NATURAL FIBER ROPE

Under this heading come Manila, sisal, hemp, coir, cotton, and flax. Rope takes its name from the species of plant from whose fiber it is made. Fiber rope is impregnated with oil when manufactured which adds about 10 percent to its actual weight. The oil lengthens the life of the rope by keeping out heat and moisture. As the oil leaves it, the rope tends to deteriorate more rapidly. The strength of fiber rope becomes less with use. A used rope can be deceptive; unlike a wire rope the strands do not wear flat, thereby giving a visible sign of weakness. The fibers stretch and untwist but this does not plainly indicate weakness. Do not place a maximum strain on a rope, which has been under a load for a long period, or has been close to the breaking point. Rope safety decreases rapidly with constant use, depending upon the working conditions and amount of strain. When natural fiber rope gets wet, the line shrinks in length. Keep fiber ropes dry and in a well ventilated space to prevent the rope from rotting.

MANILA is a hard fiber, which comes from the bark of the abaca plant. It is the most important natural rope in the world. It grows almost exclusively in the Philippines and takes its name from the port from which it is exported. It possesses a lightness, strength, and durability with which no other natural fiber can compare. It is glossy, has a brilliant sheen, and is smooth and pliable. Manila fibers are referred to as "Silvers" by the cordage industry due to their natural color. Saltwater has little effect on it, and therefore it is used almost exclusively for marine cordage. Until the advent of synthetic fibers it was used primarily for mooring lines, and it still finds considerable use aboard ship.

The abaca plant and the banana plant are very closely related and resemble each other in appearance and habits of growth. The plant is a large treelike herb 15 to 20 feet high. The stalk is from 6 to 22 feet in length and from 6 to 18 inches in diameter. The bark is formed in ribbon like strips of fiber over a fleshy core. The fiber is removed, cleaned and dried, and then baled for shipment to the cordage mill. Manila fiber absorbs oils and preservatives directly into the fiber. Consequently, it will resist deterioration from bacterial rot or mildew for a long time. Manila is still use extensively in the paper industry for high quality paper products such as money and hygiene products.

SISAL is made from a hard fiber obtained from the leaves of *Agaue sisalana.* It is sometimes known as sisal hemp, but is entirely different from true hemp. True sisal comes mainly from East Africa, the Dutch West Indies, and Haiti. Henequen is sometimes called Yucatan or Cuban sisal but this is not correct. Sisal fibers are white to yellowish-white in color. Unlike Manila, sisal lacks gloss, is stiff and harsh to the touch, and is easily injured by exposure to the weather. The length of the fiber is 2 to 4 feet as opposed to 6 to 10 for Manila. It is only about 80 percent as strong as Manila. During World War II when Manila was not available, sisal was substituted. Because of its stiffness and tendency to kink, seamen breathed a sigh of relief when Manila came back on the market. Aboard ship today it is little used except as small stuff although some finds its way aboard yachts. Sisal fiber takes only a surface coating of oil or preservatives, which leach-out rapidly.

HEMP comes from the *Cannabis sativa* plant. There is only one true species of hemp but considerable confusion arises about its correct name because there are many other somewhat similar fiber producing plants. The commercial fibers obtained from them are frequently and incorrectly called hemp. Several of these are Manila hemp, sisal hemp, New Zealand hemp, and Mauritius hemp. Hemp is grown in the United States, USSR, Italy, France, and Korea. It was probably the first fiber used for manufacturing rope in this country in Boston about 1640. Hemp fiber is coarse and about 80 percent as strong as Manila, but is used for entirely different purposes. It was formerly used for standing rigging, and still may be used on the ratlines of the few remaining square-riggers where its stiffness is an asset. When tarred it stands up well in wet weather. In the present day, however, most all hemp is made up as marline and is used extensively in the bosun's locker where small stuff is appropriate. Serving is marline tightly wound on the rope by means of a board or mallet.

JUTE is a glossy fiber used for making burlap sacks, mats, rope comes from Southern Asia, Bangladesh. Comes from the *corchorus capsularis* and *corchorus olitorius.*

COIR rope is made from coconut husk fiber and is a buoyant rope that does not become waterlogged. It has about half the strength of Manila. It was formerly used on tugs for lashing lighters and barges together, but has fallen into disuse and today is almost unknown in the maritime industry.

COTTON and **FLAX** ropes, are made of common cotton and flax, respectively. Only smaller sizes are used aboard ship. Cotton signal halyards and leadlines are common. Flax cordage was commonly used for boltrope on sails because of its soft and flexible qualities. It has now largely been replaced by synthetics, but some flax sail twine may still be found. Cotton is used to make what is commonly called “white-line”.

FLAX is extremely strong when wet. It gains approximately 100 percent tensile strength over dry strength. Its wet strength is comparable to that of nylon. Flax and hemp ropes are very stable and have low elongation and elasticity comparable to Manila.

** Reference: American Merchant Seaman's Manual*

NATURAL FIBER ROPE CONSTRUCTION METHODS

Making fiber line or wire rope is essentially a series of twisting operations. The direction in which the various parts may be twisted should be understood since this will control the naming of the type of fiber line or wire rope.

Standard natural fiber rope construction is three strand twisted rope. In the first stage of construction, individual plant fibers are formed into bundles or yarns. In stage two, yarns or threads are formed by taking bundles of fiber or yarns and twisting them together in the opposite direction. In stage three, the piled yarns or threads are then twisted again to form strands again, in the opposite direction of the yarns. Finally, three formed strands are twisted to produce the finished rope. Three right-handed laid strands laid up left-handed are referred to as hawser-laid.

Fibers are twisted to form yarns in a direction opposite then the yarns are twisted to form strands.

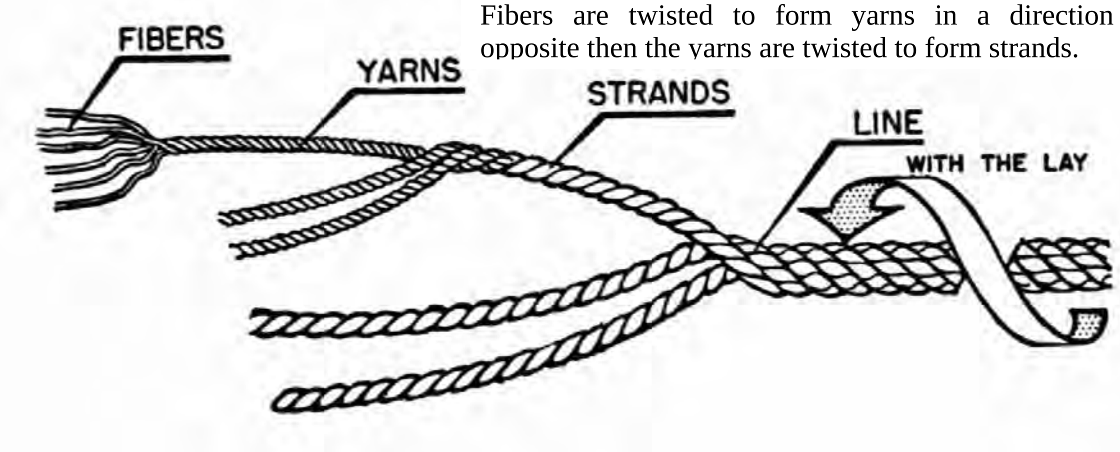


Figure 1 – 4 Stage Construction of Natural Fiber Rope

Rope performance will be determined by its strength, stretch, wear resistance, and handling flexibility. The finished rope should be flexible but firm, thereby maximizing resistance to wear, snagging and hockling/kinking. Premium fiber rope should resist any effort to unlay or open the lay of the rope. Each strand of the rope should be manufactured with a balanced twist to create a firm round strand for maximum wear and durability. The lay of the rope should be uniform and consistently smooth otherwise the lay tension will be out of balance and strength is affected.

A hockle (or cockle) is actually a kink in an inner yarn that forces the yarns to the surface. Hockles can be corrected by stretching the line and twisting the free end to restore the original lay. A cockle can reduce line strength by as much as a third. Braided line will not kink or hockle.

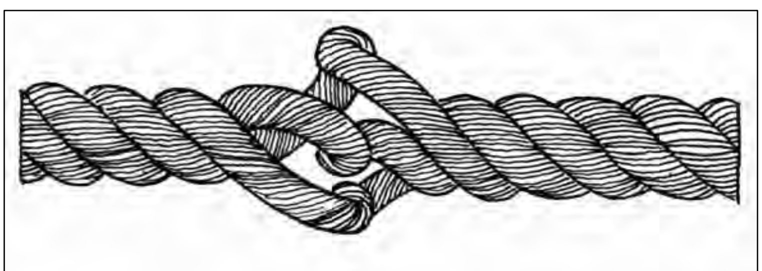


Figure 2 - Hockle (Cockle) or Kink

The “lay” of the lines refers to the direction of twist in the strands. Right lay line should be coiled clockwise. Left lay line should be coiled counter-clockwise.

NATURAL FIBER ROPE STRENGTH COMPARISONS

All rope is compared to the characteristics of manila because all of the empirical strength formulae are based on manila circumference. Manila is therefore 100% of strength (Reference American Merchant Seaman's Manual). Rope tensile strengths are based on tests of new and unused rope of standard construction in accordance with manufacturer's standard testing methods. It can be expected that strengths will decrease as soon as a rope is put into use. Natural fiber rope is measured by line circumference.

Manila	100%
Hemp	80%
Sisal	80%
Jute	60%
Coir	50%
Cotton	25% dry 120% wet
Flax	25% dry 250% wet

Figure 3 - Strength comparisons based on line of equal circumference

SIZE OF FIBER ROPE

SMALL STUFF: 1-3/4" in circumference or less than 1/2" in diameter or less than 24 thread stuff being the larger size.
LINE: Rope size 1-3/4" in circumference up to 5" circumference.
HAWSER: Rope 5" in circumference or larger.

MISCELLANEOUS TYPES OF NATURAL FIBER LINE

SPUN YARN: 2, 3 or 4 stranded line, tarred, left-hand lay.
MARLINE: 2 stranded line, may be tarred or untarred, left-hand lay.
ROUND LINE: 3 stranded line, tarred hemp usually larger than houseline, right-hand lay. It is also referred to as Ratline.
HOUSELINE: 3 stranded line, tarred hemp, left-hand lay.

SYNTHETIC FIBER ROPE MATERIALS

Though initially more expensive than natural fiber ropes, synthetic ropes have proven to be more efficient and cost effective long term for most applications. Man-made fiber ropes are stronger and more durable. They are generally not affected by rot or mildew, or most chemicals, and may be stored wet or dry. As a result, the service life of synthetics exceeds that of natural fiber ropes.

Each of the various types of synthetic fibers described below possesses different characteristics and properties. All of these fibers are continuous filaments of long molecular chain polymers that extend the length of the rope. These filaments may be either extruded or spun, and are normally either termed as monofilament (larger single filaments) or multifilament (multiple smaller fibers). Sunlight is the factor most likely to impair the strength and durability of synthetic line.

NYLON is a very strong fiber. Due to its elasticity, nylon can absorb sudden shock loads that would break ropes of other fibers. Nylon stretches readily (40 - 50%). The critical point is 40%. It has very good resistance to abrasion and will last many times (about 5 times) longer than natural fiber ropes. Nylon rope is resistant to rot, oils, gasoline, grease, marine growth or most chemicals. Advantages of nylon rope over manila rope are that nylon rope is stronger and can hold a load even when a considerable number of the yarns have been abraded. With respect to the elasticity of nylon mooring lines under load, nylon will stretch and thin out but will return to normal size when free of tension. **Nylon stoppers should be used with nylon line.**

POLYESTER (DACRON) is very strong, but not quite as strong as nylon rope. The difference between the two ropes is that polyester does not have the stretch and elasticity of nylon, but has better resistance to ultraviolet degradation from sunlight. Polyester is superior to nylon on wet abrasion.

POLYPROPYLENE * is lightweight, strong rope that is extensively used in many different applications. It is a floating rope and is resistant to rot, oils, gasoline or most chemicals. Polypropylene rope is available in monofilament fiber, which is smooth surfaced, multifilament fiber, which has a somewhat velvety appearance and feel, and slit film fiber, which is produced in varying textures. However, polypropylene melts easier than other synthetic lines.

POLYETHYLENE * is one of the best known synthetic fiber ropes. A floating rope somewhat like polypropylene except slightly heavier. Also, polyethylene's handling characteristics are a little different than polypropylene. It is not as strong as polypropylene, size for size.

KEVLAR and **KEVLAR BLENDS** are the strongest of the modern synthetic ropes. They are approximately 5-6 times stronger that Manila of the same size. Kevlar has low stretch and elasticity, but has only fair resistance to ultraviolet degradation from sunlight.

**** Special notice:*** *Polypropylene and Polyethylene are subject to deterioration when exposed to direct sunlight. These products are designed to give you many hours of use; however, the life of the product will be extended when stored away from sunlight. The product should be replaced when signs of excessive deterioration are indicated by discoloration, broken filaments, raveling, etc.*

SYNTHETIC FIBER ROPE TYPES

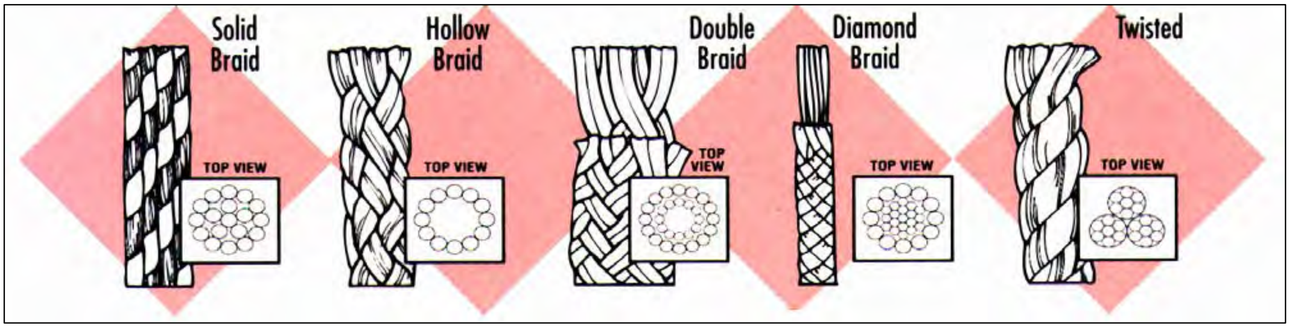


Figure 4 - Synthetic Fiber Rope Types

MONOFILAMENT is extruded in round fibers. Not as soft or flexible as multifilament. Available in polypropylene and polyethylene ropes only.

MULTIFILAMENT is soft, flexible, small diameter, continuous filaments. Available in nylon, polyester and polypropylene ropes.

SLIT FILM is polypropylene or polyethylene is extruded in sheet film form, and then slit to make flat fibers.

SPUN is very fine fibers with lengths of 1/2 to 1-1/2 inches are twisted into string then into rope. Available in cotton and polyester ropes only.

TEXTURED FIBERS are crimped to give loft to the fiber. Available in polyester, nylon and polypropylene.

ROPE DEFINITIONS

BONDING is a liquid coating to increase resistance to abrasion and prevent water absorption.

NATURAL is natural color, unbleached cotton.

WHITE is a specified cotton color not to be confused with natural.

POLISHED (GLAZED) is cotton cordage that has been run through a gum and pigment polish to give it a high gloss.

DERBY is a special solid braid line manufactured with bright multifilament polypropylene yarn. The color is extruded into the fiber, not dyed after production. Widely used for horse halters and leads, and as a decorative barrier rope in theaters, banks, or anywhere crowd control is needed.

SYNTHETIC FIBER ROPE CONSTRUCTION METHODS

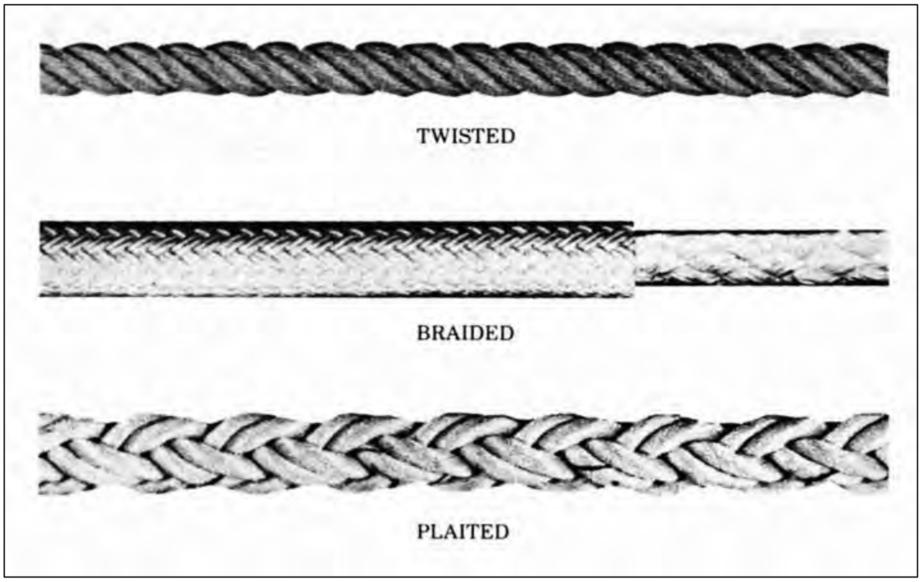


Figure 5 - Synthetic Rope Types

TWISTED ROPES are formed by taking one or more bundles of fiber and twisting into a strand. Formed strands are then twisted to produce the finished cordage. In the final stage of construction, twisted synthetic rope is heat set and stabilized to assist fiber, twist and lay tension formation to assure all the required are built into the rope for utmost performance.

