ROPE, a flexible, tenacious, and continuous body, formed of hemp, hair, fibres, &c. These are first spun into thick threads called rope-yarns, then several of these rope-yarns are twisted together by means of a wheel, and form what is called a strand; and lastly, three or four strands properly twisted together form a rope. A rope of small thickness is called a cord, and when very thick, such as may be used for mooring ships, it is called a cable. All the kinds of rope, from the finest whipcord to cables of the largest size, are included under the general name of cordage. See the following article. The uses of rope are too obvious to require enumerating.

M. Amontons, an ingenious French experimental philosopher, who flourished at the close of the seventeenth century, appears to have been the first who thought of making experiments to determine the rigidity of ropes. His experiments were performed with a very ingenious apparatus of his own contrivance and construction, and from them he deduced a table of the forces which under certain circumstances are requisite to bend ropes. His conclusions were founded on the following hypothesis, namely, that in ropes of the same thickness passing over rollers, and loaded with equal weights, the difficulty of bending each rope is less when the diameter of the roller over which it passes is greater, and greater when that diameter is less; but this increase and decrease of rigidity does not exactly follow the reciprocal ratio of the diameter. The table we have mentioned was first published in the Memoirs of the Academy of Sciences for 1669. Dr. Desaguliers, who lived somewhat later, also published a table, shewing what forces are required to bend ropes of different diameters, stretched by different weights, and passing round rollers of different sizes. The result of a series of experiments on ropes, made by this ingenious philosopher, was, that the difficulty of bending a rope round a roller, is, *cæteris paribus*, inversely as the diameter of the roller. Experiments on the friction and rigidity of ropes were afterwards made by M. Coulomb. He employed for this purpose both the apparatus used by M. Amontons, and also a machine of his own contrivance; and the general results of his experiments were as follow:

1. The rigidity of ropes increases, the more the fibres of which they are composed are twisted. 2. It increases in the duplicate ratio of their diameters. The result obtained by Amontons and Desaguliers, was different, namely, that the rigidity of ropes increases in the simple ratio of their diameters. 3. The rigidity of ropes is in the simple and direct ratio of their tension. 4. It is in the inverse ratio of the diameters of the cylinders about which they are coiled. The result obtained by Dr. Desaguliers was the same. 5. In general the rigidity of ropes is directly as their tensions and the squares of their diameters, and inversely as the diameters of the cylinders about which they are coiled. 6. The rigidity of ropes increases so little with the velocity of the machine, that in calculating the effects of machinery, it need not be taken into the account. 7. When small ropes are penetrated with moisture, their rigidity is diminished; but on the contrary, moisture increases the rigidity of thick ropes. 8. Covering ropes with pitch increases their rigidity and diminishes their strength. This increase of rigidity is however more perceptible in thick ropes than in those that are slender. Ropes that are alternately immersed in water and exposed to air, should be pitched; as such a covering keeps them the longer serviceable. 9. The rigidity of ropes coated with pitch, is a sixth part greater in frosty weather than in heat of summer; but this increase of rigidity does not follow the ratio of their tensions.

Rope Making, the art and act of forming fibrous, flexible, and tenacious substances into cordage. The Chinese, and other eastern people, make their ropes of the ligneous parts of a variety of plants; such as the reed, the bamboo, the stem of the aloe, the fibrous covering of the cocoa-nut, the filaments of the cotton-pod; and with the blades of some grasses, as the sparte, or lygeum of Linnæus. Of these, the sparte and aloe are to be preferred for strength; but the bark of certain vegetables is found to be most productive of materials for rope making; accordingly the bark of the liden-tree, the willow, the bramble, and even of the nettle, have been frequently employed for this purpose. But none of all these has been found so well adapted in all respects to the manufacture as hemp and flax; the latter is however chiefly employed in making small lines; but for ropes and larger cordage, hemp has the preference. The finest, most flexible, and strongest hemp used in this country, is obtained from Riga the capital of Livonia on the Baltic; it is called Riga rein-hemp, and though on the whole the best of any, yet its fibre is not so long as that of some of the inferior kinds. The other kinds, in the order of their estimated goodness, are as follows: Petersburg braak, Riga outshot, Petersburg outshot, and the hemps obtained from Koningsburg, Archangel, Sweden, and Memel. The cordage of the royal navy, of East India ships, and of some of the largest shipping in the merchants' service, is formed of some the best of these kinds. There is also another denomination of hemp called chucking, which comes from various places; it is long in the fibre, but coarse and harsh, and does not admit of splitting, so as to be completely dressed. It is however very serviceable, and tolerably strong; and though unfit for fine work, it serves very well for rough inferior cordage. Lastly, there are two or three other kinds known to the rope-makers, as the codilla, half-clean, &c. serving for inferior purposes; but these are entirely or mostly broken fibres of the fore-mentioned kinds, separated from them in dressing.

