Basic Rigging for Rope Rescue

This manual is provided compliments of

Bucks County Community College

Instructor: Roger Tobias

For additional training information contact Bucks County Community College,
Public Safety Training & Certification at 215-340-8417 or 888-BUCKS77

www.bucks.edu/publicsafety

ADMINISTRATIVE DETAILS

- Instructor and student introductions
- Course schedule
  - *Times*
  - *Location*
  - *Outdoor Site*
- Classroom
  - *No smoking*
  - *Restroom location*
- Paperwork

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Referenced Texts & Materials

- CMC Rope Rescue Manual - *James Frank and Jerrold Smith*
- On Rope - *Allen Padgett and Bruce Smith*
- High Angle Rescue Techniques - *Tom Vines and Steve Hudson*
- U. S. Cave Rescue Techniques - *Steve Hudson*
- Rope Rescue Technician Program - *NFPA 1006*

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Course Goals

- *Introduce students to rope, rope hardware, patient packaging and basic haul systems used in various aspects of rescue.*
- *The intent of this course is to provide **BASIC ROPE RIGGING** experience for anyone interested in rope rescue, but also those who don't want to, or are unable to rappel.*

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Student Equipment

- *Note taking materials*
- *Helmet with chinstrap*
- *Clean leather work gloves*
- *Work or hiking boots*
- *Students will need a 20' piece of 1 inch tubular webbing for knot practice*
- ***TURNOUT GEAR IS NOT ACCEPTABLE!***

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Course Objectives

- *Be able to tie the following knots and hitches: Clove Hitch, Bowline, Half Hitch, Double Fishermen, Water Knot, Butterfly, Tensionless Anchor and the Figure 8 Family (5).*
- *Be able to secure a person into a stokes basket.*
- *Participate in a stokes basket handling exercise.*

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Course Objectives

- *Be able to construct and operate a 1:1, 2:1, 3:1 and 4:1 mechanical advantage system complete with safeties.*
- *Be able to move from haul to lower while the system is under tension.*
- *Be able to construct appropriate anchor systems.* (Tensionless Anchor, Wrap 3 - Pull 2, Anchor Strap, etc.)

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Course Objectives

- *Be able to demonstrate, the raising and lowering of a patient in a stokes basket, on a low angle or embankment.* *(The use of a live load is prohibited)*
- *Be able to construct an "A-Frame" from ground ladders to be used for confined space operations.*

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Important NFPA Standards

- **NFPA 1983 –** *Standard on Fire Service Life Safety Rope & System Components*
- **NFPA 1670 –** *Standard on Technical Rescue Operations & Training*
- **NFPA 1006 –** *Standard for Rescue Technician Professional Qualifications*
- **NFPA 1500 –** Eliminated the "use once and destroy" portions of ropes, harnesses & hardware

NFPA – National Fire Protection Association

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Rope Characteristics

Two Basic Fibers

- **Natural Fibers**
  - *Manila*
  - *Sisal*
  - *Cotton*
- **Synthetic Fibers**
  - *Nylon*
  - *Polypropylene*
  - *Polyethylene*
  - *Polyester*
  - *Kevlar*

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Natural Fiber - Manila

- *Grown in Manila in the Philippines. It's a hard fiber that comes from the leaf stems of the abaca plant.*
- *The longest fiber is only as tall as the plant can grow. Usually only 3' long!*

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Natural Fiber - Sisal

- *Sisal fiber is the most common substitute for manila.*
- *Sisal is a hard fiber with about three - fourths the tensile strength of manila.*

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Natural Fiber - Cotton

- *Cotton fiber is used when a soft, pliable rope is needed. The tensile strength is slightly less than that of sisal and considerably less than that of manila.*
- *Cotton rope is most susceptible to physical abrasion and damage.*

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Natural Fiber Rope

Advantages

- ***Lightweight***
- ***Low cost***

Disadvantages

- ***Deteriorates rapidly***
- ***Water damages the fibers***
- ***Severely affected by chemicals/ abrasion***
- ***Low tensile strength***

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Natural Fiber Rope

- ***Natural fiber ropes (manila, sisal and cotton) commonly break due to radius bending!***
- ***After much testing and evaluation, natural fiber rope is no longer accepted for use in life safety applications!***
- ***It is acceptable to use natural fiber rope for utility purposes only!***

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Synthetic Fiber - Nylon

- ***Nylon is one of the best materials used in rope construction!***
- ***It has a high resistance to abrasion, high tensile strength, resistant to moisture & most chemicals.***
- ***Acids and ultraviolet rays will harm nylon after repeated or concentrated exposure.***
- ***Nylon has about three and one-half times the tensile strength of manila rope.***
- ***Nylon works comparatively well when wet.***

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Synthetic Fiber - Polypropylene

- *Polypropylene rope is one of the most lightweight ropes available.*
- *It's resistant to water damage and its ability to float make it popular for water rescue applications.*
- *Polypropylene rope has excellent resistance to rotting, mildew and abrasion.*

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Synthetic Fiber - Polyethylene

- *Polyethylene fiber is made from the same synthetic fiber as polypropylene.*
- *Polyethylene is similar to polypropylene in weight, strength, elasticity and chemical and abrasion resistance.*
- *Polyethylene has no moisture absorption and will float indefinitely.*

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Synthetic Fiber - Polyester

- *Polyester rope is used where a high strength, low-stretch rope is necessary.*
- *It is NOT subject to damage from water, sunlight, most chemicals or moderately high temperatures.*
- *Polyester is also fairly resistant to damage caused by flexing or abrasion.*

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Synthetic Fiber - Kevlar

- ***Kevlar has high tensile strength and heat resistance.***
- ***Improvement is needed in Kevlar's shock absorbing capabilities;* therefore, *the use of Kevlar rope for rescue purposes is limited!***

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Synthetic Fiber Rope

Advantages	Disadvantages
❑ *Resists abrasion*	❑ *Acids & ultraviolet rays can be harmful to rope*
❑ *High tensile strength*	
❑ *Works well when wet*	
❑ *Some resistance to mild chemicals*	

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Rope Construction

Ropes fall into one of two categories:

Static
or
Dynamic

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Rope Construction

- ***Static rope stretches very little. Only 1 - 2 percent under normal loads.***
- ***Dynamic ropes stretch more than static lines both under weight and shock loads.***

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Rope Construction

- **The most common types of rope construction are:**

Laid (Twisted) Rope
Braided Rope
Braid-on-Braid Rope
Kernmantle Rope

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Laid (twisted) Rope

- ***Twisting a rope leaves all 3 load-bearing STRANDS exposed to abrasion at various points along the rope.***
- ***Although this exposure allows for easy inspection, it also means that any damage will IMMEDIATELY affect the ropes strength!***

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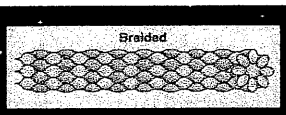
Laid or Twisted

Constructed by twisting individual fibers together to form strands or bundles. These strands (3) are then laid or twisted together to form the finished rope.

Braided



Constructed by uniformly intertwining strands of rope together (similar to braiding a person's hair)

~~Some natural fiber, but mostly synthetic~~

Resists twisting under a load

All load bearing strands are exposed and subject to direct abrasion and damage

Braid-on-Braid

Jacketed rope with a braided core and a braided sheath

50% of strength in braided sheath

50% of strength in braided core

Does not resist abrasion well

Sheath may slide along core

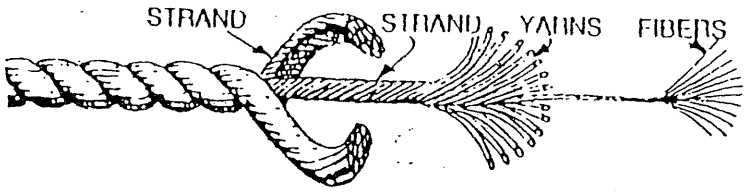


Fig. 2-11. Laid Ropes.

Fig. 2-12. Solid Braid.

Fig. 2-13. Dynamic kernmantle rope. Braided sheath woven over a twisted-strand shock-absorber core.

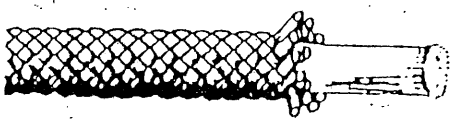


Fig. 2-14. Static kernmantle. A protective sheath woven tightly over a load-bearing parallel-fiber-bundle core.

Kernmantle Rope

- **DYNAMIC KERNMANTLE** - *is most commonly used as a sport rope for rock or ice climbing!*
- **STATIC KERNMANTLE** - *is most commonly used as rescue rope!*
  - *Block Creel – All life safety ropes are manufactured with continuous filament fibers that run the entire length of the rope.*

When in use, a rope is commonly referred to as a LINE!

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LIFE SAFETY ROPE

Ropes used for rescue must conform to the standards set forth by NFPA 1983!

NFPA defines life safety rope as "rope dedicated solely for the purpose of supporting people during rescue, firefighting or other emergency operations and training evolutions".

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Rope Care & Maintenance

- *Inspect all ropes after each use.*
- *Inspect the rope visually and by touch.*
- *Inspect the sheath to be certain it is not sliding on the core.*
- *In order to keep records and evaluate data on ropes, you should keep a "Rope Log" detailing all information on each rope.*

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PMI

ROPE LOG

PURCHASED FROM

PURCHASE DATE / /

PO #

SERIAL #

I.D. MARKING

MFG'S LOT #

DATE OF MFG

COLOR

DATE IN SERVICE

ASSIGNED USE

DIAMETER/LENGTH

INSPECT ROPE FOR DAMAGE OR EXCESSIVE WEAR BEFORE AND AFTER EACH USE.
IMMEDIATELY RETIRE ALL SUSPECT ROPES.

date used	location	type of use	rope exposure	date inspected	inspector's initials	rope condition and comments

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toll free 800.282.7673 phone 706.764 1437 fax 706.764.1531 email info@pmirope.com web www.pmirope.com

A typical rope log

ROPE LOG

Rope Type RESCUE Rope Size 200' x ½" Rope # 1

Manufacturer Wellington Puritan Model Static Kernmantle Rope Color Red/White
Purchased From CMC Date 8-16-86 Bag Color Orange

Date	Sign-Out	Response	Use	Possible Damage/Comments	Sign-In
8/16				In SERVICE	DWK
9/1	RW	86-085	Rappel	None	RW
9/2	DWK	Inspection	—	OK	DWK
10/6	Tim	86-087	System Belay	Slipped off Edge Roller	Carl D.
10/7	DWK	Inspect	—	OK - washed + dicked	DWK

FIGURE 5-1

Rope Care & Maintenance

- *Inspect all ropes for any exterior damage such as heat sears - caused by friction, nicks, cuts, fuzziness and for any soft or mushy spots which indicate weak spots.*
- *One way to check Kernmantle rope is to carefully inspect the sheath (mantle) while placing it into its storage bag.*
- *While doing so, place slight tension on the rope and feel for any lumps, depressions, soft or mushy spots in the rope.*

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Rope Care & Maintenance

CLEANING NATURAL FIBER ROPE

- *Natural fiber rope cannot be cleaned effectively since water cannot be used in the cleaning process.*
- *Wipe or gently brush the rope to remove as much dirt and grit as possible.*

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Rope Care & Maintenance

CLEANING SYNTHETIC FIBER ROPE

- *Contact the manufacturer for specific instructions!*
- *Cool water will have less chance of damaging the rope. Avoid any type of bleach and be certain only mild soap solutions are used.*

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Rope Care & Maintenance

- ***Once rope has been washed, it may be dried by placing the rope on a flat, clean, dry surface out of direct sunlight.***

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Cleaning Synthetic Fiber Rope

Two principal methods to clean synthetic fiber rope:

Hand Launder: ***Wipe the rope with a cloth or scrub with a brush and thoroughly rinse.***

Special Rope Washer: ***Some manufacturers make a rope washer that connects to a standard faucet. The rope is fed manually through the washer, thus being cleaned on all sides at the same time.***

When to Replace/Retire Rope

- ***SHEATH WEAR*** – If more than half the thickness of the sheath yarns are broken.
- ***SHOCK LOAD*** – If the rope is subjected to a severe shock load.
- ***CHEMICAL CONTACT*** – If the rope is exposed to fumes or actual contact with any chemicals known to be harmful.
- ***LOSS OF FAITH*** - Did someone else use your rope and you're not sure they took care of it.

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When to Replace/Retire Rope

- ***REDUCTION IN DIAMETER*** - If the rope has places where the sheath necks down to a smaller diameter like an hourglass.
- ***HARD, SOFT or MUSHY*** – If the rope as places that feel harder or softer than the rest of the rope.
- ***AGE*** – If your rope is old and worn out. The number of years rope will last depends on storage conditions, fiber type and usage.

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Rope Do's & Don'ts

DO'S	DON'TS
▪ *Make sure the rope is adequate for the job.*	▪ *Walk or stand on rope.*
▪ *Wash rope often with clean, cold water.*	▪ *Stand in-line with rope under tension.*
▪ *Inspect rope for damage each time you rig it, while in use, and when you bag it up.*	▪ *Allow chemicals to come into contact with rope.*
▪ *Keep life safety ropes separate from utility ropes.*	▪ *Use static rope for dynamic belays.*
▪ *Pad rope at all points of contact to avoid abrasion.*	▪ *Store rope in sunlight.*
	▪ *Overload your rope.*
	▪ *Overheat your rope.*

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Test Strengths for ½" Rope

Blue Water Superline – 9,000 lbs.

PMI (regular & flex) – 9,200 lbs.

Smith Safety Products – 7,600 lbs.

Wellington Puritan – 9,000 lbs.

New England (KM-III) – 10,000 lbs.

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Test Strengths for 7mm Prussik Cord

Blue Water – 2,600 lbs.

Wellington Puritan – 2,000 lbs.

PMI – 3,550 lbs.

New England – 2,200 lbs.

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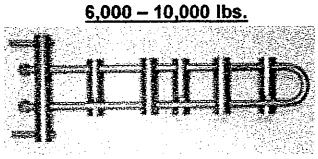
HARDWARE

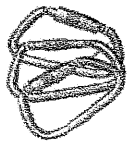
Rope Rescue Hardware

8,000 – 12,000 lbs.

6,000 – 10,000 lbs.



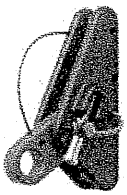
9,000 – 12,300 lbs.



7,000 – 8,200 lbs.

7,000 – 8,200 lbs.

10,500 – 12,000 lbs.



4,500 – 6,000 lbs.

Steel carabiners are made from 12-mm rod stock steel

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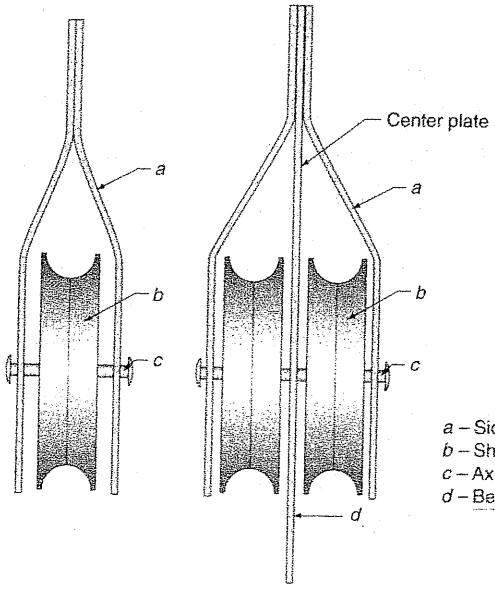
Rope Rescue Hardware



a – Side plates
b – Sheave(s)
c – Axle
d – Becket (on double pulleys)

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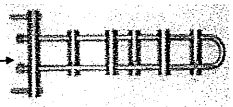
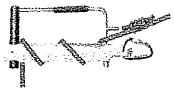
Rope Rescue Hardware

- **Descent Control Devices (DCD's) can be classified in one of four categories:**
  - Eight-Plates 
  - Closed End Brake Bar Rack 
  - Tube Type 
  - Miscellaneous 

The Closed End Rack is the best device for engineering rescue lowering systems.

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Rigged Prussik Minded Pulley

Single Pulley – 7,000 to 8,200 lbs.
8mm Prussik – 2,600 to 3,750 lbs.

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Rope Rescue Hardware

Anchor Straps – 8,000 to 10,000 lbs.
1" Webbing – 4,000 to 5,000 lbs.

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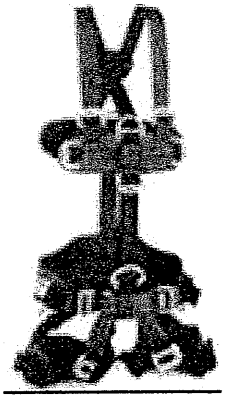
Rope Rescue Harnesses

Class 2



Class 3

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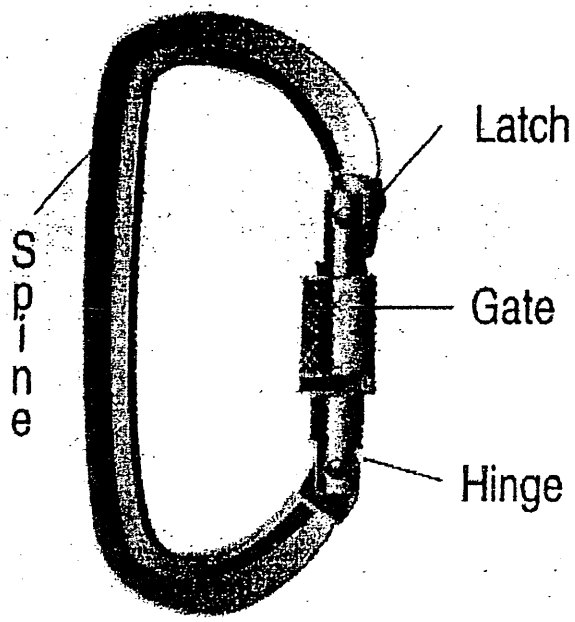
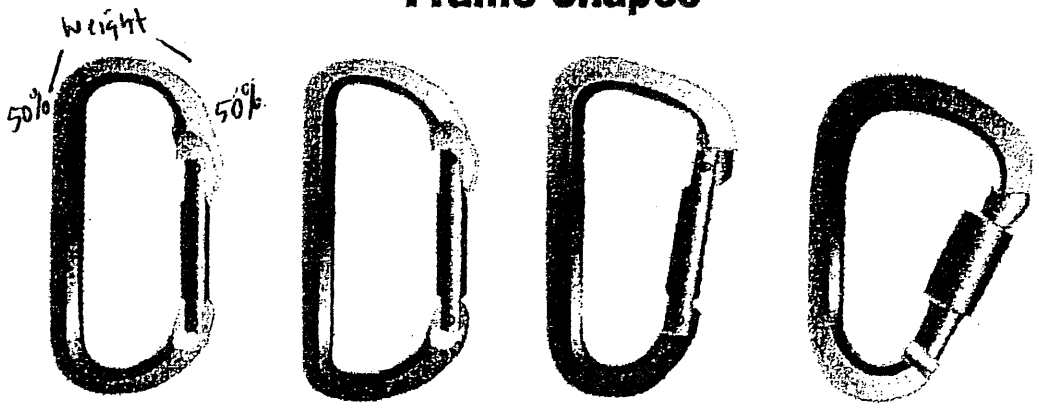
Aspects of the Carabiner



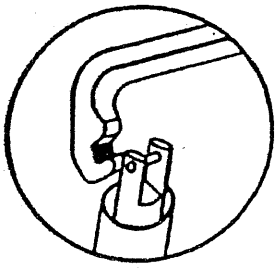
IMPORTANT

Frame Shapes



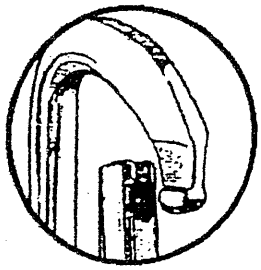
Latch Designs

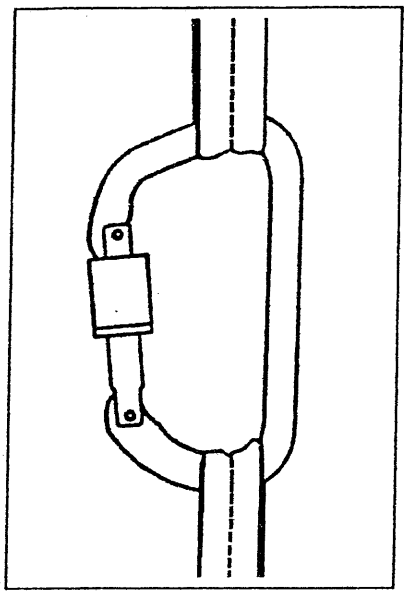
PIN LATCH



CLAW LATCH

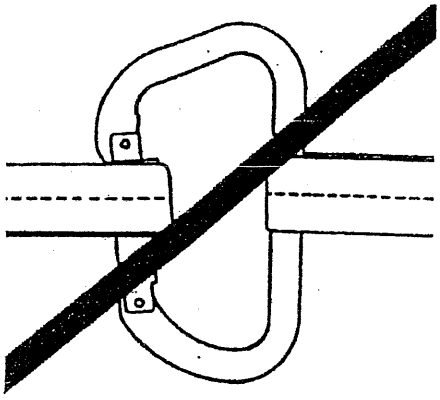
KEY LATCH



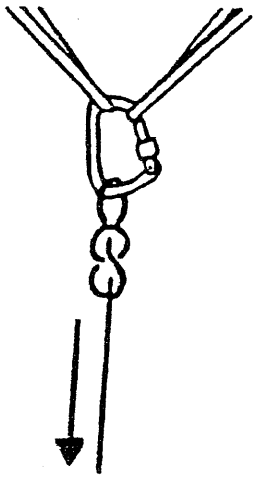


The Correct way to Load a Carabiner

A Crossloaded Carabiner

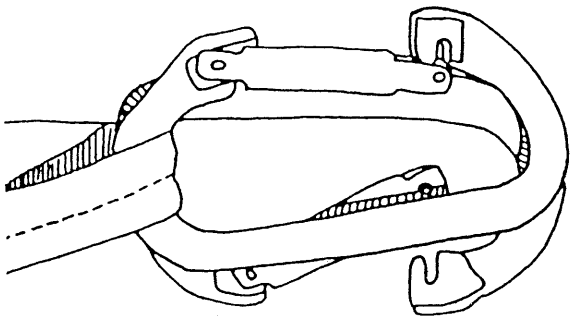


3 Way Loading

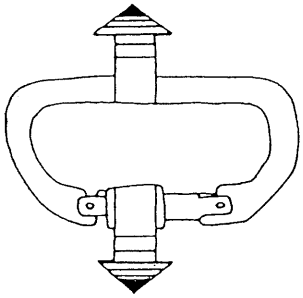


Basic Carabiner Information

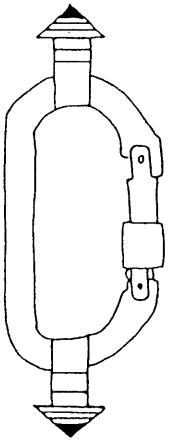
Opposite and Opposed Oval Carabiners



Loading a Carabiner

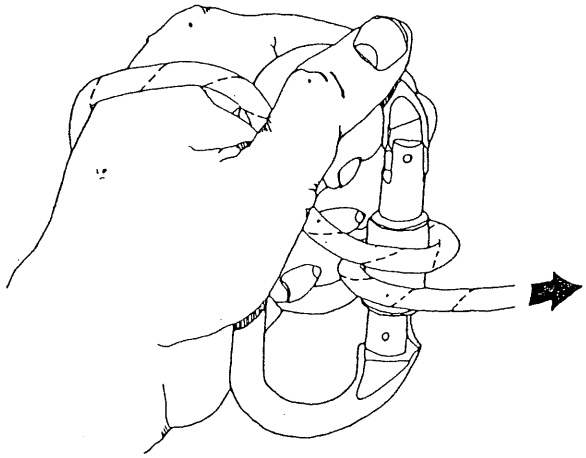


Incorrect and Dangerous:
Load is on short axis.



