Ropes & Knots

24

Section III - Truck Company Operations

Software

Hardware

Knots & Hitches

Equipment Tool Ties

High-Rise Escape Pack

Rope / Rescue Systems

Revised - December 2018

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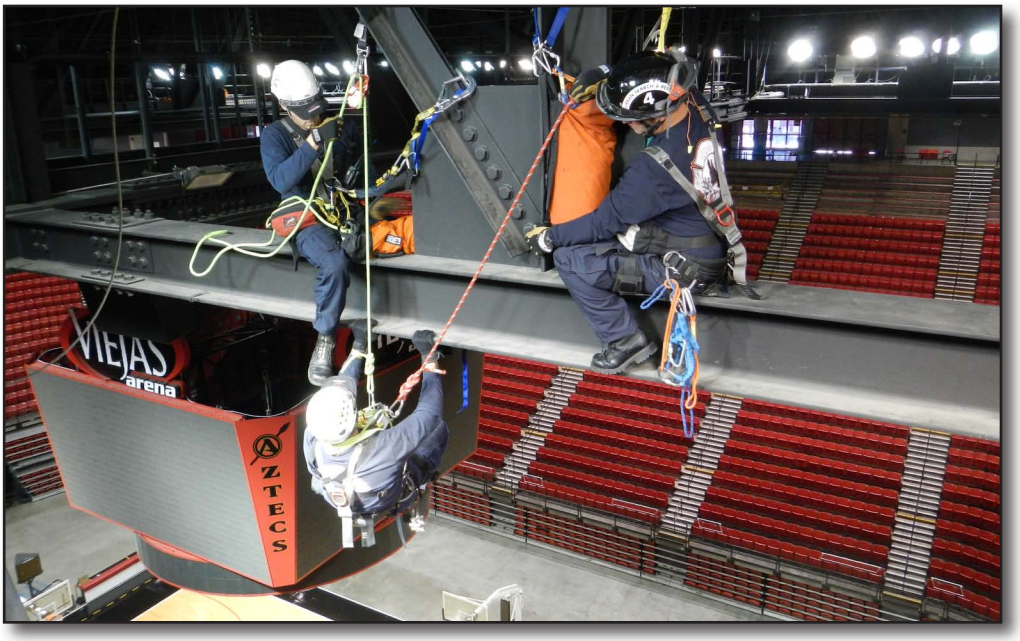
Chapter 24 Table of Contents

Objectives

- Identify types of rope and related equipment.
- Identify the proper PPE associated with rope rescue operations.
- Tie all knots correctly and safely.
- Correctly tie all equipment ties and hitches.
- Demonstrate the proper care and maintenance procedures for ropes carried on SDFD apparatus.
- Describe safety precautions associated with lifeline ropes and knots.
- Describe the rope classification system utilized by the SDFD.
- Locate the I.D. tag attached to rope used by the SDFD.
- Describe the difference between static and dynamic rope.
- Properly identify and tie anchors supporting rope rescue operations.
- Demonstrate knowledge of each of the knots and hitches used by the SDFD for life safety, rescue, and salvage operations.
- Identify the appropriate knot or hitch for a given operation in which rope must be utilized.
- Describe contents and use of all rope rescue equipment carried on SDFD apparatus.



Introduction

Down a drainage 300 feet below a roadway, on the outside of the NBC building downtown performing a window washer rescue, or performing an emergency escape out a window from a burning building, rope will be utilized as your lifeline. It is incidents like these that you appreciate the need for having the best training and equipment possible. Knowing all aspects of your equipment through training and inspection will give you the ability to effectively, safely, and efficiently perform rescues to the best of your ability.

The use of ropes, knots, and hitches during emergency operations is a fundamental skill that all firefighters should fully comprehend. Rope can be used in a wide variety of operations including lifelines, hoisting and lowering equipment, anchoring, rigging, and even crowd control. Firefighters must have the a firm knowledge of this chapter in order to select the proper types of rope, knots, or hitches for an operation; must be able to quickly and accurately tie the knot or hitch; must be able to recognize a correctly tied knot or hitch after they have been tied.

Improper use of ropes or knots can result in failure of the operation causing injury, loss to life, or damage to property. An understanding of the design and construction of ropes, as well as knowledge with their selection, use and care, are critical to minimize the risks involved with their use. This chapter will describe the ropes and related equipment utilized by The San Diego Fire-Rescue Department. It will also cover safety, PPE, and the knots that all firefighters must know.

Software

Software is a general term used to describe rope, webbing, prusik cord, load releasing hitches, anchors and harnesses. The following section will describe the characteristics and specifications of each of these software items in more detail.

Rope

Ropes have been used to move people and equipment since prehistoric times. Early ropes were constructed out of cotton, rawhide, hemp, agave, or whatever fibrous material was available. Today, the SDFD primarily uses ½" Nylon Static Kernmantle Rope. All SDFD Companies carry a rope for utility (non-lifeline) operations and a 75' lifeline rope in the high-rise escape pack. Additionally, Truck Companies, Rescue 4, USAR 41, and select Engine Co's carry an assortment of lifelines for other rescue related applications.

Rope Construction

Figure 24-1 Kernmantle Rope Construction

The San Diego Fire-Rescue Department uses nylon ropes. These ropes, interchangeably referred to as lifelines, are designed in a kernmantle arrangement. The kern is a high-strength continuously stranded inner core that is covered by an outer braided protective sheath called the mantle. The kern (inner core) is constructed of parallel nylon filaments that run the entire length of the rope and constitute about 75% of the rope's strength. The mantle provides approximately 25% of the rope's strength and protects the kern from abrasion and contamination.

Rescue 4 and USAR 41 also carry rope made from 100% polypropylene instead of nylon for use in water rescue. These polypropylene ropes are useful in water applications due to their ability to float.

Static vs. Dynamic Ropes

Static ropes are designed to keep stretching to a minimum; less than a two percent stretch factor under normal loads. Static lines are most appropriately utilized for hauling because the rope is less likely to stretch as the load is pulled or lifted. Even though the stretch is minimal, static rope still acts as a very good energy absorber under impact. Even though the term 'static' is used, it should not be confused with "no stretch" rope. It is estimated that static lifelines will break when they have been elongated to a 20% increase over their normal length. Static lines are temperature-rated to perform efficiently up to 350°F. This type of rope will melt at temperatures of 480°F and greater.

Figure 24-2 Half-Inch Nylon Static Kernmantle Rope used by SDFD

With a few exceptions, static "low stretch" kernmantle ropes are used by all companies on the San Diego Fire Department. Rescue 4 and USAR 41 carry static "no stretch," high tenacity polyester fiber ropes that can be used for high lines, offsets and long rappels.

Dynamic ropes are most commonly encountered in recreational applications, such as rock climbing. Dynamic ropes are preferred for applications where climbers must work in an unsafe position (e.g., above a belay or in positions where there is great likelihood of falling). If the climber were to fall, there is a need for the rope to stretch in order to absorb the shock and break the fall to prevent injury to the climber. Dynamic rope has a rated stretch factor of anywhere from 9% to 17% under normal loads (200 lbs). SDFD apparatus do not carry dynamic rope because there are few situations that a firefighter would be climbing above a belay.

Rope Classifications

Rope is classified as either a lifeline, training line or utility line.

Lifelines (Operations / Front Line Use)

Front-line use ropes, also referred to as lifelines by the SDFD, are ropes used for the purposes of rappelling, lowering, hauling, belaying, rigging or supporting any rescuer or victim load in operations. Damaged or compromised rope must be removed from service immediately, regardless of the life left on the rope. If a lifeline is used for anything other than a life safety rope, such as stabilizing a heavy object (e.g., vehicle or structure) the rope should be downgraded to a utility line.

Figure 24-3 Lifeline Rope Bag Bag

Lifelines come in a variety of lengths depending on their application. To assist with quickly identifying lifeline, the SDFD places all lifeline in orange bags (with the exception of the high-rise escape pack which is in a red bag).

Under emergency and life-threatening conditions, if rope is available and will safely accomplish the task, USE IT, irrespective of its most appropriate use.

Lifelines

- Location: All Companies
- Size: ½”
- Lengths:
  - 150’ / 300’ / 600’ - Main life and belay lines
  - 18’ / 25’ / 50’ – Tag Lines
  - 75’ – High-Rise Escape Pack
- Service Life: 0 to 5 years
- Preferred Use: Rappelling, belay or safety line, lowering and hauling

Water Rescue Lines

- Location: Rescue 4 and USAR 41
- Size: ½”
- Preferred Use: Water related rescues only

Training Lines

Traininng lines are ropes that my be used for the purposes of rappelling, lowering, hauling, belaying, rigging or supporting any rescuer or victim load in **training** situations only. Damaged or compromised rope must be removed from service immediately, regardless of the life left on the rope. If a training line is used for anything other than its intended purpose, such as stabilizing a heavy object (e.g., vehicle or structure) the rope should be downgraded to a utility line.

Traiing Lines

- Location: Training / Fire Academy
- Size: 1/2”
- Lengths: 150’ - 300’
- Service Life: 5 to 10 years
- Preferred Use: Rappelling, belay or safety line, lowering and hauling

Utility Ropes

Utility ropes are used for any purpose other than supporting the weight of a person. Examples of utility rope usage include securing equipment, hoisting/tying off tools, and stabilizing objects or vehicles. Utility rope is former lifeline that has either expired its service life or has been damaged/compromised but still deemed to be safe for non-life loads. Utility rope has a maximum service life of 15 years, where it is then destroyed. Utility rope is generally cut into 150’ lengths and is carried in a yellow bag.

Figure 24-4 Utility Rope Bag

Utility (working) Lines

- Location: All Companies
- Size: 1/2”
- Lengths: 150’
- Service Life: 10 to 15 years
- Preferred Use: Stabilizing heavy objects, crowd control, tool tie off

Identification Tags

Identification tags are secured to the rope by means of a clear shrink tube. Each tag will contain the following information:

- SDFD
- Length
- Use (lifeline, training, utility)
- Company ID (apparatus #)
- Inventory No. (Rope officer use)
- Date in service

SDFD LUCID is the acronym used to remember what is located on the ID tag.

The following is an example of a typical Rope I.D. tag:

SDFD Jan 2012

150' Lifeline

App 1901 #2033

Rope Strengths

Due to rope purchases from different manufacturers, slight specification variances exist between individual ropes. Therefore, the strengths and specifications presented here represent only comparative averages. All of the ropes carried on SDFD apparatus meet or exceed the minimum standards required by the NFPA to perform rescues.

The kilonewton (kn) is the industry standard unit of measurement for rope systems.

1 kn = 225 lbs of Force

Minimum Breaking Strength

Minimum breaking strength is the load whereby a single strand (free of knots or sharp bends) breaks. High breaking strengths are desirable, especially in static lifeline ropes. The minimum breaking strength for new, two-person rope, shall not be less than 9600 lbs, 40kn of force.

Maximum Working Load

The maximum working load for two-person rope shall be expressed in pounds and calculated by dividing the new rope minimum breaking strength by a safety factor of not less than 15. Therefore, SDFD rope is designed to have a maximum working load of not more than 640 lbs and shall be classified as a two-person life safety rope. A rescue load is considered to be 600 lbs; the weight of a victim, a rescuer and the necessary equipment used for the rescue.

Rope Care and Maintenance

Ropes require very little maintenance. Nevertheless, they can become defective if not properly cared for. It is extremely important that all firefighters understand a few basic principles of rope handling and maintenance.

Avoid jumping, walking, sitting, standing, or allowing objects to drop on rope, as this type of mistreatment can damage the fibers. Ropes should contact the ground as little as possible. Contact with dirt by laying the rope on the ground or by dragging it will allow small dirt particles to become imbedded in the sheath, possibly working their way to the rope core and slowly cutting the fibers.

Always protect you rope at potential abrasion points. Sharp or rough edges and sharp bends can cut the fibers of a rope and should be avoided whenever possible, especially if the rope is moving back and forth over them. Most ropes are retired because they become frayed, not because of the number of falls held. If you cannot avoid contact with sharp edges, padding (edge protection) should be placed between the rope and the surface. Any time there is contact between the rope and a surface which may abrade the rope, padding should be placed between the two. Retire your rope if you can see the core at an abraded area or if the rope feels lumpy or flat in spots.

Figure 24-5 A debris carrier can be used for edge protection

Never allow chemicals to come in contact with rope. Chemical exposure may weaken or severely damage the nylon. Avoid products, including indelible markers, which contain benzene, phenol (pine oil cleaners), carbon tetrachloride, formaldehyde, and petroleum products (gasoline). Avoid exposing rope to sunlight for long periods of time (i.e., during storage) as ultraviolet radiation will significantly shorten the life of nylon rope.

Do not overload ropes as this can cause hidden damage without actually breaking the rope. As a general rule, the safe working load as presented above should not be exceeded when using rope.

Rope should be washed, as needed, with clean, cold water using mild non-detergent soap. Do not bleach rope. Air dry the rope away from direct sunlight. DO NOT dry rope in a dryer. Dirt that is left on rope and associated hardware can cause wear if not properly removed. Transport and store rope in a protective bag. As a final rule, always inspect rope with an un-gloved hand for damage each time it is used and again as it is being recoiled or bagged.

Rope Inspection

In order to ensure the quality and strength of ropes they shall be inspected before and after each use. Often inspection will reveal that the rope needs to be cleaned to remove dirt and abrasives from it. There are important conditions and flaws which firefighters should look for when inspecting rope:

Figure 24-6 Spot Abrasion

• Dirt or foreign particles imbedded in the rope fibers.

• Spot abrasions.

• Soft spots.

• Broken or brittle fibers.

• Inconsistencies in the diameter of the rope that may suggest damage to the central core.

• Lumpy or flat spots throughout rope

If any of the following rope conditions occur, notify the Rope Officer and have him/ her inspect the rope:

• Excessive contact with dirt and grime.

• Contact with any form of chemical which could ruin the rope (e.g., acid, petroleum, and vapors.

