Tempe Fire Department Policies and Procedures
Ropes, Knots, & Related Equipment
405.15
Rev 12-15-97

PURPOSE

A knowledge of ropes and knots and their proper application is an essential skill in many emergency situations. All Emergency Services personnel must be familiar with the ropes and allied equipment used by the Department and adequately trained in their use. Using the wrong knot or one tied improperly could cause an accident, resulting in injury or loss of life. This policy will describe the ropes and related equipment utilized by the Tempe Fire Department and their characteristics as well as the knots that all members must know.

ROPES

Types and Characteristics

The Tempe Fire Department utilizes the following types of rope:

Lifelines - There are two types of ropes used in rescue operations currently. The first is kernmantle. This rope is 100% nylon. It has 80% of its strength in the core (kern) and 20% of its strength in the protective sheath (mantle). It is tightly braided and cannot be spliced. Nylon loses 10-15% strength when wet, however, when dry, strength is restored. Sunlight will damage nylon. Our kernmantle nylon ropes are static, which means it only stretches from 2-4% when loaded. Dynamic ropes are constructed differently and stretch as much as 20% or more when loaded. Climbers use dynamic rope. We currently do not use them.

The second type of lifeline we use is the Lifestron rope manufactured by Tichnor International. The core is double-braided nylon and the sheath is polyester. The core and sheath have 50% strength each. It is a looser braid than that of kernmantle rope and comes with an eyesplice that replaces a knot at the end of the rope. Polyester resists sunlight better than any other rope material and is strong and abrasion-resistant. Each strand of the sheath represents 2% strength. It also has a good resistance to corrosives and solvents.

Polypropylene Rope - These ropes are located on some companies in closed buckets. Polypropylene rope is light and it floats. It stretches, cannot take heat, and is weakened by exposure to sunlight.

Personal Safety Line - These ropes are located in a pouch on the waist strap of each SCBA. Each safety line consists of 30' of 3/16" double-braided Dacron over Kevlar. This rope can withstand high heat without loss of strength. Two locking carabiners are attached to each personal safety line.

Water Rescue Rope (Throwbags) - A combination of nylon and polypropylene (spectra) that is bright yellow and floats.

Strengths

1" nylon webbing (tube)	4,000 lbs. min
Kernmantle 9mm (accessory cord)	4,400 lbs. min
Kernmantle 6mm (personal prusiks)	1,600 lbs. min
Kernmantle 8mm (prusiks)	3,300 lbs. min
Kernmantle 7/16" 7000 lbs. min	
Kernmantle 1/2"	9000 lbs. min

Kevlar personal safety line 3/16"	4,000 lbs. min	
Lifestron 1/2"	9,500 lbs. min	10,500 lbs. avg
Lifestron 5/8" (lifeline)	16,500 lbs. min	18,250 lbs. avg
Polyester 3/8" (prusiks)	3,800 lbs. min	
Polypropylene 5/8"		
6,000 lbs. apprx (50% stronger than manila)		
Slings (nylon)	8,500 lbs. min	
Spectra 3/8" (water throw bag)	4,500 lbs. min	

These strenghts are for current ropes, however they vary with manufacturer.

Strength Losses

Shock-loading our ropes (surging, sudden loads) or loading quietly to 40% of the breaking strength may permanently damage the rope. Ropes have a memory, and if subjected to such a load they are to be replaced. Knots, sharp bends, and angles all weaken rope strength.

Bowline - 50%.
Figure-8 on bight - 25%-30%.
Right angle bend (building edge) - 50% (pad all edges).
Running rope through an eye splice to form a loop - 20%.
An eye splice with a carabiner has no loss.

Effects of Heat

Friction devices create heat. (Example: Figure-8 descender on long rappel.)

280°F Polypropylene melts.
350°F Nylon/polyester reach critical temperature and will lose strength rapidly as heat increases.
480°F Nylon/polyester melts.

Care and Maintenance

Ropes should be kept clean, dry, and away from rust. The oxidation process will weaken the rope. Our lifelines are kept in rope bags. The rope is fed into the bag and shaken down so it will feed out easily. If the rope has an eyesplice, it should be at the top of the bag.

Dirt will damage the fibers inside a rope. Walking on the rope will grind dirt into the core and damage the fibers thus weakening the rope strength. The ropes can be washed in a machine with mild detergent on the cold setting. Daisy chain the rope (electrician loop) so the rope does not get tangled in the machine. Air dry the rope. Never use a dryer.

AFFF foam will attack nylon fibers. If nylon is soaked in it for 24 hours it would lose approximately 15% of its strength. Polyester is not affected. Washing the rope will remove the foam.

Each rope must be inspected before and after each use for damage and wear. If the sheath is damaged so that the core is exposed or if there is a doubt on the integrity of the rope, take it out of service. Each lifeline is numbered and has a record card kept inside of its respective bag. Each weighted use and washing is to be kept on the record card.

KNOTS

Definitions:

- A *knot* is tied in a rope.
- A *hitch* is tied around an object. When the object is removed, the hitch falls apart.
- A *bend* ties two ropes together.

The basic elements of a knot are bight, loop, and round turn (Figure 1).

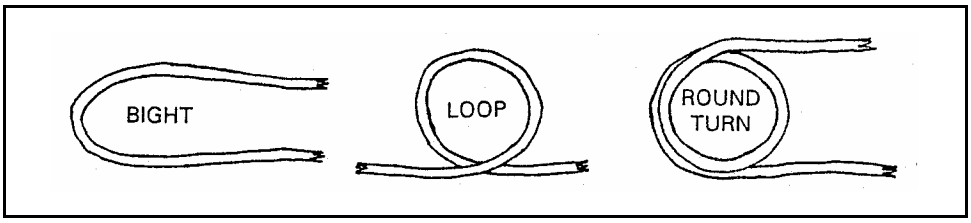


Figure 1

There are two ends to each rope:

Standing End - The long or working end of the rope, the end where the pulling is done, also called the fall line on hoisting systems.

Running End - Where a knot is tied, or the end tied around something.

Our knots should not slip, hold when load is applied, and untie easily when slack.

Square Knot

This knot is used to tie two ends of rope together. Our most common use is in the swiss seat, harnesses, or in bandages. A half-hitch or overhand safety should be tied with the tails on each side of the knot to insure that the knot will not slip.

Cross the two running ends of the ropes to be tied (Figure 2).

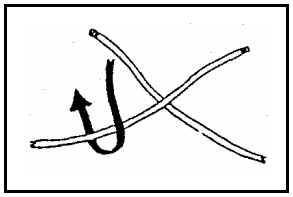


Figure 2

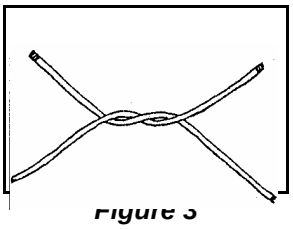


Figure 3

Then take the end on the left and pass it toward you and around the other rope forming an overhand knot (Figure 3).