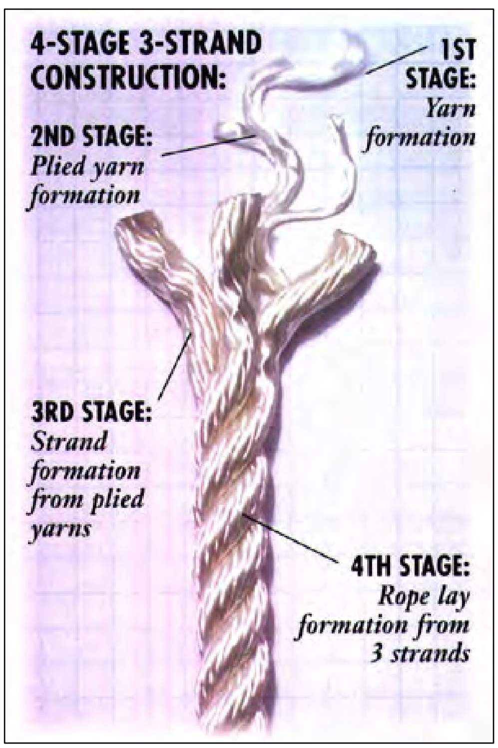


Figure 6 - 4 Stage Construction of Synthetic Rope

PLAITED ROPES are 8 to 12 strands plaited or interwoven together to form the finished rope. Eight strand-plaited rope is laid-up with four right-twisted and four left-twisted strands. These strands are paired and work like a four strand braid. Thus, there are two pairs of right-laid and two pairs of left-laid strands formed into a rope that is more or less square.

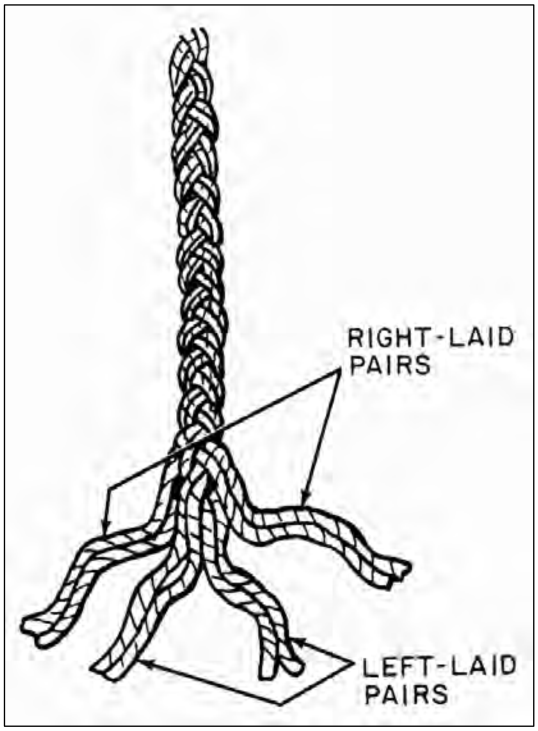


Figure 7 - Plaited Rope Construction

Figure 8 - Plaited Spun Polyester & Nylon

BRAIDED ROPES

SOLID BRAIDS are constructed of various bundles of fiber interlocked together in a circular braiding pattern. Braided lines with a solid core cannot be spliced.

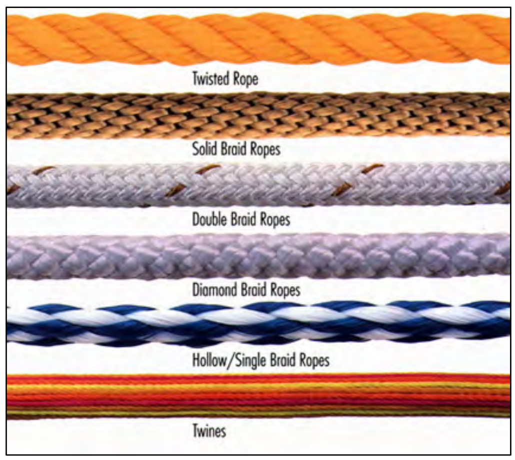
HOLLOW BRAIDS are constructed of various bundles of fiber braided over and under each other in a circular direction. This rope has no core.

DOUBLE BRAIDS are actually two ropes in one, and are sometimes called braid-on-braid ropes. The jacket is braided over a braided core.

DIAMOND BRAIDS are constructed from various bundles of fiber braided in a herringbone pattern to form a jacket over a parallel fiber center core. They are referred to as maypole braids.

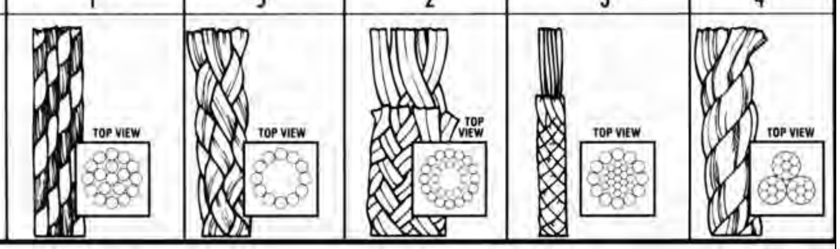
TWINES are constructed by taking various bundles of fiber and twisting or braiding in a spiral direction to form a finished product.

Stuffer-braid rope is filled with a yarn core.



CHARACTERISTICS	SOLID BRAID	HOLLOW BRAID	DOUBLE BRAID	DIAMOND BRAID	TWISTED
Number of Strands or Carriers	9, 12 or 18	8, 12 or 16	16, 24 or 32	8 or 16	3
Spliceable	No	Yes	Yes	No	Yes
Strength to weight	5	2	1	4	3
Flexibility	3	1	2	4	5
Flattens Under Load	No	Yes	No	Yes	No
Rotates Under Load	No	No	No	No	Yes
Mechanical Elongation	1	4	5	3	2
Cost Per Size	2	4	1	3	5
Working Load (as a % of Tensile)	15-20%	15-20%	15-20%	15-20%	8-14%
Abrasion Resistance	1	5	2	3	4

* **WARNING:** This guide is designed for general reference only. The construction comparisons assume using the same rope fiber and size. Expert advice should be sought when choosing a rope where protection of life or property is involved.



FIBER ROPE COMPARISON TABLE

	NATURAL FIBERS			SYNTHETIC FIBERS					
	Manila	**Sisal**	**Cotton**	**Nylon**	**Polyester**	**Poly-propylene**	**Poly-ethylene**	**Kevlar**	**Spectra**
STRENGTH									
Breaking Tenacity-Dry (grams/denier)	5.0-6.0	4.0-5.0	2.0-3.0	7.0-9.5	7.0-9.5	6.5	6.0	18-26.5	30.0
Wet Strength vs. Dry Strength	Up to 120%	Up to 120%	Up to 120%	85-90%	85-90%	100%	100%	95%	100%
Shock-load Absorption Ability	Poor	Poor	Very Poor	Excellent	Good	Very Good	Fair	Poor	Fair
WEIGHT									
Specific Gravity	1.38	1.38	1.54	1.14	1.38	0.91	0.95	1.44	0.97
Floats	No	No	No	No	No	Yes	Yes	No	Yes
ELONGATION									
Percent at Break	10-12%	10-12%	5-12%	18-25%	12-15%	15-25%	15-25%	1.5-3.6%	3.5%
Creep (extension under sustained load)	Very Low	Very Low	Very Low	Moderate	Low	High	High	Very Low	Moderate
EFFECTS OF MOISTURE									
Individual Fiber Water Absorption	Up to 100%	Up to 100%	Up to 100%	2-8%	<1%	None	None	3.5-7.0%	None
Dielectric Properties	Very Poor	Very Poor	Very Poor	Poor	Good	Excellent	Excellent	Poor	Excellent
DEGRADATION									
Resistance to UV in Sunlight	Good	Good	Good	Good	Excellent	Poor*	Fair*	Fair	Fair
Resistance to Rot and Mildew	Poor	Poor	Poor	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
Storage Requirements	Dry Only	Dry Only	Dry Only	Dry or Wet	Dry or Wet	Dry or Wet	Dry or Wet	Dry or Wet	Dry or Wet
ABRASION RESISTANCE									
Surface	Good	Fair	Poor	Very Good	Excellent	Good	Good	Fair	Very Good
Internal	Fair	Fair	Fair	Excellent	Excellent	Good	Good	Fair	Excellent
THERMAL PROPERTIES									
Melting Temperature	Does not melt Chars at 300°	Does not melt Chars at 300°	Does not melt Chars at 300°	420-480°	490-500°	330°	275°	800° Begins to decompose	297°
CHEMICAL RESISTANCE									
Resistance Acids	Poor	Poor	Poor	Fair	Good	Excellent	Excellent	Fair	Excellent
Resistance to Alkalis	Poor	Poor	Fair	Very Good	Fair	Excellent	Excellent	Fair	Excellent
Resistance to Oils and Gas	Poor	Fair	Poor	Very Good	Very Good	Very Good	Very Good	Very Good	Very Good
CHEMICAL RESISTANCE									
Effect of Organic Solvents	Fair Hydrocarbons remove protective lubricants	Good	Poor	Soluble in some phonetic compounds and in 90% formic acid	Soluble in some phonetic compounds	Soluble in chlorinated hydrocarbons at 160°	Soluble in chlorinated hydrocarbons at 160°	Resistant to most ketones, alcohols, oils, hydrocarbons	Soluble in chlorinated hydrocarbons at 160°

** Black rope is best. It absorbs heat more readily but is less affected by ultra-violet light from the sun.*

MARLINESPIKE SEAMANSHIP

Marlinespike Seamanship is a general term that covers all phases of rope work. It includes knowledge of the different materials used for construction, construction properties, the care, handling, knotting and splicing of both fiber and wire rope of all sizes. A thorough knowledge of marlinespike seamanship is of fundamental importance to every seaman, as rope in its many forms is used constantly aboard ship. Every seaman should be capable of putting on a whipping, making an eye splice in both fiber and wire rope, a short splice, and a round seizing with both wire and hemp seizing stuff. A seaman must be able to tie the important knots in the dark.

To become an expert in the art of handling rope, a seaman must have a clear understanding of all the fundamentals of rope work together with the experience that comes with practice.

KNOTTING DEFINITIONS

BIGHT is a loop in a rope. It is the part of the rope between the end and the standing part, formed by bringing the end of the rope around, near to, or across its own part.

BITTER END or **END** is the running end or the free end of a line. It is the end of the line that is worked with. It is the inboard end of a cable or rope. On the anchor chain, it is the last link made fast to the bottom or side of the chain locker.

STANDING PART is the long unused or belayed end. It is the remaining part of the line including the end that is not worked. It is the part of a line, which is secured. In knotting, it is the part of the main rope distinguished from the bight or the bitter end.

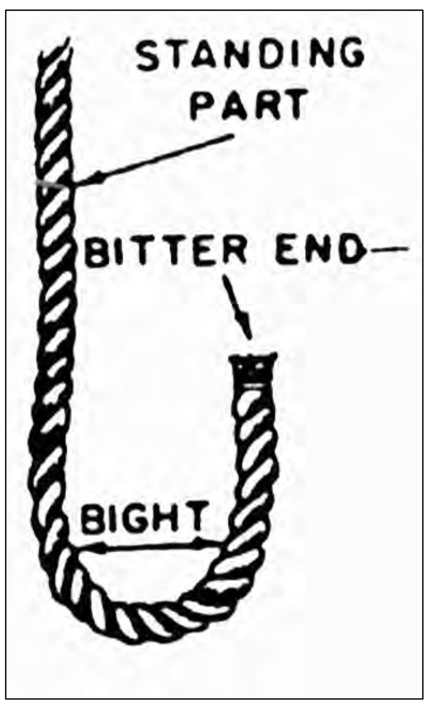


Figure 9 - Rope Nomenclature

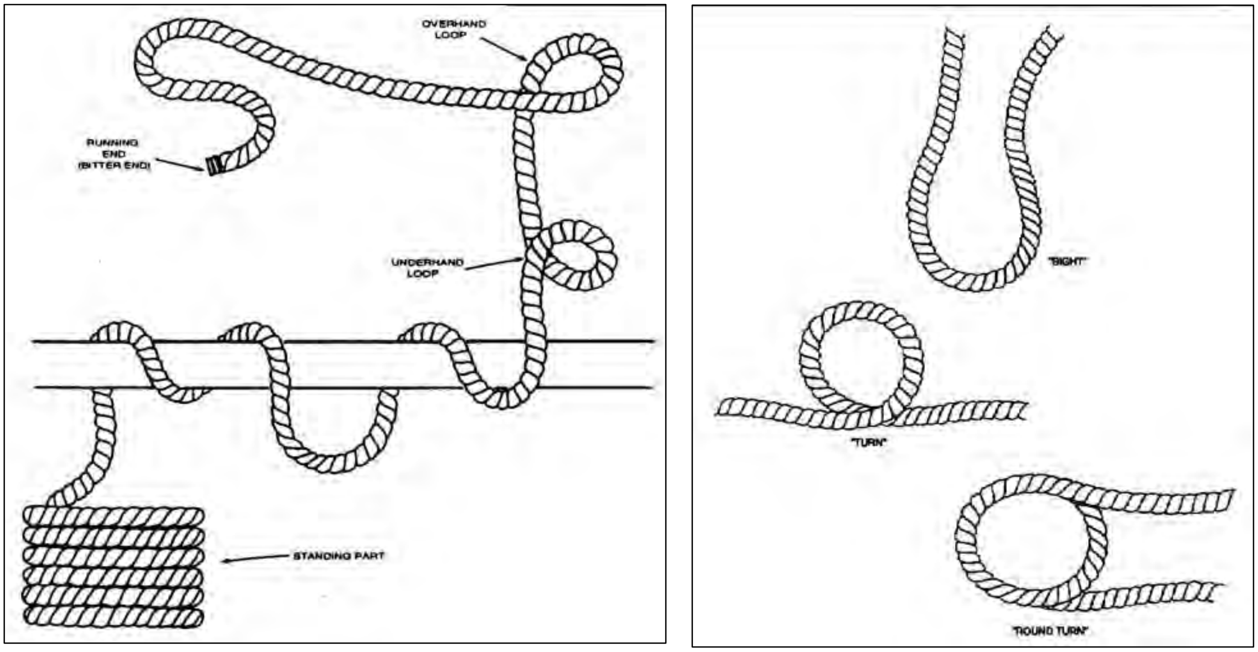


Figure 10 - Bends and Turns

OVERHAND LOOP means a loop made in a line by crossing the bitter end over the standing part.

UNDERHAND LOOP means a loop made in the line by crossing the bitter end under the standing part.

BEND means to twist or turn a rope or line so as to fasten it to another rope, object, spar or ring. Unbend means to untie or cast adrift.

UNLAY means to separate the strands of a rope.

VEER means to allow rope or chain to run out or slack off.

KNOTTING

Knots can decrease rope strength by as much as 60 percent. The table, which follows, provides typical strength loss due to knotting.

