CHAPTER FOUR

KNOTS

INTRODUCTION

4.01 In ropework, the use of a variety of **proven** knots, properly applied and tied, is essential to the safe and efficient conduct of the activity.

4.02 This chapter outlines the most commonly recommended knots and roping terminology. There are many varied knots and terms used in ropework but we should aim for simplicity and ease of operation.

ROPING TERMINOLOGY

4.03 In order to standardise the language and names associated with roping and rope work, terminology as depicted in Figure 4:1 is used.

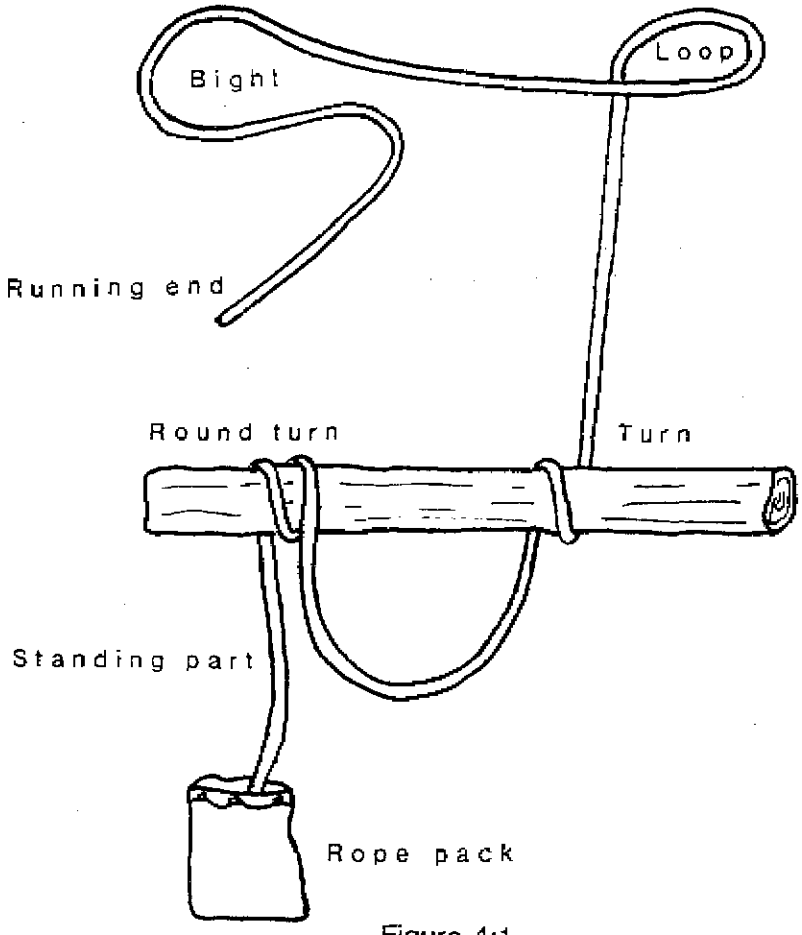


Figure 4:1
Common Roping Terminology

4.04 EXPLANATION OF TERMS

An explanation of the above terms follows:

a. **Bight** - A bight of rope is a simple bend in which the rope does not cross itself.

b. **Dressing** - The proper aligning and tensioning of the rope throughout a knot.

c. **Loop** - A simple bend of rope in which the rope **does** cross itself.

d. **Round Turn** - One **complete** turn of a rope around a spar or another rope.

e. **Running End** - The free end of rope which can be used.

f. **Standing Part** - The part of rope which is fastened.

g. **Turn** - A partial turn of a rope around a spar or another rope.

QUALITIES OF A GOOD KNOT

4.05 While knots vary in their specific use, all proven knots have certain characteristics in common:

a. They are relatively easy to tie.

b. It can easily be determined whether or not they are tied correctly.

c. Once tied, they remain tied.

d. They have minimal effect on rope strength.

e. They are relatively easy to untie after loading.

WARNING NOTE

Knots must be tied with a minimum tail of 75mm

KNOTS AND HOW THEY AFFECT ROPES

4.06 ROPE STRENGTH

Every knot diminishes the strength of rope to some degree. The reason for this is that in any sharp bend of a rope (less than four times the diameter of the rope), the filaments on the outside of the bend carry the majority of the load on the rope. The filaments on the inside of the bend will carry very little of the load or none at all.

4.07 Knots with sharp bends cause more of a strength loss in rope than do knots which have open bends. Ultimately, the kind of knot, along with other elements of a vertical rescue system, must be taken into consideration when deciding on a safety factor for a rope.

WARNING NOTE

An improperly tied knot, or the incorrect application of a knot, could result in serious injury or death

4.08 THUMB (OR OVERHAND) KNOT

This is the basis of many knots and can be used to secure other knots.

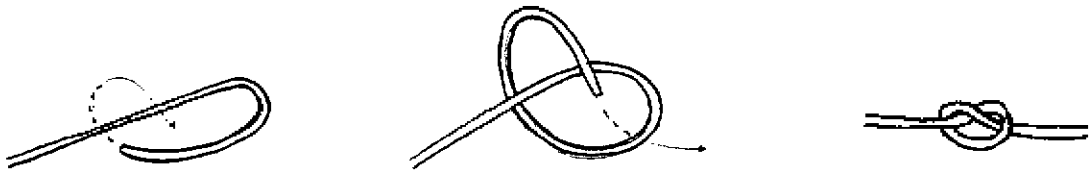


Figure 4:2
Thumb (or Overhand) Knot

4.09 FIGURE OF EIGHT KNOT

The Figure of Eight Knot can be used as a stopper knot, tied a minimum of one metre from the bottom end of a rope to prevent a person from abseiling off the end, or at the top end of rope to prevent it from accidentally slipping through equipment.

4.10 The Figure of Eight Knot is the foundation of the Figure of Eight on the Bight and the Figure of Eight Loop.

Figure 4:3
Figure of Eight Knot

WARNING NOTE

As with all knots, figure of eight knots should be dressed (the rope aligned and uncrossed) and compacted (all ends pulled down so that the knot is compact). this ensures that the knot has its greatest holding power, while reducing the rope strength as little as possible

4.11 FIGURE OF EIGHT ON THE BIGHT

This knot is used to form a secure loop in a rope for clipping into such items as karabiners.

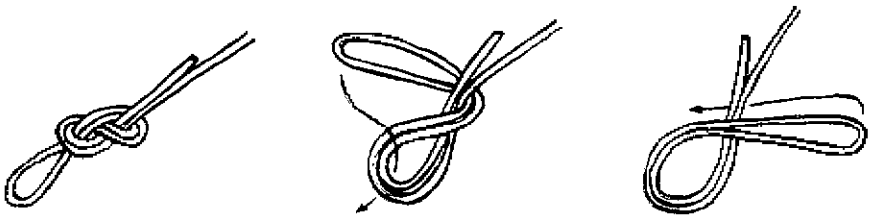


Figure 4:4
Figure of Eight on the Bight

4.12 FIGURE OF EIGHT LOOP

The Figure of Eight Loop (or follow through) is primarily used as a main harness tie in. It can be used to form a loop at the end of a rope in situations where a Figure of Eight on the Bight can not be tied. An example would be a situation such as a tall tree, where a Figure of Eight on the Bight can not be dropped over the anchor, and the Figure of Eight Loop can easily be tied around it. The advantages of the Figure of Eight Loop are that it:

a. is easy to identify;

b. has a relatively low effect on rope strength; and

c. is easy to untie after pressure is applied.

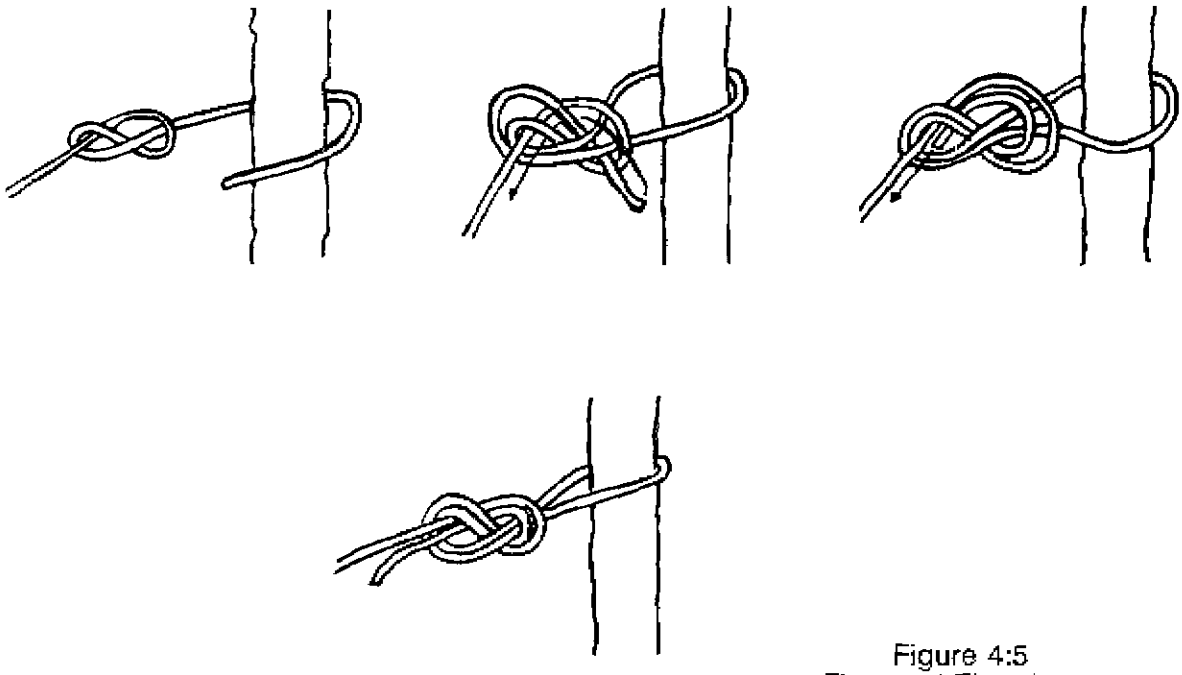


Figure 4:5
Figure of Eight Loop

4.13 TYING THE LOOP

Suggestions for tying the Figure of Eight Loop are as follows:

a. Note that the knot begins with the tying of a Figure of Eight Knot as a foundation, well back from the end of the rope.

b. After the Figure of Eight is tied, the end of rope is passed around the anchor point, then taken back through parallel to the first knot. Every contour of the first knot is followed, with both rope ends going in the same direction.

WARNING NOTE

The figure of eight on the bight and the figure of eight loop are not safe when subjected to a three-way loading. In all cases where a secure loop is required in the middle of a rope, the alpine butterfly should be used

4.14 ALPINE BUTTERFLY

The Alpine Butterfly excels as a mid-rope knot to form a fixed loop with three-direction loading capability. It is very easy to tie and untie after loading.

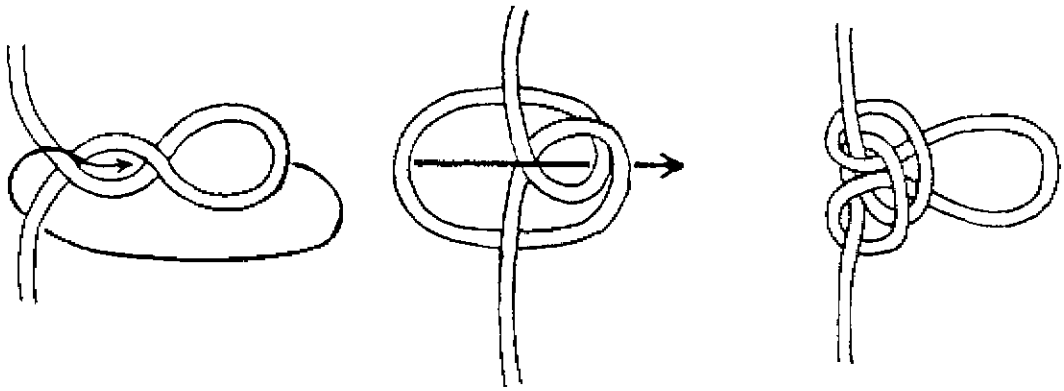


Figure 4:6
Alpine Butterfly

4.15 CLOVE HITCH

The Clove Hitch can serve as an adjustable belay knot when formed in the middle of a rope. It has the advantage of being easy to tie and to adjust.