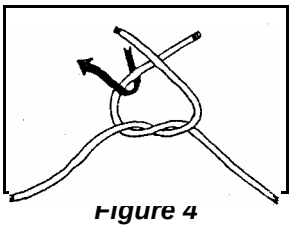


Figure 4

Cross the two running ends above the overhand knot (Figure 4).

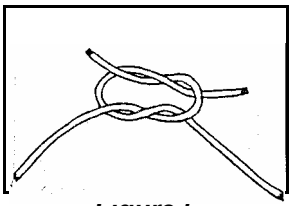


Figure 5

Then take the end on the left and pass it away from you and around the other rope, forming an overhand knot opposite the first

Clove Hitch

This is a self-tightening knot used in hoisting. Usually used as a base knot in conjunction with a half hitch.

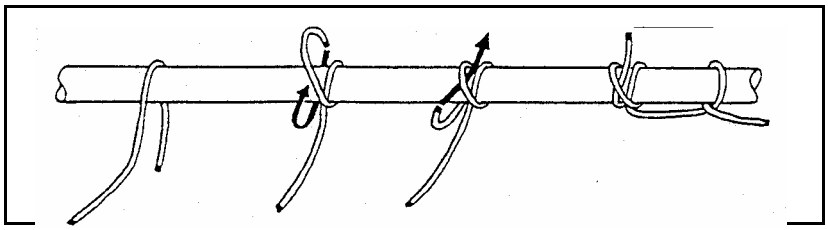


Figure 6

For tying the knot on a rail, first place the running end of the rope over the rail away from you. Then bring the end around the rail crossing over itself forming a half hitch. Now go back around the rail and under the rope that crossed forming a second half hitch opposite the first. For a safety, form a loop and place it over the rail forming a half hitch down from the clove hitch (Figure 6).

There are times when a pre-formed clove hitch can be slipped over an object such as a pike pole or extinguisher. The pre-formed clove hitch is tied as follows.

Place enough of the running end in front of you to form the clove hitch. Grasp the rope with your hands about 1'-2' apart depending on the size hitch needed (Figure 7).

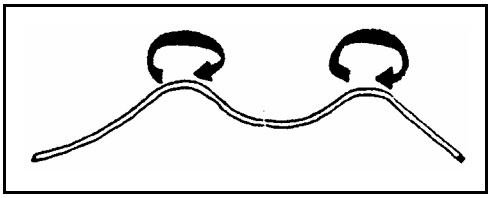


Figure 7

Twist the rope in each hand 180° in a clockwise direction forming two loops. Take the loop on the right and pass it away from you and behind the one on the left (Figure 8).

Place the two loops together. This is the pre-formed clove hitch (Figure 9).

Then place the hitch over the object and pull the standing and running ends opposite directions to tighten (Figure 10).

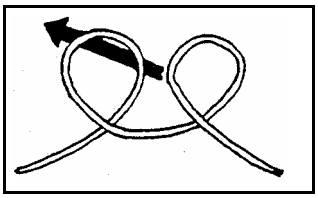


Figure 8

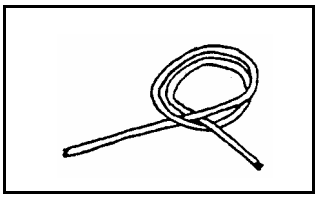


Figure 9

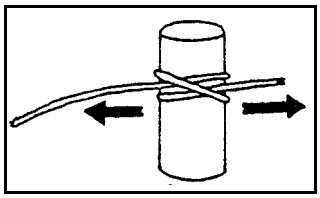


Figure 10

Bowline

The bowline is used to form a loop or tie a rope around an object. It will not slip.

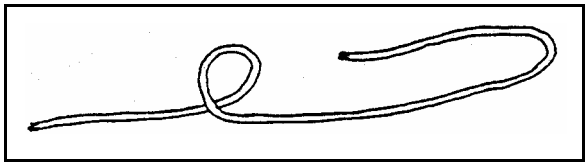


Figure 11

Take a half turn in the running end forming a loop far enough from the end to leave enough rope for the task (Figure 11).

Pass the running end through the loop away from where the rope crosses at the base of the loop. Then pass the end around the standing rope and back through the loop. This forms a bight that interlocks with the loop (Figure 12).

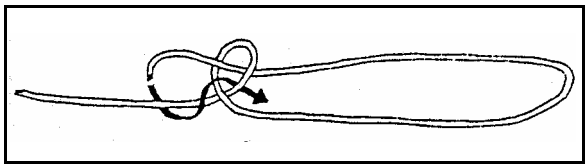


Figure 12

When tightened, the tail of the running end pictured is inside the loop formed (Figure 13). (It will not effect the strength of the knot if the running end was passed around the standing end in the other direction so that the tail was on the outside of the loop.)

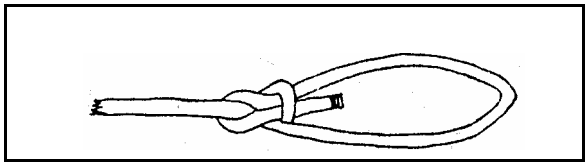


Figure 13

Becket Bend

This knot is used to tie two ropes together. It is a form of a bowline using a bight and loop interlocked.

With the running end of both ropes to be tied facing each other, form a bight in the rope on the left. Pass the end of the rope on the right through the bight then around the standing and running ends of the rope on the left. Then pass the end under the standing part of the rope on the right forming a loop that is interlocked with the bight (Figure 14).

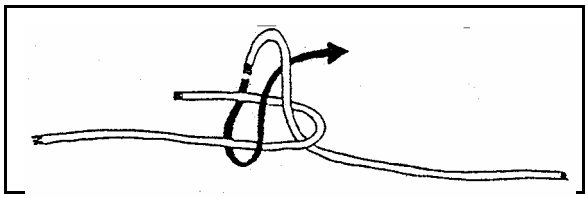


Figure 14

Hoisting Knots

The rope used to hoist small tools in most cases will be the one on hand or the personal Kevlar rope. For large items such as straight ladders or a fan, a larger and stronger rope such as our Lifestron, will be used.

Axe Hitch

For an axe, lay the rope on the ground and place the axe head on it with 2' of running end protruding. Hold the standing end of the rope against the handle with the handle vertical. Pass the running end around the handle and the standing end of the rope and back under itself forming a loop around the handle (Figure 15). Then take a turn in the standing rope of the handle and loop it over the handle forming a half hitch (Figure 16). This knot can be used on a sledge hammer also.

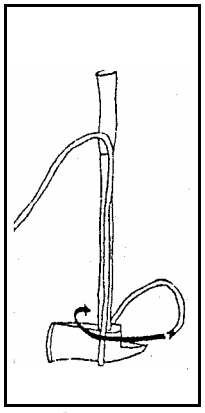


Figure 15

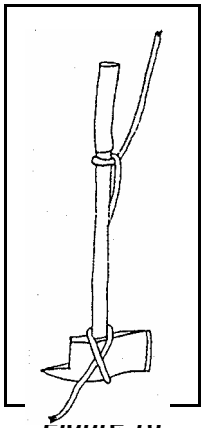


Figure 16

Use a clove hitch and two half hitches for a pike pole, pry bar, haligan, etc. (Figure 17).