- Visible damage is evident to the fibers in the outer jacket.
- Exposure to temperatures in excess of 320 F.
- An excessive load was hauled by the rope (i.e., a load in excess of 50% of the tensile strength).
- An object has fallen on the rope from an extreme height and/or at extreme speeds.

The Rope Officer will downgrade or retire the rope if in his/her opinion it is unsafe to use in life-and-property saving operations. It is important that you consult the Rope Officer before re-using a rope that has experienced any of the above conditions, as it may not withstand any weight due to weakening from the fault.

Rope Log

A rope log that outlines the ropes history and usage shall be maintained for all life safety rope. For SDFD that includes all Lifelines and High-rise Escape lines. Specifics of the log will include at a minimum:

- The manufacturer
- Model
- Lot number
- Date placed in service
- Rope color
- Rope Diameter
- Rope length
- Bag color
- SDFD rope number
- Tensile strength
- History of rope
- Inspection information

Nylon Webbing

Nylon webbing is a narrow fabric strap that comes in a variety of widths. Webbing can either be flat or tubular in construction and has a wide variety of uses for firefighters and rescuers. SDFD utilizes a 1" nylon tubular webbing for its operations. This webbing can be used for anchors, slings, emergency harnesses, tying off equipment, ladders, and hose lines among many other applications.

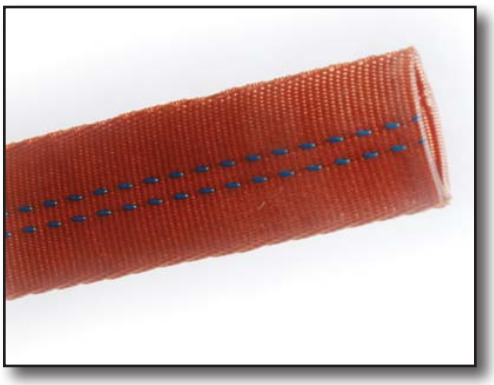


Figure 24-7 1" Nylon Webbing

A red, 16' nylon tubular webbing strap is issued as part of the standard PPE that is to be carried by every firefighter in the SDFD. It takes the form of utility straps and is used in a number of fire and rescue operations. Nylon webbing has properties similar to those of nylon rope and is considered a static line. Often the tubular webbing is referred to as "shuttle loom," alluding to its method of construction, which is a spiral weaving of monofilament nylon.

NOTE: In 2016 the SDFD converted their webbing standards to match the CSFM color and length standards. Prior to 2016 the utililty strap issued as part of the standard PPE was an orange 16' utility webbing. Be aware that these lengths may continue to be in circulation for the near future.

Classification and Strengths

Nylon webbing does not carry an identification tag but should be clearly marked with the date placed in service near the end of the webbing. The SDFD uses a standardized color scheme to quickly identify the lengths of webbing carried on the apparatus:

1" x 5'	Green	Anchors
1" x 12'	**Yellow**	**Chest Harness**
1" x 15'	Blue	Litter Tie Ins
1" x 16'	Red	Utility Strap/Sit harness/Swami Belt
1" x 20'	Orange	Litter Lashing/Anchors

1" nylon tubular webbing has a tensile strength (minimum breaking strength) of 4000 lbs. Where as rope uses as safety factor of 15:1, webbing uses a safety factor of 5:1, setting a maximum working load of 800 lbs.

Inspection

Webbing should be inspected after each use. Surface wear should be taken seriously because there is no protection sheath to reinforce its strength. As well, webbing has a tendency to wear faster than rope due to its larger surface area. Whenever a utility strap appears to be scuffed, stiff, cut, or discolored, retire it from service and obtain another. Remember, nylon webbing is constructed from the same materials as nylon rope and can be affected in the same manner, so follow the same precautions that would be appropriate for rope.

8mm Cord

8mm cord, often referred to as prusik cord because it is commonly used to make a prusik loop, is actually just nylon kernmantle rope. Instead of being a ½" in diameter like lifeline, this rope is only 8mm in diameter. 8mm cord has a minimum breaking strength of 2600-3000 lbs, 12kn. Like webbing, it is used with a safety factor of 5:1, thereby creating a maximum working load of 600 lbs.

Figure 24-8 8mm "prusik" cord

8mm cord is commonly used for hauling light-weight equipment, tag lines during search and rescue and several other applications in rescue rope systems such as gain savers, braking, and belaying. 8mm cord is also used in SDFD drop bags and to create prusik loops.

Drop Bags

Each drop bag contains 75 feet of 8mm cord, one alloy carabiner, and a nylon Cordura waterproof bag.

To use the drop bag for hauling equipment, simply secure the attached carabiner to a fixed object, ensure the area directly below is clear, and drop the entire bag to the ground. Keep in mind that 75 feet of line will extend approximately six stories. The equipment to be hoisted will be tied to the line using the appropriate knot, then hauled aloft. Equipment may be lowered in a similar manner, taking care not to let the line slip through the hands.

Figure 24-9 Drop Bag

The drop bag is also an effective tool for use in search and rescue for large areas. The 75 foot line can be used as a tether to tie a firefighter to a fixed object or to another firefighter during a two-person search pattern. Each engine and truck company is issued four drop bags, which are secured to the backpack frame of each SCBA. Carrying the bags on the SCBA ensures that each firefighter will have access to the line during all potential IDLH incidents.

Drop Bag Safety

- Never rappel using the drop bag rope, as the small diameter line could cause a rapid, uncontrollable descent with disastrous consequences.
- Always make certain the area directly below is cleared of personnel before raising or lowering equipment.
- Alert all personnel in the area whenever equipment is being lowered or hauled.

Drop Bag Maintenance

After extended use, the drop bag and line can become dirty and will require cleaning. Simply wash the bag and line separately in clear water, or a mild detergent solution, then rinse thoroughly. There is a 5 year life expectancy just like all lifelines. If damaged or shock loaded notify the department rope officer and send it in for inspection.

Prusik Loops

Prusik loops are constructed out of 8mm cord and used in a number of applications such as hauling, braking, or gain saving. In a mechanical advantage rope system used for raising, the prusik grabs the rope and pulls it in the direction of the haul. A prusik used for gain saving holds the rope while the mechanical advantage system is reset. A prusik used for braking is set whenever the system is stopped and you don't want any movement in the system. For example, in the belay system, the tandem prusiks grab the belay line to prevent it from moving if there were a mainline failure.

The 8mm cord used for prusiks are cut to a length of 70" for the longer red prusiks and 57" for the shorter green prusiks. They are cut at this length to be compatible with 2" prusik minding pulleys. After the 8mm cord has been cut a double fisherman knot is tied joining each end, forming the prusik loop. Once these prusiks have been tied, they should remain tied.

Figure 24-11 Double Fisherman's Knot

Prusik Loop Safety

Prusik loops/cord should be inspected after purchase, prior to being placed in service, after each use, and at least semi-annually. Due to the critical nature of using prusiks to support live loads, any prusik showing minimal wear or damage should be removed from service. All software should be taken out of service after five years of service regardless of its condition.

When inspecting a prusik loop, look for damage to the sheath. Specifically, any type of glassing over of the line which indicates excess friction or heat applied to the prusik.

Load Releasing Devices

A load releasing device is used to absorb shock forces to a rope system anchor or transfer a load from one rope to another. For example, if the prusik loops of a tandem prusik belay have been accidentally locked up, a load releasing hitch may be used to transfer the weight from the belay line to the main line in order to free the locked prusik loops. A load releasing device is also used when converting a "haul" line to a "lower" line (covered in depth in the Technical Rope Rescue Chapter). The load releasing devices used by SDFD are the mariner's hitch and the pre-made load releasing strap.

Figure 24-12 Pre-Made Load Releasing Strap

Mariner's Hitch

The mariner's hitch is constructed from a 12' length of 1" webbing, two steel carabiners and one aluminum carabiner.

Pre-Made Load Releasing Strap

The pre-made load releasing straps have the same function and general operation as the mariner's hitch, however, it is much stronger because it is made from high strength webbing and hardware. The pre-made load releasing strap has a breaking strength of nearly 18,000lbs, 80kn. An additional benefit of the load releasing strap is that the webbing is wider than the mariner's hitch, which provides a higher degree of control during release.

Harnesses

There are three classes of rescue harnesses recognized in the fire service. Class I harnesses, also known as a seat harness, fastens around the waist and around the thighs and is intended to be used for emergency escape with a load up to 300 lbs. A Class II harness fastens in the same manner as a Class I but is rated for up to 600 lbs.

Class III – Full Body Harness

For the primary method of attaching to rescue systems, SDFD personnel will use a Class III full body harness. This harness is characterized by a sit harness and chest harness that are connected together to create one harness that is rated for loads of up to 600 lbs. These harnesses are available on all truck companies, select engine companies, Rescue 4, USAR 41 and Hazmat. All these harnesses will have a tag stating its compliance with NFPA 1983.

Figure 24-14 Class II Harness

Class III Harness Components

- Front waist connection point - Attachment point for the mainline carabiner and the belay line rope; it holds you in a sitting position for rappels, stretcher tending or working on rope.
- Sternal connection point - This connection point is utilized for the connection of the safety line, also known as the belay line, also referred to as the chest attachment point.
- Dorsal "D" connection point - The attachment point on the upper back; it is typically used in confined space entries to ensure the smallest profile of the rescuer. This can be used for mainline or belay line connection points, but not for both simultaneously.
- Shoulder connection point - On most of the newer harnesses you will also find attachment points on the shoulders. With the use of a spreader bar to clear the head, the wearer can be suspended in a straight bodily position for vertical movement through a very narrow opening. Found on Rescue 4 and USAR 41.

Figure 24-15 Class III Harness - Front View (L) and Dorsal View (R)

Harness Fitting

When selecting a harness, look for one that fits your body size and shape best. The waist should fit above your hips. Buckles should not be digging into any bones, straps should not pinch, and the leg straps should fit comfortably between the legs.

Harness Safety

Any harness will wear over time, therefore, all harnesses should be inspected before and after every use. Treat your harness like any other software and store it accordingly. Check the webbing for cuts, worn or frayed areas, broken fibers, soft or hard spots, or discoloration. Check the stitching for pulled threads, abrasion or breaks. Finally, if the harness is subjected to shock loads, fall loads, or abuse other than normal rappel or rescue use, send it in the department rope officer for inspection.

Victim Harness

The victim harness is used to quickly attach and secure a victim to a line when performing a rescue. It is a pre-made harness that uses colored straps to easily identify the proper connecting points. This harness uses a ring and snap design that allows the harness to be put on the victim quickly and without the victim having to step into the harness. The tie-in point also doubles as a "handle" for controlling the victim's position. It also comes with a storage bag attached to the harness so it cannot be lost and prevents tangling when accessing the victim. This harness can be adjusted to fit small children to large adults.

Figure 24-16 Victim Harness

Improvised Harness

An improvised harness constructed from webbing can be used for an emergency rappel or as an emergency harness for a victim. This by itself is considered a class I harness with a rated working load of 300 lbs.

Modified Diaper

A seat harness constructed out of webbing that can be quickly applied. This harness is used when deploying the high-rise escape pack. This harness can also be used as a back up to the victim harness when performing a victim pick-off evolution.

Chest Harness

When not using a class III harness, a chest harness must be utilized and can quickly be made out of a 12' piece of webbing. The one exception to using a chest harness is when an emergency bailout must be performed.

Hansen Harness

A hansen harness is full body harness that can quickly be donned using one piece of 16' webbing. It should only be utilized for victims in an emergency situations.

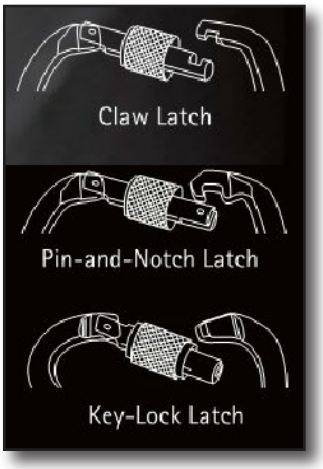
Figure 24-17 Modified Diaper

Figure 24-18 Chest Harness

Figure 24-19 Hansen Harness

Hardware

Hardware is the critical link between the user and the rescue system or anchor, allowing for the safe operation and a secure attachment. Carabiners, descenders, ascenders, pulleys, edge protection are all examples of hardware.



Carabiners

Carabiners are used to attach pieces of equipment together in rescue systems. Carabiners vary in size, material, shape, gate design and construction. SDFD utilizes both aluminum and steel carabiners with a locking gate. A non-locking carabiner should never be used for life loads. There are several styles and shapes of carabiners in existence, but in general they all have similar main parts; the spine, the gate and the latch.

There are three different types of latches you might encounter. With steel carabiners you will either see a "pin and notch" or the "claw." Some of the newer aluminum carabiners large and small will have the newer "keyhole" style latch. This configuration allows for attaching to rope or webbing without catching the notch.

Figure 24-20 Steel Carabiner

Steel Carabiners

Steel carabiners are considered "general use" carabiners and should be used to build the rope rescue system and anchors. The minimum breaking strength for steel carabiners is in excess of 15,000 lbs. Steel carabiners are distinguishable from aluminum carabiners by their dull finish and heavier weight.

Aluminum Carabiners

Aluminum carabiners are considered "light use" carabiners and are used for the connection of the rescuer to the rope system and attachments to their harness. The aluminum carabiners are generally smaller in size than the steel carabiners and are rated to 6,900 lbs. If at any point the rescuer anticipates carrying a rescue load, as in a victim pick-off where the victim is **directly connected** to the rescuers harness, then a general use carabiner shall be used. Light use carabiners are designed for single person loads.

Figure 24-21 Alluminum/Alloy Carabiners

It should be noted that larger aluminum carabiners with a black gate may be found in the SDFD inventory. These aluminum carabiners are rated to 10,600 lbs and can be used for both general use and light use functions. When in doubt, use a steel carabiner for building the system.