We are altogether ignorant of the time, place, and people to which rope making owes its origin. If, as we can hardly suppose, the art was unknown to the antediluvian world, it must have been known shortly after the flood, and practised to a considerable extent; as it baffles the boldest conjecture to account for the manner by which prodigious masses of stone, weighing several tons, could possibly be elevated to the summits of immense structures, five or six hundred feet perpendicularly above the common level, without the constant aid of very powerful machinery; and it is not easy to conceive how machinery could be applied to any considerable extent without the assistance of ropes.

The invention of shipping and sailing, though probably posterior by some ages to that of building, would necessarily, even in its early advances, require the use of cordage. Undoubtedly the manufacture continued for a long time in a very rude state; but even in its infancy, strength must have constituted an indispensable requisite. At the present day, the art of rope making has made rapid advances

Rope Making.

Fig. 1.

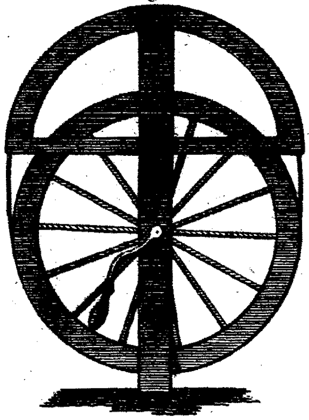
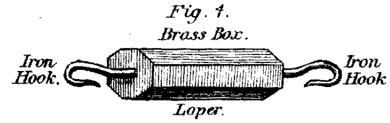
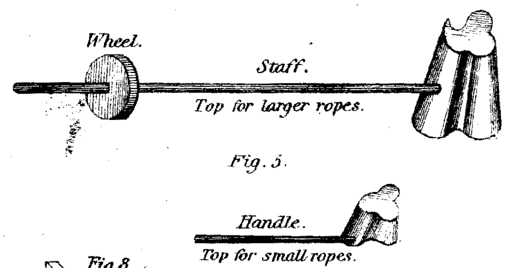


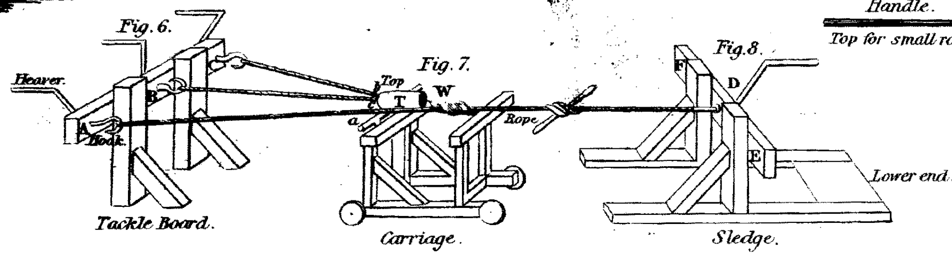
Fig. 2.

Fig. 3.

Fig. 4.

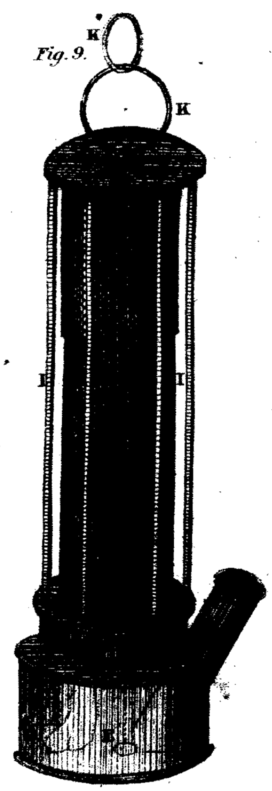






Safety Lamp.

Fig. 9.



Sailing.

Fig. 10.

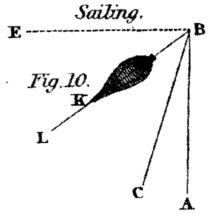


Fig. 11.