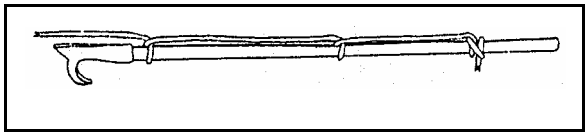


Figure 17

For hose lines, first tie a clove hitch 1' from the nozzle (Figure 18).

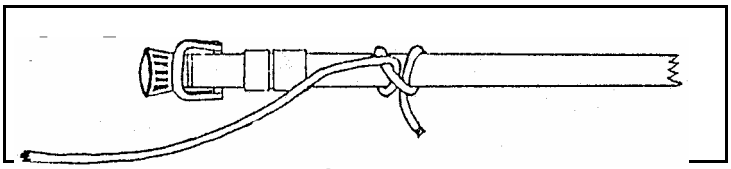


Figure 18

Then take a turn in the standing end and form a loop for a half hitch. Pass the loop under the nozzle ball and over the tip of the nozzle (Figure 19).

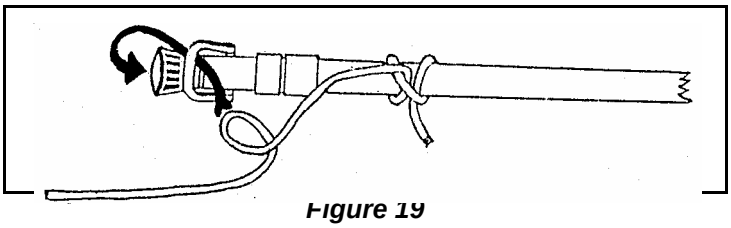


Figure 19

When the half hitch is tightened it will hold the nozzle in the closed position during hoisting (Figure 20).

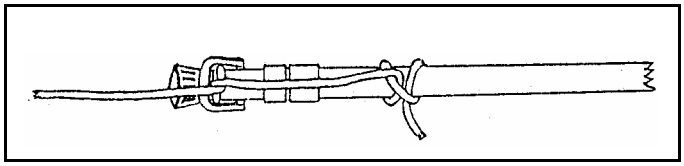


Figure 20

To hoist an extinguisher tie a clove hitch on the base of the extinguisher. Then form a loop for a half hitch and place it around the top, under the handle (Figures 21 & 22).

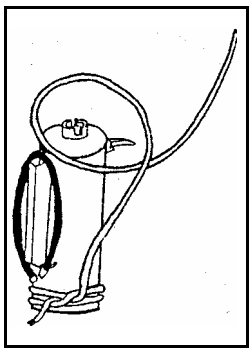


Figure 21

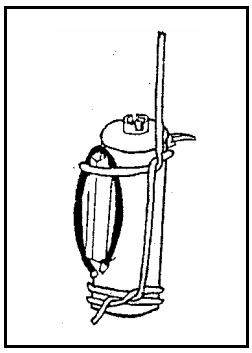


Figure 22

The ladders small enough to hoist will be an A-frame, straight, or attic. The attic ladder can be hoisted as a pike pole in the collapsed position. Form a large loop using a bowline knot in the hoisting line. Pass the loop under the beam three rungs from the head of the ladder. Then place the loop over and around the head of the ladder (Figure 23).

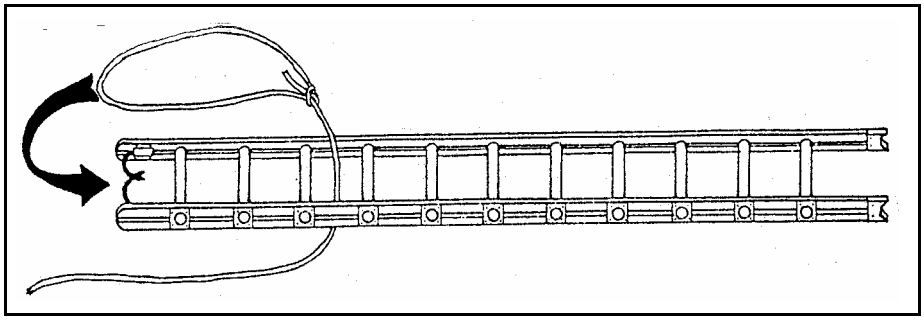


Figure 23

Pull the standing end to tighten (Figure 24).

This forms a half hitch on both beams at the third rung (Figure 25).

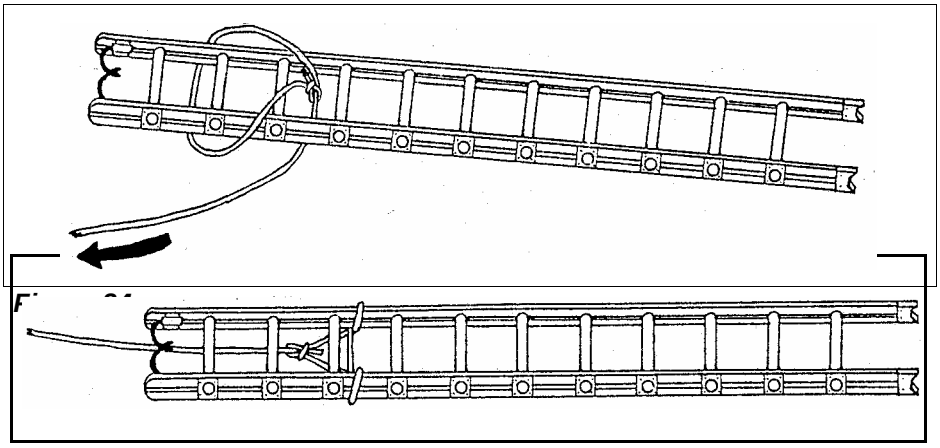
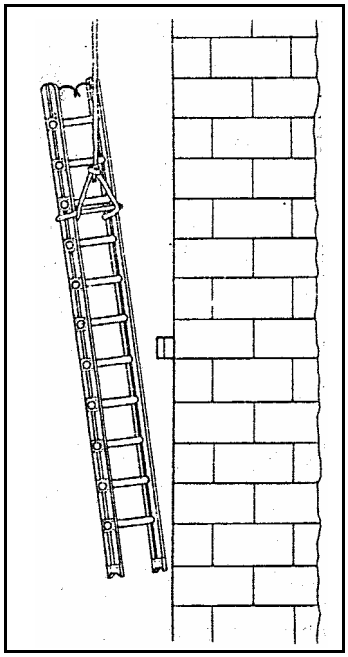


Figure 25

With the knot side of the ladder (as shown in Figure 26) against the building, the head of the ladder will project away from the building with the heel of the ladder dragging. This is the proper way to hoist. To lower, simply turn the ladder over so that the knot side is away from the building. This will project the heel away from the building with the head dragging.



In the case of heavy or large items (i.e., exhaust fan, Hurst tool, etc.) that have to be hoisted above grade, the larger hoisting lines must be used. The running end of the rope should be passed through the handles or frame and tied back to the standing with a bowline. A guy line can be tied to the base of the item using a clove hitch. The guy line is manned from the ground to help maneuver the item around obstacles during the hoisting process.

