

Ropes and Knots

The fire service has for many years accepted rope as an important and necessary item of equipment carried on emergency apparatus. To utilize rope to maximum advantage it is essential that firefighters are knowledgeable in its construction, care and maintenance, and knots suited for firefighting and emergency operations.

This chapter will be broken down into the following sections:

- 3.1 Construction**
- 3.2 Care and Maintenance of Rope**
- 3.3 Knots**
- 3.4 Hoisting Tools**



Section 3.1**Construction of Rope**

There are many terms used by manufacturers of rope; however there are three terms that should be known. The three terms are fibers, yarns, and strands. Rope is constructed of strands, strands are made up of yarns, and yarns are constructed from fibers.

Rope fibers come from a variety of sources and have direct impact on the strength, weight, elasticity, life and buoyancy of the rope. Rope fibers can usually be classed into one of two categories; natural fibers and synthetic fibers. Some common natural fibers used are mania, sisal, hemp, and cotton. Some common synthetic fibers used are nylon, polyester (Dacron), polyethylene, and polypropylene.

Studies show that when natural fibers such as manila get wet, the tensile strength is reduced by 50% no matter how well it is dried afterwards. Even when properly stored, manila rope will lose 10% of its strength per year. Lab tests also show that manila starts to disintegrate after at temperatures above 200° F. Nylon and polyester on the other hand show little effect until temperatures reach the range of 300-400°F.

Some synthetic ropes, such as polyethylene and polypropylene, have the ability to float. This makes them well suited for water rescue. After the yarn is prepared it may then be made into laid, braided, or kernmantle rope.

Laid Rope

Strands are formed from two or more yarns depending on the size of the finished rope, the number of yarns being the determining factor. A strand is usually $\frac{1}{3}$ of a rope, although four strand ropes are also made. The strands have a permanent twist in a direction that is opposite to that of the finished rope. This reversing of twists with each step in rope making is necessary to maintain the ropes form and structure. The lay of rope is the direction in which the strands are twisted. Most rope is right-laid. The strands spiral upward to the right when the rope is held vertical.