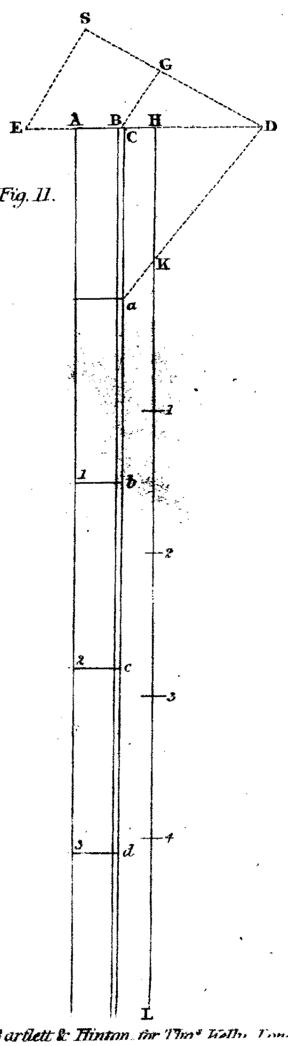
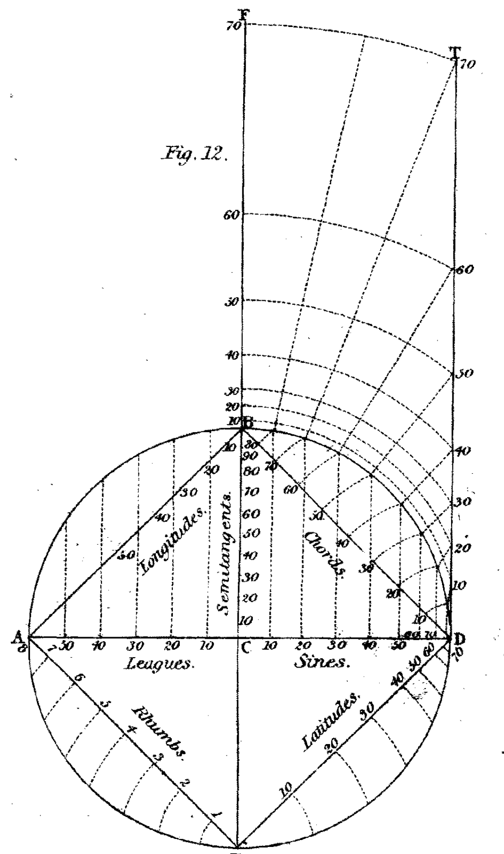


Fig. 12.



Oxford, Printed by Bartlett & Hinton, for Thos Kelly, London 1826

wards a state of perfection, and there are scarcely any limits to its usefulness; there are very few arts which are not in some measure, either directly or indirectly, indebted to the rope-maker. Cordage constitutes the very muscles and sinews of a ship; and every improvement which can be made in its preparation, whether it regard strength or pliableness, must be productive of great service to the mariner; and not less so to the commerce, the arts, and the defence of nations.

In the practice of this art, the first object is to unite the strength of a great number of fibres, so that the aggregate may be capable (each being equally stretched,) of supporting the greatest weight possible. To accomplish this in the completest manner, it should seem that the fibres ought to be laid parallel to each other, and that the bundle of fibres thus disposed, be securely fastened at each end. This might indeed do, if a yarn or rope of only three feet and a half long were all that was required, for that is the average length of the fibres. But ropes, each of nearly a thousand times that length are wanted, and therefore some expedient, differing from the former, for making these, must be adopted. The expedient is to lay the fibres if you please, parallel as before, and then so to twist, or entangle them with each other, that the strength of any single fibre shall be insufficient to overcome the resistance of the friction occasioned by their entanglement, that is, the fibre will sooner break than be drawn out. The manner of disposing of the fibres to make a yarn of some length may be conceived as follows. First, lay as many fibres, unequal in length, as are necessary for the thickness of the yarn, close together and parallel; their upper ends coming all together, consequently no two of the lower ends can come together. Secondly, lay on the above fibres as many more equal ones, so that the ends of no two may be opposite to one another, but that each may lap six or eight inches over the lower end of its corresponding fibre of the first parcel; the lower ends of no two of these last can, it is plain, fall opposite to each other. Do the same with a third parcel of equal fibres, letting each lap over as before the end of its corresponding one in the second parcel; and proceed in this manner to any proposed length; then, Fourthly, twist the whole, cautiously at first, and a yarn will be formed of the length required; and so firmly will the fibres be held together by the friction arising from the twisting, that not one of them can be drawn out from the yarn. We do not pretend to say that this is precisely the mode in which rope-makers perform this part of their work, but it proceeds upon this principle.