Figure-8

The primary knot used in rescue is the figure-8 in various configurations. Form a loop at the running end of the rope (Figure 27). Place the running end over the standing part (Figure 28). Then pass the running end through the loop (Figure 29).

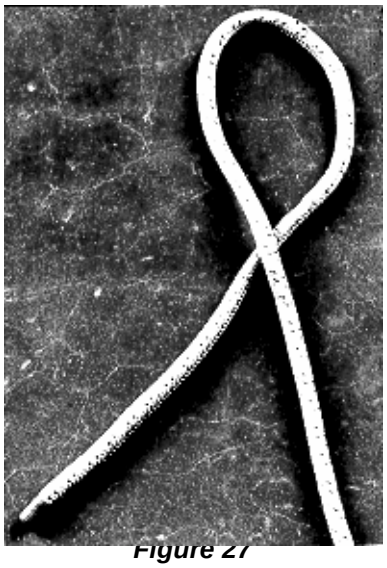


Figure 27

Figure 28

Figure 29

Figure 8 on a Bight

This knot forms a loop at the end of the rope to be used an as eyesplice.

Figure 30

Double the rope back on itself, allowing for the size of loop desired, plus the knot (Figure 30).

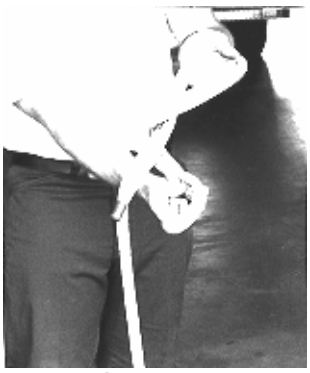


Figure 31

Pass the loop end around the standing part (Figure 31).

Figure 32

Then pass the loop end back over and through the loop formed (Figure 32).

Dress the knot by making all ropes lay parallel to one another and tighten each of the four ropes coming from the knot one at a time (Figure 33).

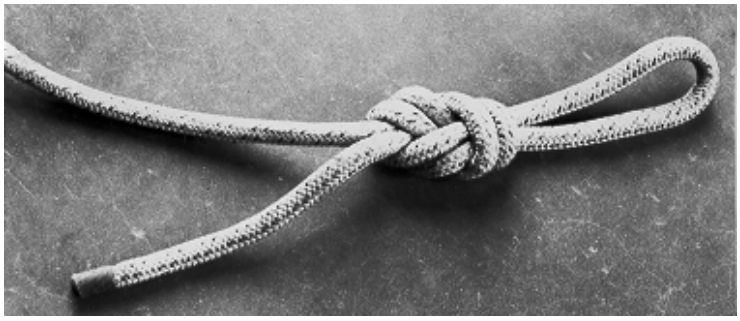


Figure 33

The tail can be half-hitched around the standing part for a safety (Figure 34). (an overhand is preferred if there is enough tail)

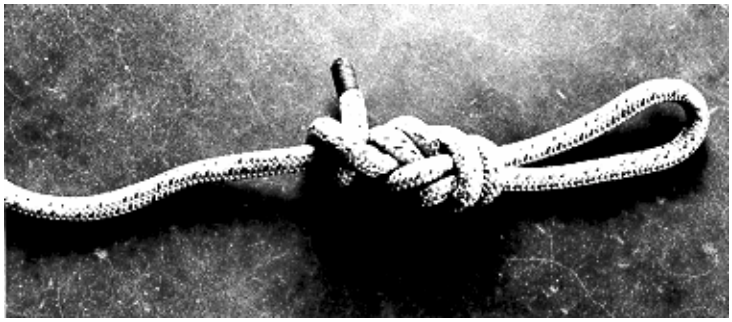


Figure 34

Figure 8 on a Bight with Two Loops (One Unequal)

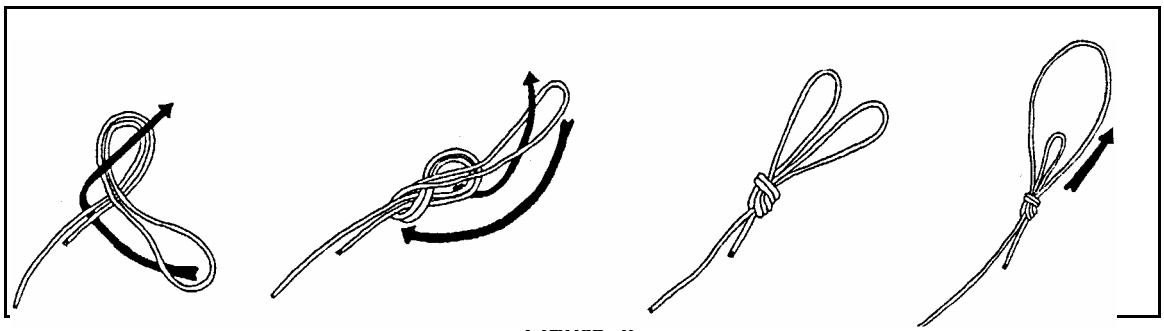


Figure 35

The double loop figure 8 on a bight can be used for a 2 point anchor or to strengthen a connection point with double rope strength. The unequal loops can be used to make a load distributing anchor with 2 or 3 points (see High Angle PP 208.04).

Figure 8 Follow Through Around an Object (traced).

This knot is used to tie a figure 8 on a bight around an object.

Tie a figure-8 down the running end of the rope with enough tail to go around the object and complete the knot (Figure 36).

Run the tail around the object and back through the point where it came out of the first knot (Figure 37).

Figure 36

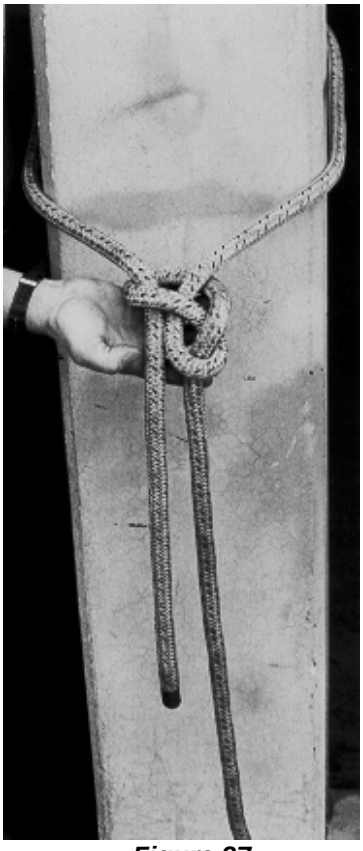


Figure 37

Now with the tail or running part, follow through and trace the first figure 8 and dress the knot (Figure 38).

Figure 38

Splicing With a Figure 8 Follow Through (Figure 8 Bend)

Used to splice two ropes or form one rope into a large loop.

Tie a figure 8 in the running end of one rope. Place the other end in the opposite direction (Figure 39).

Starting end-to-end, put the running end of the rope through the first part of the figure-8 (Figure 40).

