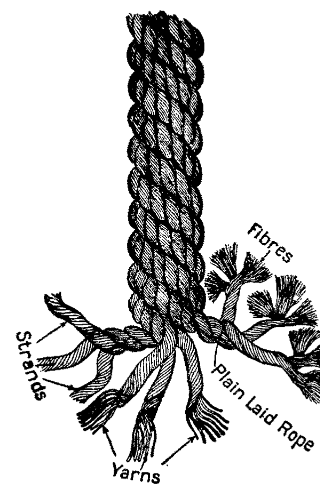
ROPE (AS. *rāp*, Goth. *raips*, OHG. *reif*, cord, Ger. *Reif*, ring; of uncertain etymology). Technically, cordage 1 inch or more in diameter. The term "cordage" is used in a collective sense to include all sizes and varieties of cords and rope from harvester twine to the largest cables. It is probable that ropemaking was among the earliest of industries. The materials first used for the purpose were probably the fibres of various plants, the inner bark of trees, and the hides of animals cut into thongs and twisted. Sculptural representations of ropemaking are found upon ancient Egyptian manuscripts, showing that they made use of flax and the fibres of the date tree as well as of rawhide. Herodotus states that the Persians manufactured cables 28 inches in circumference of flax and papyrus with which to aid in constructing the bridge of boats upon which the army of Xerxes crossed the Hellespont. Peruvians used fibres of the maguey for rope and twisted cables of sufficient strength to carry the primitive suspension bridges.

Prior to the year 1820 hand labor, aided only by the clumsy wheels and other imperfect contrivances pertaining to the old-fashioned rope-walk, was exclusively employed in the manufacture of rope. In that year some machines were constructed in England for twisting hand-spun yarn into strands, and a few were imported into the United States. Next came the introduction of machines for spinning the threads from raw material. The first machinery for this purpose was constructed in Massachusetts in 1834. American machines are now extensively employed in Europe, and American cordage is held in such high estimation that it is exported to all parts of the world.

Materials. The materials employed for ropemaking include hemp, flax, cotton, manila, sisal, jute, and other vegetable fibres. Russian hemp for tarred rigging has long maintained a reputation for superiority; its great strength and durability are attributed to the method of retting the fibre under water. Italian hemp is also excellent and for some uses unsurpassed. Manila hemp (see HEMP, MANILA) is perhaps more extensively used in the manufacture of cordage than any other material, as its great pliability and strength particularly adapt it for the running rigging of vessels and for a multiplicity of ordinary uses. Sisal, from Yucatan, and East Indian jute are largely used for the manufacture of the cheaper grades of cordage. See FLAX; HEMP; JUTE; SISAL.

Ropewalk Ropemaking. The old walk was usually from 1000 to 1400 feet long. Fibres of hemp were hackled or straightened out by drawing the material through a steel-toothed comb. The workman then wound a bundle of hemp about his body, attaching one end to one of a series of hooks on a whirl or looper, drawing out the fibres from the bundle with one hand and compressing them with the other, experience teaching the number of fibres to draw out and how to twist them so as to hold firmly to the hook. He then walked slowly backward down the walk, making his yarn as he went, the spinning being done by the wheel or whirl turned by an assistant, the spinner seeing that



A CABLE-LAID ROPE.

the fibres were equally supplied and joining the twisted parts at the ends. Two or more spinners might be going down the walk at the same time, and at the end two would join their yarns together, each then beginning a new yarn and returning on the walk to the end, where the second spinner again took his yarn off the whirl and joined it to the end of the first spinner's yarn, so that it continued on the reel. When a sufficient number of yarns were spun they were twisted into strands and the strands into ropes, horse power being usually employed.

The next improvement was the introduction of machines for twisting the yarn into strands and laying the strands into cables. The nature and operation of these machines can best be explained by describing a modern ropewalk plant, the reader taking care to remember, however, that at first hand-spun yarn was employed instead of the present machine-spun yarn. Most large rope, such as towing lines and ship cables, is walk-laid rope. The first operation is to wind the yarn on large bobbins. These bobbins are put on a framework of wood located near one end of the ropewalk, and the ends of the yarns from them are passed through holes in an iron gauge plate, known as the face plate, and then through a cast-iron tube, which acts to collect the separate yarns into a closely laid cylindrical bundle. After being passed through the tube the yarns are fastened on a hook of the forming machine, which runs on a track the entire length of the walk and which at the same time twists the yarns left-handed into a strand. To lay these strands into a rope two laying machines are required, one at each end of the walk, which are known as the upper and lower machines. As many of the strands as are required for the rope are stretched at full length along the walk and are attached to the hooks on the laying machines. The upper machine has but one hook, to which all the strands are attached and which operates in one direction, while the lower machine has as many hooks as there are strands and operates in the opposite direction. To keep the strands equidistant they are placed in the grooves of a conical wooden block called a top, which is attached to an upright post on a car called a top stud. The top is pushed up close to the upper laying machine at the beginning of the twisting process, and, as the twisting proceeds, the strands closing in behind it gradually force it down the walk until the lower laying machine is reached and the rope completed.

