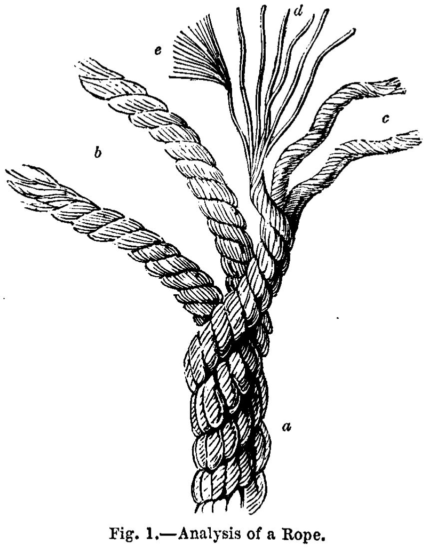

Fig. 1.—Analysis of a Rope.

the length of 3½ feet, it becomes necessary, in order to obtain rope of greater length, so to twine them together that the strength of any single fibre shall be insufficient to overcome the resistance caused by the friction of those surrounding and compressing it; so that it will sooner break than be drawn out from the mass. This requisite entanglement is produced by twisting, which causes the fibres to compress each other; and it not only enables the ropemaker to produce cordage of any required length, but also, by making the rope hard and compact, increases its durability, and enables it to resist the penetration of water, which would rapidly impair its strength. While however some degree of twist is absolutely essential to the cohesion of a rope, any twist beyond that which simply prevents the fibres being drawn out without breaking, is injurious. A skein of fibres, or a rope, may be twisted so hard that any further attempt at twisting would break it; and such a skein will evidently have no power to support a weight, each fibre being already strained to the utmost extent that it will bear. In fact, whatever force is exerted by any fibre in compressing the rest, may be considered the same as a weight hanging on that fibre, and must be subtracted from its absolute strength before its useful effect can be ascertained; the available strength of a rope being the remainder of the absolute strength of its component fibres after deducting the force exerted in twisting them.

Were a rope to be formed by simply twisting together, in one direction, the whole of the fibres of which it is composed, there would be nothing to prevent its untwisting as soon as left to itself. It is therefore necessary to twist the fibres in comparatively small portions, and so to combine these into a rope that the tendency to untwist in one part may counteract the like tendency in another. Thus the same force which would cause the component parts, if separate, to become loose or untwisted, is employed, when they are combined into a rope, to keep the whole firm and compact. This is illustrated in *fig.* 1, which may be considered as the unravelled end of a cablet or small cable. The cablet *a* may be untwisted into three smaller ropes, *b*; untwisting either of these in the opposite direction, we find it to consist of three smaller ropes, *c*; each of these may be untwisted into several small strings, *d*; and each of these consists of several distinct fibres of hemp, *e*. Thus several fibres form a *yarn*, several yarns a *strand*, three strands a *rope*, and three ropes a *cablet*.

With *fig.* 2 as an illustration, we may briefly describe the hand method of rope-making. The first process consists in twisting the hemp into thick threads, called rope-yarns. This process, which resembles ordinary spinning, is performed with various kinds of machinery. The common mode of spinning rope-yarns by hand is performed in the rope-ground, or rope-walk, an enclosed slip of level ground 600 feet or more in length. As many of the operations of a ropery would be impeded by wet weather, or by the unchecked heat of the sun, it is not unusual to cover the walk with a slight roof. At one end of this ground a spinning-wheel is set up, which gives motion by a band to several small rollers or whirls. Each whirl has a small hook formed on the end of its axis next the walk. Each of the spinners is provided with a bundle of dressed hemp, laid round his waist, with the bight or double in front, and the ends passing each other at his back. He draws out a sufficient number of fibres to form a rope-yarn of the required size; and, after slightly twisting them together with his fingers, he attaches them to the hook of a whirl. The whirl being now set in motion by turning the wheel, the skein is twisted into a rope-yarn; the spinner walking backwards down the rope-walk, supporting the yarn with one hand, which is protected by a wetted piece of coarse cloth or flannel, while with the other he regulates the quantity of fibres drawn from the bundle of hemp by the revolution of the yarn. The degree of twist depends on the velocity with which the wheel is turned, combined with the retrograde pace of the spinner. Great care is necessary in this operation to make the yarn of uniform thickness, and to supply the hemp equally from both sides of the bundle; because, if a considerable body of hemp be supplied to a yarn that is becoming too thin, it will not combine perfectly with it, but will form a loosely connected wrapper; and any irregularity in the last-mentioned particular will cause the fibres to bear the strain unequally.