Carabiner Safety

Special care must be taken when attaching carabiners to a system, anchor or harness:

- Make sure to direct the load along the long, major axis closest to the spine of the carabiner.
- Always lock the carabiner and back off a ¼ turn when in use
- Do not side load the carabiner because this will dramatically decrease the strength capability of the carabiner, upwards of 50%.
- Avoid connecting carabiners together as this can create a torque load, and if the carabiners are not locked a twisting motion can disconnect them.
- As with any rescue equipment do not drop or throw carabiners.
- Inspect carabiners carefully:
    - Make sure the gate opens and closes easily and that the screw lock closes without any friction.
    - Examine the carabiner for excessive wear and for any cracks or bends in the shape.

Descenders

Descenders are used as a friction device/brake for rappelling, lowering systems, and belays. There are two primary descenders used by the SDFD, the figure 8 descender and the brake bar rack. The figure 8 device is most commonly used for rappelling, while the brake bar rack device is primarily used for lowering.

Newer descent control devices, such as the Petzl ID and MPD, are currently in use by Rescue 4 and USAR 41 and should only be operated by trained technical rescue team personnel. These descenders have an auto-locking feature and simplify the RPM and Belay systems.

Brake Bar Rack

The brake bar rack is the primary tool used in lowering systems and is the resistance tool used in the RPM. The rack allows for a wide range of adjustment in the amount of friction, which is necessary to account for the weight of the rope when lowering several hundred feet. The racks can be made of either aluminum or steel. The aluminum bars provide greater friction than the steel brake rack bar, allowing for a greater amount of control. The downside to aluminum bars it that they wear out faster. Steel brake rack bars do not dissipate heat as efficiently as aluminum, are usually hollow, but have a longer service life.

Figure 24-22 Brake Rack

The brake bar rack has a J frame and provides a wide range of friction. The bars are easy to adjust for rigging and for varying the friction. They have a minimum breaking strength of 6,900lbs or greater, depending on the manufacturer. The top bar, also known as the hyper bar, extends out to the side and has

Figure 24-23 MPD

a pin sticking up. The hyper bar makes tying off the rack easier and can also be used to add friction to the rack.

There is either an indicating notch or a label to identify where to lay the rope to ensure proper loading of the rack. The second bar will have a straight slot while lower bars have a slightly angled slot. The straight slot allows the bar to flop loose if the rack is loaded incorrectly. The angled slots on the on the other bars help keep the bars in place on the rack when rigging it.

When inspecting the brake bar rack, check for significant wear on the bars. If more than 15% of the material is missing, or any sharp edges have developed, remove it from service and notify the department rope officer. Check the frame to make sure it has not been bent. The nut at the end of the J should be secure at all times.

Figure 8 Descender

Figure 24-24 Figure "8" Plate

The Figure 8 Descender with ears is still the most common tool used for rappelling in the fire service. Once rigged onto the rope, it cannot come off accidentally. When used in long rappels, it does have a tendency to twist the rope and does not have the range of friction adjustment like the brake bar rack. The Figure 8 is best suited for single person loads and short rappels. Most Figure 8's are constructed out of aluminum but can also be found in steel. The minimum breaking is around 5,000lbs.

The "ears" on the Figure 8 serve a couple purposes. They prevent the rope from sliding up and over the top of the Figure 8 creating a knot, stopping the descent. The ears also make it easier to lock off when you want to stop.

Like the brake bar rack, when inspecting the Figure 8 check for significant wear. If more than 15% of the material is missing or any sharp edges have developed, remove it from service and notify the department rope officer. Check the ears to make sure they have not been bent. Under a significant load, the shape of the Figure 8 can be distorted, thereby compromising the hardware.

Pulleys

Figure 24-25 Prussik Minding Pulley

Pulleys are used in rescue systems to change the direction of pull or to generate a mechanical advantage. Pulleys are generally made stronger than other components in the system. When using a pulley, the load can be twice the system load. The minimum breaking strength is not less than 8,093 lbs. The SDFD carries 2" blue and 4" red prusik minding pulleys. They are made of anodized aluminum sheaves (wheel) mounted on a sealed ball bearing. There is a large carabiner hole to accommodate multiple carabiners and smooth, rounded edges to minimize rope fraying. There are some double sheave models out there to accommodate multiple lines to create greater mechanical advantage. The sheave tread size is ½" for ½" rope, and will work with smaller diameter lines.

When inspecting pulleys the side plates should rotate easily but not feel loose. Check for distortion, cracks, bends, or elongation of the carabiner hole. The

sheave should turn freely. Use an air hose to remove dirt from within the pulley. Pulleys can be washed in soap and water if necessary, but make they are dry before storage.

Collection Plates

Collection plates are used to organize various carabiners and hardware attached to a system anchor. The small holes on the plate keep carabiners from jamming together making them easy to access when changing or adding hardware. The large hole acts as a collection point for rigging multi-point anchor systems. The collection plate is also used for pre-rig systems like the RPM.

Figure 24-26 Collection Plate

The anchor plate can be constructed from either aluminum or steel. Both have a minimum breaking strength greater than 11,000lbs.

When inspecting anchor plates, look for dents, cracks, or distortion in the holes. Look for nicks, sharp edges or bends in the plate. Remove from service and return to department rope officer for inspection.

Steel Collection Ring

Another piece of hardware used to organize carabiners is a collection ring constructed of steel. These were used before the creation of anchor plates. They have a minimum breaking strength greater than 10,000 lbs. They are smaller and can be pulled in multiple directions without twisting the carabiners. Steel collection rings are commonly used as a connection point for litters and control lines.

Figure 24-27 Collection Ring

Ascenders

Anytime you descend a rope, you should be prepared to come back up. Ascenders allow you to grip the rope in order to climb it. When used in rescue systems, the more descriptive term "rope grab" has replaced the term "ascender." The original rope ascending devices were knots, such as the Prusik Hitch. The SDFD utilizes the Prusik Hitch as the primary means for ascending a rope. Although SDFD Truck and Engine companies use software to ascend rope, it is important to discuss the various hardware ascenders in use by Rescue 4, USAR 41, and the rescue industry.

Gibbs & Petzl Ascender

Hardware mechanical ascenders have been created to act like a Prusik Hitch while adding some advantages. Because the load is placed on the cam instead of the frame, the Gibbs type rope ascenders do not grip the rope until loaded. The two models you will see are "Gibbs Ascender" and the "Petzl Rescuecender." These cam type ascenders are used in some organizations as a ratchet, or hauling cam, in a mechanical advantage system because of their self-tending function. The SDFD does not use them in this manner because of the small

Safety Knots

Past practice has been to place an overhand safety on all knots using the tail of the rope. Industry leaders (CMC Rescue) are no longer emphasing this safety knot as long as the tail of the rope or webbing is the length of the palm of your hand and the knot is dressed tight.

tendency of the device to fail or cut the rope when an excessive load is applied to the system.

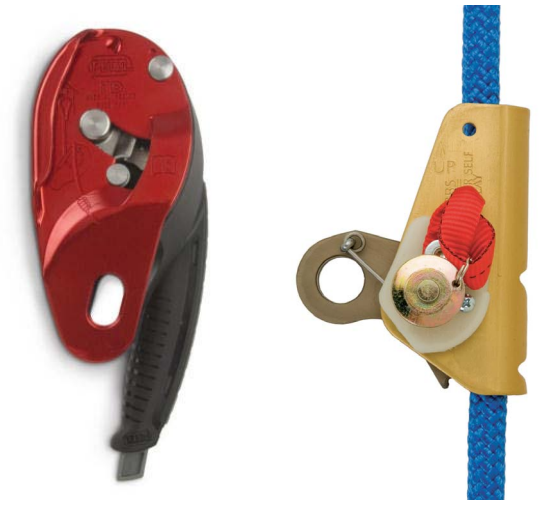


Figure 24-28 Ascenders

Ascender Handle

The other type of ascender that is found on Rescue 4 and USAR 41 is the ascender handle. There is a trigger that releases the cam so the rope can be inserted, allowing for a one hand operation. The disadvantage to using the ascender handle is that the teeth on the cam to help grip to the rope may dig into the ropes sheath. As a result, rope failure can occur at a much lower load. The ascender handles should only be used for personal use, not for a two person load.

Training is very important when using these devices. Always follow the manufacturer guidelines when operating. Since there are several models out there, use the manufacturer suggestions for inspection and care.

Edge Protection

Rope failure usually involves a situation where the rope has suffered an abrasion or received an impact load while bent over an edge. The more rope bends, the higher the level of abrasion. Edge protection is particularly important in a fixed line that sways back and forth over the edge as it is loaded and unloaded.

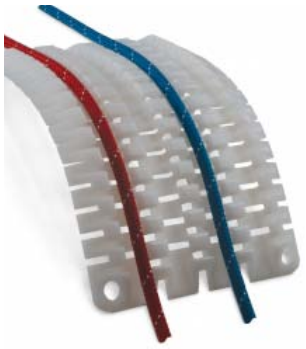


Figure 24-29 Edge Protection

There are several goals in placing edge protection. Protect the rope, protect the surface, reduce friction, and keep the rope clean. There are many options available for edge protection. Choosing the best option for the problem is the key.

The primary goal is to protect the main line and belay line from abrasion and sharp bends. When conducting a lowering or raising operation, the rope is in motion. It is important to protect the surface from the rope, such as dirt or rock being loosened and falling down on the rescuer and victim. When the rope is allowed to run over soft dirt or long stretches of any rough surface, it produces additional friction that in turn needs to overcome by the system in place. Edge protection also provides a way to keep the rope clean. This is not the highest priority during rescue operations, but it will increase the life expectancy of the rope and is good rope management.

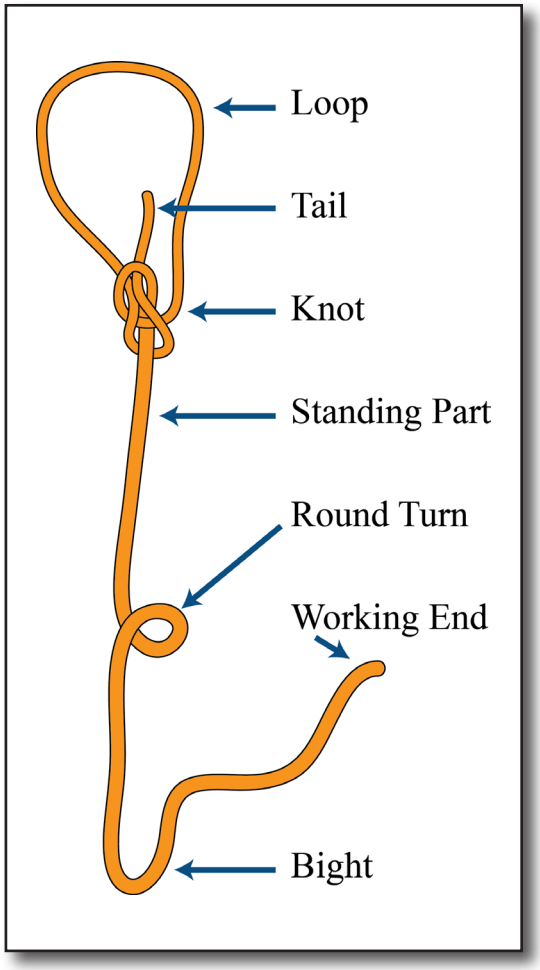
The different types of edge protection range from old pieces of hose to more advanced equipment like edge rollers. It is important to know what equipment you have available to protect your rope and take into consideration the hazards that edges have on a rope rescue operation.

Knots & Hitches

There are several considerations to be aware of concerning knots. Knots should be easily tied, easily untied, and easily identified. A good knot should minimize strength loss to the rope as well. For example, the figure 8 family of knots allows retention of 80% of the rated strength of the rope, while the bowline retains only 50%.

Rope & Knot Terminology

- **Bend**- Ties two ropes or pieces of webbing together. They must be the same diameter or width.
- **Bight**- Formed when the line is doubled back, but does not cross.
- **Dressing a Knot**- Making sure that the rope strands are smooth within the knot.
- **Hitch**- Attaches a line to an object, including another rope.
- **Knot**- Generic term that is also specifically used for any knot that is not a hitch or a bend.
- **Loop** - Formed when the rope doubles back and crosses itself.
- **Round Turn** - A complete turn of the rope or webbing.
- **Running End**- The part of the rope that is the free end that is used for hoisting, pulling or belaying.
- **Standing Part**- The part of the line attached to something, usually an anchor. The fixed part as opposed to the working end.
- **Tail**- The free end of the rope or web extending out of the knot.
- **Working End**- The end of the rope used to tie the knot.



SDFD Knots & Hitches

There are many knots available that provide a similar function. However, SDFD has chosen the following knots in order to standardize operations, eliminate confusion, and because the knot retains as much of the ropes strength as possible. Additionally, these knots are easy to tie, easy to untie, and are easily identified. All firefighters should be able to readily tie the following knots and identify them by name.