Correct:
Load is on
long axis.

Using Prusik Rope To Loosen a Stuck Nut



TEST STRENGTHS

The information compiled on TEST STRENGTHS is taken from various Manufacturers Catalogs.

It is recommended that you read the specifications on all ropes and hardware before purchasing and be certain it has a NFPA approval rating.

Basic Knots for Rope Rescue

- A ***KNOT*** is a configuration of bights, loops and round turns.
- A ***BEND*** is a configuration where two ends of the rope are joined.
- A ***HITCH*** is a configuration that is tied around an object. Comes apart when not attached to an object.

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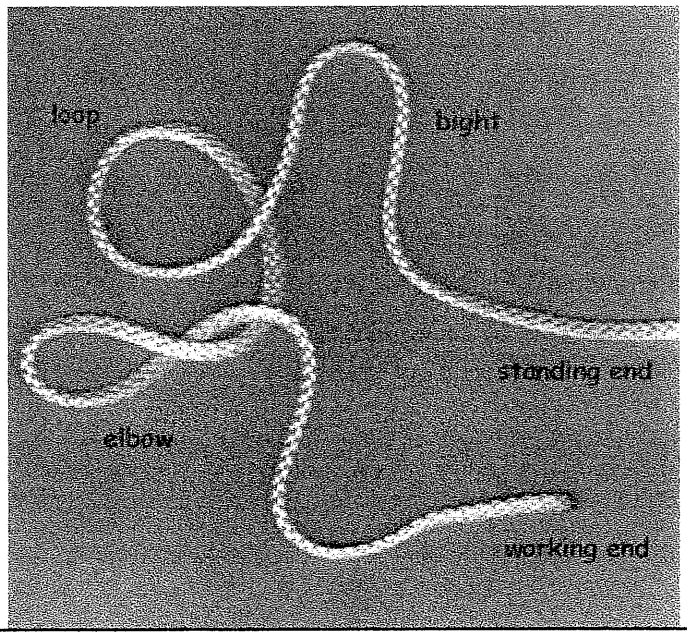
KNOT/ROPE TERMINOLOGY



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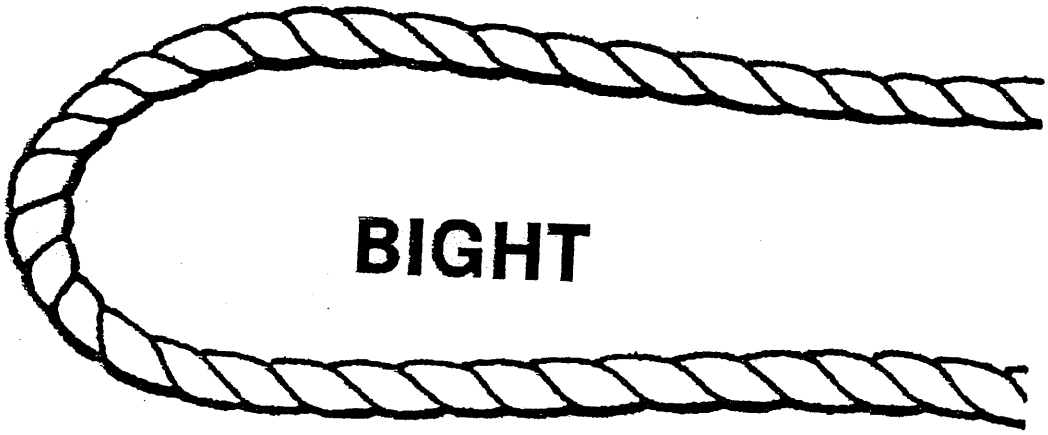
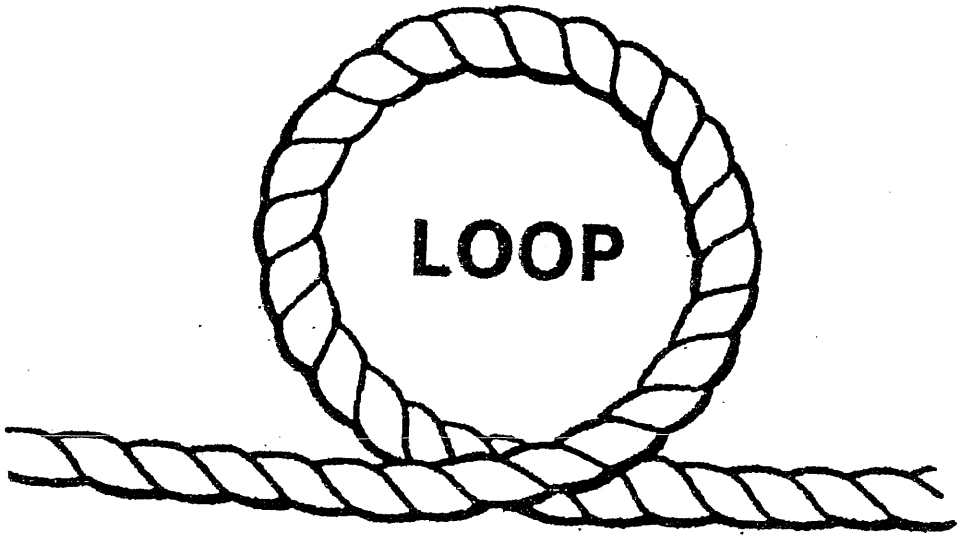
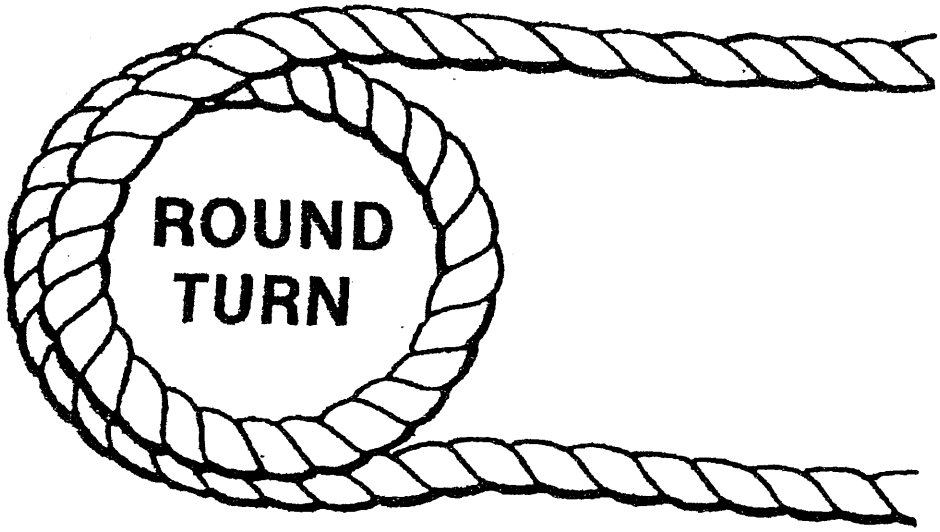

BIGHT


LOOP


ROUND
TURN

Basic Knots for Rope Rescue

OVERHAND KNOT
HALF HITCH
BUTTERFLY KNOT
FIGURE 8 FAMILY (5)
BOWLINE
CLOVE HITCH
WATER KNOT
DOUBLE FISHERMEN
GIRTH HITCH
PRUSIK KNOT

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Knots Weaken a Rope

Fig 8 - 20%
Double fig 8 loop - 20%
Fig 8 on a bight - 20%
Fig 8 follow through - 20%
Fig 8 Bend - 20%
Double Fisherman – 21%
Overhand - 26%
Bowline - 33%
Water knot - 36%

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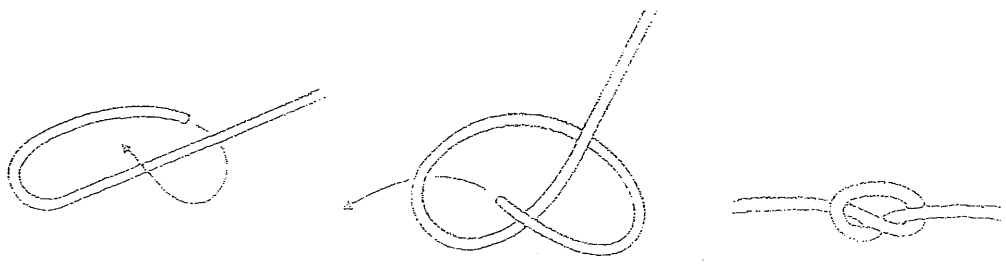
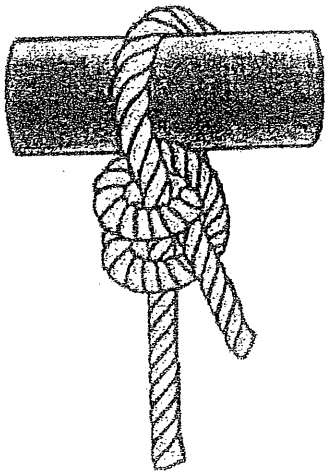
Overhand Knot

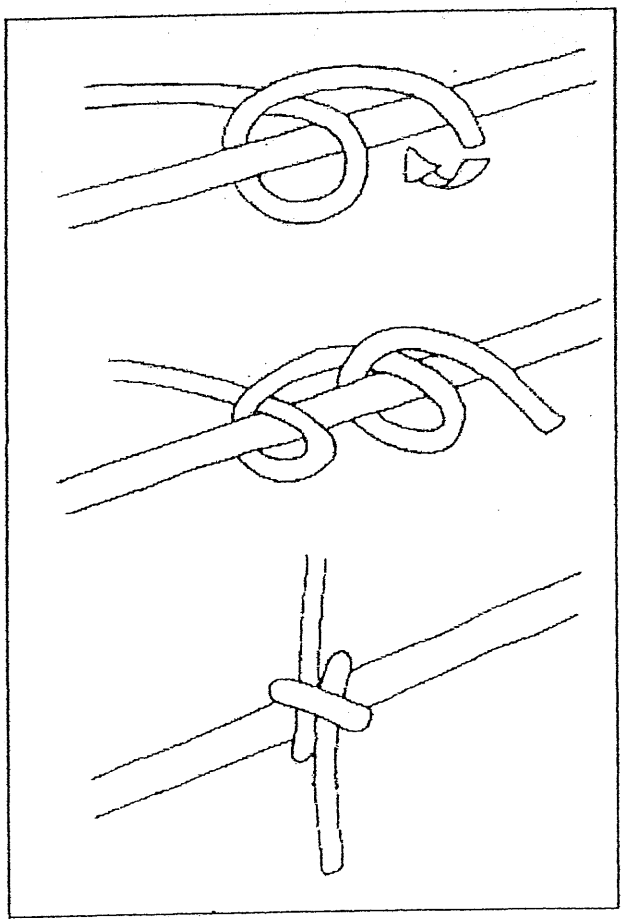


Half Hitch

This is the capsized overhand knot. It is very useful to carry light loads which have to be removed easily. This hitch is also used, in conjunction with the clove hitch to raise and lower firefighting tools.



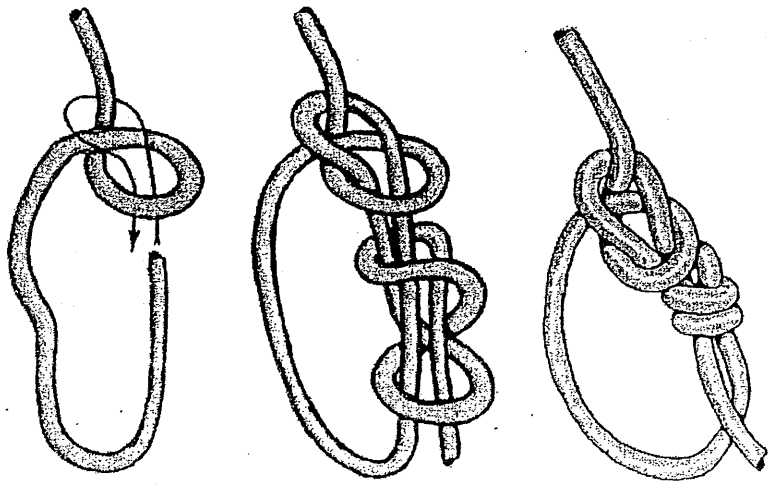
Clove Hitch



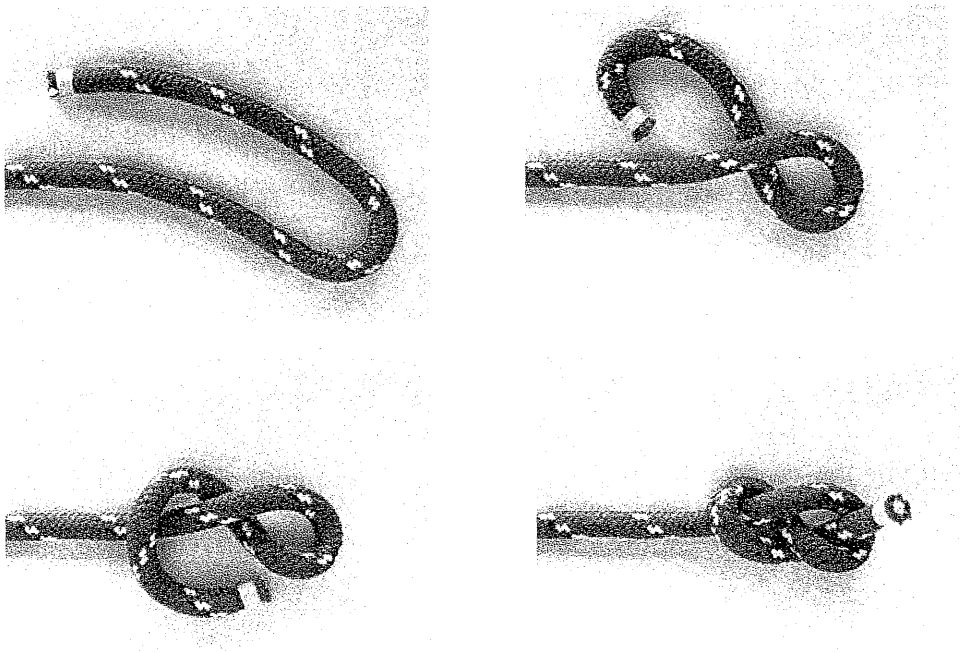
This hitch is probably the most used hitch in the Fire Service. Careful attention should be paid while using the Clove Hitch as without extra support, it is untrustworthy in any situation, except as a crossing knot. It is used extensively for raising and lowering firefighting tools. If you use it, work it up properly; pull length-wise only at both ends before you load the working end.

Bowline Knot

The Bowline Knot creates a loop that will not slip when loaded. Due to its simplicity, security, and its relationship with the Sheet bend, this knot is widely used all over the world. The bowline knot reduces the strength of a piece of rope by approximately 33%. If the loop is expected to be heavily loaded, the bowline is, in fact, not secure enough. There is a rule of thumb which states that the loose end should be as long as 12 times the circumference for the sake of safety a safety is also a good idea.



SIMPLE FIGURE 8



Used as a Stopper Knot at the end of a rope or as a Foundation Knot to tie the Figure 8 Bend & Follow Through.

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Figure Eight Knot

The Figure Eight knot is probably the most useful of all "loop" knots. It is easy to tie, easy to undo after a load has been applied, and puts the least amount of stress on the rope when tied tight. It creates a loop that will not slip and can be tied anywhere in the rope. There are generally two methods used to tie a figure eight knot. The first method is used when a piece of equipment is clipped into the loop and is commonly called a Figure Eight on a Bight, the second when the knot is used to tie into something, like a climbing harness and is commonly called a Tracer Eight. The Figure Eight knot reduces the strength of a piece of rope by approximately 20%. The figure eight can be tied two ways as a bight and as a follow through.

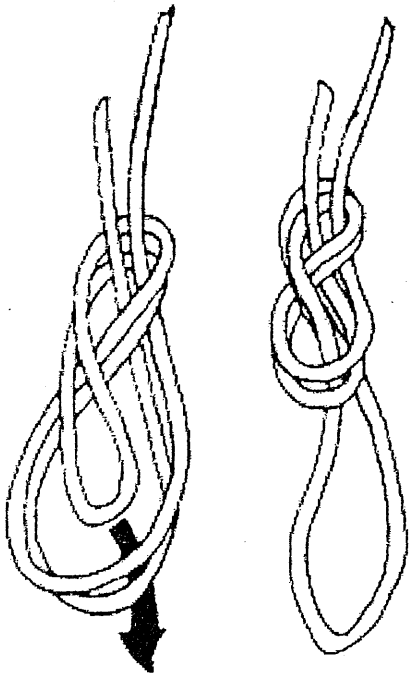


Figure Eight on a Bight

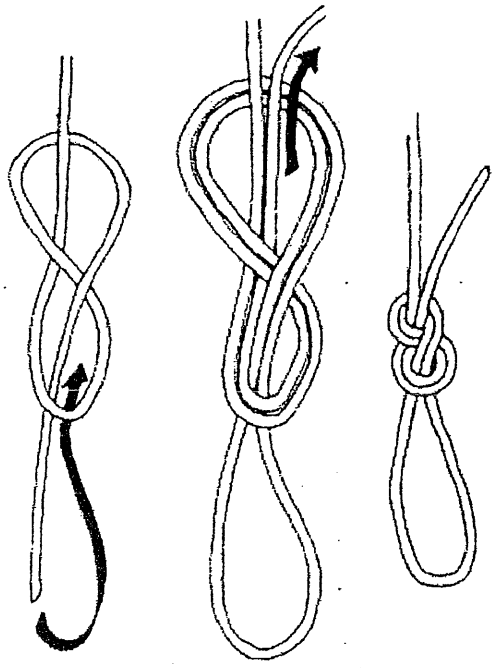
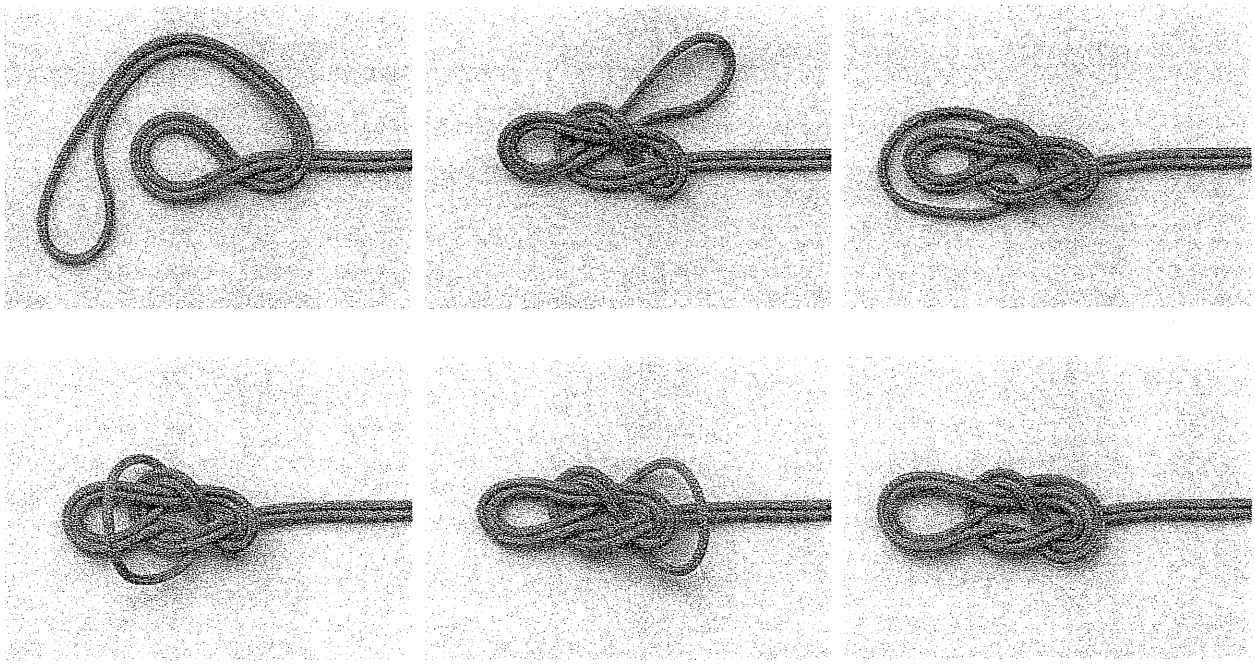


Figure Eight Follow Through

DOUBLE LOOP FIGURE 8



Used to create 2 loops in the end of a rope. Also used to create Self-Equalizing Anchors.

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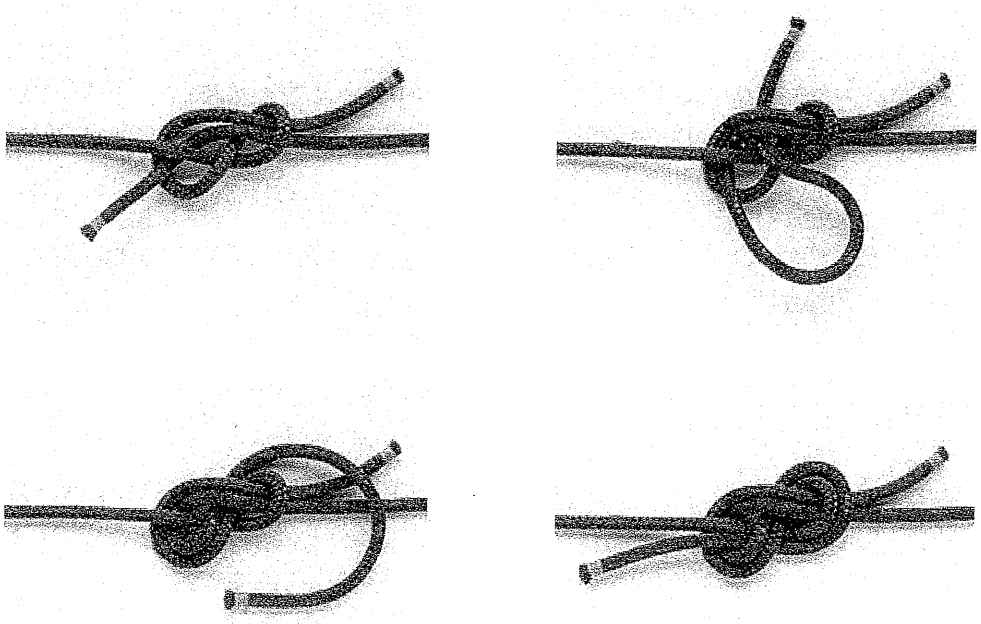
FIGURE 8 BEND

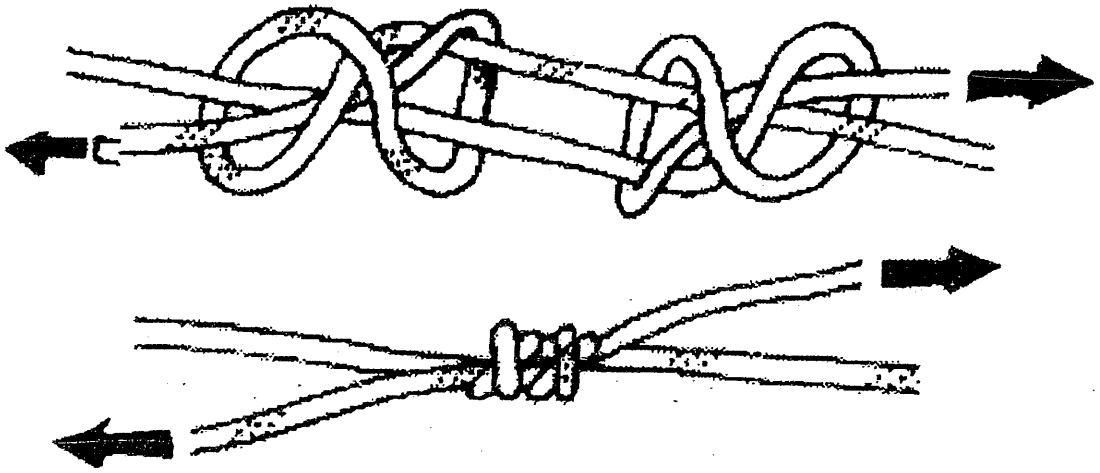


Used to join 2 ropes together of equal size.