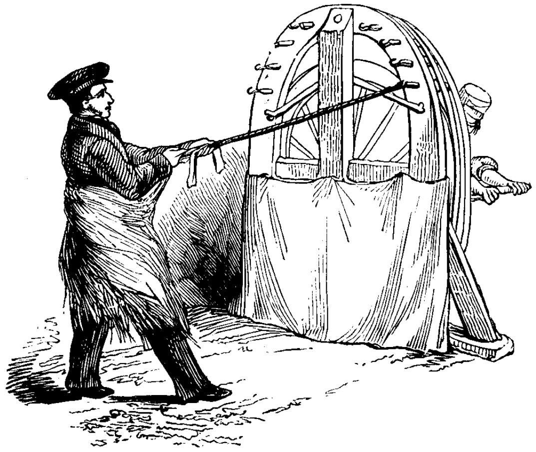

Fig. 2.—Rope-yarn Spinning.

The best mode of supplying the hemp is in the form of a thin flat skein. When the spinner has traversed the whole length of the rope-walk (or sooner, if the yarns are not required to be so long), another spinner detaches the yarn from the whirl, and gives it to a person who carries it aside to a reel; while the second spinner attaches his own hemp to the whirl-hook. The hemp, being dry and elastic, would instantly untwist if the yarn were now set at liberty. The first spinner therefore keeps fast hold of it all the while that the reeler winds it up, walking slowly up the walk, so as to keep the yarn equally tight all the way. When it is all wound up, the spinner holds it until another is ready to follow it on the reel. Sometimes, instead of being wound on a reel as they are made, the yarns are laid together in large hooks attached to posts at the side of the walk until about four hundred are collected together, when they are coiled up in a *haul* or skein, in which state they are ready for tarring.

The common size of rope-yarns is from one-twelfth to rather more than one-ninth of an inch diameter; 160 fathoms of white or untarred yarn weighing from two and a half to four pounds.

The next process is *warping* the yarns, or stretching them to a given length, in order that they may, when formed into a strand, bear the strain equally. When the rope is to be tarred, that operation is usually performed upon the yarns immediately after their being warped; as the application of tar to the yarns previous to their combination is necessary to the complete penetration of the whole substance of the rope. The most common method of tarring the yarns is to draw them in hauls or skeins through the tar-kettle by a capstan; but sometimes the yarns are passed singly through the tar, being wound off one reel on to another, and the superfluous tar being taken off by passing the yarn through a hole surrounded with spongy oakum. Great care is required in this process that the tar may boil neither too fast nor too slow, the common heat being from 212° to 250° Fahr. The degree of impregnation necessary depends on the kind of cordage; cables and water ropes needing a considerable quantity of tar, while for standing and running rigging it is sufficient that the yarns be well covered.

In making large cordage, it is not usual to twist together, at once, as many yarns as would suffice to form a rope of the required thickness; a suitable number of yarns, frequently from fifteen to twenty-five, are formed into a strand, and three or more such strands are afterwards combined into a rope. The twist of the strand is in an opposite direction to that of the yarns of which it is composed; in order that, as before mentioned, the tendency to untwist in the individual yarns may be counteracted, and taken advantage of to prevent the untwisting of the strand. In closing or laying the rope, three strands, or sometimes four, (in which case a small central strand or heart is added) are stretched at length along the walk and attached at one end to separate but contiguous hooks, and at the other to a single hook; and they are twisted together by turning the single hook in a direction contrary to that of the other three. A piece of wood called a *top* (see *fig.* 3), in the form of a truncated cone, is placed between the strands, and kept during the whole operation gently forced into the angle formed by the strands, where they are united by the closing or twisting of the rope. As the rope shortens in closing, one end only of the apparatus is fixed, the other being on a moveable sledge, whose motion up the ropewalk is capable of regulation by suitable tackle attached to it, or by loading it with weights. The top also is mounted on a sledge, for closing large cordage; and its rate of motion may be retarded, in order to give greater firmness to the twist of the rope. The art of the ropemaker, in this operation, consists in so regulating the various movements that the strands may receive separately at one end just as much twist as is taken out of them at the opposite end, by their twisting the contrary way in the process of combination.