Continue to follow the first figure 8 with the running end, keeping the ropes parallel (Figure 41).

When follow through is complete, you have one 8 parallel to another with the tails on opposite ends. Dress the knot, tighten, and tie safeties with the tails (Figure 42).

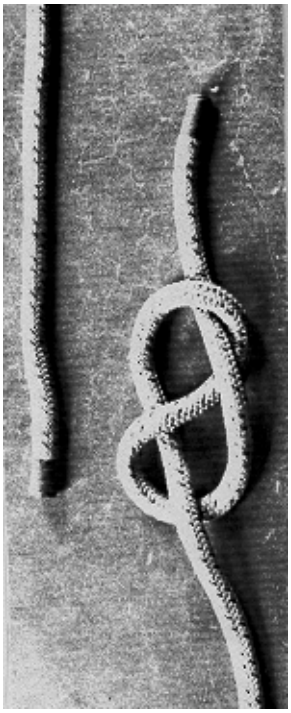


Figure 39

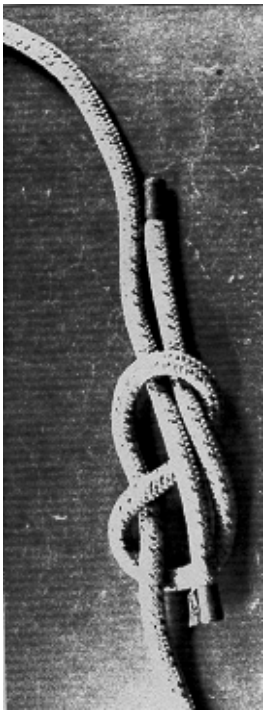


Figure 40

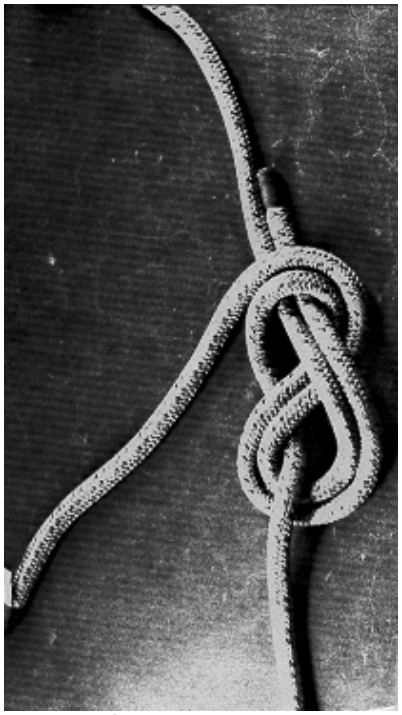
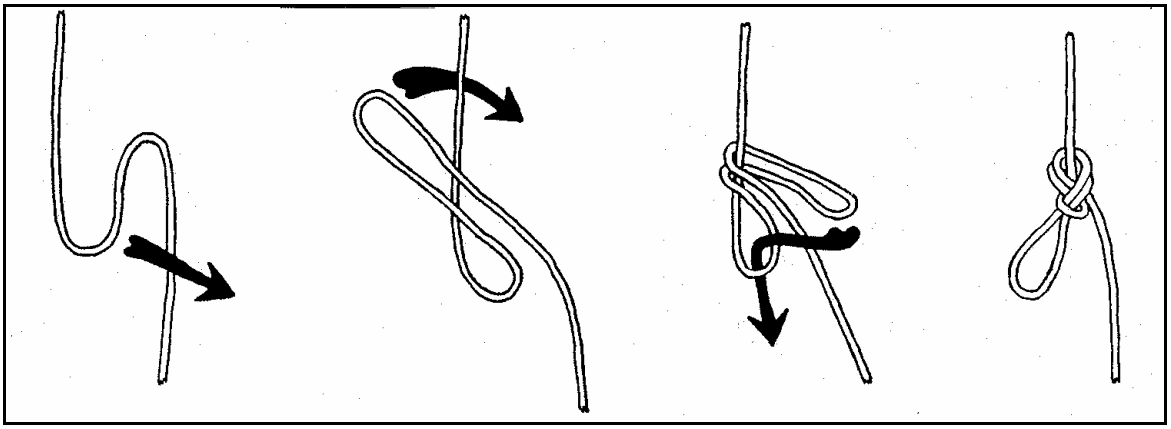


Figure 42

Figure 41

In-line Figure 8

Used for attachment to mid-line; ex; sharing a belay line with a victim on a mid-face pick off.



In-Line Figure 8

Blood Knot (Double Fisherman's Bend)

This knot is used in tying rope into prusiks. Once tight it is more or less permanent. The prusik is a rope tied in a loop used as an ascender in high angle rescue.

Cross the ends of the rope forming a loop as shown. Then take the running end on your right and go down and around the end on the left, forming a loop around the end on the left (Figures 43 & 44).

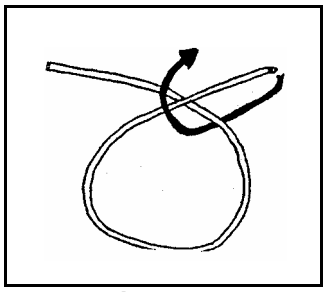


Figure 43

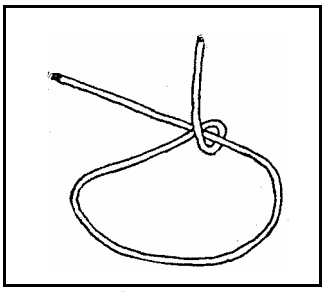


Figure 44

Take the running end of the loop you just formed and pass it around the running left end and the standing part of the loop to the left of the loop just formed. Then bring the end along the left running end parallel yet opposite and back through the loop formed. Pull both ends of the rope opposite directions from the knot to tighten (Figures 45 & 46). This is the first half of the knot. Turn the rope over and tie the other side in the same manner.

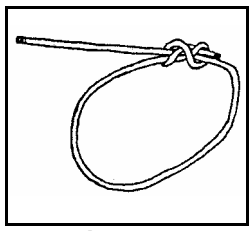


Figure 45

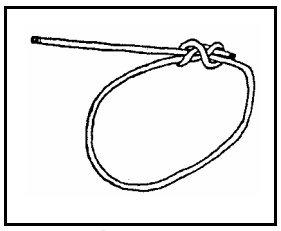


Figure 46

Water Knot (Bend)

This knot is used to tie our personal multi-purpose strap into a loop or tie any webbing together. A form of the knot attaches the small carabiners to our personal safety line. That knot is tied by forming an overhand on a bight with a loop big enough for the carabiner.

Tie a loose overhand knot in one end of the strap. Starting opposite the tail of the knot, trace the other end of the strap back around the overhand knot forming another overhand on the first one (Figures 47 & 48).