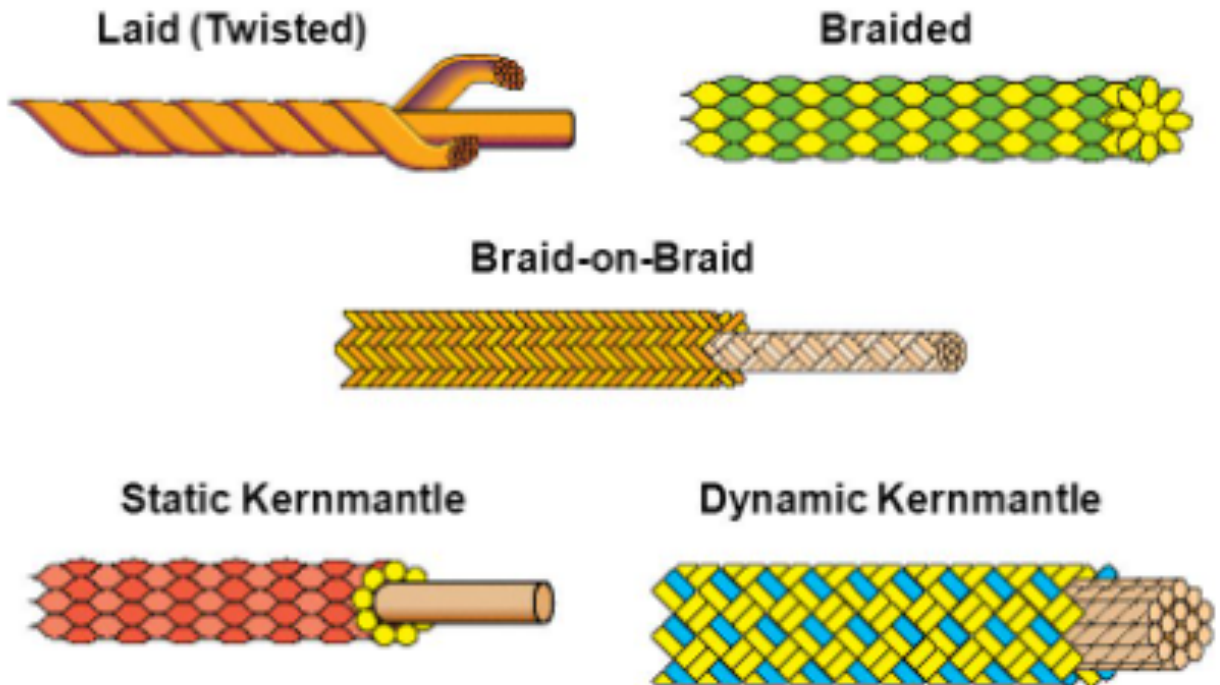
Braided Rope

Braided rope is constructed by braiding strands together, usually around a central core. The purpose of the central core is to provide the rope with form and structure. The central core contributes to the strength of braided rope in cases where the core is of the same construction as the outer portion (braid on braid rope).

Kernmantle Rope

Kernmantle rope is constructed of an inner core or “kern” and is covered by a woven outer sheath or “mantle”. The kern is made up of fibers running through the whole length of the rope. These fibers make up 70-90% of the rope’s strength. The mantle is a woven outer sheath that surrounds the kern to protect it from abrasion and other damage. There are two types of kernmantle rope, “dynamic” and

“static”. Dynamic ropes are designed to stretch to reduce the impact load on a falling climber. Dynamic ropes stretch 40-60% at their breaking load. Static rope is the type of rope used for rescue. The stretch of most static ropes is around 2% at their working load and up to 20% at their breaking point. 11mm Static kernmantle rope is the rope used at PFD for rope rescue.



Section 3.2**Care and Maintenance of Rope**

The best service from rope may be obtained by following the basic principles of care outlined in this section. Because it is not feasible to test rope properly in the field, rope that has been in service for some time should be considered to be weaker than its original condition. Constant inspection and good care will bring about the longest life and best service from rope.

Care of Synthetic Rope:

Since all fibers of a rope contribute to its strength, try to avoid running rope around sharp corners or angular bends, and dragging it over rough, dirty, gritty or splintered surfaces. Pad these areas if they can't be avoided. When bending a rope, the radius that the rope is bent around should be at least three or more times the diameter of the rope. When pulling on a rope use a steady pull, not sudden jerks. Do not walk on rope. The impact of a shoe grinding dirt particles into the rope can seriously damage its fibers. Although synthetic rope is not subject to mildew, precautions are necessary to keep rope dry or if wet, to thoroughly dry it before storing.

Maintenance of Synthetic Rope:

If the rope is very dirty, it can be washed in a front loading, nonplexi-glassed windowed, washing machine (glass windowed is OK). Soap such as Ivory Snow can be added (not a detergent or soap containing chlorine bleach). The rope should be placed in the washing machine in the same manner a roof rope is stored on the rig, chained. Synthetic rope should be cut with a hot knife. If a hot knife is not available, melt the end together after the rope is cut making sure that the melted portion of the rope is shaped like a bullet, not like a mushroom. Remove all kinks or knots and store in a dry, well ventilated room. Keep loose coils off the floor, preferably on a wooden peg. Never treat a rope. A good rope is properly lubricated by the manufacturer for its useful life.

Do not store rope:

- With petroleum products, corrosives, acids, chemicals, or any equipment that may produce vapors of these products.
- With items that may cause mechanical damage.
- Next to heat sources.
- With sharp bends in it.
- In direct sunlight.
- Where it may contact concrete.

Inspection of Synthetic Ropes

Rope should be inspected after every use and especially after it has been loaded. Slide the rope through one's hands and feel for:

- Any change in texture, stiffness or diameter such as an "hourglass" effect.
- Abrasion of the sheath (such as significant fraying on Kernmantle rope sheath/exterior)
- Hard spots. Examine rope visually for:
 - Exposed core fibers (white in most static ropes) pulled through the sheath or exposed from abrasion or damage to the sheath.
 - Discoloration. An obvious change from the ropes original color, particularly brown, black, or green, could indicate chemical damage.
 - Glossy marks. These could indicate heat fusion damage.
 - Contamination with unknown substances.

