CHAPTER 4

RIGGING LAB ACADEMY

ROPE RESCUE COURSE TEXT MANUAL

AWARENESS LEVEL
OPERATIONS LEVEL
TECHNICIAN LEVEL

Rope Rescue Course Text

Disclaimer:
This book is intended for the exclusive use of participants of the RRG Rigging Lab.

Rope rescue is inherently dangerous, even if the techniques, procedures and illustrations in this book are diligently followed, serious injury and/or death may result. This book makes no claim to be all-inclusive on the subject of rope rescue. There is no substitute for quality training under the guidance of a qualified instructor.

Insofar as the author of this book has no control over the level of expertise of the reader of this material, or the manner this information is used, the author assumes no responsibility for the reader's use of this book.

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Knots, Bends, and Hitches

Throughout the evolution of rope rescue there has been much debate over which knot is right for this type or that type of application.

Although the knots represented in this book are substantial, it is not intended to be the last word on the subject. In this chapter you will find many combinations of knot craft that is incorporated in the rescue world, most of which we have found useful on several occasions. Hopefully, by reading this chapter you will learn some new knots, and possibly generate some new ways of incorporating them.

Strength of a knot is not as important as the quality and skill in which it is tied. Knots do not break in a system that is built within normal safety parameters by skilled technicians. The vast majority of system failures in the vertical realm can be attributed to human error.

What are Knots, Bends, and Hitches?
The standard definition of a knot is a rope intertwined with itself, a bend is the intertwining of two ends of rope, and a hitch is a knot that is dependent on a host object. In the true spirit of the art of knot craft, defining knots deserves a little more than "intertwined rope!"

The first thing that comes to mind when we visualize "rope intertwined with itself" is the broken body of a rock climber lying dead on top of a heap of "intertwined rope", only because he lacked the skill in tying the appropriate knot somewhere in his system.

Or as Clifford Ashley (probably history's greatest authority on knots) put it**,** *"A knot . . . is either exactly right or it is hopelessly wrong."*

By its very nature, vertical rescue is dependent on rope, and the most elemental skill in using rope is tying it into a knot. There are no gray areas, no "in betweens" in tying knots, Mr. Ashley goes on to *say "Make only one change and either an entirely different knot is made or no knot at all may result."*

This statement holds true in this business of high angle rescue, there is but only a careless visual difference between a slipped Figure Eight, and a Figure Eight on a Bight Follow Through. The Figure Eight on a Bight Follow Through is a great knot for securing a rappel harness, and under the same application, the slipped Figure Eight will drop you like a rock!

Knots, bends, and hitches are defined by their function. It is the responsibility of the rescuer to use the most appropriate knots for the job at hand.

As with all systems within a vertical rescue, safety is a team issue. At least two (2) qualified team members should inspect all knots involved in the rescue operation before anyone is allowed to move into the hazard zone.

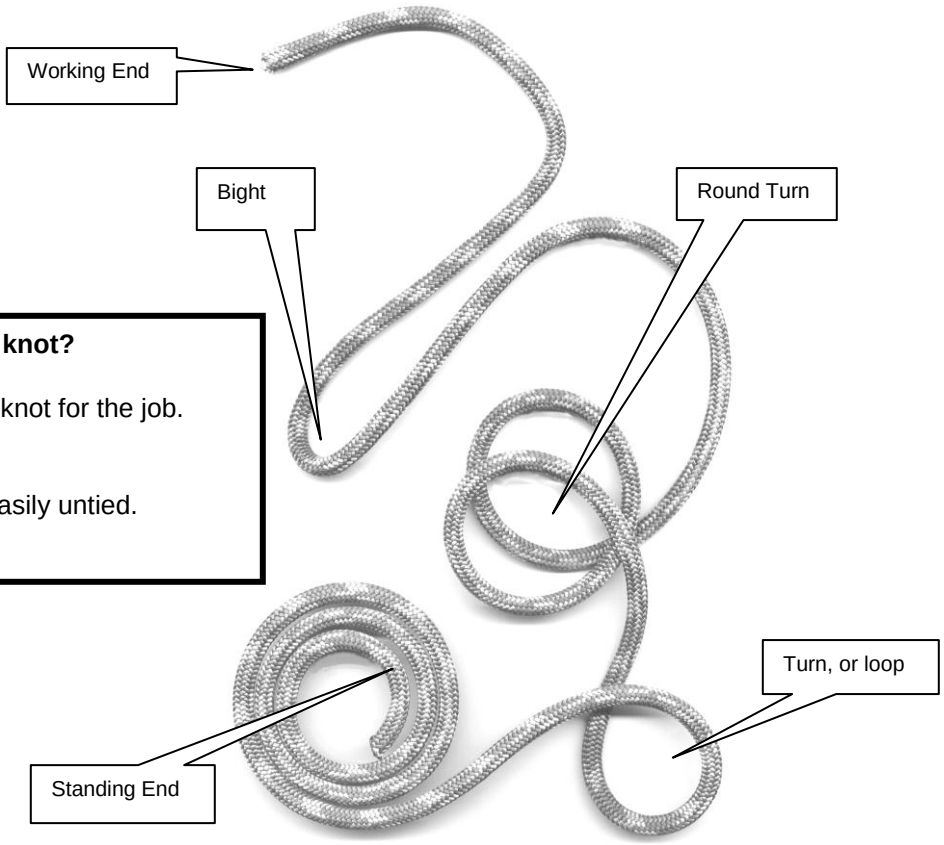
In summery, knots are the first link in the success, or failure of a vertical emergency.

Knot Families:
In this chapter on knots, you will find a slightly different presentation with the division of knots, bends, and hitches. We have found over several years of teaching knot skills, that knots, and bends, are easier to learn if they are kept within the context of their respective “families.”

Example, it is very simple to follow the progression from an “overhand” to an “overhand on a bight”, to a “double overhand”, to a ”double overhand bend”.

Hitches, because they are dependent on a host object, are categorized in their own section.

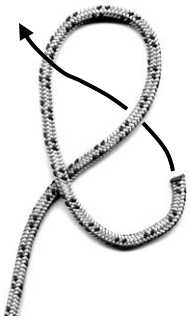
Elements of a Knot



What makes a good knot?

- Most appropriate knot for the job.
- Recognizable
- Cleanly dressed.
- When required, easily untied.

The Overhand Family



Overhand

The overhand (the half hitch or single hitch is the most basic knot) is the second most elemental knot. It was probably the first knot ever tied in a vine by ancient man.

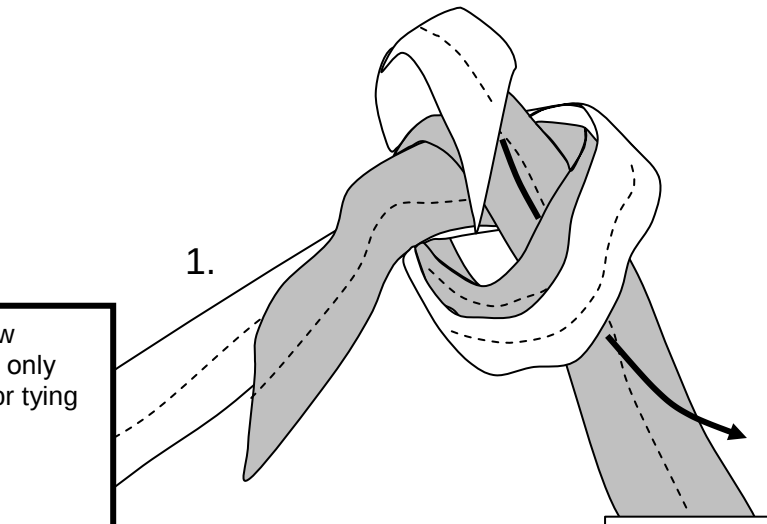
As with all knots, the overhand and the overhand on a bight have some interesting characteristics, with both, good and bad points, depending on the application. The overhand and the overhand on a bight have consistently tested very high in pull tests. A rope looses only approximately 15% of its strength when an overhand on a bight is tied.

The down side to the overhand is it becomes almost impossible to untie after it has been set with a heavy load (one person or greater). In addition, a single overhand is not recommended as a stopper knot, or as a back-up knot for other knots. The reason for this is, that a "hand" set overhand tied at the working end of a rope, tends to become loose over a period of time, and in some cases, may "self" untie. For back-up applications, as in backing the bowline, use a "double overhand" or a Yosemite back-up (see bowlines).

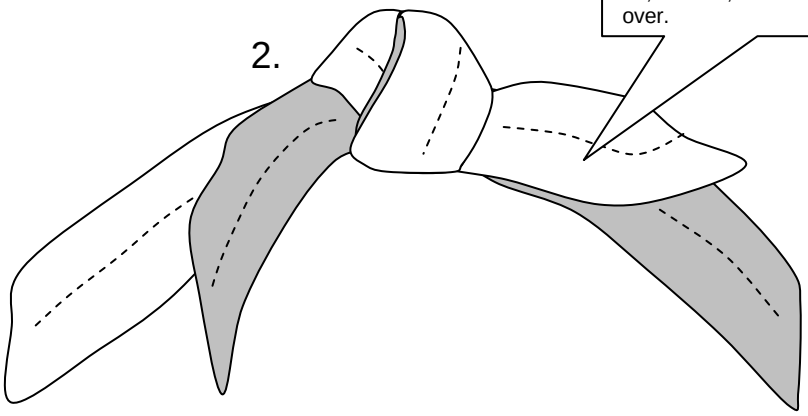
Overhand On A Bight

Overhand Follow Through Bend (Using Webbing)

The “Overhand Follow Through Bend” is the only acceptable method for tying two working ends of webbing together.



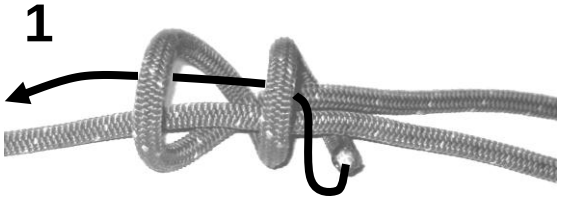
After setting the knot, there should be, at least, a 2" tail (per side) left over.



The Double Overhand Follow-through Bend

This Bend is used to combine two working ends of rope, i.e. extending a line, or for making accessory cord loops. Some teams advocate a triple overhand bend. 3 overhands is over-kill, 2 will more than do the job.

1



2

After the first Double Overhand is tied, rotate the entire ensemble clockwise and repeat the first three steps.

3

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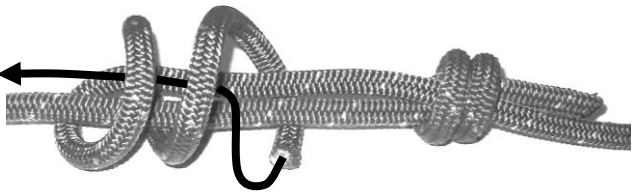

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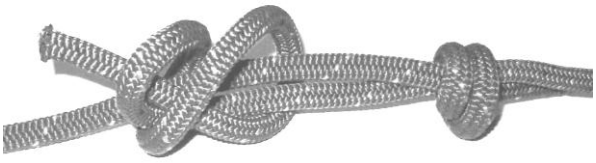


6

After the two Double Overhands are tied and the tails are pre-tensioned about 1 ½ " long (the tails will tension to about 1" in length when the bend is set), pull on the standing parts so that the two knots slide together as shown below in steps 7 and 8. When this bend is tied correctly, two inter-locking Xs will form on one side (7) and the other side will look parallel.