Knot	Strength Lost
Anchor Bend	20-40%
Bowline	37%
Bowline on bight	40%
Bowline, Running	81%
Carrick Bend	37%
Clove Hitch	25%
Figure Eight	63%
Fisherman's Knot	55%
French Bowline *	38%
Granny	52%
Overhand Knot	50-60%
Rolling Hitch	50%
Sheepshank	53%
Sheet Bend	40%
Square Knot	46%
Stopper Hitch	22%
Two Half Hitches	32%

** French bowline bight is 109% of the lines strength because the weight is supported by two (2) parts. Source Boatswain's Mate 3 & 2, NAVEDTRA 10121-G1.*

KNOTS TO KNOW

Knot	Application
Barrel Hitch	Hoisting bulky objects
Bowline	Loop or temporary eye
Bowline, French	Man over the side
Bowline, On a Bight	Additional strength in a double eye
Bowline, Running	Bowline forming a noose
Carrick Bend	Join two hawsers together
Catspaw	Used to grip a hook or shorten-up a sling
Clove Hitch	Securing one end
Fisherman's Bend	Attacking line to a ring or loop
Half Hitch	Temporally secure a line
Overhand/Figure Eight	Unreeving or temporary whipping
Rolling/Timber Hitch	Secure a spar or pole
Round Turn & Two Half Hitches	Making a line fast to a spar or ring
Sheep Shank	Shorten a line
Sheet/Becket Bend	Joining two lines of different size
Square/Reef Knot	Lashing, joining two lines of same size
Stopper Hitch	Holds strain of another line temporarily
Whipping	Prevents unlaying

ANIMATED KNOT TYING PRESENTATIONS

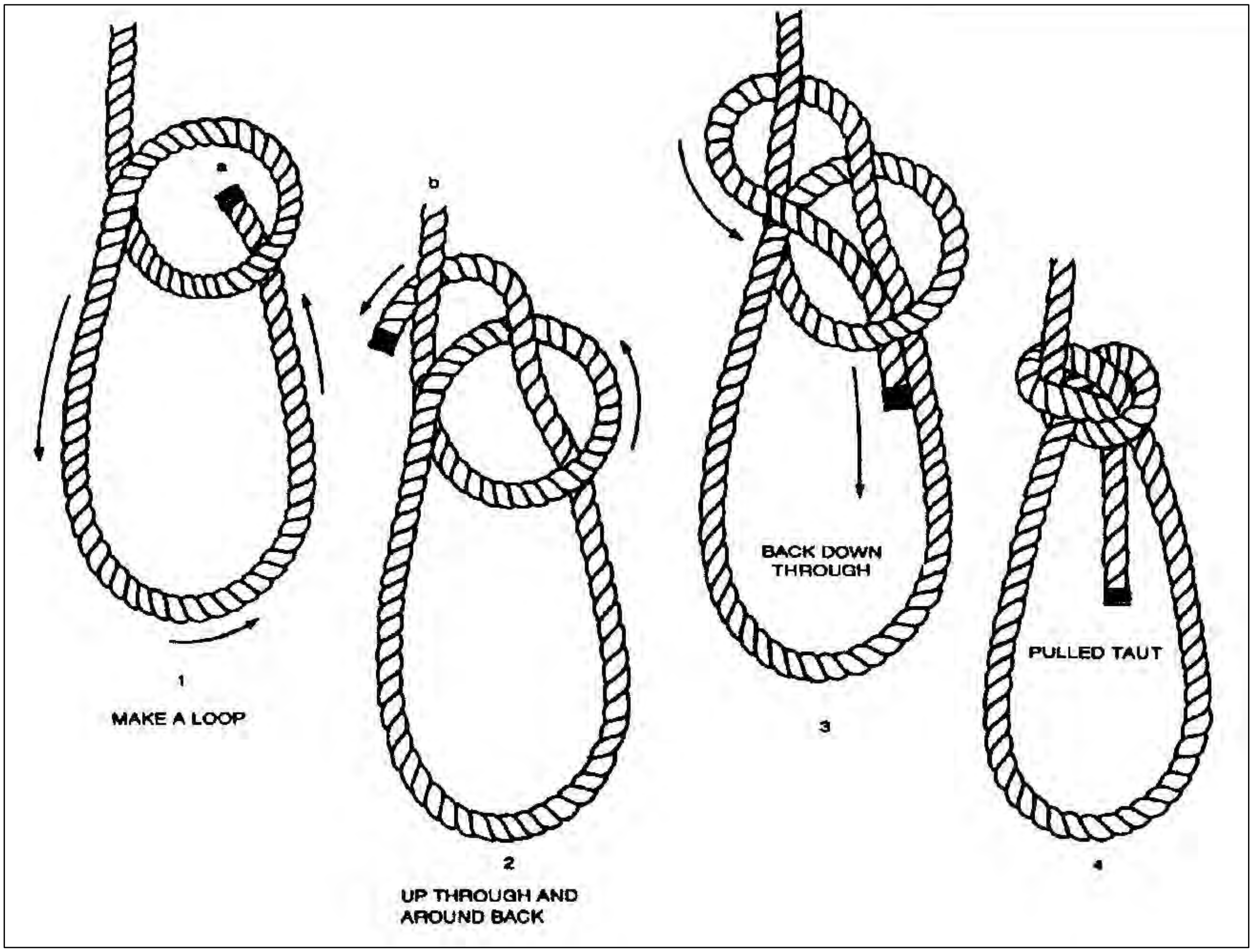
Boy Scout's Knot page is maintained to assist boy scouts and adult scouters find resources in tying knots. You will find links to animated knot tying directions and tips at these links:

http://www.webofroses.com/scouting/knots.html
http://www.42brghtn.mistral.co.uk/knots/42ktmenu.html
http://www.seascout.org/general_resources/download_area.html#img12

Click on the Hyperlink to go to the files.

BOWLINE

The bowline is a versatile knot. Use it anytime you need a temporary eye in the end of a line. It also works for tying two lines securely together, though there are better knots for this. An advantage of bowlines is that they do not slip or jam easily.

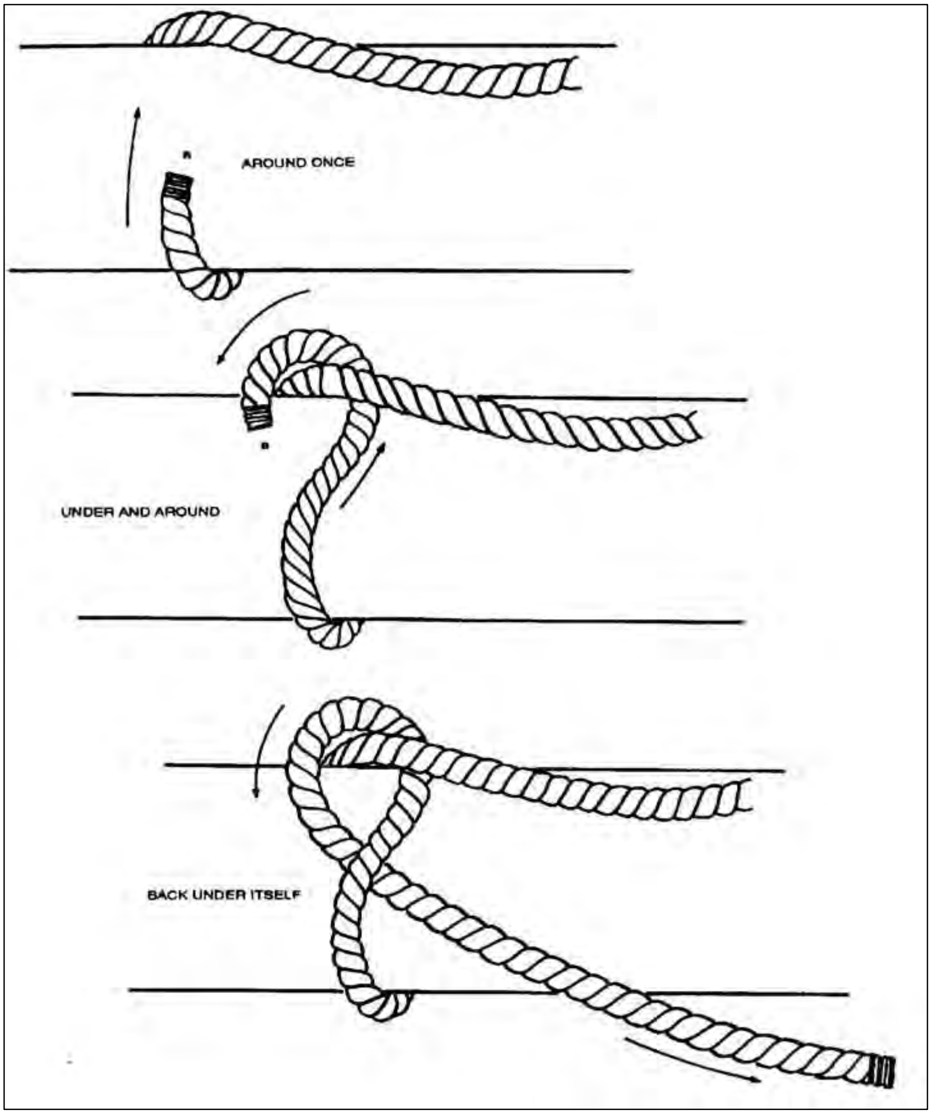


Animated knot tying directions:

http://www.42brghtn.mistral.co.uk/knots/42ktbowl.html

HALF HITCH

Hitches are used for temporarily securing a line to objects such as a ring or eye. One of their advantages is their ease in untying. The half hitch is the smallest and simplest hitch. Tie it only to objects having a right hand pull. Since a single half hitch may slip easily, use care in cases where it will encounter extreme stress.

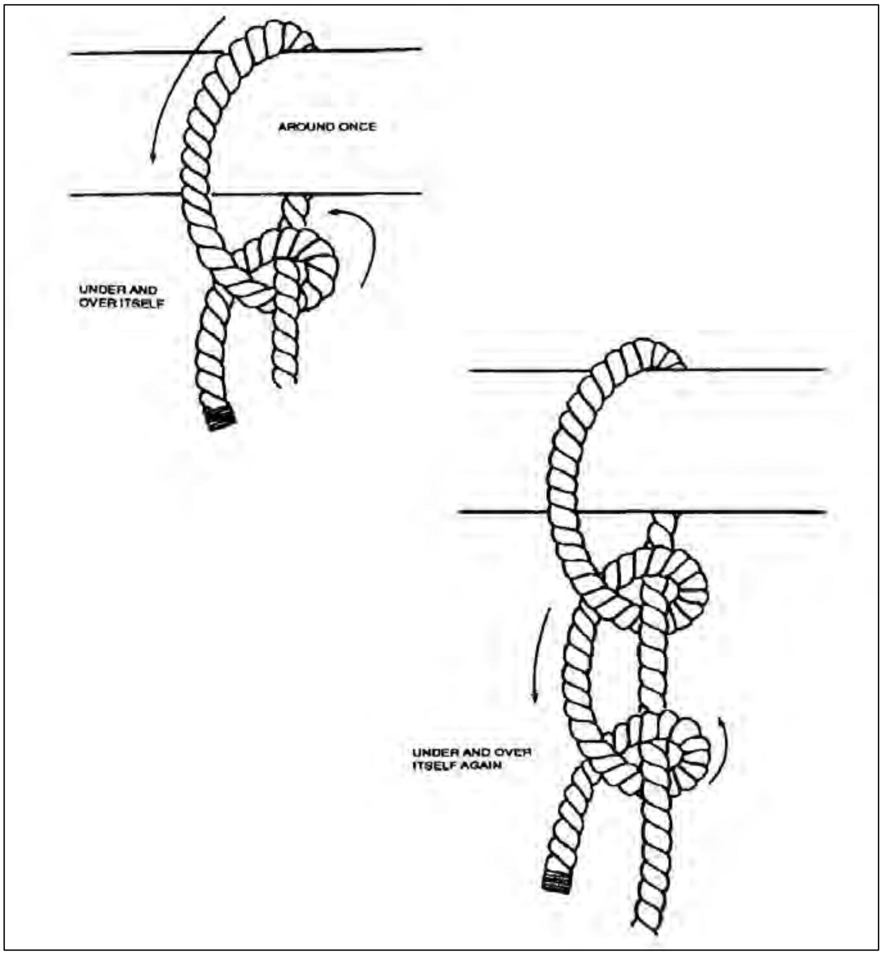


Animated knot tying directions:

http://www.42brghtn.mistral.co.uk/knots/42ktclov.html

TWO HALF HITCHES

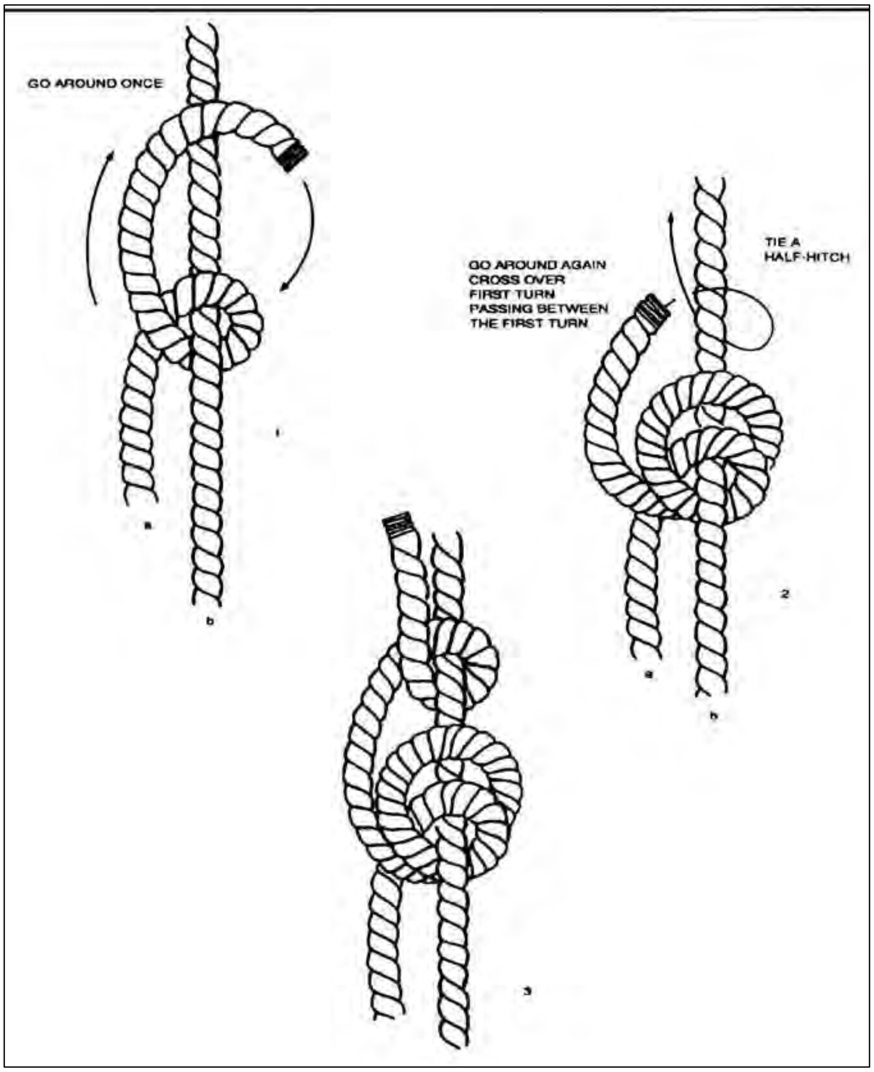
To reinforce or strengthen a single half hitch, tie more. Two half hitches make a more reliable knot than a single half hitch. Use them to make the ends of a line fast around its own standing part. A round turn or two, secured with a couple of half hitches, is a quick way to secure a line to a pole or spar. Two half hitches are needed to secure a line at an angle where it might slide vertically or horizontally.



Animated knot tying directions:
http://www.42brghtn.mistral.co.uk/knots/42ktrndt.html

ROLLING HITCH (STOPPER)

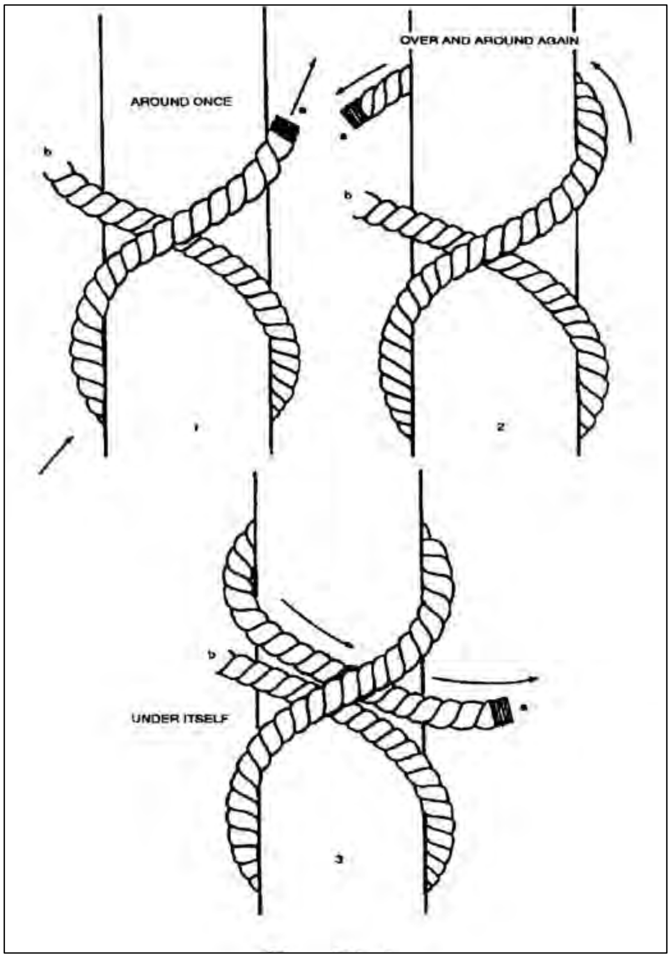
A rolling hitch is used to attach one line to another, where the second line is under a strain and cannot be bent. A rolling hitch can be used to secure a line around a spar.



Animated knot tying directions:

CLOVE HITCH

A clove hitch is preferred for securing a heaving line to a towline. It is the best all-around knot for securing a line to a ring or spar. Correctly tied, a clove hitch will not jam or loosen. However, if it is not tied tight enough it may work itself out. Reinforce it with a half hitch.