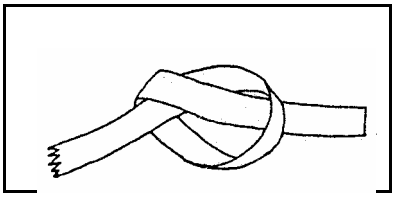


Figure 47

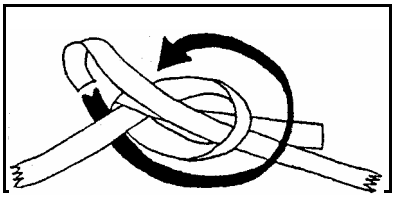


Figure 48

Rescue Knot

This knot is a form of bowline with three loops. It can be used on victim or yourself when no harness is available.

Measure from the running end of the rope 1-1/2 arm lengths (Figures 49 & 50).

Form the loop end of a bight at this point by doubling the rope back on itself (Figure 51).

Figure 50

Figure 51

Cross the running end of the bight over and on top of the standing end forming a loop in your left hand (Figures 52 & 53).

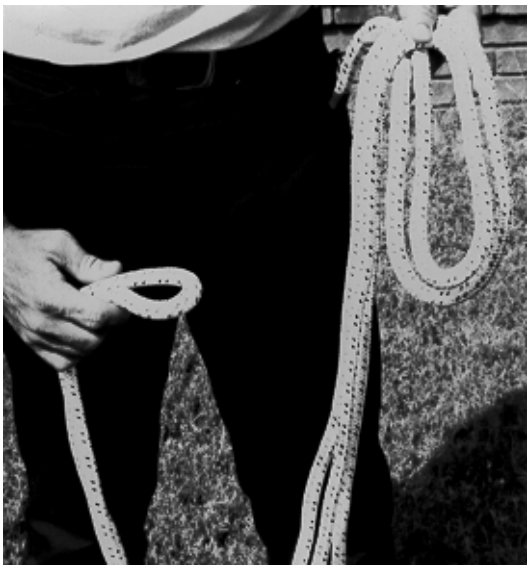


Figure 52

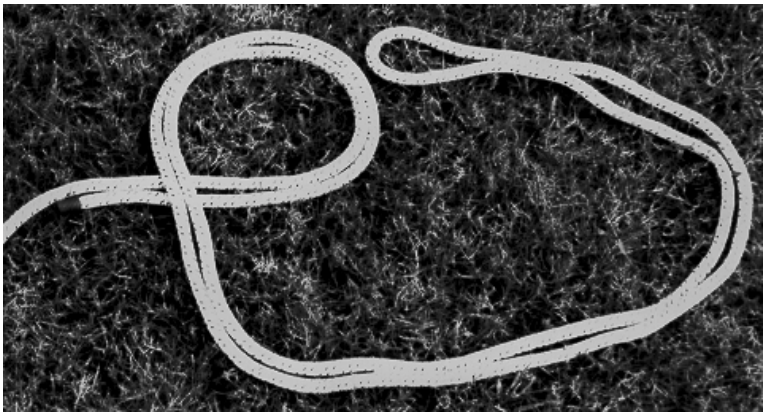


Figure 53

Bring the running end of the bight through the loop from the bottom (Figures 54 & 55).

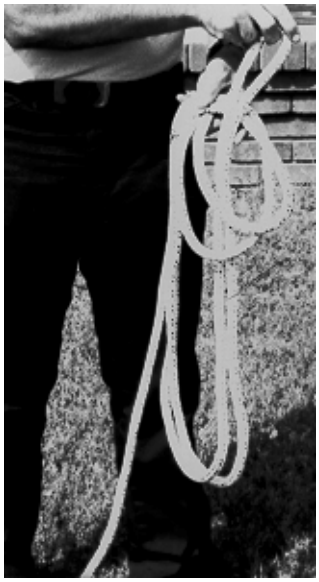


Figure 54

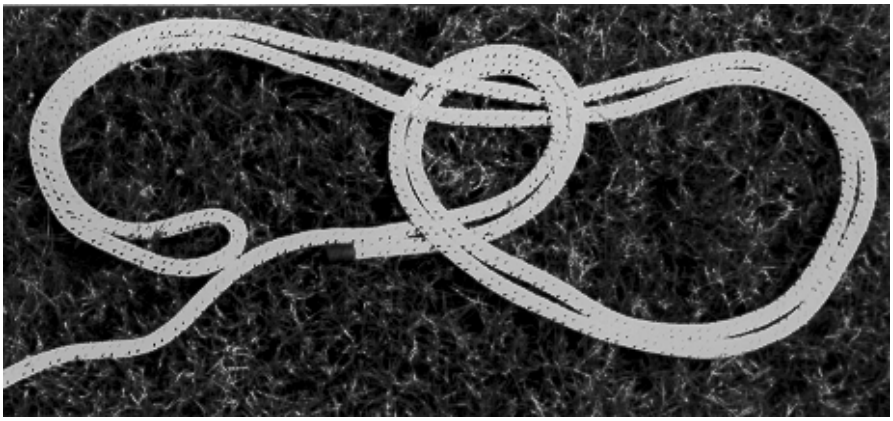


Figure 55

Pull the running end of the bight through the loop to adjust the size of the two loops formed at the bottom of the knot for the legs (Figures 56 & 57).

Figure 56

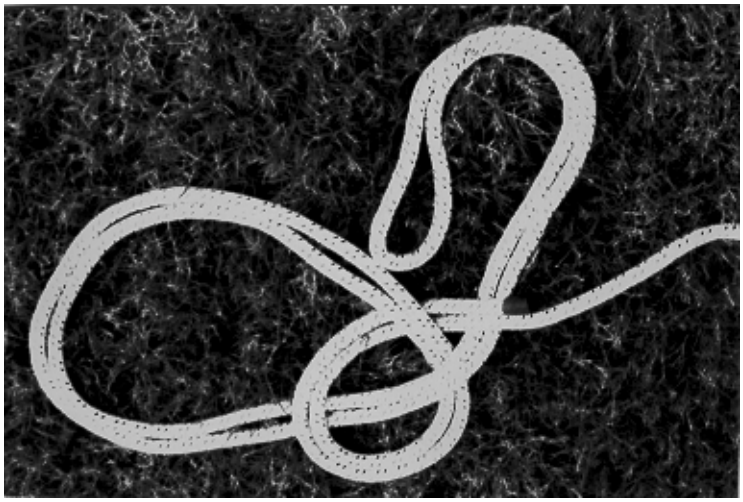


Figure 57

Pass the running end of the bight around the standing end of the loop first formed and then back through the loop forming a bowline. The running end of the bight now forms a third loop that is larger than the first two for the legs. This loop goes around the body (Figures 58 & 59).

Figure 58

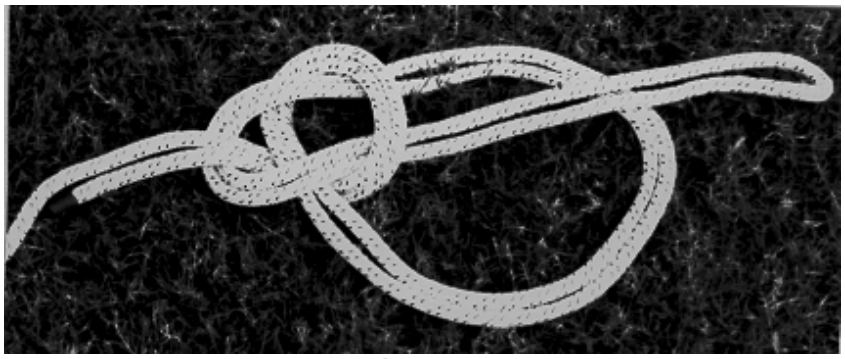


Figure 59

Tighten and dress the knot. Take a half hitch safety around the standing end with the tail (Figure 60).