A skein of fibres may be twisted so very hard, that any attempt at further twisting will break it. Such a skein can have no strength to support a weight, each fibre being already loaded as much as it can bear; and therefore any weight added would break it. Whatever force is actually exerted by a twisted fibre, in order that it may sufficiently compress the rest to hinder them from being drawn out, must be considered as a weight hanging on that fibre; and must be deducted from its absolute strength of cohesion, before the strength of the skein can be estimated. The strength of the skein is evidently the remainder of the absolute strength of the fibres, after the force exerted in twisting them has been deducted. Hence arises that fundamental principle in rope making, namely, that all twisting, beyond what is necessary for preventing the fibres from being drawn out without breaking, diminishes the strength of the cordage, and is therefore to be avoided. Thus it is necessary to twist the fibres of hemp together, in order to make a strand; but twisting is not all; something must be done to prevent the skein from again untwisting as soon as it is let loose from the hand; some method must be adopted to make the tendency to untwist in one part, act against and counterbalance the like tendency to untwist in another; in the properly accomplishing of this, consists one of the principal difficulties of rope making. The following observations, for distinctness sake, apply chiefly to the larger cordage, such as forms the standing and running rigging of a ship; but they are easily extended, with proper modification, to the smaller kinds.

The first part of the rope making process consists in twisting the hemp; that is, making rope-yarns. These are spun in various ways, according to the nature of the machinery employed, and the cordage to be made. It will be necessary first to enclose a slip of level ground for a rope-walk; it must be about 600 feet long, and of a breadth sufficient to contain the number of machines intended to be employed; and it may be either covered with a slight roof, or left open at top. A spinning wheel is then to be set up at the upper end of this walk of a form resembling that in Plate cxxxv. Fig. 1. The band of this wheel goes over several rollers called whirls, turning on pivots in brass holes. The pivots at one end come through the frame, and terminate in little hooks. The wheel being turned by a winch gives motion in one direction to all those whirls. The spinner has a bundle of dressed hemp round his waist, with the two ends meeting before him. The hemp is laid in this bundle in the same way that women spread the flax on the distaff. There is great variety in this; but the general aim is to lay the fibres in such a manner, that as long as the bundle lasts there may be an equal number of the ends at the extremity, and that a fibre may never offer itself double or in a bight. The spinner draws out a proper number of fibres, twists them with his fingers, and having got a sufficient length detached, fixes it to the hook of a whirl. The wheel is now turned, and the skein is twisted, becoming what is called a rope-yarn, and the spinner walks backwards down the rope-walk. The part already twisted draws along with it more fibres out of the bundle. The spinner aids this with his fingers, supplying them in due proportion as he walks away from the wheel, and taking care that the fibres come in equally from both sides of his bundle, and that they enter always with their ends, and not by the middle. He should always endeavour to enter every fibre at the heart of the yarn. This will cause the fibres to mix equally, and will make the work smooth, because one end of each fibre is by this means buried among the rest, and the other end only lies outward; and this, in passing through the grasp of the spinner, who presses it tight with his thumb and palm, is also made to lie smooth. The greatest fault that can be committed, is to allow a small thread to be twisted off from one side of the hemp, and then to cover this with hemp supplied from the other side; for it is evident, that the fibres of the central thread make very long spirals, and the skin of fibres which covers them must be much more oblique. This covering has but little connection with what is below it, and will easily be detached. But even while it remains, the yarn cannot be strong, for on pulling it, the middle part which lies the straightest, must bear all the strain, while the outer fibres that are lying obliquely, are only drawn a little more parallel to the axis. This defect will always happen if the hemp be supplied in a considerable body to a yarn that is then spinning small. Into whatever part of the yarn it is made to enter, it becomes a sort of loosely connected wrapper. Such a yarn, when untwisted a little, will have the appearance of Fig. 2, while a good yarn looks like Fig. 3. A good spinner therefore endeavours always to supply the hemp in the form of a thin flat skein with his left hand, while his right is employed in grasping firmly the yarn that is twining off, and in holding it tight from the whirl, that it may not run into loops or kinks. Both the arrangement of the fibres and the degree of twisting, depend on the skill and dexterity of the spinner, and he must be instructed, not by a book, but by a master. The degree of twist depends on the rate of the wheel's motion, combined with the retrograde walk of the spinner. We may suppose him arrived at the lower end of the walk, or as far as is necessary for the length of his yarn. He calls out, and another spinner immediately detaches the yarn from the hook of the whirl, gives it to another, who carries it aside to the reel; and this second spinner attaches his own hemp to the whirl-hook. In the mean time, the first spinner keeps fast hold of the end of his yarn; for the hemp, being dry, is very elastic, and if he were to let it go out of his hand, it would instantly untwist, and become little better than loose hemp. He waits, therefore, till he sees the reeler begin to turn the reel; and he goes slowly up the walk, keeping the yarn of an equal tightness all the way, till he arrives at the wheel, where he waits with the yarn in his hand till another spinner has finished his yarn. The first spinner takes it off the whirl-hook, joins it to his own, that it may follow it on the reel, and begins a new yarn.