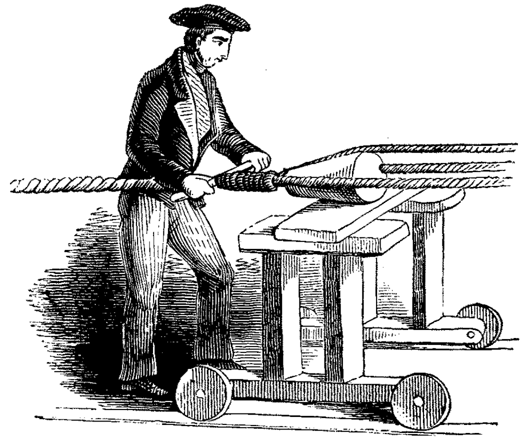

Fig. 3.—Laying a Rope.

Such is the method, more or less modified by the kind of machinery employed, of forming a *shroud-laid* or *hawser-laid* rope; and such appears to have been the whole process of rope-making until cordage of very large size was called for by the progress of navigation. In making such it was not found advisable to increase the number of yarns in a strand; it being difficult, when their number is very great, to throw an equal strain upon each, and thereby obtain their aggregate strength. To obviate this inconvenience, cables, or such large ropes as are said to be *cable-laid*, are formed by the combination of smaller ropes twisted round their common axis, just as shroud-laid ropes are composed of strands twisted round their common axis. As cable-laid ropes are harder and more compact than others, this mode of formation is adopted for ropes to be exposed to the action of water, even though their thickness may not be very great.

Ropes formed by plaiting instead of twisting are made use of for some purposes in which pliability is especially needed; they being more supple and less liable to entanglement than those of the ordinary make. Such ropes are preferred for sash-lines, clock-lines, &c., and generally where the rope has to pass over pulleys of small diameter.

Originally all the yarns composing a strand were selected of the same length. This arrangement was defective, as it is evident that when a number of yarns are stretched at length in a cylindrical mass, they will lie at different distances from the centre of the cylinder; so that, when twisted together, as all the yarns must form spirals of the same number of turns, those which are near the outside, forming spirals of large diameter, will be stretched to their full extent; while those near the centre, forming spirals of smaller diameter, will be less shortened by the process of twisting, and must therefore be more or less puckered up, according to their proximity to the centre of the mass. The first successful attempt to remedy this defect by varying the length of the yarns according to their position in the strand, was that under Captain Huddart's patent of 1793; since which time many further improvements have been effected in this essential point.

This brings us to notice briefly the application of machinery to rope-making, which may be said to have begun about the year 1783, and to have been the subject of numerous ingenious inventions since that date. One series of machines relates to the combining of the hempen fibres into yarns; another to the twisting of yarns into ropes; while the more complex kinds include both of these actions. Mr. Lang, of Greenock, was the first to produce successfully machine-spun yarns, intended to get rid of the irregularities and defects of those formed by hand. By his process the hemp is more completely heckled, or divided into fibres, than in the common mode of proceeding; and the advantage of each fibre being laid at full length in the yarn, instead of being doubled, as in hand-spinning, is ensured. By a modification of the usual process, the fibres of hand-spun yarns may be laid in at full length, instead of being doubled, as when they enter the yarn by their bight; but experiment has not shown any great advantage from such a mode of spinning. That some improvement in this operation was needful, may be inferred from the result of a comparison between Mr. Lang's machine-spun yarns and those of equal grist spun by hand; the result showing the strength of the former to exceed the latter by fifty-five per cent. Mr. Sherman, of Liverpool, patented a method of rope-making intended to obviate the necessity for a long shed or rope-walk. The machinery comprises rotating tables with hollow shafts or axes; spindles project from the surfaces of the tables; bobbins are mounted on the spindles; and hemp is wound on the bobbins. The number of bobbins depends on the number of yarns and strands. The ends of the yarns are passed through holes in a draw-plate beyond the hollow shaft of one table, then through the hollow shaft, then through another shaft; and so on. The yarn from each bobbin thus becomes twisted round that of the other bobbins on the same table; then round the similarly twisted strands of another series; and then of a third. The finished strand or rope is drawn from the tube of the last table, and is wound upon a reel ready for use. A modification of this planetary system, as the inventor calls it, suffices for twisting the strands into a rope.

