be hard or soft; and this circumstance is regulated by the proportion of the wheel, *b*, to the pinion *i*, from which it receives motion; and these can be changed when it is required to spin different kinds of silk. The operation of the machine is very simple; the bobbins filled with silk in the winding-machine, *fig. 1*, are put loose upon the spindles at *e*, and the flyers are stuck fast upon the top of the spindles: the threads are conducted through the eyes of the flyers *b*, and of the layers *L*, and are then made fast to the reel *K*, upon which it will be seen that there are double the number of skeins to that of the spindles represented, because

one half of the number of the spindles is on the opposite side of the oval frame, so that they are hidden. With this preparation the machine is put in motion, and continues to spin the threads by the motion of the flyers, and to draw them off gradually from the bobbins, until the skeins upon the reel are made up to the requisite lengths. This is known by a train of wheel-work at *n o p*, consisting of a pinion, *n*, fixed upon the principal spindle *R*, turning a wheel *o*, which has a pinion fixed to it, and turning a larger wheel *p*; this has another wheel upon its spindle, with a pin fixed in it, which at every revolution raises a hammer, and strikes upon a bell, *s*, to inform the attendant that the skeins are made up to a proper length. When this machine is employed for the first operation of twisting the organzine, the wheel, *b*, must be larger, and the pinion, *i*, smaller than represented, in order that the reel, *K*, may be turned slowly, and the threads will therefore receive a stronger and closer twist. Also, the handle *B* is turned in an opposite direction to that in which it must move for the final throwing off the two or three twisted threads together; and as it must also move for twisting the raw threads together for the warp of silk-stuffs, and for weaving stockings, this reverse movement makes no alteration in the machine, except that it will give twist in a contrary direction; for it is always necessary, when two or more twisted threads are combined by twisting, that the twist of the original threads shall be in the opposite direction to that twist which unites them into one thread, in the same manner as for making ropes, organzine silk being in fact small rope, and stocking-silk or warp being only yarn. The silk which is intended to be dyed, is previously twisted very slightly in this machine, and of course in that direction which will suit the purpose for which it is ultimately intended; *viz.* whether for yarn or organzine.

The great mills for twisting silk, originally introduced by Messrs. Lombe, though very complicated, are simple in their operation, because the complexity arises from the great number of spindles which are actuated by the same movement, every one of which produces its effect independent of the others, and in the same manner as the oval which we have described. A machine is contained in a circular frame, of which the diameter varies from 11 to 13, 15, and even 17 feet; but 15 feet is the general size of the original Piedmontese machines. In the centre of the frame is a perpendicular axis or spindle, coming up through the floor of the chamber, and rising to the ceiling; it is put in motion by a communication of wheel-work from a water-wheel, or otherwise from a horse-wheel. The axis has upon it two, three, or four horizontal wheels, according to the height of the machine, which revolve with it, and are of a sufficient size to fill nearly all the interior of the circular frame, and act upon the pulleys or rollers of the spindles, which are supported vertically in the frame, and arranged round the machine, at equal distances, in a circle, the number being proportioned to the dimensions of the machine. The spindles are also arranged in as many different stages of height as there are wheels upon the vertical spindle; for the circumference of each wheel presses against the rollers of the spindles which are arranged round it; and thus, when the wheel revolves, it gives a very rapid motion to all the spindles at once, by the contact of the edge of the wheel, but without any strap, as in the oval. Each spindle has a bobbin, filled with silk, fitted upon the top of it, and from this the silk is carried up to a horizontal reel, which is turned round slowly by the machine, and draws off the thread gradually from the bobbin: the flyer, being all the while in rapid motion, twists the thread upon itself, or, if two or three threads are previously wound together upon the bobbin, they will be twisted

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twisted round each other. Each reel serves to take up the thread from several spindles which are situated beneath it: thus, in a mill of fifteen feet diameter, there will be six spindles beneath each reel.