Retiring Rope:

When rope has reached the point that its useful life is over, or it has been loaded and the safety or strength of the rope is unsure, it needs to be replaced and the original should be retired.

A rope should be retired when:

- One or more defects are found when inspecting it.
- More than half of the outer sheath yarns are broken.
- The rope has been subjected to shock loading.
- The rope has been subjected to the kind of overload for which it was not designed, such as towing a vehicle.
- The ropes diameter and texture is not uniform throughout the length.
- The reliability of the rope is suspect because of the amount of use, age or suspected damage.

Section 3.3

Knots

Emergency situations requiring the use of rope and securing knots occur with sufficient frequency as to warrant adopting a set of appropriate knots. The following knots have been selected as being of value to firefighters performing emergency and routine duties. It is strongly recommended that firefighters practice the listed knots often enough to develop confidence, dexterity and speed. For the purpose of simplification, all bends, hitches, etc., will be referred to as "knots".

THE SAFETY KNOT:

Ropes made of synthetic fibers are more slippery than natural-fiber ropes making it necessary to back up some knots with a safety knot. The safety knot will prevent the "working end", or "bitter end", from backing or slipping out of the knot.

TERMS USED IN ROPES/KNOTTING:

Working end, or bitter end, is the end of the rope used in forming the knot.

The standing part is the inactive length of the rope between the working end and the running part.

Running part is the part of the rope that is used for work, such as pulling or hoisting.

A bend is a knot that joins two rope ends together.

A hitch is a knot that attaches a rope directly to an object. It has to be wrapped around something to keep its form.

The bight is formed by bending the rope back on itself but does not cross.

A loop is made by crossing the end over or under the standing part.

A turn is the same as a loop with the rope passing around an object.

A round turn is taken by looping the rope twice around an object.

Setting or drawing up a knot is tightening a knot slowly and evenly to make sure that the knot keeps its place and shape.

Dressing a knot is making sure that the rope is arranged in proper position, so as to maximize the strength of the knot. Dressing makes it easier to see that a knot is tied correctly and increases the strength of the knot.

Loading the rope is when pressure of a load is applied to a knot or the end of a rope or both. Improper loading could result in a knot failure. When loading the rope or knot, it should always tighten the knot, not pull it apart.

FINISHED KNOTS

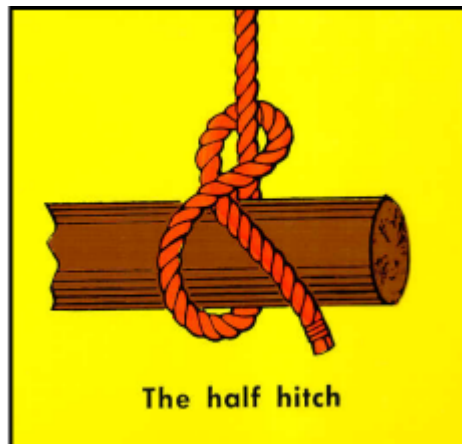
Girth Hitch: The girth hitch is a standard knot used to attach a loop (sling or rope) to some anchor. Very easy to do, it can be done even if both ends are tied. Both ends should have the same load; otherwise it will not be reliable.



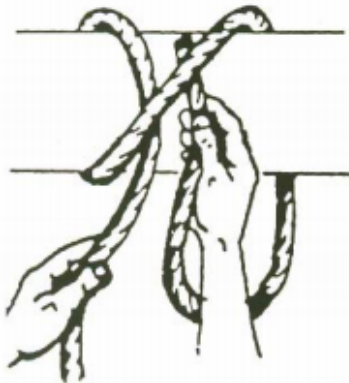
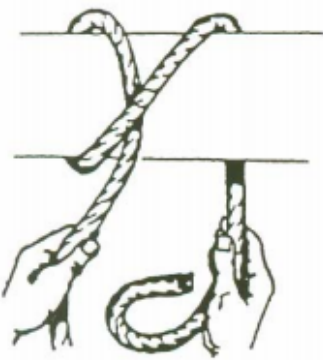
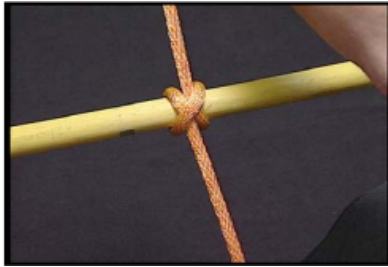
Simple Hitch (not Half Hitch) AKA: Single Hitch. A simple hitch is used in between two knots to better secure the rope to an object such as when hoisting a pike pole or axe.