Rope-yarns, for large rigging, are from a quarter of an inch to somewhat more than a third of an inch in circumference; or of such a size, that 160 fathoms weigh from three and a half to four pounds when white. The different sizes of yarns are named from the number of them contained in a strand of rope of three inches in circumference. Few are so coarse, that sixteen will make a strand of British cordage; eighteen is not unfrequent for cable yarns, or yarns spun from harsh and coarse hemp; twenty-five is, we believe, the finest size which is worked up for the rigging of a ship. Much finer are indeed spun for sounding-lines, fishing-lines, and many other uses. Ten good spinners will work up above six cwt. of hemp in a day; but this depends on the weather. In dry weather the hemp is very elastic, and requires great attention to make smooth work. In the warmer climates, the spinner is permitted to moisten the rag with which he grasps the yarn in his right hand, for each yarn. No work can be done in an open spinning-walk in rainy weather, because the yarns would not take the tar, and would rot if kept on the reel. The second part of the process is the conversion of the yarns into a rope, cord, or line. We shall begin with the simplest possible case, the union of two yarns into one line. This is not a very usual fabric for rigging, but we select it for its simplicity. When hemp has been split into very fine fibres by the hatchel, it becomes exceedingly soft and pliant, and after it has lain for some time in the form of fine yarn, it may be unreeled and thrown loose, without losing much of its twist. Two such yarns may be put on the whirl of a spinning wheel, and thrown, like flaxen yarn, so as to make sewing thread. In this way, sailmakers' sewing thread is manufactured; and when it has been kept on the reel, or on balls or bobbins, for some time, it retains its twist as well as is required. But this is by no means the case with yarns spun for great cordage. The hemp is so elastic, the number of fibres twisted together so great, and the diameter of the yarn, which is a sort of lever on which the elasticity of the fibre exerts itself, so considerable, that no keeping will make the fibres retain this constrained position. The end of a rope-yarn being thrown loose will immediately untwist, and this with considerable force. It would, therefore, be a fruitless attempt to twist two such yarns together; yet the ingenuity of man has contrived to make use of this very tendency to untwist, not only to counteract itself, but even to produce another and a permanent twist, which requires force to undo it, and which will recover itself when this force is removed. The component parts of a rope are called strands, and the operation of uniting them with a permanent twist is called laying or closing. Lines and cordage, less than one and a half inches in circumference, are laid at the spinning wheel. The workman fastens the ends of each of two or three yarns to separate whirl-hooks. The remote ends are united in a knot. This is put on one of the hooks of a swivel called the loper, represented in Fig. 4, and care is taken that the yarns are of equal length and twist. A piece of soft cord is put on the other hook of the loper; and, being put over a pulley several feet from the ground, a weight is hung on it, which stretches the yarn. When the workman sees that the yarns are equally stretched, he orders the wheel to be turned in the same direction as when twining them. This would twine them harder; but the swivel of the loper gives way to the strain, and the yarns immediately twist around each other, and form a line or cord. In doing this, the yarns lose their twist; but this is restored by the wheel. This simple operation would, however, make a very bad line, it would be slack, and not hold its twist; for, by the turning the loper, the strands twist immediately together, to a great distance from it. By this turning of the loper the yarns are untwisted. The wheel restores their twist only to that part of the yarns that remains separate from the others, but cannot do it in that part where they are already twined round each other, because their mutual pressure prevents the twist from advancing. It is, therefore, necessary to retard this tendency to twine, by keeping the yarns apart. This is done by a little tool called the top, represented in Fig. 5, which is a truncated cone, having three or more notches along its sides, and a handle called the staff. This is put between the strands, the small end next the loper, and it is pressed gently into the angle formed by the yarns which lie in the notches. The wheel being now turned, the yarns are more twisted, or hardened up, and their pressure on the top gives it a strong tendency to come out of the angle, and also to turn round. The workman does not allow this till he thinks the yarns sufficiently hardened. Then he yields to the pressure, and the top comes away from the swivel, which immediately turns round, and the line begins to lay. Gradually yielding to this pressure, the workman slowly comes up towards the wheel; the laying goes on, till the top is at last close to the wheel, and the work is done. In the mean time, the yarns are shortened, both by the twining of each, and the laying of the cord. The weight, therefore, gradually rises. The use of this weight is evidently to oblige the yarn to take a proper degree of twist, and not run into kinks.