Family of Figure 8 Knots

Figure 8 Stopper Knot

Figure 8 On-A-Bight

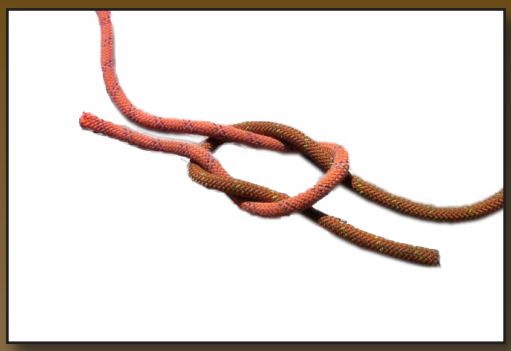
Figure 8 Follow Through

Figure 8 Bend

In-Line Figure 8

Double Figure 8

Additional Knots



Square Knot

Water Knot

Bowline Knot

Running Bowline Knot

Butterfly Knot

Double Fisherman's Knot

Hitches

Clove Hitch

Half Hitch

Trucker's Hitch

Tensionless Hitch

3-Wrap Prussik Hitch

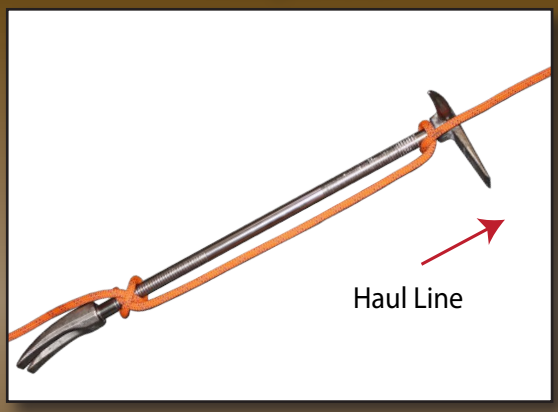
Hand Cuff Hitch

Equipment & Tool Ties

Pick Head Axe

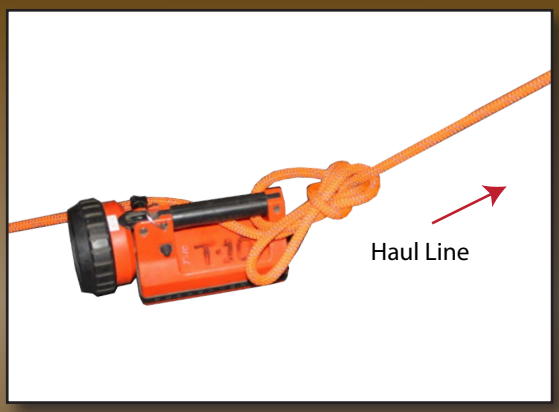
The pick head axe is tied with a figure 8 on a bight passed down over the handle and around the head of the axe. A half hitch is then placed on the handle of the axe using the haul line.

Haligan Bar



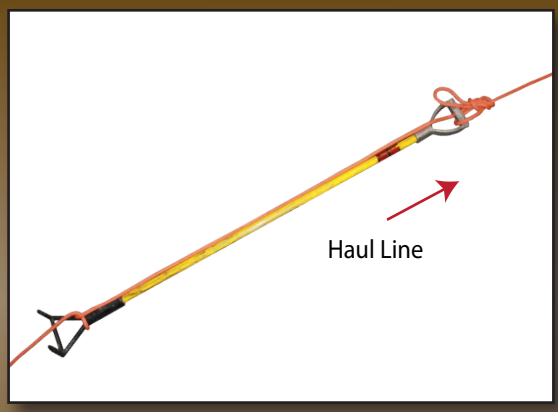
A clove hitch is placed near the claw of the haligan bar. A half hitch is then placed on the neck of the bar, passing the haul line between the pick and the adz.

D Handled Tools



Tools with a "D" handle can be hauled aloft using a bowline on a bight knot passed through the "D" handle.

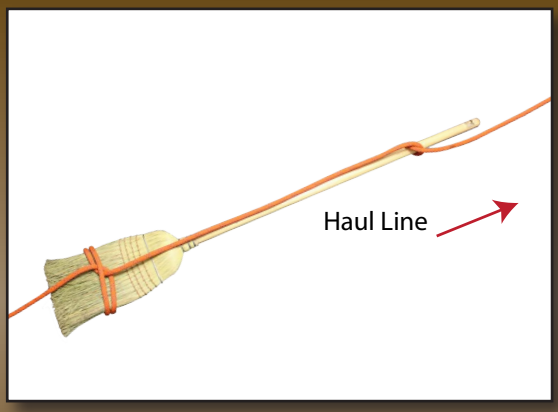
Roof Hook



Tools with a "D" handle and a shaft, such as the roof hook or scoop shovel, can be tied with a bowline on a bight through the handle and a half hitch on the down line to control the tool from below.

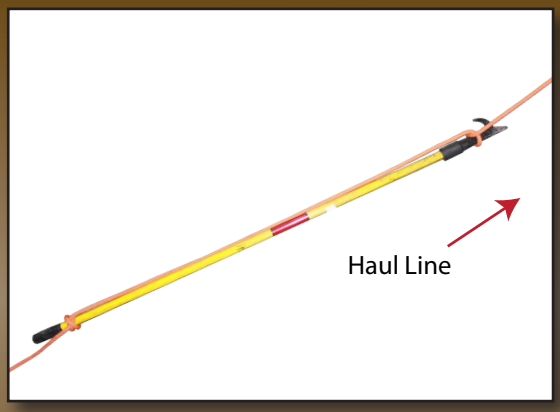
Equipment & Tool Ties (continued)

Corn Broom



A clove hitch is tied around the broom and a half hitch is placed around the broom handle using the haul line

Pike Pole

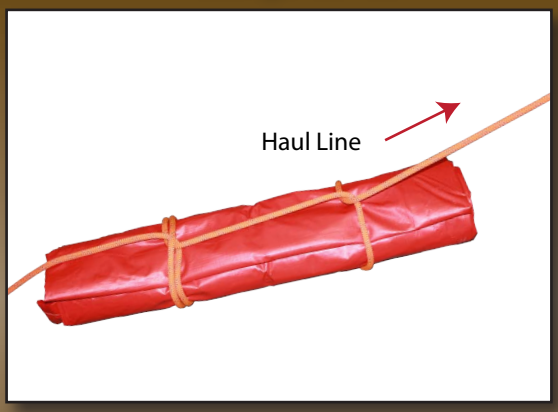


A pike pole is tied using a clove hitch around the handle and a half hitch around the hook and pike on the haul line.

Tool Box

Tool boxes are tied using a hand cuff knot. The loops of the knot are passed around both ends of the box securing the lid. This knot can be hauled with either end of the rope.

Salvge Cover



Salvage covers are hauled using a clove hitch and a half hitch on the haul line.

Equipment & Tool Ties (continued)

Hoseline & Nozzle Method #1

A clove hitch is tied just below the base of the coupling. Next a half hitch is placed around the nozzle before the shut-off butt and a second half hitch is placed around the nozzle after the shut-off butt.

Hoseline & Nozzle Method #2

Hoseline & Nozzle w/ Webbing #1

When using webbing, a cow hitch is tied just below the base of the coupling. Next a half hitch is placed around the nozzle before the shut-off butt and a second half hitch is placed around the nozzle after the shut-off butt.

Hoseline & Nozzle w/ Webbing #2

An alternative and faster method using webbing is to pass a loop of the webbing through the bail of the shut-off butt and hook it behind the nozzle. Then place a half hitch around then nozzle with the remaining tail of the webbing.

High Rise Escape Pack

The purpose of the high-rise escape pack is to provide an emergency means of vertical egress for firefighters should there escape route be cut off. Although the name implies the rope pack be used for high-rise incidents, whenever a crew goes above or below ground, the high-rise escape pack will shall be taken. The high-rise escape pack may be used at other, non-vertical incidents at the discretion of the company officer.

Equipment

The packs contain the necessary equipment for four firefighters to rappel down six stories or less. When necessary to supply/support additional personnel, rescue packs from companies not involved in interior operations should be utilized.

The high-rise escape pack contains the following equipment:

- One red rope bag
- One 75’ length of kernmantle rope with one attached steel carabiner
- Four figure 8 descending plates
- Four aluminum locking carabiners
- One 15’ orange webbing for an anchor
- Four additional 1” tubular webbing for four crew member

Procedures

1. **Secure the rope end with the carabiner to a solid anchor.**

    1.1. Use the webbing as a three bight anchor or wrap the rope end around a solid object and create a tensionless anchor.

    1.2. Lock the carabiner.

Note: The rope will be thrown out the window at this point. Make sure a stopper knot is 5' from the end of the rope.

Figure 24-30 Secure rope to a solid anchor

2. **You will demonstrate your ability to tie an overhand bend in the 1" nylon webbing. (Webbing should be carried tied in the High Rise Escape Pack)**

    2.1. Loosely tie an overhand knot with one end of the strap.

    2.2. Pass the second end though the knot from the side where the first end terminates.

    2.3. Follow the strap through the loosely tied knot with the second end to finish.

    2.4. Tighten

3. **Tie a modified diaper rappel seat with the 1" nylon webbing.**

    3.1. Place loop, both ends, behind you.

    3.2. Place thumbs in loop and pull loop taut with the knot in the small of the back.

    3.3. With one length running across the small of the back and the other beneath the buttocks, bring the thumbs with the loops around the front at the waistline.

    3.4. Reach through the loop on each side and between the legs.

    3.5. Grasp the length running beneath the buttocks with both hands.

    3.6. Separate your hands while pulling the strap up through the two loops to your waistline.

    3.7. Pull taut in preparation to connect carabiners. (If possible tie the resulting loops with square knot to maintain tautness)

Figure 24-31 Tie a modified diaper seat harness

4. **Attach carabiner to modified diaper loops.**

    4.1. Unscrew carabiner safety lock.

    4.2. Squeeze the spring loaded section to open.

    4.3. Attach through both loops of modified diaper repel seat.

5. **Attach the rope to the Figure 8 plate.**

    5.1. Reach out the window approximately 6"-8" past the outside edge of the sill.

    5.2. Grasp the rope and form a bight.

Figure 24-32 Attach rope to the figure 8 plate

5.3. Hold the 8 plate flat with the large hole and ears away from you.

5.4. Feed the bight down through the top of the large hole, with the length to be used for repelling coming off the left or right side of the 8 plate.

5.5. Pull the bight towards you, opening the bight.

5.6. Lift the bight over the small end (stem) of the Figure 8.

5.7. Position the bight across the shank between the large and small holes on the top of the 8 plate.

5.8. Pull the bight taut on the 8 plate.

Figure 24-33 Position rope around body and exit building

6. Attach 8 plate to carabiner on modified diaper repel.

6.1. Attach carabiner to small hole of 8 plate, locking device up.

6.2. Lock the carabiner making sure the locking device is facing up.

7. Position rope around the body.

7.1. Holding the 8 plate in front, with the rope to be used as brake coming off the left side of the 8 plate, take the rope around your left side and across your back to your right side.

7.2. Bring the rope under the right arm up to the front up and over the right shoulder so that the rope is now hanging off the right shoulder down the back.

NOTE: The rope may be routed around the right side to the left arm, etc. If the rope comes off the right side of the 8 plate.

8. Exiting the window - single person rappel.

Figure 24-34 Begin rappel

8.1. Assure that the rope is properly positioned across the back, under the arm and over the shoulder.

8.2. Place both hands on the window sill.

8.3. Put the left foot out the window and sit on the sill.

8.4. Slide the right foot out the window while placing left knee against the building wall.

8.5. Place both knees against the wall and lean back putting your weight on the brake rope and 8 plate.

8.6. Place left hand around 8 plate and rope, prior to grabbing

NOTE: The right leg may be placed out the window first, providing the rope is in the left.

9. Rappelling down the building.

9.1. Stand up on the outside wall while leaning back.

9.2. Position the legs, spread apart approximately 18”-24” for stability. (Shoulder width)

9.3. Place left hand around 8 plate and rope, then reach up to shoulder

and slip thumb under rope.

9.4. Lift the rope off shoulder while gripping the rope with right hand. Slide left hand down to the harness prior to rappelling.

9.5. Left hand may hold harness, but do not place hand on 8 plate as glove and hand may be pulled into it with rope.

10. Controlling the descent.

10.1. Loosen grip on rope to let it slide through hand to control descent.

10.2. Bring rope in hand backward to take tension off back and speed up descent.

10.3. In emergency, bring right hand with rope forward to 8 plate to stop.

10.4. To lock in at a certain point/elevation, bring rope to 8 plate and tie off with 2 hitch.

10.5. While descending look for a landing, window, fire escape or other safe position to re-enter the structure.

Figure 24-35 Control the descent

11. Completing rappel.

11.1. To complete rappel after reaching ground, take 3-4 steps away from landing area while pulling slack through 8 plate, then move back to landing area. (This will allow the next firefighter to begin their rappel)

11.2. Disconnect carabiner from harness.

12. Safety Precautions.

12.1. Use of bag is restricted to a maximum of 6 stories.

12.2. Protect rope from glass, sharp edges, fire and other hazards.

12.3. Wait until rope is clear of personnel before starting descent.

12.4. Tie a Figure 8 stopper knot approximately 5 feet from end of rope to prevent rappelling off the rope.

Figure 24-36 Disconnect carabiner from harness

Maintenance

- Inspect after each use and monthly for damage.
- Complete rope log after each rappel and/or use.
- Wash rope, as needed, with clean, cold water.
- Store in an area free from moisture, direct sunlight, and exposure to chemicals and petroleum products.
- Notify the Rope Officer of any suspected damage.
- For replacement of damaged or lost equipment, contact Fire Station #4, Rope Officer.

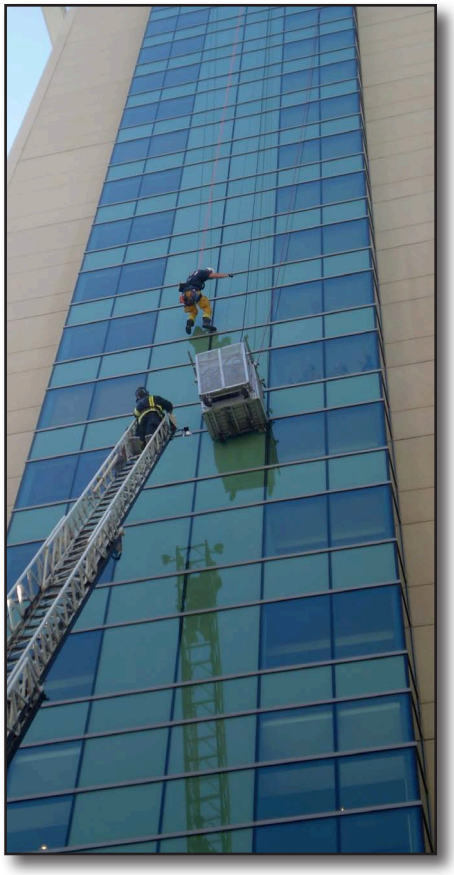
Safety Precautions

- Use of the pack is restricted to a maximum height of six stories.
- Protect kernmantle rope from glass, sharp edges, fire, and other damage. Pad rope at points of contact.
- Do not begin descent until preceding person has cleared the rope.
- Use only safe and proper techniques.
- Tie a figure 8 stopper knot approximately 5’ from the end of the rope to prevent rappelling off the rope.
- First person down will hold the bottom of the line and maintain tension while second person descends.
- At no time shall the rope in the rescue pack be utilized to haul or carry equipment.