Captain Huddart's rope-making machinery, above adverted to, is very ingenious. In order to get rid of the unequal strain upon the exterior and interior of a rope, Huddart saw that the outer yarns of every strand ought to be somewhat longer than the inner, to compensate for the greater circumference round which they have to turn. This he accomplished in a beautiful way. Bobbins are arranged in a skeleton frame, each poised on a pivot and loaded with yarn; the number of bobbins depends on the thickness of the strands to be made. The ends of all the yarns are passed through an equal number of small holes in a plate, and combined into one close group, which is slightly compressed by passing through a tube, and then wound on a reel. The mechanism between the plate and the reel rotates on a horizontal axis, thereby imparting a twist to the assemblage of yarns. The free rotation of the bobbins, the arrangement of the holes in the plate, the position of the tube, and the velocity of revolution—all combine to produce a strand of any desired hardness of twist, without undue strain upon any of the yarns. The strand thus produced is a smooth uniform piece of cordage, varying in thickness according to the size of the rope to be made; for a 12-inch cable, the strand is about an inch thick and contains 80 yarns. Being worked by steam power and having facilities for renewing the bobbins as they are exhausted, this machine can produce a rope any length.

The strength of twisted cordage has been made the subject of numerous experiments. Réaumur, early in the last century, found that a well-made small hempen cord broke in different places with 58, 63, 67, and 72 lbs., its mean breaking weight being 65 lbs.; while the three strands of which it was composed bore 29½, 33½, and 35 lbs. respectively; so that the united absolute strength of the strands was 98 lbs., although the average real strength of the rope was only 65 lbs., showing a loss of strength from twisting equal to 33 lbs. It appears that the cord used by Réaumur was of very unequal quality, as another portion of it broke with 72 lbs., while its strands bore separately 26, 28, and 30 lbs.; which shows the diminution of strength from twisting to have been from 84 to 72 lbs., the loss being in this instance only 12 lbs. The later experiments of Sir Charles Knowles indicates a diminution of strength nearly equal in amount to the first-mentioned of Réaumur. He found a white or untarred rope of 3⅕ inches in circumference break, on an average of several trials, with 4552 lbs.; while the aggregate strength of its yarns, which were 72 in number, and bore on an average 90 lbs. each, was 6480 lbs.; the loss being equal to 1928 lbs., or about 30 per cent. Duhamel endeavoured to ascertain what degree of twist would produce the most useful effect. He caused some ropes to be made, so that only one-fourth of the length of the yarns was absorbed in twisting, instead of the usual proportion of one-third. These ropes were tried in shipping, and found to be lighter, thinner, and more pliant than those of the ordinary make. The following statement shows the comparative strength of ropes formed of the same hemp, and the same weight per fathom, but twisted respectively to two-thirds, three-fourths, and four-fifths of the length of their component yarns :—

Degree of twist.	Weight borne in two experiments.	
⅔	4098 lbs.	4250 lbs.
¾	4850	6753
⅘	6205	7397