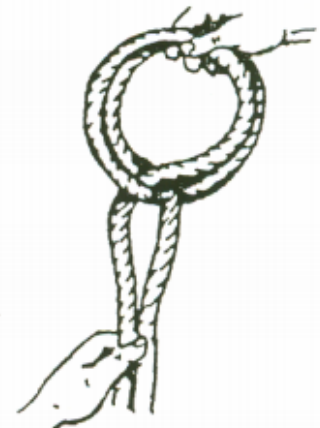
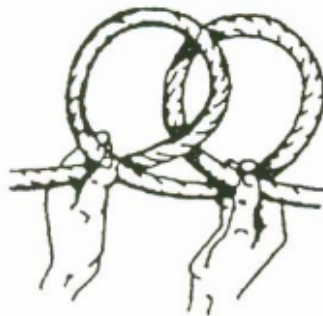
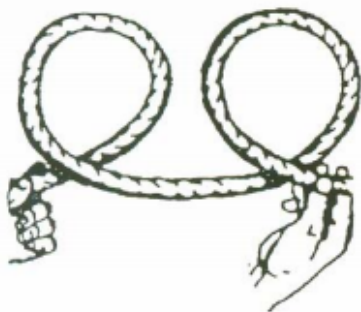
Half Hitch or Safety Knot The half hitch is the start of a number of other hitches and is useful all by itself as a temporary attaching knot. Although this is probably the simplest knot of all, you have to be a skilled knot-tier to know how to tie and use it in a safe way. The loose end of the rope is nipped against the object and the standing part. The best nip is obtained against an edge or shoulder. If the load is released and the standing part shaken, the hitch is spilled instantly.



Clove Hitch -The Clove Hitch has many uses, including equalizing anchors. Without extra support, it is an untrustworthy knot in most situations. Back it up with a half-hitch for security if tied at the end of a rope. This knot is extremely useful when hoisting tools, hose, nozzles, etc. It is also used to tie open/closed gated wye(s) and nozzle bales.

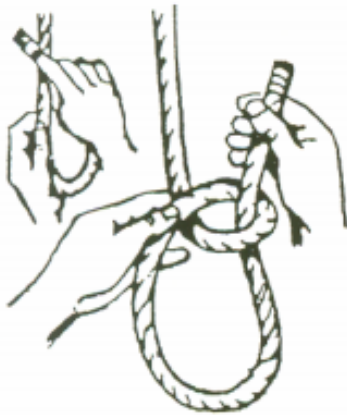


(Clove hitch on the end of a rope)



(Clove hitch in the middle of a rope)

Bowline- The Bowline Knot is one of the most used loop knots. It was once known as the king of knots because of simplicity, security, and its relationship with tensioning systems. The bowline is used to form a loop in a rope. It can be tied in the hand or tied to an object. This knot should be secured with a safety knot.



(Bowline)



(Bowline with a safety)

Square Knot - The square knot is only useful in simple applications. It is easily tied and will not jam, so it is always easy to untie. Sailors used it for binding rolled sails. When tied properly it will have a square look to it.