63

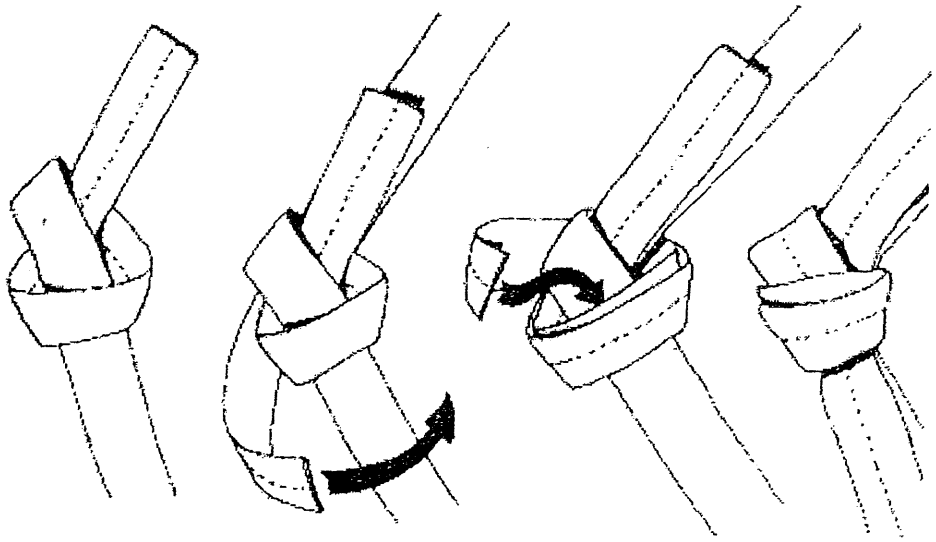
Double Fisherman's Knot

This knot is to tie two ropes together, creating either a Prussik loop or one long rope. It is strong and reliable, but difficult to untie after loaded. The Double Fisherman's knot reduces the strength of a rope by approximately 21%.



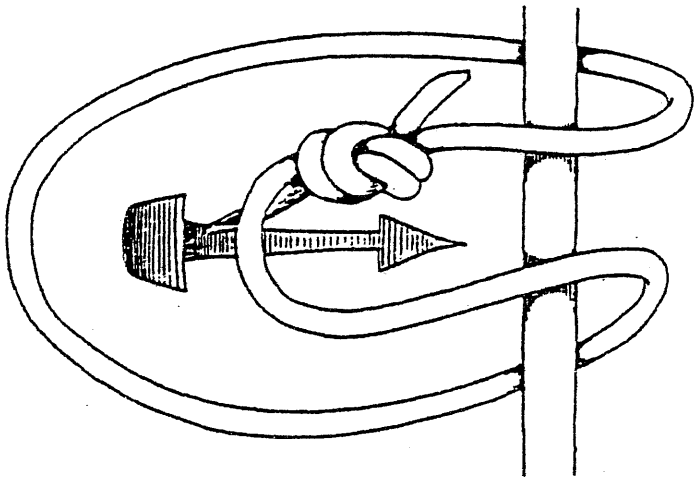
Water Knot

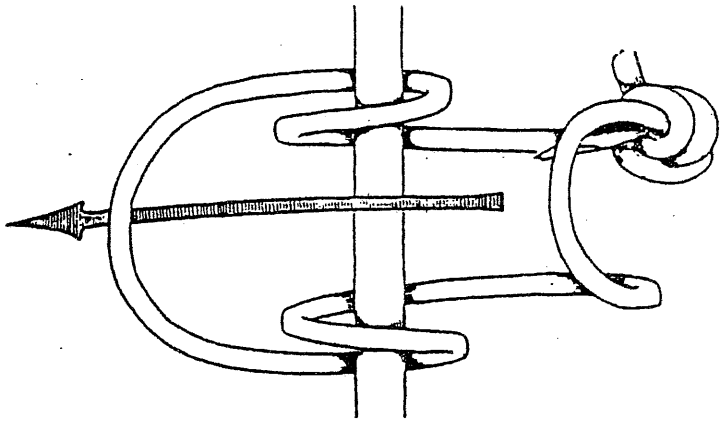
The water knot is arguably the strongest knot you can tie in webbing. It is essentially an overhand follow-through. The Water knot reduces the strength of a piece of webbing by approximately 36%.

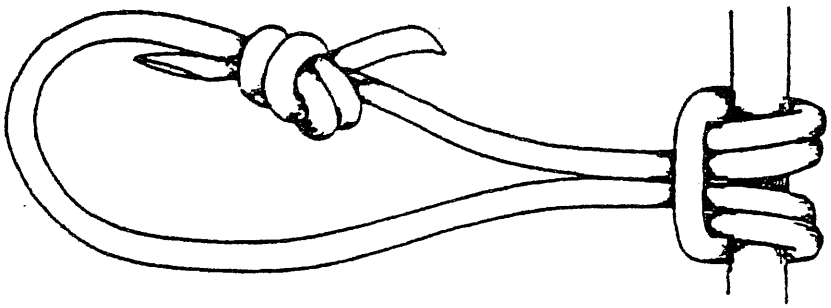


How to Tie a Prussik on a Rope

The Prussik is the most common cinching knot. Essentially, it is a multiple girth hitch around the main rope. It can be loaded in either direction. When loaded, it cinches down on the rope, but when unloaded it slides freely. The gripping power of the Prussik can be improved by increasing the number of wraps around the main rope.

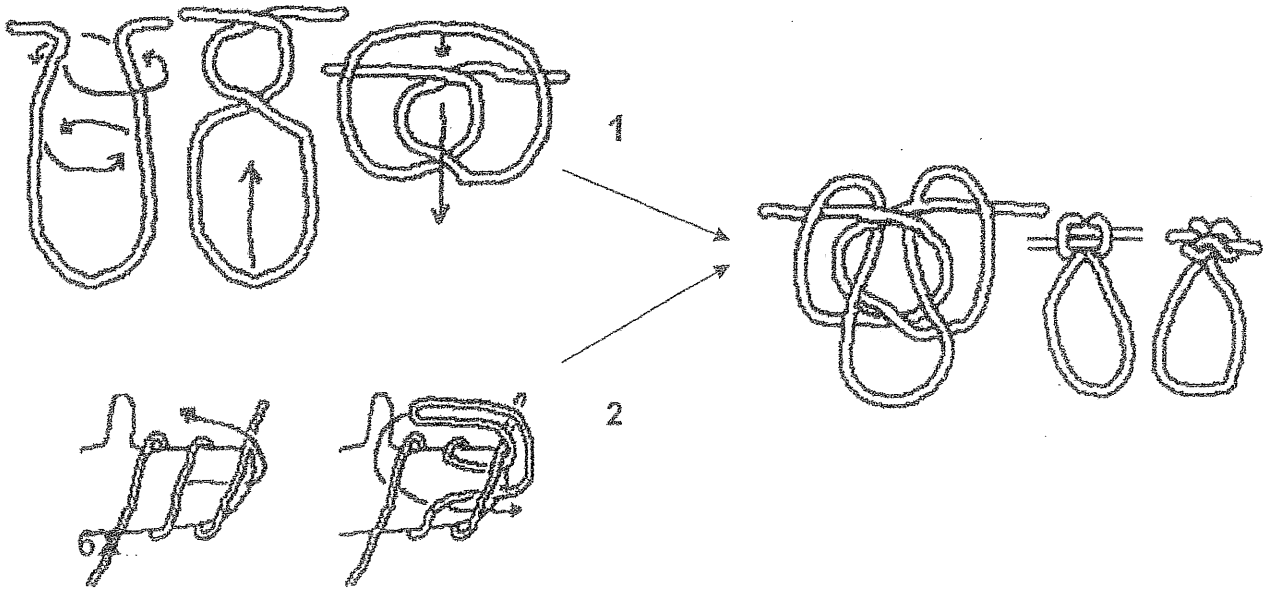






Butterfly Knot

The Butterfly knot is an excellent, easy to tie loop for applications needing a loop in another place other than the rope-end, but somewhere in the middle. It has an excellent lead, and is secure even if the forces on both ends are stronger than the load in the loop. The butterfly knot reduces the strength of a piece of rope by approximately 25%.



ROPE PROTECTION

Pad your rope at all points of contact that might abrade or cut the rope!

You may use manufactured edge rollers, canvas pads, rubber fire hose etc.

Kernmantle Rescue Ropes should be stored in bags for optimal protection.

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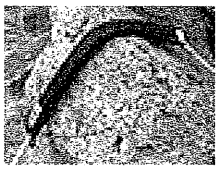
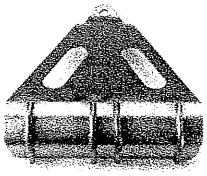
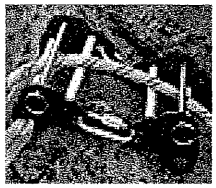
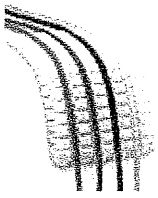
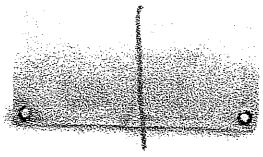
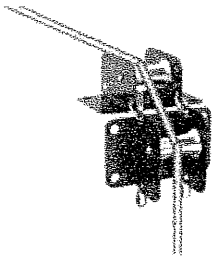
ROPE PROTECTION

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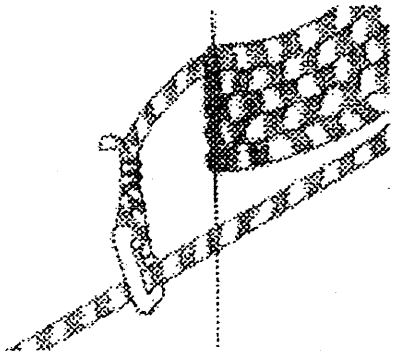
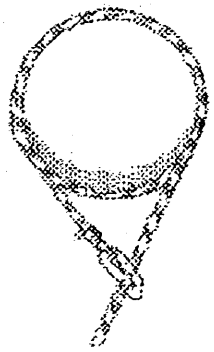
Tensionless Anchor Wrap

The Tensionless Anchor Wrap is a "Full Strength" anchor providing the anchor itself is rated to hold 15 times the expected load. When tied properly no tension is placed on the safety knot which equates to 100% of the strength of the rope being available. In its purest form the Anchor Wrap requires no equipment other than the rope itself. This lends itself to be one of the most popular anchors for securing the standing end of ropes. The Anchor Wrap reduces the strength of a rope by 0%.

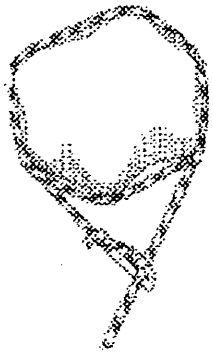


Tensionless Hitch

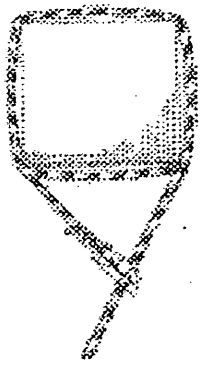
Tensionless Hitch
Finished With a Knot



Best



Okay



Weakest

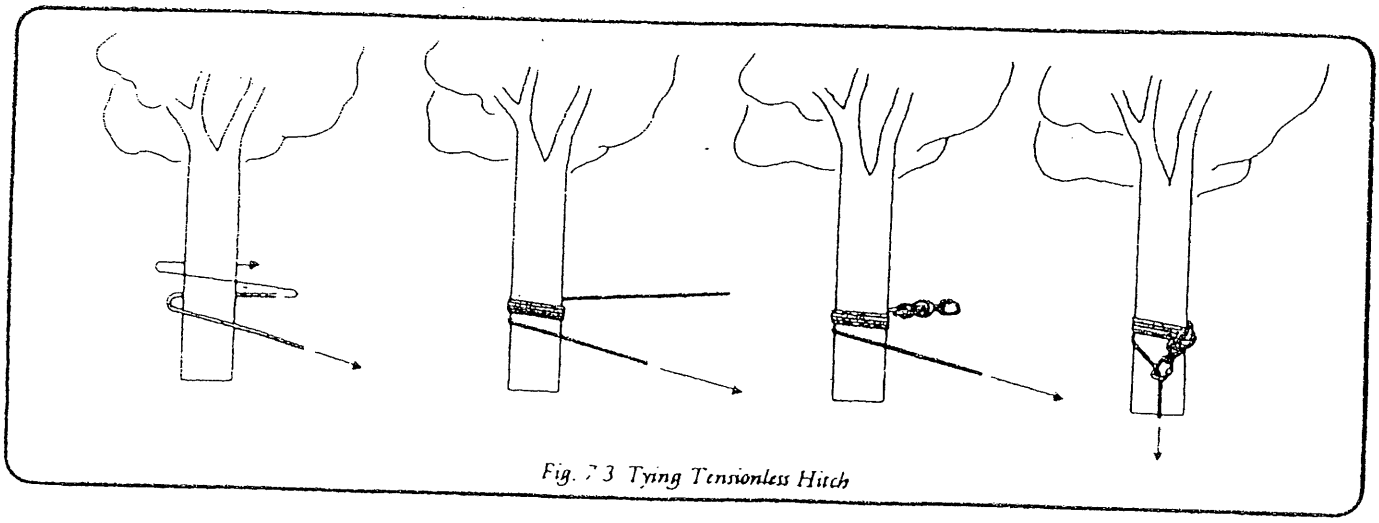


Fig. 7.3 Tying Tensionless Hitch

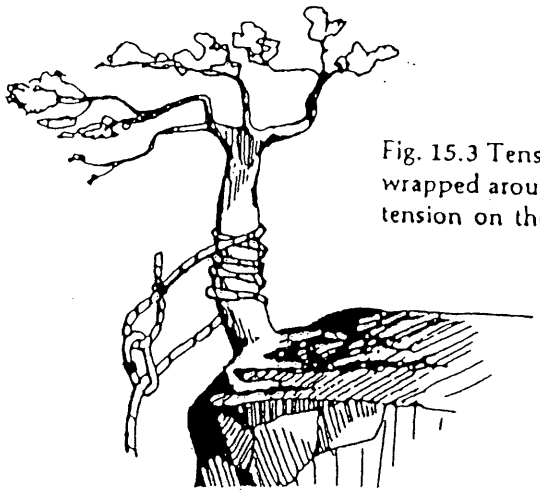
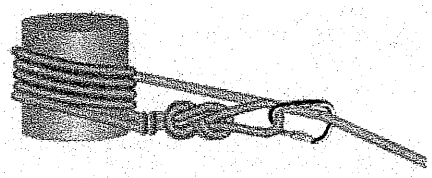
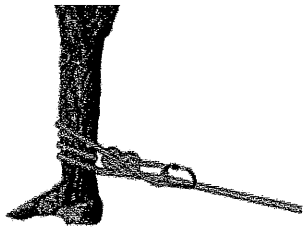


Fig. 15.3 Tensionless anchor. Rope is wrapped around tree until there is no tension on the knot.

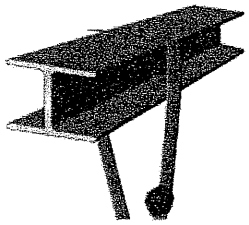
ANCHORS



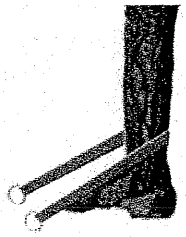
Tensionless Anchor



Tensionless Anchor



I-Beam Anchor



Anchor Strap

Anchors – objects secure enough to be used safely for attaching of ropes

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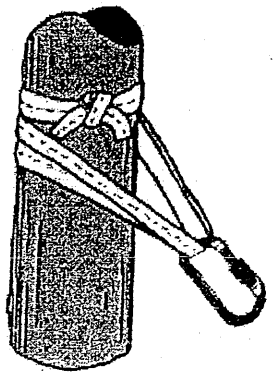
Wrap 3 – Pull 2 Anchor

The Wrap Three/Pull Two anchor is one of the most popular anchors tied in webbing. Part of the strength of this anchor is that, if tied properly, it acts as a kind of tensionless anchor. If the wraps are dressed so that the knot faces forward, on the bight left against the anchor, that knot sees much less force than it would otherwise. Therefore, less reduction in line strength. A single Wrap Three/Pull Two anchor has been tested to 18,000 lbs.; not too bad considering a single piece of webbing is usually rated from 4,200 lbs. to 4,500 lbs.



2-Point Self-Equalizing Anchor

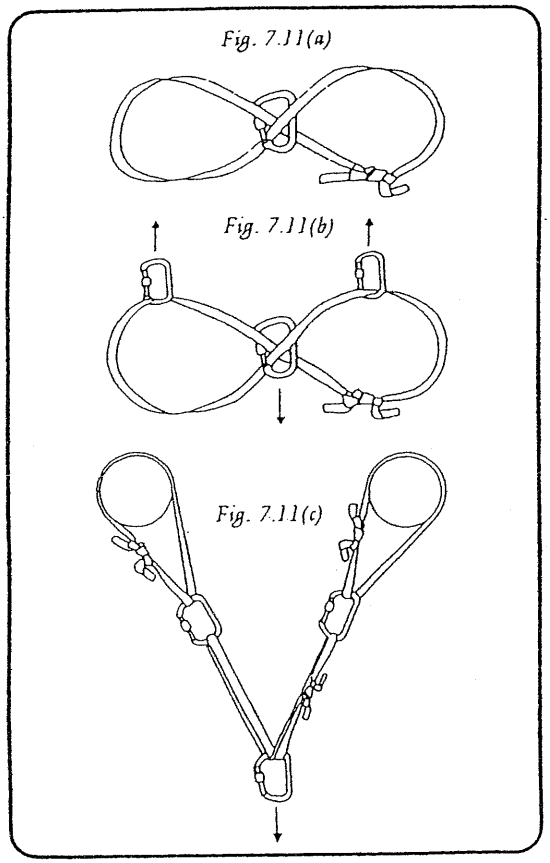


Fig. 7.11 Simple Self-Equalizing Anchor

- Avoid bulky rope or webbing, and adjust the system so that knots are less likely to run through carabiners when the system readjusts.
- Design the systems so that there will be as little drop as possible should any anchor fail.
- Avoid rope or webbing made of materials such as Kevlar™ or Spectra™ since they do not have the shock absorbing qualities of materials such as nylon.
- Make all of the anchor points in a self-equalizing system as bombproof as possible.

A Simple, Two-Point Self-Equalizing System

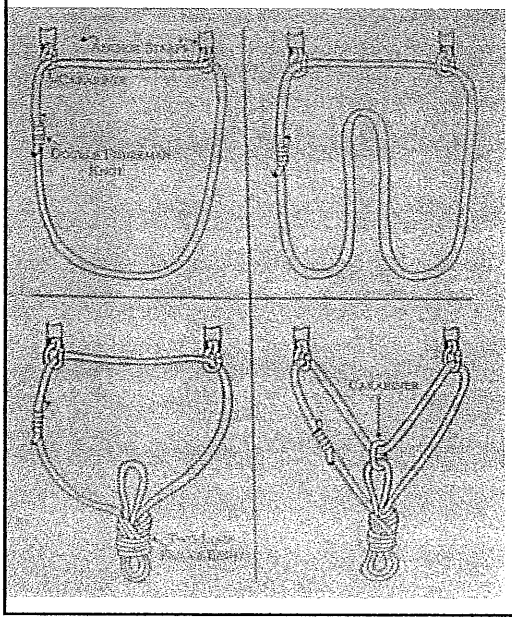
One of the simplest of the self-equalizing anchors involves two anchor points and uses a sling and a carabiner.

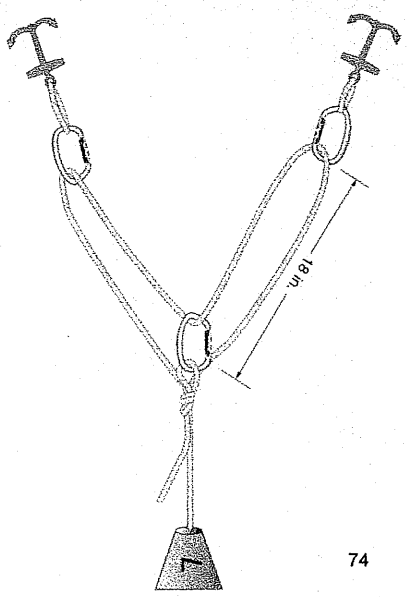
CREATING A SIMPLE TWO POINT SELF-EQUALIZING ANCHOR

(See Figure 7. 11)

1. Configure a loop of webbing or rope in the shape of an "8."
2. Clip a large locking carabiner across the inside loop.
3. Take each end of an outside loop and clip it into an anchor point.
4. Clip the carabiner on the inside loop into the main line.