The result of these experiments led Duhamel to try the practicability of making ropes without any twist, the yarns being wrapped round to keep them together. These had great strength, but very little durability, the outer covering soon wearing off, or opening at bendings, so as to admit water, and occasion the rope to rot. But while such untwisted skeins of rope-yarns, or *salvages,* are unfit for most of the purposes to which cordage is applied, they are used with advantage for the tackle of great guns and some other purposes for which the greatest strength and pliancy are required. The usual reduction of length by twisting is one-third; this applies to *shroud* or *hawser*-laid ropes; those which are *cable*-laid are further shortened, so that 200 fathoms of yarn are required to make 120 fathoms of cable. Ropes formed in the common manner, with three strands, do not require a *heart,* or central strand; because the angles formed by the union of the three cylindrical strands are so obtuse that the pressure of the operation of laying or closing the rope causes the strands to fill them up completely; but when the number of strands exceeds three, a heart is essential to keep them equidistant from the axis of the rope, and to fill up the vacuity that would otherwise be left by their not meeting in the centre. The heart can however add very little to the strength of the rope; as its fibres lie much straighter than those of the outer strands, and, not being able to extend with them when the rope is stretched, are soon pulled asunder. The following simple rule for calculating the strength of ropes is given by Robison:—Multiply the circumference of the rope in inches by itself, and the fifth part of the product will express the number of tons the rope will carry. For example, if the rope be 6 inches in circumference, 6 × 6 = 36, the fifth of which is 7⅕, the number of tons which such a rope will sustain. The following rules for calculating the *weight* of cordage may also prove useful:—To find the weight of shroud or hawser-laid rope, multiply the circumference in inches by itself, then multiply the product by the length of the rope in fathoms, and divide by 420, the product will be the weight in cwts. Example: to find the weight of a 6-inch hawser-laid rope, 120 fathoms long, 6 × 6 = 36 × 120 = 4320, which, divided by 420 gives the weight of the rope, 10 cwt. 1 qr. 4 lbs. Again: to find the weight of cable-laid cordage, multiply its circumference in inches by itself, and divide by 4. The product will be the weight, in cwts., of a cable 120 fathoms long; from which the weight of any other length may be readily deduced. Example: required the weight of a 12-inch cable, 120 fathoms long; 12 × 12 = 144, divide by 4, and the product, 36, is the weight in cwts.

Mr. Chapman, master ropemaker at Deptford Dockyard, in a treatise recently published on this subject, gives the following names, lengths, and weights of certain kinds of rope or line as usually made in England :—

Kinds.	Length.	Weight.
Deep sea lines	120 fathoms	36 lbs.
”	”	34
”	”	32
”	”	28
Hand lead lines	20	4
Hambro’ lines, 12 threads . . .	23	3
” 9 ”	”	2¼
” 6 ”	”	1½
Fishing lines	25	1
”	”	¾
”	”	½
”	”	¼
Samson lines	30	1½
”	”	1¼
”	”	1
”	”	¾
Log lines	25	1 to 3
Marline	12 skeins	4
Sewing twine	24 ”	8 to 9
Reefing twine	24 ”	8 to 9

Much of the cordage used on shipboard requires the process of *serving* before it is fitted for its work. This consists in binding a smaller rope very tightly round a larger one, to preserve it from rotting after friction. It is done as shown in *fig.* 4, where a horizontally-stretched rope is being "served" or covered with spun yarns. A mallet, having a concave groove on the side furthest from the handle, is laid on the rope; two or three turns of spun yarn are passed tightly round the rope and round the body of the mallet. A boy passes a ball of yarn continually round the rope; while a man winds it on by means of the mallet, the handle of which serves as a lever to enable him to strain every turn as tightly as possible. The yarn thus appears like a screw whose threads pass almost transversely round the rope.

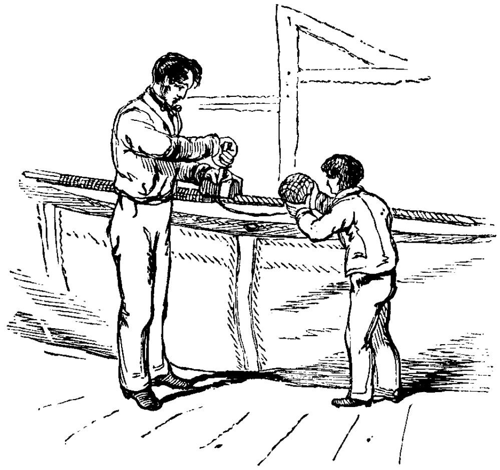

Fig. 4.—Serving a Rope.