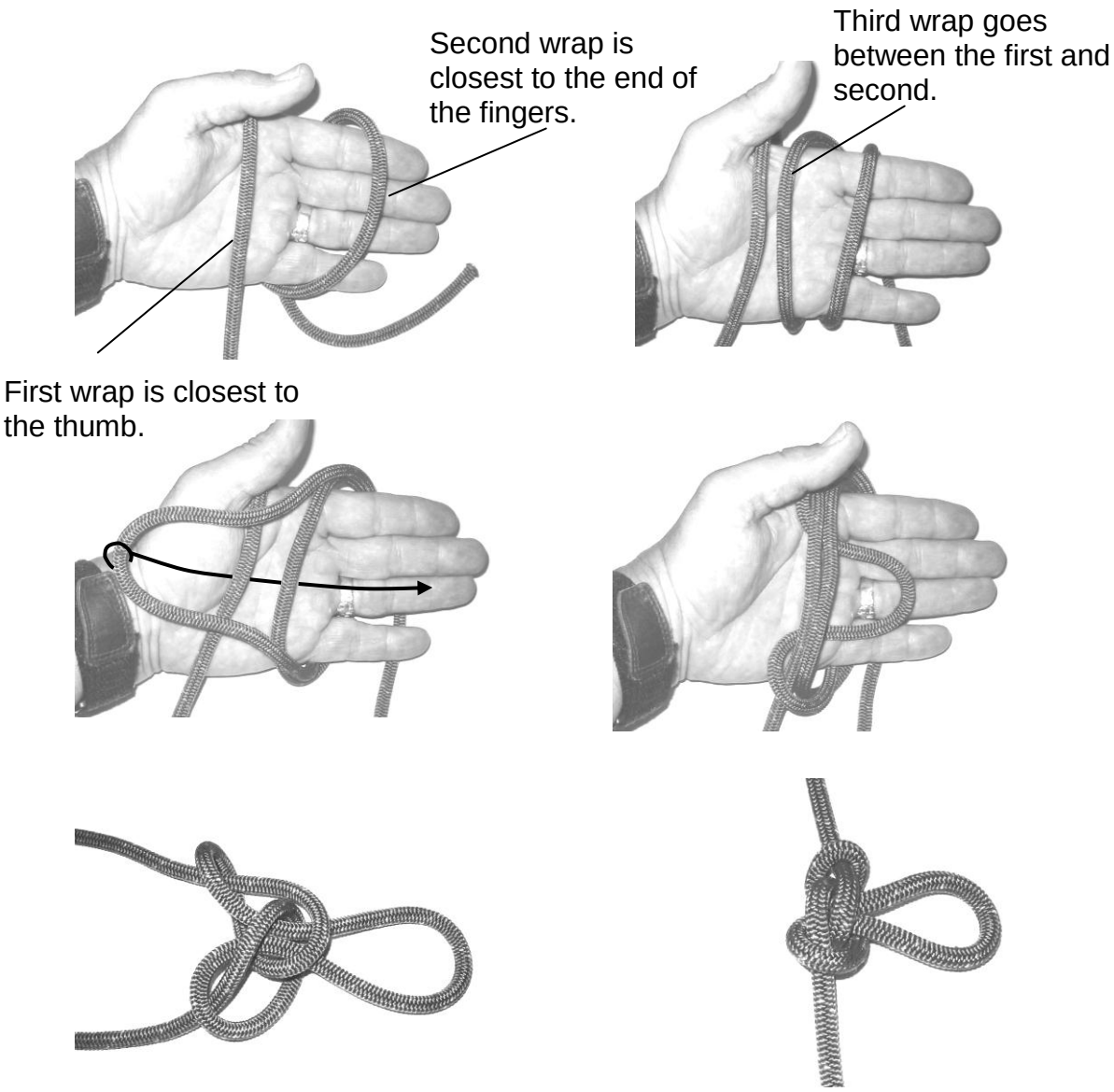
7

8

ne loo o

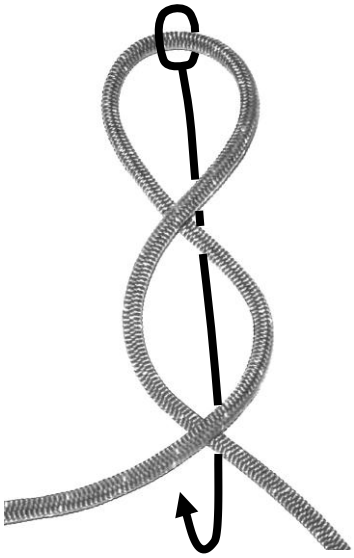
In addition to its mid-line qualities, the Butterfly has three distinct loops, when the knot is opened up, can be loaded in three different directions.

It is considered part of the overhand family, and it is a close cousin to the “Ashley Bend”, the Striate Bend and the “Hunters Bend”.



Butterfly Tied From a Bight

Many time it is preferable to tie the butterfly from a bight, this technique allows for a precise location of the final loop. This is a valuable tool when rigging multiple tensioned back-tie anchors as shown in the bottom photos.



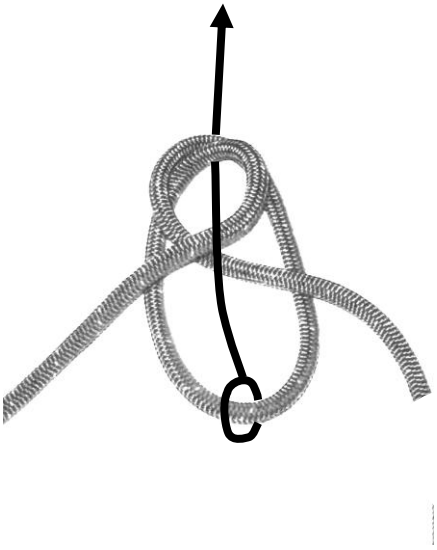
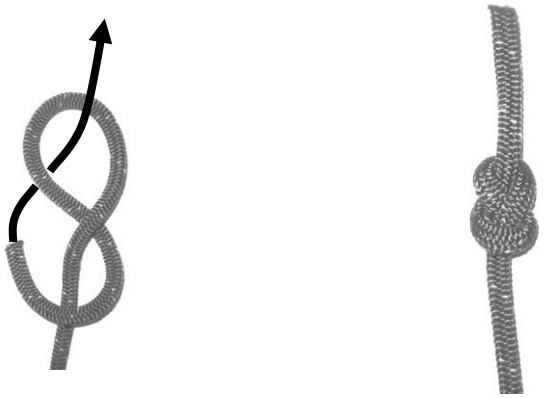


Figure Eight Family

Figure Eight, and the Figure Eight on a Bight
The *Figure Eight* is the base knot for the entire figure eight family of knots. The figure *Eight on a Bight* is one of the two most used knots (the other being the Bowline) for rescue anchoring.

Some notable advantages with the *Figure Eight*, and the *Figure Eight on a Bight* is that they are very recognizable, which makes mistakes in tying these knots obvious. In addition, the Figure Eight and the Figure Eight on a Bight are easy to learn and remember.



Although the *Figure Eight on a Bight* is a slightly stronger knot than the Bowline, the trade off is that the *Figure Eight on a Bight* is definitely harder to untie after being subjected to a heavy load. In addition, given equal loops, the gain of the Figure Eight on a Bight is double the size of the Bowline. Sometimes this is not a huge issue, but when working under a high directional, using ½" rope, every bit of working space counts.

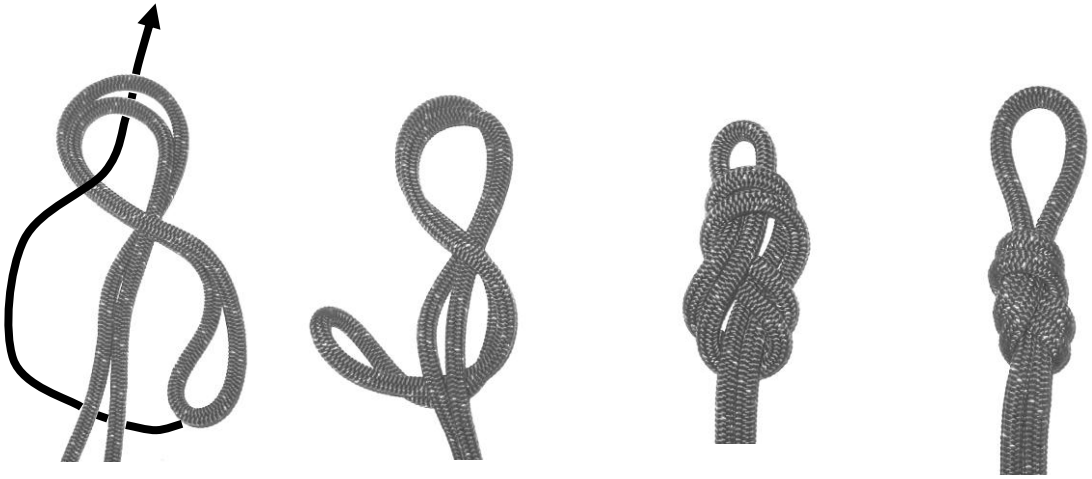
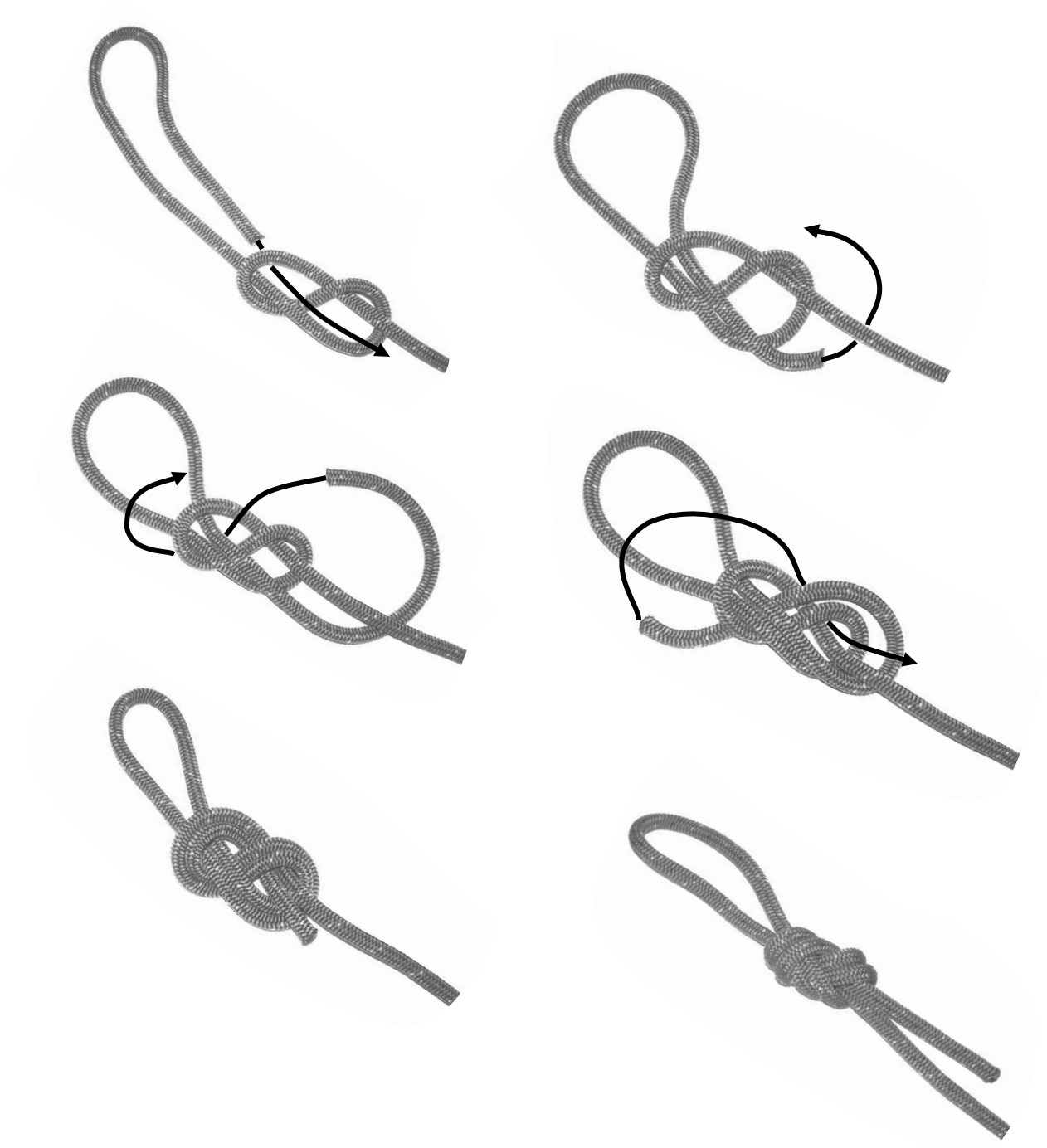