To explain this machine more clearly, we will give a description of one of thirteen feet diameter, which has four large wheels and stages of spindles, two of which are for giving the first preparation to the organzine: the spindles revolve in a direction from right to left. The spindles of the other two stages are for the finishing the twist, and also for twisting the single threads which are to be used for warp or for stocking-weaving: they revolve in a contrary direction to the former. The frame of the machine consists of two wooden circles of thirteen feet diameter, one placed upon the floor of the mill, and the other at a height of fifteen feet above, the two being united by fourteen upright pillars of wood, which altogether compose a large cylindrical frame or lantern. Each stage contains eighty-four iron spindles, placed vertically, and supported in the stage, which is formed of two wooden circles, extended round between the fourteen uprights of the lantern, and fixed one above the other, at about a distance of four inches asunder, so as to support the spindles between them, in the same manner as the pieces, G, H, of the oval last described.

The circles of the stage are of a rather less diameter than the two circles which compose the top and bottom of the lantern; so that the spindles will be rather within the circle of the frame of the lantern, and admit the wheels of the central axis to act upon them. For this purpose, each of the circles of the stage is made up by fourteen segments fixed between the uprights, and each segment supports six spindles, making up the number of eighty-four in the whole circle. The spindles, like those of the oval, are sharp-pointed at the lower end, and the points rest in small holes made in pieces of glass, which are let into the lower circle of the stage, whilst the upper circle sustains the spindle at a height of four or five inches above the point, leaving full one-third of the length of the spindle projecting above, for the purpose of fitting the bobbin upon it. The upper circle of the stage is rather smaller than the lower, because the spindles do not pass through it, but through holes in small pieces of hard wood, which project from it, so as to be exactly above the pieces of glass which sustain the points of the spindles. Each spindle has a small roller fixed upon it in the space between the two circles of the stage, and it is the contact of the rim of the great wheel upon these that causes the revolution of the spindles when the wheel revolves. In order to make the contact certain, the exterior rim of the great central wheel is made in several segments, and each segment has a constant tendency to recede from the central axis by the action of a weight, and thus presses against the rollers of the spindles. In order to give the reverse movement of the spindles, which we have before spoken of in the description of the oval, the great wheels for two of the stages are made differently from those which we have just described, so that the segments of the rim will act upon the outsides of the rollers of the spindles, instead of the insides: for this purpose the wheels are made larger than the stages in which the spindles are placed, and from the rim of the wheel small pillars rise up to support the segments, which act upon the rollers of the spindles in front or withoutside of the circles, instead of the inside, as is the case with the other stages, in consequence of which the spindles of these stages turn in opposite directions. The reels are placed over the bobbins, to take up the threads when twisted; and the rollers of the different spindles are made smaller or larger, as is required, to give more or less twist to the silk

operated upon by them; for the velocity with which the spindles revolve, compared with the rate at which the reels take up the thread, determines the degree of twist which the thread will have; and to render this equable, the reels which draw off the silk from the bobbins of the spindles are turned regularly with the motion of the machine by means of wheel-work, which is more easily conceived than described: it is sufficient to state that it receives its motion from the central vertical axis. There is also a layer adapted to each reel, with a wire-eye to receive each thread; and the layers having a slowly reciprocating motion, distribute the threads regularly upon the reels, in a similar manner to that first described for the oval. One of these reels is placed between each of the uprights of the machine, so as to make fourteen reels in the whole circle of each stage, and every reel serves to take the silk from the bobbins of six spindles. The whole machine in the four stages contains 336 spindles.

A machine of four stages is so high, as to reach through two floors of the mill, and for this purpose the upper floor is made with a large round opening, to admit the machine: this floor serves the people who attend the machine, and change the bobbins when exhausted, and also remove the finished silk from the reels.

The spindles in the upper stages are usually devoted to the first twisting of the single threads for the organzine, and therefore turn the reverse way, as before mentioned; and as the silk is afterwards to be thrown, or re-twisted, they are drawn off from the bobbins by large bobbins of three inches diameter, and four inches long, instead of the reels. These bobbins are stuck fix together upon a long spindle, situated horizontally, and turned by similar wheel-work to that which actuated the reels; they have similar layers to conduct the silk regularly upon the bobbins from one end to the other, so that the operation is not at all different.

In many of the best silk-mills, they have abandoned the original method of turning the spindles, for the preparation of organzine, the reverse way, by making the action of the wheels upon the outside, instead of the inside, of the circle of spindles. Instead of them they employ two different machines, one for the first operation on organzine, and the other for the second operation, both of them constructed with the wheels withinside: but the motion of the two machines is reversed to each other.