Safety Note - When training with the high rise escape pack, you must always use a belay line

Rope Rescue Systems

Rope rescue is a very technical and high risk operation. Because rope rescue incidents are fairly infrequent, an emphasis to continuously train and practice these skills cannot be overstated. All SDFD truck companies and select engine companies carry the necessary equipment to perform basic low and high angle rope rescue; Rescue 4 and USAR 41 carry additional equipment to perform more technically advanced rope rescues. For this reason all firefighters are responsible to know how to safely build and operate the following rope rescue systems and perform the following evolutions:



- Anchors
- Tandem Prusik Belay
- RPM
  - Lower
  - Rappel
  - Haul using a 3:1 mechanical advantage (Z Rig)
- Stokes Basket / Litter Rescue
  - Low Angle
  - High Angle
- Victim Pick-Off
- Lyfe Pulley System

Systems Bag

The "systems bag" contains all of the necessary hardware and software to build a basic rope rescue system, excluding the ropes for the main and belay lines. The bag is separated into four pockets:

- Side Pocket 1 - Complete RPM setup
- Side Pocket 2 - Complete Tandem Prusik Belay setup
- Front Pocket 3 - Spare Software (webbing and prusiks)
- Inside Pocket - Spare Hardware, Pre-Tied Anchors, Tag Lines

These standardized systems bags can be found on all SDFD truck companies, heavy rescue units, and select engine companies.

Figure 24-37 Systems Bag

Systems Bag

RPM Bag

- (1) Anchor Plate
- (1) Load Releasing Strap
- (1) Brake Bar Rack
- (5) Steel Carabiners
- (1) Aluminum Carabiner
- (2) Prusik Minding Pulley's
- (2) Green Prusiks

Belay Bag

- (1) Collection Ring
- (2) Load Releasing Straps
- (5) Steel Carabiners
- (2) Aluminum Carabiners
- (1) Red Prusik
- (1) Green Prusik

Software

- (4) Green Webbing
- (4) Blue Webbing
- (4) Orange Webbing
- (4) Yellow Webbing
- (4) Green Prusiks
- (4) Red Prusiks

Hardware Bag & Rope

- (5) Steel Carabiners
- (5) Aluminum Carabiners
- (2) Prusik Minding Pulley's
- (1) Collection Ring
- (2) Figure Eight Plates
- (2) 50' Taglines
- (2) 30' Pre-Tied Anchors
- (2) Edge Protection

Anchors

Anchors are the foundation of all rope rescue systems. A good anchor is one that is considered "bomb proof." There should be no question or doubt if the anchor will hold the weight placed on the system. Good anchors include mature trees, large vehicles, or solid structural members or framing. There are several considerations when selecting an anchor:

- Will the anchor hold the weight of a fall or impact, "bomb proof?"
- Will the anchor damage the rope (fray, cut, melt, etc) ?
- Is the anchor in line with the system or is a change of direction necessary?
- Is the anchor too close/far from the edge to build a mechanical advantage system?

When possible, separate anchors should be utilized for the RPM and Belay systems.

Picket Anchor System

In the event that no suitable anchor is present, pickets may be placed into the ground to create your own anchor system. Picket systems are most commonly used in beach/cliff rescue and other remote areas. SDFD Lifeguards are well trained in the use of picket systems.

Pickets are made of 1" diameter cold rolled steel and 4 feet long. These Pickets may be used in either an in-line configuration or triangle configuration. The SDFD recognizes two types of picket systems that can be used for rescues, the windlass picket system and the *Rescue 3* picket system.

Rescue 3 Picket System

The Rescue 3 picket anchor plate is a simple piece of rescue hardware that makes building a picket anchor system for rescue easy. Machined out of a solid piece of aluminum, this anchor plate is rated at 8000 pounds and has no moving parts. It provides optimum spacing for the pickets and eliminates the need to use webbing to tie one picket to another. On the end of the anchor plate is the attachment point, is raised for easy access. This system will allow for the pickets to be pulled in unison compared to a windlass system where webbing will pull one picket at a time when initial forces are applied. This is allowing all 3 pickets to share the load and lock in place together compared to one at a time for the windlass.

Figure 24-38 Rescue 3 Picket System

Rescue 3 Picket System

Rating - 8000 lbs (hard packed soil)

Safety

- Check for underground utilities prior to driving pickets
- Safety test all anchors in the direction of use
- Watch for signs of weakness or failure
- Always have independent anchors for the main line and belay line

Inline Picket System

- Place anchor plate on the ground with the raised anchor attachment point in the direction you want to pull
- The raised front portion hole is where you will place your webbing or carabiner for your anchor system. You MUST ensure this is pointed upwards.
- Place 1st picket in the 1st hole (not raised hole) with a 15 degree angle away from the load and drive 2/3 of total length into firm soil (soft or sandy soil drive in 3/4 of total length)
- Place 2nd picket in 3rd hole and repeat previous steps
- Place 3rd picket in 5th hole and repeat previous steps

Windlass Picket System

As an alternative to using the Rescue 3 picket system, a windlass picket system may be constructed. The two most comonly used windlass picket systems are the in-line windlass picket system and the triangle windlass picket system

In-Line Windlass Picket System

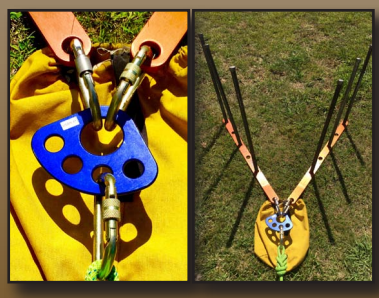
In situations where there will only be one direction of pull on the anchor, a 1-1-1 inline picket system can be used. This system is set up with three pickets placed in line. Each picket is spaced one picket length from the other. The load is then shared by all three pickets through a windlass.

Rescue 3 Picket System (Continued)

Triangle Picket System

- Create a triangle that is no more than a 45 degree angle with (2) anchor plates
- Do not overlap the anchor plate attachment points and ensure the plates do not rub against each other
- At the triangle point you will need a collection plate, figure 8 plate or collection ring (see below pictures) and two carabiners. You will attach a carabiner at each attachment point of the anchor plate and the collection ring/plate.
- Attach your system to the collection ring, 8 plate, or collection plate

Collection Ring



Collection Plate

Figure 8 Plate

Video- *https://youtu.be/pPOYzc8418w*

Triangle Windlass Picket System

In situations where there may be a shift in the angle of the load, a 1-1-1 triangle inline picket system can be used, This sytem is set up similar to the in-line picket system, only in a trianglular formation.

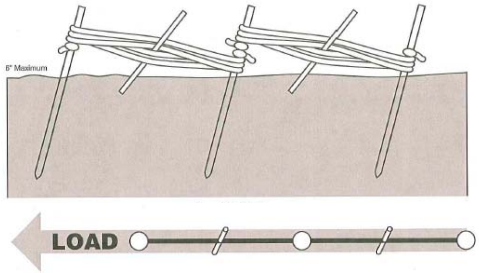


Figure 24-40 In-Line Windlass Picket System

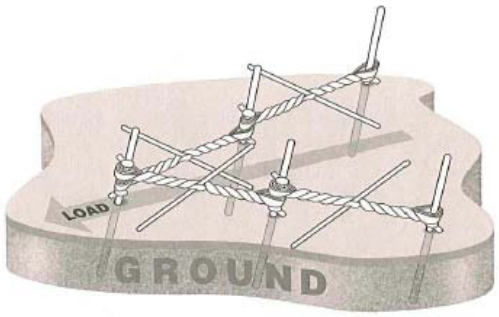
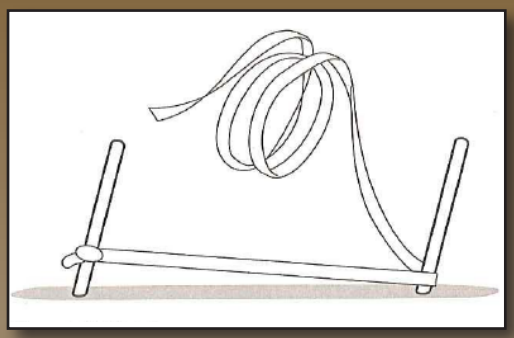


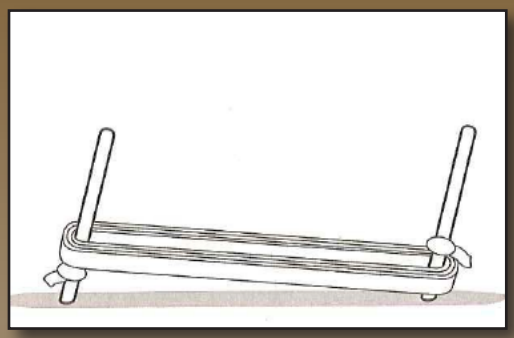
Figure 24-39 Triangle Windlass Picket System

Windlass Picket System

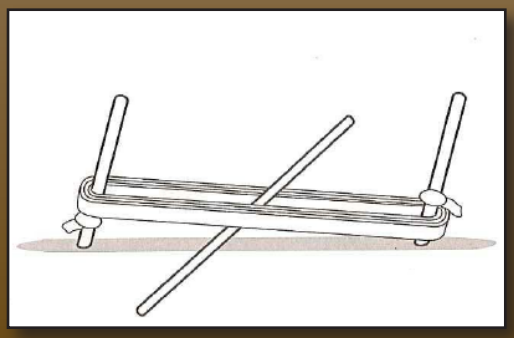
- Pickets should be 1” diameter cold rolled steel, 48” in length.
- The tensioning device should be 18” to 24” long and 1/2” to 3/4” in diameter.
- Pickets should be drive into the ground at an angle of 15 degrees, tilted away from the load.
- Pickets should be driven into the ground 24” to 36.”
- Pickets should be spaced one picket length away from each other.
- 3 pickets in-line in hard compact soil will generate an anchor able to withstand 5000 lbs.



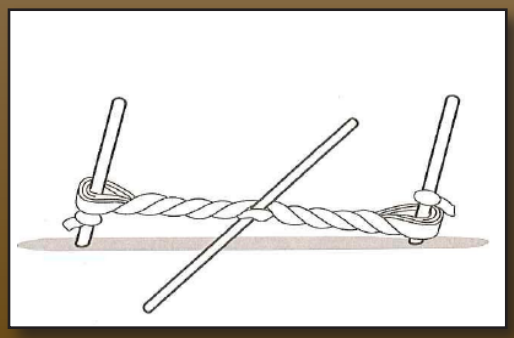
Secure the end of the windlass material tothe base of the front picket, approximately 2” - 6” from ground level with a clove hitch



Form a series of wraps around the base of one rear picket and the tie off point of the front picket and secure the end of the windlass material to either picket with a clove hitch. A minimum of 4 wraps is required when using webbing; tie together pieces of webbing to make it long enough if needed.



Tighten the windlass by inserting a tensioning device between the wraps and turning it, this will cause the loops to twist and tighten.



Continue to tighten until the front picket starts to move. Secure the tensioning device by driving it into place or placing it on the ground.

Anchor Attachments

Although there are many safe techniques for creating anchor attachments, SDFD has approved the following methods to help standardize our operations.

3 Bight Anchor

Tie the webbing in to a loop with a water knot and wrap it around the post. Connect the two bights of the webbing with a carabiner. The pre-tied rope anchors found in the systems bag are intended to be used to create a 3 bight anchor.

3 bight anchor strength, 1" nylon tubular webbing - 8500 lbs

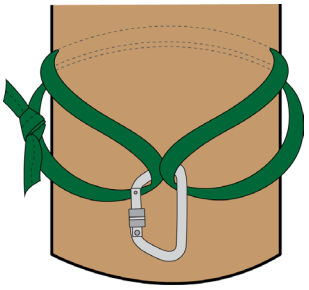


Figure 24-41 3 Bight Anchor

Wrap 3 Pull 2 Anchor

Wrap the webbing around the anchor point three times and tie a water knot. Pull two of the loops out to connect to the carabiner and so the third loop tightens around the post. Position the water knot so it is in the load side of the post.

Wrap 3 Pull 2 Anchor Strength - 8000 lbs

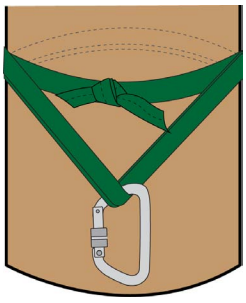


Figure 24-42 Wrap 3 Pull 2 Anchor

Tensionless Anchor

A tensionless anchor only requires the use of the rope and a carabiner. Tie a figure 8 on a bight to the end of the rope. Wrap the rope around the anchor a minimum of 3 full turns and clip the figure 8 knot back on to the standing part of the rope with a carabiner. When tied correctly, no tension should be placed on the carabiner. The purpose of the carabiner is to simply keep the rope from slipping down the anchor.

Tensionless anchor strength = Strength of the rope (9600 lbs)

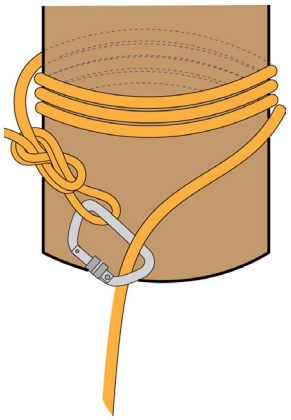
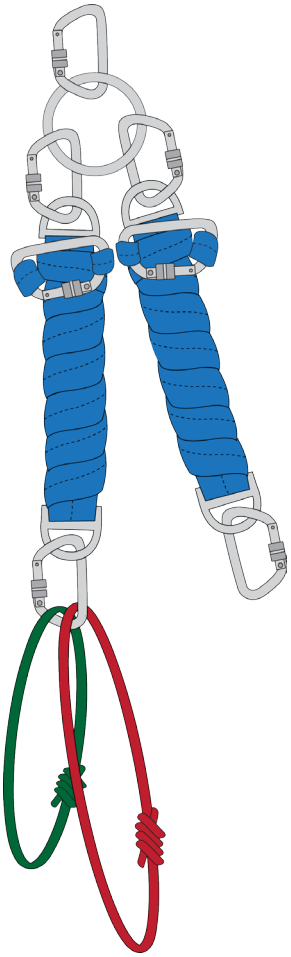


Figure 24-43 Tensionless Anchor

Tandem Prusik Belay



Whenever a “life” load is placed on a rope system, a safety back-up line known as a belay must be used in the event of a failure on the main system. The belay consists of a separate rope, hardware, and anchor from the main system.