Machine Ropemaking. The greater part of medium-size rope is made by ropemaking machines, as distinguished from the ropewalk. In describing ropemaking by machines reference will be had particularly to the working of Manila hemp, the material most extensively used, but Russian, sisal, and other hemps are manipulated in essentially the same manner. The treatment of jute requires a rather different process, owing to its shorter and weaker fibre. The bales of Manila hemp, averaging in weight about 270 pounds each, are opened, and, after the fibre has been lightly shaken apart, it is placed in layers which are sprinkled lightly with oil to soften and to lubricate the fibre previous to its passage through the machines. The first mechanical operation is called scutching and consists in passing the hemp over revolving cylinders bristling with sharp steel prongs or teeth, which straighten out the fibres and remove the coir or fine broken particles, the dirt, and other foreign substances. It is then passed on to the breakers, which are large frames each about 25 feet long, consisting of two endless chains covered with long steel pins. The first chain feeds the fibres to the second, which runs much slower, the effect being to comb or straighten out the fibres and draw them into a continuous ribbon or sliver. Following this operation comes the passage of the hemp through the spreaders and drawing frames, machines similar to the breakers, but smaller, and furnished with steel pins and teeth of gradually increasing fineness, which still further comb and straighten out the fibres—a number of slivers being put together behind each machine and drawn down to one sliver again at the end of each machine. This drawing is repeated several times through machines of various degrees of fineness, in order to make the sliver even, without which it would be impossible to spin fine even yarns. This process is completed on a very fine drawing frame called a finisher, and from this the material emerges in complete readiness for spinning. The spinning is done on spinning machines or jennies, each operating two spindles, moving at about 1500 revolutions per minute. The spinning twists the fibre right-handed into yarn, about 1000 yards of which are wound upon each bobbin. The next process is to form the yarn into strands and lay the strands into rope, and this is performed upon machines known as formers and layers. For the larger sizes of rope there are usually separate machines, but for rope ½ inch in diameter and less the former and layer are combined into a single machine. The former consists of a circular iron disk, at the centre of which is erected a perpendicular shaft, carrying at its end a head or die. The plane of the disk may be either horizontal or vertical. Around the edge of the disk are spaced several bobbins or spools full of yarn, the number of spools used depending upon the number of yarns in the final strand. The free end of the yarn from each spool is carried to the head, where, by a revolving motion of the disk, they are twisted together and wound off on to a spool or drum. If we substitute for the spools of yarn just described spools filled with twisted strands, we have in its essentials a layer. When former and layer are combined, each spool on the large disk is replaced by a small disk and head, which twists a strand, the several strands being led to the head of the main disk and there twisted into completed rope, which is wound off on to a drum or reel.

Special Ropes. Cables for drilling oil and water wells have to be made unusually long and run all the way from 1400 to 3500 feet in length and from 1⅞ to 2½ inches in diameter. They are composed of three strands of Manila ropes, laid together with a very hard lay, so that they will not untwist when used for drilling, and also will resist the continual wear and rubbing against the side of the casing and the wall of the well. Cables of this kind are always made on machines and not in the rope-walk. These machines have to be exceedingly large and heavy to carry this amount of rope, and only a few mills in the world are equipped for making well-drilling cables. For making tarred rope the yarns are first run through copper tanks filled with heated tar; the yarns enter through holes in an iron plate and are drawn through the tank by machinery. As the yarns emerge from the tank the superfluous tar is removed by means of pressing rollers. Tarred rope may be made any size by the methods already described, but a large proportion of tarred yarn is made into small cordage.

Strength of Rope. The strength of rope varies with the material of which it is made, the weight of the rope per fathom, etc. The following figures, compiled from Kent's *Mechanical Engineer's Pocket Book* (8th ed., New York, 1913), give some general information on this matter:

MATERIALS	Circ. in inches	Weight, lbs. per fathom	Strength, lbs.
Untarred hemp	1.53–6.9	0.42– 7.77	1,670–33,808
Tarred hemp...	1.44–7.12	0.38–10.39	1,046–31,549
Cotton rope....	2.48–6.51	1.08– 8.17	3,089–23,258
Manila rope ...	1.19–8.9	0.2 –11.4	1,280–65,550

The comparative strength of hemp, iron, and steel ropes is indicated in a general way by the following figures from Weisbach; girth required to give tensile strength of 40 tons—hemp, 12 inches; iron, 4⅝ inches; steel, 3¾ inches.

For a description of the manufacture of wire rope, see WIRE ROPE. For details of the strength and efficiency of rope and its application to transmission of power, consult J. J. Flather, *Rope Driving* (New York, 1897), and William Kent, *Mechanical Engineer's Pocket Book* (8th ed., ib., 1912).