All the ropes hitherto described are round or cylindrical; but *flat* ropes are also made, chiefly for mining purposes. They are either formed of two or more small ropes placed side by side, and united by sewing, lapping, or interlacing with thread or smaller ropes; or of a number of strands of shroud-laid rope similarly united. In either case it is necessary that the component ropes or strands be alternately of a right-hand and left-hand twist, that the rope may remain in a quiescent state. The latter method of making flat ropes was first patented by Mr. Chapman, in 1807; and he considered it to afford the strongest possible combination of rope-yarns, his belts or flat ropes appearing to be even stronger than *salvages* (which are skeins of rope-yarns without any twist) of the same number of yarns. This seeming inconsistency is occasioned by the imperfection of hand-spun yarns; because if each

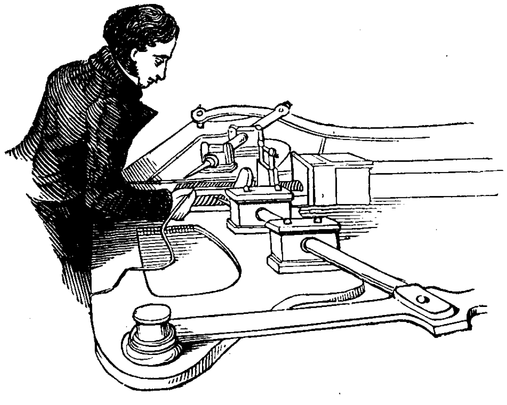

Fig. 5.—Flat-rope Making.

yarn bears its own strain unaided, it will break at its weakest part; whereas, if combined, the mean strength of each will be rendered available. Huddart's flat-rope machine, of more recent invention, is shown in part in *fig.* 5. Supposing four round ropes be needed to make one flat rope, four reels are so placed that the ropes can unwind from them with facility, and pass side by side through a steam-heated box, where the tar becomes a little softened, and the ropes more easily worked. They next pass through a groove or recess closed in tightly at top, bottom, and sides, except holes at the sides to admit large needles. A piercer, or sharp-pointed rod of steel, is then forced entirely through the whole of the four ropes, by leverage produced by steam power; and a man immediately passes a needle and thread through the hole. Two piercers are employed alternately, one on either edge, making holes as fast as two men can introduce needles and thread. The thread here spoken of is sometimes yarn as much as half an inch in thickness, requiring great force to draw it tightly.

Much attention has been devoted to the discovery of the best method of preserving ropes from decay, especially when exposed to the action of water. The operation of tarring, which has been almost universally practised for this purpose, effects it very imperfectly, and materially diminishes the strength of the cordage. Taking the mean of several experiments by Duhamel, it seems that untarred ropes bore a greater weight, by nearly 30 per cent., than those to which the tarring process had been applied; and he states that it is decided by experience that white cordage in continual service is one-third more durable than tarred, that it retains its force much longer when kept in store, and that it resists the ordinary injuries of the weather one-fourth longer. Notwithstanding these facts, it is found that for cables and ground-tackle, which are much exposed to the alternate action of water and air, tarring is a valuable preservative; though cordage that is only superficially tarred is said to be stronger than such as is tarred throughout, and better able to bear the alternations of wet and dry. The removal of the defects and bad qualities of common tar was the object of a patent taken out by Mr. Chapman. Unsuccessful attempts had been made to substitute oils and various fat substances, which would be insoluble in water, for tar; but they had been found to impede the operation of twisting. Chapman improved the ordinary tar, first, "by boiling the tar in water one or more times, each of which extracts a portion of its superabundant acid, and its mucilage, which contains a disengaged acid;" and, secondly, "by continuing these processes until the tar has thrown off a larger portion of its essential oil, and becomes more pitchy than usual; and, finally, by restoring the requisite plasticity through the addition of substances less injurious and less volatile, and therefore more continuous: namely, by the addition of suet, tallow, animal oils, or suitable expressed oils." Of the advantages attending this process, an idea may be formed from the subjoined statement of the relative strength of the cordage without any tar, with common tar, and with Chapman's purified tar. The rope contained twelve yarns in each strand; part was tried immediately, and the rest steeped in water for about three months, then removed to a foundry stove for three months, and finally kept at the ropery nine months; when another trial gave the following results:—

Description of Rope.	Portion of original strength retained.
White	5·7 per cent.
Common tarred	33·0 ,,
Tarred with purified tar	43·8

Sir Joseph Banks had some ropes tarred with *teak* tar, by way of experiment, and found them to be one-third stronger than those done with common tar. Tanning has been tried for the preservation of ropes, but apparently without realising any decided advantage. The solution employed in kyanising, and a solution of caoutchouc, have also been tried as preservatives; but common tar still continues to be the chief substance used for this purpose.