Fig. 5. represents a single spindle of a throwing machine, which, though the same in its action as the great mill, is different in its construction. G and H represent portions of the rails or circles of the stage which support the spindle, and *aa* is a part of the rim of the great wheel of the central axle. This wheel is not made in segments, as before described, but is made very truly circular, and covered with leather on the edge, that it may act with more force to turn the roller, *t*, of the spindle. The point of the spindle rests in a glass cap, supported by the rail G, and the roller, *t*, is always made to press against the rim of the great wheel, *aa*, by a small lever, *d*, and a string, which, after turning over a pulley, has the weight, *c*, made fast to it, to press the spindle always towards the wheel. In this machine, instead of the reel, the thread is taken up by a bobbin, K, is put into a frame, *m*, which moves on pivots, and by a weight, *n*, is pressed down so as to make the bobbin bear upon the edge of a wheel, *b*, which is kept in constant and regular motion, by the same kind of movement which turns the reels of the great machine. The intention of this is, that the action of the wheel, *b*, to turn the bobbin, being communicated by pressure against the part upon which the silk is to wind, will be constant,

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stant, and will not draw more when the bobbin is large and full, or less when it is empty, as must be the case when the motion is given to the axis of the bobbin.

After the silk is twisted in a right-hand direction, if it is intended for yarn, or for dyeing; or in a left-hand direction, if it is prepared for organzine; it must be wound on fresh bobbins, with two or three threads together, preparatory to twisting them into one thread. In the original machines at Derby this was done by women, who, with hand-wheels, wound the threads from two or three of the large bobbins, upon which the silk is gathered instead of the reels, and assembled them two or three together upon another bobbin, of a proper size to be returned to the twisting mill. We have seen an attempt for a machine to perform the doubling, which is slightly represented in *fig. 4*. The whole machine itself is very similar to the winding-machine, *fig. 2*, but instead of the swift, the bobbins from the throwing-mill are placed in front at *A*, *fig. 4*, two or three in a row. The threads from these are passed over the rail *m*, and beneath a piece of wood, *n*, both which, being covered with cloth, have the same effect to clean the silk by drawing through them, as the fingers of the winder. *B* is the bobbin upon which the two or three threads are to be wound together; it is turned by a wheel, *F*, upon which it rests, the same as the bobbins of the winding-machine; and *D* is the layer, which, for convenience, is in this case placed behind the bobbin, *B*; and the wire-eye, *d*, which receives the three threads, is made to reach over to the front. The additional apparatus consists of a small piece of wood, *e*, which slides freely up and down, in a hole, through a fixed board, *f*. On the top of the slider, *e*, is an eye of wire, through which one of the single threads of silk passes in its passage from between the pieces *m, n*, to the bobbin *B*: there is one of these sliders, *e*, to each of the three threads; *t v* is a lever moving on the centre *w*; the end *t* is immediately beneath the small sliders *e*, and the end *v* is formed to a hook, to catch into the notches which are made in the end of the bobbin *B*. A small counter weight, *x*, always causes the hook, *v*, of this lever to recede from the bobbin; but if any one of the three threads break, it suffers the slider *e*, which belongs to it, to descend upon the end, *t*, of the lever, and depresses the end of the lever, so as to bring the hook, *v*, in a situation to catch a tooth of the bobbin *B*, and stop its motion. By this means the winding of three threads together is rendered equally certain with the winding of one; for when any one breaks, the operation of winding on that bobbin stops, until the attendant repairs the broken thread, and puts the machine again in motion. We have lately been informed, that a machine for winding two and three threads together is becoming common in the silk-mills, but we do not know if it is the same with this one, which however is not evidently impracticable.