A cord made in this way, has always some tendency to twist a little more. However little friction there may be in the loper, there is yet some; so that the turns which the cord has made in the laying, are not enough to balance completely the elasticity of the yarns; and the weight being appended, causes the strands to be more nearly in the direction of the axis; in the same manner as it would stretch and untwist a little any rope to which it is hung. On the whole, however, the twist of a laid line is permanent, and not like that upon thread doubled or thrown in a mill, which remains only in consequence of the great softness and flexibility of the yarn. The process for laying or closing large cordage is considerably different from this. The strands of which the rope is composed consist of many yarns, and require a considerable degree of hardening. This cannot be done by a whirl driven by a wheel-band; it requires the power of a crank turned by the hand. The strands, when properly hardened, become very stiff, and when bent round the top, are not able to transmit force enough for laying the heavy and unpliant rope which forms beyond it. The elastic twist of the hardened strands must, therefore, be assisted by an external force. All this requires a different machinery, and a different process.

At the upper end of the walk is fixed up the tackle-board, Fig. 6. This consists of a strong oaken plank called a breast-board, having three or more holes in it, such as A, B, C, fitted with brass or iron plates. Into these are put iron cranks, called heavers, which have hooks or forelocks, and keys, on the ends of their spindles. They are placed at such a distance from each other, that the workmen do not interfere with each other while turning them round. This breast-board is fixed to the top of strong posts, well secured by struts or braces, facing the lower end of the walk. At the lower end is another breast-board fixed to the upright posts of a sledge, which may be loaded with stones or weights. Similar cranks are placed in the holes of this breast-board. The whole goes by the name of the sledge; Fig. 7. The top necessary for closing large cordage is too heavy to be held in the hand: it therefore has a long staff, which has a truck on the end, and rests on the ground; but even this is not enough in laying great cables. The top must be supported on a carriage, as is shewn in Fig. 8, where it must lie very steady; and it needs attendance, because the master workman has sufficient employment in attending to the manner in which the strands close behind the top, and in helping them by various methods. The top is, therefore, fixed to the carriage, by lashing its staff to the two upright posts. A piece of soft rope, or strap, is attached to the handle of the top by the middle, and its two ends are brought back and wrapped several times tight round the rope, in the direction of its twist, and bound down. This is shown at W, and it greatly assists the laying of the rope by its friction. This both keeps the top from flying too far from the point of union of the strands, and brings the strands more regularly into their places.