WARNING NOTE

The clove hitch must not be used as a final anchor knot

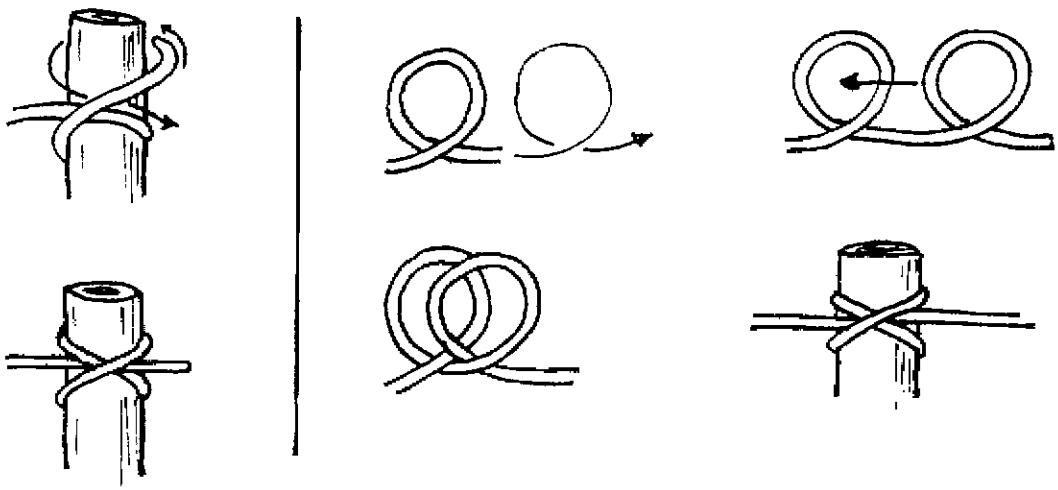


Figure 4:7
Clove Hitch

4.16 DOUBLE FISHERMANS KNOT

This knot is used for joining ropes of equal or unequal thickness, but it has the disadvantage of being hard to untie after loading. It can be used for joining cord to form a Prusik loop.

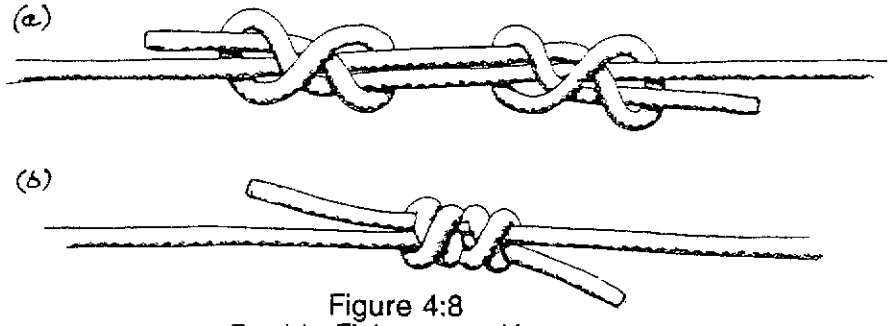


Figure 4:8
Double Fishermans Knot

4.17 ROUND TURN AND TWO HALF-HITCHES

The Round Turn and Two Half-Hitches can be used for tying a rope to an anchor point. It has the advantages that it will not over-tighten, it is easy to adjust, and it imposes minimal stress on the rope. When tied in synthetic rope, this knot must be secured with a Thumb Knot around the standing part.

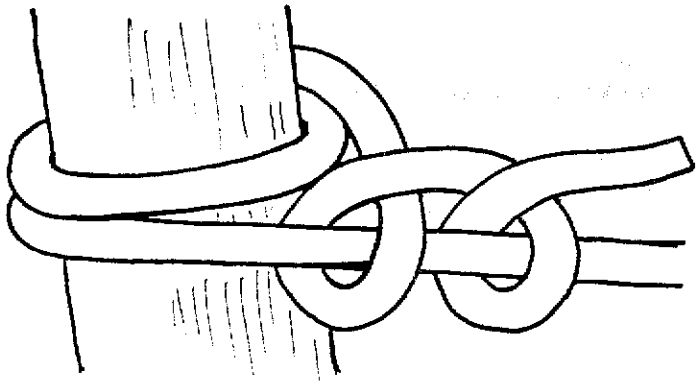


Figure 4:9
Round Turn and Two Half-Hitches

4.18 TAPE KNOT

The only knot suitable for joining tapes to form slings is the Tape Knot. (Figure 4:10)

WARNING NOTE

The tape knot should not be used with rope. because of the flat nature of tape, it has the quality of contouring over itself. rope does not have this quality, and a tape knot tied in rope may easily come undone

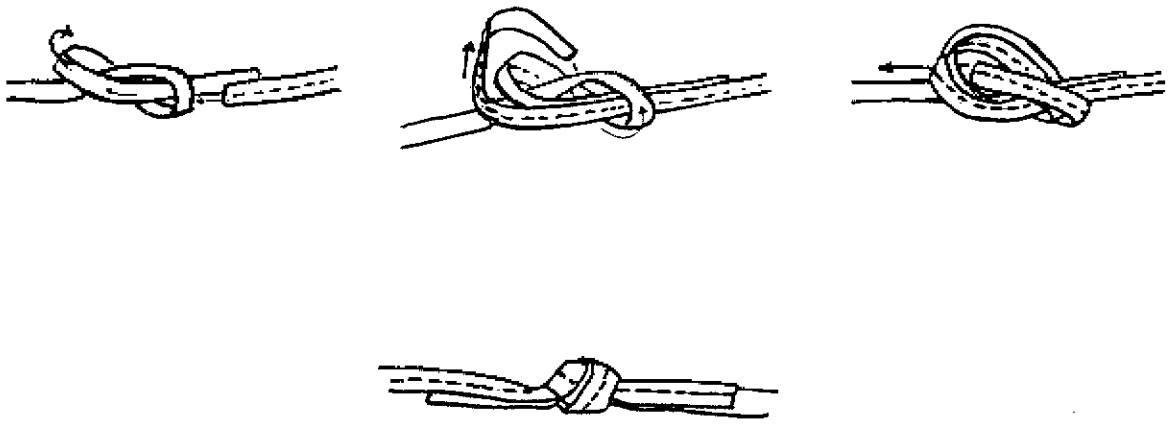


Figure 4:10
Tape Knot

4.19 TAPE KNOT SAFETY

Safety points for the Tape Knot must be observed as follows:

a. Always leave at least 100 mm of tape in the ends of Tape Knots **after they are tied and pulled tight.** Although it contours well in a Tape Knot, webbing tends to be slippery, thus ends that are too short tend to slip through under load.

b. A Tape Knot should be **inspected frequently.**

c. Be certain that the tape follows flat through the knot. A twist in the tape inside the knot will allow the knot to slip at relatively low loads.

4.20 PRUSIK KNOT

The Prusik Knot is a means of attaching a cord loop to a rope. Figure 4:11[b] shows a two-wrap Prusik normally sufficient for Prusiking or for light loads. The three wrap Prusik shown in Figure 4:11[c] is normally used for rescue attachments.

WARNING NOTES

The prusik knot should never be subjected to a shock load as it may slip

The prusik cord must be at least 3mm smaller in diameter than the main rope to provide an effective camming action

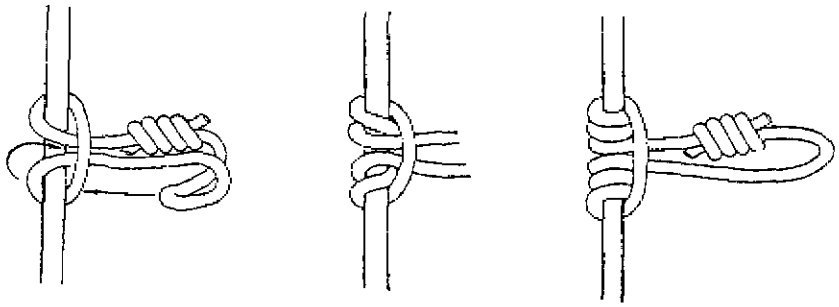


Figure 4:11
Prusik Knot

4.21 KLEMHEIST KNOT

The Klemheist Knot has the same uses as the Prusik Knot, but has the added advantage in that it can be formed with tape on a fixed rope.

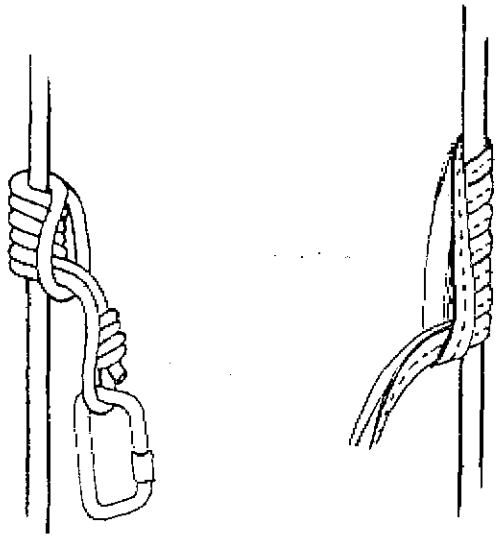


Figure 4:12
Klemheist Knot

4.22 BACHMANN KNOT

The Bachmann Knot has the same applications as the Prusik Knot, but the inclusion of a karabiner provides a handle for ease of movement of the knot on the fixed rope.

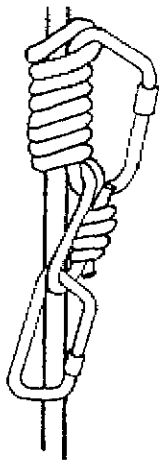


Figure 4:13
Bachmann Knot

KNOT STRENGTHS

4.23 The tying of any knot in a rope will reduce the rated strength of the rope by up to one third (1/3). Care must therefore be exercised in selecting the correct knot for the task at hand (refer to paragraph 3.39).

4.24 BREAKING STRAINS

The following chart shows the **approximate** residual breaking strains of new rope in which rescue knots have been formed:

Thumb (Overhand) Knot	45-55%
Figure of Eight Knot	55-65%
Figure of Eight on the Bight	60-70%
Figure of Eight Loop	60-70%
Alpine Butterfly	65-70%
Clove Hitch	60-70%
Double Fishermans Knot	60-70%
Round Turn and Two Half-Hitches	60-65%
Tape Knot	60-65%

CHAPTER FIVE

HARDWARE

INTRODUCTION

5.01 Rope, tape and other software are critical to the vertical rescue system. Another vital link in the system is a category of equipment known as **hardware.** This category includes a variety of equipment, usually constructed of metal, that performs specific functions in the vertical environment.

> **WARNING NOTE**
>
> **Home-made equipment has no place in vertical rescue**

KARABINERS

5.02 Known also as krabs, 'biners or snaplinks, these are the most common item of hardware in vertical rescue. They are normally a 'D' or modified 'D' shaped metal link, having a spring-loaded opening section (the gate) in one of the long sides.

5.03 GATES

The gate allows ropes and slings to be clipped into the karabiner for attachment purposes. Karabiners are manufactured from either high tensile steel or alloy, and may have either a plain opening gate, or one fitted with a screw locking device which prevents the gate from accidental opening. Consequently, karabiners are referred to as either **snaplinks** or **screwgates.**

5.04 RATED STRENGTH STAMP

Most manufacturers stamp the rated strength of the karabiner into the metal for easy reference.

5.05 CARE IN USE

As these devices are made of quality steel or alloys, care should be taken not to drop them or knock them on hard surfaces. Small stress points can be introduced into the metal which may then cause deterioration of the device. Figure 5:1 shows the basic parts of a screwgate karabiner.

5.06 RESCUE USE

Rescue karabiners should be of screwgate pattern with a minimum rated strength of 2500kg. **Snaplink style karabiners are not recommended for rescue.**

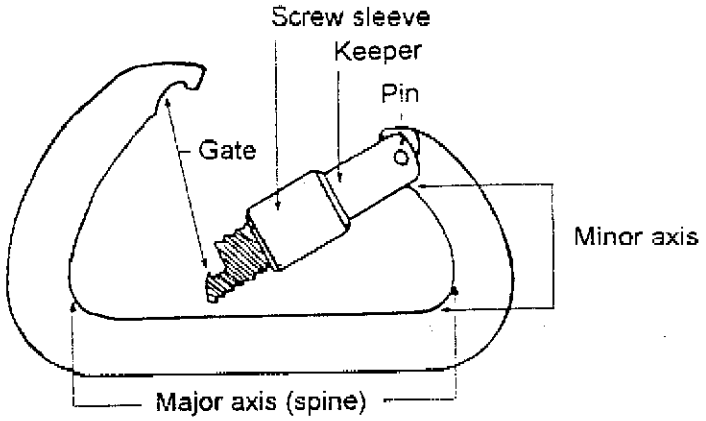


Figure 5:1
The Karabiner

5.07 VARYING STRENGTHS

Because they must carry their equipment with them as they climb, rock climbers have great concern for weight. Consequently, karabiners made primarily for rock climbing tend to be lightweight. Some of these are constructed of hollow aluminium and have rated strengths as low as 1500kg. **They must not be used for rescue.**

5.08 Karabiners for more demanding use, and where more than one persons body weight may be involved, such as in rescue, need higher rated strengths. These karabiners are made from steel or solid alloys.

5.09 SIZES

Another difference relates to size. Again, because climbers place a premium on weight and bulk, their karabiners tend to be relatively small. But in situations where large amounts of material must be connected inside the karabiner, such as in rescue activities, the karabiner will need to be larger. Additionally, larger karabiners are easier to handle in a cold environment.

5.10 GATE OPENINGS

Along with the differences in size and weight, there are also differences in the widths of karabiner gate openings. For some activities, the gate opening will have to be larger than normal. In rescue activities, for example, a karabiner may have to be clipped over a rescue litter rail of around 25mm in diameter. Only a few karabiner designs will open this wide.

5.11 ACCIDENTAL GATE OPENING

The main job of a karabiner is to maintain its link with the other elements of the vertical rescue system. To do this, the karabiner gate must remain securely closed. If it does not, then the connecting elements will come apart and the system will fail.