The bobbins, being thus filled with double or triple threads, are carried back to the throwing machine, and are there spun or twisted together, the manner of doing which does not differ from the operation which we have before described. In this second operation the silk is taken up by reels instead of bobbins, and is thus made up into skeins. The degree of twist varies with the purpose for which the silk is intended; and the wheels which give motion to the reels are for this purpose adapted to the degree of twist which the silk is desired to have. The silk, being now spun, requires only the preparation of boiling to discharge the gum, and render the silk fit to receive the dye, and also to render it soft and glossy. The silk is boiled for about four hours, in a boiler filled with water, into which a small quantity of soap is put; this opera-

tion dissolves the gum, which before could be felt upon the silk, and rendered it harsh. After the boiling, it is well washed in a current of clear water, and when dried, will be found to have lost about one-fourth of its weight: at the same time the volume of the silk is sensibly increased, and it has acquired that soft texture and glossiness, which are the principal beauties of silk. This change is produced by the dissolution of the gum, which, in the first instance, was the only adherence of the fibre to form a thread, but by the operation of the twisting the fibres are firmly united, and no longer require the gum. It is also necessary, in order to give a fine dye to the silk, that the gum should be removed, because it would prevent the entrance of the dyeing matter to the centre of the thread, and thus impair the beauty of the colour. If the silk was thus boiled before the twisting, nothing but a fine entangled down or wool would be obtained, and it would require spinning, by a similar process to that of cotton, before a thread could be obtained. This, indeed, is necessary for that portion of waste silk which is drawn from the cocoons in the first operation of reeling; also for those cocoons which are reserved for breeding, and from which the moths eat their way out by holes, which render it impracticable to wind off the silk. This waste silk, when carefully spun by a spinning-wheel, is called spun silk, and the thread is not inferior to the regular silk which is wound off: indeed, the winding off the silk into a thread united by its gum, is of no advantage farther than as a preparation for spinning, from which process the thread obtains its strength.

The silk is now in a state for use: if it is for stocking-weaving, or sewing, or if intended for weaving into stuff, it only requires warping to be put into the loom. The operation of warping is to put together all the threads which are to compose the warp of the intended piece of stuff, and lay them parallel, so that the warp, being put into the loom, will have no slack threads, nor any which are strained too tight. Formerly, this operation was performed by stretching the threads out at length in a field, or by extending them in a frame, and winding them backwards and forwards over pegs. The warping machine now universally employed is shewn in *fig. 6*, where *A A* is a tressel or stool, which supports the small bobbins *b, b*, upon which the silk is wound. The number of these is equal to the number of threads which the warp of the intended piece of stuff is to have in its breadth. The threads from all these bobbins are drawn over wires *d, d*, which are in front of the bobbins, and are then all brought together, and passed through an opening in a piece of wood *D*; this conducts the threads all together upon a large reel *E E*, which is supported in a frame *F F F*, and turned round by means of a pulley at the lower end of its axle, from which an endless band is continued to a second wheel *G*, mounted on a spindle, and turned by a handle. This latter spindle is supported in a sort of stool *H*, upon which a child fits down, and at the same time turns the handle and puts the reel in motion, so as to draw the warp or assemblage of threads off from the several bobbins, and lay it upon the reel *E*. The piece of wood *D* is fitted upon one of the upright pieces, *F*, of the frame, to slide freely up and down upon it, and is suspended by a cord, which, after passing over a pulley *f*, is wrapped round the spindle of the machine at *c*: by this means, the motion of the reel, *E*, draws the cord, and raises up the piece *D*, so as to lay the warp upon the circumference of the reel, in a regular spiral, from one end to the other, and prevent the coils lapping one upon another. When the required length of warp is wound upon the reel, the ends of all the threads are cut off, tied together, and thus drawn off from the reel and rolled up into a large ball,

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in which state the weaver takes it, and mounts it in his loom.

For the subsequent operations of weaving we shall refer to the article WEAVING, because the weaving of silk goods is the same as for any other, except that finer and more beautiful articles are produced in this substance than in any other. Some information on the details of weaving mechanism will be found under our articles DRAUGHT of Looms, DRAW-Loom, DIAPER, DIMITY, and DORNOCK; and though these are rather the weaving of linen and cotton than silk, the same principles apply to silk, as will be more fully explained under WEAVING; where a description of weaving ribbands and figured silks will be given.