2-POINT SELF-EQUALIZING ANCHOR





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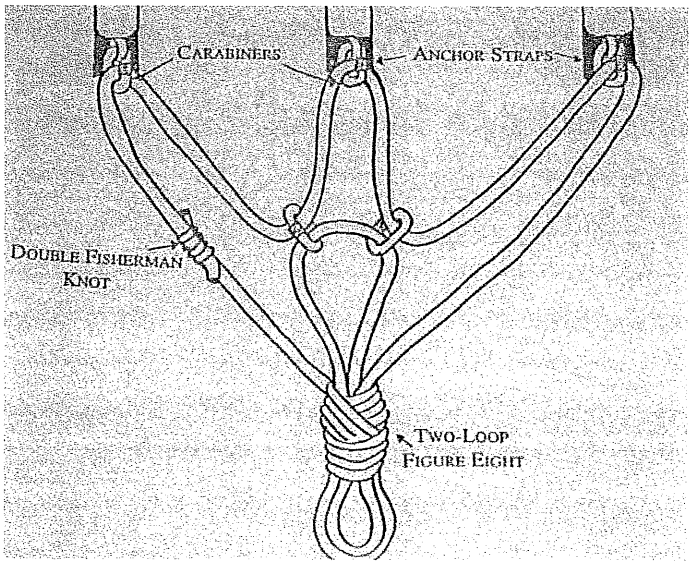
3-POINT SELF-EQUALIZING ANCHOR



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Complex Self-Equalizing Anchor

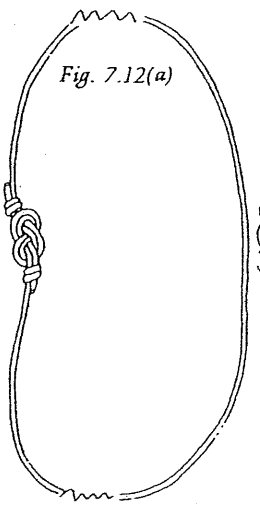


Fig. 7.12(a)

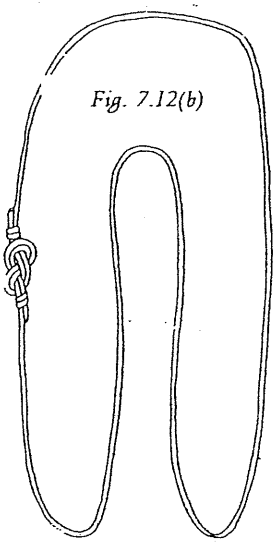


Fig. 7.12(b)

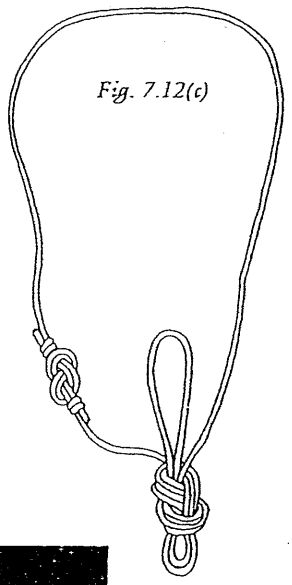


Fig. 7.12(c)

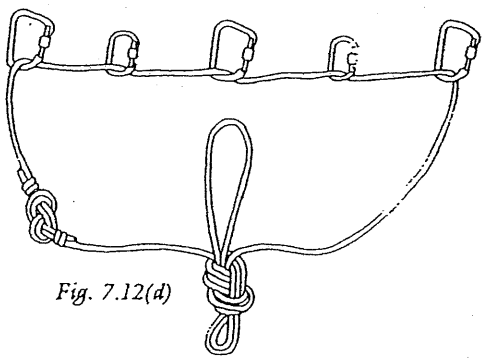


Fig. 7.12(d)

WARNING NOTE

Self-equalizing anchor systems present the potential for dangerous shock loading as one anchor point pulls out and others take the load.

To minimize potential shock loading:

a) Try to keep anchor points close to one another. If this is not possible, it may be better to extend far away anchor points with static rope to keep the self-equalizing anchor's loop as small as possible.

b) Rig self-equalizing anchors with a minimum of slack in the system.

c) Avoid webbing in self-equalizing anchors since it does not slip (and equalize) as easily through the system's carabiners.

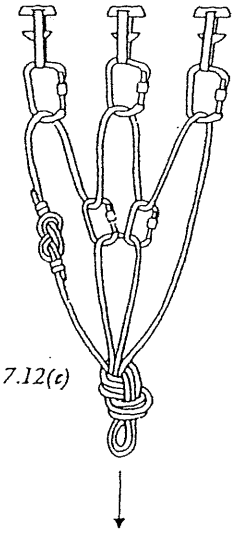


Fig. 7.12(e)

Fig. 7.12 Complex Self-Equalizing Anchor

Establishing a Picket System *(See Figure 7.13)*

Pickets

One alternative in a natural area where there are no anchors is the picket system. Though it can work very well when properly rigged, it usually takes a great deal of time to properly establish a picket system.

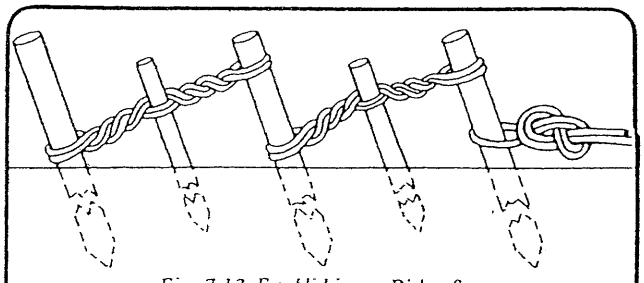
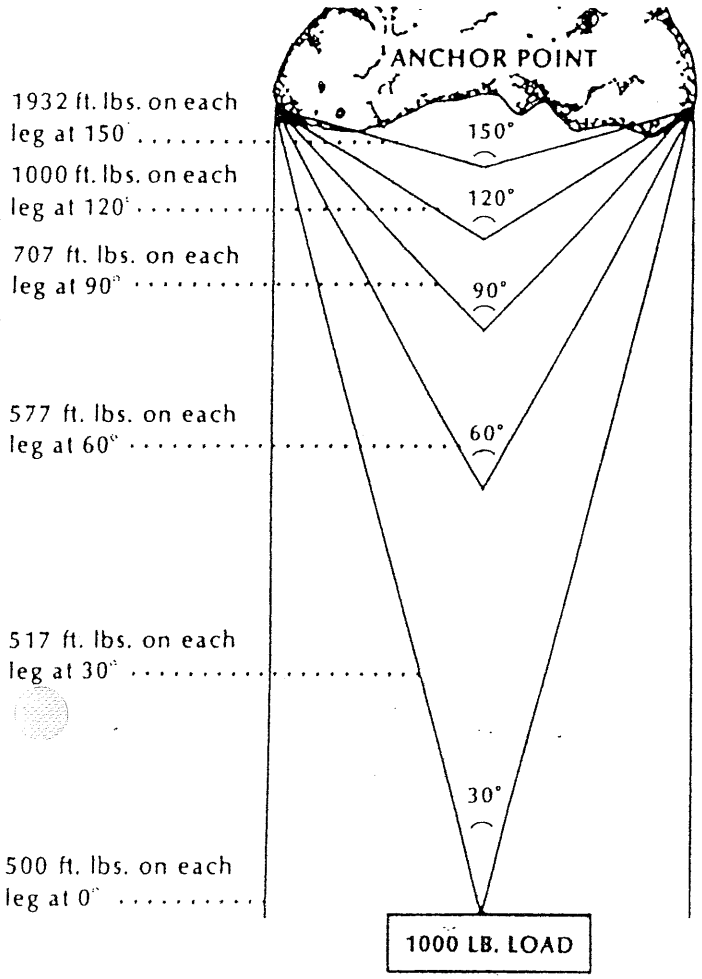


Fig. 7.13 Establishing a Picket System

1. The pickets should have a minimum length of five feet, so that there will be a minimum of three feet in the ground and a maximum of two feet above ground.
2. Drive the pickets at an angle of 15 degrees away from the force to be anchored.
3. Connect the pickets in each row together by lashing from the top of the first picket (the one closest to the load) to the bottom of the next picket. Continue in this manner until all rows of pickets are lashed together.
4. Tension the lashings by twisting with a stick four to six turns. Drive this stick into the ground to secure it.
5. Connect the main line by clipping it to the front picket in each row with a self-equalizing anchor system as described above.

Sling Angle/Load Relationships



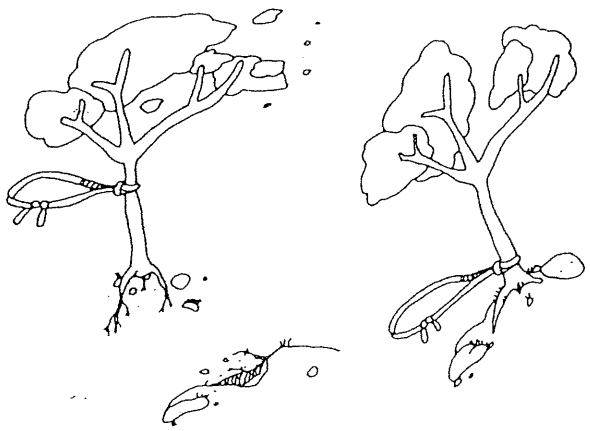
This diagram shows how the load increases at sharper sling angles. The load on each leg of the sling at 150° is four times grater than at 0°. For maximum safety and economy, never use sling angles greater than 90°.

WARNING NOTE

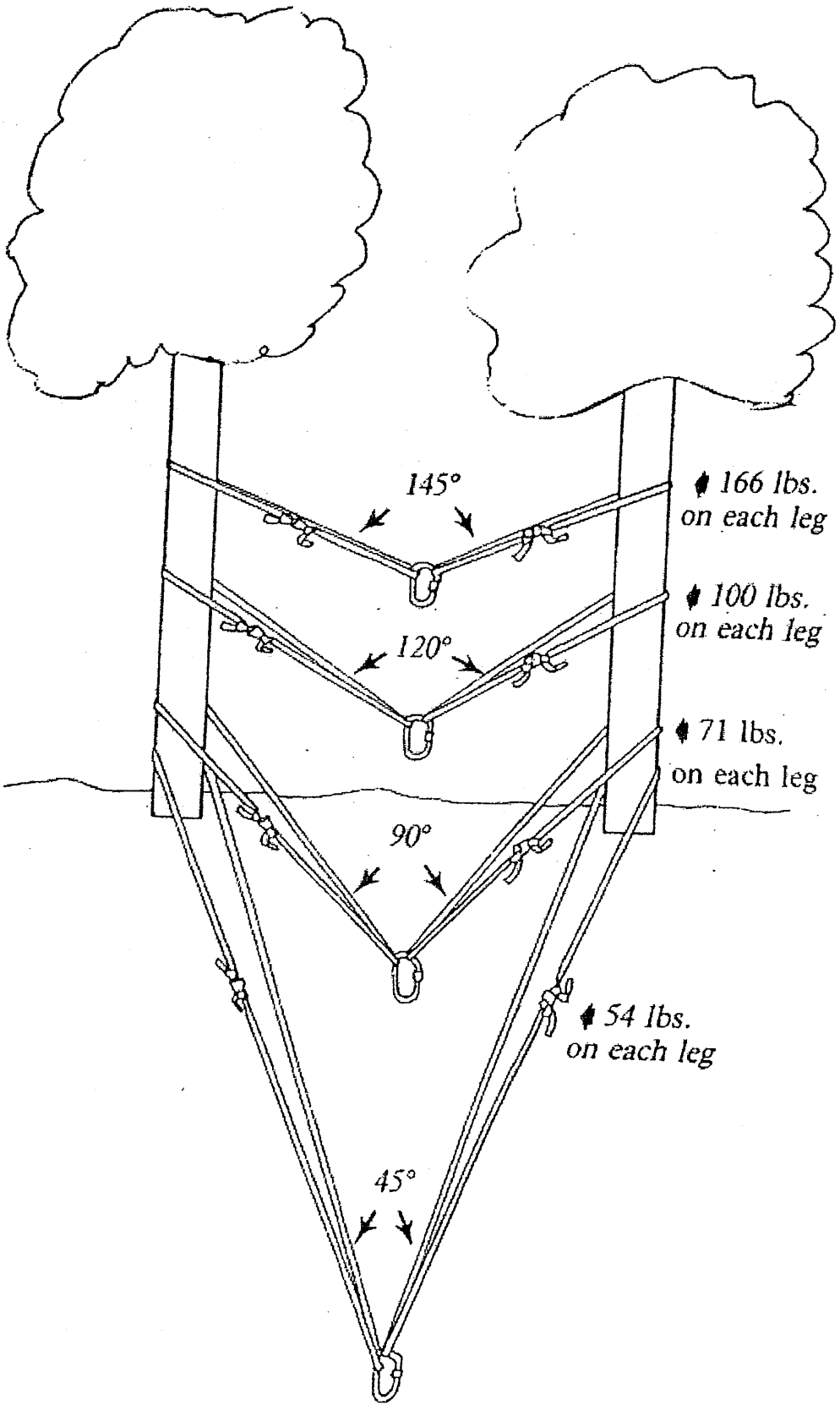
A primary concern for rigging any type of complex anchor is not to create too wide an angle between the legs of the anchor system. Ideally, this angle should not exceed 90 degrees, and must never exceed 120 degrees. Beyond this point, the forces *on each anchor* and other elements of the system will be greater than the total load itself.

You should remember that any angle in an anchor system will increase the loading on anchors and other elements of the system. Only when the angle between the legs of the anchor system is 0 degrees will each leg carry half the load. (See Figure 7.9 for diagrams of how angles affect the forces on anchor points and other elements of the system.)

An anchor is strongest when tied next to the base of the anchor point.

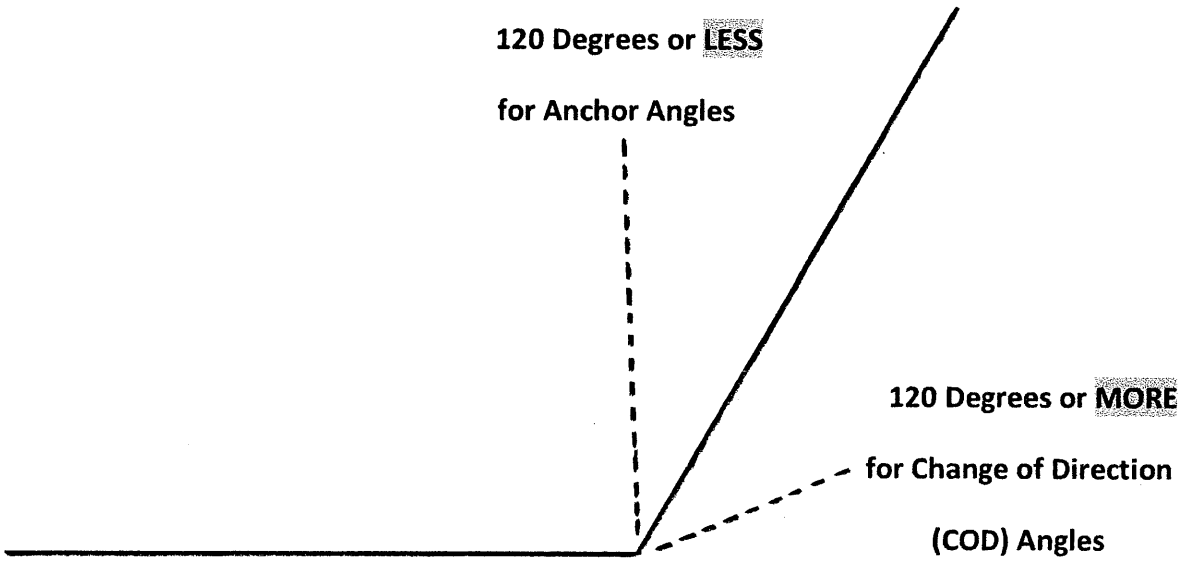


Effects of Angles on Anchor Placements



100 lbs. Load

ANGLES TO REMEMBER



Multi-Point Anchor Angles - (Use 120 or <)	
Angle Formed	**% Weight added to Each Anchor**
0	50%
5	50.05%
10	50%
15	50%
20	50%
25	51%
30	52%
35	52%
40	53%
45	54%
50	55%
60	58%
65	59%
70	61%
75	63%
80	65%
85	68%
90	71%
95	74%
100	78%
105	82%
110	87%
115	93%
120	100%
125	108%
130	118%
135	131%
140	146%
145	166%
150	193%
155	231%
160	287%
165	382%
170	575%
175	1136%
180	5600%

Directionals

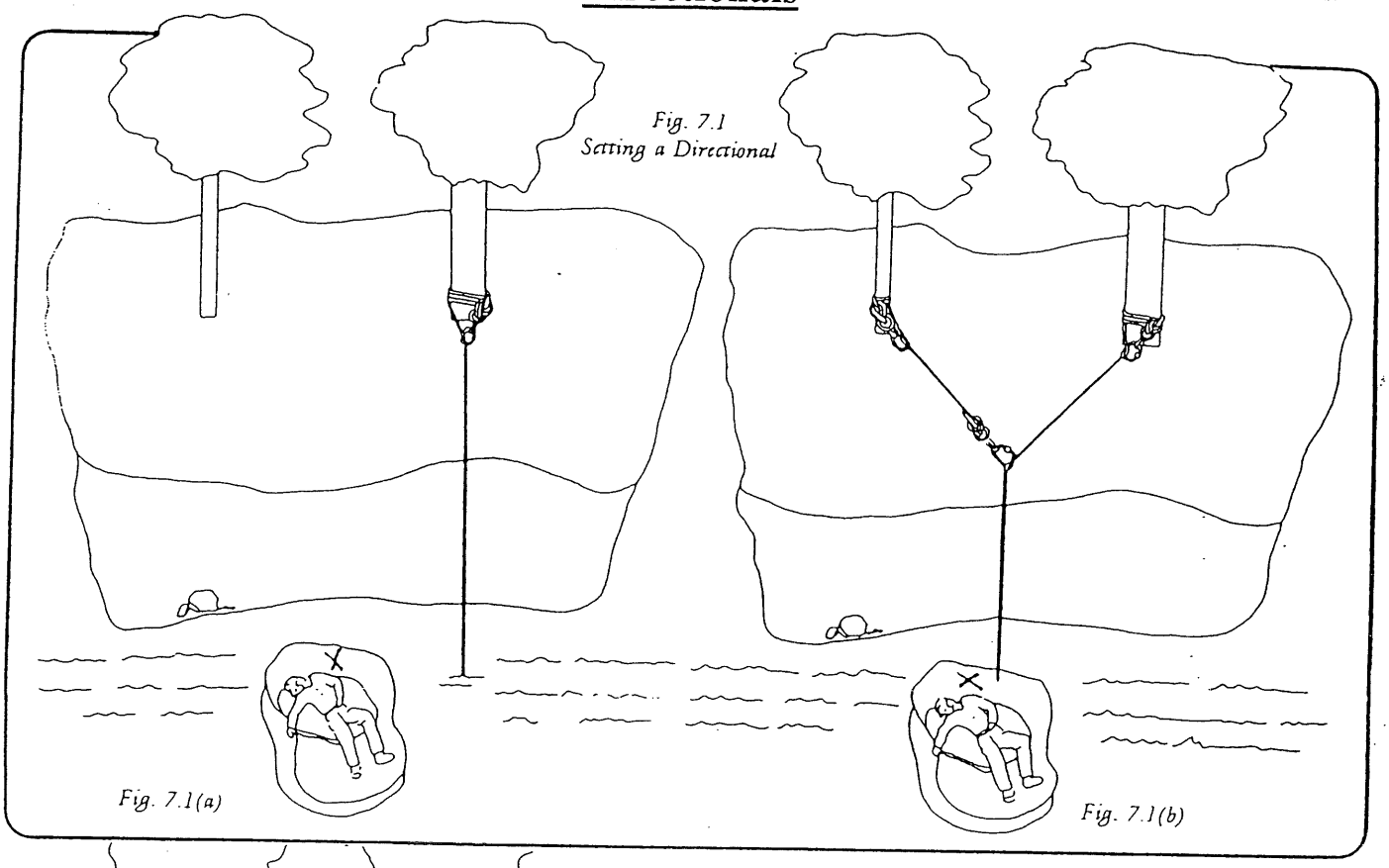


Fig. 7.1
Setting a Directional

Fig. 7.1(a)

Fig. 7.1(b)

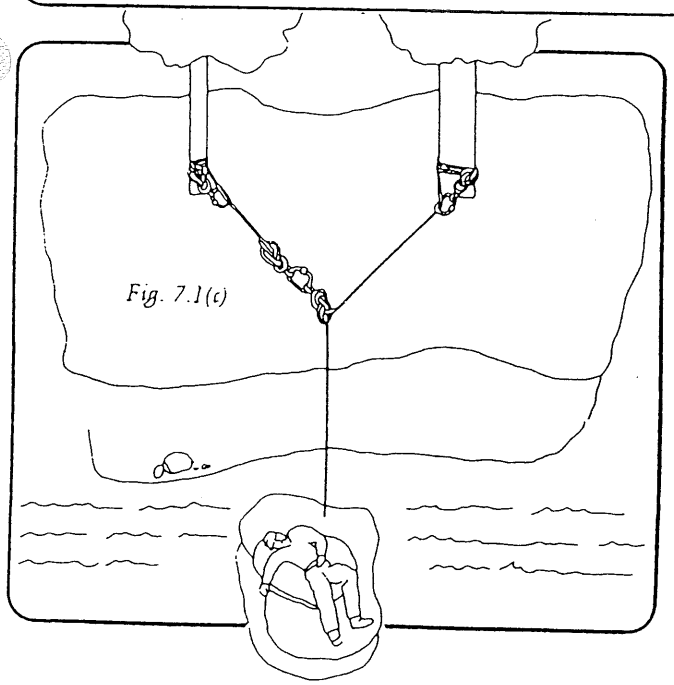


Fig. 7.1(c)

Location of Directionals

When you establish anchors and directionals you must keep in mind how safe and accessible their locations are for the high angle personnel who work with them. In Figure 7.1 above, for example, you could possibly make some improvements by changing the location of the anchors and directional. If there were anchor points, such as the trees, far enough distant back from the edge of the drop, then you could rig the anchor system and the directional on the top.

As a result:

a) Those people rigging the anchors and the directional would be in less danger of falling.

b) The rigging would be more accessible to the people and therefore would be more in their control.

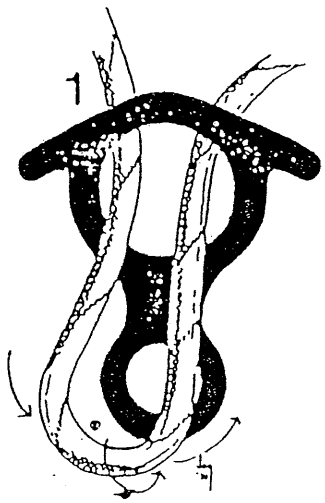
c) With the rope running over the edge, not all the weight would be directly on the anchor; part of it would be taken by the edge of the drop. (The drawback would be possible abrasion on the rope.)

WARNING NOTE

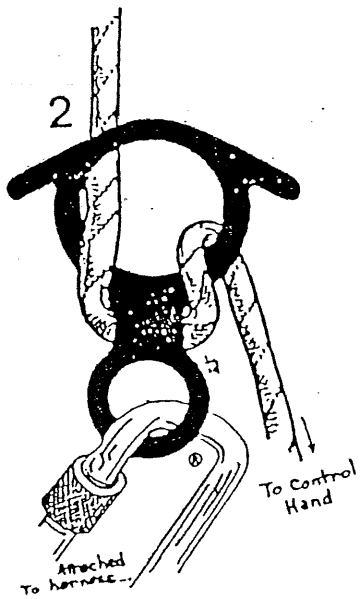
1. Depending on the angle the primary anchor rope makes with the directional rope, there will be greater forces on the anchor system than if there were only a single anchor. In this illustration, for example, there will a greater force on the directional anchor than on the main anchor. A directional is in effect creating a multiple anchor system. See discussion later in this chapter on how multiple anchors create forces on the system depending on the angles the ropes create.

2. Remember, that should the directional fail, there will be a significant *pendulum*, the main line will drop, and the main line anchor will be shock-loaded.