5.12 There are several ways in which karabiner gates may come open accidentally. Among the most common situations are:

a. where the karabiner is pressed against an edge or surface, forcing the gate open as shown in Figure 5:2; and

b. where a rope or section of tape is pulled across the karabiner gate, forcing it open (Figure 5:3).

5.13 AVOIDING GATE OPENING

Where there is a chance that a karabiner gate may accidentally open, and only snaplink (non-locking) krabs are available, then two karabiners should be used in a **reversed and opposed** attitude as shown in Figure 5:4.

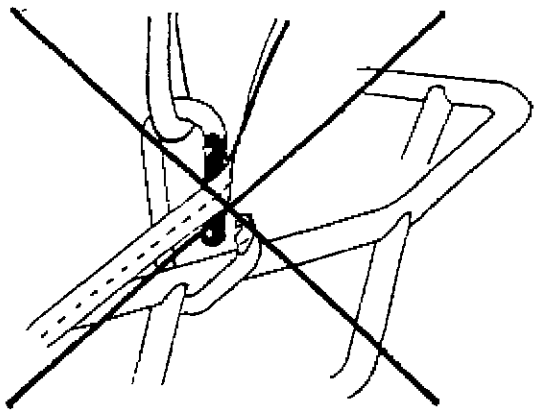


Figure 5:2

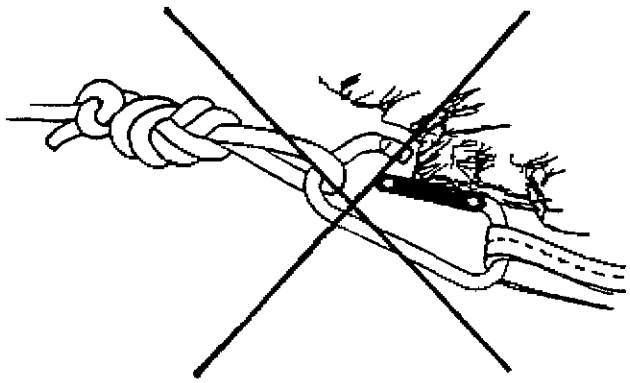


Figure 5:3

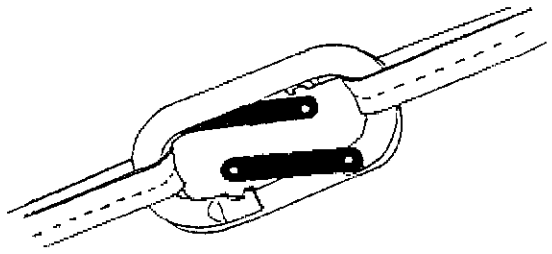


Figure 5:4
Reversed and Opposed Snaplinks

5.14 LOCKING KARABINERS

While two reversed and opposed karabiners are usually very secure, a single locking karabiner is easier and safer. Though specific designs will vary depending on the manufacturer, locking karabiners usually fall into the following categories:

a. A locking sleeve moves on screw threads over the nose of the karabiner to ensure closure.

b. A sleeve turns around a pin on the gate to move up and over the nose.

c. A spring-loaded sleeve makes a quarter turn to unlock from the nose of the karabiner. This style, known as a **Twistlock**, is convenient to use but can come open very easily. It therefore should not be used for rescue purposes.

d. A sleeve moves downwards over the gate hinge to hold the gate locked.

5.15 Of all of the types of locking karabiners, the screwgate style described in 'a' above tends to be the strongest and most secure for rescue purposes.

5.16 ADDITIONAL CONCERNS WITH LOCKING KARABINERS

Any karabiner which regularly becomes unlocked without apparent reason must be withdrawn from service. Karabiners are designed to be locked only to finger tightness. In their concern for safety, and in some anxiety, some people will tend to over-tighten a karabiner gate, and then be unable to unlock it. This most commonly occurs when the gate is tightened while the krab is under load, and unlocking it is readily accomplished by again subjecting it to a load.

WARNING NOTE

All equipment used in vertical rescue is designed to be used in a specific manner of function. This is particularly true of karabiners. Any equipment not used in the designed manner may fail, resulting in injury or death. Karabiner usage is explained in paragraph 5.19

5.17 KARABINER USAGE AND SAFETY

Karabiners are designed to be loaded along the major axis or spine as shown in Figure 5:5. As previously stated, the gate is the weakest point of a karabiner, and any side loading such as is shown in Figure 5:6 places an unnatural force on the karabiner, severely reduces its strength, and may cause it to fail.

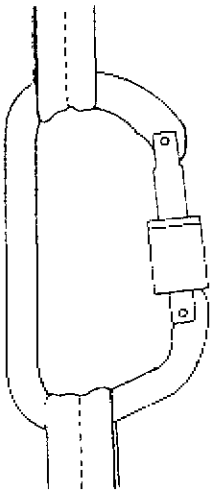


Figure 5:5

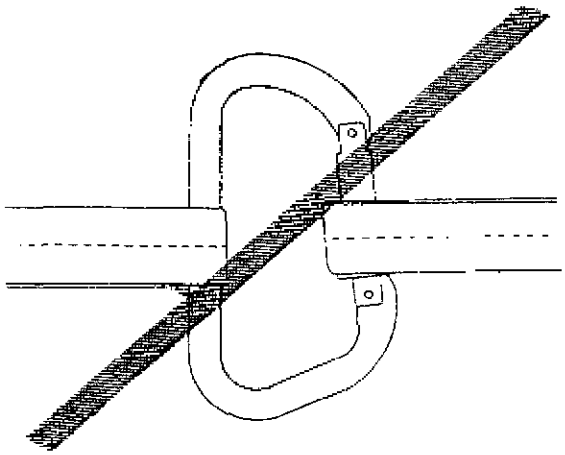


Figure 5:6

5.18 With some karabiner designs, vibration can cause the gate locking sleeve to unscrew. Karabiners should always be used in a manner which will ensure that gravity will keep the sleeve in place. Whatever the type of karabiner in use, it is the rescuers responsibility to monitor it at all times to ensure that the gate remains closed.

WARNING NOTE

Maximum strength is only achieved with the karabiner gate locked. Karabiners must not be used unless the gate is closed and locked

MAILLONS

5.19 GENERAL

Maillons are alternatively known as 'quicklinks' or 'screwlinks', and are used for many rescue tasks. As can be seen from Figure 5:7, they come in a range of sizes and shapes, with rated strains for the steel versions as high as 6000kg. Like karabiners, they are produced in steel or special alloys, and their high strength, spanner lockable sleeve and absence of a weakening gate make them suitable for a range of techniques. The triangular 'delta' maillons are particularly useful where a three-way loading may be imposed, as with a stretcher bridle.

5.20 RESCUE REQUIREMENTS

It is recommended that only those links marked with the name 'Maillon Rapide' and with a rated strength stamped on the device be used for rescue.

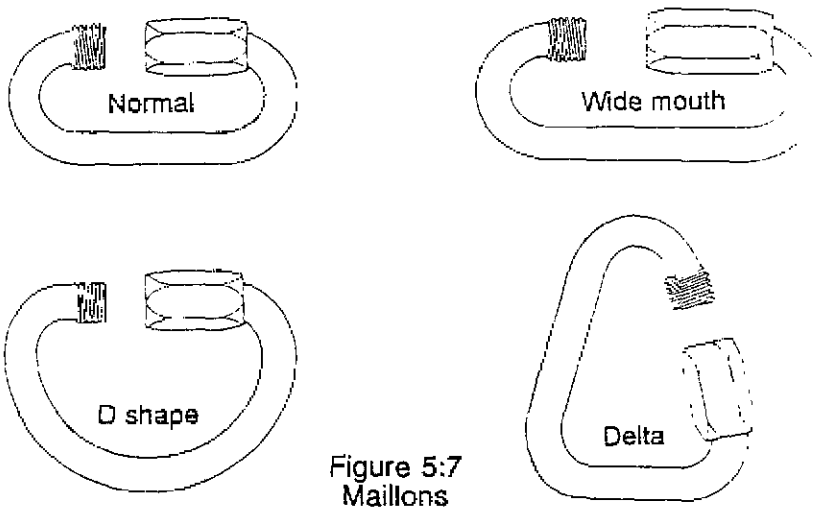


Figure 5:7
Maillons

BELAY PLATES

5.21 The belay plate, often referred to as the Sticht plate, has proven to be a safe form of belay.

> **WARNING NOTE**
>
> **Belay plates are not safe for abseiling as there is insufficient mass of metal to absorb friction heat**

5.22 FITTING

A bight of rope is passed through the slot in the belay plate and clipped into the anchor attachment karabiner as shown in Figure 5:8. A small keeper cord should be attached to the hole in the plate and looped inside the attachment karabiner. During rope movement, this will prevent the plate from sliding out of reach.

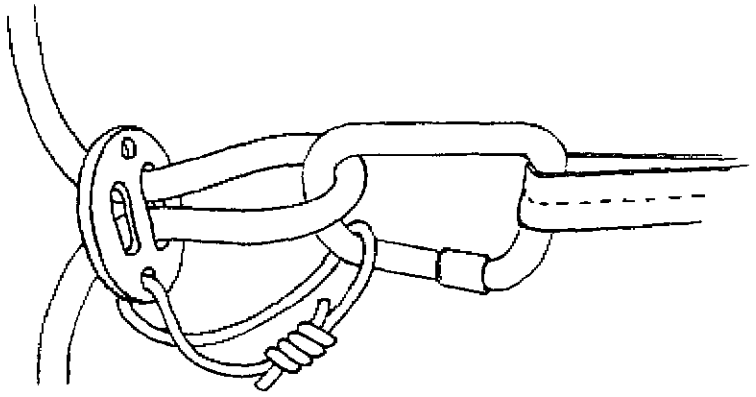


Figure 5:8
Belay Plate

5.23 OPERATION

With minimal effort, the rope will run freely through the belay plate, unless the plate is jammed against the karabiner. A falling load automatically causes the plate to jam against the karabiner.

5.24 One version of belay plate is fitted with a spring to maintain the proper distance between the plate and its karabiner, allowing the rope to pay out more freely. To initiate a belay requires determined effort to snug the spring-loaded plate, tightly against the karabiner.

DESCENDERS

5.25 More detailed notes on the use of descenders is included in Chapter 8 - Descent. This section provides a summary of the equipment used in abseiling and lowering.

5.26 DEFINITION

Descenders are friction devices which are placed on the rope and attached to a rescuer to allow them to descend the rope at a controlled speed. They can also be used to lower people or equipment.

5.27 COMMON TYPES

The descenders most commonly used in rescue are the figure 8 and the in-line variable friction device. These are detailed in paragraphs 5.28 and 5.29 respectively.

5.28 FIGURE 8 DESCENDERS

a. **Description** - These descenders are **one person** abseil devices roughly in the shape of an '8', but with rings of unequal size. (Figure 5:8) The smaller ring, or lower one when in use, is clipped to the harness by means of a screwgate karabiner. The larger ring is the one through which the rope passes to create friction. It should be noted that all figure 8 descenders will twist and cause kinks in the rope.

b. **Variations** - Some figure 8 descenders are manufactured with projecting 'ears' or 'horns' (Figure 5:10) to prevent the rope slipping and jamming as shown in Figure 5:11 due to incorrect rigging and technique.

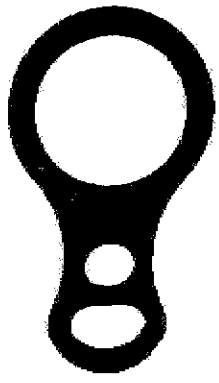


Figure 5:9

Figure 5:10

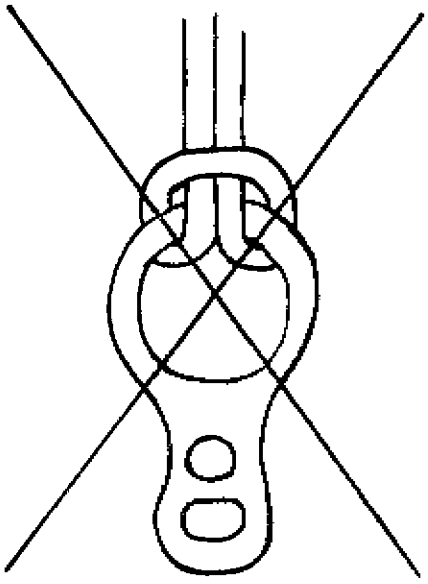


Figure 5:11

5.29 IN-LINE VARIABLE FRICTION DESCENDERS

a. **Applications** - In-line variable friction descenders offer a great deal of control and the ability to vary the amount of friction. They can be used for very long descents, and can sustain loads of more than one person. These devices do not kink the rope, but they are not suitable for belaying.

b. **Whaletail and Goldtail Descenders** - The 'Goldtail 200' and Rescue Whaletail' are large aluminium block descenders which provide good heat dissipation and in-line friction control. Both devices have rated strengths in excess of 2500 kg and both are suitable for abseiling and lowering operations.

c. **Preparation** - The rope is reeved between the pegs or bars in accordance with the manufacturers specifications, and the sliding gates are locked for security. The devices are secured to the harness or anchor by means of a screwgate karabiner. The amount of friction is varied by increasing or decreasing the number of bars/pegs around which the rope is reeved.