Silk is distinguished by different names according to its different states. Thus,

SILK, Spun, is that taken from the ball, without fire, and spun into thread without any coction: such as is most, if not all, that is brought into England from the Levant; *i. e.* from Persia by the way of Turkey, from Bengal in India, and from China. The raw spun silk is commonly worked up into two sorts, called *organize* and *tram*: the former is made by giving a throw or twist to each thread of raw spun silk singly, and then doubling two of these twisted threads together, and twisting them smartly together; this forms the warp or length of a piece when manufactured. The tram, or shoot, which makes the breadth of the piece, is formed by twisting two or more threads of raw silk slack. The waste raw silk, or refuse in reeling, &c. is collected, carded, and spun, and called *fosfs* silk; this is doubled and thrown, and often made into a cheap sort of silk-stockings, which are very strong and durable.

In the French silk-works, the greatest part of this raw silk passes for little better than a kind of fine floretta; yet, when spun, it makes a bright thread, and serves for the manufacture of stuffs of moderate value and lustre. But the spun silks of the Levant, whence most of our's come, are exceedingly fine and beautiful. The difference arises hence, that in France, the best balls are reeled off in boiling water, and only the refuse made into spun silk; whereas, in the Levant, there is no such thing as reeling or winding on the fire, but the silks are all sent in bales, or packs, as they are drawn from off the balls; so that they are only distinguished by their quality of fine, middling, and coarse.

SILK, Boiled, is that which has been boiled in water, to facilitate the spinning and winding. This is the finest of all the sorts of silk manufactured in France, and is seldom used but in the richest stuffs; as velvets, taffeties, damasks, brocades, &c.

There is also another kind of boiled silk, which is prepared by boiling, to be milled; and which cannot receive that preparation, without being first passed through hot water. By the laws of France, it has been prohibited to mix raw with boiled silk; both as such a practice spoils the dyeing, and as the raw silk corrupts and cuts the boiled.

SILKS, thrown or twisted, are such as, besides their spinning and winding, have received their milling or throwing.

This they receive in a different degree, as they are passed oftener or seldomer over the mill; properly, however, thrown silks are those in which the threads are pretty thick-thrown, and twisted several times.

The thrown silk comes to us chiefly from Leghorn, Genoa, Naples, and Messina.

SILKS, Slack, are such as are not twisted, but are prepared, and dyed for tapestry, and other works with the needle.

SILK, Eastern or East Indian. That popularly thus called is not the work of the silk-worm, but comes from a plant that produces it, in pods, much like those of the cotton-

tree. The matter this pod contains is extremely white, fine, and moderately glossy; it spins easily, and is made into a kind of silk, that enters the manufacture of several Indian and Chinese stuffs.

SILKS, French. It is only in the most southern provinces of France that silk is cultivated, mulberry-trees planted, and worms bred. The principal places are Languedoc, Dauphiné, Provence, Avignon, Savoy, and Lyons. This last place, indeed, furnishes very few silks of its own growth; but it is the great staple whence the merchants of Paris, and the other cities, are to fetch them. At least, they are obliged to have them pass through Lyons, if they bring them from other places, either by land or sea. There have been computed to enter Lyons, *communibus annis*, six thousand bales; the bale valued at one hundred and sixty pounds weight; of which six thousand bales, there are one thousand four hundred from the Levant, one thousand six hundred from Sicily, one thousand five hundred from Italy, three hundred from Spain, and one thousand two hundred from Languedoc, Provence, and Dauphiné.

At the time when the manufactures of Lyons were in their prosperity, there were reckoned to be eighteen thousand looms employed in the silk manufacture; but in 1698, there were not reckoned four thousand. However, this manufacture afterwards revived, and a great part of Europe has been supplied from hence with brocade and rich silks. The decay has not been less notable at Tours; they had formerly there eight hundred mills for winding and preparing the silks; eight thousand looms to weave them; and forty thousand persons employed in the preparation and manufacturing of them; but these have been reduced to seventy mills, twelve hundred looms, and about four thousand persons. The revolution has, however, made such an alteration in the manufactures and trade of France, and they are still (1816) in so unsettled a state, that no correct estimate of them can be obtained.

SILKS, Sicilian. The commerce of the silks of Sicily has been very considerable; and the Florentines, Genoese, and Luccefe, are the people who have chiefly availed themselves of it. Great quantities were yearly brought thence, especially from Messina; part of which they used in their own manufactures, and sold the rest to their neighbours the French, &c. with profit. The Italians had this advantage, especially the Genoese, over other people, that, having large establishments in the island, they were reputed as natives, and paid no duty for the export.