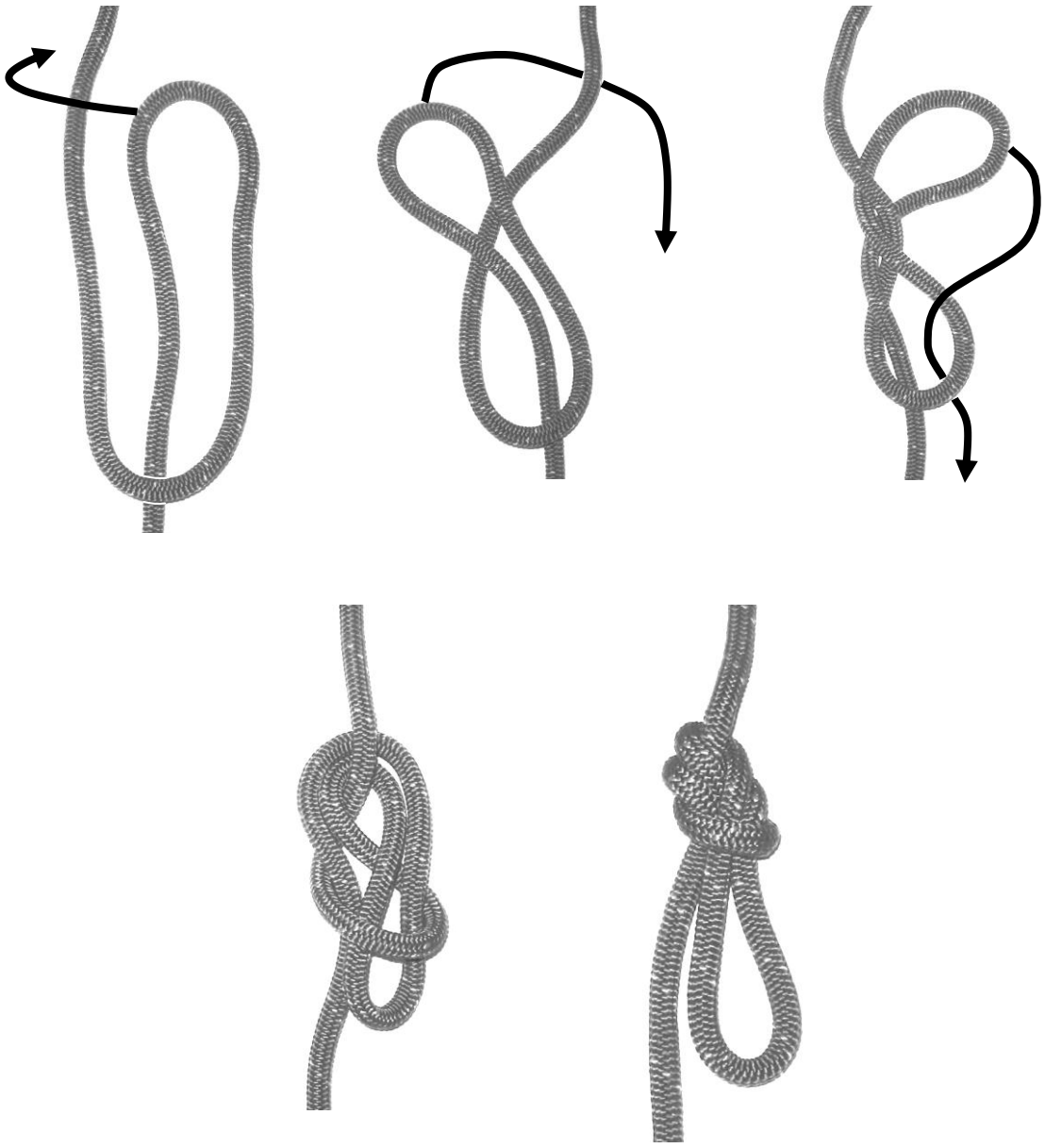
Figure Eight Follow Through

Although the end result of this knot is the same as the Figure Eight On a Bight, the way it is tied and it's function is much different. This knot is typically used when the need is to tie around an object. Care must be taken to correctly retrace the original Figure Eight. As with many knots, this knot is very susceptible to failure if it is not tied correctly.



Directional Eight or Inline Eight

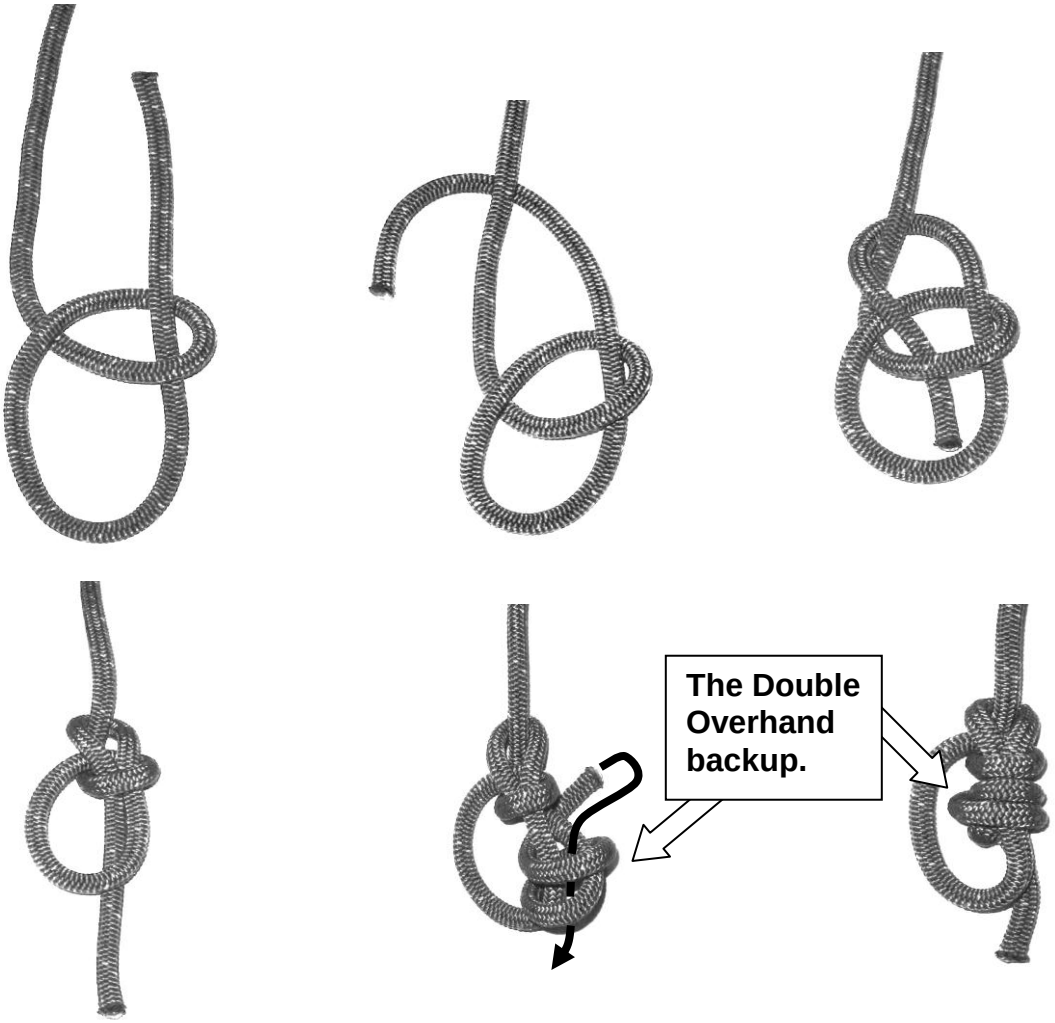
Another knot from the family of eights, the Directional Eight is very useful as the first step of an unequal Two Loop Figure Eight Follow Through (next page). This knot has lost some appeal as a midline knot for me personally because I do not feel it is as functional as the Bowline with a Bight, the Butterfly, and the Clove Hitch. Some of the inherit flaws with this knot is that it is extremely hard to untie after heavy loading, it may capsize if pulled the wrong way, and many people have problems tying it correctly.



The Bowline Family

The *Bowline* is the most versatile knot in rope rescue. Although not quite as strong as the “Figure Eight on a Bight” the *Bowline* is a strong anchor knot (Keep in mind that the difference in strength between these two knots will not affect the overall efficiency of a rescue system). The *Bowline* does have an advantage in that it is substantially easier to untie.

The *Bowline* is strong under tension, and susceptible to “self untying” when in a relaxed position, because of this fact, I will show two techniques I feel are the most suitable for this purpose, the Double Overhand back-up, and the Yosemite back-up (also known as a retrace).