There are several methods available for belaying, however, the industry standard for the fire service as well as the SDFD is to use the Tandem Prusik Belay system. The Tandem Prusik Belay system consists of the following:

- 1 Collection ring & steel carabiner
- 2 Load releasing straps or Mariners hitches
- 1 Long 70” prusik loop (Red)
- 1 Short 57” prusik loop (Green)

Note - A prusik minding pulley may be found attached to some belay systems. This pulley should only be used to haul up rope in the belay system with no life load on them. Belaying a life load during a raising operation with the pulley causes the prusiks to loosen and not grab the rope should the main system fail.

Belay Exception

As mentioned previously, a belay must be used whenever a “life load” is placed on a rope system. In situations where the rescuer is placed in imminent danger and immediate exit of an IDLH is required by means of a rope, a belay is not practical or realistic. However, when **training** with the high-rise escape pack or practicing other “bail out” tactics, a belay must be utilized at all times.

Tandem Prusik Belay - Lowering Operation

To belay a rescuer during a lowering operation, the belayer tends the prusik hitches so that they do not grab the belay rope line while the lower is under way. You should be able to feel a little bit of friction as you pull the belay line through the hitches. If the main line fails, the prusik hitches will be pulled out of the belayer's hand as the belay system catches the load. If the prusik hitches become too loose around the rope, there is a chance they might not grab quickly enough to catch a falling load on the main line. For this reason the belayer must pay close attention to the prusik hitches.

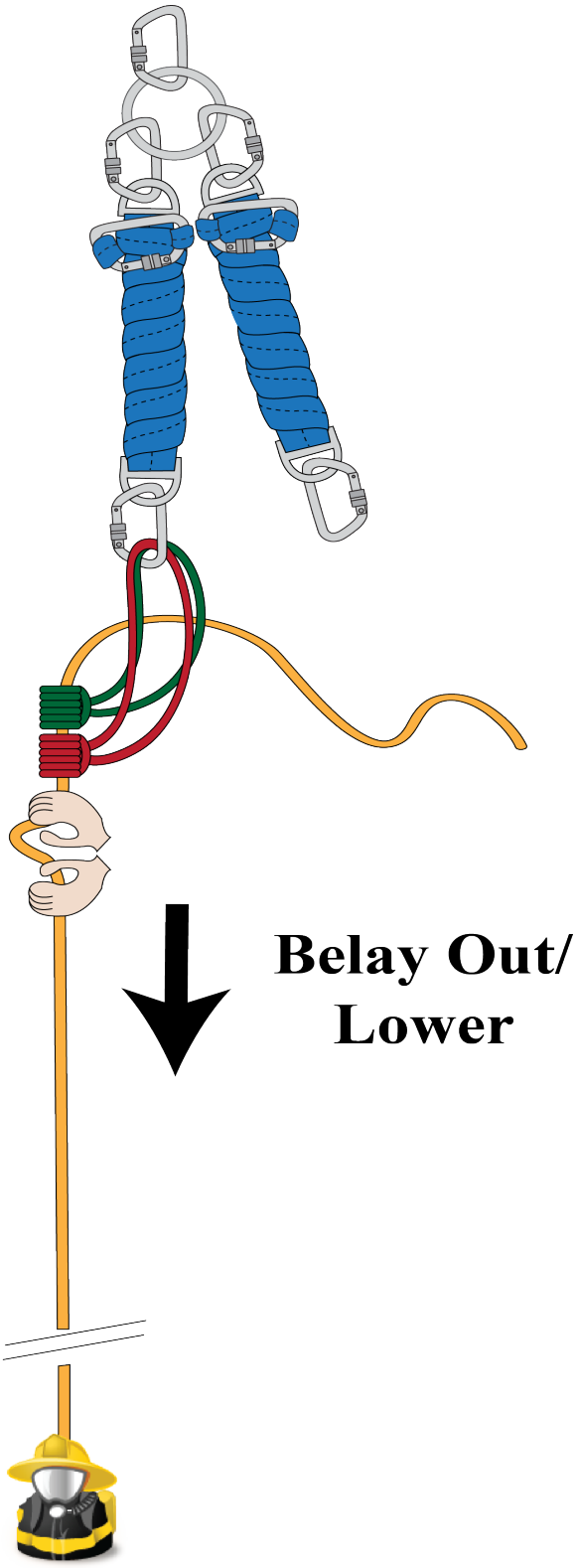
The belayer must also work in close coordination with the operators of the main line during the entire operations. Good communication is an absolute must!

If the belayer lets out too much slack in the line, the rescuers may take a significant fall before the belay line engages and catches them.

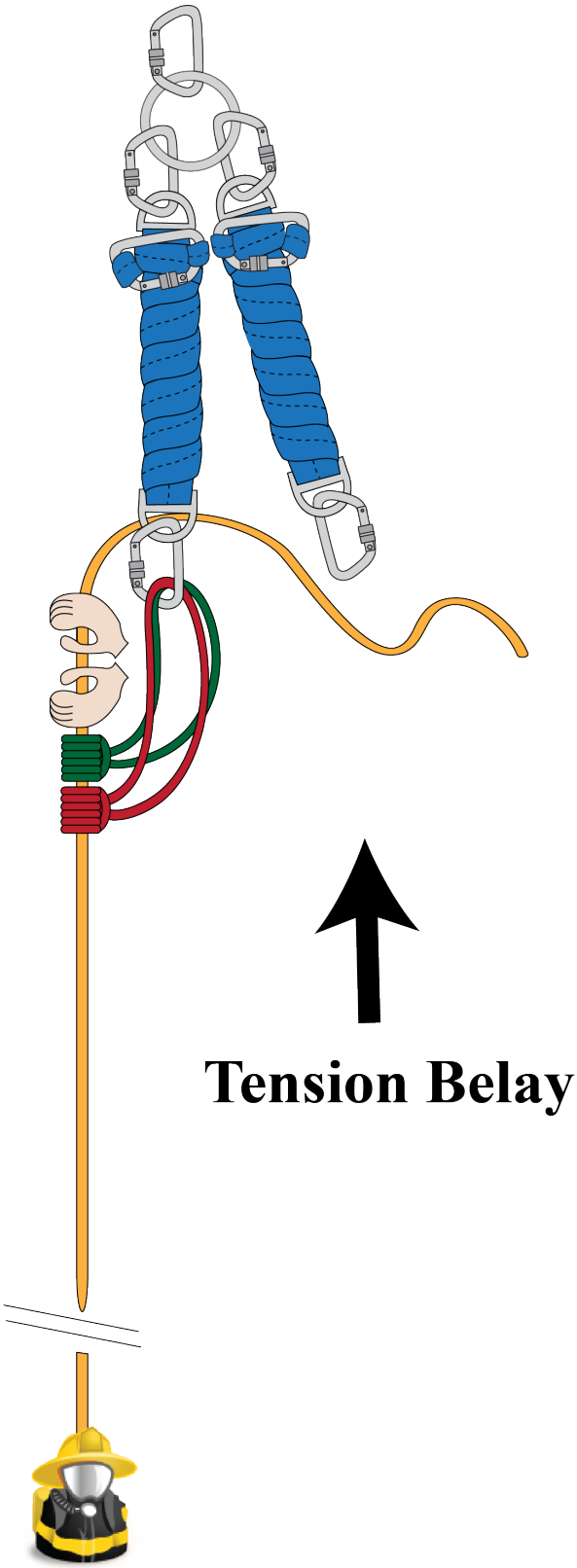
Conversely, if the belayer is not feeding out enough rope to keep up with the lowering of the main line, the load may inadvertently transfer over to the belay line causing the prusik hitches to lock-up. If this occurs two options are available to unlock the prusiks hitches:

1. The load can be transferred back to the main line by releasing the Load Releasing Straps or Mariner's Hitch. Once the load is transferred over the back-up load releasing strap is connected to the pulley and prusik hitches so the operation can immediately continue.

2. The load can be transferred back to the main line by pulling up/hauling the main line until the load is back on the main line. The belayer then quickly unlocks the prusiks and the operation can again continue. This is the preferred and fastest method, however, may not always be possible if limited personnel are at scene.

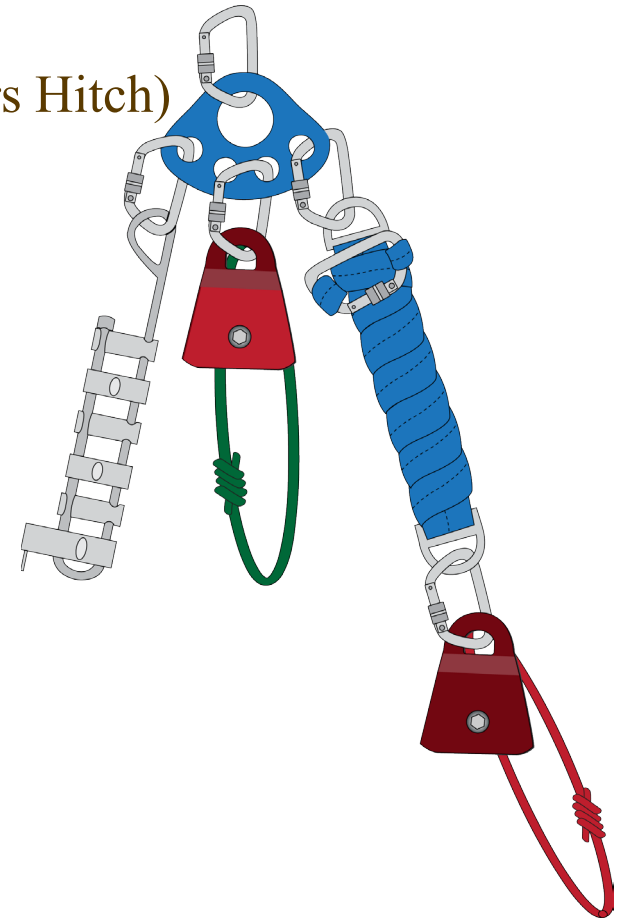


Tandem Prusik Belay - Raising Operation



To belay a rescuer during a raising operation, the belayer simply pulls the rope through the prusik hitches. Keeping slack out of the belay system is important to minimize the distance the rescuer will fall before the belay system engages and catches them.

RPM
(Rack - Pulley - Mariners Hitch)



The RPM is a rope rescue system that is pre-attached to a collection plate for quick deployment. It is the primary rope rescue system in use industry wide. The RPM allows the user to build a variety of rope rescue systems, including but not limited to:

- Rappel system
- Lower system
- Hauling system
- Tandem Prusik Belay

The equipment used to construct a RPM

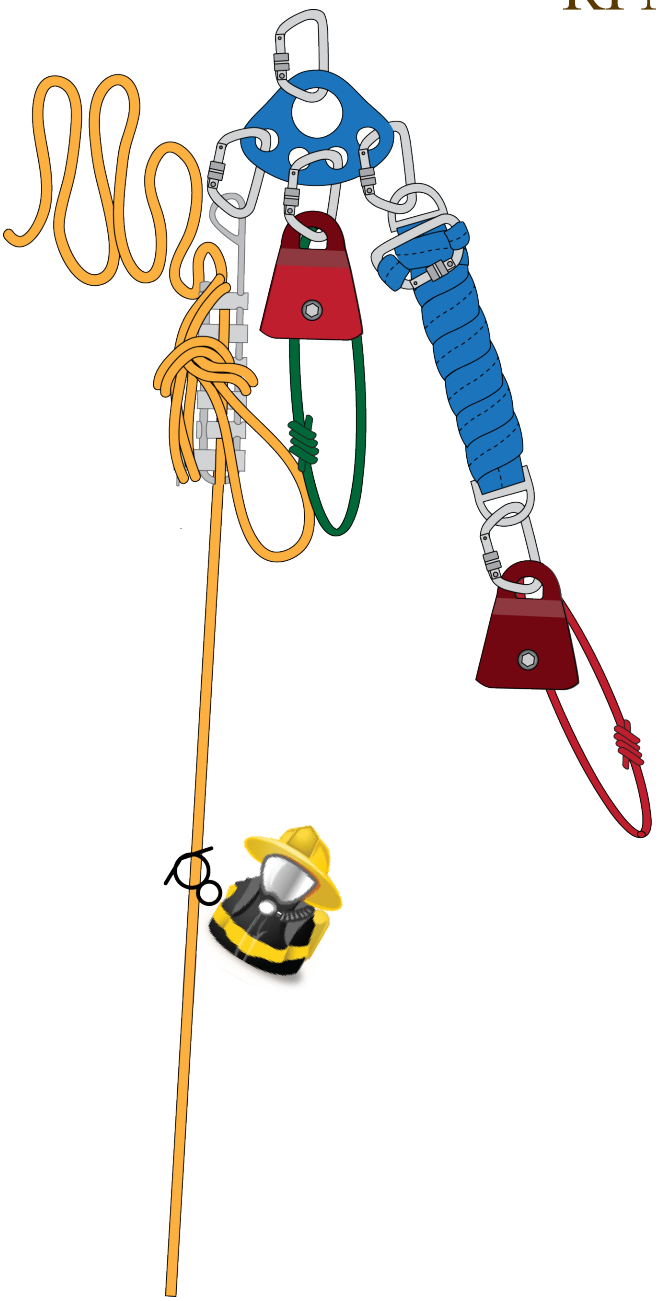
- 1 Collection Plate
- 4 Steel Carabiners
- 1 Brake Rack
- 2 Prusik loops
- 2 Prusik minding pulley's (can be 1 prusik minding and 1 regular pulley)
- 1 Load release system with 2 Carabiners (pre-made Strap or Mariners hitch)

Assembly

(Looking down at plate, small hole at top, multiple holes towards you)

- Connect one carabiner to single hole at the top of the plate
- Connect second carabiner to the far left hole bottom of plate
- Attach Brake Rack, to carabiner, opening of rack facing to left
- Connect third carabiner to next hole to right
- Attach prusik minding pulley (or regular pulley) and short prusik to carabiner
- Attach the Load Release System to the far right hole
- Attach a prusik minding pulley to the hanging carabiner on the load release system
- Attach the remaining Prusik to the same carabiner
- The RPM is now ready to be placed in service

RPM - Rappel System



The RPM can be setup to be used as a rappel system.