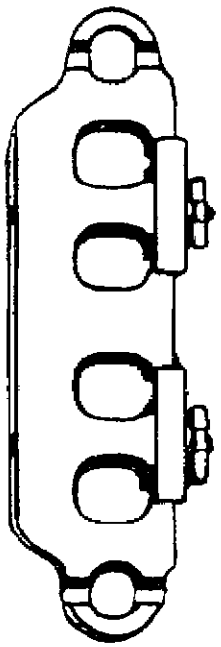


Figure 5:12
Goldtail 200

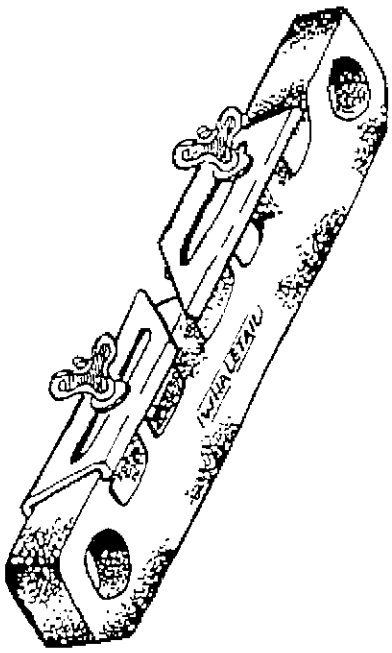


Figure 5:13
Rescue Whaletail

5.30 RAPPEL RACK

The common rappel rack consists of two primary elements:

a. An inverted 'U' shaped frame, one leg of which is longer than the other. The end of the longer leg has an eye through which a karabiner can be connected.

b. A series of bars, each with a hole drilled at one end so that they can slide freely on the short side of the frame. On their other ends, the bars are notched so that the end of the bar will clip into the long side of the frame. The rope is reeved through the bars, and when under tension, will hold the bars in place on the frame (Figure 5:14). In the most common configuration, the rack is arranged with a 25mm diameter grooved 'top bar' (at the top) to keep the rope in the middle of the bars as it runs through the rack. Usually, five aluminium 19mm bars fill out the remainder of the rack.

5.31 RESCUE RAPPEL RACKS

Some rappel racks have rated strengths of 700kg or less. 'Rescue' racks can be obtained with much higher rated strengths, and with the ability to accept larger diameter ropes.

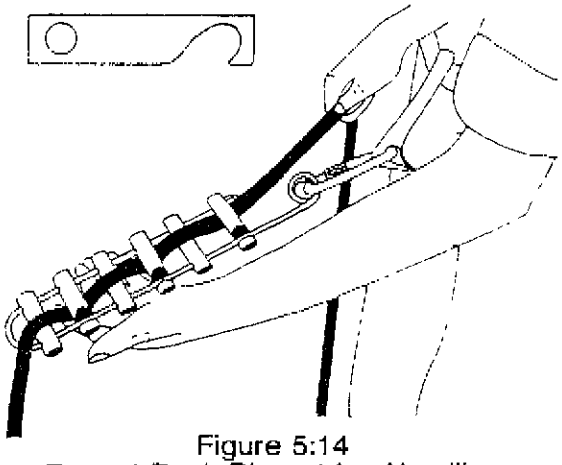


Figure 5:14
Rappel Rack Rigged for Abseiling

ASCENDERS

5.32 The traditional method of rope ascent using a pair of cord slings and Prusik knots (paragraph 4.21) works well, and every rescuer should be able to ascend in this way. For a rescue operation mechanical ascenders are recommended as they can also be used for a wide range of rope attachment purposes.

5.33 MECHANICAL

Mechanical ascenders work by means of a cam which jams the rope so that the ascender will slide up the rope but not down. Most rely on a spring to keep the cam in contact with the rope, and small teeth on the cam to give positive grip. Once the cam 'bites', it will only hold more strongly as the load increases, so a strong spring is not necessary.

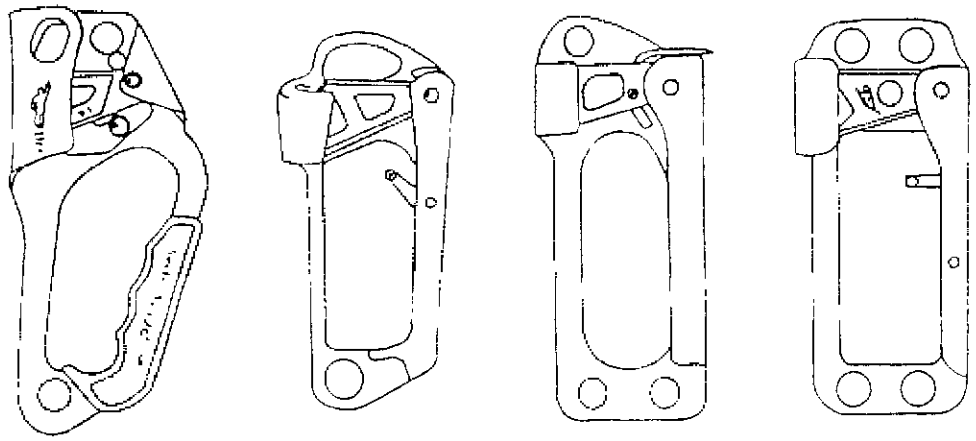
5.34 OTHER TYPES

Other ascenders use the load to activate the cam via a lever. This gives the advantage that teeth are of minor importance so the device has a good grip even on wet or muddy ropes. A second advantage is that non-spring ascenders have very little rope drag. They move up the rope more easily and last longer due to reduced wear.

5.35 SELECTION CRITERIA

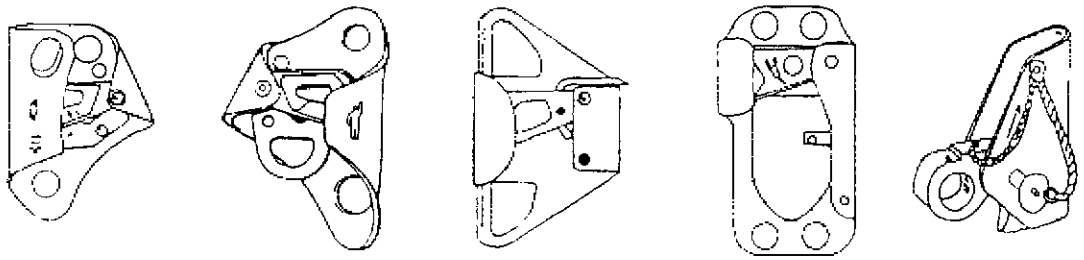
The choice of ascenders should be made in terms of suitability for an ascent system, ease of use, simple loading of the rope, cam open setting and overall weight.

5.36 Many ascenders are made with an integral handle in left and right hand versions to allow for comfort of use. Short, compact ascenders can be used for virtually any application. Some are specially designed for use as chest mounted ascenders. Others are less specific and can be mounted anywhere in an ascent rig.



Petzl "Expedition" *Jumar* *CMI "5004"* *SRT "Caver"*

Figure 5:15
Some Common Handled Ascenders



Petzl "Basic" *Petzl "Croll"* *CMI "Short"* *SRT "Climber"* *Gibbs*

Figure 5:16
Some Common Non-Handled Ascenders

WARNING NOTE

Ascenders must never be subjected to any form of shock loading

5.37 WEAR AND WEAKENING

Spring ascenders begin to slip when their teeth become excessively worn or their springs weaken. This usually becomes apparent when ascending iced or muddy ropes, where the already blunt teeth become clogged.

5.38 CARE AND MAINTENANCE

It is possible to purchase replacement cams and springs for most ascenders. The frame of less durable ascenders may also be sufficiently worn that it is better to withdraw the ascender from service. When the frame wears out first, the leading or trailing edge may become razor sharp as the rope wears it away. Ascenders require very little maintenance apart from the obvious need to clean them occasionally.

5.39 STRENGTH

The connecting point between the ascender and the rope is the weakest point of the system. Under static loads, most ascenders will cut into the rope sheath and slide before they will fail structurally. The sliding motion normally tends to be arrested by the bunching of the rope and sheath below the cut.

WARNING NOTE

Most ascenders will start to damage the rope at between 450 and 600kg, and the speed of onset of damage and the final effect will tend to depend on the design of the ascender cam

PULLEYS

5.40 Pulleys are designed primarily to reduce rope friction. They can be used in mechanical advantage systems, for changing directions on a working rope, or for horizontal/diagonal travel on a rope.

5.41 CHARACTERISTICS OF A VERTICAL RESCUE PULLEY

Rescue pulleys should have the following characteristics:

a. The **sheave** should have a diameter at least four times the diameter of the rope.

b. The **cheek plates** should be moveable so that the pulley can be placed on the rope at any point without having to feed the rope through. They should also extend beyond the edge of the sheave to protect the rope from abrasion.

c. The **axle** should have rounded ends which will not snag rope, other gear, or rock.

d. The **bearings** should be of such construction as to allow the sheave to turn freely when loaded.

e. A **rated strength** in excess of 1500kg.

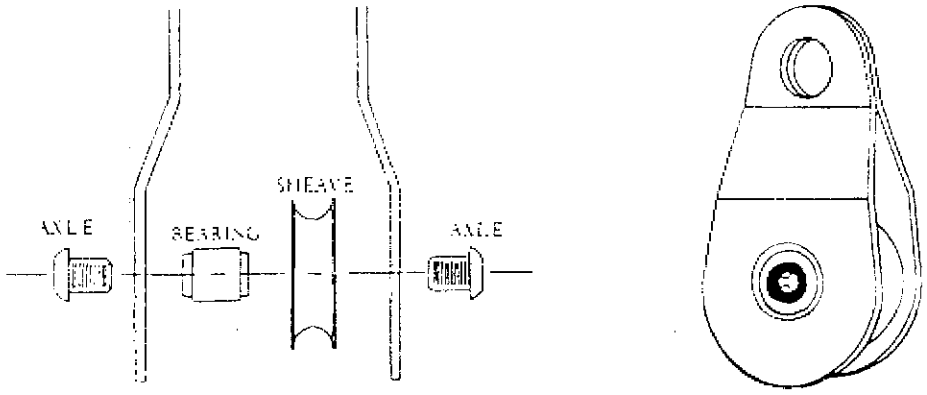


Figure 5:17
Parts of a Rescue Pulley

5.42 SPECIALISED PULLEYS

There are a number of pulleys specially designed for vertical tasks. Among these is the knot passing pulley shown in Figure 5:18. The wide sheaves on these pulleys are designed so that knots such as the Double Fishermans, used to bend rope lengths together, will easily pass over them.

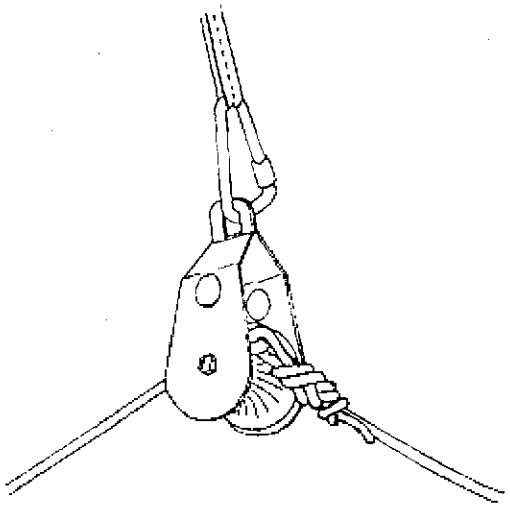


Figure 5:18
Knot Passing Pulley

5.43 CARE AND MAINTENANCE

Pulleys must be carefully inspected prior to use to ensure that they are in good condition and will not damage the rope.

EDGE ROLLERS

5.44 BENEFITS

In a vertical operation, the contact which the rope makes with the cliff or building edge will be a critical factor. Whilst edge rollers are quite expensive, they are far more efficient than an edge mat or rope protector, and are a worthwhile investment. They will act to protect the rope passing over an edge, and will greatly reduce friction during a hauling operation.

5.45 COMMON DESIGNS

There are various types of rollers produced to suit different environments, and special problem areas can often be overcome by linking two or more edge rollers together. Edge rollers are available in the two main designs (shown in Figure 5:19) as follows:

a. **Single Unit Rollers** - These consist of a single sheave set into a flat based frame. They are commonly used linked together as illustrated, and when anchored fore and aft, work well on all surfaces and edges.

b. **Roof Rollers** - These normally consist of two sheaves set into a frame which will lock on the edge of a parapet wall or other structures with a 90 degree angle.