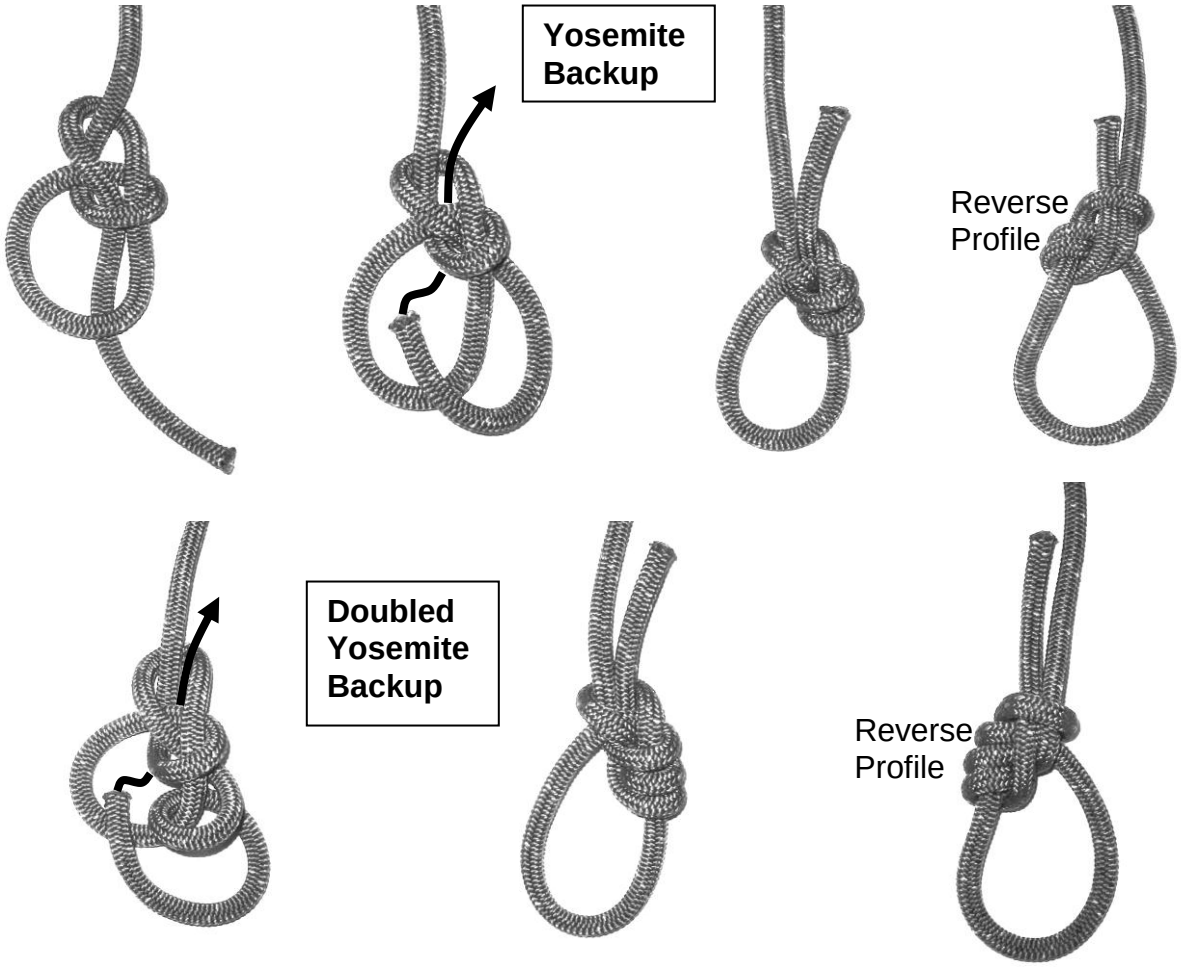


Yosemite backup to the Bowline (Yosemite Bowline)

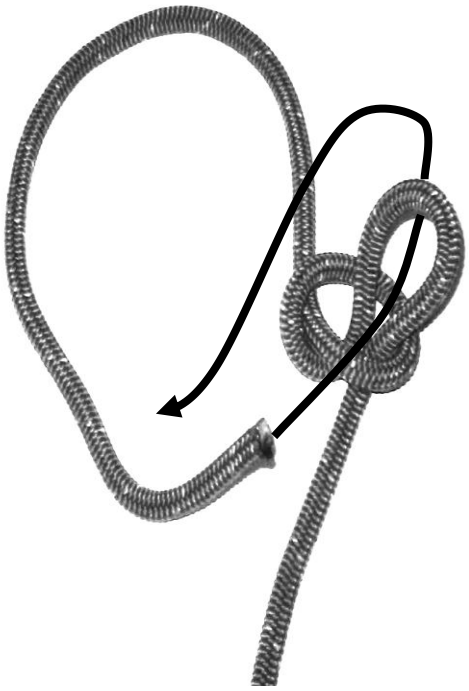
As I stated earlier, the Bowline needs a backup knot. Under tension there are no problems with the Bowline (even with dynamic rope). It is during those times when the Bowline is in a relaxed position that it becomes susceptible to coming undone, mandating a backup. Note, the Double Long Tail Bowline does not require a backup because the long tails that are used as secondary attachments for the rescue package keep the knot from undoing.

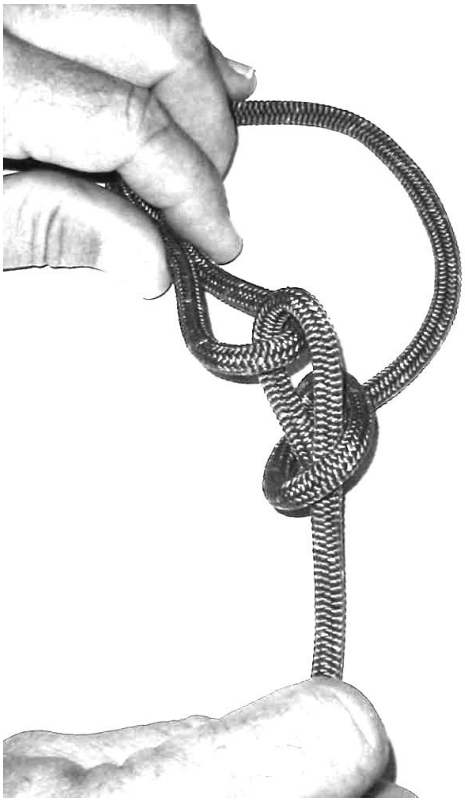
The Double Overhand Backup is the most secure backup (shown on the previous page). The Double Overhand also adds more bulk to the loop of the Bowline; this is what makes the Yosemite backup so popular. It is much cleaner, keeping the loop free, and it is also very reliable.

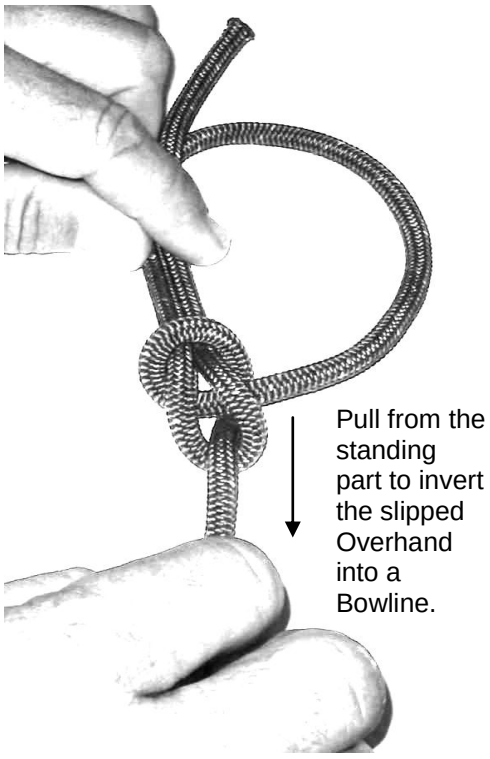
The Yosemite is my favorite backup, but I have noted with dynamic rope and some static rope that even the Yosemite does not completely lock, still giving the bowline a spongy feel and wanting to untie. It is with this type of rope that I will tie a Doubled Yosemite.



Snap Bowline/Climber's Bowline







Snap Bowline/Climber's Bowline

The Snap Bowline, also known as the Climber's Bowline, is nothing more than a nick name that defines a specific way to tie the knot.

This is a graphic example of how the Bowline is an inverted slipped Overhand. Indeed, this method of tying the Bowline takes advantage of this fact.

This technique works well when facing an anchor or an object that you must be tie the Bowline to. It is extremely quick, and makes the initial adjustment of the loop very easy.

The Bowline With A Bight

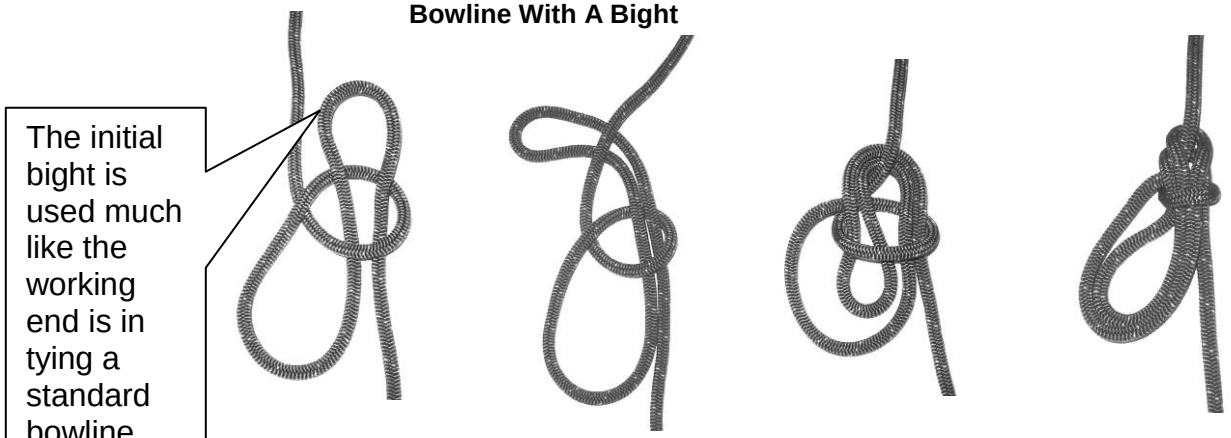
The *Bowline With A Bight* is a great mid-line loop. It is easy to tie, untie, and is very recognizable.

The *Bowline With A Bight* rivals the “Butterfly” for a mid-line loop(s), not as easy to tie as the “Butterfly”, but flows better in the direction of pull.

The *Bowline With A Bight* has all but eliminated The “Bowline On A Bight” because it is definitely more usable, and it has no problem with shearing.

There is the potential for problems if the loop created by the initial bight is pulled in the opposite direction of the intended flow of the knot. The *Bowline With A Bight* may invert and turn into a slipped overhand, because of this, the *Bowline With A Bight* must have a carabiner through both, the main loop, and the loop created by the initial bight, or it must be backed up like the standard bowline.

Bowline With A Bight



The initial bight is used much like the working end is in tying a standard bowline.

The initial bight should not be left unsecured. Either put a carabiner through both loops or finish it with a Yosemite backup.

Using the Yosemite backup for this knot is also a clever way to employ two secure loops pulling in separate directions.

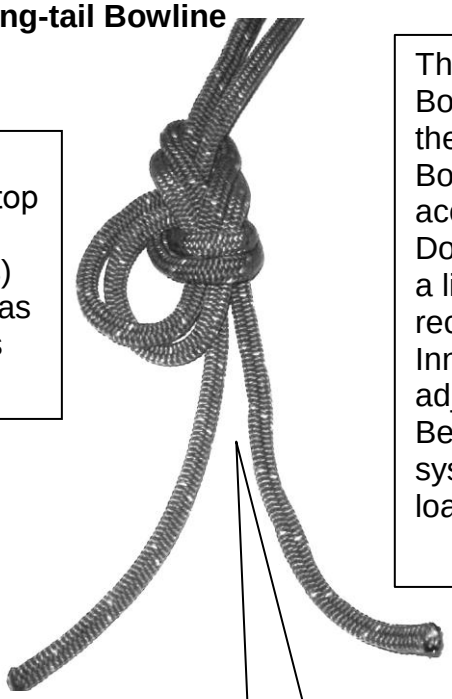
Doubled Long Tail Bowline

The *Doubled Long Tail Bowline* is used in creating the yoke, the culmination point at the rescue end of the main line and the belay line.
The yoke is the point of attachment for the rescue adjunct, i.e. high angle/steep angle litter attachment, and “team based pick-off” rescue package attachment.