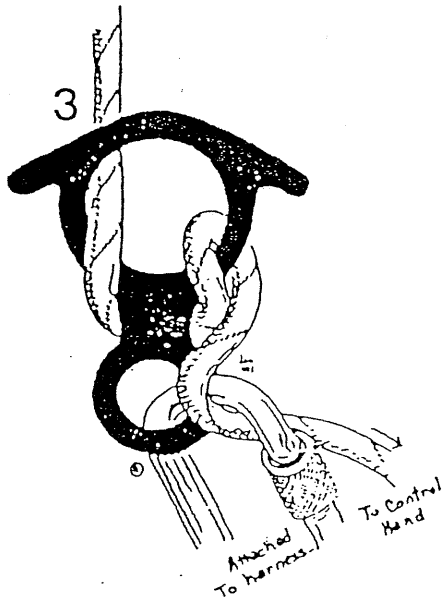
Change of Direction Angles - (Use 120 or >)	
Change of Direction Angle	% of Weight added to Anchor
0	200%
5	199.90%
10	199%
15	198%
20	197%
25	195%
30	193%
35	191%
40	188%
45	185%
50	181%
60	173%
65	169%
70	164%
75	159%
80	153%
85	147%
90	141%
95	135%
100	129%
105	122%
110	115%
115	107%
120	100%
125	92%
130	85%
135	77%
140	68%
145	60%
150	52%
155	43%
160	35%
165	26%
170	17%
175	8%
180	0%



Up through/Down over.

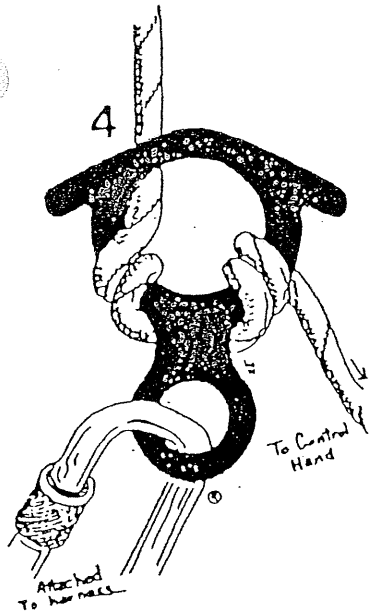


Right handed-Right side.
Left handed-Left side.

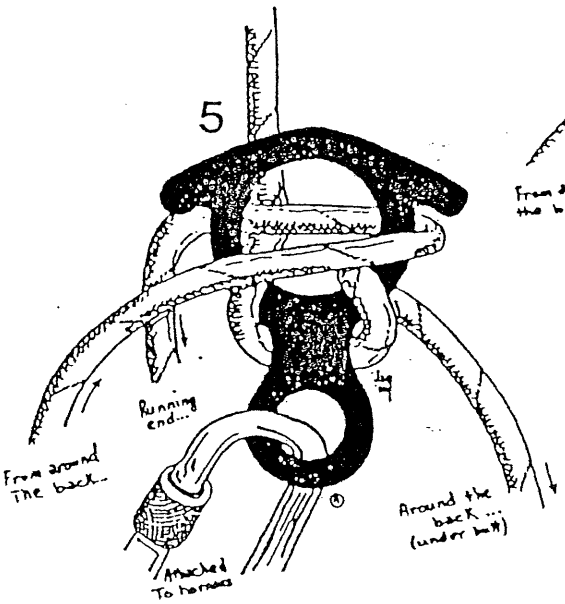


Controlling extra weight
w/additionl friction.

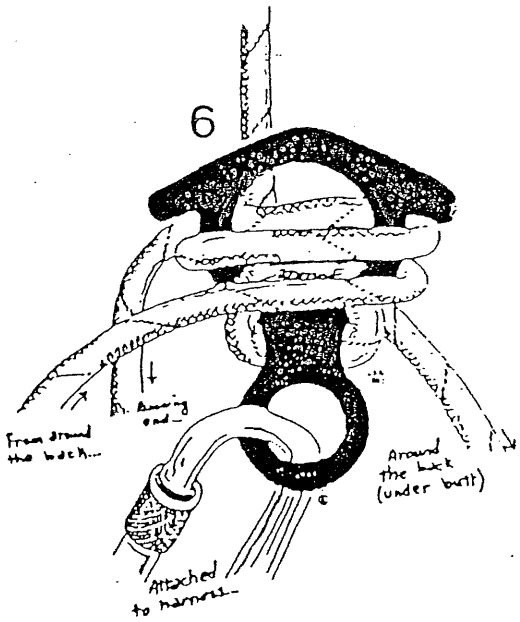
Figure -8-



Double wrap
for heavy loads.

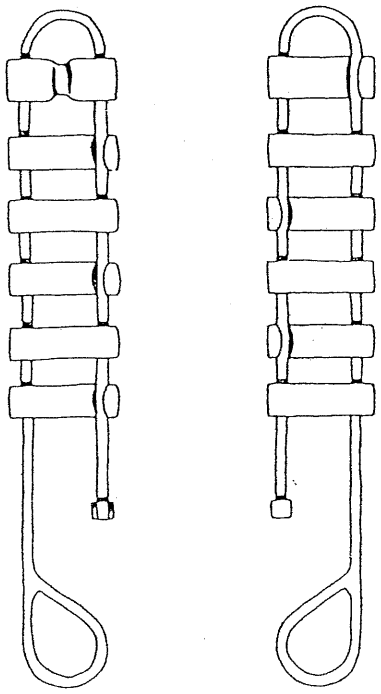


Tying off.



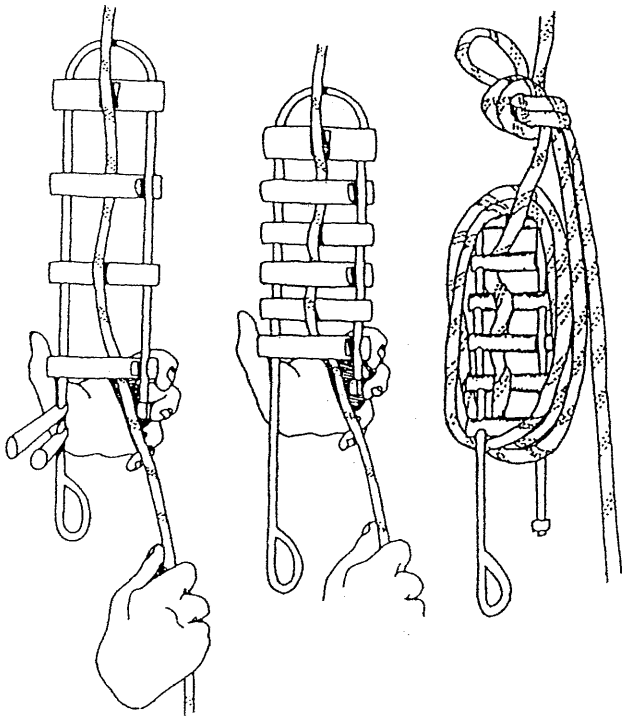
Completed tie-off
w/safety wrap.

Rappel Rack Rigged for a Right Handed Person

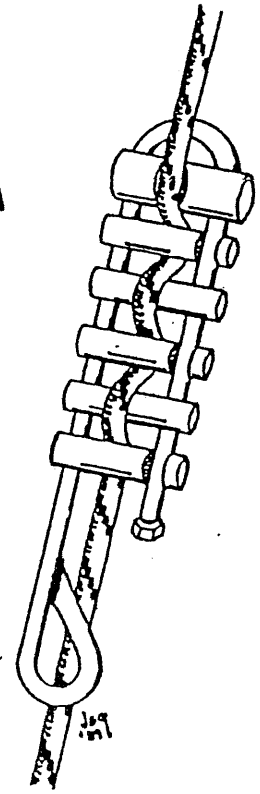


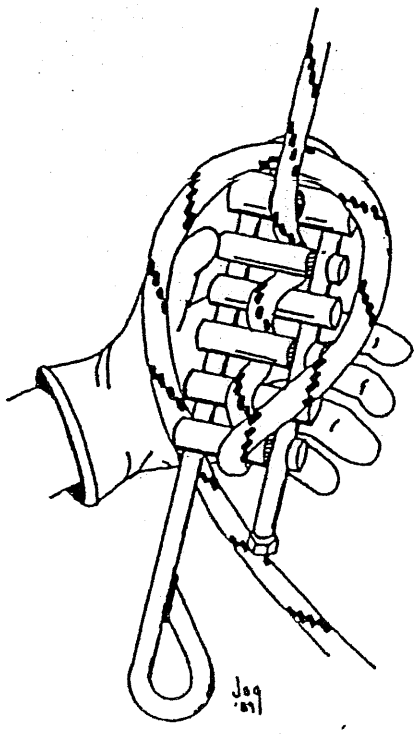
Front Back

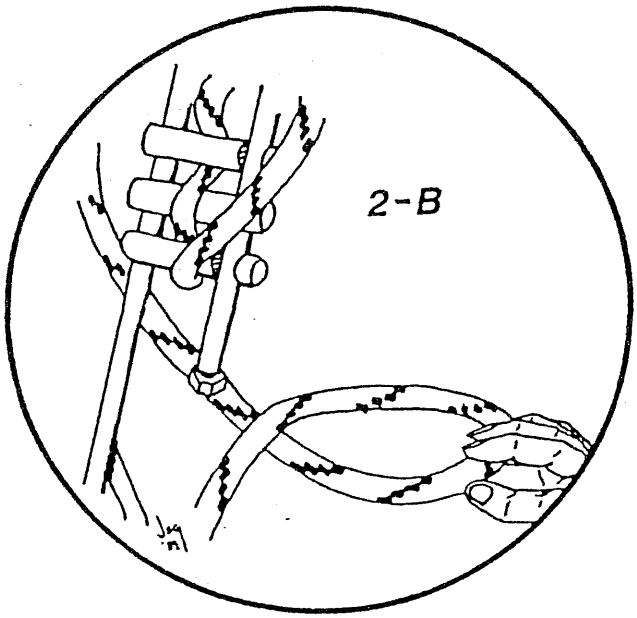
Left: bars spread for minimum friction.
Center: bars together for maximum friction.
Right: rack locked off with a safety knot.



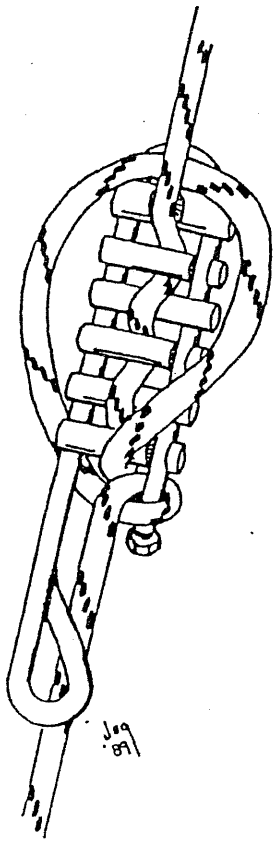
2-A

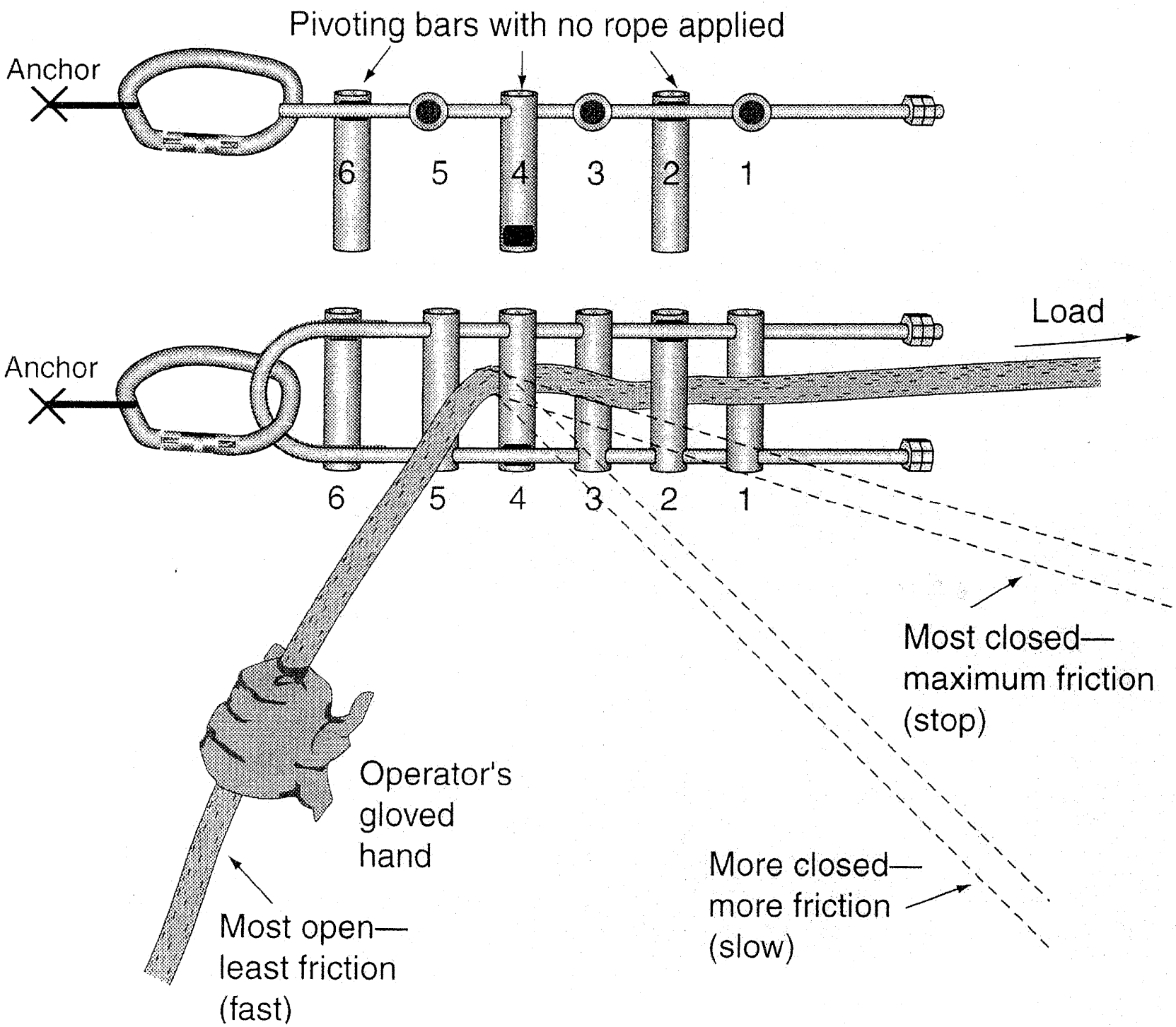






2-B

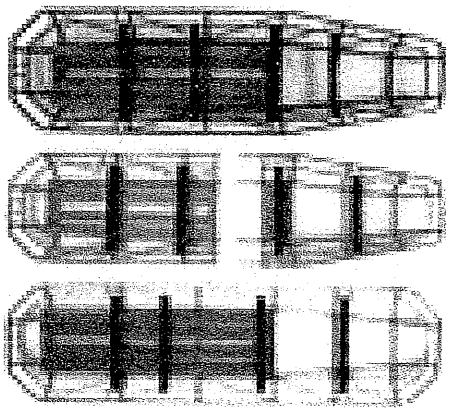


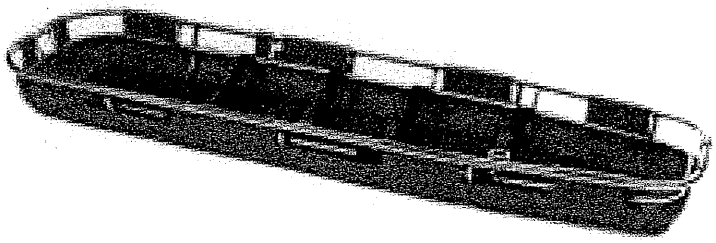

Pivoting bars with no rope applied
Anchor
6
5
4
3
2
1
Anchor
Load
6
5
4
3
2
1
Most closed—
maximum friction
(stop)
Operator's
gloved
hand
More closed—
more friction
(slow)
Most open—
least friction
(fast)

STOKES BASKET TIE-IN

Integrated Harness System - is designed to keep the victim from moving up & down in the litter!

(Practice Tie-Ins)





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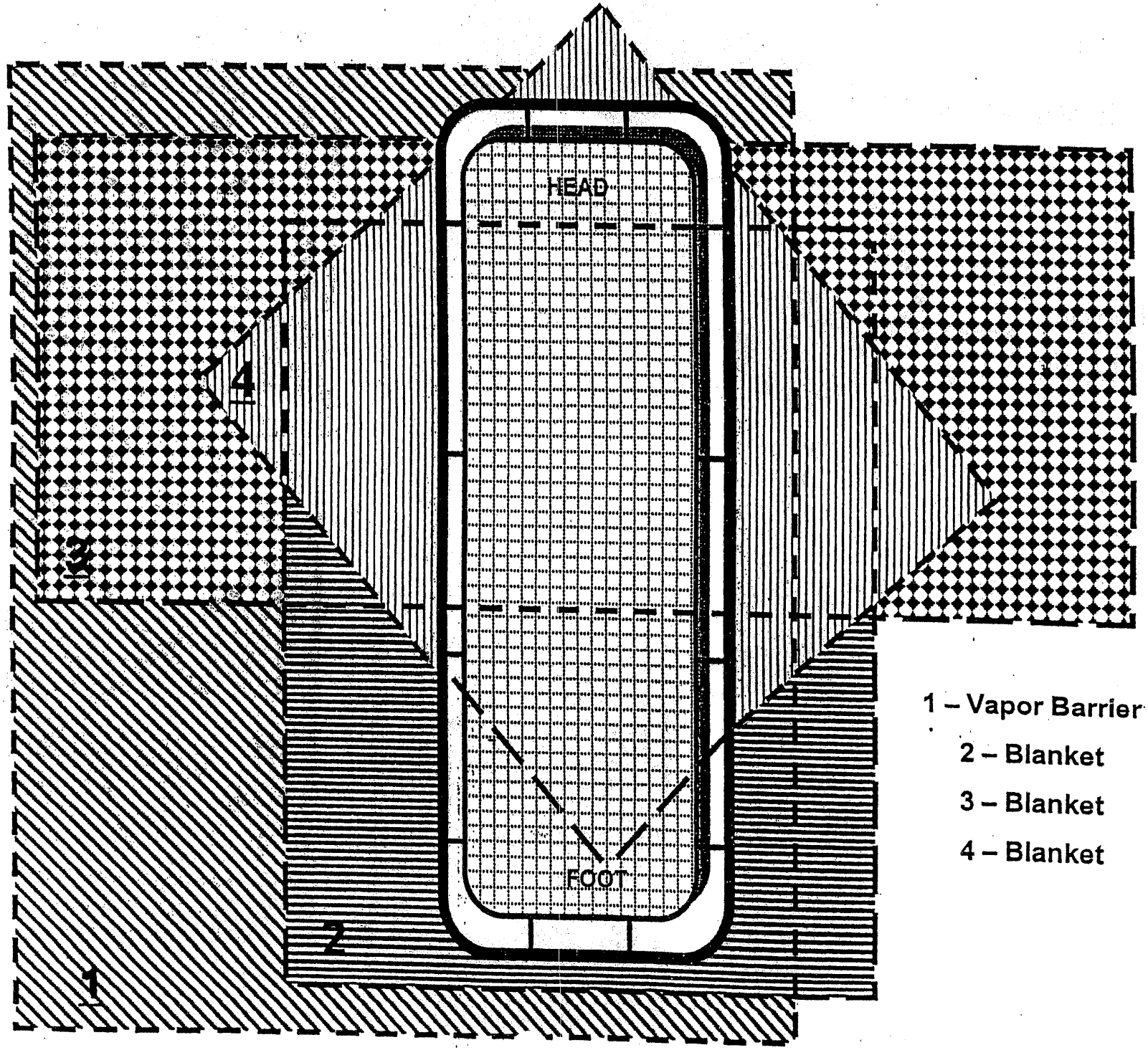
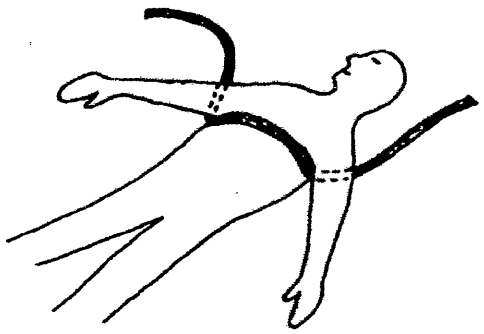
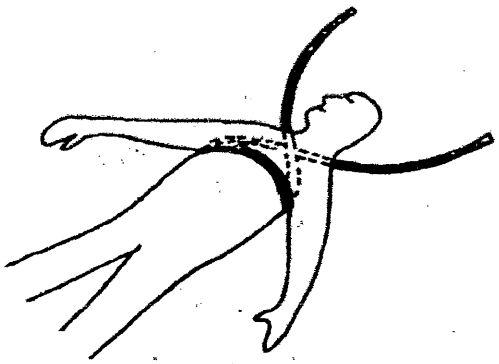
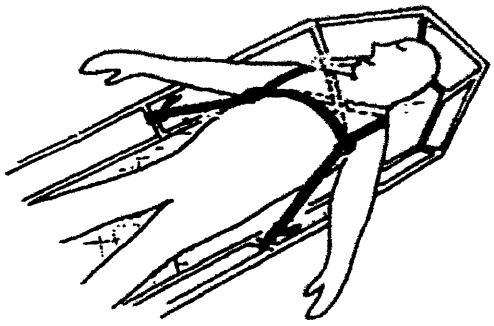
1" tubular webbing is the best material to use for securing a patient to the Stokes


HEAD
FOOT
4
3
2
1
1 – Vapor Barrier
2 – Blanket
3 – Blanket
4 – Blanket







LITTER ATTACHMENT
UPPER TORSO

PURPOSE:
Secure patient against movement toward head of litter.

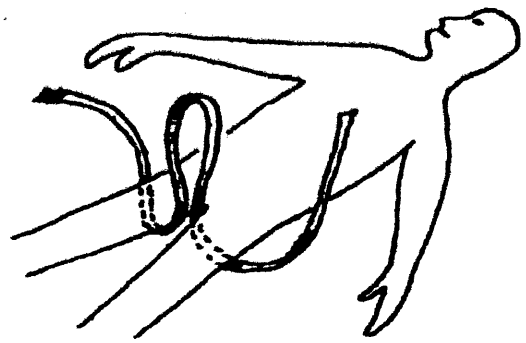
Step 1: Place strap across chest and under arm pits.

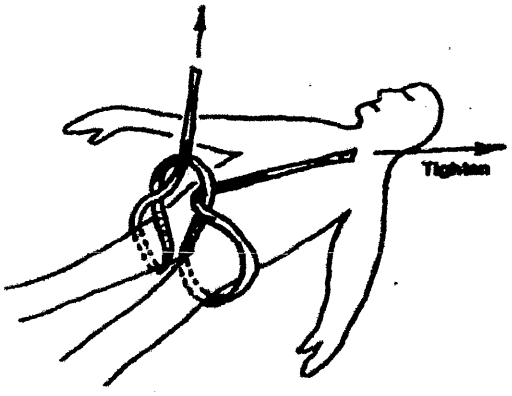
Step 2: Cross ends behind patient's back.