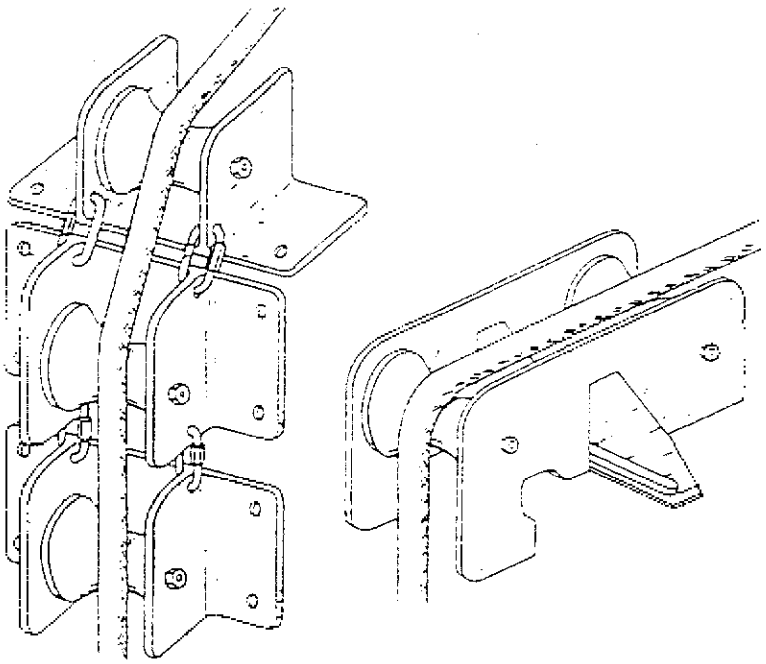


Figure 5:19
Styles of Edge Roller

STRETCHERS

5.46 SPECIAL REQUIREMENTS

A seriously injured victim in the vertical environment requires the comfort, protection and security of a rescue stretcher. Improvised stretchers or stretchers designed for 'ground level' operations simply have no place in vertical rescue.

5.47 COMMON TYPES

The patients injuries and the environment will dictate the type of stretcher to be used. Some examples of common stretcher types are shown in Figure 5:20.

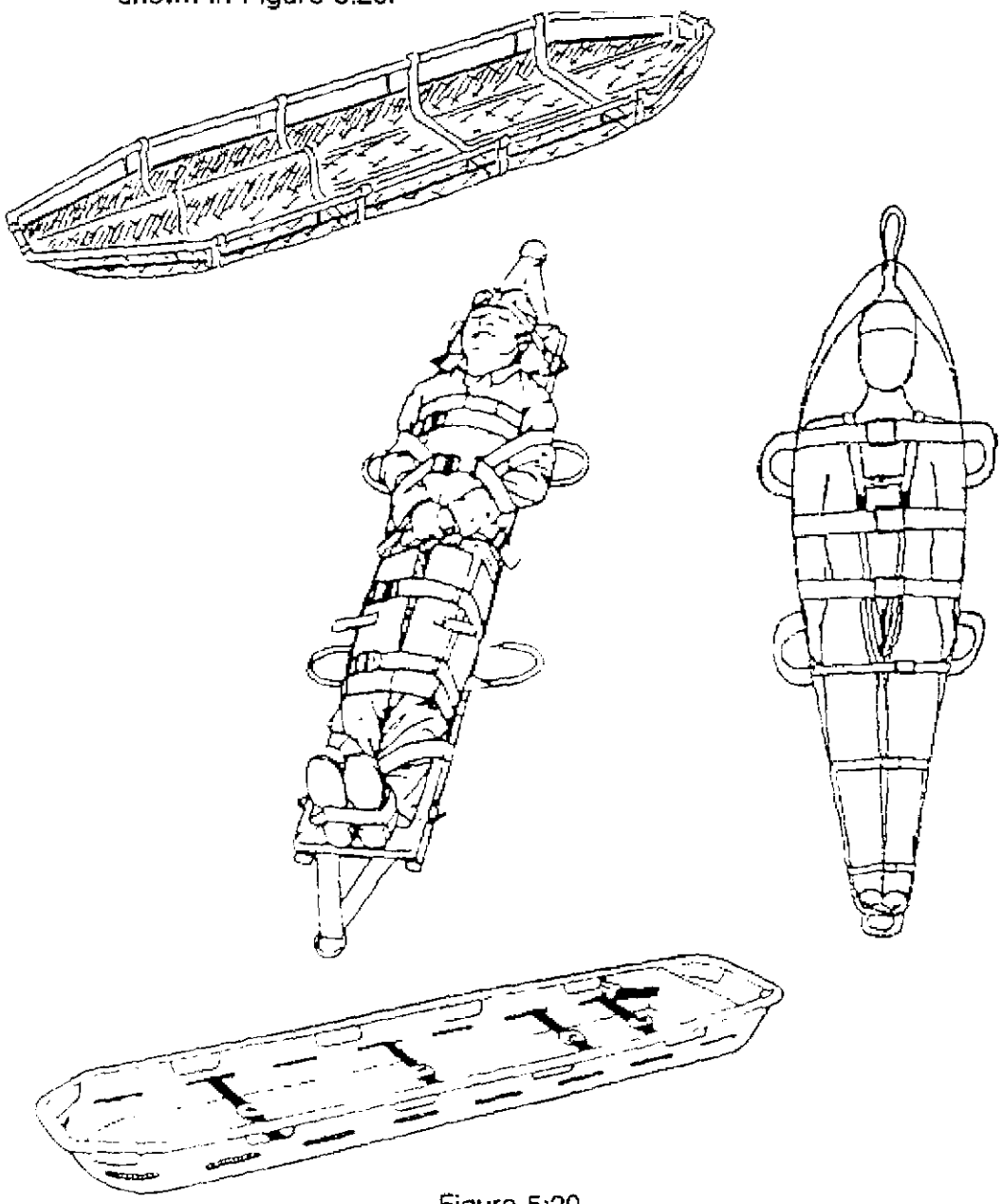


Figure 5:20
Some Typical Rescue Stretchers

LIGHTING

5.48 PORTABLE LIGHTS

In addition to the rescuers helmet light, a range of portable lighting units can be used for night operations.

5.49 FLOODLIGHTS AND SPOTLIGHTS

Where floodlights and spotlights are used, care must be taken to avoid blinding personnel, and lights should be so set up as to avoid forming areas of deep shadow.

5.50 STROBE AND CHEMICAL LIGHTS

Personal waterproof strobe lights and cold chemical light tubes are available. These can be used to show the location of personnel and equipment. The use of strobe lights must be carefully monitored however, as they can cause temporary blindness to personnel.

5.51 Each form of operational lighting has a number of disadvantages. It is recommended that a range of options be tried, and that all rescuers should be trained to operate in night exercises.

CHAPTER SIX

ANCHORS

INTRODUCTION

6.01 Any ascent, descent or rescue system is reliant upon its anchors. A common cause of accidents in the vertical environment is anchor failure, with most failures as a direct result of human error.

6.02 GENERAL PRINCIPLES

The following principles apply to anchorage for vertical rescue operations:

a. When establishing anchor systems, points capable of sustaining multi-directional loads should be selected, and the risk of a severe shock loading must always be considered.

b. Rescue systems should have a minimum of two independent attachment points, although these can be made to a single strong anchor. Therefore, wherever possible, a belay rope should be anchored independently to a rescue rope.

c. Anchor systems should be kept as simple as possible, with a minimum number of 'links' in the chain.

d. Software must be protected against sharp edges and wear points.

e. Anchor points, slings and attachments must be checked regularly throughout the operation.

f. Anchors systems should be set up so that the rescue rope crosses the cliff or structure edge as close as possible to a 90 degree angle.

g. Where multiple anchor points are used, the angle at which the anchor slings meet **must never be more than 120 degrees and should preferably be less than 90 degrees.**

TYPES OF ANCHORS

6.03 In vertical rescue there are two classes of anchors. They are described in paragraphs 6.04 and 6.05 below:

6.04 NATURAL OR EXISTING

These anchors are those found on the rescue site. They include:

a. trees and large rocks;

b. building structures; and

c. girders, columns, poles etc.

6.05 The best available point should be selected with due regard to strength, stability and direction of load. Natural anchor points should be used in preference to assembled or improvised points.

6.06 ASSEMBLED OR IMPROVISED

a. **Picket Anchors and Buried Holdfasts** - These are described in the *Australian Emergency Manual - Disaster Rescue*. The use of these types of anchor should never be overlooked in vertical operations, as it may well be that they are the simplest solution to an anchorage problem.

b. **Vehicles** - In many situations, the simplest and quickest anchor system will involve the placement of a vehicle in the most advantageous position. When vehicles are used, the following points should be considered:

(1) The vehicle should be placed at right angles to the direction of load wherever possible.

(2) The vehicle must not be required to be moved until the rescue is completed.

(3) The vehicle must be immovable. The parking brake should be set, and the vehicle should be in a low gear. Preferably, the wheels should be chocked and the keys removed and handed to the team leader.

(4) The attachment should be made to the strongest part of the vehicle that is accessible. Chassis members and towing frames or hooks are all suitable.

(5) Software must be kept clear of areas of contamination, abrasion and heat.

c. **Pitons, Bolts, Hexcentrics and Friends** - These and other personal climbing protection may be used in the absence of other anchors (Figure 6:1). The safe placement of climbing protection requires extensive training and experience which is beyond the scope of this manual. **Appropriate training must be sought from climbing/caving instructors.**

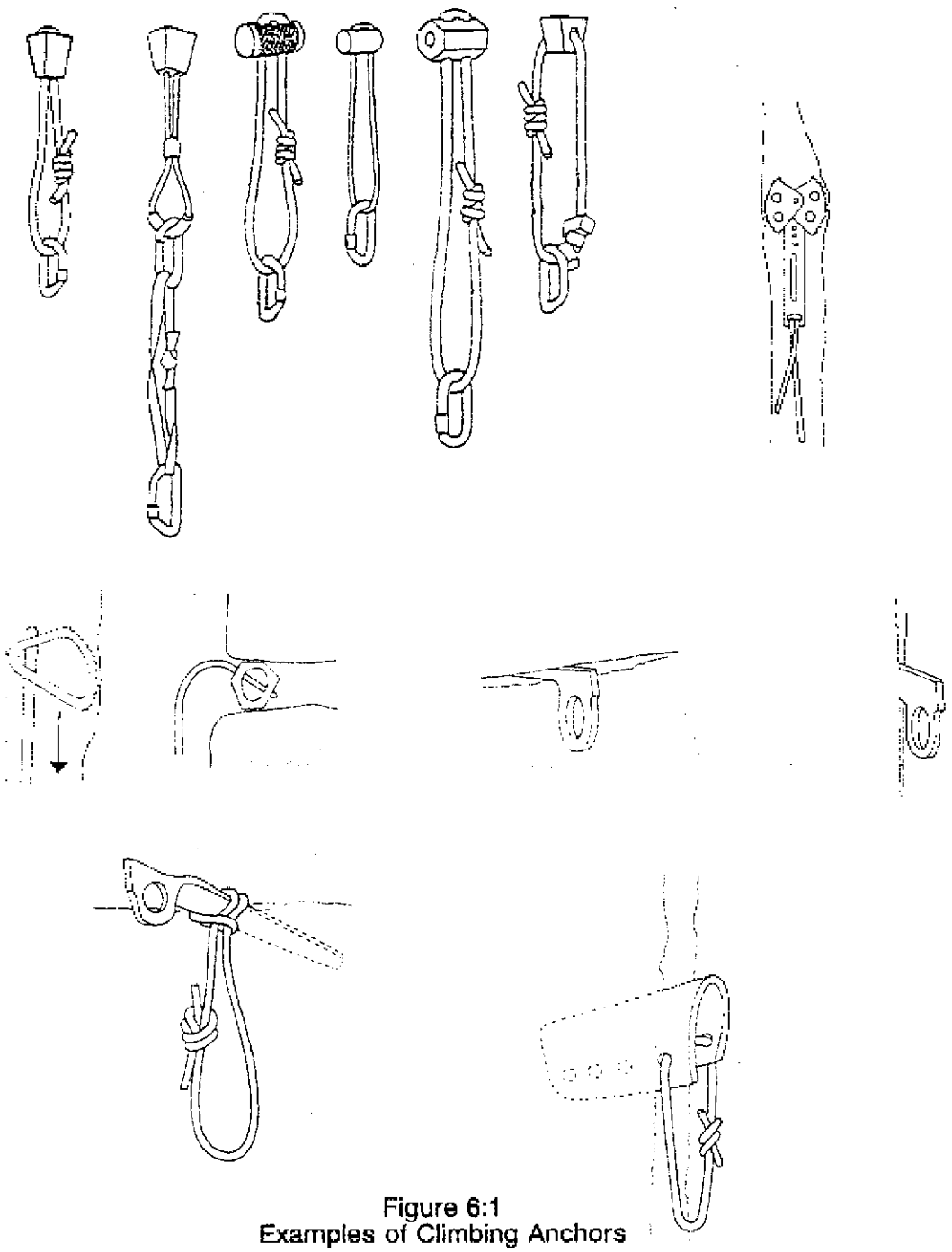


Figure 6:1
Examples of Climbing Anchors

ATTACHMENT TO ANCHORS

6.07 ADVANTAGES OF SLINGS

Slings or independent short ropes should be used for attachment to anchors. This method of attachment provides the advantages of:

a. maximum use of available rope lengths;

b. reduction of the risk of damage to the main rope;

c. speed of attachment; and

d. ease of replacement.

6.08 USE OF TWO SLINGS

Where a single anchor point is used, it is recommended that attachment should be by means of **two** tape slings connected to the same attachment karabiner. Each point of a multiple anchor system requires only one sling. The use of two slings is recommended to provide additional protection against anchor failure due to abrasion/cutting of the tape.