Mr. Chapman gives the following notice of the mode of classifying the work in her majesty's dockyards. Petersburg hemp is mostly used for cables and cablets; Italian hemp for bolt rope and breechings; and Riga hemp for all other cordage. To make Petersburg hemp into No. 20's, the hemp is given to the hatcheller in bundles of 70 lbs.; he takes out 7 lbs. of shorts, and gives 63 lbs. of heckled hemp to the spinner, who spins it into 18 threads of 170 fathoms and 3½ lbs. each. To make Riga hemp into No. 25's, the hemp is given to the hatcheller in bundles of 56 lbs.; he takes out 5 lbs. of shorts, and gives 51 lbs. of heckled hemp to the spinner, who spins 18 threads of 170 fathoms and $2\frac{8}{10}$ lbs. each. In using Italian hemp, 16 lbs. of shorts are taken out of 112 lbs. of hemp; and the remaining 96 lbs. are made up into bands of 1¾ to 3½ lbs. each, according to the size of the yarns to be made. Much old-fashioned routine still prevails in the royal dockyards, in defining exactly how many porters, parters, hatchellers, wheelturners, spinners, &c., shall be employed for each ton of hemp.

We have hitherto spoken only of hemp as the material employed; but several other kinds of vegetable fibre have been made use of in the manufacture of cordage; and some appear greatly to exceed hemp in strength. In a comparative trial made at Paris between ropes made of hemp and of the aloe from Algiers, the latter was found to bear 2000 kilogrammes, while the former, of equal size, bore only 170. Ropes have been formed also of long wool; but they are only about one-third as strong as the best hempen cordage of the same size. Ropes composed of fibres of hemp intermixed with threads of caoutchouc are very valuable for some purposes, owing to their superior strength and elasticity. Their power of bearing sudden jerks without injury is a highly important property. Such a rope was used with the grapnel or anchor of the great Nassau balloon, and was found to arrest the balloon without any unpleasant check when the grapnel caught. Ropes made of thongs of ox-hide twisted together are used in the rope-bridges of Peru, and for some other purposes. Coir or cocoa-nut fibre has lately been much used for this purpose, owing to the high price of Russian hemp; it wears well, weighs little, and is cheap; and is useful for hawsers and warps owing to its great elasticity.

Wire Ropes.—Iron is the substitute which is now engaging most attention. Ropes formed of this metal are found to effect a great saving of expense from their durability and superior lightness. From a paper communicated by Count Breunner to the British Association in 1838, it appears that such ropes had been introduced about seven years before, in the silver mines of the Harz Mountains, and had been found so advantageous as almost entirely to supersede flat and round ropes of hemp in the mines of Hungary, and most of those in the Austrian dominions. The count observes that these iron ropes are nearly equal in strength to solid bars of the same diameter, and equal to hempen ropes of four times their weight. One of them had been in use for upwards of two years without any perceptible wear, though a common flat rope performing the same work would not have lasted much more than one year. The diameter of the largest rope in ordinary use is one inch and a half, and it is composed of three strands, each containing five wires. Great care is observed in the manufacture of these ropes, that the ends of the wires may be set deep in the interior of the rope, and that two ends may not occur near the same part. In use, it is necessary that the ropes be wound on a cylinder of not less than eight feet diameter, and be kept well coated with tar, to prevent oxidation. In one case mentioned by Count Breunner, so great a saving of power was effected, that four horses were doing as much work with a wire rope as six with a flat hempen rope.