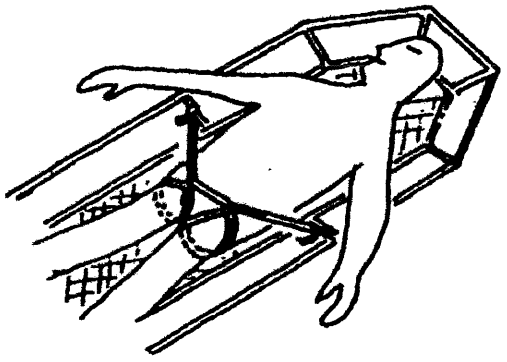
Step 3: Pass ends under chest loop utilizing round turns.

Step 4: Secure ends to vertical bars of litter below cheat. Arms may be secured under webbing.

- All webbing knots are tied with a round turn and two half-hitches.
- This attachment should be used in conjunction with the foot stirrups and exterior lashing.
- If litter is to be raised or lowered in vertical position, secure ends to litter above shoulders.







LITTER ATTACHMENT
PELVIC

PURPOSE:
Secure patient against movement toward foot of litter.

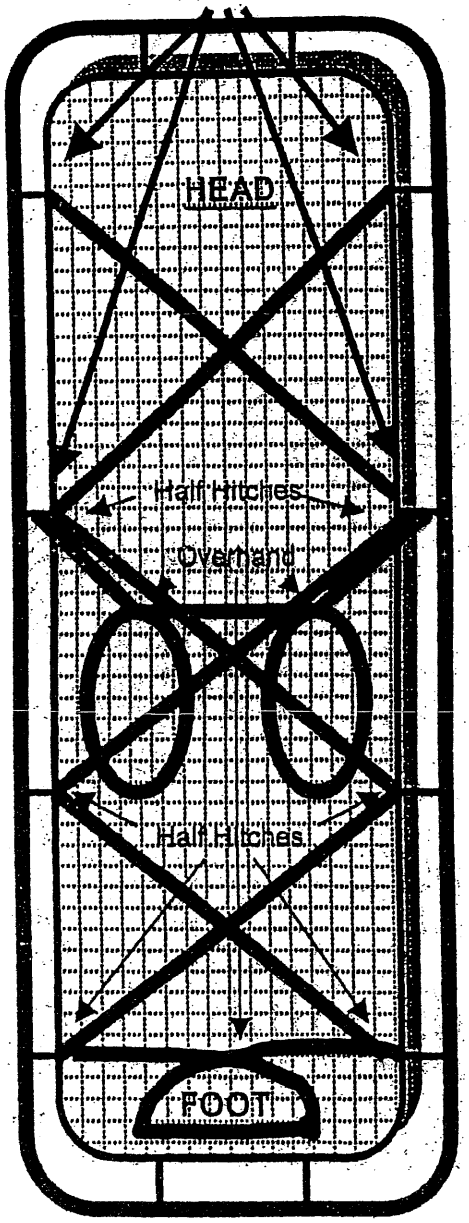
Step 1: Form bight between legs at crotch. Pass ends under legs.

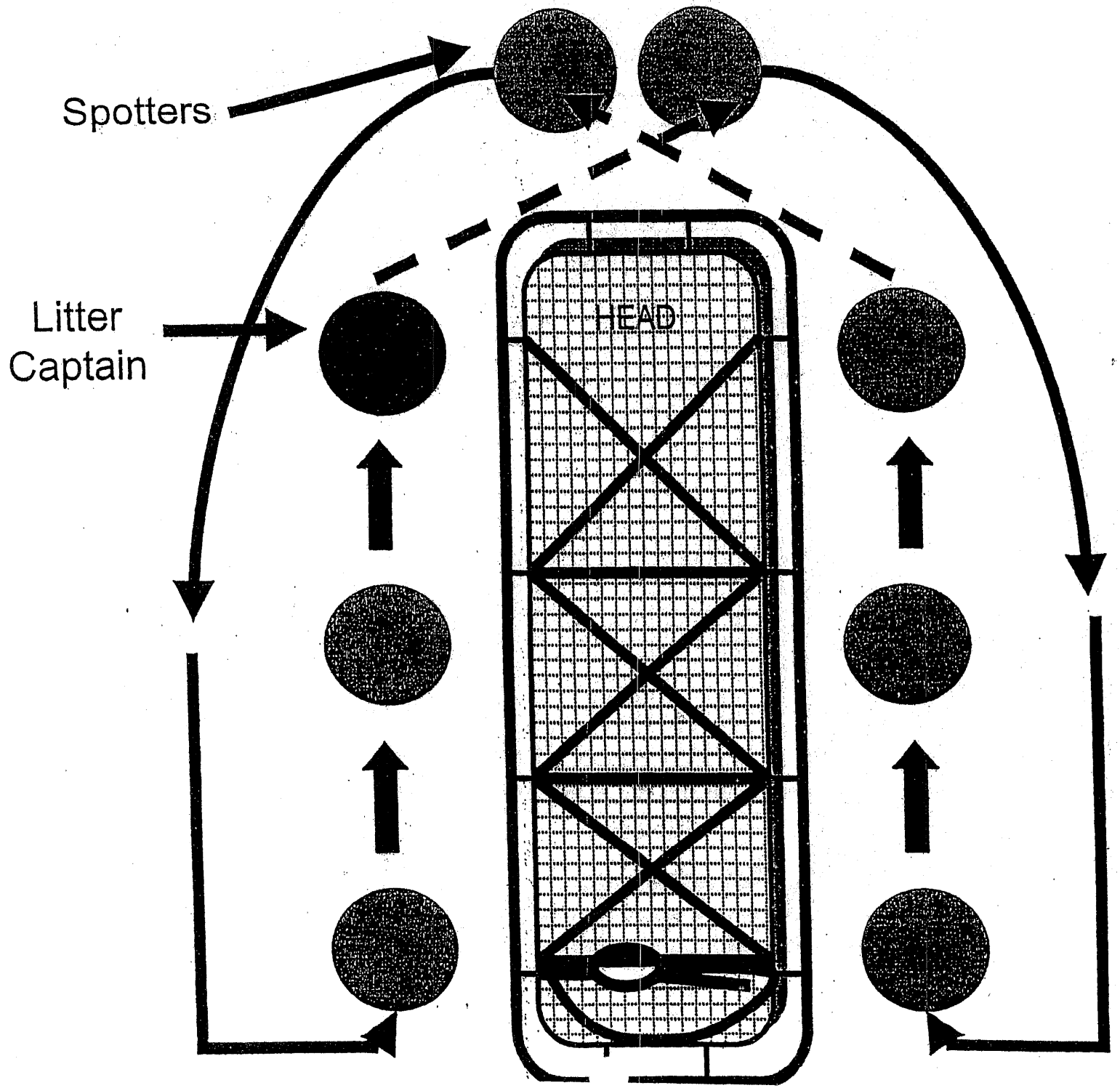
Step 2: Pass ends through bight and tighten.

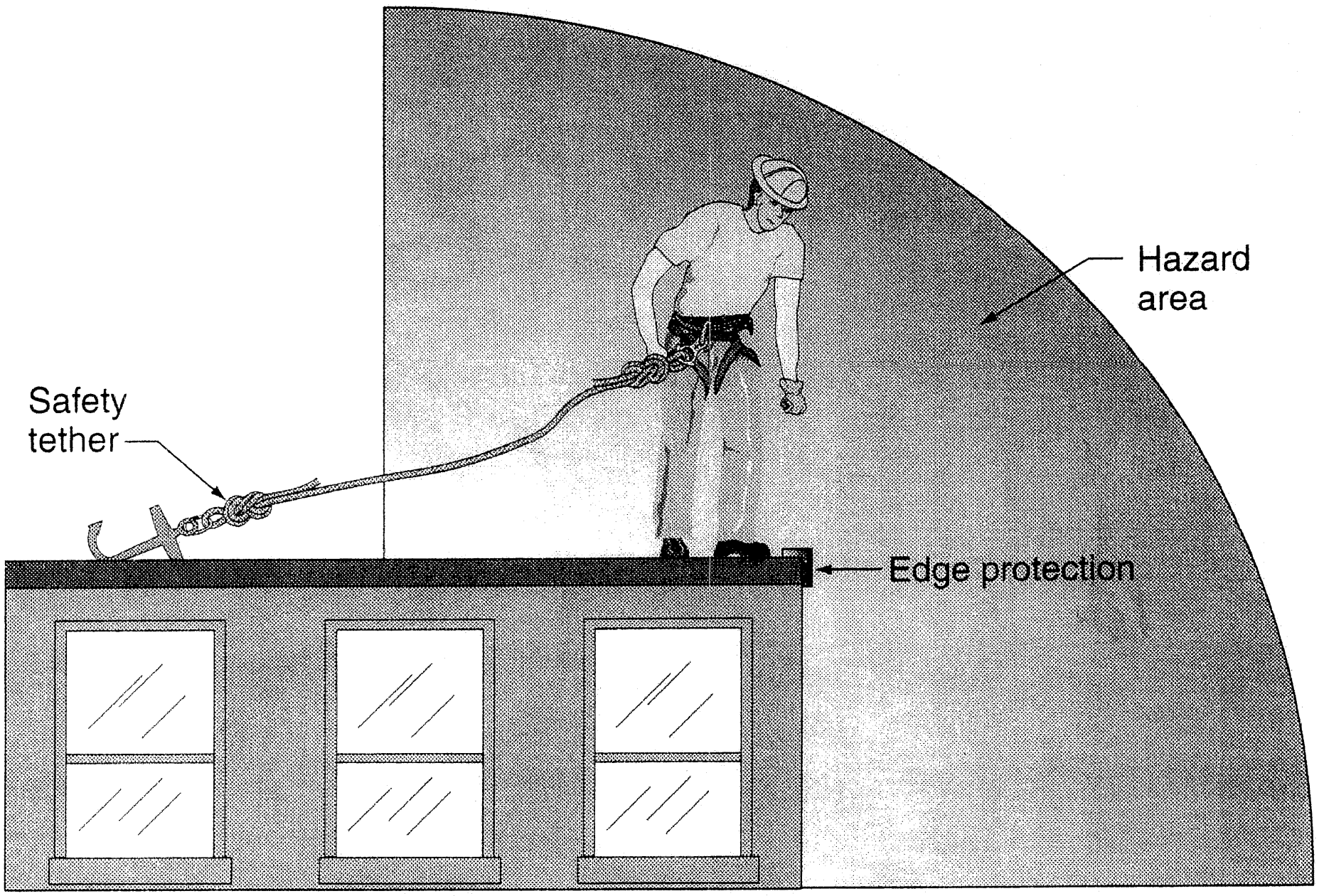
Step 3: Secure ends to vertical bars of litter. Tie points should be superior to pelvic area. Arms may be secured under webbing.

- All webbing knots are tied with a round turn and two half-hitches.
- This attachment may be used in lieu of or in combination with foot stirrups.

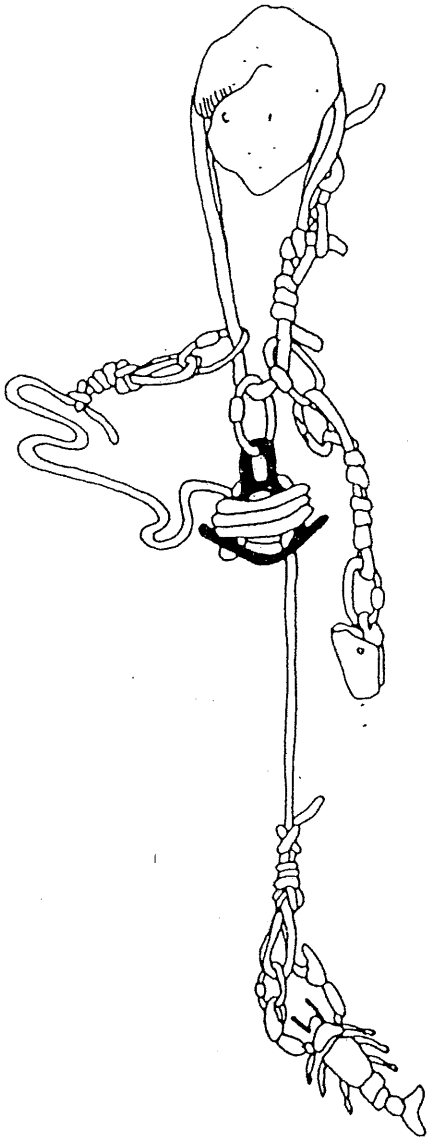
Round Turn w/3 Half
Hitches or 1 Clove Hitch



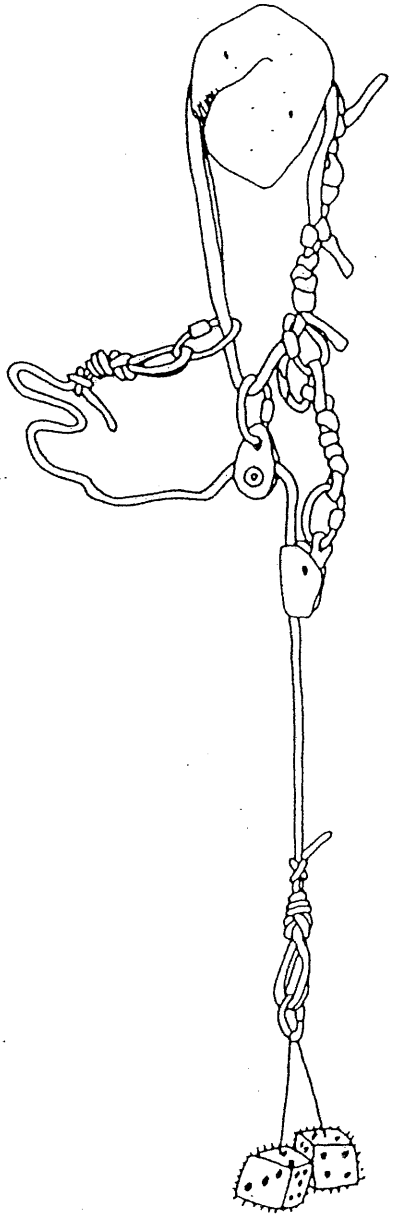

Spotters
Litter
Captain
HEAD


Hazard
area
Safety
tether
Edge protection

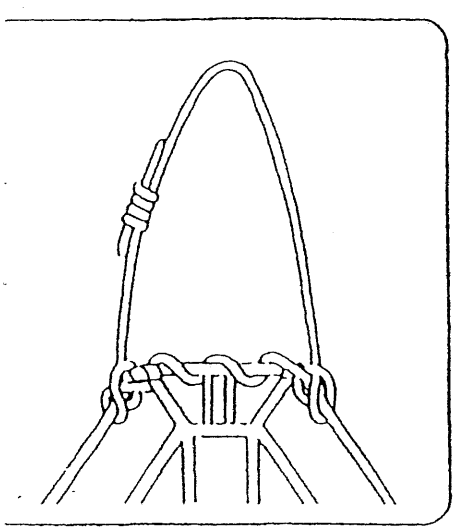
Lowering System

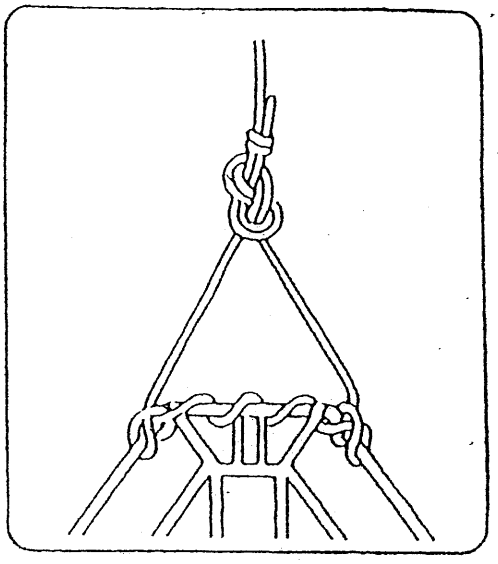


Lowering System Belay



LOWERING SYSTEM SET-UP





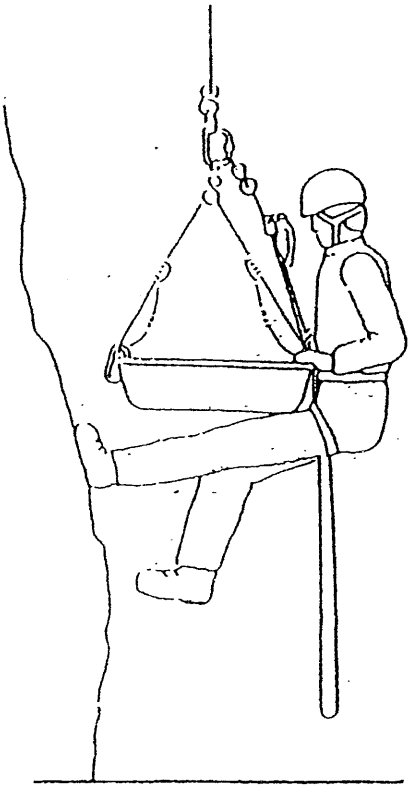


Fig. 14.16 Posture for Litter Tender

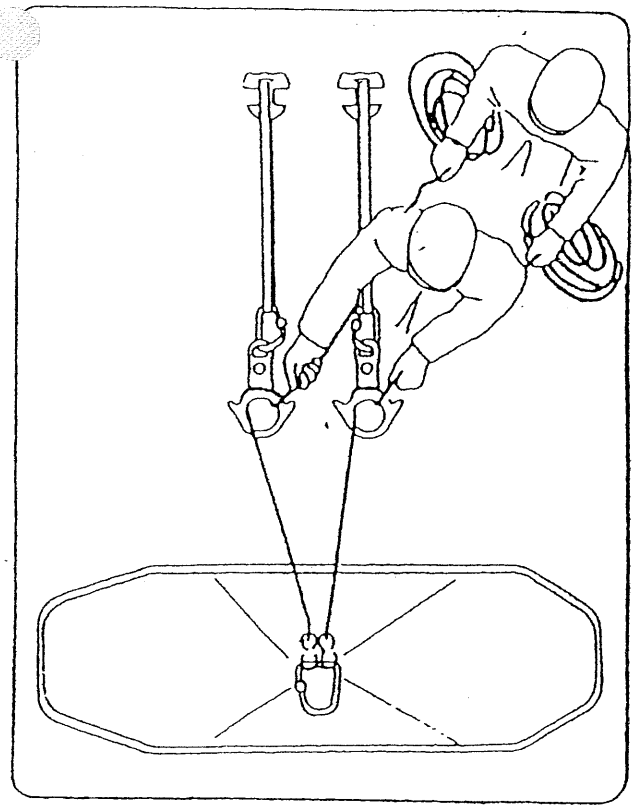
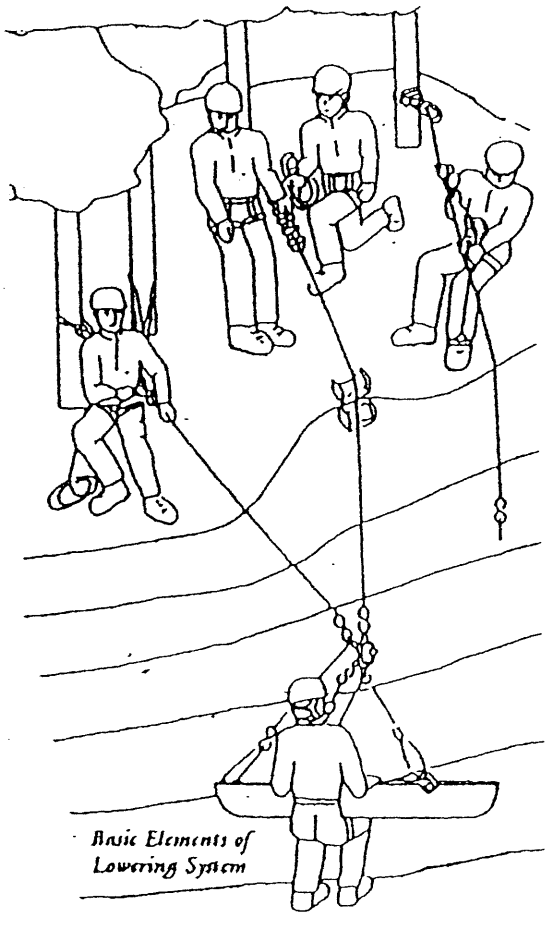
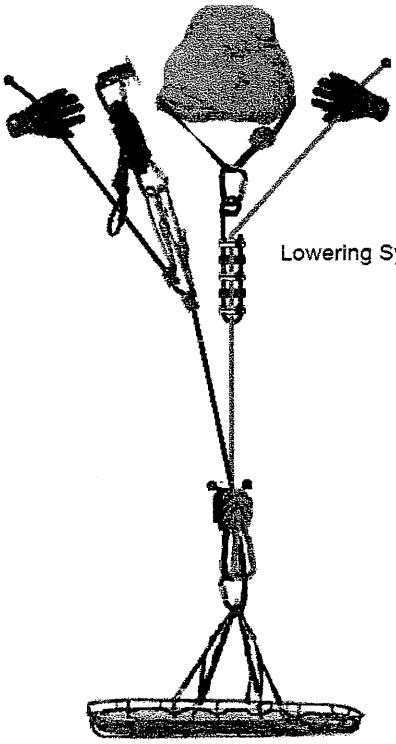


Fig. 14.17 Figure 8 Lowering for Litter

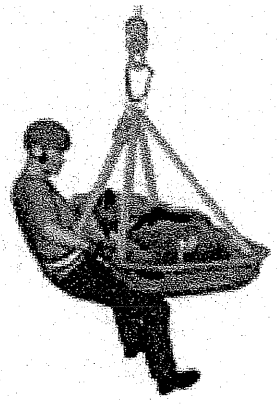


Basic Elements of Lowering System

LOWERING SYSTEM



Lowering System



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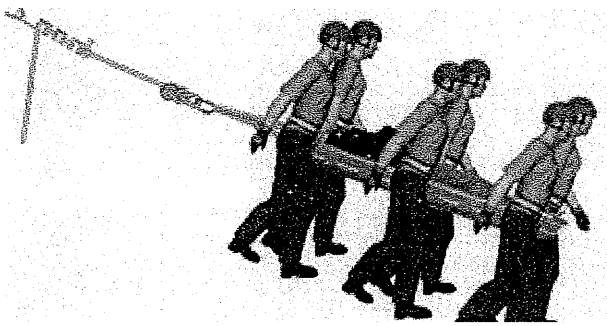
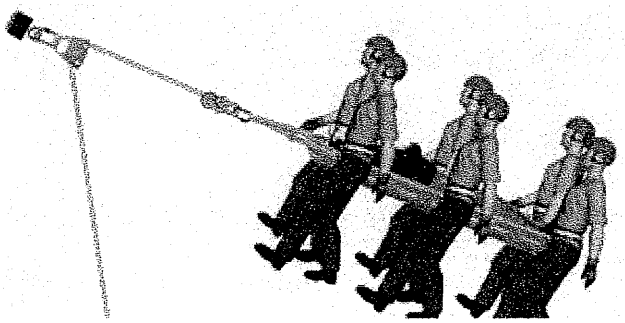
Lowering Systems generally develop **LESS** system tension than raises