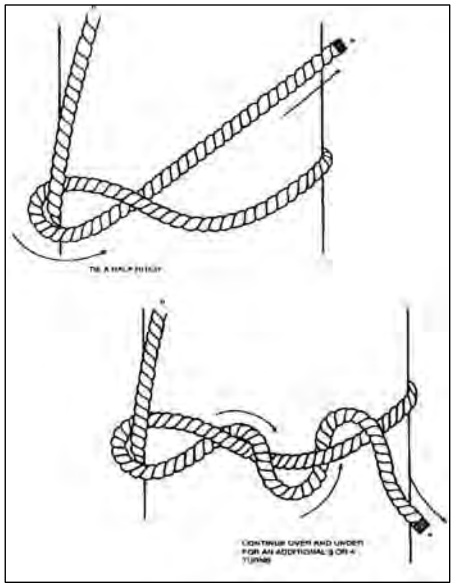


Animated knot tying directions:

http://www.42brghtn.mistral.co.uk/knots/42ktclov.html

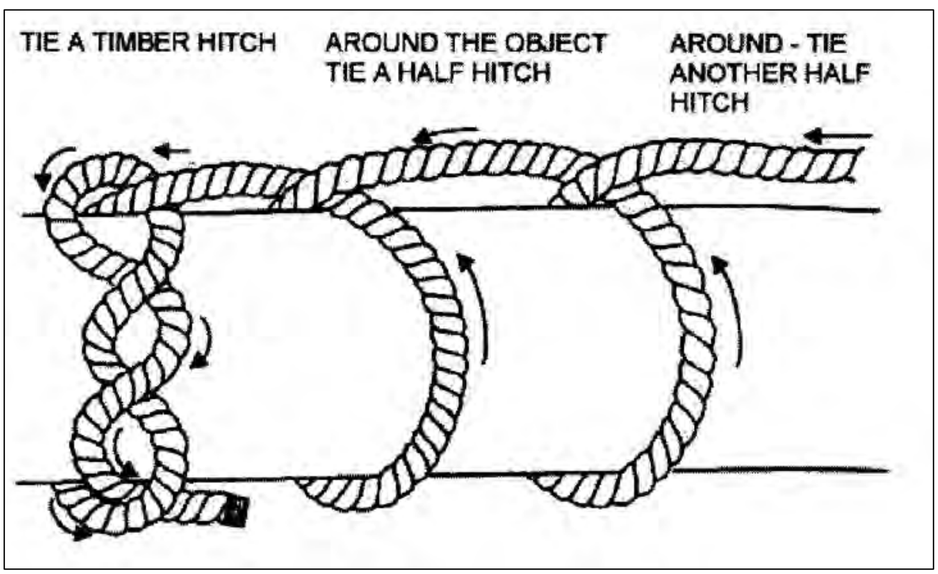
TIMBER HITCH

Timber hitches are used to secure a line to logs, spars, planks or other rough-surfaced material. Do not use it on pipes or other metal objects.



Animated knot tying directions:
http://www.42brghtn.mistral.co.uk/knots/42kttimb.html

DOUBLE TIMBER HITCH



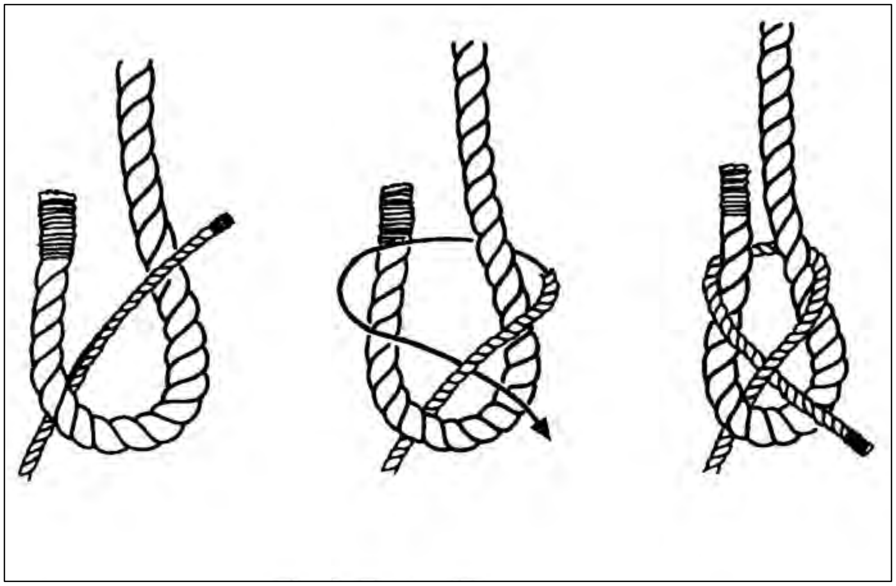
ROUND TURN AND TWO HALF HITCHES

Used to secure a rope to a pole, or to start or finish a lashing. Pass the running end of the rope over the pole twice. This knot has a redeeming feature - it rarely jams.

Animated knot tying directions:
http://www.42brghtn.mistral.co.uk/knots/42ktrndt.html

SINGLE BECKET/SHEET BEND

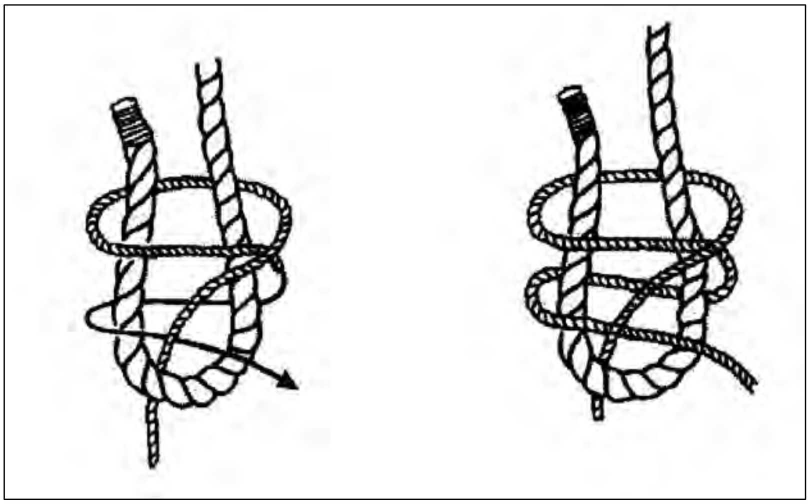
Lines can be lengthened by bending one to another using a becket bend. It is the best knot for connecting a line to an eye splice in another line. It can be readily taken apart even after being under a load. Single becket bends are used to join line of the same size or nearly the same size. It is intended to be temporary.



Animated knot tying directions:
http://www.42brghtn.mistral.co.uk/knots/42ktshtb.html

DOUBLE BECKET/SHEET BEND

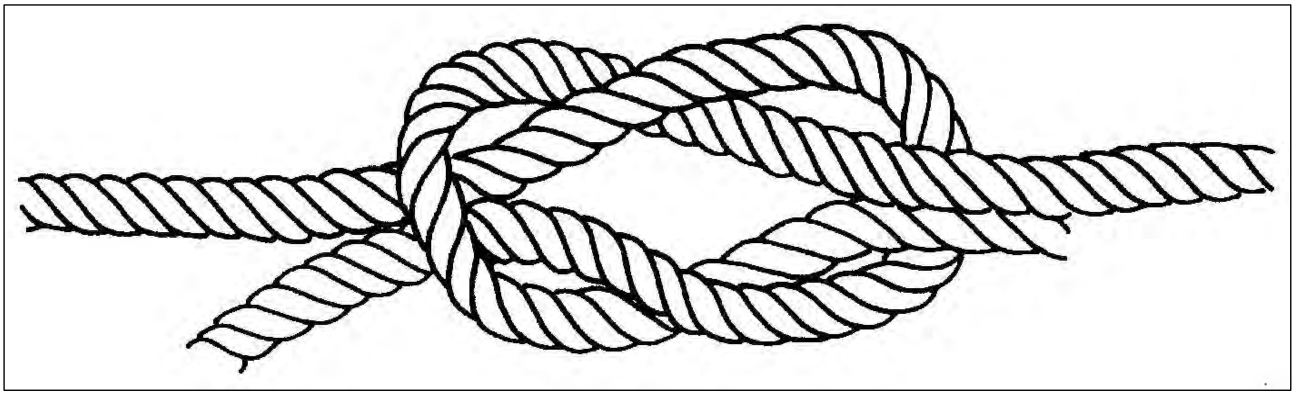
The double becket bend works for joining lines of unequal size. A double sheet bend would be used to properly secure a gantline to a bosun's chair.



Animated knot tying directions:
http://www.42brghtn.mistral.co.uk/knots/42ktdshb.html

REEF/SQUARE KNOT

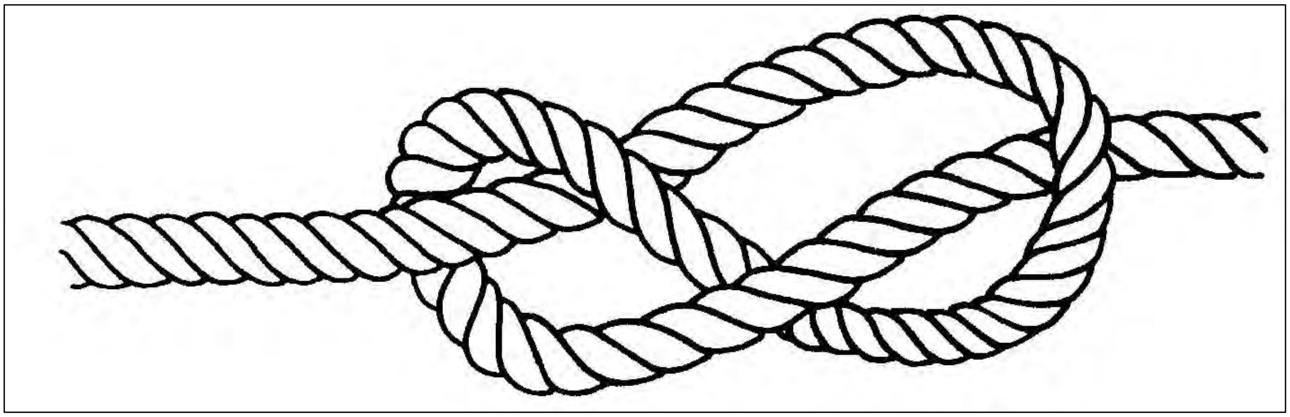
Called a square knot by Boy Scouts, the reef knot is one of the most commonly used knots in marlinespike seamanship. Reef knots are rarely used on vessels because they jam badly under strain. Also, reef knots do not effectively hold lines of different sizes or materials. Reef knots are best used to finish securing laces (canvas cover, awning, sail to a gaff, etc.), temporary whippings, and other small stuff. A square knot is best used to join two lines of equal size.



Animated knot tying directions:
http://www.42brghtn.mistral.co.uk/knots/42ktreef.html

FIGURE EIGHT (STOPPER) KNOT

A figure eight knot is an overhand knot with an extra twist. It will prevent the end of a line from feeding through a block or fairlead when heavy loads are involved. It is also easier to untie and

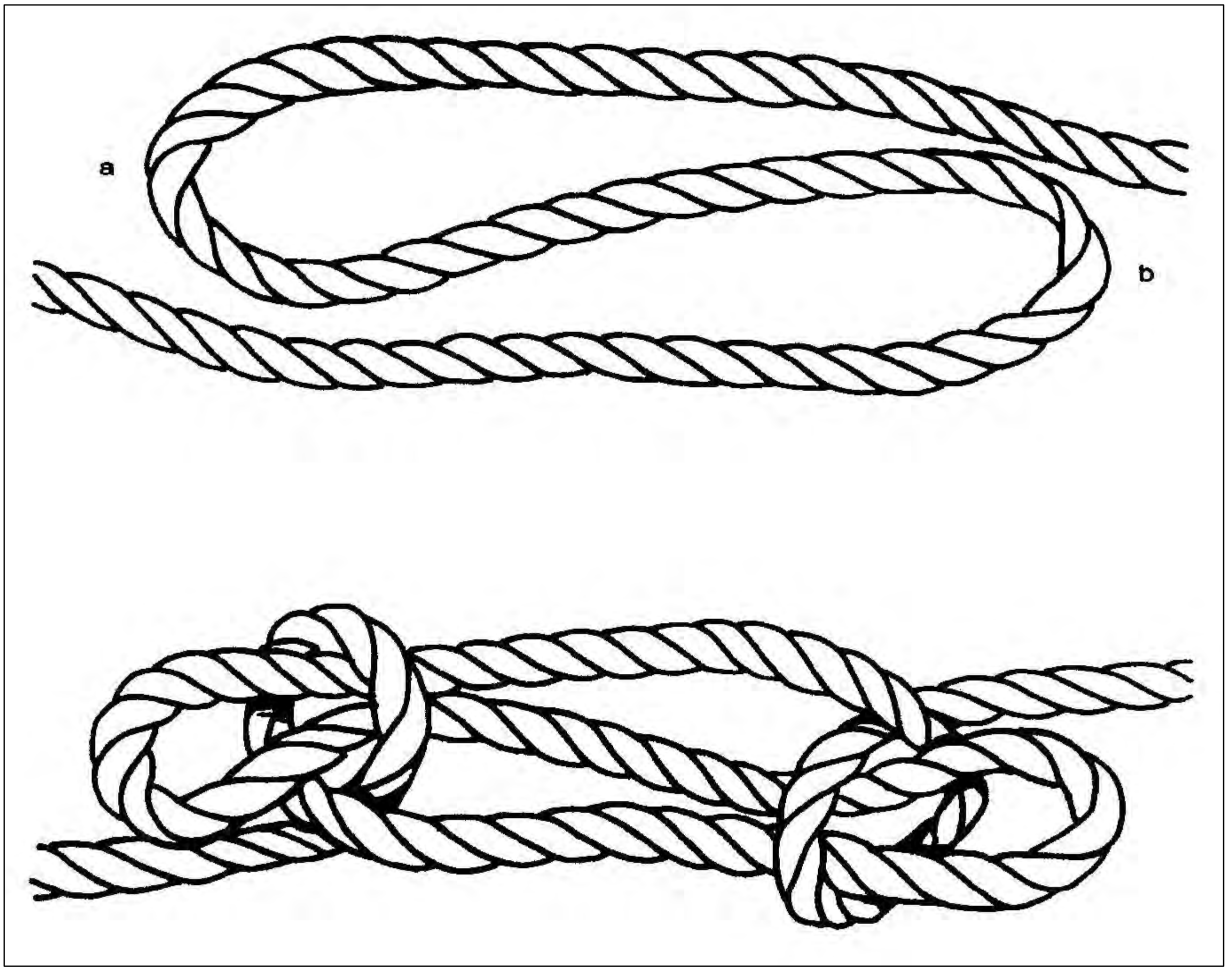


does not jam as hard as the over hand knot.

Animated knot tying directions:
http://www.42brghtn.mistral.co.uk/knots/42ktfig8.html

SHEEPSHANK

This hitch is used for temporarily shortening a piece of line. It consists of two bights of line, side-by-side, with a half hitch at either end.