The doubled bowline is the adjunct attachment point, and the long tails are secondary attachment points for the rescuer and victim. The long tails may be tied at any length to meet the need of the type of adjunct used.

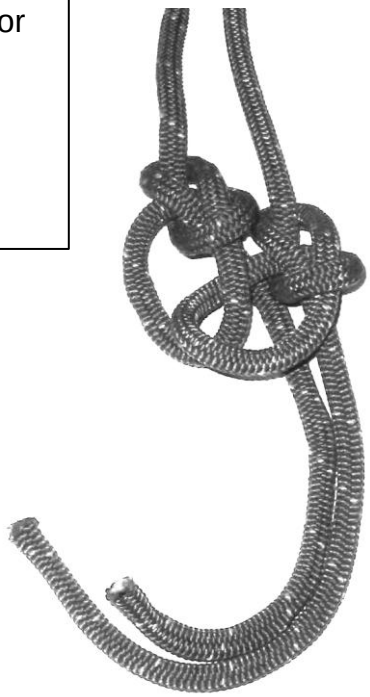
Doubled Long-tail Bowline

Keep the “gain” (the top to bottom dimensions) of the knot as compact as possible.



The Inner-woven Bowline (Also known as the Inner-locking Bowline) is also quite acceptable. I find the Doubled Long-tail to be a little cleaner and more recognizable. Yet, the Inner-woven allows for adjustability of the Belay line after the system has been loaded.

The long tails may be adjusted to meet the secondary attachment needs of the rescuer and victim.

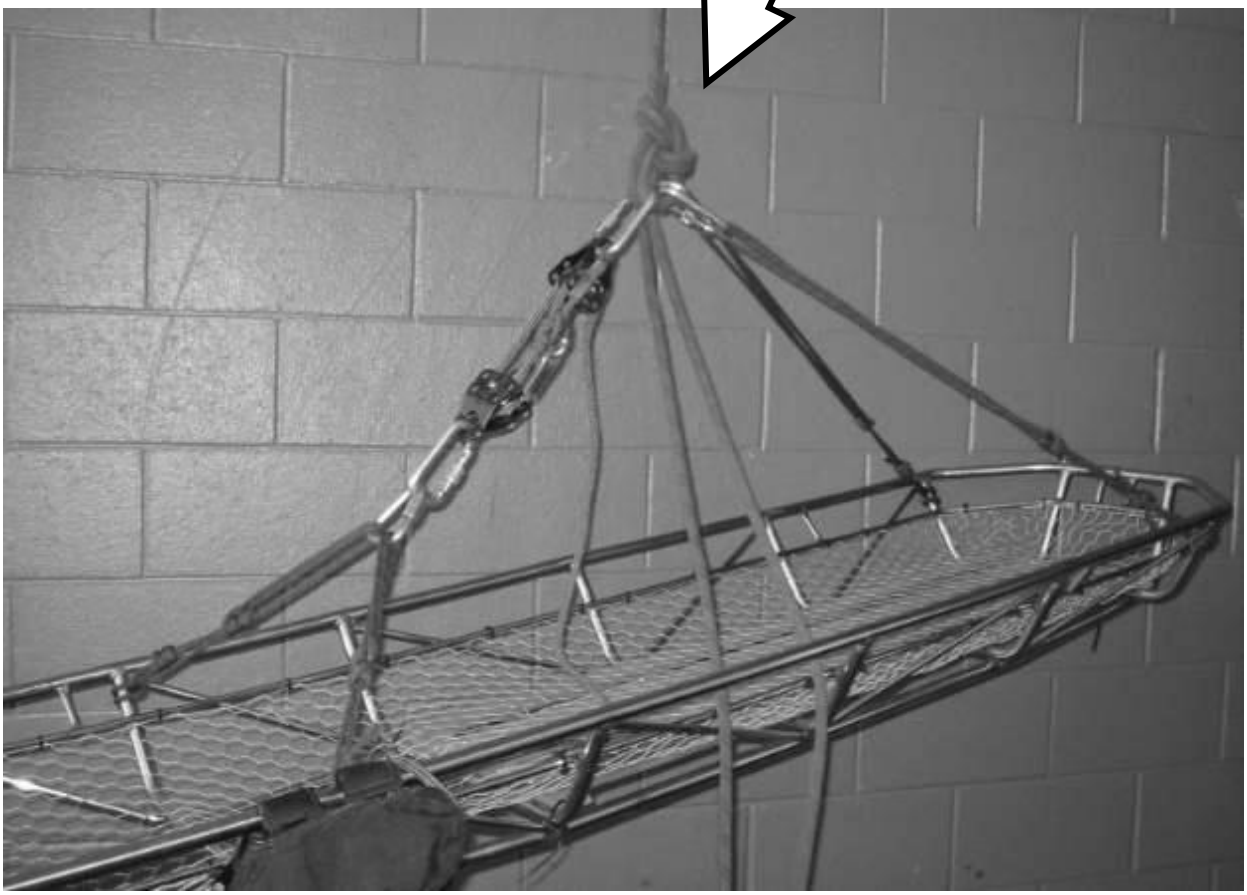


Inner-woven Bowline

The Doubled Long-tail Bowline is the perfect knot for a collection point for team based rescue adjuncts, easily and safely loaded in multiple directions.

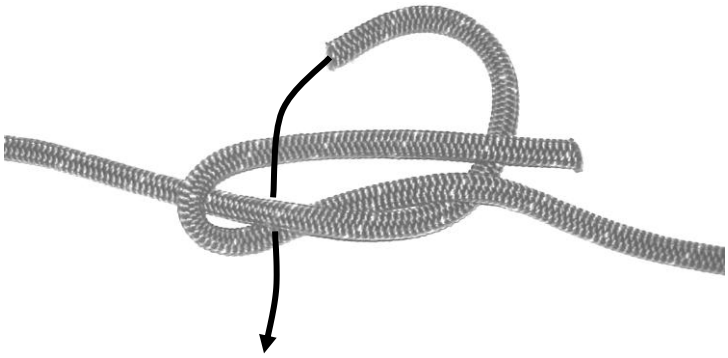
This knot is half the gain of a Figure Eight on a Bight, allowing for added space under a high directional anchor system.

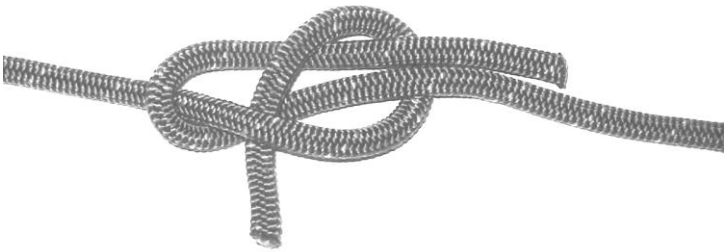
The Bowline is substantially easier than the Figure Eight on a Bight to untie after it has been used for system loads.



Becket Bend
With one good look you can see why the Becket Bend is considered a part of the Bowline Family. It is the same basic formation, with the difference being, the Bowline creates a loop, and the Becket Bend brings two ends of rope together.

As with the Bowline, the Becket Bend is very secure, yet easy to untie after it has been set. Also, (same as the Bowline) the Becket Bend must be backed up when it is used to support a live load.





Double Becket Bend

The Double Becket Bend is a more secure bend than the (single) Becket Bend because of the round turn that captures the bight of the opposite rope. Although many knot experts claim the Double Becket Bend is secure enough by itself, we still maintain the Double Becket Bend needs back-up knots as well.

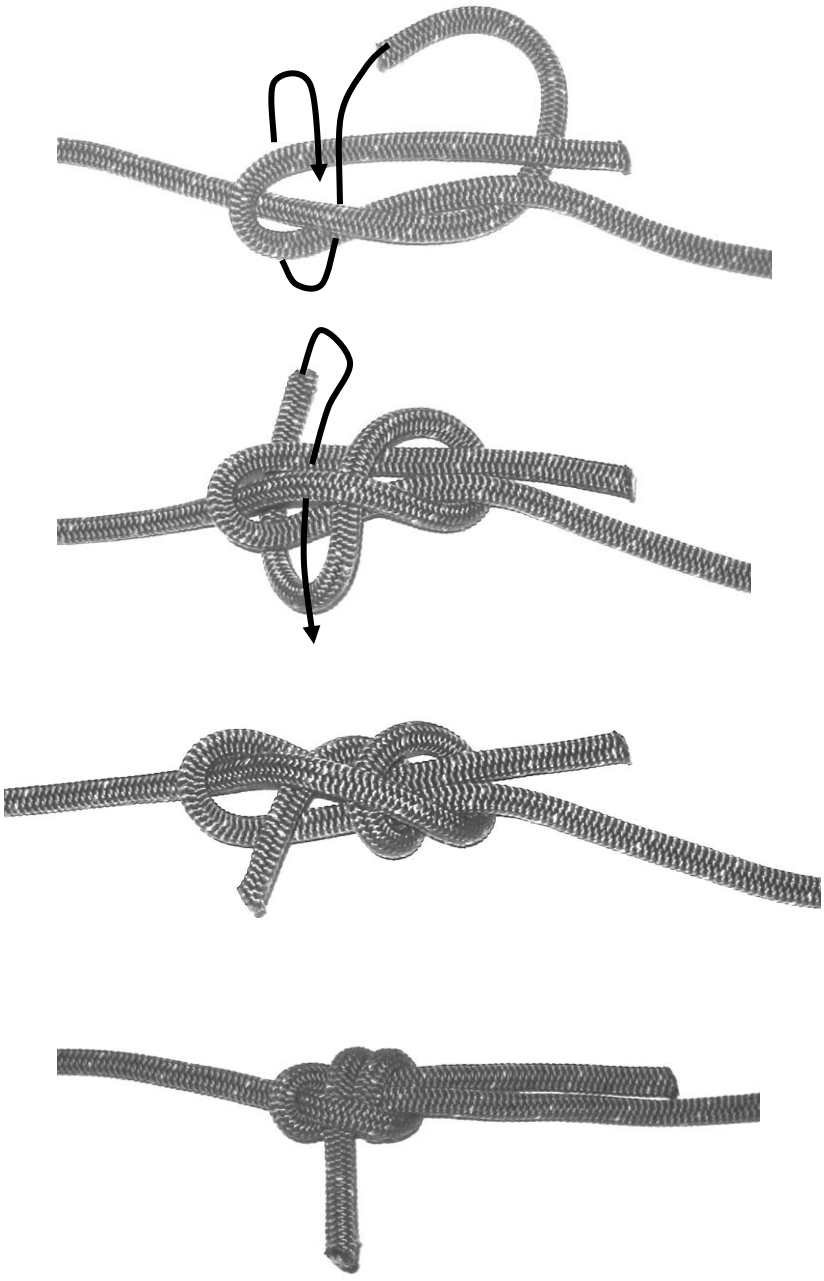
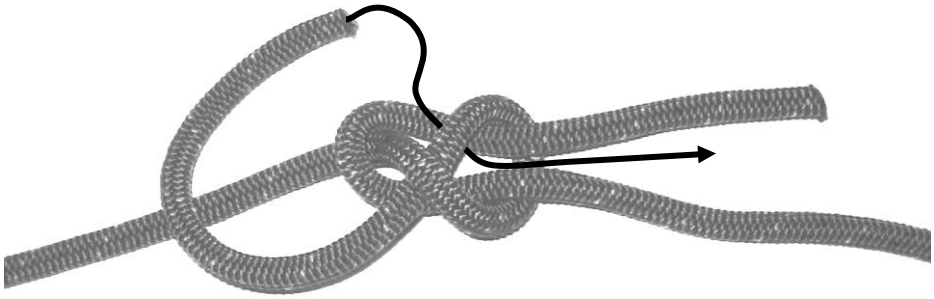
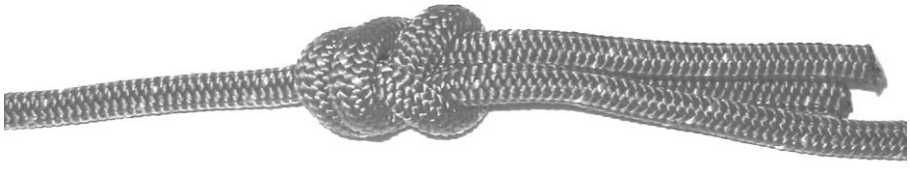


Figure Eight Becket Bend

The Figure Eight Beck Bend is nothing more than a method of backing up the Becket Bend and the Double Becket Bend. It most likely got its name because of the resemblance the back up has to a Figure Eight.