Part of the Sicilian silks is raw, the rest are spun and milled; of which last kind, those of St. Lucia and Messina are the most valued. The raw unwrought silks were always sold for ready money; the others, sometimes, in exchange for other goods. See SICILY.

SILKS, Italian. The silks brought from Italy are partly wrought, and partly raw and unwrought. Milan, Parma, Lucca, and Modena, furnish none but the latter kind; Genoa most of the former; Bologna affords both kinds. The finest Italian wrought silk comes from Piedmont, Novi, Bergamo, and Bologna; and is imported into England from the ports of Nice, Genoa, and Leghorn.

The silk we have from Italy is generally thrown, and serves for warp for our manufactures.

SILKS, Spanish, are all raw; and are spun, milled, &c. in England, according to the several works in which they are to be used.

SILKS, Turkey, are all raw. One advantage we have in the commerce of the Levant, in silks, wanting in those of Sicily, is, that the latter are confined to a particular season of the year; whereas the former are bought at all times.

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They are brought from Aleppo, Tripoli, Sayda, and from the isle of Cyprus, Candia, &c. But the principal place of commerce, especially for the silks of Persia, is Smyrna. The silks are brought hither in caravans, from the month of January to September. The caravans in January are laden with the finest silks; those of February and March being indifferent ones; the rest, the coarsest. They all come from the several provinces of Persia, chiefly those of Ghilan and Shirvan, and the city of Schamachia, situate near the edge of the Caspian sea; from which three places, a Dutch author assures us, there have not come less than thirty thousand bales of silk in a year. Ghilan produces the best and greatest quantities of silk; next to this are Shirvan and Erivan, then Mazanderan, and lastly Astrabad; but the latter is much inferior, serving only for a manufacture mixed with cotton; that of Mazanderan and Astrabad is seldom or ever exported.

Ardeuil, or Ardebil, another city of Persia, not far distant from these silk countries, is the place where silks are laid up, and whence the caravans set out for Smyrna, Aleppo, Scanderoon, and Constantinople; and it is this city, with Schamachia, that have always been esteemed the centre of the silk trade; which has been several times attempted to be removed from Smyrna, and the Mediterranean, in favour of Archangel, and the White sea, by carrying them across Mulcovy, by the Volga and Dwina, two rivers that traverse the principal provinces of that vast empire.

This new course of the Persian silks into Europe was first proposed by Paolo Centurio, a Genoese, to the czar Basil, under the pontificate of Leo X. The French had the same design in 1628. The duke of Holstein, in 1633, sent ambassadors to the court of Persia, purely with the same view. And in 1668, the czar Alexis Michael attempted the thing himself; but he was disappointed by the rebellion of the Cossacks, and the surprize of Astrakhan.

In 1688, the commerce of Persian silks had nearly been removed from Smyrna by an earthquake, which almost overturned the whole city; and, doubtless, the removal had been effected, but for the vigorous means used by the Turks to prevent it. Smyrna, however, still remains in her ancient possession; and the several nations of Europe continue every year to send their fleets, to fetch away the silks.

SILKS, China, Japan, and Indian. Several provinces of China are so fertile in mulberry-trees, and their climate is so agreeable to the nature of silk-worms, that the quantity of silks there produced is incredible; the single province of Tchehiang might supply all China, and even a great part of Europe, with this commodity. The silks of this province are the most esteemed, though those of Nankin and China be excellent.

The silk-trade is the principal in China, and that which employs the most hands; but the European merchants who deal in it, especially in wrought silks, are to be careful of the spinning, &c. the waste being usually very great, as the French East India company have found to their cost.

Japan would not afford fewer silks than China; but that the Japanese, a barbarous and distrustful people, have interdicted all commerce with strangers, especially with Europeans, excepting with the Dutch; who are said to be admitted on certain impious terms, related by Tavernier, but which, we must own, we cannot credit. The Dutch have endeavoured to vindicate themselves from these by the pens of several famous writers.