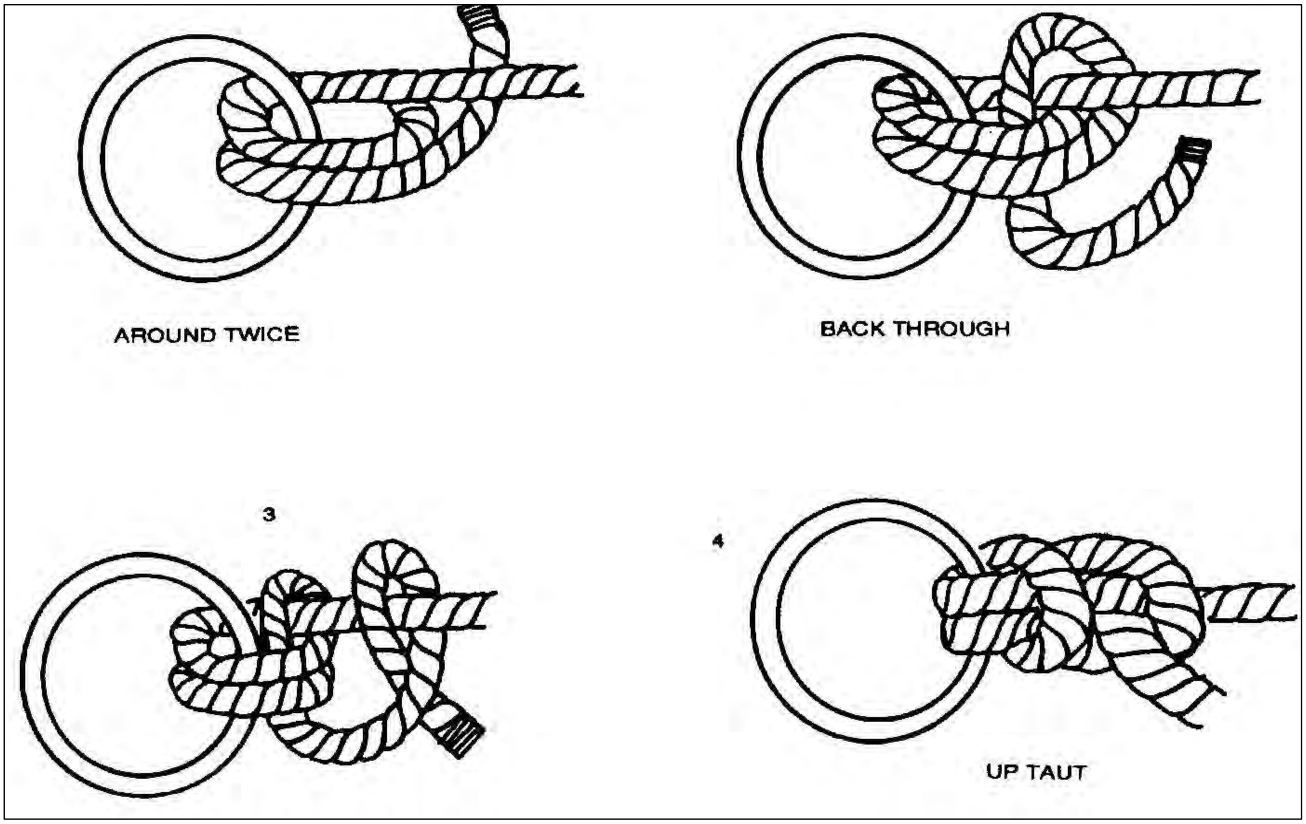


Animated knot tying directions:

http://www.42brghtn.mistral.co.uk/knots/42ktshep.html

FISHERMAN'S KNOT OR ANCHOR BEND

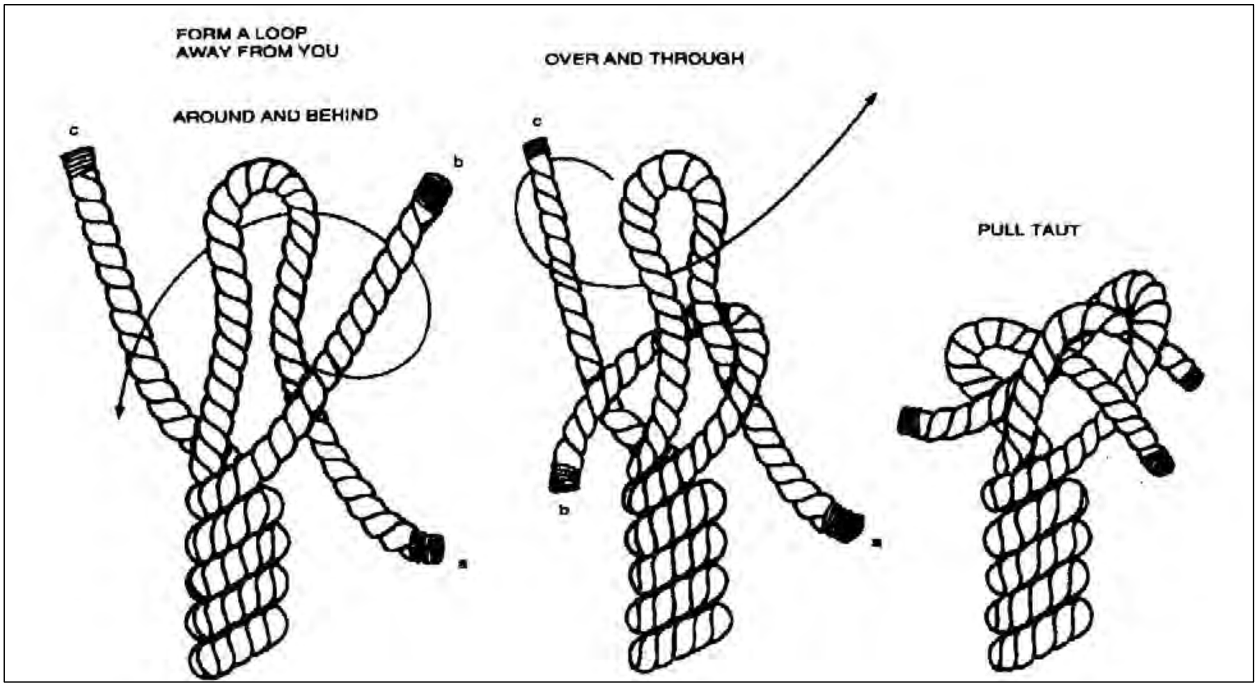
This bend is used to secure a line to a ring in an anchor or mooring buoy. It can also be tied around a spar.

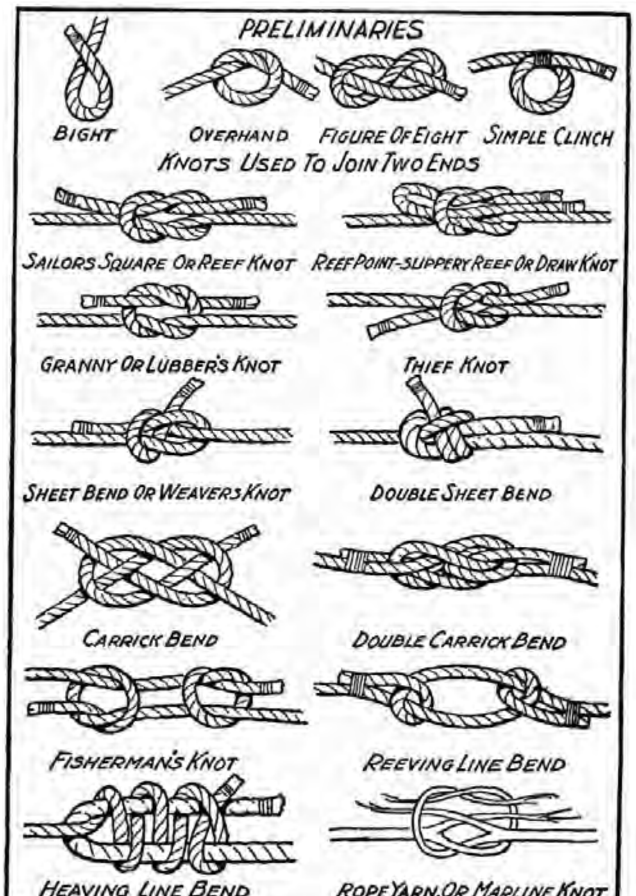


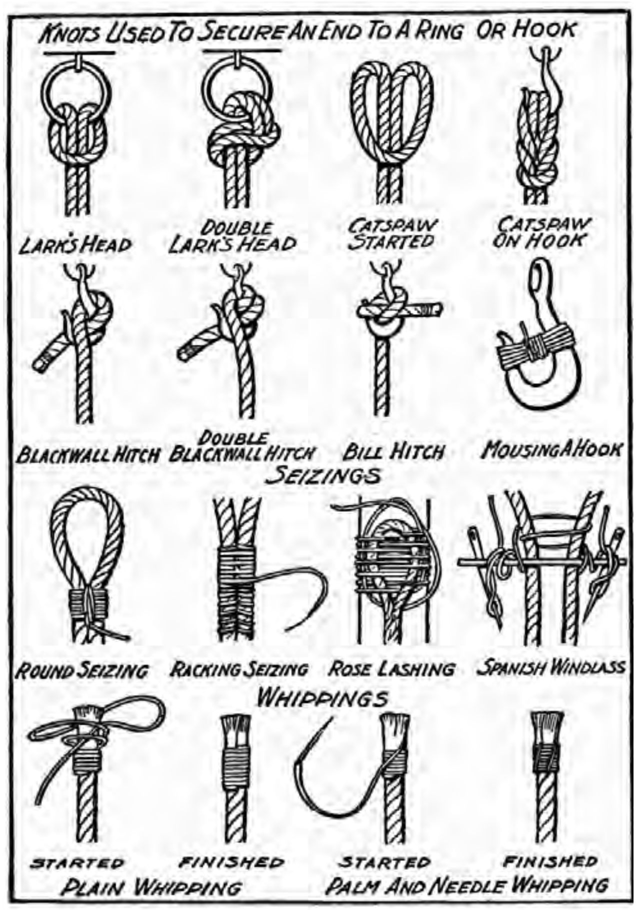
http://www.42brghtn.mistral.co.uk/knots/42ktfish.html

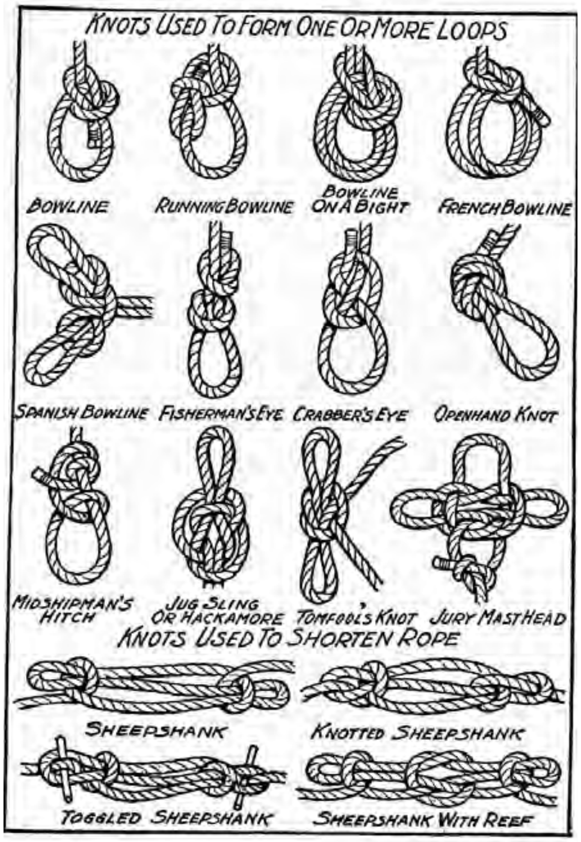
CROWN KNOT

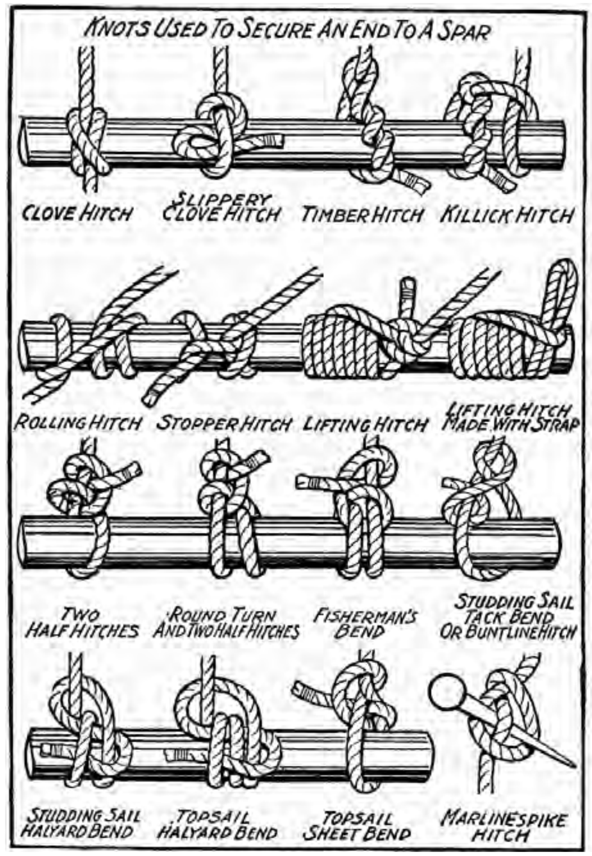
A crown knot may be used to prevent an unwhipped line from unlaying.

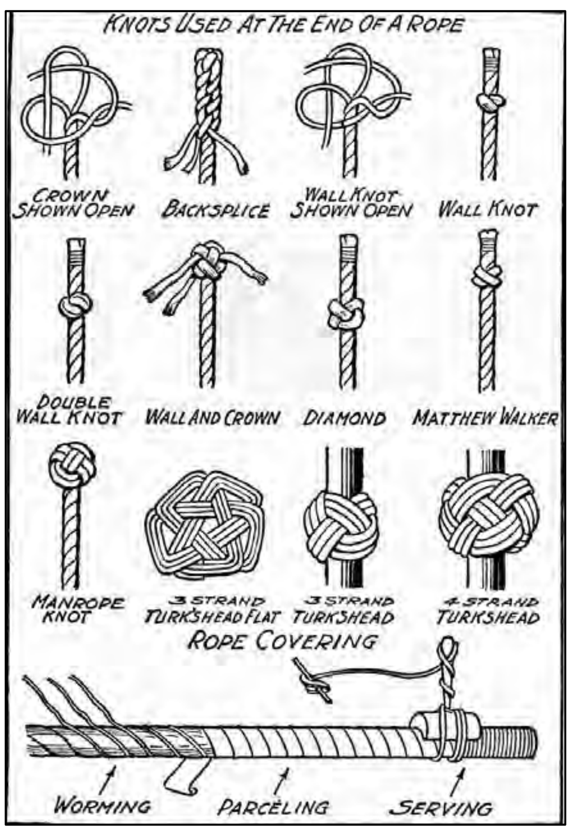







KNOTS USED TO FORM ONE OR MORE LOOPS
BOWLINE
RUNNING BOWLINE
BOWLINE ON A BIGHT
FRENCH BOWLINE
SPANISH BOWLINE
FISHERMAN'S EYE
CRABBER'S EYE
OPENHAND KNOT
MIDSHIPMAN'S HITCH
JUG SLING OR HACKAMORE
TOMFOOL'S KNOT
JURY MAST HEAD
KNOTS USED TO SHORTEN ROPE
SHEEPSHANK
KNOTTED SHEEPSHANK
TOGGLED SHEEPSHANK
SHEEPSHANK WITH REEF


KNOTS USED TO SECURE AN END TO A SPAR
CLOVE HITCH
SLIPPERY CLOVE HITCH
TIMBER HITCH
KILLICK HITCH
ROLLING HITCH
STOPPER HITCH
LIFTING HITCH
LIFTING HITCH MADE WITH STRAP
TWO HALF HITCHES
ROUND TURN AND TWO HALF HITCHES
FISHERMAN'S BEND
STUDDING SAIL TACK BEND OR BUNTLINE HITCH
STUDDING SAIL HALYARD BEND
TOPSAIL HALYARD BEND
TOPSAIL SHEET BEND
MARLINESPIKE HITCH


KNOTS USED AT THE END OF A ROPE
CROWN SHOWN OPEN
BACKSPLICE
WALL KNOT SHOWN OPEN
WALL KNOT
DOUBLE WALL KNOT
WALL AND CROWN
DIAMOND
MATTHEW WALKER
MANROPE KNOT
3 STRAND TURK'S HEAD FLAT
3 STRAND TURK'S HEAD
4 STRAND TURK'S HEAD
ROPE COVERING
WORMING
PARCELING
SERVING

SPLICING

For greater strength and permanency, splicing rather than knotting is used to fasten two (2) ropes together. A splicing is stronger than a knot. Use the manufacturer's recommended splices for maximum efficiency. Other terminations can be used but their strength loss with a particular type of rope construction should be determined, not assumed.

Type of Splice	Strength Lost	Efficiency
Eye Splice	10%	90%
Short Splice (in line)	5-10%	90-95%
Long Splice	15%	85%

SPLICING: For three strand manila use three rounds of full tucks. Synthetics are spliced in the same manner as manila, except you should use one more tuck than for the same size manila line. It is often advisable to add two-thirds and a one-third tuck to taper the splice to assure greater strength. For heavy towing applications a back tuck is recommended.

EYE SPLICE IN THREE STRAND PLAID LAID LINE

The eye splice makes a permanent loop (the eye) in the end of a line.