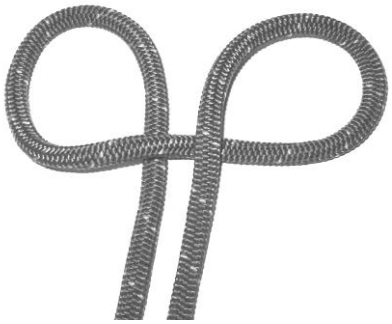


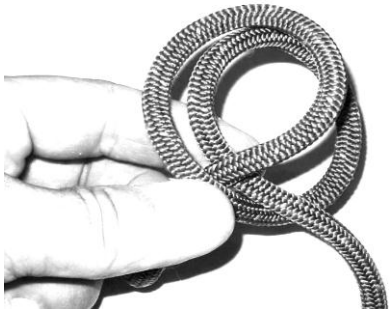


Hitches

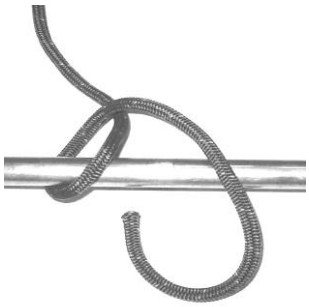
Hitches are a type of knot that, for the most part, is dependent on a host object for maintaining its form and function. When the host object is removed from the hitch, or the hitch is removed from the object, the hitch will come apart.

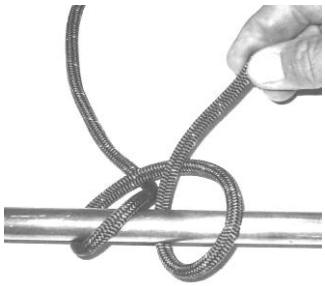
Clove Hitch

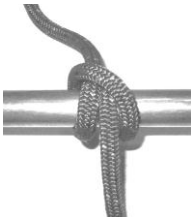




Clove Hitch Tied Around an Object

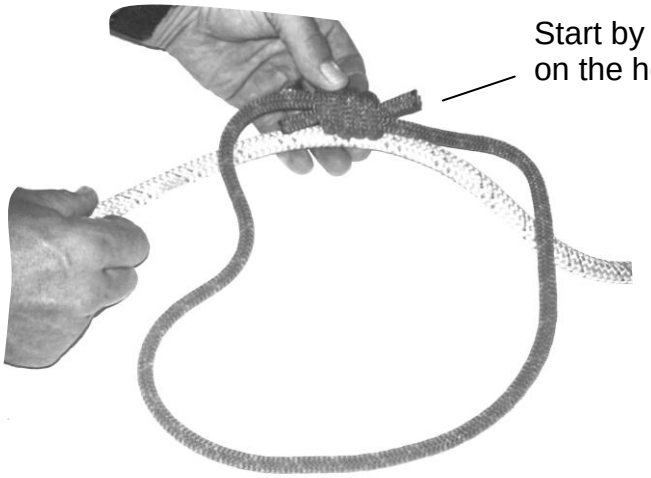




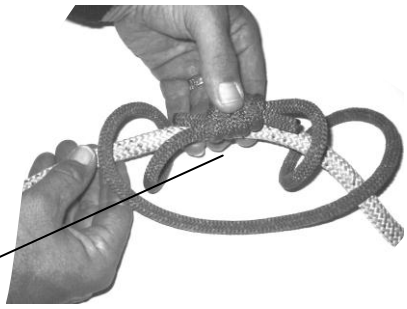


Prusiks

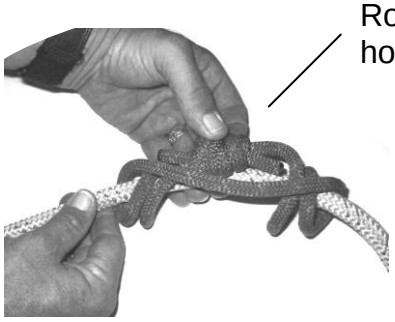
Prusiks, without a doubt, are the most used hitch in rescue work. The Prusik is used in everything from personal attachment points for ascending, to system uses such as Tandem Prusik Belays, and Haul Prusiks for mechanical advantages. The ability to tie the prusik correctly is a must for all rope rescue personnel.

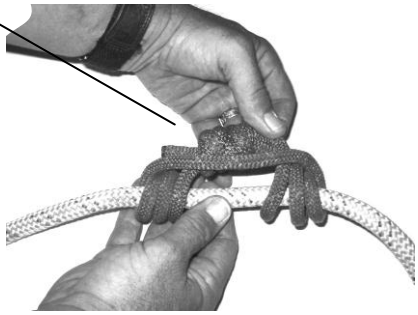


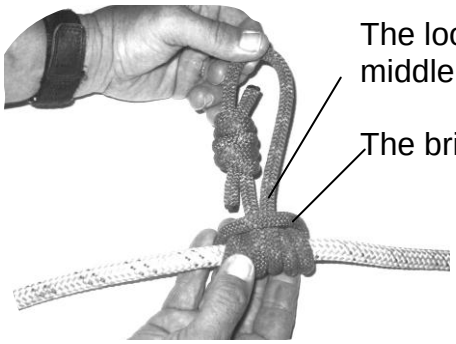
Start by placing the bend on the host rope.



Roll the bend around the host rope three times.







The loop should originate from the middle of the knot.

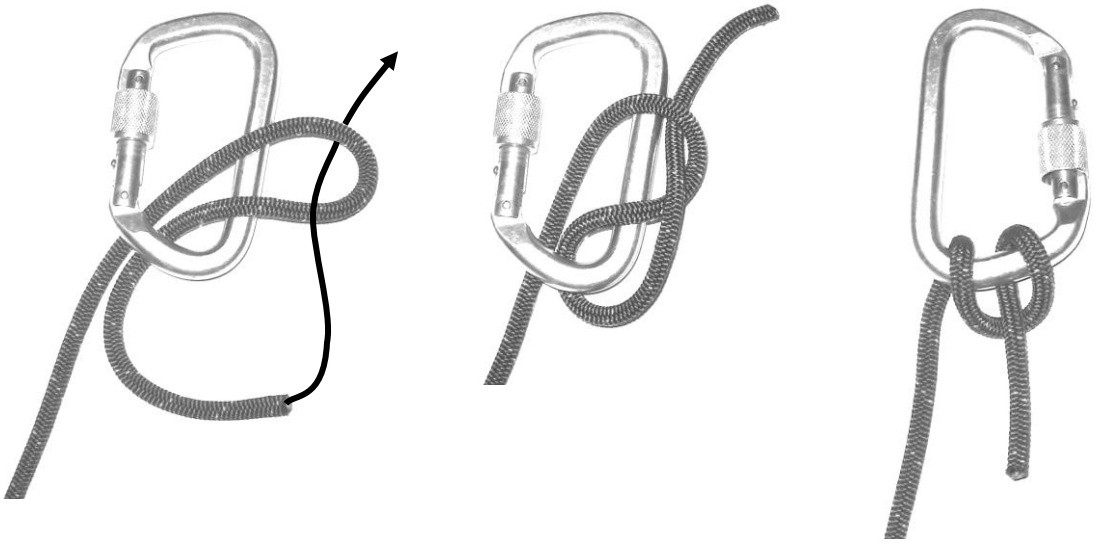
The bridge should run end to end.

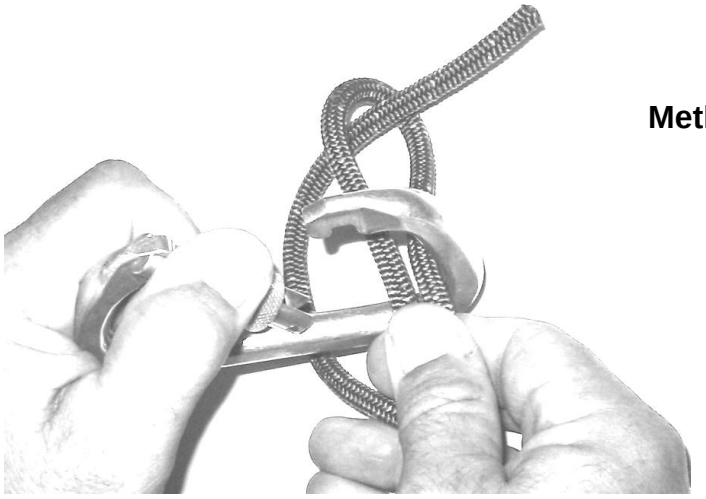
Dress the prusik and offset the bend to one side of the loop.

Munter Hitch

The “Munter Hitch” may be used as a single person belay, it is also an important part of the Load Releasing Hitch.