1. Connect the anchor plate to a bomb proof anchor

2. Lay out enough rope to the ground before you feed your rope through the brake rack in the event that you must convert from a rappel to a lower.

3. Feed the rope through the brake rack and properly lock it off.

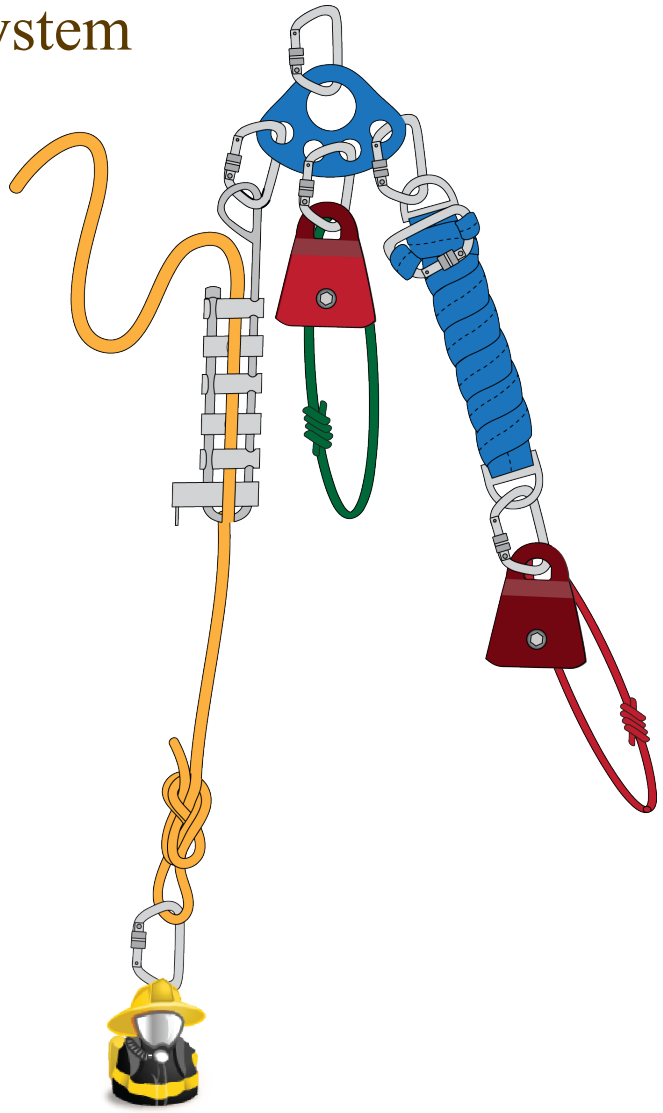
4. Take your rope bag and drop it over the side/ below

5. The RPM is now ready for a rescuer to load the line and rappel

The RPM as a rappel system is not the preferred method to use when performing a victim rescue or pick-off. When used as a rappel, the rescuer must utilize both hands to control their descent and does not have the ability to stabilize the victim immediately upon reaching them as they must lock off their descent device. Additionally, communicating through the use of a radio is difficult during a rappel.

Some instances that might call for the use of the RPM as a rappel may include poor visibility by the lowering crew, poor communication/radio reception and/or a non-rescue situation.

RPM - Lowering System



As previously mentioned, the lowering system is the preferred method for performing a rescue/victim pick-off. The lower system allows the rescuer to keep their hands free, as well as to pre-attach prusiks and carabiners to their main and belay lines, for immediate victim stabilization.

A minimum of 4 personnel are required to effectively perform a safe lowering operation. Performing a safe operation requires practice, good communication and strong team work by all crew members involved.

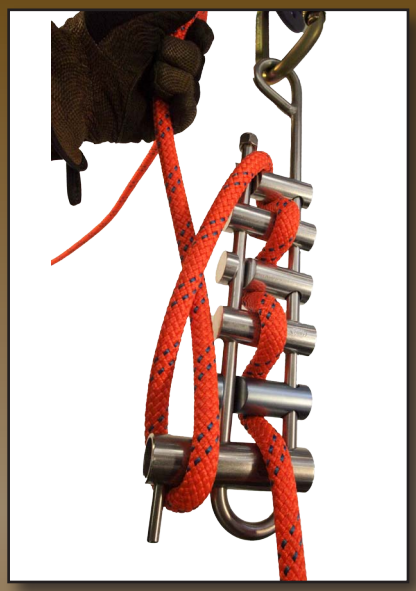
Minimum Required System Personnel for a Lower

1. Coordinator & Safety Officer
2. RPM Operator
3. Belay Operator
4. Rescuer

Operation

1. Connect RPM to a bomb proof anchor
2. Tie a figure 8 on a bight and attach a carabiner. This will attach to the rescuer's seat harness.
3. Feed the rope through all bars of the brake rack and properly lock off
4. Once the rescuer is ready and the tandem prusik belay has been attached, the rescuer can be lowered.
5. Unlock the brake rack bar and slowly begin unweaving the rope from the friction bars on the rack
    - 5.1. As one bar is removed, slowly spread the remaining bars apart to allow the rope to feed out and lower the rescuer.
    - 5.2. To slow or stop the rescuers descent, move the rope forward toward the rescuer.
6. Never let go of the rope during a lower unless it has been properly locked-off to the brake rack.
7. Once the rescuer reaches the victim, properly lock-off the brake rack.

Brake Bar Rack



Locking off the Brake Rack to use as a Rappel or safety lock

- Using the up-line wrap around the 6th bar
- Pull and tighten up-line back towards the hyper bar
- Wrap line around the hyper bar pulling down line towards the 6th bar
- Bring line back up and wrap a second time around hyper bar
- Create a two foot bight
- Use this bight to tie a overhand knot around the body of the brake rack
- The brake rack is now locked in a static position which can be used as a rappel

Figure 8 Lock-Off

Feed bight of rope down through the 8 plate and back up over the neck

Attach 8 plate to seat harness with a carabiner.

Pass the rope around your left side, along your back, to your right side and prepare to rappel.

To lock-off, pass the rope behind the 8 plate, around the cleat and back to your right side.

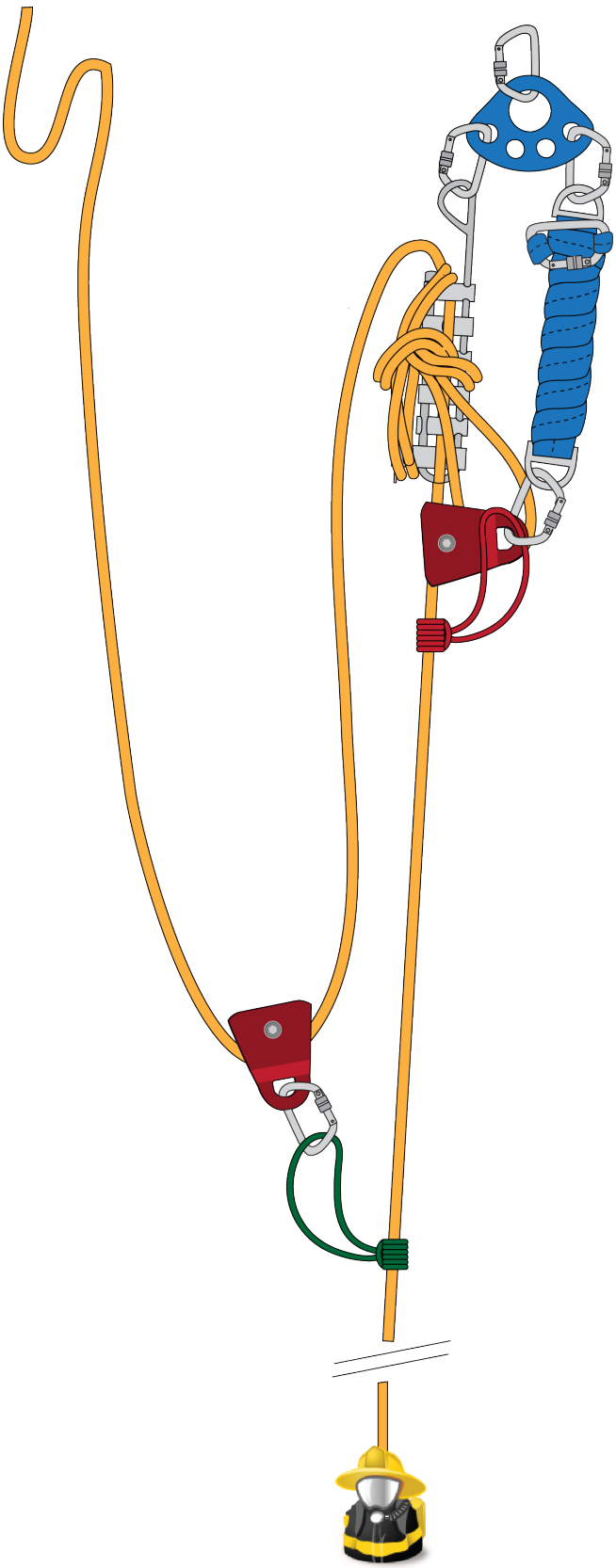
Repeat a second time

Pull a bight through the center of the 8 plate

Tie an overhand knot around the entire 8 plate with the bight

Clip the remaining bight back into your seat harness with another carabiner

RPM - 3:1 Hauling System (Z Rig)



The RPM allows the user the flexibility to convert from a lower system to a hauling system in the event that the rescuer and victim cannot be lowered to the ground and must come back up. The RPM can be converted into a "Z-Rig" system which gives the user a mechanical advantage of 3:1.

When converting from a lowering to hauling operation, the golden rule is to always add components before you subtract components.

Converting from a Lower to a 3:1 Haul

1. Check the anchor to ensure that it will support a hauling evolution

2. Make sure that the lower and belay system are locked

3. Using the prusik from the load release system, attach a three (3) wrap prusik to the rescuer's line (Main line)

3.1. Re-attach the prusik to the carabiner on the load release system (Gain Saver)

3.2. Place the pulley from the load release system on the rescuer's rope between the prusik and the brake rack

3.3. Re-attach the pulley to the carabiner on the load release system and lock the carabiner

3.4. Tension the prusik towards the load

4. Using slack from the up-line create a bight

4.1. Running parallel to the rescuer's rope stretch the bight towards the load

4.2. Remove the remaining pulley, prusik and carabiner from the RPM

4.3. Place the prusik on the rescuer's rope (next to the bight of the slack line) (Hauling Prusik)

4.4. Place the pulley on the bight of the slack line

4.5. Using the carabiner connect the pulley to the prusik (lock the carabiner)

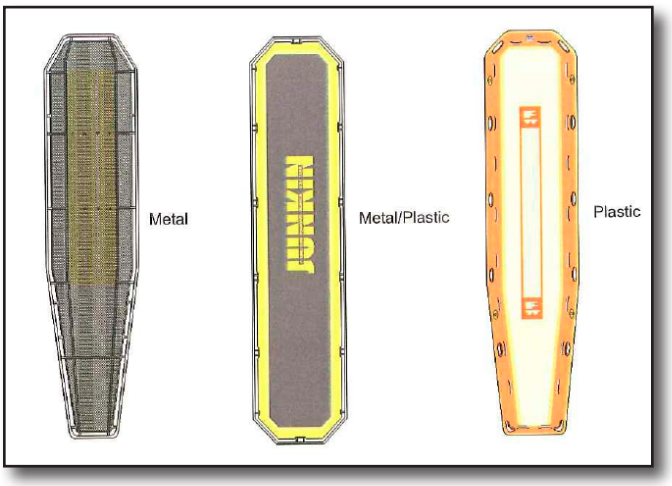
RPM - 3:1 Hauling System (cont.)

5. Unlock the brake rack
6. Using the brake rack transfer the weight to the gain saver
7. Once the weight has been transferred unload the brake rack
8. Pull the slack out of the system
9. Re-set your hauling prusik
10. You have changed over from a static line to a 3:1 hauling system

Rescue Litter & Victim Lashing

The rescue litter, or Stokes basket as it is commonly referred to, has been the standard for victim removal over terrain for many years. It can be carried by hand over mild terrain, or used in tandem with ropes or ladders to negotiate sttep or rough terrain. The rescue litte by itself does not provide spinal immobilation. A victim requiring C-spine immobilization should first be placed on a backboard, then placed in the litter.