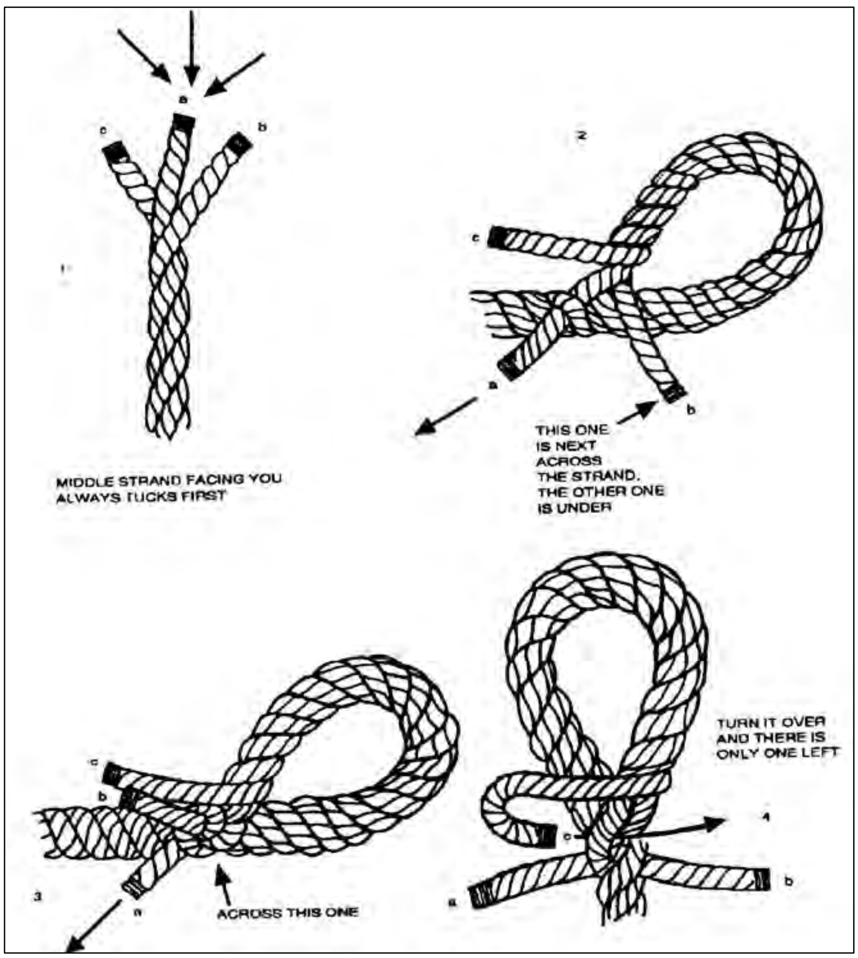


Figure 11 –Eye Splice

SHORT SPLICE

A short splice is used to permanently connect two ends of a line. It is important to note that a short splice is never used in a line that must pass over a pulley or sheave.

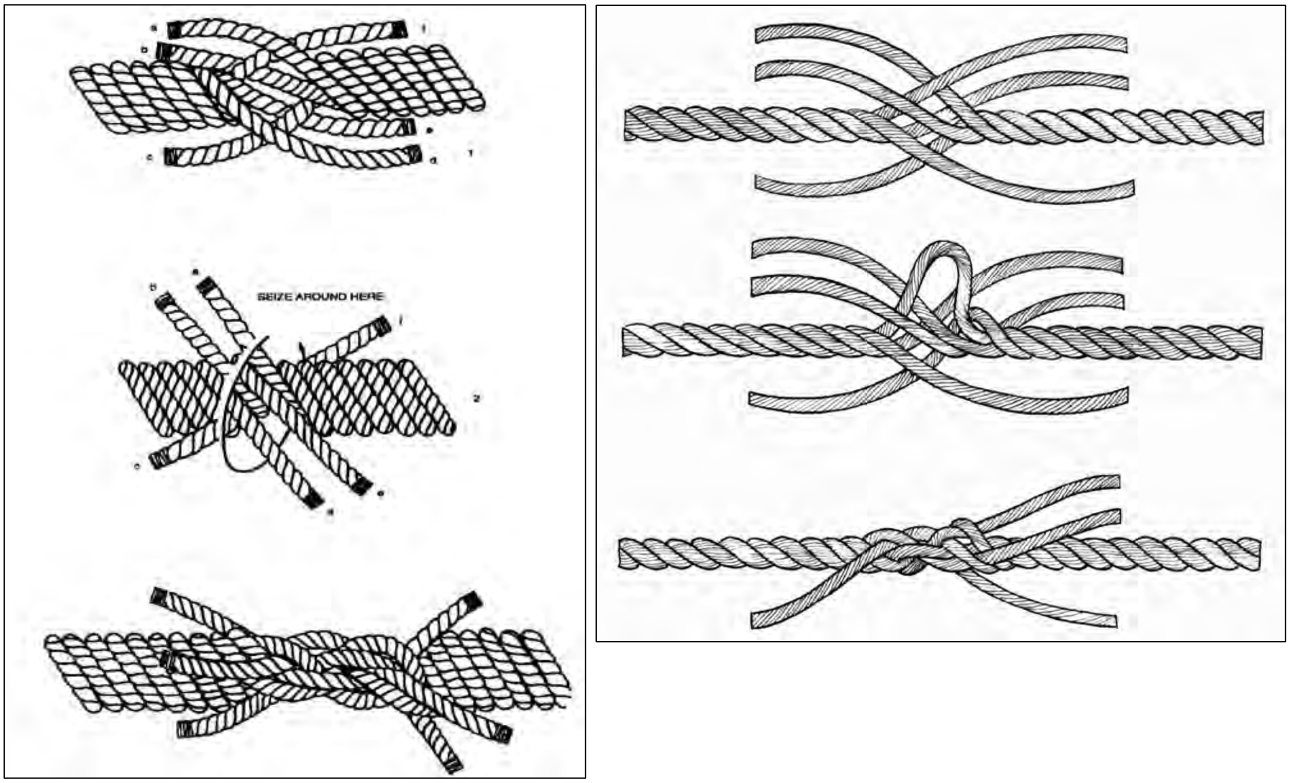


Figure 12 - Short Splice

The best splice for repairing a parted synthetic fiber mooring line is a short splice. A short splice is stronger than two lines joined by a knot. A short splice in a line doubles the size of the line. The strongest way to join the ends of two ropes is with a short splice.

LONG SPLICE

A long splice is used to permanently connect two ends of a line. It is important to note that a long splice is used in a line that must pass over a pulley or sheave.

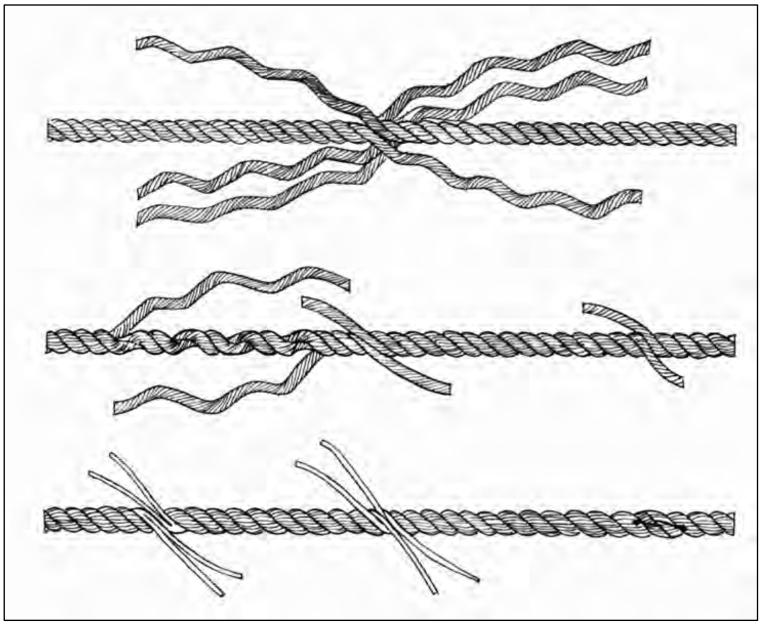
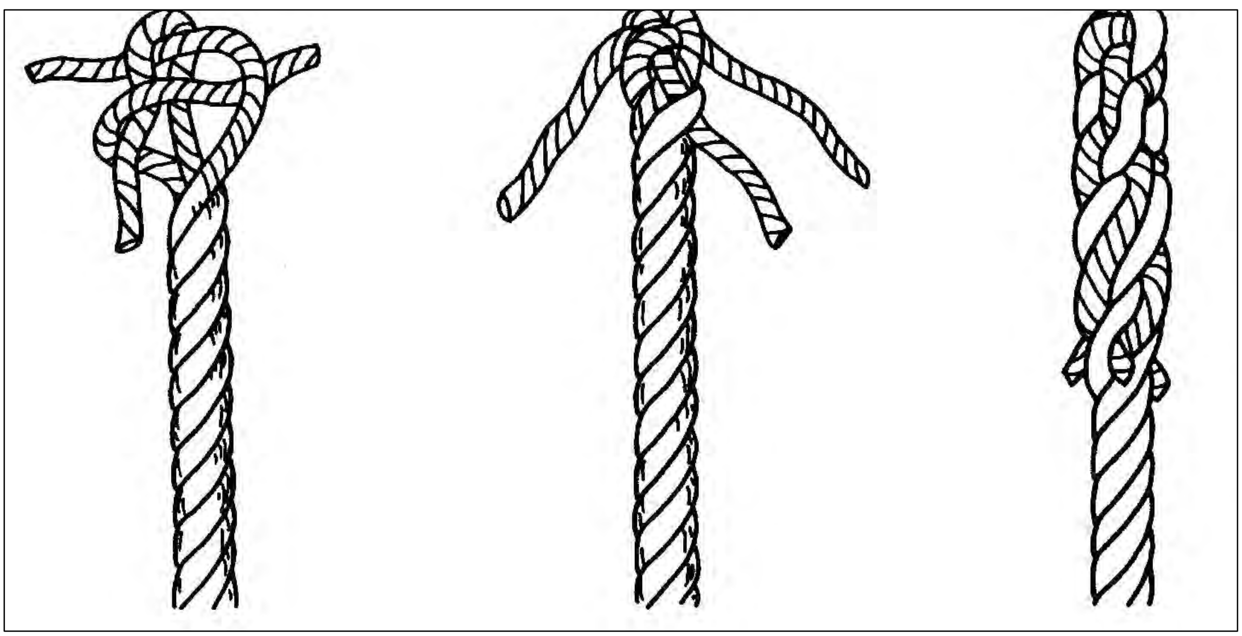


Figure 13 – Long Splice

BACK SPLICE IN THREE STRAND PLAIN LAID LINE

Use a back splice to finish off the end of a line. It can be used on the ends of fender lines. Start with unlaying the strands at the end. Then bend them back on the line, and then interweave them back through the strands of the standing part.



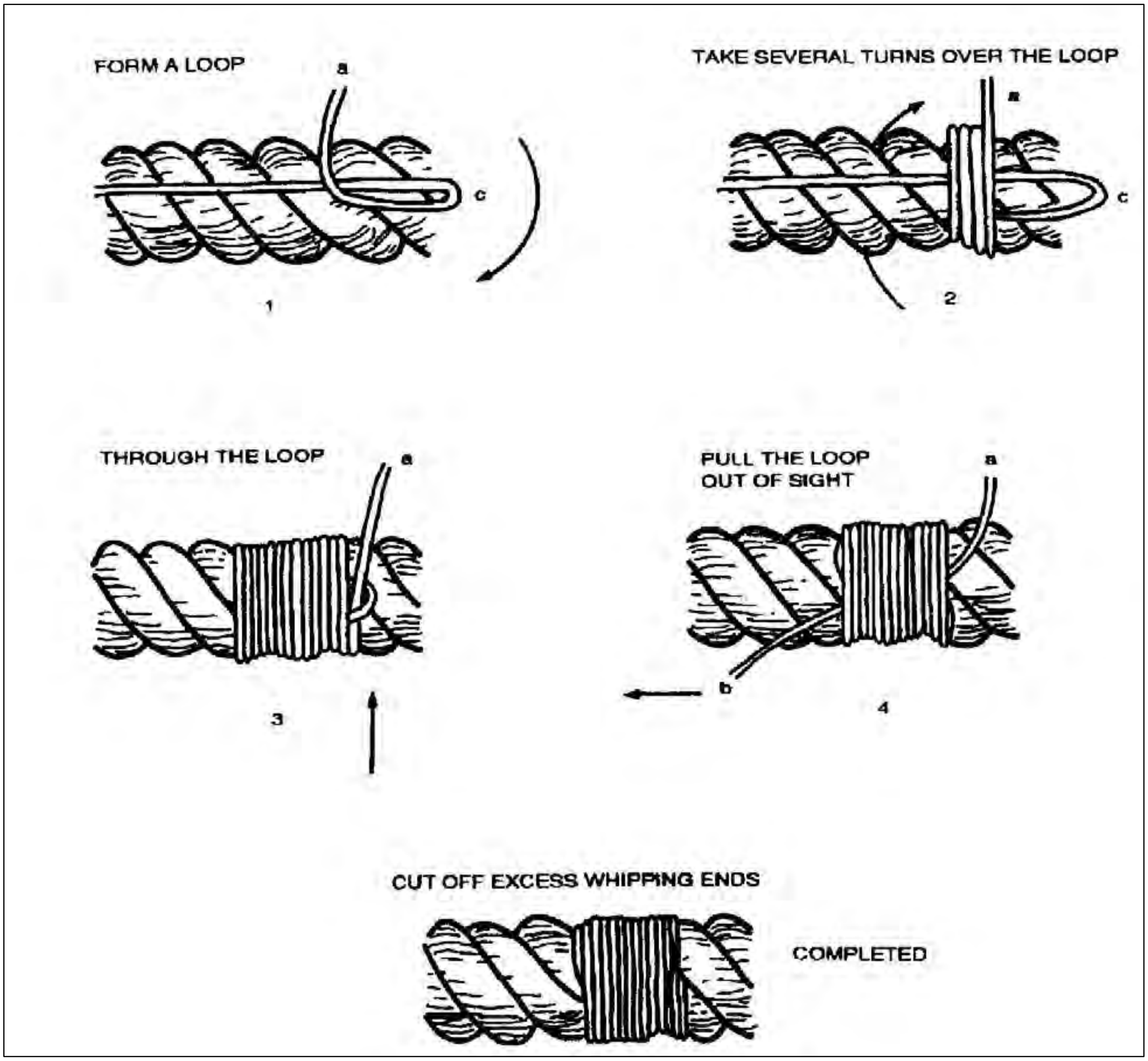
THIMBLES

Thimbles should be used in eye splices wherever possible. Ordinarily pear or round shaped thimbles are usually satisfactory for manila. Due to the greater strength and stretch of synthetics, special heavy duty reinforced thimbles should be used. There are several manufacturers making special synthetic rope thimbles. It is advisable to use thimbles that have guides or lugs on the outside to hold the rope in place. As a synthetic rope stretches, the eye will elongate and the thimble will have a tendency to "pop" out. Pear shaped thimbles should be seized in the eye on both sides and the double rope at the thimble vertex. This seizing should be done under tension of possible.

Figure 14 - Thimbles

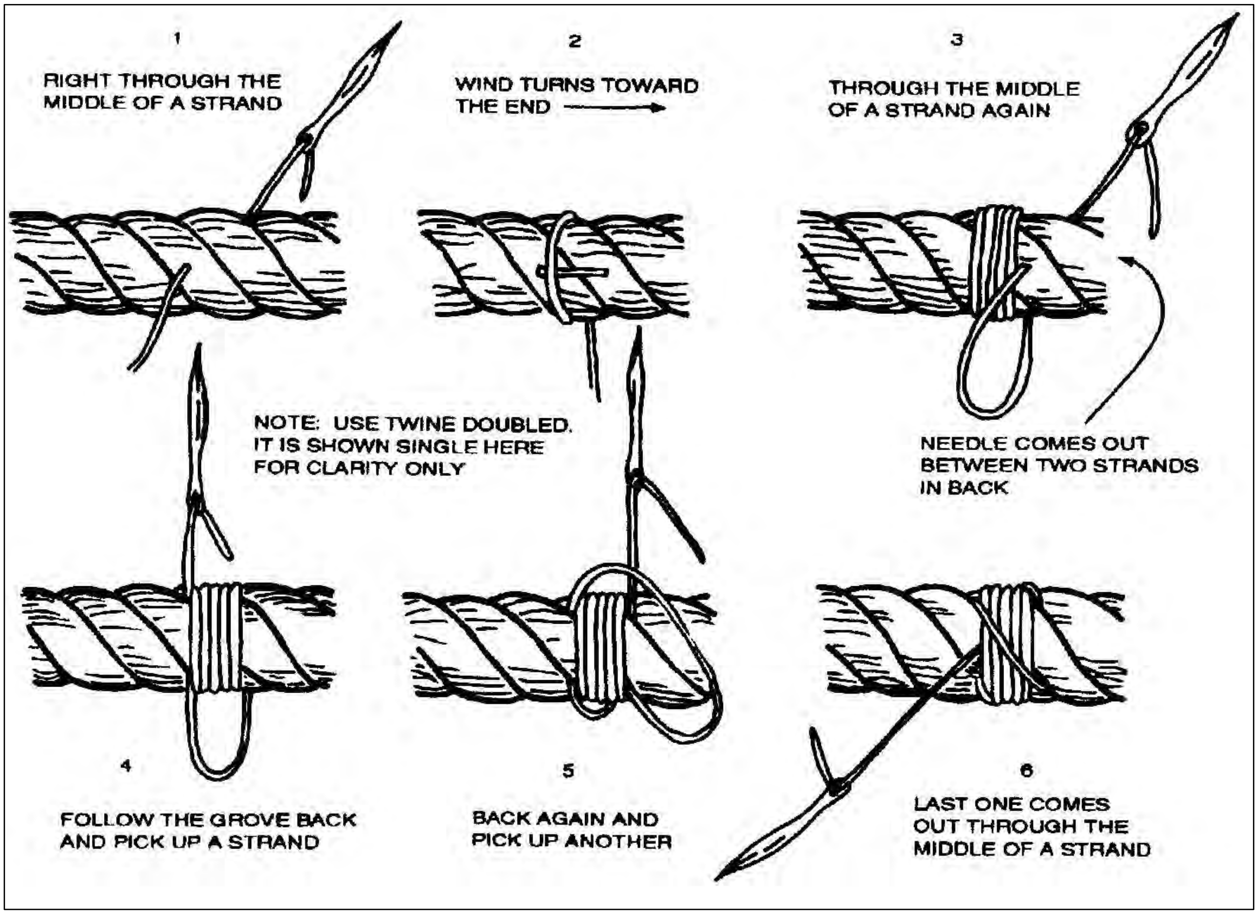
TEMPORARY WHIPPING

Sometimes called the common whipping, temporary whippings make temporary repairs and secure strands of lines while splicing. They are not very durable and easily unravel if snagged. They are normally done using sail twine, although almost any small stuff will do. The procedures below instruct how to make temporary whipping.