Method 1

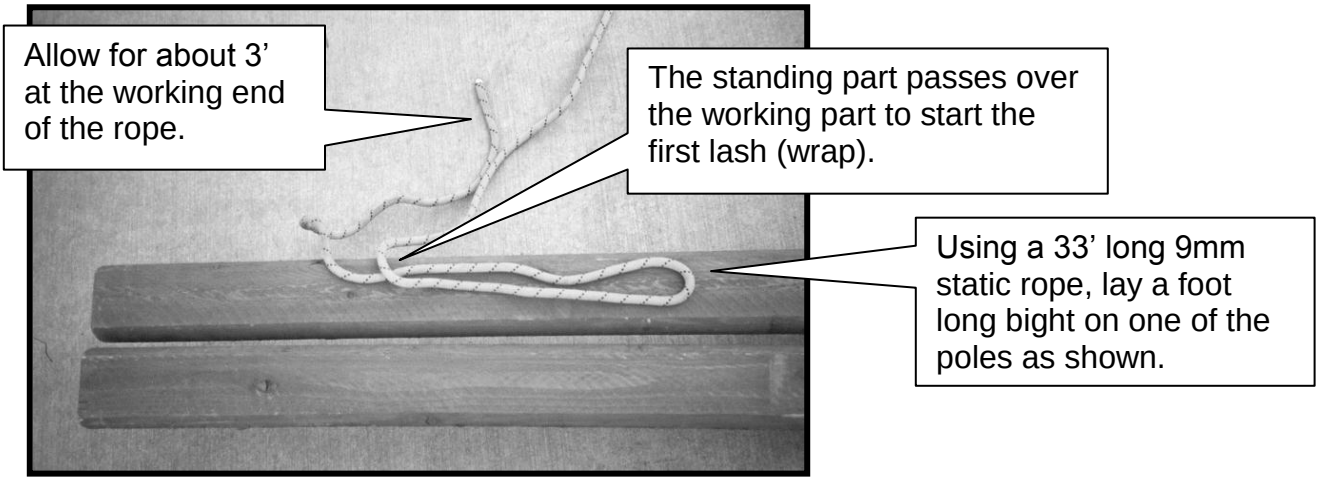


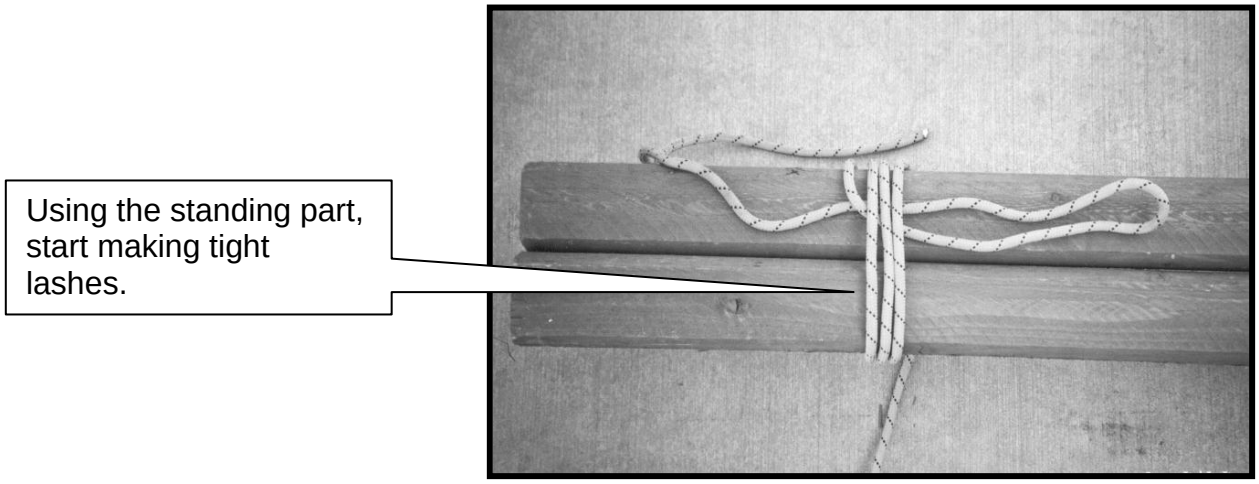


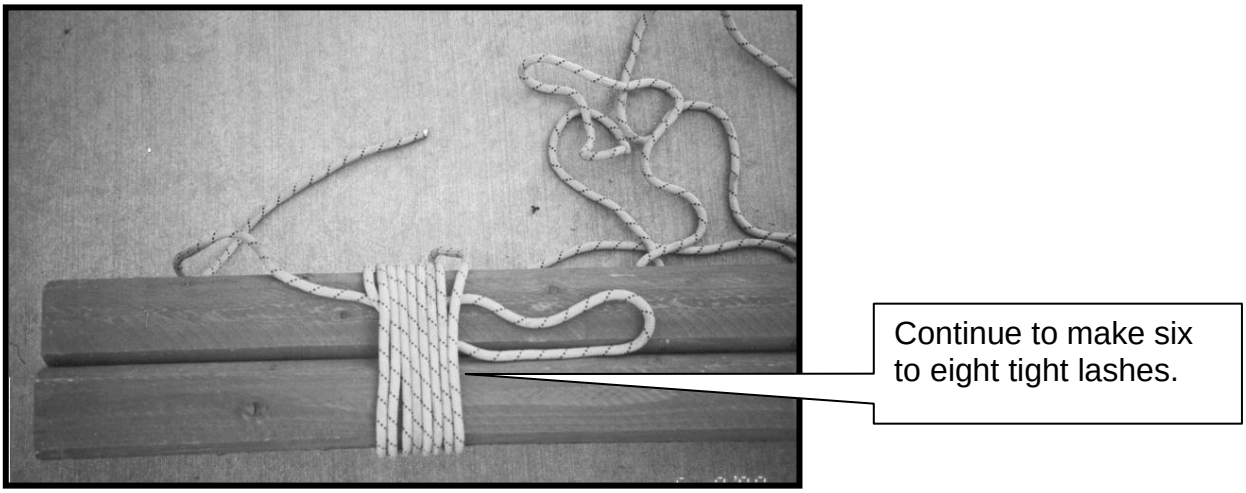
Method 2

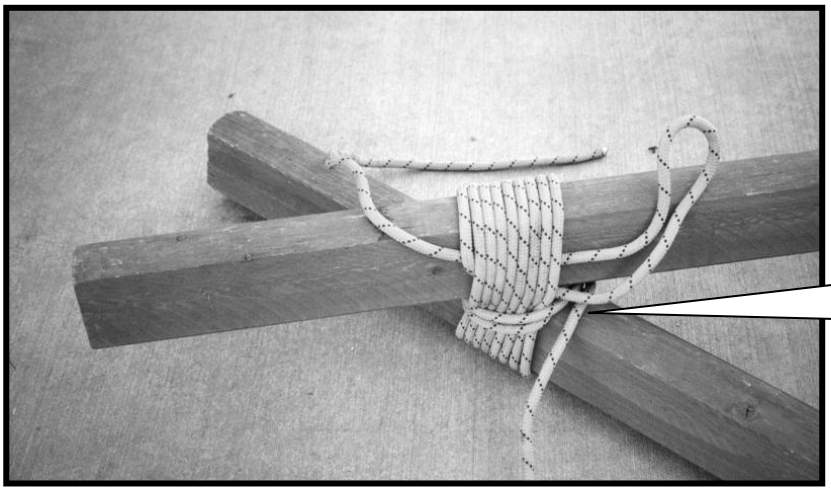
Lashing and Frapping

Lashing and frapping is an important knotting skill in the construction of high directionals, typically seen in conjunction with “A” frames.



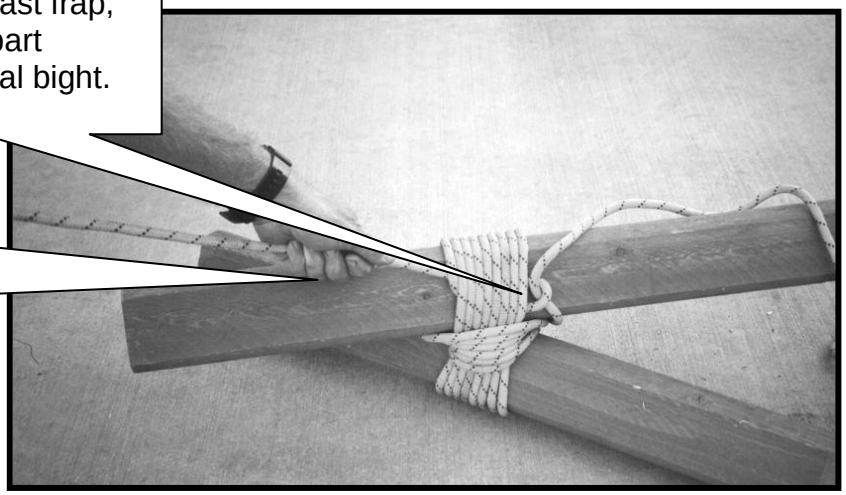




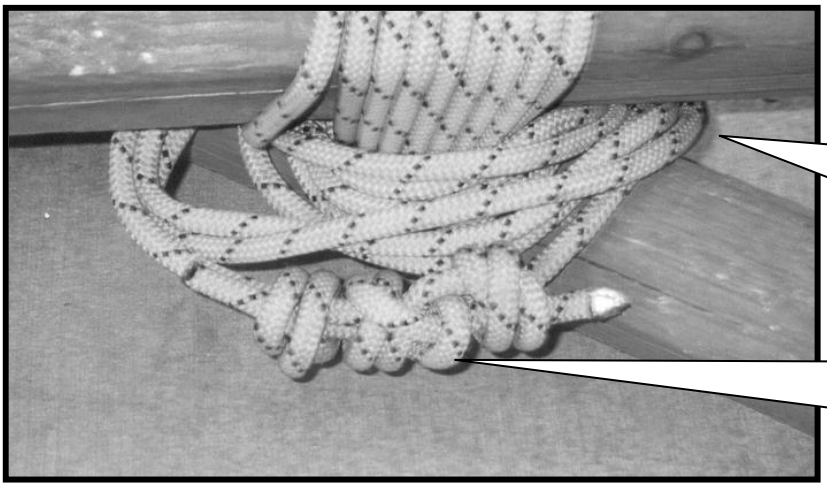


Open the poles, and start making six fraps (the middle wraps of the system).

After making the last frap, put the standing part through the original bight.

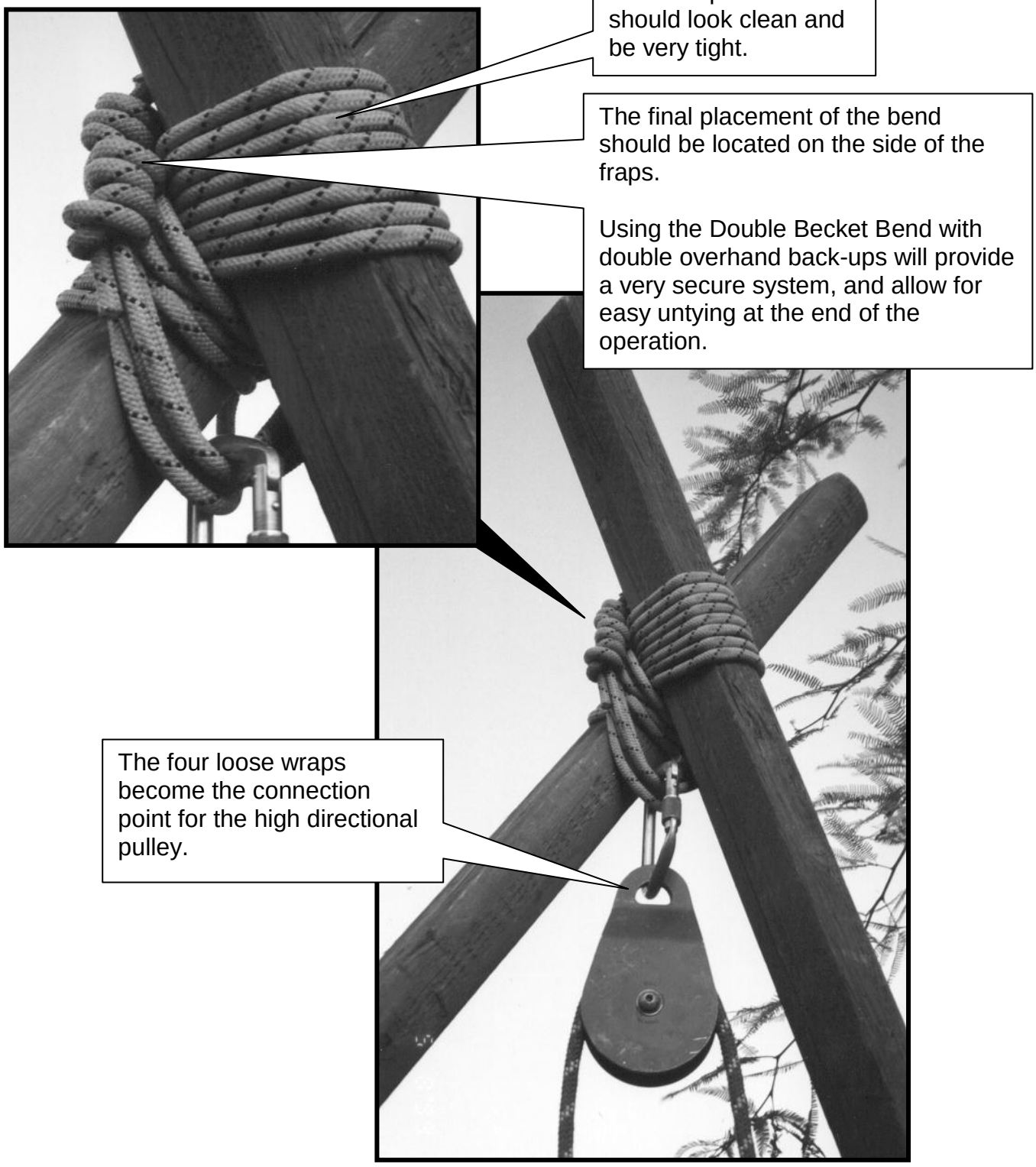


Lock the standing part by pulling the working end, and jamming the standing part behind the lashes.