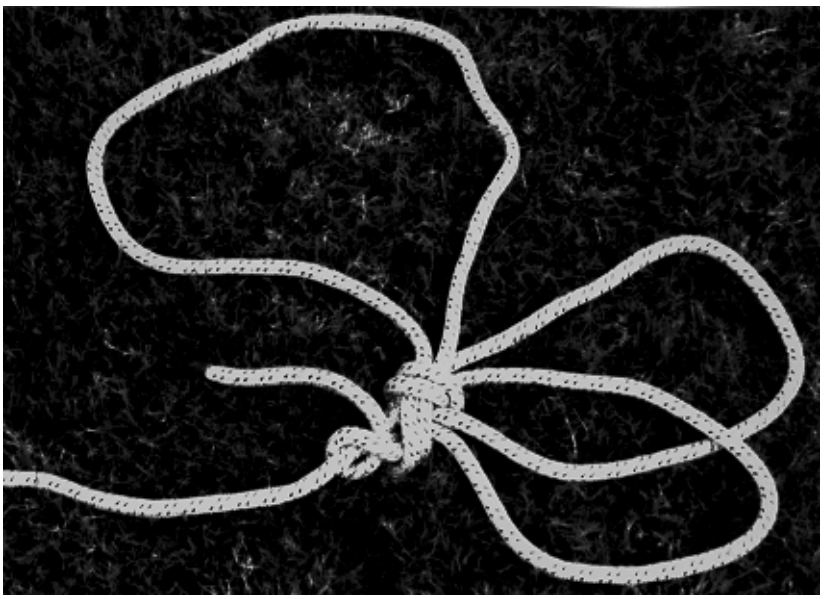


Figure 60

Now put the legs into the small loops. Put the large loop around the body by placing over one shoulder and under the opposite arm you are now ready to hoist (Figures 61 & 62).

Figure 61

Figure 62

This knot will hold an unconscious person if adjusted properly.

Overhand Knot

(See Square Knot, Figure 3.)

Butterfly Knot

This knot is used to tie a loop mid-rope for equipment attachment, etc. It can also be used to tie a damaged portion of rope out of a line until the rope can be replaced. This would only be done if the rope was in use on an emergency scene (Figure 63).

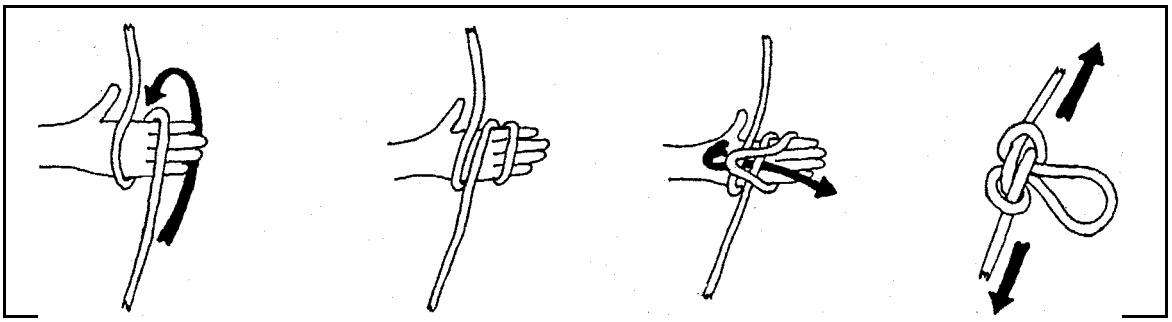


Figure 63

RELATED EQUIPMENT

Carabiners (Beaners)

Carabiners are metal-looking devices for connecting ropes, stokes baskets, figure-8 descenders, pulleys, prusiks, etc. (Figure 64). Our rescue carabiners are high strength steel (9,400 lbs.) and match the strength of our rescue ropes. The two carabiners that are attached to our personal safety lines are aluminum alloy and rated at approximately 5,000 lbs. A carabiner's strength is along its long axis -- do not side load.

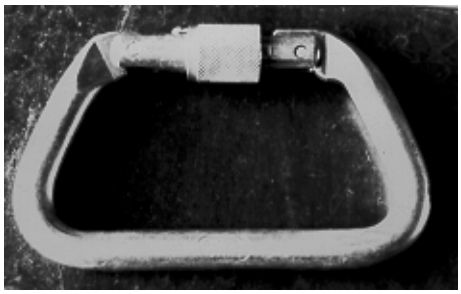


Figure 64

Care should be exercised in its use. If dropped on a hard surface with any force a hairline crack can develop that cannot be easily detected. Your life depends on this equipment. If you think it is damaged, take it out of service.

Figure 8 (Eight Plates)

A figure-8 is a friction device used to descend (Figure 65). Our figure-8 descenders are made of an aircraft alloy which is very strong (10,000 lbs.) but lightweight. They are matched to the strength of our rescue ropes.

Care should be exercised in their use. If dropped on a hard surface with any force, a hairline crack can develop that cannot be easily detected.

Figure 65

Gibb's Ascender

A Gibb's ascender is a device that moves one direction on a rope and lock on to the rope when pressure is applied in the other direction. It should be noted that the Gibb's Ascender will destroy the rope at or above 7,500 lbs. of tension, and cut the rope at 3000 lbs. of shock load. Quiet loads up to 1,000 lbs. will not damage the rope. Because of these characteristics, the Gibb's should never be used in belay systems.

Place the Gibb's ascender next to the rope with the arrow facing the direction of travel desired (Figure 66).

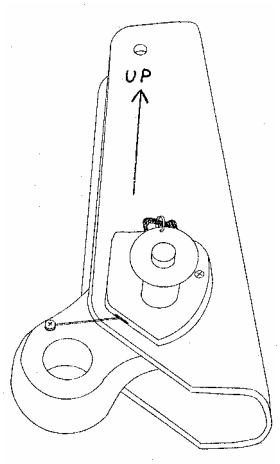


Figure 66

Push the button on the pin and remove it to disassemble (Figures 67).

Figure 67

Place the body around the rope and reassemble (Figures 68 & 69).

Figure 68

Figure 69

6 Bar Rappel Rack

A friction device used in system descents and rappels comprised of a welded stainless steel frame with aluminum bars. 10,000 lbs. strength. The only descent device to use for multi-person loads.