The first operation is warping the yarns. At each end of the walk are frames called warping frames, which carry a great number of reels or winches filled with rope-yarn. The foreman of the walk takes off a yarn end from each, till he has made up the number necessary for his rope or strand; and bringing the ends together, he passes the whole through an iron ring fixed to the top of a stake driven into the ground, and draws them through: then, a knot is tied on the end of the bundle, and a workman pulls it through this ring till the intended length is drawn off the reels. The end is made fast at the bottom of the walk, or at the sledge, and the foreman comes back along the skein of yarns, to see that none are hanging slacker than the rest. He takes up in his hand such as are slack, and draws them tight, keeping them so till he reaches the upper end, where he cuts the yarns to a length, again adjusts their tightness, and joins them all together in a knot, to which he fixes the hook of a tackle, the other block of which is fixed to a firm post, called the warping-post. The skein is well stretched by this tackle, and then separated into its different strands. Each of these is knotted apart at both ends. The knots at their upper ends are made fast to the hooks of the cranks in the tackle-board; and those at the lower ends are fastened to the cranks in the sledge. The sledge itself is kept in its place by a tackle, by which the strands are again stretched in their places, and every thing adjusted, so that the sledge stands square on the walk, and then a proper weight is laid on it. The tackle is now cast off, and the cranks are turned at both ends, in the contrary direction to the twist of the yarns. In some kinds of cordage the cranks are turned the same way with the spinning twist. By this the strands are twisted and hardened up; and as they contract by this operation, the sledge is dragged up the walk. When the foreman thinks the strands are sufficiently hardened, which he estimates by the motion of the sledge, he orders the heavers at the cranks to stop, and the middle strand at the sledge is taken off from the crank. This crank is taken out, and a stronger one put in its place at D, Fig. 7. The other strands are taken off from their cranks, and are all joined on the hook which is now in the middle hole. The top is then placed between the strands, and being pressed home to the point of their union, the carriage is placed under it, and it is firmly fixed down. Some weight is now taken off the sledge, and the heavers begin to turn at both ends. Those at the tackle-board continue to turn as they did before; but the heavers at the sledge, turn in the opposite direction to their former motion; so that the cranks at both ends are now turning one way. By the motion of the sledge-crank the top is forced away from the knot, and the rope begins to close. The heaving at the upper end restores to the strands the twist which they are constantly losing by the laying of the rope. The workmen judge of this by making a chalk mark on intermediate points of the strands, where they lie on the stakes which are set up along the walk for their support. If the twists of the strands be diminished by the motion of closing, they will lengthen, and the chalk mark will move away from the tackle-board; but if the twist increase by turning the cranks at the tackle-board, the strands will shorten, and the mark will come nearer to it.

As the closing of the rope advances, the whole shortens, and the sledge is dragged up the walk. The top moves faster, and at last reaches the upper end of the walk, the rope being now laid. In the mean time, the sledge has moved several fathoms from the place where it was when the laying began. These motions of the sledge and top must be exactly adjusted to each other; and the rope must be of a certain length. Therefore the sledge must stop at a certain place. At that moment the rope should be laid; that is, the top should be at the tackle-board. In this consists the address of the foreman, who has his attention directed both ways. He looks at the strands, and when he sees any of them hanging slacker between the stakes than the others, he calls to the heavers at the tackle-board to heave more upon that strand. But he finds it more difficult to regulate the motion of the top. Considerable force is required to keep it in the angle of the strands, and it is always disposed to start forward. To prevent this, some straps of soft rope are brought round the staff of the top, and then wrapped several times round the rope behind the top, and kept firmly down by the lanyard or bandage, as shewn in the figure. This both holds back the top, and greatly assists the laying of the rope, causing the strands to fall into their places, and keep close to each other; which is sometimes very difficult, especially in ropes composed of more than three strands. It will greatly improve the laying of the rope, if the top have a sharp, smooth, tapering pin of hard wood, pointed at the end, projecting so far from the middle of its smaller end, that it may get in between the strands which are closing. This supports them, and makes their closing more gradual and regular. The top, its notches, the pin, and the warp or strap which is lapped round the rope, are all smeared with grease or soap, to assist the closing. The foreman judges of the progress of closing chiefly by his acquaintance with the walk, knowing that when the sledge is abreast of a certain stake, the top should be abreast of a certain other stake. When he finds the top too far down the walk, he slackens the motion at the tackle-board, and makes the men turn briskly at the sledge. By this the top is forced up the walk, and the laying of the rope accelerated, while the sledge remains in the same place; because the strands are loosing their twist, and are lengthening, while the closed rope is shortening. When, on the other hand, he thinks the top too far advanced, and fears that it will be at the head of the walk before the sledge has got to its proper place, he makes the men heave briskly on the strands, and the heavers at the sledge-crank softly. This quickens the motion of the sledge by shortening the strands; and by thus compensating what has been overdone, the sledge and top come to their places at once, and the work answers the intention.