LOW ANGLE LOWERING



LOW ANGLE RAISE



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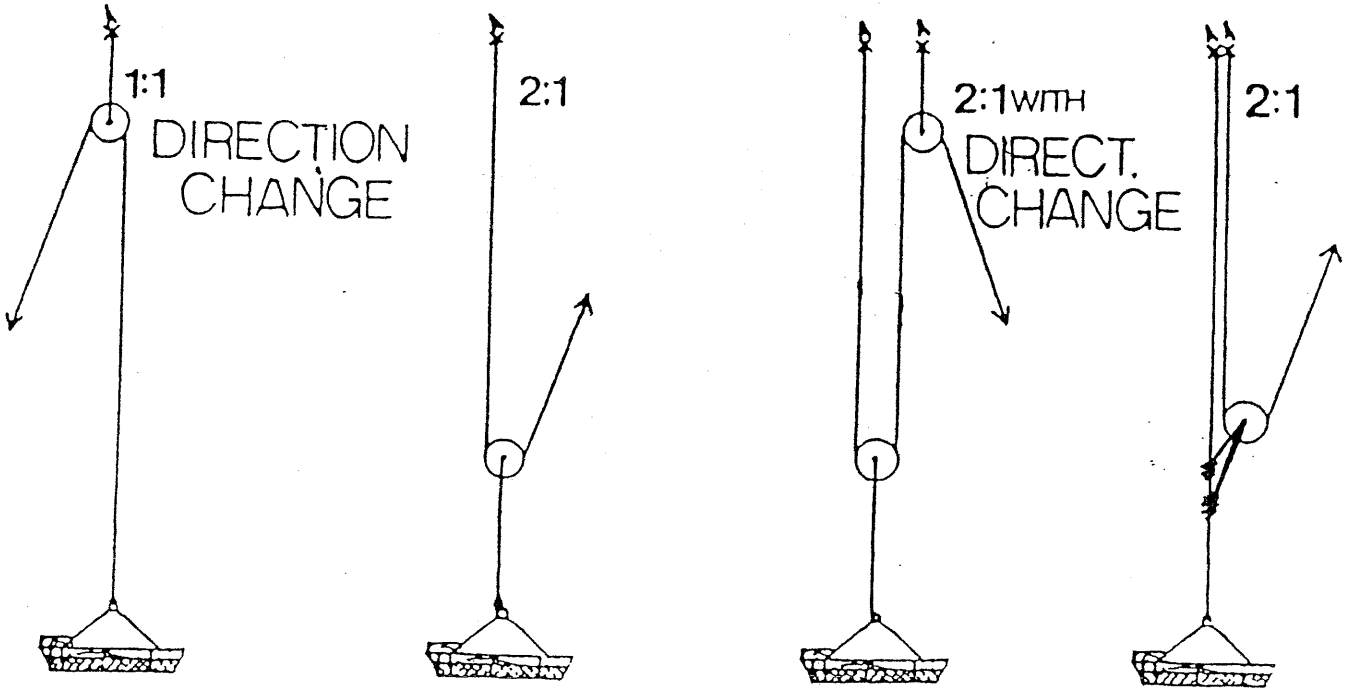
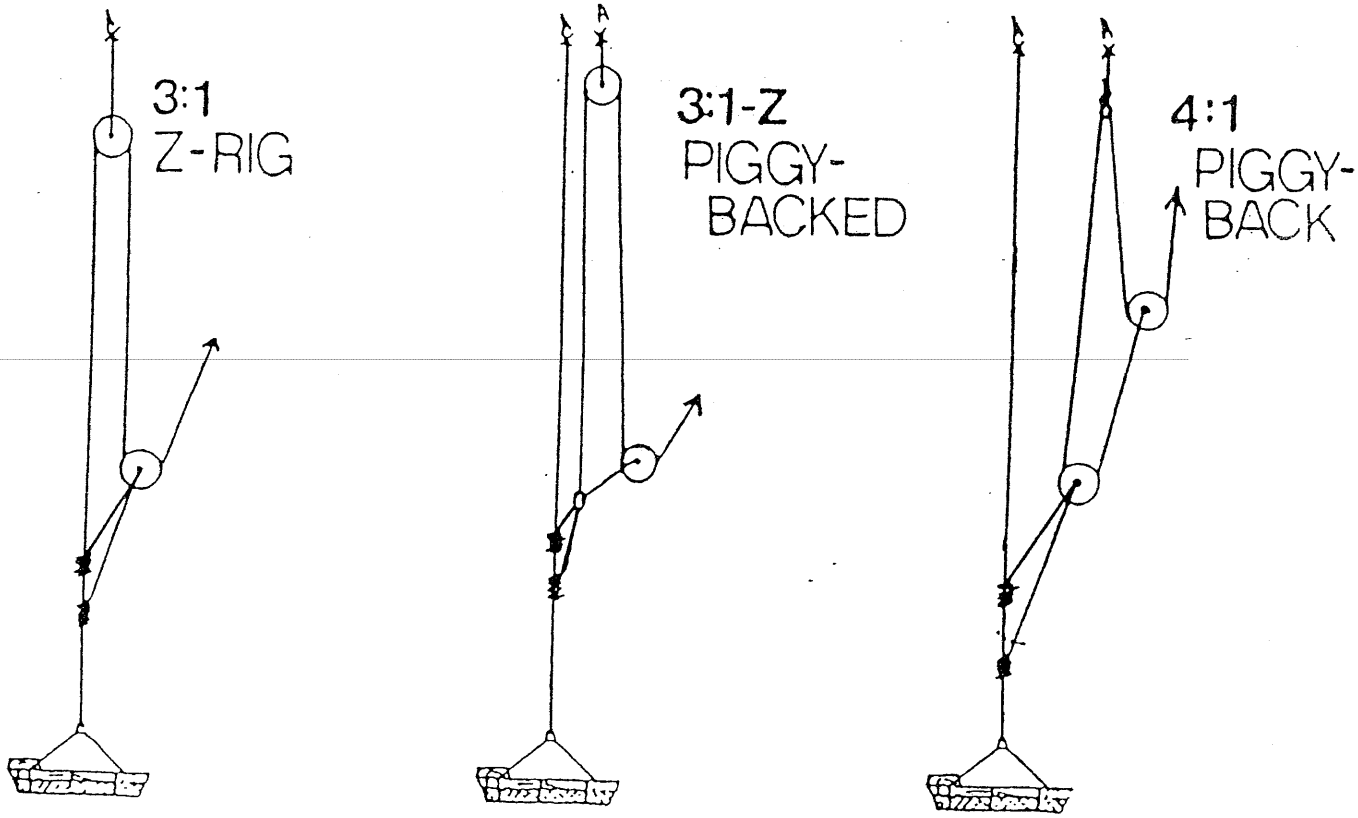
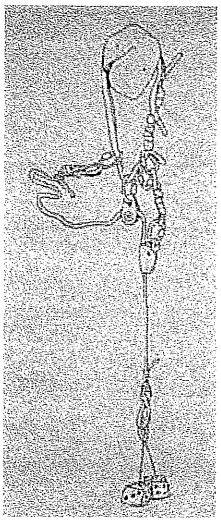
Mechanical Advantage Haul Systems



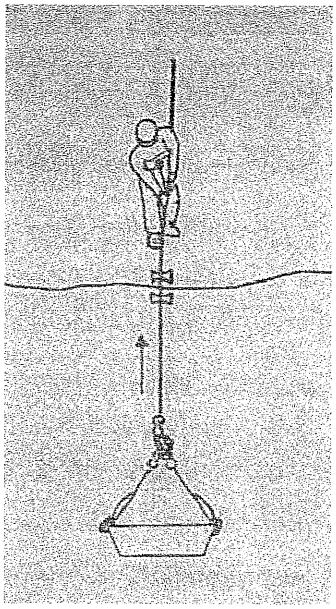


Lole

1:1 Mechanical Advantage



Belay System



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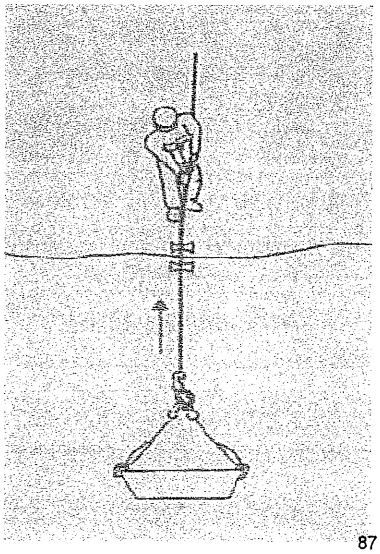
1:1 Mechanical Advantage

- This system provides no real mechanical advantage at all
- If the load weighs 600lbs., you will need to pull 600lbs
- For every 1' of pull the basket moves 1'



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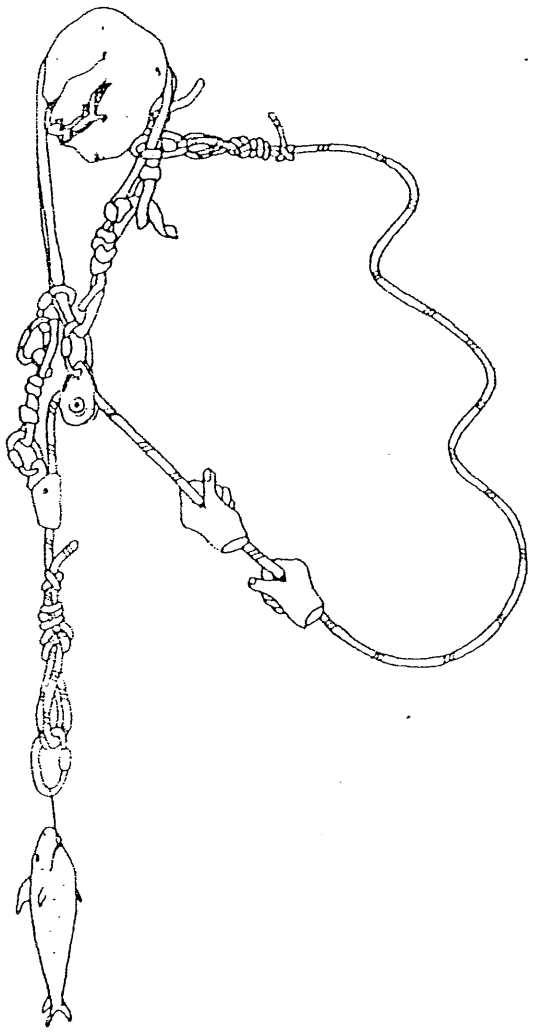
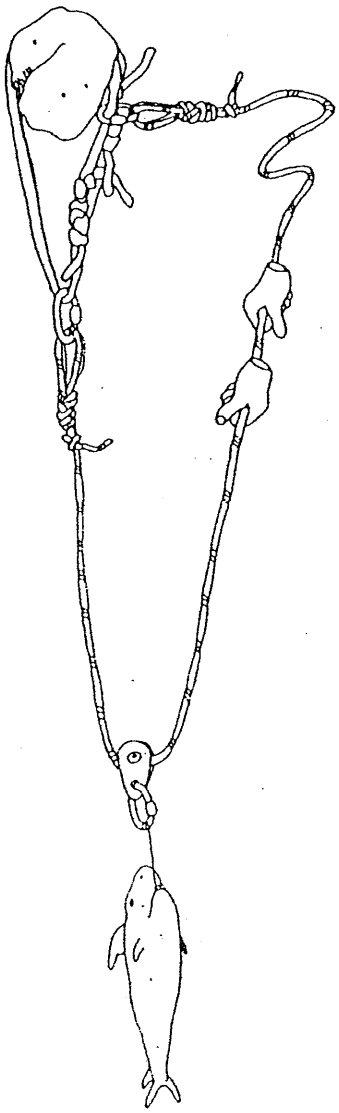
(A one person rescue load is generally assumed to be 300 pounds)

The 1 to 1 System With a Change of Direction



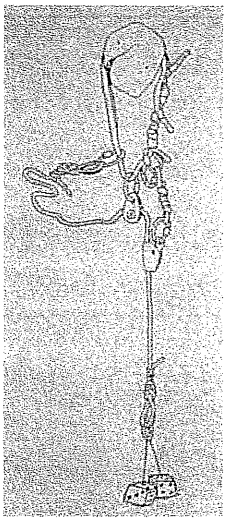
The 1 to 1 gives no Mechanical Advantage at all. If there are enough people around to haul on the rope it is faster than setting up a 3 to 1 System. Run the rope through a pulley and connect the pulley to the anchor with a locking carabiner. Attach the Brake Gibbs on the load side of the pulley using a Mariners Knot. The pulley provides a direction change that allows the haul team to move in the most efficient direction. It is fast and simple, but requires a lot of human pulling power.

The 2 to 1 Mechanical Advantage System

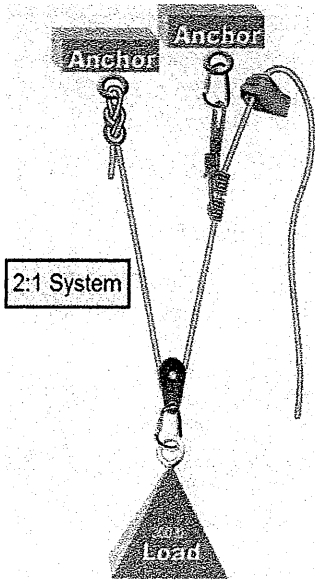


A 2 to 1 System is useful in applications where you want to cut the load in half, such as when lowering a single person who may have to be raised back up. Note that the pulley is attached to the load. If the pulley were attached to the anchor you would only have a change of direction, not a mechanical advantage. Generally, a 3 to 1 is as fast to set up and gives you a greater mechanical advantage.

2:1 Mechanical Advantage



Belay System



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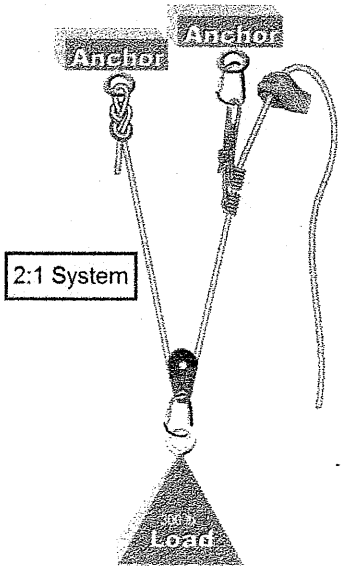
(A two person rescue load is generally assumed to be 600 pounds)

2:1 Mechanical Advantage



- **If the load weighs 600lbs., you will need to pull 300lbs**
- **For every 2' of pull the basket will only move 1'**

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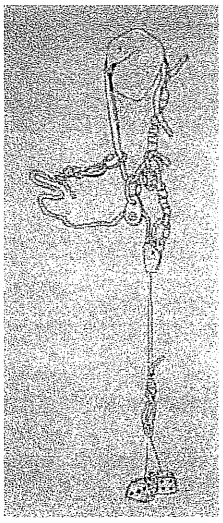
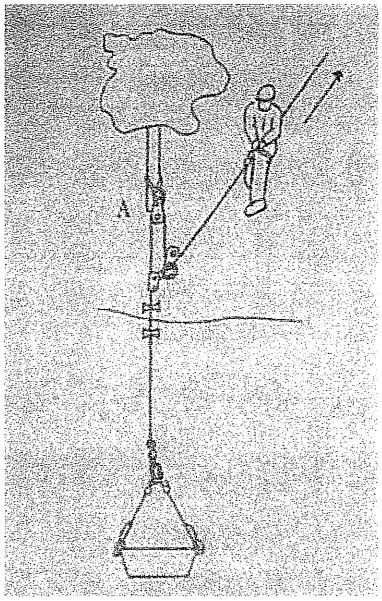
3:1 Mechanical Advantage



Belay System

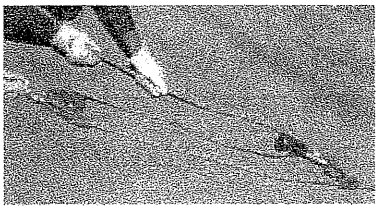


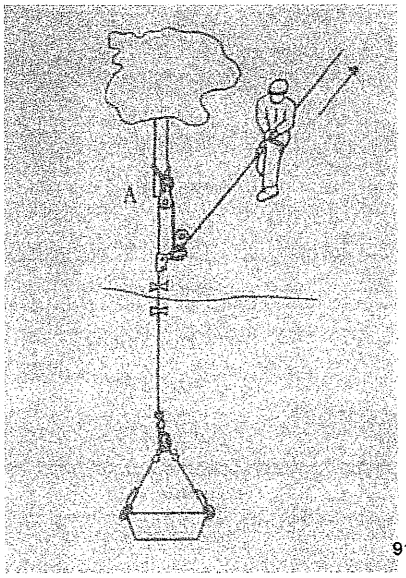
90

A one person rescue load is generally assumed to be 300 pounds

3:1 Mechanical Advantage

- **If the load weighs 600lbs., you will need to pull 200lbs.**
- **For every 3' of pull the basket will only move 1'**





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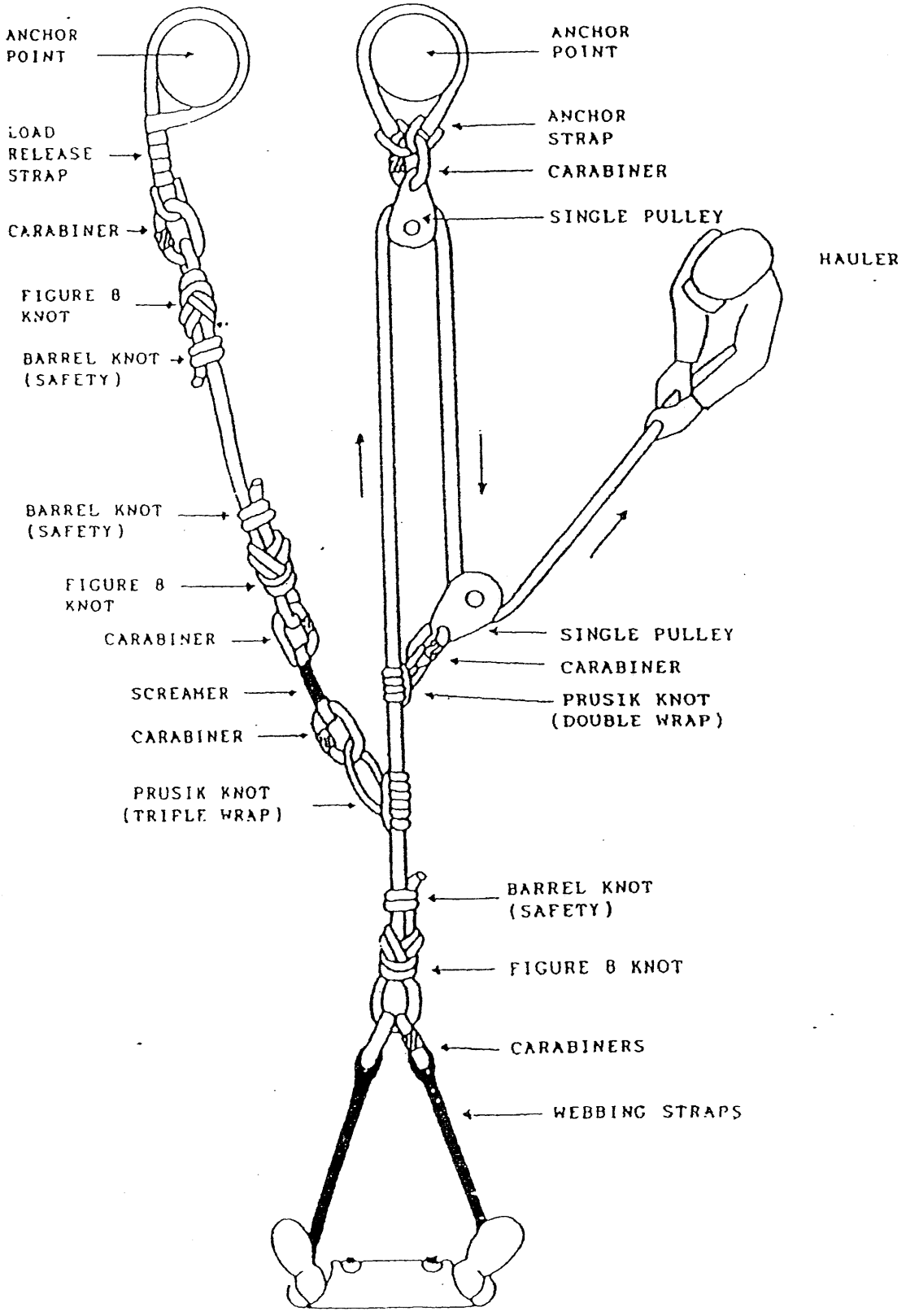
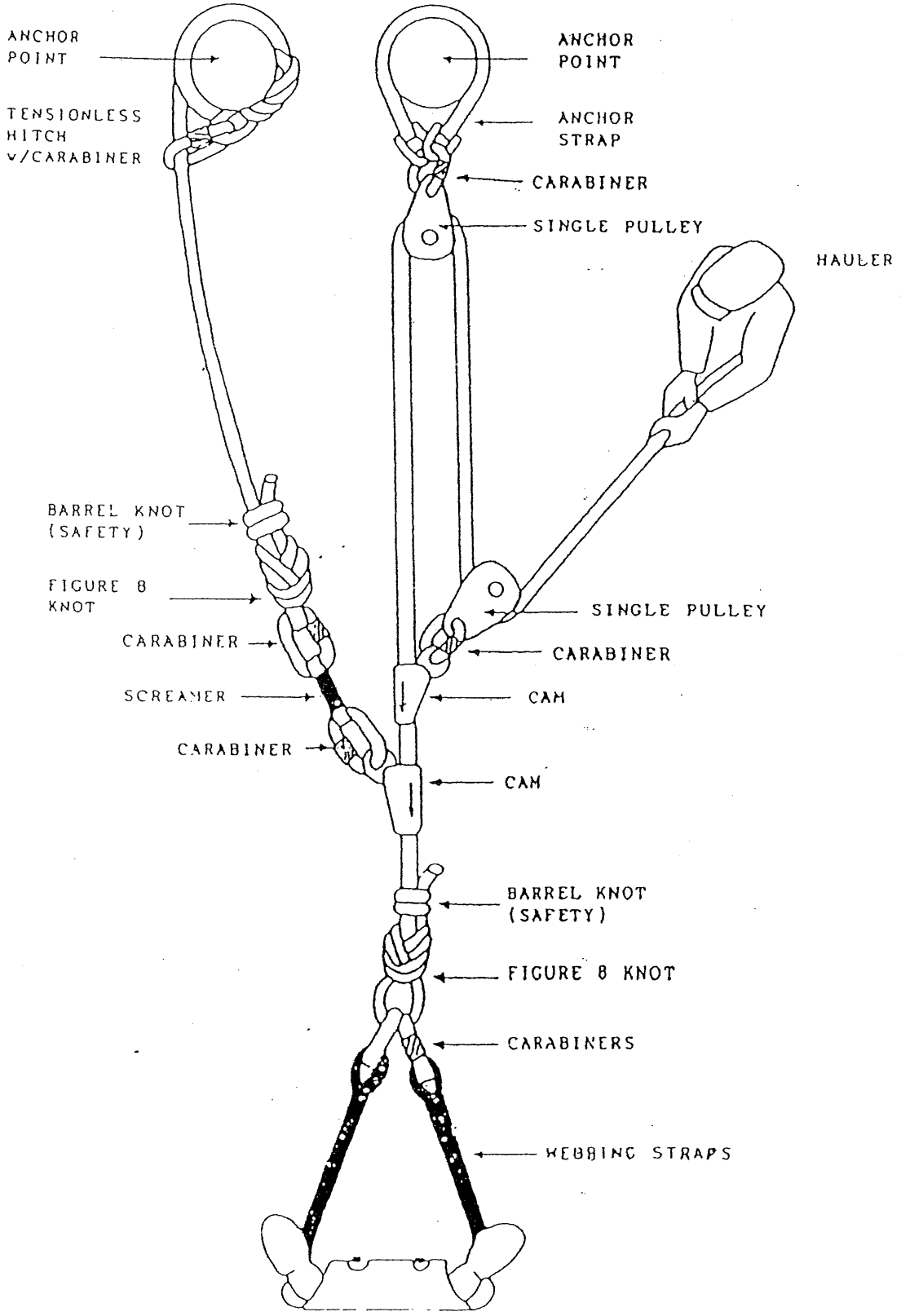
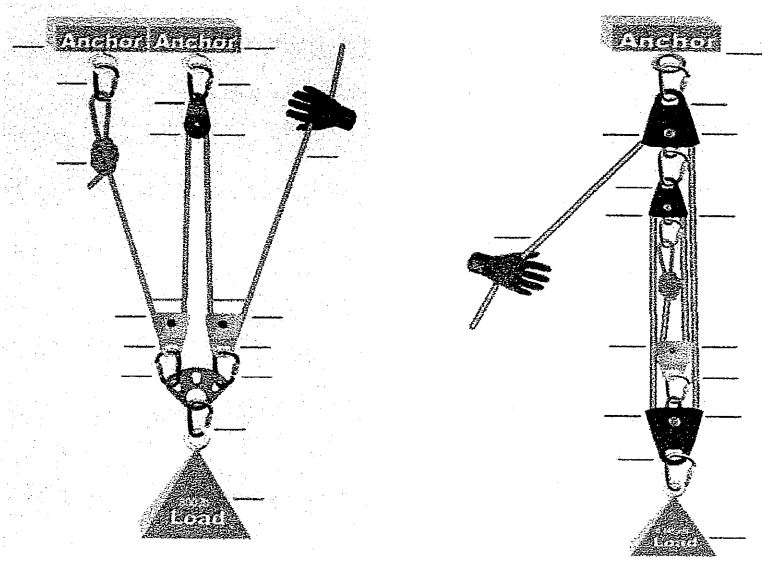
3:1 HAULING SYSTEM
(With Prusik)