6.09 METHODS OF ATTACHMENT

Only **screwgate karabiners** or **malllons** should be used for system attachment to anchor points. Some examples of the use of slings for attachment to anchor points are shown in Figure 6:2.

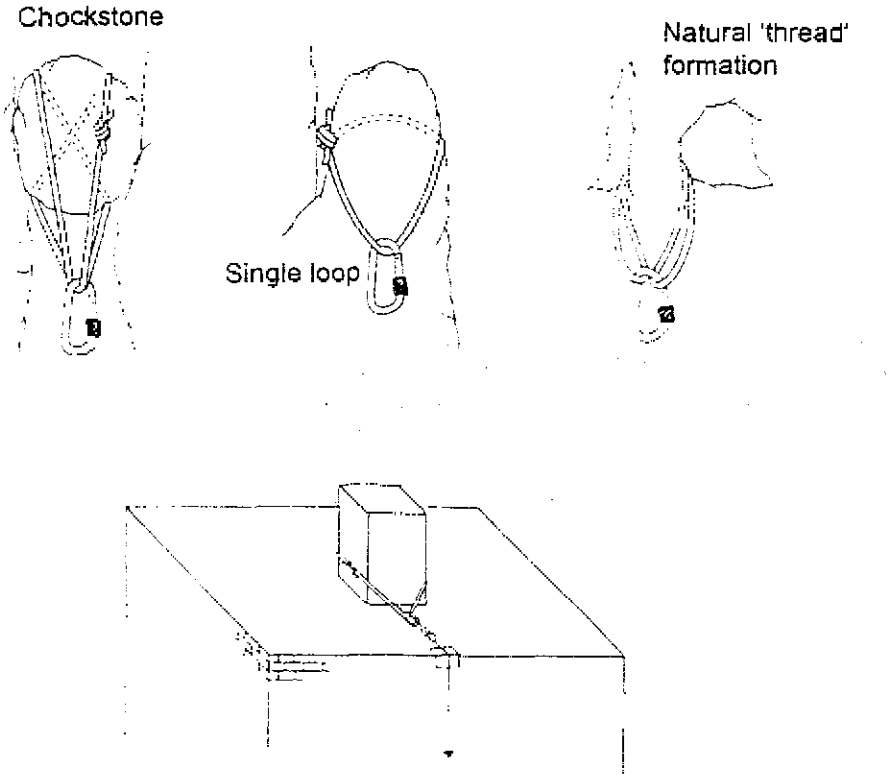


Figure 6:2
Examples - Attachment to Anchor Points

6.10 Wherever possible, tape slings should be taken completely around an anchor point, and the karabiner clipped through both sling ends, rather than impose a weakening link by the use of a Larks Head. (Refer Figure 6:2)

WARNING NOTE

Anchor karabiners should be rotated or placed so that their gates are free of contact with any object. (Refer figure 6:3)

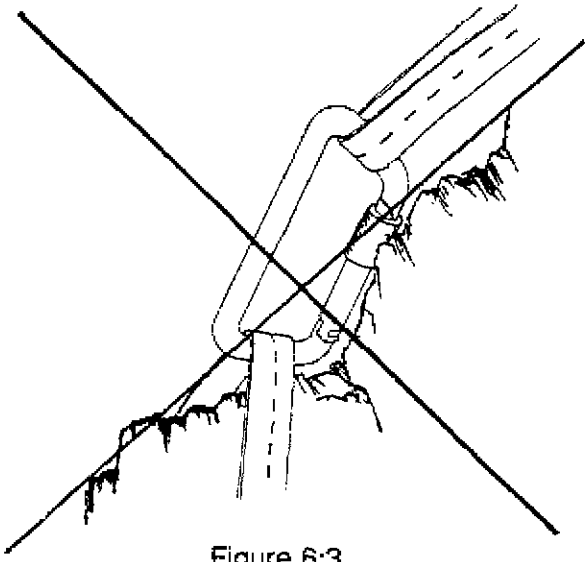


Figure 6:3
Avoid Dangerous Contact.

6.11 SLING ANGLES AND LOADNINGS

When the load must be shared between **two** anchor points, the load is not necessarily shared equally. Too great an angle between the two legs will only achieve an overload of both anchors.

6.12 The angle between the two legs should preferably be kept below 90 degrees, and **under no circumstances should it exceed 120 degrees** or excessive loadings will be placed on the two legs of the system (Refer Figure 6:4).

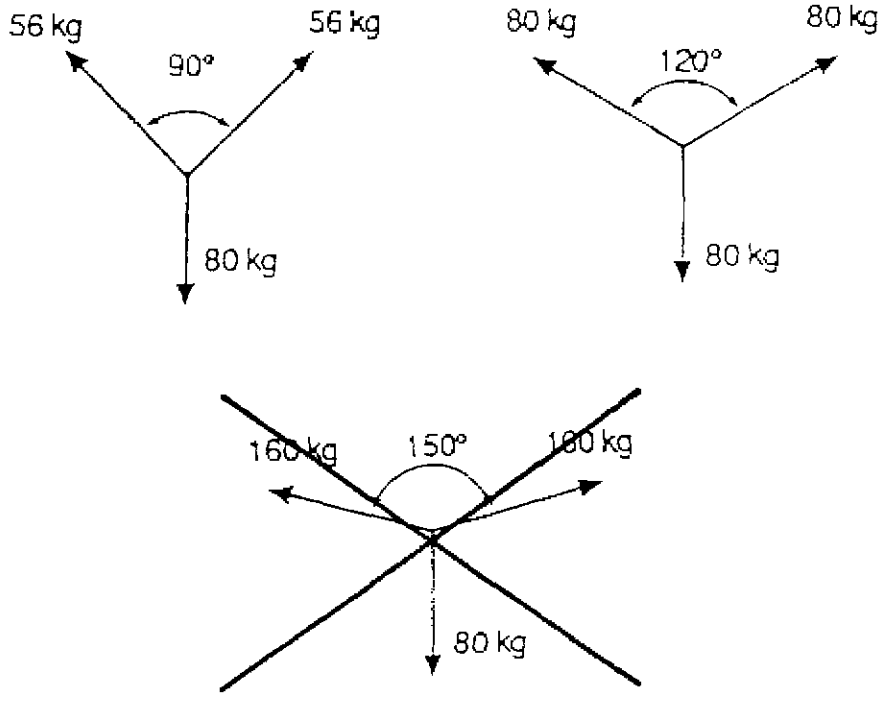


Figure 6:4
Sling Angles and Loadings

6.13 The sling leg angles are critical, and the legs must be balanced and adjusted under a test load (where safe and practical) of two rescuers pulling along the operational line from the central attachment point until the load is distributed evenly between the two anchor points. **The operational line must bisect the angle formed by the two sling legs.** Where one (or both) of the anchor points is remote from the drop, the linking slings must be made long enough to bring the central attachment point close to the work area.

6.14 LOAD-SHARING SYSTEMS

In some areas, suitable anchors are hard to find, and it may be necessary to use a number of lesser points to construct a system capable of sustaining the load.

6.15 Special anchorage options such as self-equalising and in-line load sharing systems can be set up to cope with these problems, but it must be understood that their operational requirement tends to be occasional at best. These systems are beyond the scope of this manual, and specialist training should be sought in their establishment, advantages and disadvantages.

6.16 CONCLUSION

The selection of sound and appropriate anchor points is an essential rescue skill. This chapter must be used in conjunction with the relevant sections of the *Australian Emergency Manual - Disaster Rescue* in order to provide the required level of rescuer expertise.

CHAPTER SEVEN

BELAYING

INTRODUCTION

7.01 Belaying is the controlling of a safety rope attached to personnel or equipment as a backup in case of primary system failure.

7.02 **FRICTION DEVICES**

Whilst most friction devices can be used for belaying, it is recommended that the belay plate or an Italian Friction Hitch (Munter Hitch) be used for rescue.

7.03 **USE OF STANDARD CALLS**

The standard calls described in this manual must be used at all times in belaying operations to reduce confusion.

7.04 **TERMINOLOGY**

Two further terms are used in belaying to refer to the safety rope:

a. **Active Rope** - This is the run of rope between the working rescuer and the belayer, controlled by the **active hand.**

b. **Inactive Rope** - This is the spare rope already taken in or ready to pay out, and controlled by the **inactive hand.**

WARNING NOTE

The belay systems described in this chapter are for protecting a single rescuer. They should be used with care as a backup for hauling systems as they may not be able to sustain the high loadings involved

ESTABLISHING A BELAY

7.05 **BASIC PRINCIPLES**

A belay should be established according to the following principles:

a. It must be anchored independently of the primary system;

b. The belayer must be anchored independently of the belay and not tied into the belay system;

c. It should be established with the belayer in close proximity to, but clear of, the primary system; and

d. It should be set up close to the operational line of the primary system to avoid rope angle changes.

WARNING NOTE

All ropes used in a rescue system must have similar characteristics to avoid unequal rope stretch and load reactions

7.06 ROPE MANAGEMENT

The belay **must** be managed so that there is a **minimum of slack, whilst not actually supporting any part of the load.** The belayer must remain alert throughout the operation.

7.07 BELAY PLATE

The belay plate is rigged as shown in Figure 7:1, with the rope doubled through the plate slot. Both belay plate and cord tether are then secured to the anchor point by means of a screwgate karabiner. The cord tether is essential to prevent the plate from wandering down the rope in normal use.

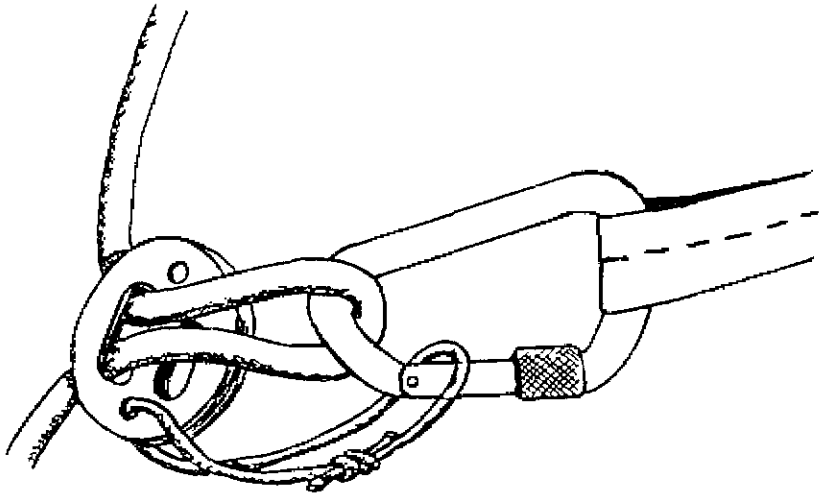


Figure 7:1
The Belay Plate

7.08 BELAY PLATE OPERATION

The operating procedure for the belay plate is simple. The belayer holds one run of rope out of the plate in each hand, controlling rope movement by a shuffling action of the hands.

7.09 SHOCK LOAD CONTROL

It is vital that the belayer maintains a firm control of the inactive rope **at all times** in order to control any shock loading. In the event of a sudden shock load, the belayer holds the inactive rope firmly and pulls this part of rope back towards the anchor point (Figure 7:2).

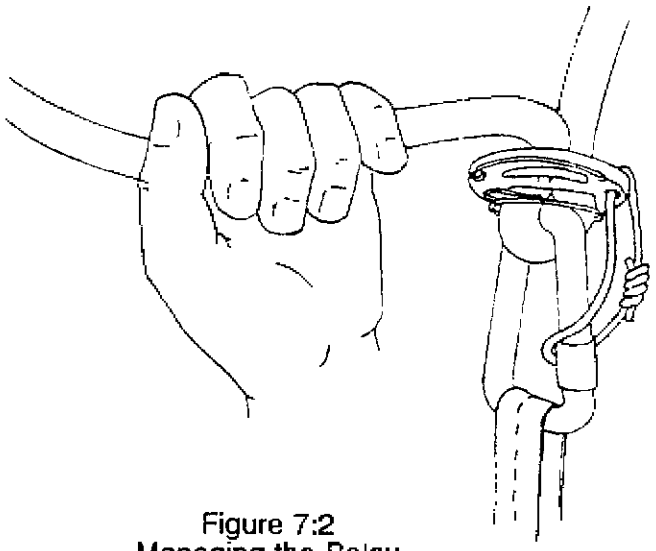


Figure 7:2
Managing the Belay

7.10 LOCKING THE PLATE

The belay plate can be locked off securely by threading a bight of the inactive rope through the anchoring karabiner and forming this bight around the active rope with two Half-Hitches.

7.11 ITALIAN FRICTION HITCH

The Italian Friction Hitch or Munter Hitch is formed with the belay rope on an anchored karabiner as shown in Figure 7:3. The Hitch is controlled in much the same manner as a belay plate, with the shuffling action of the active and inactive hands around the Hitch, and with a firm control of the inactive run of rope maintained at all times.