PERMANENT WHIPPING

Permanent whippings are made to last. To make one, take several wraps around the line using shot line or waxed nylon. Then sew the ends of the whipping line across the whipping and through the line.



SEIZINGS are used when two lines or two parts of a single rope are to be married together permanently. This should be done with "seizing stuff", which is generally rope laid, tarred American hemp of 6, 9, or 12 threads. For seizing small stuff, however, sail twine is adequate.

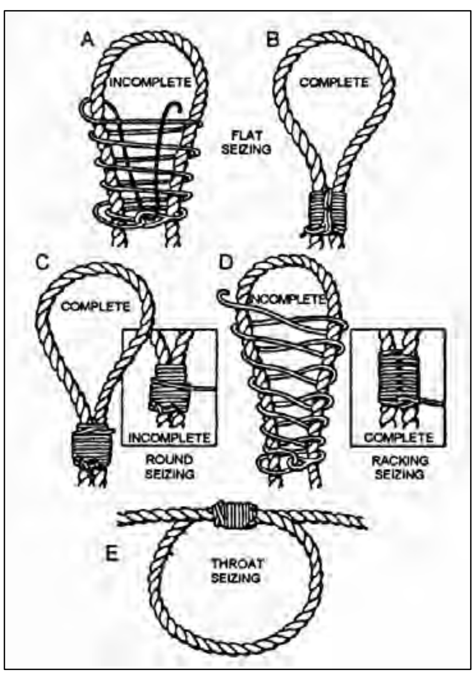
Many types of seizings were used for special purposes in old sailing ships, but the four described here should suffice for Seamen in modem ships.

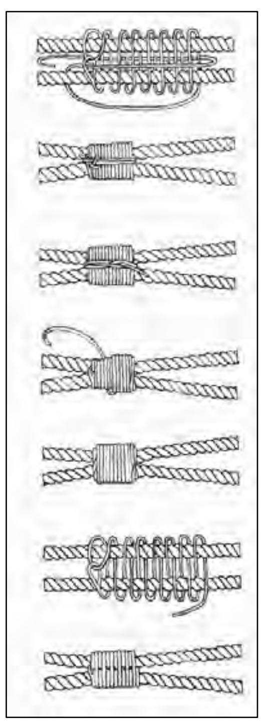
FLAT SEIZING is light and is used where strain is not too great. First, as in all seizings, splice an eye in the end of the seizing stuff. Take a turn around the line, and pass the end of the stuff through the eye. Pull it taut and double the stuff back, taking several turns around the line. Then pass the end under the turns and again through the eye. Last, tie a clove hitch over the turns and between the two parts of the line. See views A and B for the steps in making a flat seizing.

ROUND SEIZING pictured in View C shows the completed round seizing. Stronger than the flat seizing, it is used where strain is greater. Start it as you did the flat seizing, taking your turns and leading the end under them and back through the eye. Then take another row of turns over the top of the first row. Finish by tucking the end under the last turn and heaving taut or with a crossed clove hitch as in the flat seizing.

RACKING SEIZING is used where there is an unequal strain on the two parts of the line. Lay turns around the line in figure-eight fashion for about ten turns. Then pass the seizing stuff back in the opposite direction, and take a row of turns over the top of the racking as is done in a round seizing. Finish off by passing the end through the eye again, and tie an overhand knot.

THROAT SEIZING is actually a round seizing and is used wherever a temporary eye is needed in the middle of a line. View E shows a completed throat seizing.





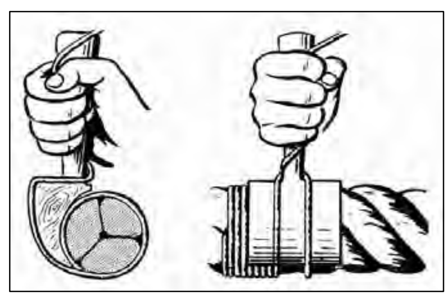


Figure 15 -Seizing methods

MOUSING HOOKS AND SHACKLES

HOOKS

A hook is moused to keep slings, straps, and so forth, from slipping out of the hook and to strengthen the hook if there is the danger that the load will bend it. This is accomplished by either mechanical means or by seizing the hook, using seizing wire or small stuff, from opposite sides. If the purpose of the mousing is to keep a strap or sling from escaping, marline or rope yarn may be used. If the purpose is to strengthen the hook, seizing wire or a shackle may be used.

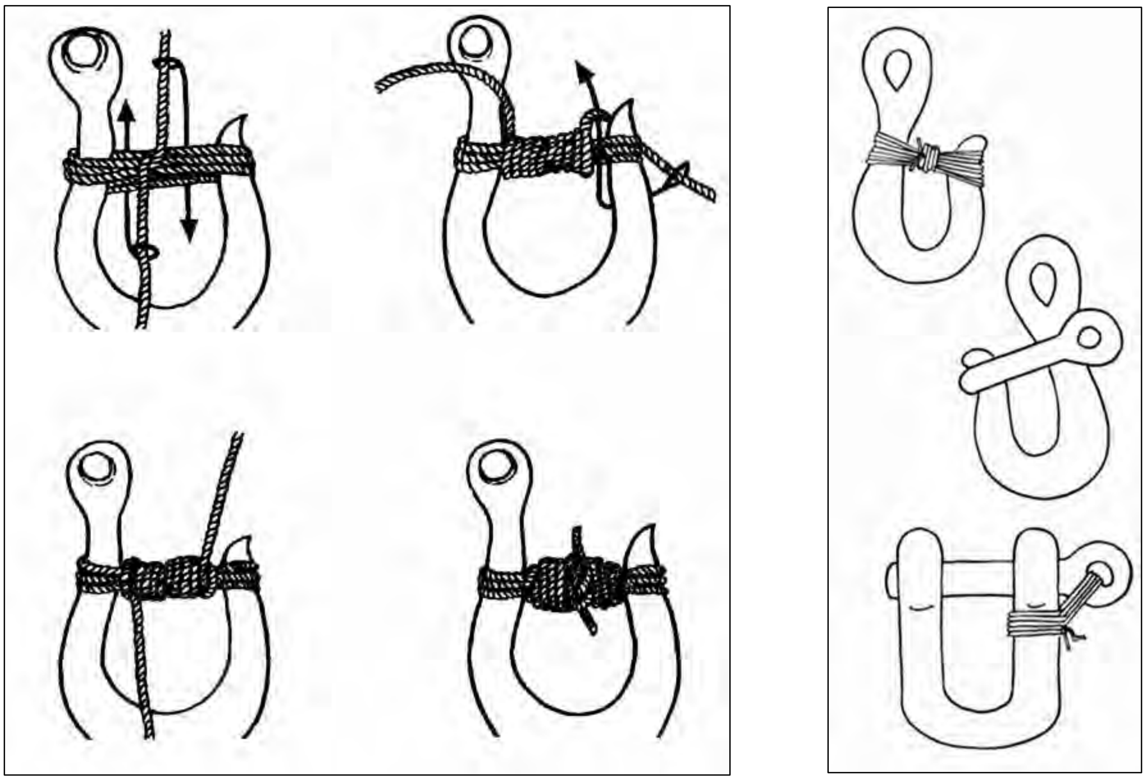


Figure 16 -Mousing methods

SHACKLES

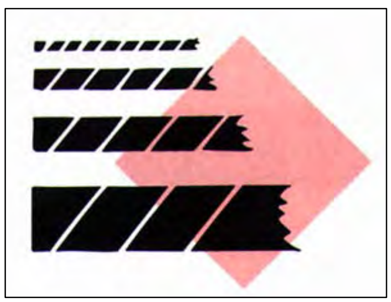
Shackles are moused to prevent the pin from backing out. This is usually done on screw pin shackles. Mousing is accomplished by taking several turns, using seizing wire or small stuff, through the pin eye and around the shackle itself in such a way so the pin cannot turn.

Critical Conditions of Use

Risk factors which must be taken into consideration when using natural or synthetic fiber rope include:

1. Small size ropes are used (because they can be more severely damaged by cutting, abrasion and sunlight).
2. Loads weights are not accurately known.
3. Operators are poorly trained.
4. Operation/use procedures are not well defined and/or controlled.
5. Rope inspection is infrequent.
6. Abrasion, cutting or dirt penetration are present.
7. Shock loads or extreme dynamic loading is likely.
8. High temperatures are present.
9. Chemicals are present.
10. Ropes are kept in service indefinitely.
11. Tensions on the rope are maintained continuously for long periods.
12. Rope can be subject to sharp bends or is used over sheaves/pulleys or surfaces with too small a radius.
13. If knots are used (because strength is reduced by up to 50-60%).
14. Death, injury or loss of valuable property may result from failure.

SAFE SERVICE OF NATURAL AND SYNTHETIC FIBER ROPES



SELECT THE CORRECT SIZE

A rope too small may fail quickly; one too large will prove expensive. Don't work any rope above one-fifth (1/5th) or twenty percent (20%) of its breaking strength. In analyzing a number of mooring line accidents in which synthetic lines were involved, we have also found that replacing manila on a "strength" basis with synthetics results in a line of too small diameter to take a stopper properly and one which presents too small a surface to the face of a gypsy head or bitt for even heaving or surging when under strain. The result is that they melt and stick and then let go all at once. It is recommended that manila mooring lines should be replaced by synthetics on a "diameter for diameter" basis rather than a "strength for strength" one. The longer wear and safer handling characteristics justify the greater initial cost.

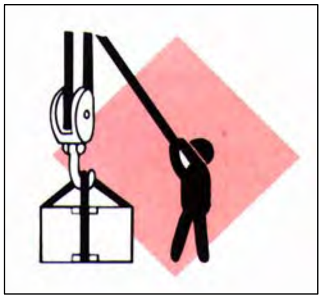
STOP UNNECESSARY WEAR

All rope will be severely damaged if subjected to rough surfaces of sharp edges. Outer and inner rope fibers contribute equally to the strength of your rope. If worn out, the rope is naturally weakened. Eliminate rubbing, drugging, dirt penetration or working over rough surfaces. Chaffing will occur with surface contact either on the rope itself or an external fitting. such as bitt, cleat, chock or block or fairlead. Care must be taken to keep all surfaces smooth and free from burrs, paint and rust. Keep sheaves smooth and free to rotate to reduce wear. Burrs should be filed down or ground smooth. Protect rope surfaces with chafing gear, such as canvas wrapped and tied around the rope. Discarded fire hose skinned on the line before splicing has proven satisfactory for this. Pad corners of sharp objects when lifting, and avoid strain on sharp bends. Remove kinks if they form.

Friction causes more failures in working lines than any other cause. Heat generated by friction will often be great enough to melt or fuse polyolefin filaments, causing a skin on the rope surface, then suddenly gives way. Nylon and Dacron must also be handled with care, especially on moving flat capstans and rendering on bitts. With new synthetics use at least six full turns on a capstan. As the rope wears in, the turns can be gradually decreased. Keep slippage of line on the capstan at a minimum.

Abrasion resistance is usually a factor of the hardness of the rope used, in both natural and synthetic fibers. The hard lay rope will stand up better in use; however, some of the ease of handling and splicing characteristics must be sacrificed. Manufacturers' medium lay will usually give satisfactory service, but in extreme cases where abrasion cannot be avoided, a hard or extra lay should be used. An advantage of nylon rope over manila rope is that nylon rope can hold a load even when a considerable number of the yarns have been abraded

With respect to the elasticity of nylon mooring lines under load, nylon will stretch and thin out but will return to normal size when free of tension. Nylon, because of its great elasticity, far excels all other materials in this characteristic. Assuming manila is one, nylon would be 8.6, Dacron 4.0, polypropylene 5.2. This high energy absorption quality can be dangerous. When a synthetic line reaches its elastic limit and parts, it will "snap back" and sometimes cause serious damage and personal injury. Avoid standing in direct line of pull.



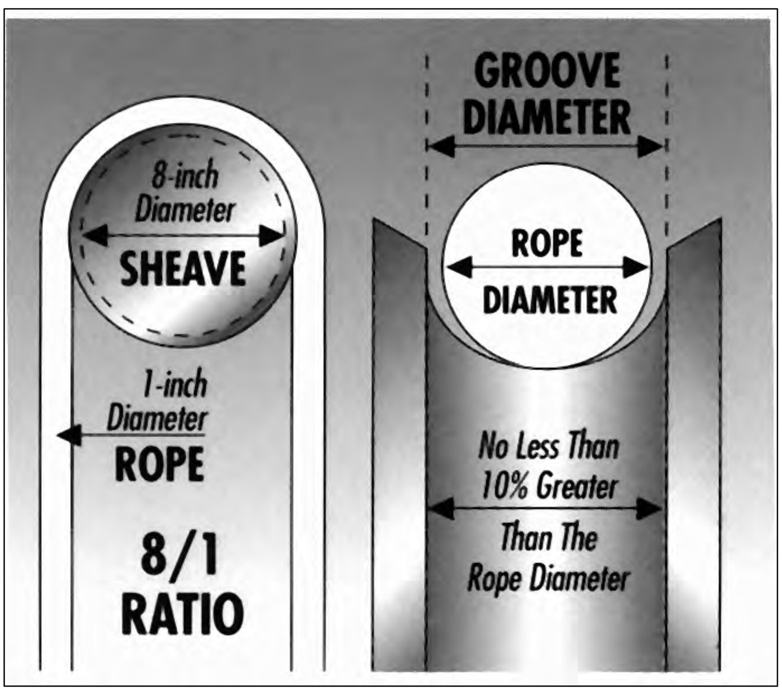
USE RIGHT SHEAVES

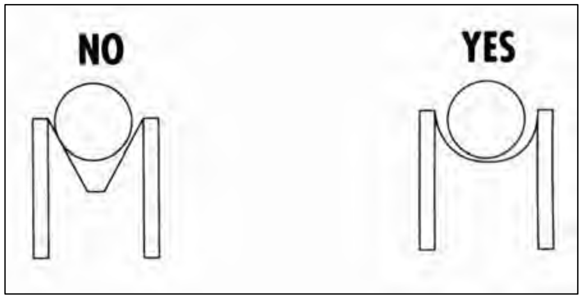
Failure to provide proper bending radius (sheaves) causes added friction and rope wear. Over a long period the fibers will crack and a loss of strength will result.

The old standard for bending radius for twisted fiber rope was three (3) times the circumference of the rope. This applies to chocks, bitts, and the cheeks of blocks. The bending radius for sheaves is two (2) times the circumference of the rope.

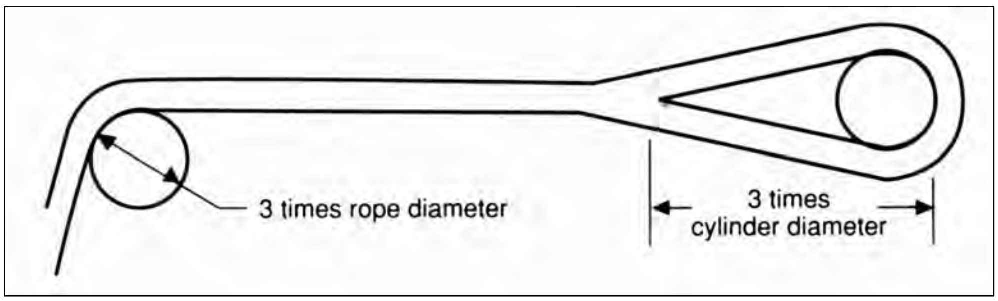
Today cordage manufactures recommend large sheave diameters. In order to assure maximum efficiency and safety

- Sheaves for twisted and plaited rope should be no less than ten (10) times rope diameter.
- Sheaves for braided rope should be no less than eight (8) times rope diameter.
- Sheaves for Kevlar braided rope should be no less than twenty to twenty-four (20-24) times rope diameter.
- For power transmission or for use with continuous load, sheaves should be at least forty (40) times the diameter of the rope.