When the top approaches the tackle-board, the heaving at the sledge could not cause the strands immediately behind the top to close well, without having previously produced an extravagant degree of twist in the intermediate rope. The effort of the crank must therefore be assisted by men stationed along the rope, each furnished with a tool called a woolder; which is a stout oak stick, about three feet long, having a strap of soft rope-yarn or cordage fastened on its middle or end. The strap is wrapped round the laid rope, and the workman uses the stick as a lever, twisting the rope round in the direction of the crank's motion. The woolders should keep their eye on the man at the crank, and make their motion correspond with his. Thus they send forward the twist produced by the crank, without either increasing or diminishing it in that part of the rope which lies between them and the sledge. Such is the general and essential process of rope-making. The fibres of hemp are twisted into yarns, that they may make a line of any length, and stick among each other with a force equal to their own cohesion. The yarns are made into cords of permanent twist by laying them; and that we may have a rope of any degree of strength, many yarns are united in one strand, for the same reason that many fibres were united in one yarn; and in the course of this process, it is in our power to give the rope a solidity and hardness which make it less penetrable by water. Some of these purposes are inconsistent with others; and the skill of a rope-maker lies in making the best compensation, so that the rope may on the whole be the best in point of strength, pliancy, and duration, that the quantity of hemp in it can produce.

The following rule for judging of the weight which a rope will bear, is not far from the truth. It supposes them rather too strong; but it is easily remembered, and may be of use. Multiply the circumference in inches by itself, and take the fifth part of the product, it will express the number of tons which the rope will carry. Thus, if the rope have six inches circumference, 6 times six is 36, the fifth of which is $7\frac{1}{5}$ tons; apply this to the rope of $3\frac{1}{5}$ on which Sir Charles Knowles made his experiments $3\frac{1}{5}\times3\frac{1}{5}=10.25$; $\frac{1}{5}$ of which is 2.05 tons, or 4592 pounds. It broke with 4550. This may suffice for a general account of the mechanical part of the manufacture. But we have taken no notice of the operation of tarring; because it would be no easy task to enumerate all the various methods employed in different rope-works. It is evidently proper to tar in the state of twine or yarn, this being the only way that the hemp could be uniformly penetrated. The yarn is made to wind off one reel, and having passed through a vessel containing hot tar, it is wound up on another reel; and the superfluous tar is taken off by passing the yarn through a hole surrounded with spongy oakum; or it is tarred in skeins or hauls, which are drawn by a capstern through the tar kettle, and through a hole formed of two plates of metal, held together by a lever loaded with a weight. Tar cordage, when new, is weaker than white, and the difference increases by keeping. The following experiments were made by M. Du Hamel, at Rochefort, August 8, 1743, and subsequently, on cordage of three inches (French) in circumference, made of the best Riga hemp.

	White.	Tarred.
Made August 8, 1741.		
Broke with	4500 pounds.	3400 pounds.
	4900	3300
	4800	3250
Made April 25, 1743.		
	4600	3500
	5000	3400
	5000	3400
Made September 3, 1746.		
	3800	3000
	4000	2700
	4200	2800

A parcel of white and tarred cordage was taken out of a quantity which had been made February 12, 1746. It was laid up in the magazine, and comparisons were made from time to time as follows:

	The white bore.	The tarred bore.	Differ.
1746, April 14,	2645 lbs.	2312 lbs.	333
1747, May 18,	2762	2155	607
1747, Oct. 21,	2710	2050	660
1748, June 19,	2575	1752	823
1748, Oct. 2,	2425	1837	588
1749, Sept. 25,	2917	1865	1052

M. Du Hamel says, that it is decided by experience, 1. That white cordage in continual service is one-third more durable than tarred. 2. That it retains its force much longer while kept in store. 3. That it resists the ordinary injuries of the weather one-fourth longer. It may be asked, Why should cordage be tarred? The answer is, 1. That tarring preserves cables and ground tackle, which are greatly exposed to the alternate action of water and air; for white cordage, exposed to be alternately very wet and dry, is found to be weaker than tarred cordage. 2. That cordage which is superficially tarred, is always stronger than what is tarred throughout; and it resists better the alternatives of wet and dry. Lastly, attempts, have been made to increase the strength of cordage by tanning; and it continues to be practised in the manufacture of nets; but it does not appear that much addition, either of strength or durability, can be given to cordage by this means. The trial has been made with great care, and by persons fully able to conduct the process with propriety. But it is found that the yarns take so long time in drying, and are so much hurt by drying slowly, that the room required for a considerable rope-work would be immense; and after all, the improvement of the cordage would be but very trifling, and even equivocal.