3:1 HAULING SYSTEM
(With Cam)



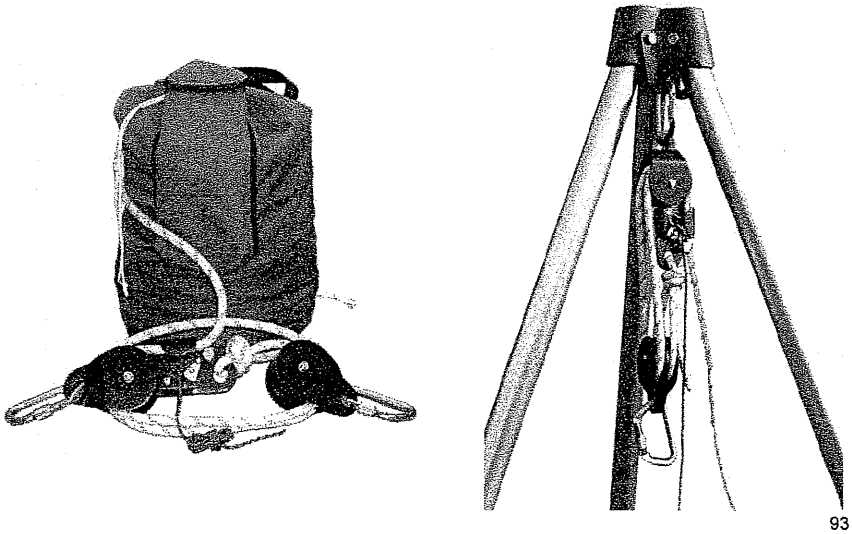
4:1 Mechanical Advantage



92

(A two person rescue load is generally assumed to be 600 pounds)

4:1 Mechanical Advantage



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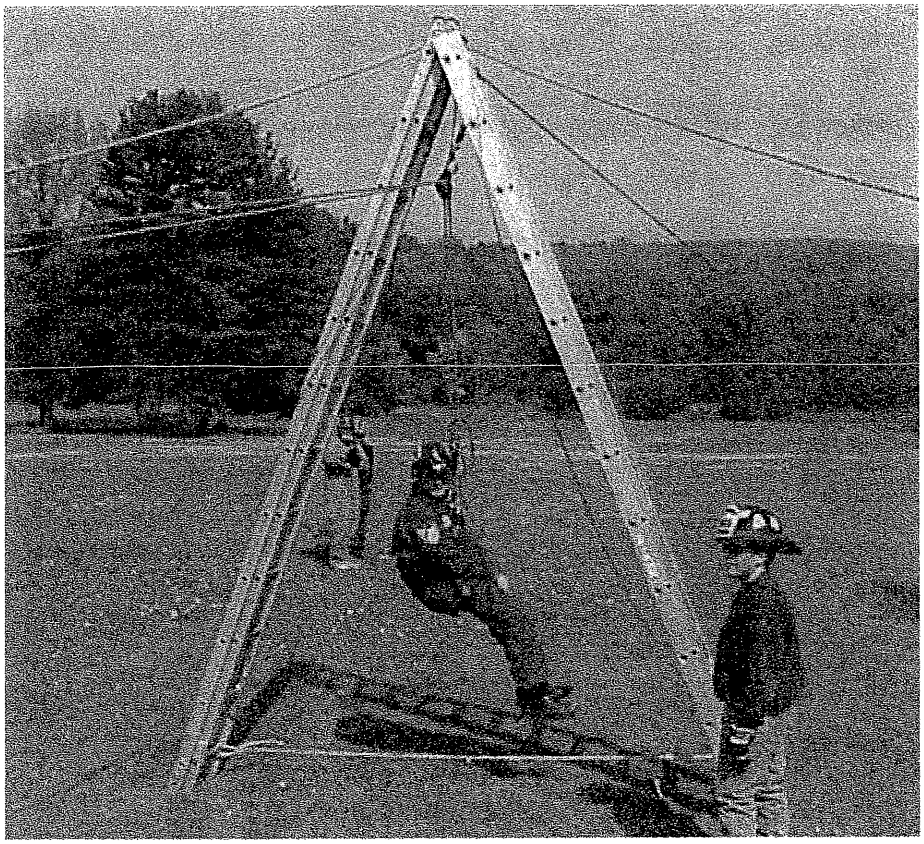
A-Frame



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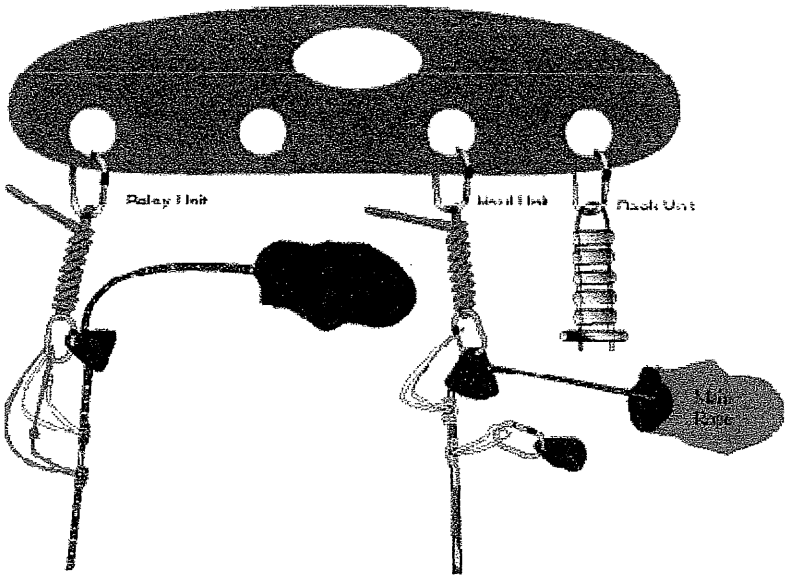
Basic Rigging Kit

Basic Rope Kit



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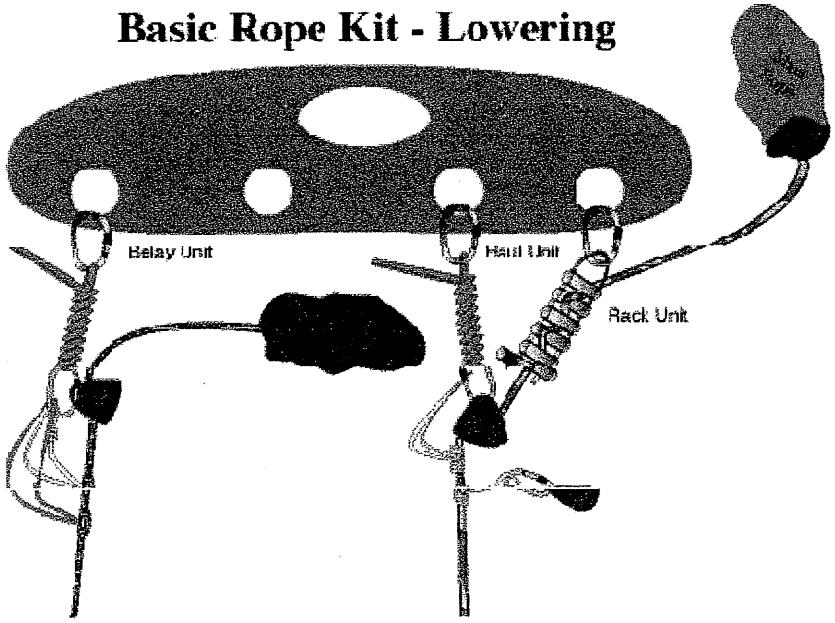
Basic Lowering Kit



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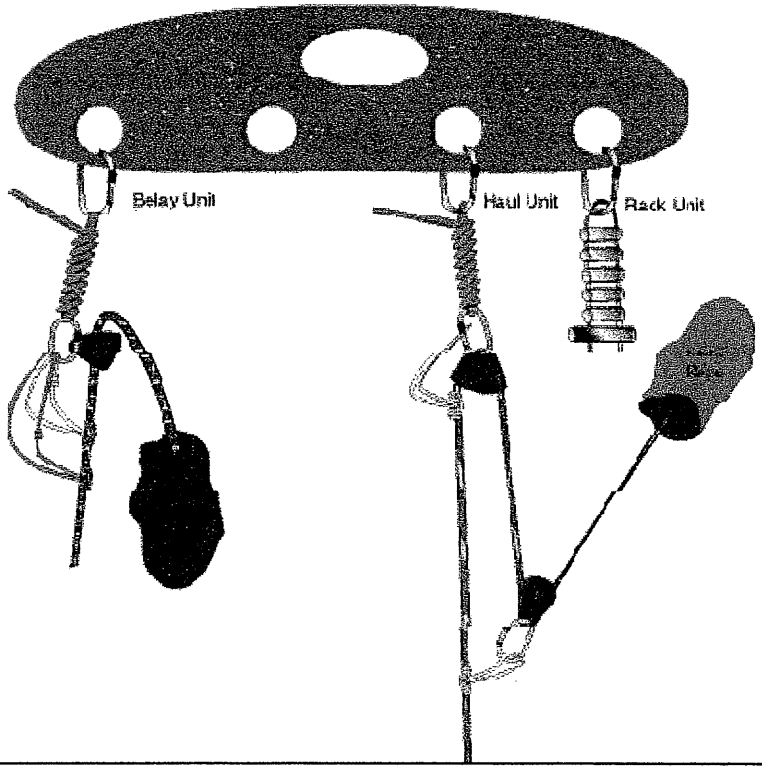
Basic Raising Kit

Basic Rope Kit - Raising



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CMC Rescue Technical Report #13

Tandem Prusiks vs. Gibbs Ascenders

Tandem Prusiks vs. Gibbs Ascenders is a big topic of conversation in rope rescue today.

For ascending, there is no discussion. Gibbs were designed for ascending, and they are a superior device for that. They easily attach, are strong, and grip well on icy or muddy ropes. They are much stronger than handled (toothed) ascenders and their cam does less damage to the rope when sliding up because it lacks the scores of "teeth" that other ascenders have.

The debate is when Gibbs are used in other than single person ascending applications, such as haul cams in mechanical advantage systems or for belays. In those uses they can cut, or de-sheath a rope at a relatively low level of force. Demonstrations in the CMC Rescue classes are routinely set where students are pulling on a rope with a 9:1, and Gibbs de-sheaths the rope. The core strands remain intact but if it were to happen during a rescue, it would mean stopping the operation and replacing the rope. Prusiks on the other hand, slip when the forces get too high. That slipping does not damage the main line, but it does warn a trained rescue team that something is wrong, perhaps the litter or the attendant's foot is stuck. The slipping also relieves some of the force, but in a gradual manner.

The difference between the actions of Gibbs vs. Prusiks is even more apparent in belay applications when a load is suddenly dropped on to the belay device, such as a main anchor failure. Tandem prusiks will slip, and may even melt while slowly stopping the falling load. Gibbs will slam on the rope, cut the sheath and some of the core, and possibly even self destruct. In CMC Rescue School tests, pins and cams have broken and side plates have blown out.

When looking at various rope training manuals over the past 30 years, one will see that the evolution has been from Prusiks to Gibbs and now back to Prusiks for haul cams in mechanical advantage systems. The ratchet, or back cam, can still be a Gibbs because it is closely connected to the anchor and does not have the possibility to see the forces the haul cam sees. However, in CMC Rescue classes, after a Gibbs is tested and everyone sees what it can do in test situations, it is then put back in the bag and hardly ever comes out of the equipment cache.

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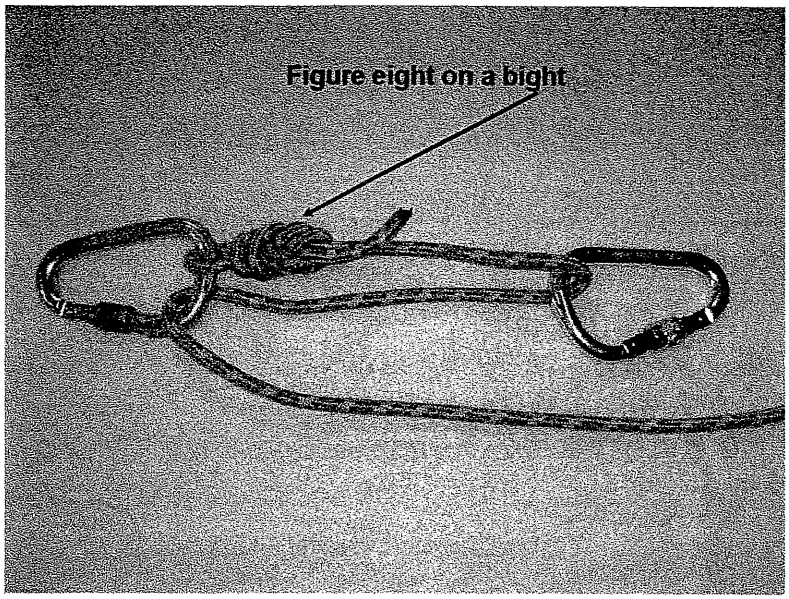
Radium Load Releasing Hitch



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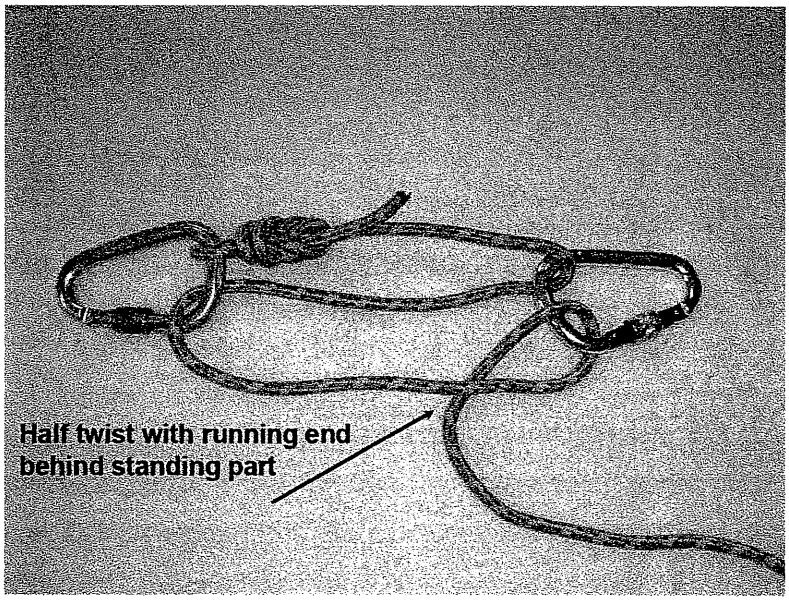
Radium Load Releasing Hitch



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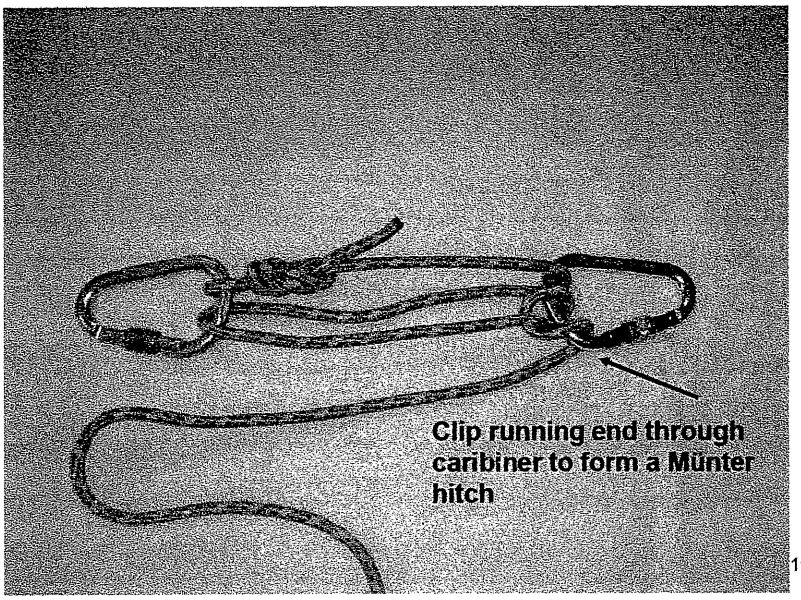
Radium Load Releasing Hitch



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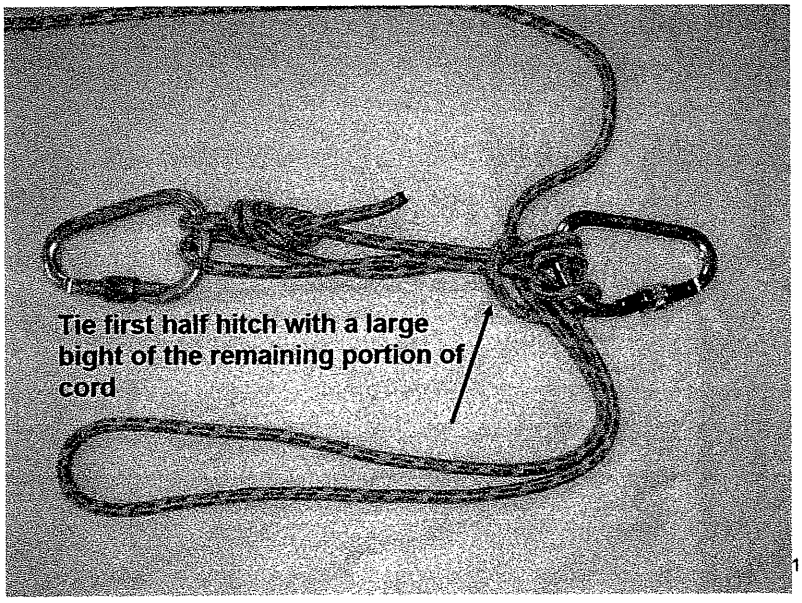
Radium Load Releasing Hitch



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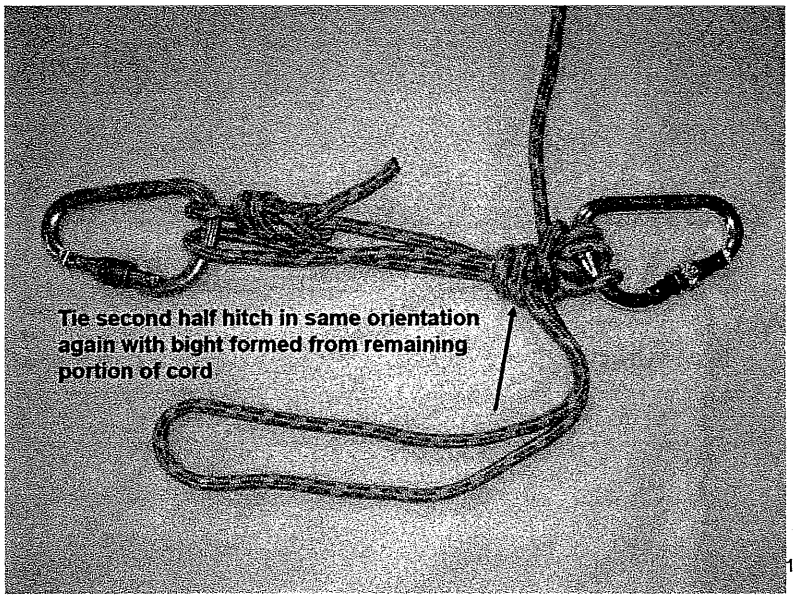
Radium Load Releasing Hitch



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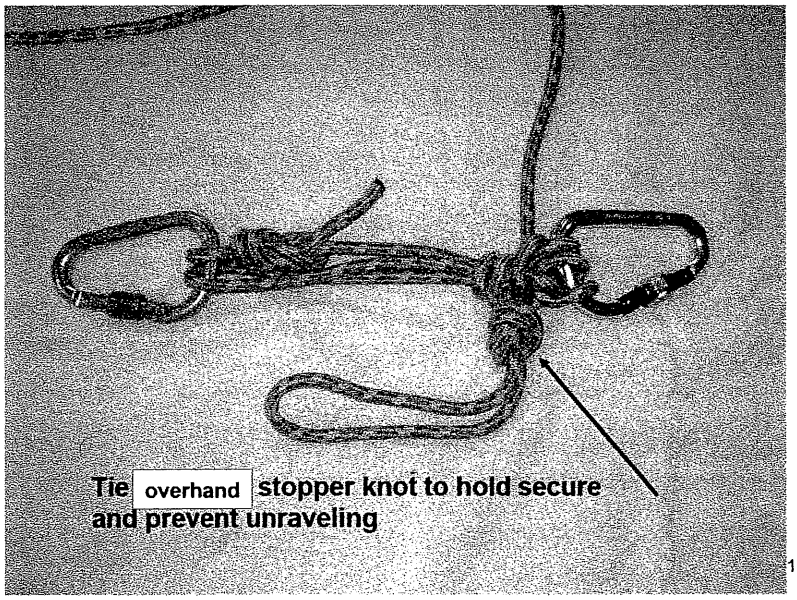
Radium Load Releasing Hitch



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