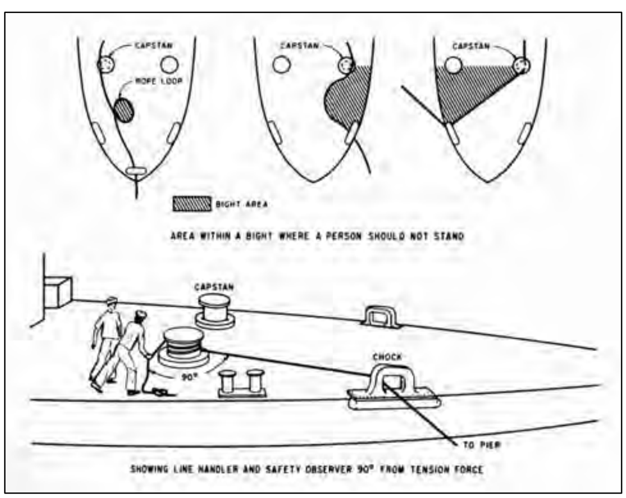


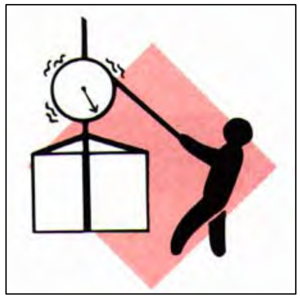
The sheave groove diameter should be no less then 10% greater than the rope diameter. Never use wire rope or V-belt sheaves. The sheave groove should be round in shape. Sheaves with V-belt grooves should be avoided, as they tend to pinch and damage the rope through excessive friction and crushing of the rope fibers.



Sharp bends significantly reduce rope strength. When a rope bends more than 10° around bitts, and chocks, or for that matter any working surface friction increases significantly. A working rope should never be subjected to a bend less than three (3) times rope diameter. A bend ratio of four (4) times, or more, will prolong rope life. Eye splice length should be at least three (3) times the diameter of the cylinder (bitt, etc.) over which the eye is to be used. A length of five (5) times diameter is perhaps best.

Never allow anyone to stand in line with or within 45° on either side of a rope under tension. Should the rope fail or other parts of the assembly fail, the recoil force could cause serious injury or damage, especially if nylon rope is in use.



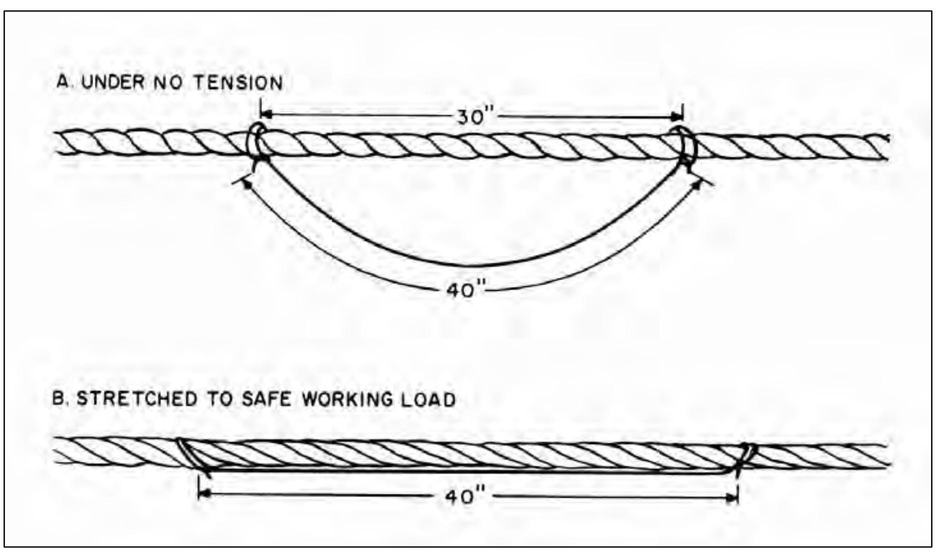


AVOID OVERLOADS

The safe working load ranges for any new rope is between 8-20% of its minimum tensile strength. Make enough allowances for safety if your rope is old or worn. Ignoring this safety factor causes early rope replacement and is dangerous to men and materials. A normal safe working load for used nylon rope in good condition is 25% of its breaking strain.

Seamen who work with natural fiber rope soon learn how to judge load and tension on such lines by the sounds that they produce. Unfortunately, although synthetic lines under heavy strain thin down considerably, they give no audible indication of stress - even when they are about to part. For this reason, a tattletale cord should be attached to synthetic lines when they are to be subjected to loads that may exceed their Safe Working Load (SWL). A tattletale cord is a bight of heavy cord or light small stuff tucked between two measured points on the working line. The line, when tensioned to its SWL, will stretch to a certain percentage of its length. When this point is reached, the small stuff becomes taut, warning that there is danger of exceeding the line's SWL.

Type of Synthetic Rope	Length of Cord (Inches)	Distance (Inches)	Critical Stretch (Percentage)
Nylon (Three Strand Twisted)	40"	30"	40%
Nylon (Double Braid)	48"	40"	20%
Nylon (Plaited)	40"	30"	40%
Polyester (Three Strand Twisted)	40"	34"	20%
Polypropylene (Three Strand Twisted)	36"	30"	20%



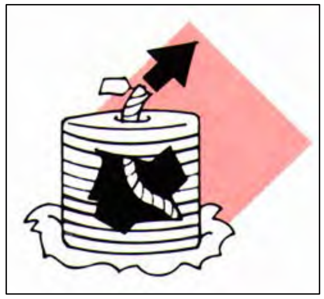
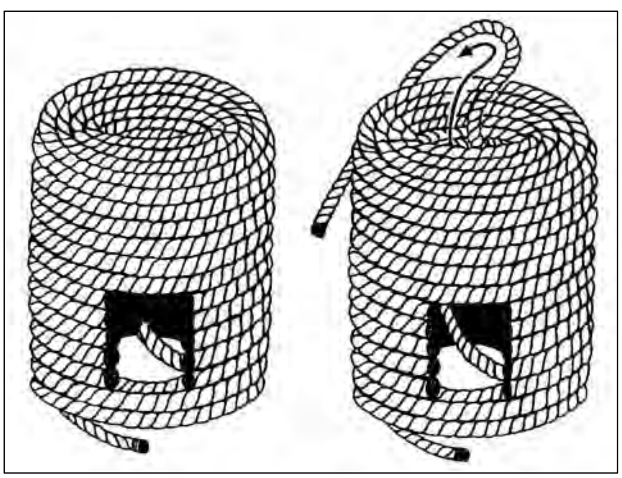


Figure 17 -Tattletale in use on a three strand twisted nylon rope

TO UNCOIL ROPE

A new coil of fiber line should be opened or uncoiled in the following manner:

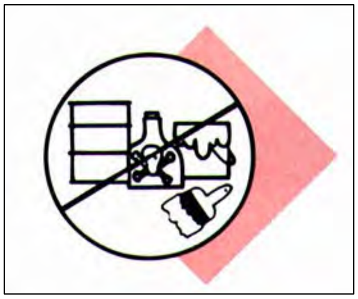
1. A new coil of rope should be placed flat on its end with the "tag" end down, positioning the bitter end down on the lower inside of the coil.
2. Remove the outside lashings and unfasten the inside bands.
3. Reach down through the eye of coil and pull out the inside end, where tag is attached. Pulling out the amount of line desired through the eye of the coil.
4. Coil the line down with the lay. Right lay fiber rope should be coiled clockwise. Left lay fiber rope should be coiled counter-clockwise.
5. Keep the burlap or covering intact to protect the coil. Uncoiling a line improperly can cause kinks in the line.



New coil of fiber rope

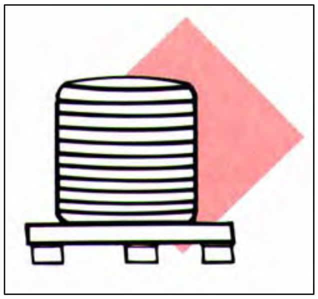
Uncoiling a new rope

A new coil of Nylon line should be opened by unreeling it from a reel.



KEEP AWAY FROM CHEMICALS

Acids, Alkalis and certain organic compounds are injurious to rope. If exposed, wash thoroughly and inspect before using. Watch for battery and building cleaning acids, caustic soda and paint. All ropes whether natural or synthetic are lubricated in the manufacturing process. Do not attempt to add lubrication, as you will in all probability do more harm than good.



STORE PROPERLY

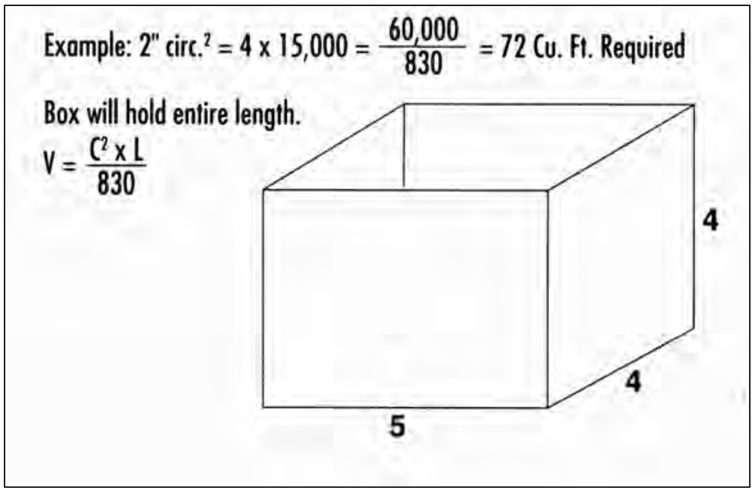
Natural fibers are weakened by mildew and rot. Manila rope must be stored in a cool dry room with plenty of ventilation to avoid dry rot and mildew. There have been several treatments impregnated into ropes during their manufacture. Most of them are copper compounds and have proven very satisfactory as long as they last. However, they all wash out in water after prolonged use and it is very difficult to replace the treatments. Synthetic ropes are not subject to dry rot and the mildew that attaches itself to them is not detrimental. Synthetics should be stored at moderate temperatures away from steam pipes, etc., and direct sunlight. Optimally, line should be stored in dry, cool place with good air circulation protected from prolonged exposure to sunlight. The line itself must be clean and dry. Wooden grates should be placed on concrete or steel floors to provide ventilation underneath the line. Rope may be stored in a ventilated box or covered with a tarp to keep temperature at minimum. Always stow lines away from steam pipes or heated metal bulkheads. Keep rats away.

BOX OR BIN STORAGE

The following formula is for computing the rope capacity of a box or bin. This formula may be used to determine how much rope of a given size can be stored in a box or bin - or to compute the size of box or bin needed to accommodate a given length and size of rope.

V = Cubic footage required
C = Rope circumference in inches
L = Length of rope in feet

(Volume = length x width x depth) l, w, d are in feet

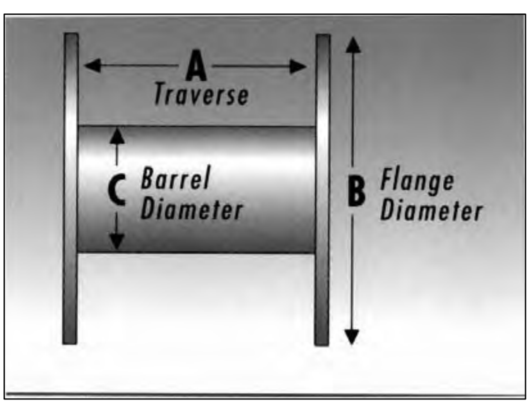


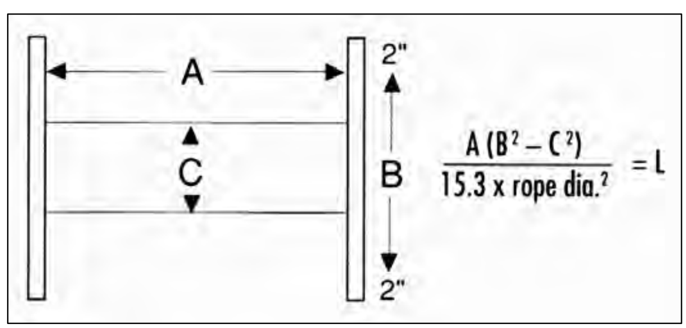
REEL OR DRUM STORAGE

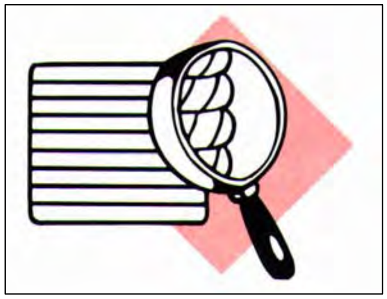
The following formula is for computing the rope capacity of a reel or drum. This formula may be used to determine how much rope of a given size can be stored in a reel or drum - or to compute the size of reel or drum needed to accommodate a given length and size of rope.

A = Reel width in inches
B = Reel flange diameter in inches
C = Reel barrel diameter in inches
L = Rope length in feet

A, B, C, and Rope Diameter are in inches, L is in feet.



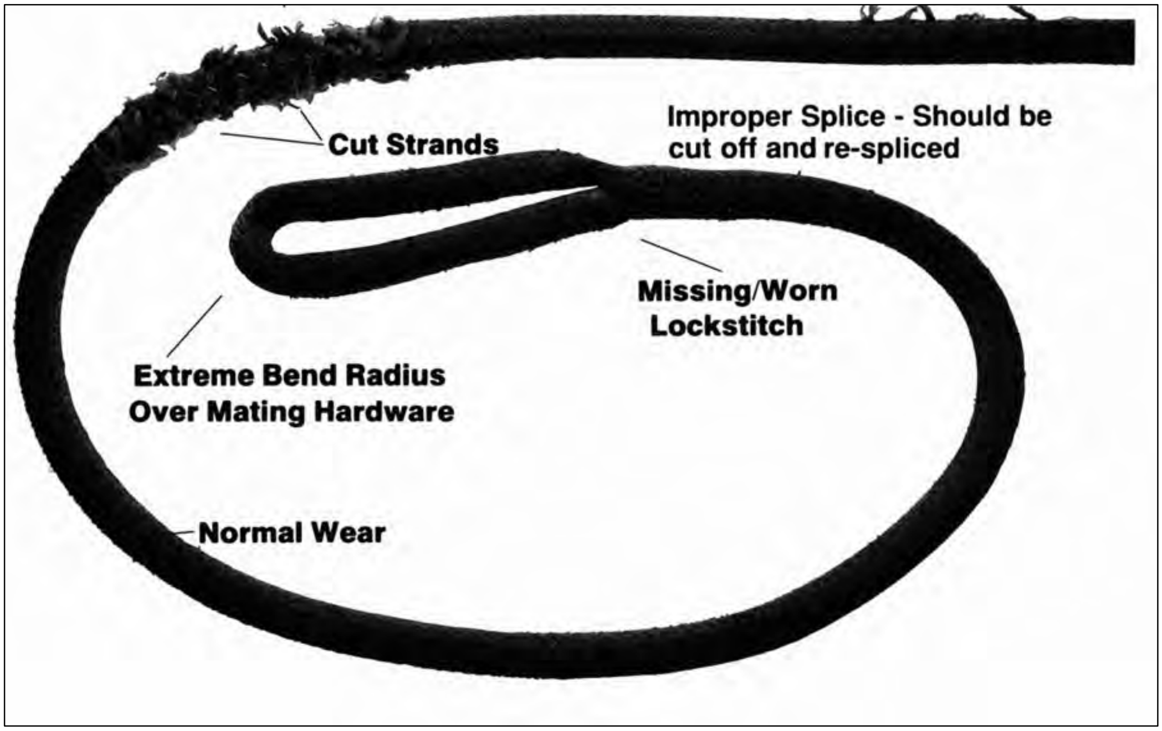




INSPECT ROPE CONDITION

Inspect rope frequently, whether working or in storage. No type of visual inspection can be guaranteed to accurately and precisely determine the actual residual strength of a particular line. Both the inner and outer fibers contribute to the strength of the rope. When either is worn, the rope is naturally weakened. Check frequently for frayed strands and broken yarns. Pulled strands should be re-threaded into the lay of the rope if possible. A pulled strand can easily snag during line handling operations. Open-up the lay and look for powdered fiber between the strands. This is an indication of internal wear. A heavily use rope will often become compacted or hard which indicates reduced strength. When the fibers show wear in any given area, the rope should be cropped to remove the damaged area and re-spliced. If there is any doubt, safe working practice requires that rope strength be downgraded or the line replaced if necessary.

It is often very difficult to detect damage to a manila rope. If there is no dry rot present, spread the strands and check for strand abrasion in the core of the rope. Try to test the fiber strength by comparing it with the fiber from a new rope. On larger ropes cut out one inside yarn, remove turn and test the individual fibers for strength, comparing it with a fiber from a new rope. An experienced rope handler can determine much by general appearance. It is much more difficult to determine internal damage in synthetic ropes. Look over the line carefully for surface cuts and chaffed places. Glazing or fussing on the surface ordinarily does not have an appreciable effect on the strength of the rope. Often this fuzziness acts as cushion to help prevent further chaffing and abrasion. Cut off a one-foot piece and count the number of broken yarns. This divided by the total number of yarns in the rope will give an approximate percentage of the strength left.



Occasionally reverse your rope, end-for-end, to distribute the wear more evenly. Use worn rope only where strength failure will not cause injury or damage.