Litters come in a variety of shapes and materials. The three most common types of litters are:



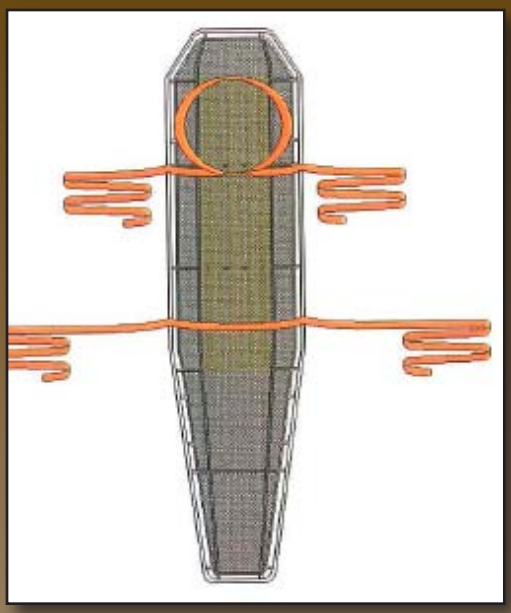
- Metal Litter aka *Stokes basket*
  - Multiple lashing points, strong, and durable
  - Backboard may not fit inside
- Metal/Plastic Litter aka *Junkin*
  - Slides easily and durable
  - Limited lashing points/options
- Plastic Litter
  - Light weight and slides easily
  - Lack structural stability and have limited lashing points

Victim Packaging

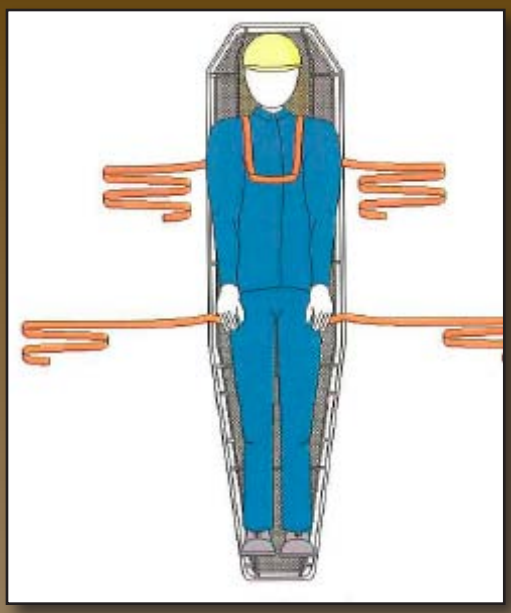
Victim packaging is an essential skill for all rescuers. If a victim is insufficiently secured to the litter, existing injuries can be worsened and new injuries can result. Victims are grenerally secured to the litter with interior and exterior lashings. Interior lashings consist of a chest and pelvic lashing that keeps the victim from sliding out the head or foot of the litter. Exterior lashing consists of webbing or other straps that are arranged across the victim from one side of the litter to the other. This keeps the victim from coming out of the top of the litter.

All victim lashings should be secured to the structural members of the litter other than the top rail in order to avoid abrasion to the lashing. Interior and exterior lashings are most commonly constructed out of 16’ and 20’ lengths of webbing, however longer sections may be needed for larger victims.

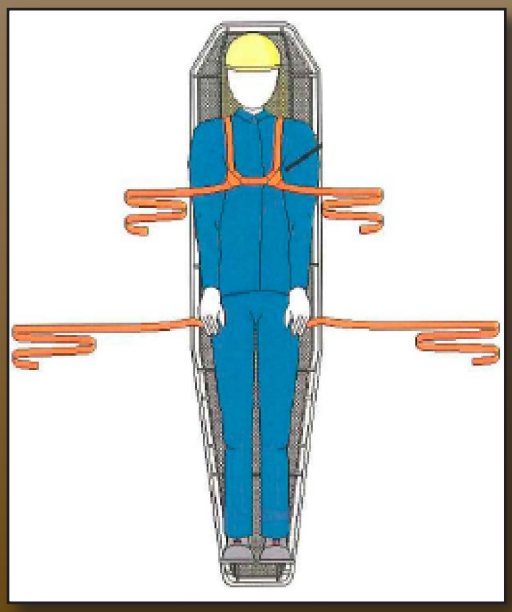
Interior Lashing



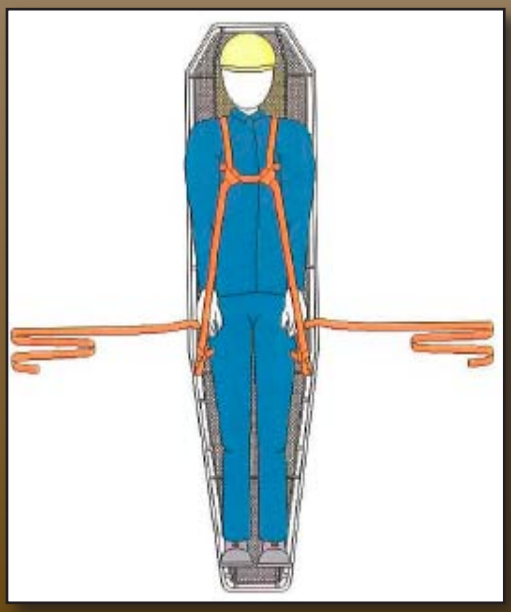
Lay two 16’ pieces of webbing across the litter and center them. Form an 18” loop in the top webbing where the victims head will be.



Chest Lash
Pass the loop over the victims head and down to their mid-chest area.

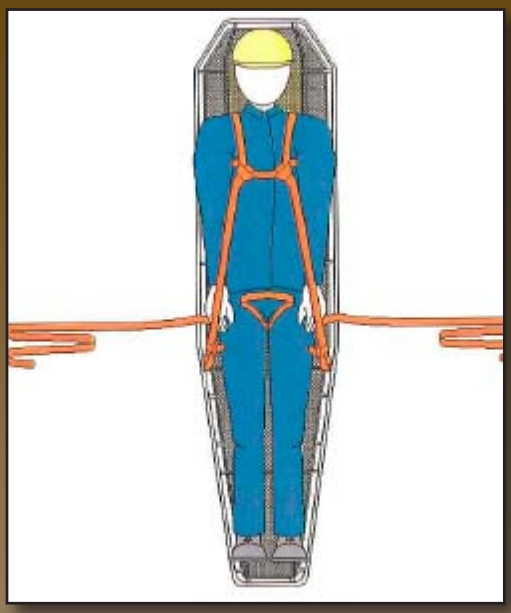


Pull webbing ends from under each arm and pass through loop on chest. Remove slack and tie an overhand knot at the intersection of the loop.

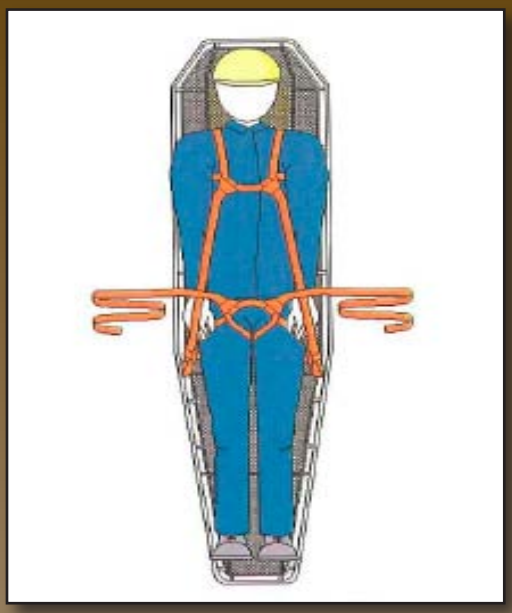


Tie a round turn and two half hitches around a rib on the litter below the victims waist.

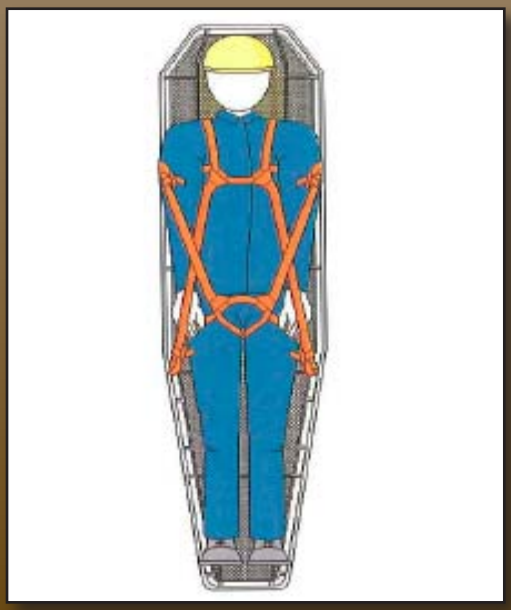
Interior Lashing (continued)



Pelvic Lash
Pull midpoint of webbing between the legs up to the victim's waist creating a 6" triangle.



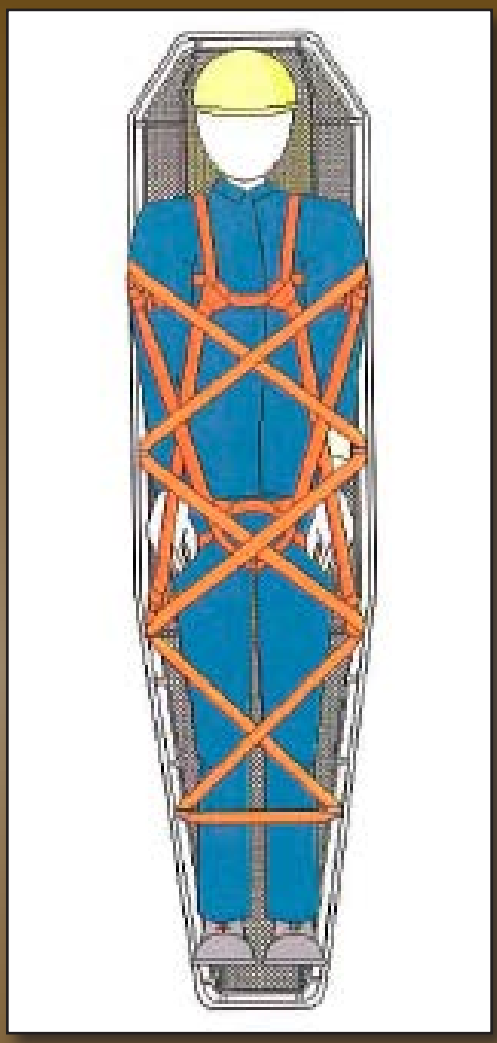
Pass the ends of webbing around thighs and through triangle, pulling upwards towards shoulders. Remove slack and tie overhand knots at loop



Tie a round turn and two half hitches around a rib on the litter near the victim's shoulders.

Overhand Knot

Exterior Lashing



1. Place a 20’ piece of webbing across the victim’s legs with the mid point at or below the knees

Note - Depending on the victim’s size, the 20’ piece of webbing may be too short. If this issue arises, tie another piece of 8’ or 12’ webbing to the 20’ webbing to lengthen it.

2. Pass the ends of the webbing around the rib at or below the victim’s knees on both sides where the rib meets the main frame. DO NOT WRAP THE MAIN FRAME!
3. Cross the webbing and pass the ends of the webbing around the next rib moving towards the head.
4. Repeat this operation until webbing passes around the ribs near the victim’s shoulders.
5. Tie a round turn and two half hitches at one end of the webbing around the rib to secure the end.
6. Tie a round turn and two half hitches with the free end around the rib to secure the other end of the webbing.

Low Angle Litter Rigging

Slopes 0 to 60 degrees

Pre-Made Low Angle Bridle

Head Lashing - Wrap an 8' piece of webbing 4 times around the top rail, avoiding the weld then connect to bridle.

3 Rescuer Litter Attachment

4 Rescuer Litter Attachment

5 Rescuer Litter Attachment

High Angle Litter Rigging

Slopes 60 to 90 degrees

Pre-Made High Angle Bridle

Connect the bridle to the main and belay line. Connect the bridle straps to the four points of the litter with carabiners facing in.

Adjust the four bridle straps to level the litter.

Attach the ropes to the rescuer. Weight the system and readjust as necessary.

Rope with 1 prussik - seat harness
Rope with 2 prussiks - chest harness (green) & foot support (red)

Victim Pick Off - From a Rappel

CMC Rescue Harness

Rappel to side of victim, lock-off 8 plate, and initiate communication with victim

Disconnect the carabiner that is attached to the belay line and let dangle from prussik.

Attach the CMC rescue harness to the prussik on the belay line and prepare harness.

Swing in and capture the victim with the black waist belt of the CMC rescue harness. Clip belt and tension around waist.

Tension the prussik on the belay line using slight pressure.

Attach the blue and red straps around the victims legs and tension.

Victim Pick Off (continued)

CMC Rescue Harness

Place helmet and goggles on the victim.

Attach an additional green prussik to the main line using a 3 wrap prussik knot.

Attach the CMC pick-off strap to the prussik on the main line making sure the V ring adjustment buckle is closest to the main line.

Attach the pick-off strap to the CMC rescue harness. Tension the prussik on the main line and apply tension to CMC pick-off strap.

Attach a chest harness to victim. Release the belay line prussik from the CMC rescue harness and re-attach to the chest harness.

Slide prussik on belay line upward, leaving a little slack so the main line will bear the victims weight. Ready for lower or raise.

Victim Pick Off - From a Lower

Refer to Chapter 26 - Academy Truck Company SOG - Drill 9, Evolution #3 for detailed instructions on how to peform a Victim Pick Off while being lowered on a rope system.

Media & Link Index

Note: You must be logged in to Target Safety to view the following videos

- Belay Video - Tandem Prussik Belay
- RPM Video 1 - Introduction & Lowering System
- RPM Video 2 - Hauling System or 3:1 Z Rig
- RPM Video 3 - Rappel System
- RPM Video 4 - Changing over a Rappel into a Haul
- RPM Video 5- Changing a Haul to a Lower
- RPM Video 6 - Manual Load Releasing Hitch
- Hi-Rise Escape Video 1 - System Set-up
- Hi-Rise Escape Video 2 - Donning Modified Diaper
- Hi-Rise Escape Video 3 - Emergency Rappel

- SDFD Academy Truck Company SOG - Ropes & Knots
- SDFD Academy Drill Sheet - Ropes, Knots & Rescue Systems

References

1. SDFD Truck Company Standard Operating Guide - 72nd Academy
2. SDFD Drill Manual, Ropes & Knots. 1994
3. SDFD Vertical Rescue Manual
4. CMC Rope Rescue Manual - 3rd Edition
5. Rescue Systems 1 - Manual - CSFM Training
6. LARRO Manual - CSFM Training

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NOTE: If you have any additional information or content that you feel would be appropriate to contribute to this Chapter or would like to report any errors or misrepresentations, please contact the SDFD Training Division or email the Drill Manual Revision Staff at

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Revisions/Updates

Date	*Revision/Update Description*