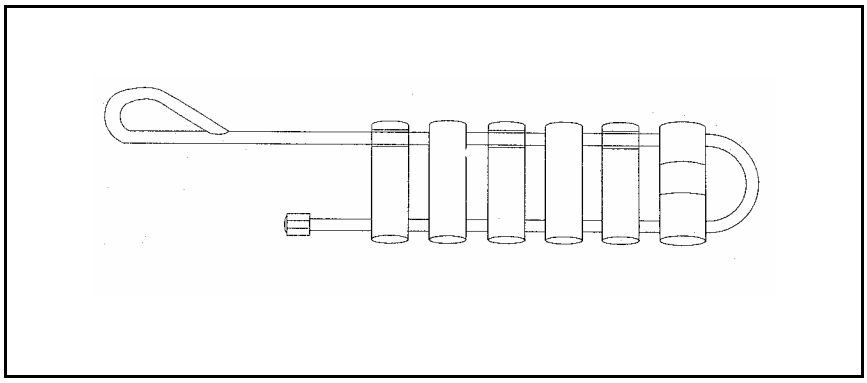


Figure 70

Rigging Plate

Stainless steel plate that enables several attachments to one anchor point. 10,000 lbs. strength.

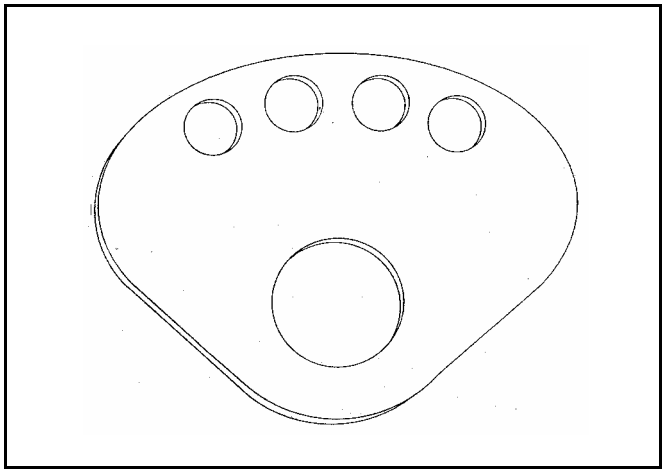


Figure 71

Prusik

These are ascenders tied with 3/8" polyester rope or 6mm or 8mm kernmantle rope in a loop using a blood knot (Figure 72).

Place the prusik around the rope. Take a wrap around the rope and back through the prusik Figure 73).

Figure 72

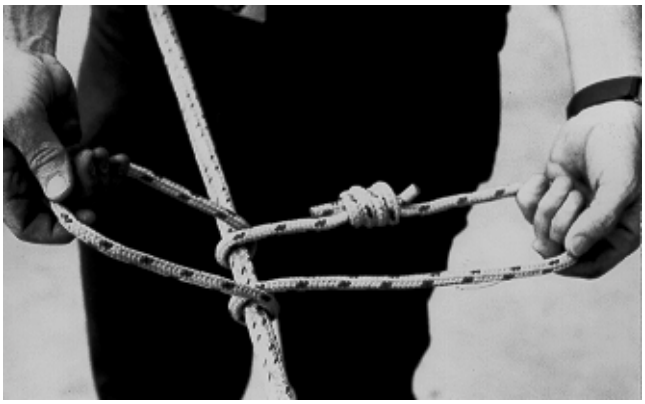


Figure 73

Take a second wrap inside the first. Now pull the end that you were wrapping tight, keeping all the wraps in line. (Figure 74 & 75).

Figure 74

Figure 75

When pressure is applied to the loop of the prusik it will lock on the rope in either direction. When slack is given it can be slid along the rope in either direction. When slack is given it can be slid along the rope in either direction. When used in hoisting or lowering systems take three wraps.

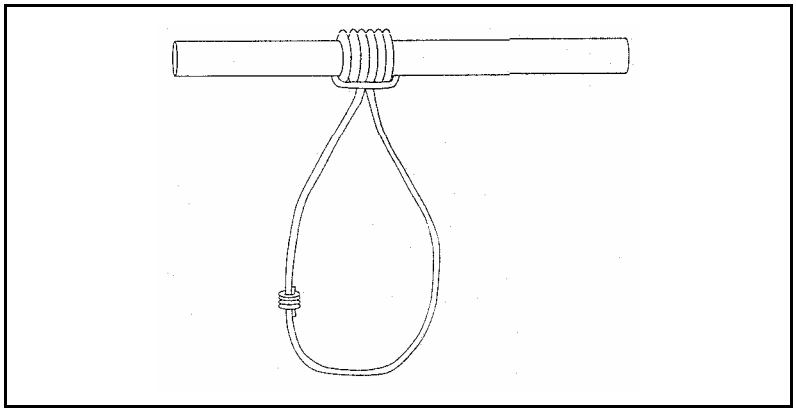


Figure 76

Pulleys **(blocks)**

Pulleys are devices that are used to change the direction of force or add mechanical advantage in a hoisting system. The pulleys used by the Tempe Fire Department are sealed ball bearing type and can be used in water.

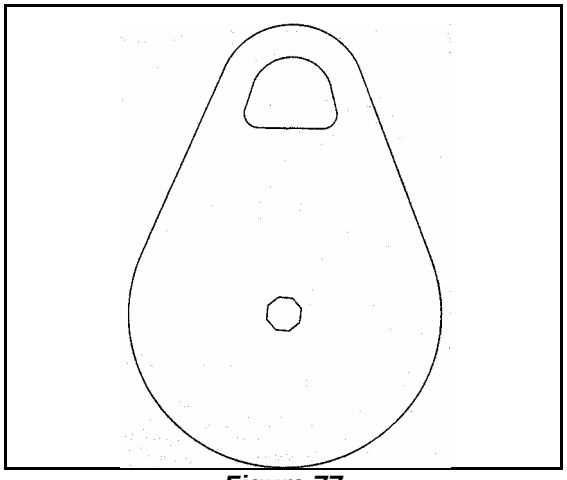


Figure 77

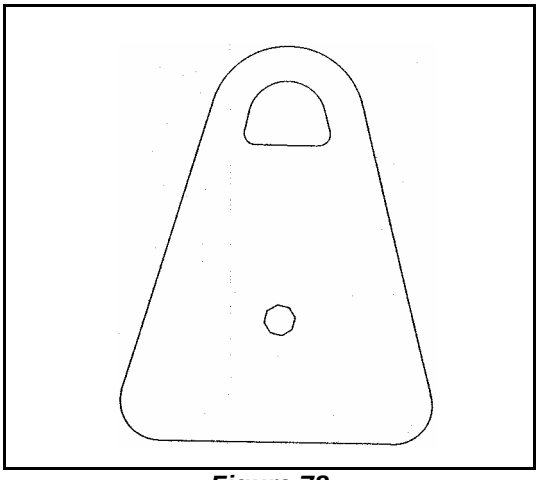


Figure 78

Webbing

1" tubular nylon, used for personal multi-purpose strap, anchors, tied harnesses, etc.

Gin Pole

Any device used to place an elevated block over an area where rescuer is to be lowered, such as an aerial or ground ladder, steel beam, wood pole, etc.

RELATED POLICIES & PROCEDURES

Personal Safety Lines
Lifeseat/Multi-Purpose Strap
Water Rescue
High Angle Rescue