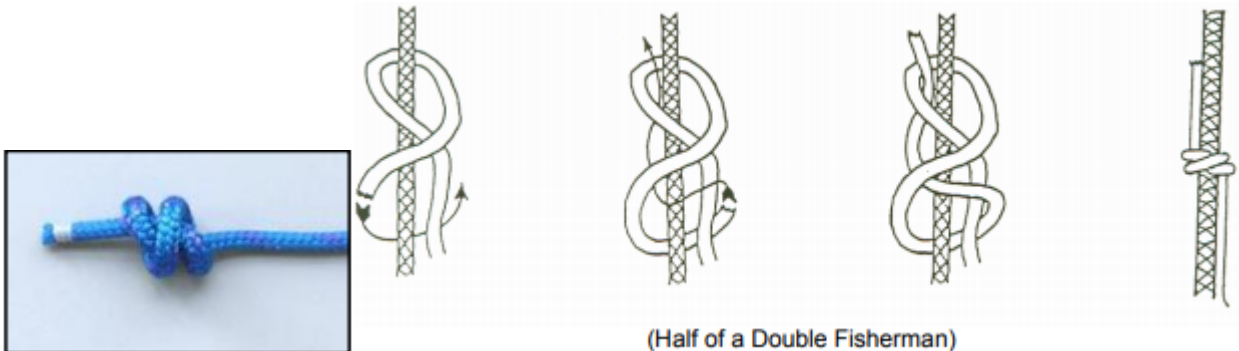


(Square knot tied on ends of rope or tying two similar size ropes together)



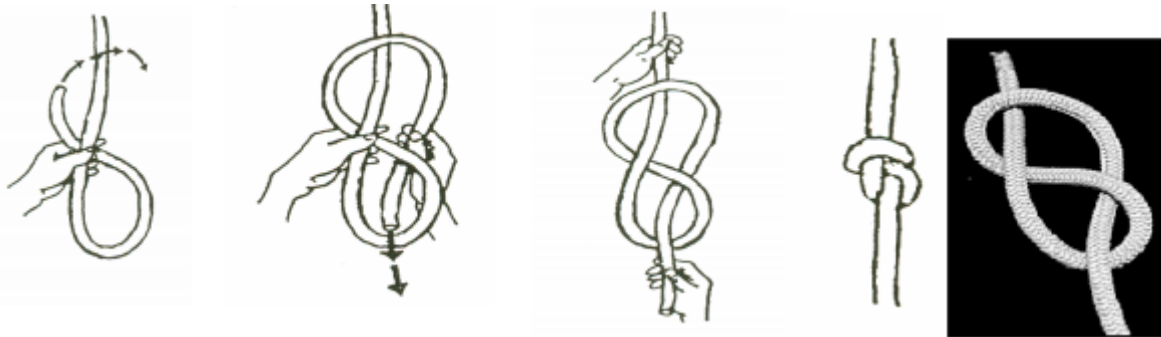
(Square knot tied around an object)

Half of a Double Fisherman :The half of a double fisherman knot is used to prevent a knot from slipping or coming apart. This safety knot is tied to the standing part then snugged up to the main knot.



(Half of a Double Fisherman)

Figure 8 -The Figure 8 is the foundation knot for the family of figure 8 knots. When tied correctly, the Figure 8 tends to be more secure and less likely to come apart under loading. It is also easily identified when tied correctly. This type of knot is less detrimental to the strength of the rope than other knots that can be. The Figure 8 itself can be made in the start or end of a rope and used as a stopper knot.



Follow Through Figure 8- The Figure 8 "follow through" is used to tie a loop into the end of a rope. It can be used as an anchor knot where the anchor is a tall object such as a tree. The loop is formed by going around the object. Do not confuse this knot with the Figure 8 Bend.