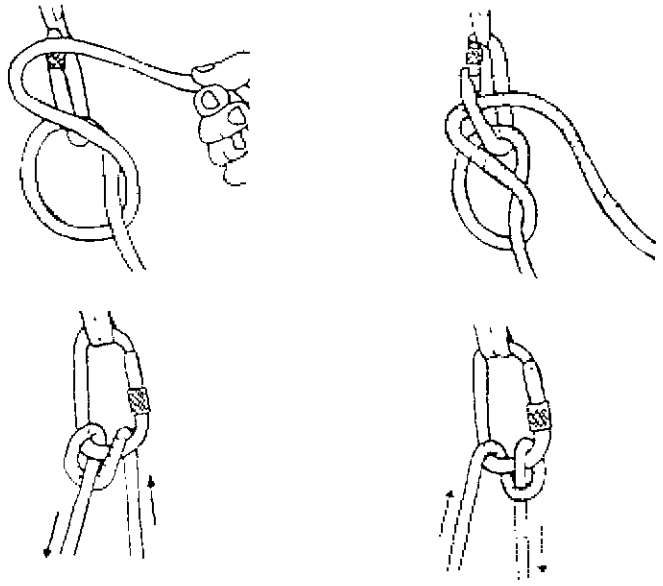


Figure 7:3
The Italian Friction Hitch (Munter Hitch)

7.12 LOCKING THE HITCH

The hitch can be tied off as shown in Figure 7:4, by the forming of two Half-Hitches around the active rope with a bight of inactive rope.

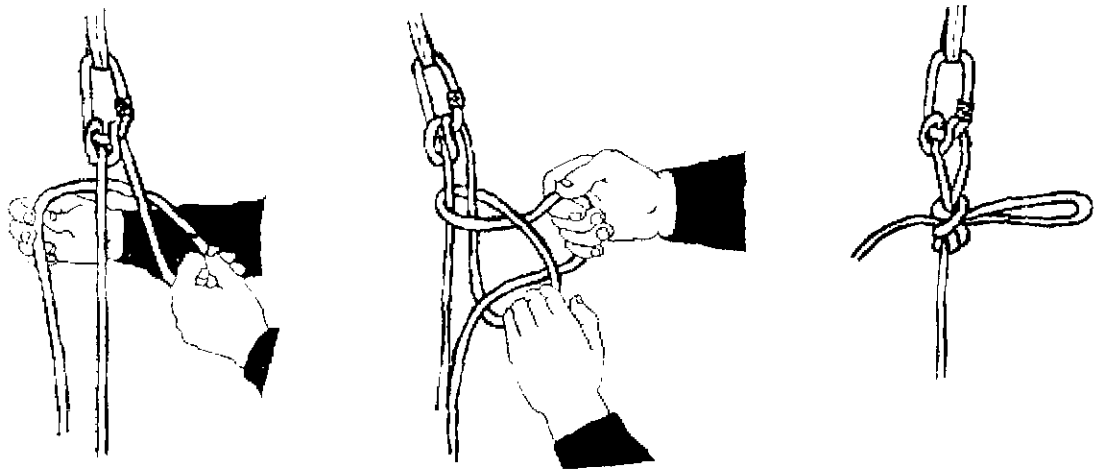


Figure 7:4
Locking the Italian Friction Hitch

BELAY CALLS

7.13 The calls used for belaying may vary between organisations however,

Call	Called by	Meaning
ON ROPE	On rope person	Ready to move
READY	Belayer	Acknowledged
TAKE IN	On rope person	Recover slack rope from the system
THATS ME	On rope person	All slack rope is taken in
SLACK	On rope person	Provide some slack rope
MOVE WHEN READY	Belayer	Belay operational, move when ready
MOVING	On rope person	Starting to move now
HOLD	On rope person	Lock belay and support my weight
CLEAR	On rope person	Belay no longer required
OFF BELAY	Belayer	Belay no longer operational

7.14 **PROCEDURE**

The above calls must be given clearly and concisely and must not be run together as this may cause confusion. **Each call should be responded to.** The response 'OK' is recommended for simplicity.

WARNING NOTE

Due to the forces imposed upon the belayer as the result of a shock load, body belays should never be used for vertical rescue activities

SAFETY

7.15 BASIC RULES

The following points should be observed at all times:

a. Belay anchors must be carefully selected and the belay set up clear of any danger zones.

b. The belayer must wear gloves.

c. Standard calls must be used.

d. With any belay, it can be anticipated that some rope will run out of the system under a high load. This provides even greater safety as the belay becomes dynamic. This rope must never be permitted to run out over attachment of other ropes of slings, or friction melting will occur.

e. The belayer must pay total attention to the task, maintaining 'hands-on' control of the rope at all times.

f. The belayer must be able to 'lock-off' a belay in an emergency.

g. As a belay may involve a moving rope on a rock face, the face person must be prepared for loose stones and other material being dislodged by the rope.

h. All belay attachments must be made with screwgate karabiners.

i. The belay must be checked by the Safety Officer prior to use.

CONCLUSION

7.16 THE IMPORTANCE OF PRACTICE

Belaying is an essential vertical skill, and while this chapter has described the principles and procedures, there can be no substitute for careful and regular practice.

7.17 SUPERVISION

It is most strongly recommended that rescuers practice these skills under very close supervision before being responsible for a belay.

CHAPTER EIGHT

DESCENT

INTRODUCTION

8.01 ABSEILING

This is the method of descending a fixed rope in a **safe and controlled** manner using a friction device.

8.02 Abseiling is only a means to an end, a special technique to be used in specific circumstances. Rapid descents and sport abseiling techniques have no place in vertical rescue.

> **WARNING NOTE**
>
> **Abseiling in a rescue environment must always be carried out using an abseil friction device**

SAFETY NOTES

8.03 Personnel must be safety-checked prior to any descent.

8.04 LOWERING

For safety reasons it is desirable that the first person is lowered down a face. This ensures that the rope reaches its destination without obstructions or knots, and enables a safety person to be available to operate a bottom brake for any further descents. (Refer to paragraph 8.11)

8.05 REVERSING PROCEDURE

With any descent system, rescuers must practise reversing the procedure so as to be able to ascend a rope. This is a simple action, but it must be practised for safety as there may be situations where it will be required.

8.06 ROPE PROTECTION

Descent ropes running over sharp edges must be protected from damage by the use of edge protection.

> **WARNING NOTE**
>
> **Abseil friction devices generate a considerable amount of heat in use. This is detrimental to synthetic fibre rope, and descents must be made in a slow and safe manner**

DESCENT OPERATIONS

8.07 PROCEDURE

The following procedure should be adopted before descending:

a. Check anchor system and rope deployment.

b. Rig friction device correctly and attach to the harness.

c. Ensure that the rope passes on the side of the body with the brake hand.

d. Check braking procedure.

e. Safety Officer or dispatcher to conduct safety check.

8.08 CONTROL AND BALANCE

Downward movement must be in a controlled and balanced manner with the optimum support of the harness. Absorb shocks by bending the knees. It must be possible to stop the descent **easily** at any time and to lock-off quickly and efficiently. **Do not descend at speed and avoid excessive shock loading caused by bouncing.**

8.09 COMPLETION

On completion of the descent, communicate your arrival and safe status. Where appropriate, disconnect from the rope and move to a safe position.

8.10 BOTTOM BRAKE OPERATOR

During training and operations a person should be positioned at the bottom of the descent to arrest the fall of an abseiler by applying tension to the rope. If required, this person may lower the abseiler in a controlled manner by reducing the tension on the rope.

DESCENT DEVICES

8.11 Figures 8:1 to 8:8 show the descent devices in most common rescue usage, along with their applications.

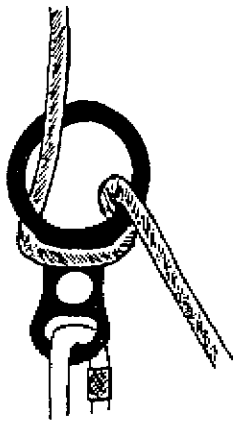


Figure 8:1
Figure 8 Descender

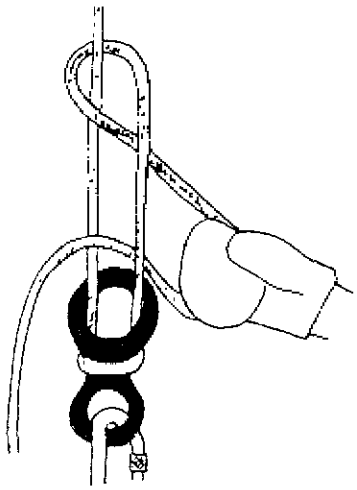


Figure 8:2
Figure 8 Lock-off

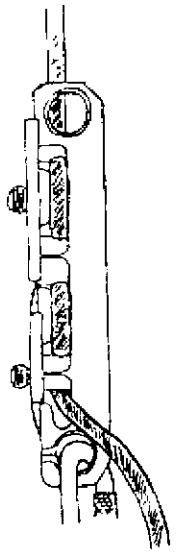


Figure 8:3
Rescue Whaletail

Figure 8:4
Locked off Whaletail

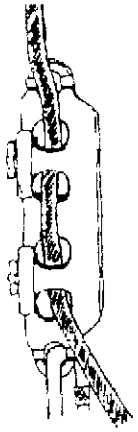


Figure 8:5
Goldtail 200

Figure 8:6
Goldtail locked off

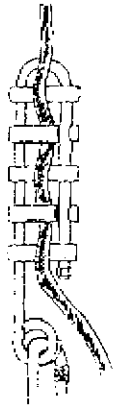


Figure 8:7
Rappel Rack Rappel

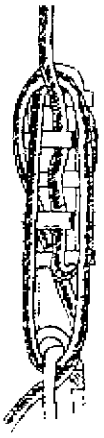


Figure 8:8
Rack Locked Off

ALTERNATIVE DESCENT METHOD

8.12 When no friction device is available for whatever reason, the Italian Friction Hitch (Munter Hitch) can be used, formed around the harness attachment karabiner.

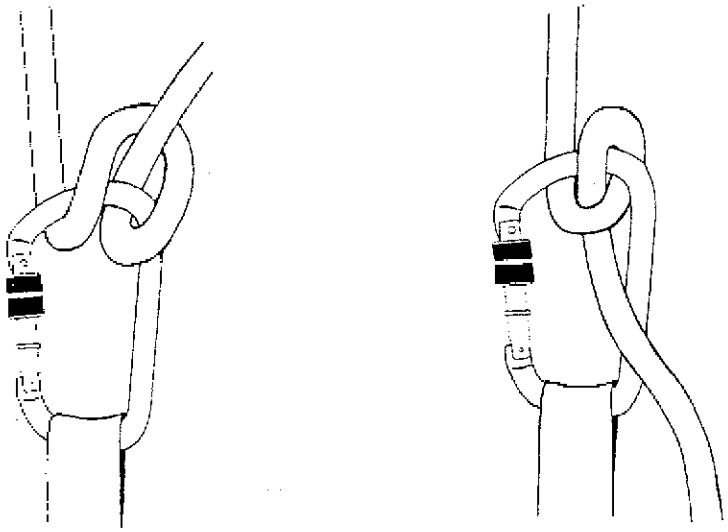


Figure 8:9
Italian Friction Hitch for Abseiling

WARNING NOTE

This method does stress kernmantel rope to a certain degree and causes exaggerated kinking of the running end

CHANGING FROM DESCENT TO ASCENT

8.13 PROCEDURE

The procedure for changing from descent to ascent is as follows:

a. Stop the descent and securely lock-off the descender.

b. Connect an ascender or Prusik Loop from the harness to the rope above the descender.

c. Check that the ascender is secure, then remove the lock from the descender and let out rope until full body weight is supported by the ascender.

d. Remove the descender from the rope and secure it to the harness gear loops.

e. Rig the second ascender or Prusik Loop (the foot rig) to the rope.

f. Safety check all attachments prior to ascending the rope.

GENERAL SAFETY

8.14 All personnel must carry a means of self-rescue such as Prusik Loops or ascenders for ascent of the abseil rope.

8.15 Attention must be paid to ensure beginners and trainees keep their full weight on the rope while descending and **do not** feel their way down by 'toeing' against the structure or cliff face.

8.16 A descent directly **above** a casualty **must be avoided.**

8.17 **STANDARD ABSEILING CALLS**

The following calls are standard for abseiling:

Call	Called By	Meaning
ON ROPE	descender	ready to move
READY	belayer	acknowledged
ABSEILING	descender	moving now
STOP	anyone	a problem arising
BELOW	anyone	something falling
CLEAR	descender	disconnected from rope

8.18 **RESPONSE**

Each call **should** be responded to. The call **'OK' is recommended for simplicity.**

CHAPTER NINE

ASCENT

INTRODUCTION

9.01 It is essential that the vertical rescuer is able to change from descent to ascent or manoeuvre on a rope tether during a stretcher rescue. This requirement calls for familiarity and practice with rope ascent techniques.

9.02 ASCENDERS

Ascending a fixed rope requires the use of special friction knots such as the Prusik, or mechanical devices known as ascenders. With these aids, the rescuer can safely and efficiently ascend a fixed rope with relative ease.

ASCENT EQUIPMENT

9.03 There are two basic types of ascender:

a. **Friction Knots** - There are several different kinds of these, but the most commonly used, and generally the most effective is the Prusik Knot.

b. **Mechanical Ascenders** - As stated in paragraphs 5.40 and 5.41, mechanical ascenders will slide easily up a rope when unloaded, and will lock in position when loaded downwards. The devices are designed for this one-way operation, however, the cam can be pivoted away from the rope when unloaded so as to move the descender down the rope or remove it from the rope.