Great quantities of both raw and wrought silk are furnished by other parts of Bengal, and by several provinces of

Hindoostan, which partly supply the natives, and afford a very considerable exportation to Europe. Several thousand bales of raw silk are annually imported from Bengal and China; some of which is, in this state, used for making princes' stuffs, but the greater part is prepared for the manufacturers by the silk-throwsters.

SILK, Laws relating to. The duties on silks and calicoes being under the same regulations with those on printed linens, the law respecting them is inserted under the article **LINEN**. By the 13 & 14 Car. II. c. 15. s. 2. no person shall exercise the trade of a silk-throwster, unless he hath served seven years' apprenticeship, on pain of 40s. a month, half to the king, and half to him that shall sue in any court of record, or at the assizes, or quarter-sessions of the peace. By 9 & 10 W. c. 43. no foreign silks, called alamodes or lutestrings, shall be imported but in the port of London, on notice first given to the commissioners of the customs, and licence had from them, on pain of forfeiture, or the value; and they shall be sold, and exported again; and the offender so importing, and also the receiver and person offering to sell the same, shall forfeit 500*l.* Being marked and sealed by order of the commissioners, any person who shall counterfeit the custom-house seal, or that of the lutestring company, shall forfeit 500*l.*, and be set in the pillory for two hours. And any person who shall buy and sell, and have in his custody, any alamodes or lutestrings, sealed or marked with a counterfeit seal or mark, shall forfeit the same and 100*l.*

However, none but custom-house officers, or persons deputed by the lutestring company, and having writs of assistance under the seal of the exchequer, shall seize lutestrings or alamodes within the bills of mortality. (5 Ann. c. 20.) The penalties shall be two-thirds to the king, and one-third to him that shall seize or sue in any court of record.

By 3 Geo. III. c. 21. and 5 Geo. III. c. 48. if any person shall import any ribbands, laces, or girdles, not made in Great Britain, whether the same shall be wrought of silk alone, or mixed with other materials, the same shall be forfeited, and may be seized by any officer of the customs, in whatever importers', venders', or retailers' hands they may be found; and the importer, and every person assisting therein, and the venders and retailers in whose custody they shall be found, or who shall sell or expose the same to sale, or conceal with intent to prevent the forfeiture, shall forfeit respectively 200*l.*, with costs. Half the said penalties to be to the king, and half to the officer who shall inform and prosecute.

But if any officer of the customs shall neglect or refuse, for one month after condemnation, to prosecute to effect any person for any of the said pecuniary forfeitures, any other person may sue for and recover the same; half thereof to go to the king in like manner, and half to him who shall sue.

And when the goods seized (being out of the limits of the bills of mortality) shall not exceed the value of 20*l.*, two justices, on information before them that such goods were seized, as unduly imported, may hear and determine the same, and proceed to condemnation or discharge.

After seizure, until condemnation or discharge, the said goods shall be deposited in one of the king's warehouses, if the seizure be within the bills of mortality; elsewhere, in the hands of the chief magistrate or constable; and the same shall be free to inspection, with leave of the court, judge, or justices, before whom the prosecution shall be.

And after condemnation, the said goods shall be publicly sold by the candle for exportation; half of the produce by

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such sale to be to the king, and half to the officer who shall seize and secure the same; and the same goods shall not be delivered out of the warehouse, till security shall be given for exportation, and that the same shall not be landed again in any part of his majesty's dominions.

By 5 Geo. III. c. 48, if any foreign manufactured silk-stockings, silk-mitts, or silk-gloves, shall be imported into this kingdom, or any part of the British dominions, the same shall be forfeited, and liable to be searched for and seized as other uncustomed goods; and every person who shall import the same, or be assisting therein, and the vendors and retailers in whose custody they shall be found, or who shall sell or expose the same to sale, or conceal with intent to prevent the forfeiture, shall, over and above the forfeiture of the goods, forfeit 200*l.*, with costs; half to the king, and half to the officer who shall inform and prosecute.

And when the goods seized (being out of the limits of the bills of mortality) shall not exceed the value of 20*l.*, two justices may proceed to the condemnation thereof. And the proceedings, in all other respects, shall be in like manner as in the case of ribbands and laces above mentioned.

SILK MANUFACTURE.