With the remaining rope, take the two ends and loosely wrap them in opposite directions (There should be about four loose wraps.)

Finish the two ends by tying a Double Becket Bend and back each end with a Double Overhand.


The final product should look clean and be very tight.
The final placement of the bend should be located on the side of the fraps.
Using the Double Becket Bend with double overhand back-ups will provide a very secure system, and allow for easy untying at the end of the operation.
The four loose wraps become the connection point for the high directional pulley.

Definitions

- **Accessory Cord –** Any low-stretch cordage [rope] made from nylon, Spectra, or Kevlar fibers and used for any number of purposes. Generally, any cord smaller than 9mm is considered an accessory cord.

- **Active Protection –** Rock climbing protection (camming devices) which have moving parts as part of the camming mechanism. Spring-loaded camming devices are considered “active”.

- **Air Monitoring –** Those actions needed to insure atmospheric safety during a confined space emergency through the use of specialized monitoring equipment. Air monitoring is the single most important diagnostic tool used in making a confined space emergency atmospherically safe. Ventilation is the prescribed treatment. Air monitoring must continue during the full extent of the rescue and must work in harmony with the ventilation sector. The areas of primary concern are:
    1. The opening of the space.
    2. The source of air being supplied to the space.
    3. The air being drafted from the space.
    4. The interior of the space (personal monitors on the entry team).

- **Anchor –** Any means of attaching the rope to an object. It may be a natural anchor such as a tree or rock formation, or an artificial anchor provided by the rescuer, such as a bolt or rock protection.

- **Anchor Types:**

    1. *Single Point” Anchors:*

    Anchors that originate from one location, such as a pole, tree, bolt, etc. A single point anchor may be bombproof or may be a marginal component of an anchor system.

    2. *Tensioned Anchors:*

    Anchors working in harmony by virtue of a back-tie system system.

- **Hard Ascender –** Hardware camming devices which grip the rope in one direction.

- **Belay System –** Protection against a fall by handling a secondary unloaded rope (belay rope) in such a manner that is may be taken in or let out yet can be secured to hold this load in case of failure of the working line or rappel line.

- **Bolt –** Artificial, reliable means of anchoring in rock requiring the drilling of holes and the placement of bolts.

- **Brake Rack –** A friction device used for rappelling or the safe control of lowering systems. Typically, the brake rack employs multiple friction bars held in place by a steel frame. The friction bars are capable of collapsing or loosening around the rope, therefore providing the needed friction for the safe control of the descent.

- **Carabiners –** Hardware used for the purpose of connecting any two points of a given rope system. Carabiners typically employ a self-closing, gate as apposed to other connecting hardware that employ manually operated screws that close the opening, see screw-links and tri-links.

- **Change of Direction Pulley –** A change of direction is a pulley on the anchor that directs the last leg of rope to the haul team, notated (cd).

- **Compound Mechanical Advantage Pulley System –** Any pulley system that is made up of two or more simple pulley systems. Example; a compound 6:1 could be a 3:1 pulling on the end of a 2:1, or a 2:1 pulling on a 3:1. The simple components are multiplied to give the compound mechanical advantage.

- **Cordelettes –** Typically, a small rope, typically 8 mm or 9 mm, and approximately 10 meters long, used for rigging. Example; small pulley systems, whipping and frapping, etc.

- **Critical Point Test –** A test rescue teams use to determine the inherent safety within a rope rescue system. In order to pass the Critical Point Test, a system must have no point or single piece of equipment which, were it to fail, would cause catastrophic failure of the entire system.

- **Directional Pulley –** A directional is a pulley or pulleys between the pulley system and the load to be raised, notated (d) or (1:1)

- **Dynamic System Safety Factors (DSSF) –** In a dynamic state, (movement and maximum system stress, with a suspended load) the ratio between the load and the weakest link in a system using the rated breaking strength of each piece of equipment in the system and a theoretical prediction of those factors that will add maximum stress to the system. For instance, any part of a given system will only hold 6000 lbs. and the work being placed on the system is 1000 lbs, including approximately 20’ of rope drag at or over the edge, will in effect double the weight of the load on a raising system. The Safety Factor would then be approximately only a 3:1. A 7: 1 Dynamic System Safety Factor is a realistic goal when a belay rope is present.

- **Ganged Mechanical Advantage Pulley System –** When a separate rope used for a MA system is attached by a haul grab to a second main rope for the purpose of lifting or lowering a load.

- **Hardware –** Those components of a rope system that are made of metal.

- **Haul Field –** The haul field is the available distance a hauler or haulers can run out or the space that they have to stand and pull.

- **High Directional –** A means of suspending a loaded rope at least 2 meters above the edge so that edge trauma is reduced. There are structural, natural and artificial high directionals.

- **Horizontal Systems –** Any adjunct rope system that is employed for the purpose of changing the original direction of the mainline and belay line systems.

- **Loaded Changeover –** Those actions needed to convert the mainline from a lowering system to a raising system while the load is suspended and under tension.

- **Litter –** A device used to contain a patient and maintain stability during the extrication process.

- **Lockout/Tagout –** Those actions needed to bring all potential hazards, typically electrical, mechanical, and engulfment, to a neutral state prior to the beginning of any rescue.

- **Mainline –** Also known as the Working Line, it is the main rope system used to do the lowering and raising of the rescue package.

- **Mechanical Advantage –** The increase of the input of power for the purpose of moving objects, typically during rope rescues, this would most often include the use of pulley systems.

- **Multipoint Anchor System –** Any combination of point anchors that are employed to make one reliable anchor. The following are the two major divisions of multipoint anchor systems:

    1. *Self Distributing: (Also known as Self-equalizing)*
    A multipoint system rigged to where the force of the load is distributed between all the point anchors. Due to friction and many other unseen factors, this distribution is not as equal as most would assumed.

    2. *Fixed Multi-point: (Also known as "Load Sharing")*
    A multipoint anchor system which is distributing during the construction of this anchor and is than fixed into place, typically by virtue of an overhand loop.

- **Passive Protection –** Rock climbing protection which has no moving parts (as opposed to active protection, which does). Examples are stoppers, hexcentrics, and tri-cams.

- **Patient Packaging –** Patient packaging is the act of getting the patient ready to be evacuated.

- **Personal Loads –** Any load equal to a single person.

- **Piggyback –** A piggyback system is a compound MA that is made up of two or more ***identical*** simple MA's. i.e. a compound 4:1 (2:1)(2:1).

- **Pulleys –** A small grooved wheel used with a rescue rope to change the direction and point of application of a pulling force. They may be used in combinations to employ mechanical advantage especially for the purpose of a raising operation.

- **Rappelling –** The act of descending a fixed rope system in a controlled manner for the purpose of vertical transportation.

- **Ratchet –** A progress capture device employed for the sole purpose of holding the load in place during the reset phase of a raising operation.

- **Reset –** Action taken to re-extend the pulley system for another haul after it has fully collapsed during a raising operation.

- **Rescue Load –** As determined at the Forth Annual Technical Rescue Symposium, 1987, a rescue load is considered to be 200 Kg, 448 lbs. It is the weight of one victim/patient, one rescuer, and associated gear.

- **Risk/Benefit Analysis –** A command decision that determines the type of action needed based on the hazards present and the risk they pose to the team and the victim.

- **Rope –** Typically, kernmantle rope is the most common rope used for rescue operations. (Because of its floating properties polypropylene is sometimes used in swiftwater rescue.) Kernmantle rope is constructed of a load-bearing core, or "kern", of nylon fibers surrounded by a braided, protective outer sheath, or "mantle". The core is completely protected by the mantle and holds most of the load. It has a high strength to weight ratio, and maintains most of its strength when wet (approximately 85%). Kernmantle rope comes in two types; Dynamic and Static.

  Dynamic rope consists of twisted or bundles that make up the core. This twisted core provides a high stretch quality. This allows as much as 40% stretch in the rope, depending on the manufacturer. Dynamic rope is very important in rescue work solely for the purpose of belaying a lead climber.

  In contrast, static kernmantle rope stretches very little, from 2-4% under load. This type of rope is made from an outer braided sheath (mantle) which is woven over straight nylon fiber core (kern). The core supports 85% of the rope's strength.

  "Static" kernmantle rope is used for rigging rescue system because of its high strength, low stretch and handling characteristics.

- **Rope Grabs –** Any device attached to a rope for the purpose of holding or grabbing, may be software or hardware.

- **Screw-links –** Hardware connectors that employ a manually operated screw to close and open the gate.

- **Size-up –** The initial evaluation of the emergency scene by the first responder.

- **Soft Ascenders –** Any number of rope hitches which grab the rope in one or both directions.

- **Software –** Any rope system component that is either rope, webbing, or is constructed of rope or webbing.

- **Static System Safety Factor (SSSF) –** In a static state, (no movement, with a suspended load) the ratio between the load and the weakest link in a system using the rated breaking strength of each piece of equipment in the system. For instance, any part of a given system will only hold 5000 lbs. and the work being placed on the system is 1000 lbs.. The Safety Factor is then 5: 1. A 10: 1 Static System Safety Factor is a realistic goal when a belay rope is present.

- **System Loads –** See “Rescue Loads”.

- **Throw –** The throw is the available distance between maximum pulley system extension and the need for a reset.

- **Tri-links –** Triangle shaped, hardware connectors that employ a manually operated screw to close and open the gate. Tri-links are particularly suited for multiple loading in multiple directions.

- **Webbing –** Widely used by rock climbers and rope rescuers, webbing is a flat nylon software that is relatively inexpensive and extremely strong. Although webbing has multiple uses, it is particularly suited for anchor rigging.

- **Working Line –** Also know as “the mainline”, the working line is the main support rope for the rescue operation.

- **Working Load Limit (WLL) –** A rating that is sometimes used in conjunction with hardware, typically screw-links and tri-links.