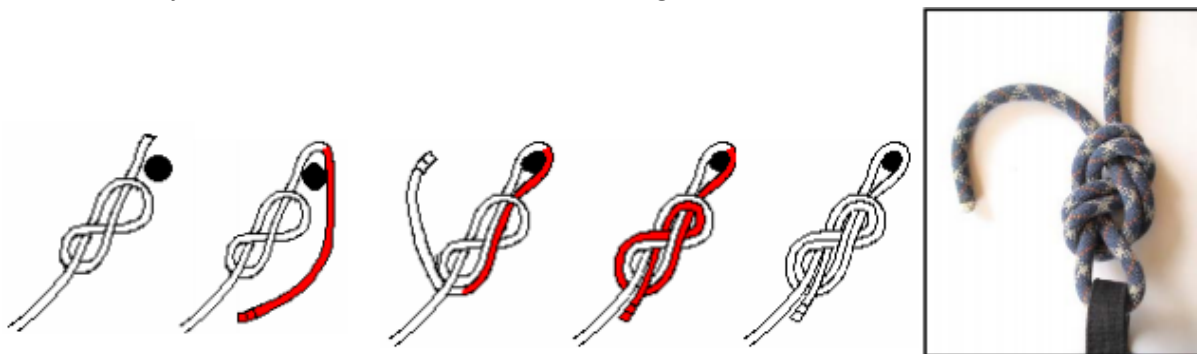
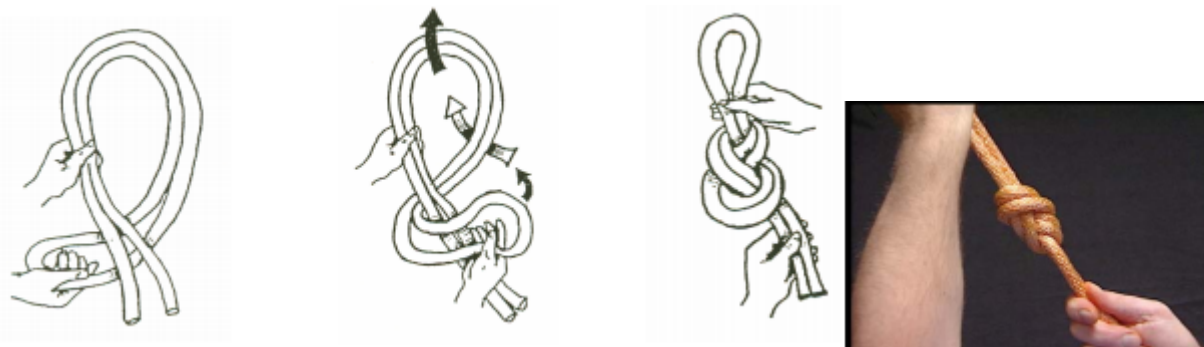


Figure 8 on a Bight- The Figure 8 on a Bight is used to make a loop in the rope. It can be tied in the middle or end of the rope. The loop formed can be clipped into for safety or anchor lines. This knot looks the same as a Follow through Figure 8 after it has been tied.



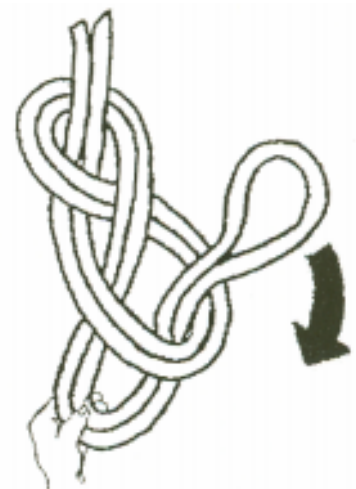
Double Loop Figure 8- The Double Loop Figure-Eight is generally considered to be strong and secure. The Double Loop Figure 8 is a knot used by climbers. It is easy to tie and untie and safer than the bowline.



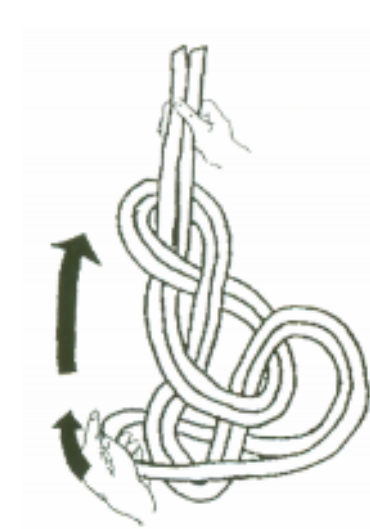
(1)



(2)



(3)



(4)