9.04 ROPE PROTECTION

Due to the continual movement of the rope during an ascent operation, the placement of rope protection at all points of rope contact is desirable.

9.05 BELAYS

During training and under certain circumstances it may be desirable to provide a belay for a rescuer ascending a fixed rope.

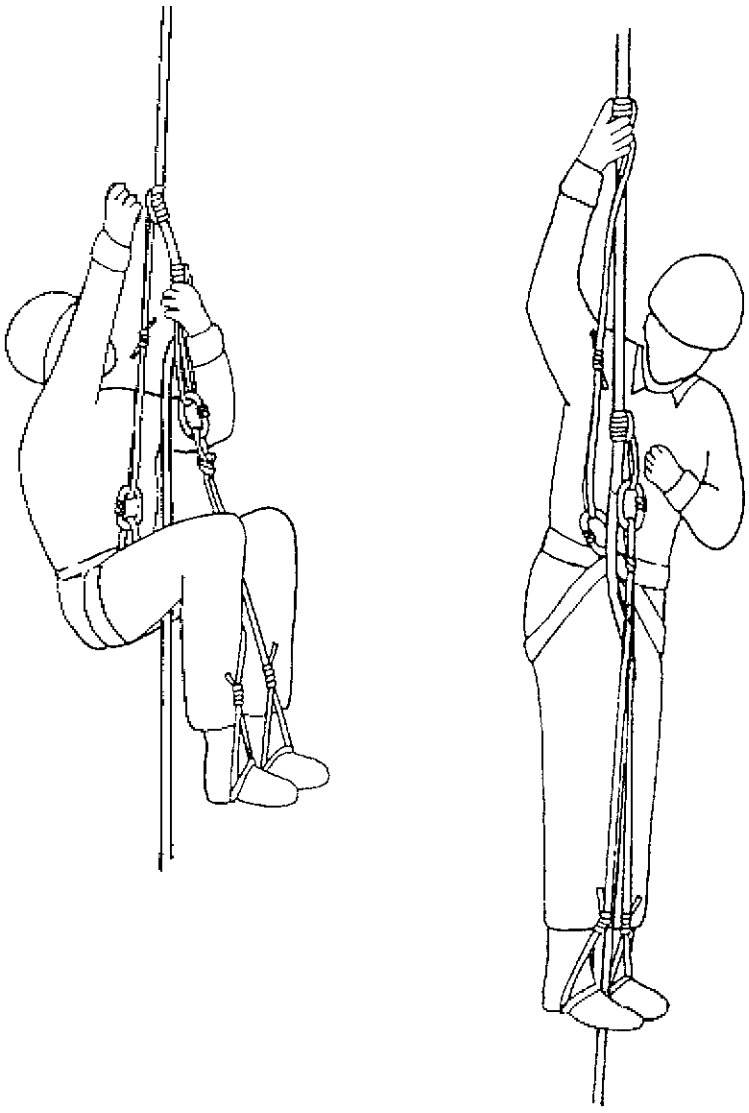
ASCENT SYSTEMS

9.06 FROG ASCENT RIG

The Frog Ascent Rig is one of the simplest and most commonly used ascent systems.

9.07 FROG RIG WITH PRUSIK KNOTS

With the standard Frog Rig shown in Figure 9:1, two stirrups are connected to the **lower** Prusik Loop, while the upper Prusik Loop is attached to the harness karabiner. The lower (foot stirrup) Prusik is also connected to the harness by a tape sling for full safety, and the rig is complete. The sytem is used as follows:



(a) (b)

Figure 9:1
Frog Ascent Rig with Prusik Knots

a. The rescuer sits supported by the harness Prusik while moving the foot rig up the rope (Figure 9:1(a)). When the foot rig is in position, the rescuer merely stands up in the stirrups (Figure 9:1(b)) and moves the harness Prusik up the rope to take a higher sitting position.

b. As additional insurance to the stirrup Prusik moving freely up the rope while in the sitting position, the rescuer can simply grasp the rope below the knot with one hand so as to tension the rope slightly while moving the Prusik knot with the other hand.

c. The ascent rig must be set up and fine tuned to suit the individual. The optimum rig is one in which ascent forces are exerted directly down the rope line. Energy expended in any sideways direction is simply wasted.

d. With the Frog system, the rescuer rests weight on one Prusik while moving the other. Ascent must be made as smoothly and steadily as possible.

9.08 FROG RIG WITH MECHANICAL ASCENDERS

This system is set up and used as follows:

a. The standard Frog Rig shown in Figure 9:1 can be set up with mechanical ascenders but the rig **must be modified** for **safety** and increased **efficiency**. The foot stirrups **must be attached** to the **higher ascender**, and the **primary harness attachment** to the **lower ascender** in a reversal of the Prusik rig. (Refer Figure 9:2).

b. The lower ascender is attached to the harness karabiner by its bottom attachment point, and to a chest harness or loop of **shock cord** around the neck, by the top attachment point.

c. This double attachment of the chest ascender allows the rescuer to concentrate on moving the foot ascender, while the act of standing up in the stirrups will cause the chest ascender to move up the rope without using the hands.

d. As additional insurance to the chest ascender harness moving freely up the rope, the rescuer should grip the rope between the feet when executing the standing movement.

e. Rescuers setting up ascent rigs with mechanical ascenders must practise and fine tune the rig for personal comfort and efficiency.

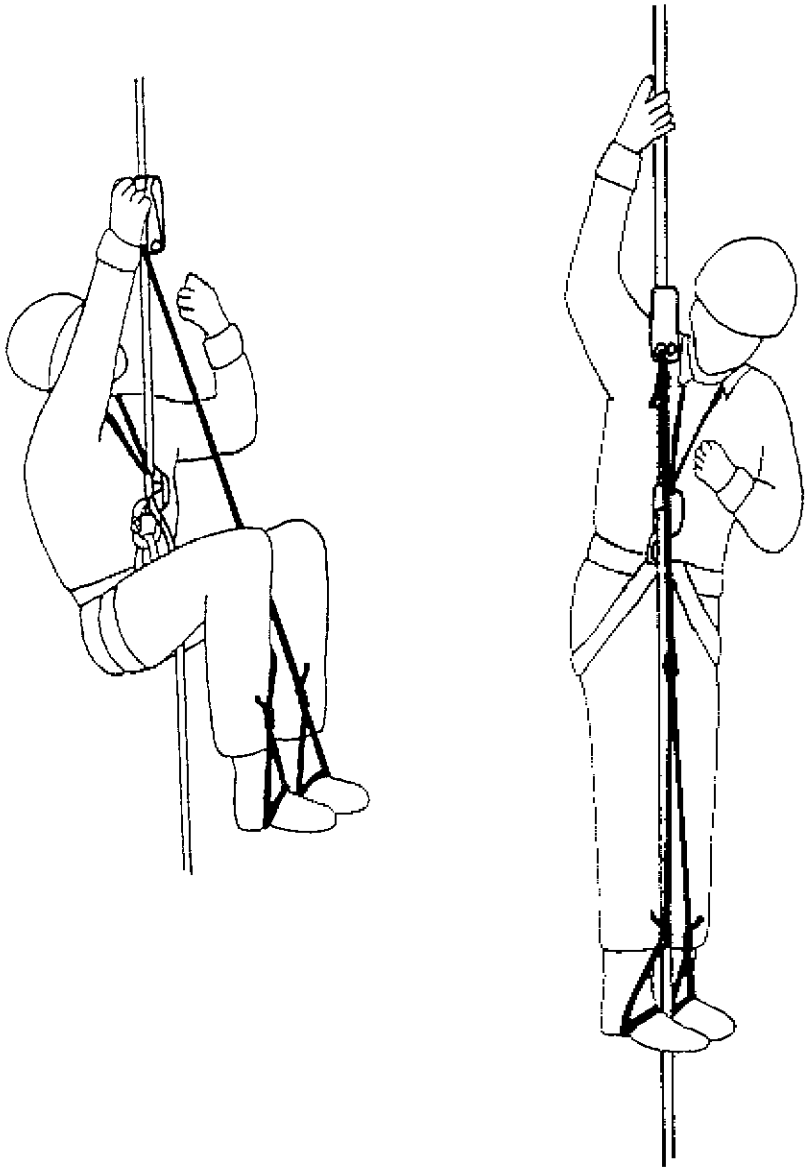


Figure 9:2
Frog Ascent Rig with Mechanical Ascenders

WARNING NOTES

No mechanical ascender is rated for any form of shock loading, and this risk must be carefully avoided

Ascenders must always be loaded in line with the ascender frame and with the rope to prevent load distortion and possible failure

When mechanical ascenders are used on a horizontal or diagonal rope, a safety karabiner must be connected from the ascender to the rope as shown in Figure 9:3

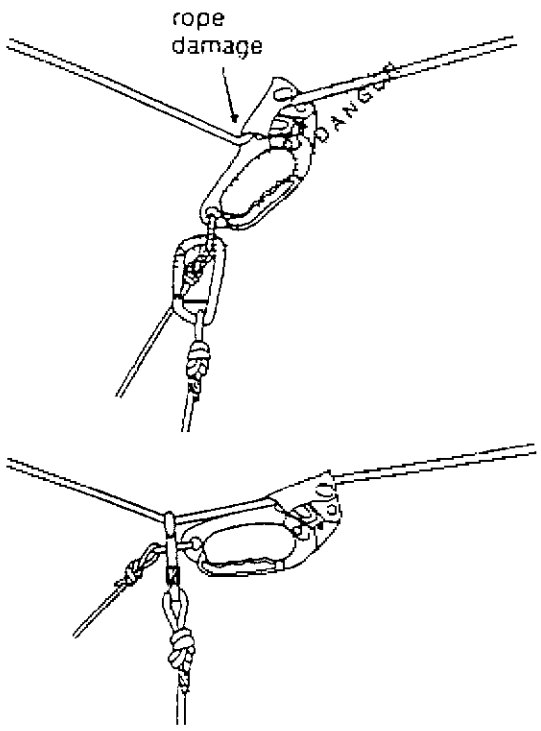


Figure 9:3
Ascender Safety Connection for Horizontal or Diagonal Ropes

OTHER ASCENT SYSTEMS

9.09 There are numerous ascent systems which suit different situations and personal preferences. Selection of a technique should be based on ascending efficiency, safety and comfort.

CHANGEOVER FROM ASCENT TO DESCENT

9.10 PROCEDURE

The procedure for changing from an ascent rig to descent is as follows:

a. Check that the ascent rig from the harness to the rope is set and secure, then remove the foot ascender rig and secure it to the harness gear loops.

b. Rig the descender to the rope below the harness ascender then connect it to the harness karabiner. With in-line descenders, it is recommended that the descender be connected to the harness before reeving the rope.

c. Take in all slack through the descender and lock it off securely.

d. At this stage, the harness ascender must be removed from the rope or tripped so that it will slide down the rope during the abseil. This is best achieved by securing a Prusik cord to the rope below the descender, standing up in this stirrup to unload the ascender and tripping it so that full body weight can come on to the locked-off descender.

e. Remove the Prusik loop, unlock the descender and abseil to ground level.

CONCLUSION

9.11 GENERAL SUITABILITY

It must be stressed that the techniques and recommendations included in this chapter are those most generally suited to vertical rescue.

9.12 PRACTISE

The standard systems must be practised under controlled and safe conditions until rescuers are proficient in basic techniques. At that time, and not before, each rescuer should then develop and fine tune their own rig.

9.13 REVERSE PROCEDURE

With any ascent system, rescuers must practise reversing the procedure so as to be able to move back down a rope. This is a very simple action, but it must be practised for safety, as there will be situations where it may be required.

CHAPTER TEN

LIFTING/LOWERING SYSTEMS

INTRODUCTION

10.01 The rescue of a trapped or injured person in a vertical environment requires a high degree of skill and experience in ropework, knots, and vertical rescue equipment.

10.02 **COMMON SCENARIOS**

In very general terms, lifting/lowering systems will be required for the recovery of all trapped and/or injured persons in the following common situations:

a. Lower casualty from high point to low level.

b. Lower rescuer from high point, collect casualty from mid-point and lower to low level.

c. Lower rescuer from high point, collect casualty at midpoint and recover to high point.

d. Lower rescuer from high point to low level, collect casualty and recover to high point.

10.03 The listing of these common scenarios highlights the requirement for an approach in which a lowering system can be rapidly converted for lifting, to reduce delay.

WARNING NOTE

In all circumstances, rescue systems must be reversible so that the direction of movement can be changed at any stage of the operation

INCORPORATION OF SAFETY BELAYS

10.04 **REQUIREMENT**

In certain circumstances, dictated either by service operational policy or by on-ground conditions, there will be a requirement to establish a belay or safety rope for the casualty and escort.

10.05 **BACK-UP**

The belay is for use only as a back-up in the event that the main hauling line becomes inoperative, or any element of the rescue system fails.

10.06 A belay should be anchored independently of the rescue system and controlled at all times so that there is a minimum of slack in the line.