Prior to the date of this memoir, patents had been obtained in this country for the manufacture of wire ropes; and they have since been improved and acted upon. The wire ropes of Mr. Andrew Smith are formed in various ways, according to their intended use. For standing rigging straight untwisted wires are employed, bound round with cloth or small hempen cordage saturated with a solution of caoutchouc, asphaltum, or other preservative from rust. Flat ropes may likewise be made of straight wires, interwoven or wrapped with hempen yarn, or sewed between canvas, &c.; but the patentee prefers using them with a slight twist. Other ropes are formed much in the same way as those of hemp; the wires taking the place of rope-yarns, and being twisted into strands, and combined into ropes, both hawser-laid and cable-laid. The twisting should not be so hard as in hempen cordage; and all the wires must be protected by an anti-corrosive composition, or by coating with tin, zinc, &c. In a patent obtained by Mr. Newall of Dundee, for improvements in wire ropes, coating with the following mixture is recommended:—Tar, six parts; linseed oil, two parts; and tallow, one part: the whole being melted together, and applied while hot. In this patent it is proposed to twist wires round a core, either of wire, hemp cord, spun yarn, or other material, to form a strand; and to lay such strands round a similar core when there are more than three strands in a rope. For joining the wires, Messrs. Smith and Newall both recommend twisting their ends together for a few inches; and the latter also suggests the possibility in some cases, of welding them. Wire ropes may be very conveniently and firmly secured at their ends by passing them through the small end of a conical collar, and doubling up, or *upsetting*, the ends of the wires which may then be welded into a solid mass, or secured by running melted brass or solder among them. The collars may then be attached, in various ways, to anything with which it is desired to connect the rope; or they may, as suggested in Newall's patent, be screwed together, so as to unite several lengths of rope. Iron is the material usually employed for wire ropes, but copper and other metals may also be used. The annexed table, showing the comparative size and weight per fathom for equal strength, gives the result of experiments with the wire-ropes of Mr. Andrew Smith, and may serve to show their great superiority to those of hemp, which they surpass even in flexibility:—

Hemp Rope.			Patent Wire Rope.			Equal to a strain of	
Size.	Weight per fathom.		Size.	Weight per fathom.			
Inches.	lbs.	oz.	Inches.	lbs.	oz.	tons.	cwts.
3	2	4	1¼	1	4	2	10
4	3	15	1½	1	9	3	10
5	6	0	1¾	1	14	6	15
6	9	0	2	2	2	8	0
7	12	3	2¼	2	9	8	11
8	14	8	2½	4	1	9	18
9	19	6	3	5	4	15	6
10	25	0	3½	7	1	24	6
11	30	0	4	11	6	29	5
12	36	8	4½	15	12	35	4

Experiments were made at Liverpool in 1857 to find the relative strength of hempen rope and wire rope for the standing rigging of ships; as determined by the corporation testing-machine at King's Dock. All the ropes were made by Messrs. Garnock and Bibby, with equal care. The following results were obtained :—

3¾ inch galvanised iron wire rope	bore a strain of . .	20¾ tons.
3¾ inch Manilla hemp rope	,, . . .	5¾
3¾ inch Russia hemp rope	,, . .	4¾
3¼ inch galvanised iron wire rope	,, . . .	16½
2¼ ,, ,,	,, . . .	8½

The advantage of iron is here very obvious; indeed this metal is found to be, for a given strength, less heavy, less bulky, one-fourth cheaper, and less affected by the atmosphere, than hemp. Soft wire makes the most pliable rope for splicing; but hard wire is stronger. Three-fourths of all the ships now rigged at Liverpool are provided with iron wire standing rigging.

Some of the machines for making wire rope act in the following way. The wire is wound in bobbins mounted in frames set on the periphery of a larger frame like a cage. The cage revolves round an axis, on the bottom of which is a fixed spur-wheel; and the lower end of the vertical axis of each bobbin-frame carries a spur-wheel gearing into this. There is thus obtained a sort of 'sun-and-planet' motion, the cage carrying the bobbin round the central axis, and each bobbin-frame revolving also on its own axis. The wires, in their progress from the bobbins, pass through holes in the top of the central axis, and are there united to form the strand or rope. In Mr. Newall's patent of 1857, the strand-wire for electric cables is drawn through dies or between rollers after the twisting, to bring it to a close cylindrical form, and thereby aid the electric conduction.

The demand for wire rope being now very extensive, for shipping and for telegraphic cables, the patents are or have been regarded as valuable property. Mr. Newall's first patent, which expired in 1854, was a subject of many legal contests, arising out of infringements.