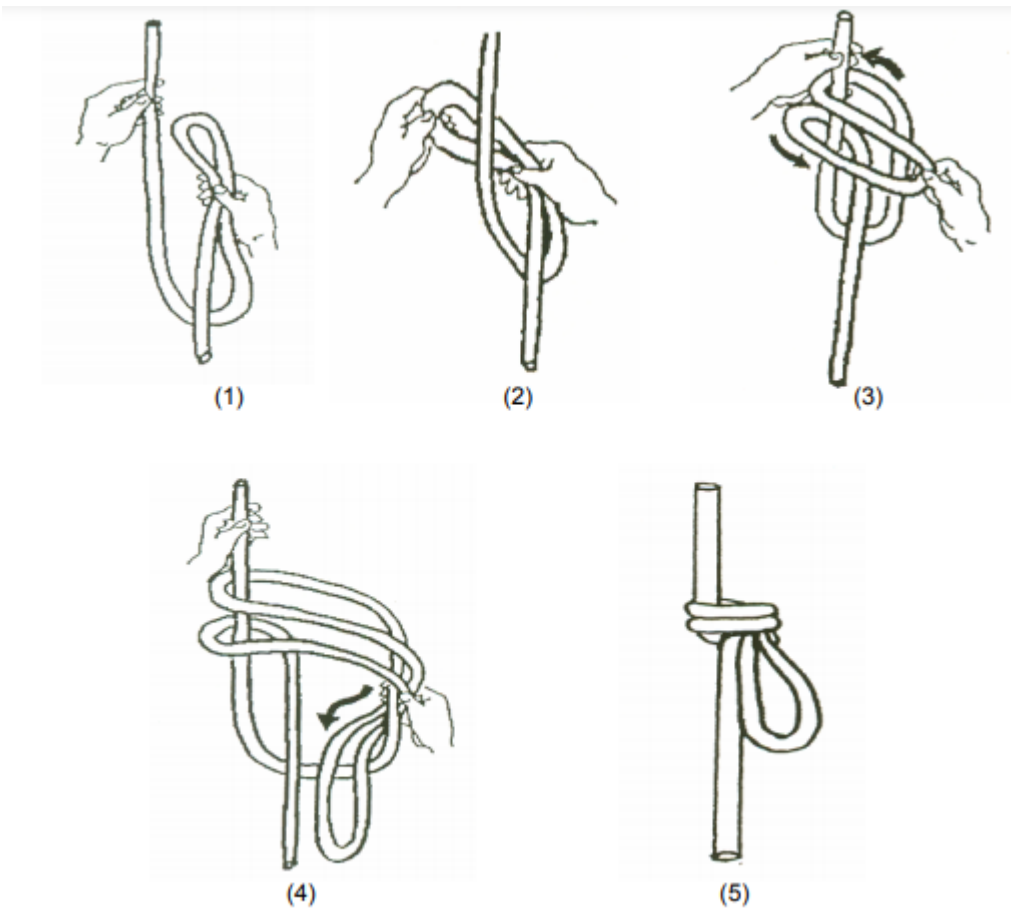


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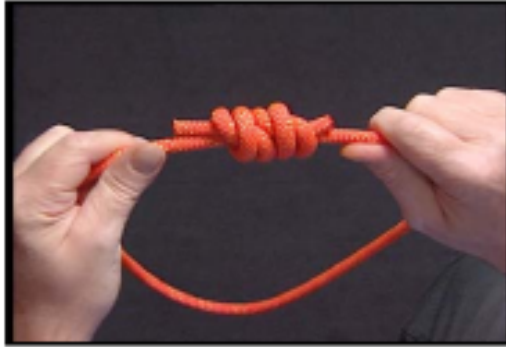


(6)

Inline (Directional) Figure 8- The Inline or “directional” Figure-Eight Loop can be tied in the middle of a rope when you don't have access to the ends of the rope. The load can only be in the direction of the loop. Proper loading is necessary to ensure that the knot tightens and is not pulled loose.



Double Fisherman's Knot- This knot is primarily used to form a Prusik Loop. It can be used to join only rope together, not webbing. Half of a Double Fisherman is used as a safety knot when tying a bowline.



Prusik Hitch -The Prusik is used as a safety knot during rappelling or a lowering operation. It is also used to ascend rope and in rescue work. It is tied very much like the girth hitch but with three wraps around it.



Munter Hitch on Carabiner- The Münter Hitch is commonly used to belay. This knot slips around a carabiner to create friction against itself. Always use a "pear-shaped" locking carabiner so the Münter Hitch does not jam.



Water Knot -The Water Knot is an overhand knot with a follow through. It is primarily used to tie two ends of webbing together.



Hasty Harness- A webbing harness that can be tied quickly using a length of webbing and using a water knot to form a loop. A carabiner should be used to bring the loops together.



Becket Bend (Sheet Bend) - This knot is used to tie together two ropes of different thicknesses.

