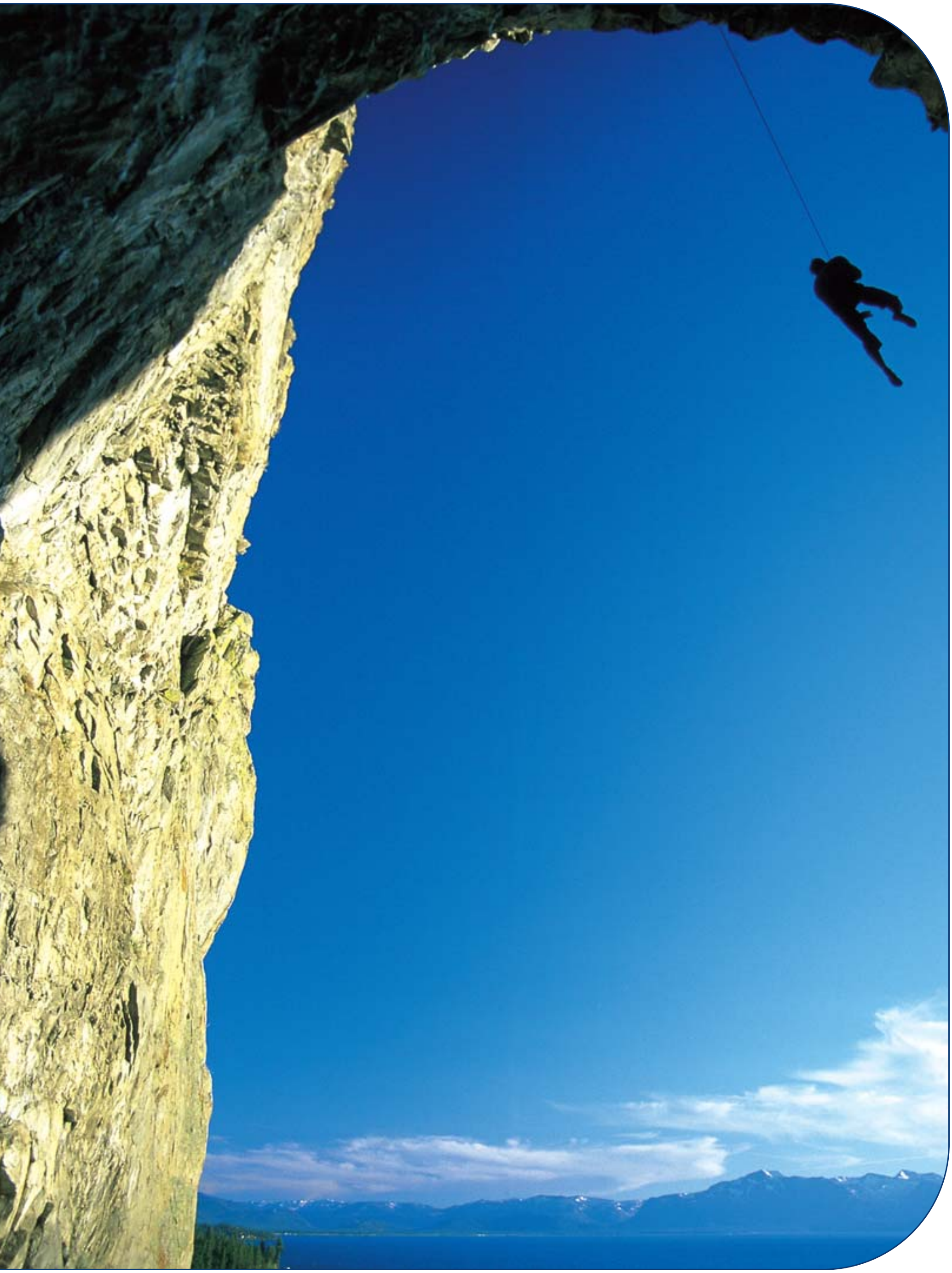
BMC

Care and Maintenance

equipment standards – equipment wear and failure – routine checks and care



Cave Rock, Lake Tahoe

Photo: *Alex Messenger*

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***Cover photo:** Al Powell on* Silence of the Seracs, *Greenland*
***Photo:** Al Powell*

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Introduction

For over 50 years the BMC Technical Committee and its predecessor, the Equipment Sub-Committee, have been issuing safety advice and investigating occurrences of failed equipment. Over that time a great body of knowledge has been built up and over 300 investigative reports have been written. Over the same period of time, several members of the technical committee have been deeply involved with others in generating UIAA and EN standards for mountaineering equipment.
This booklet aims to bring together the lessons learnt in those investigations, the knowledge of standards and key advice from manufacturers – and to become an essential reference for anyone owning or using mountaineering and climbing equipment.

For those requiring more detailed information on specific incidents, full investigation reports can be ordered from the BMC office. A complete list of the reports held is available from the BMC office or website – www.thebmc.co.uk. In addition, there are separate BMC booklets giving in depth advice on ropes and crampons. BMC Summit magazine carries regular technical articles and current news updates.

***Photo:** BMC Collection*

How to use this booklet

Each chapter is written by a member of the BMC Technical Committee who has expert knowledge in that area, and addresses the following issues:

Introduction
Defines the equipment covered, and may include a brief history of its development if appropriate.

Relevant European Standards
Details the UIAA and EN standards that the equipment must meet. It should be remembered that these standards are specified for normal and reasonable use, and that any item of equipment meeting that standard may fail if subjected to high or abnormal loads. It is a mistake to assume that equipment made to these standards will never break.

Observed faults and failures
Describes the different ways in which the equipment has been observed to fail, and the reasons for the failures.

How to prevent failures in use
Advice on how to use the equipment properly, so as to minimise the chances of its failure in use. Includes advice on how to monitor equipment for signs of failure.

Routine care & maintenance
Gives advice on how to maximise the useable lifetime of the equipment, and where relevant, includes guidance on transport and storage.

Degradation of equipment and discard criteria
Describes how the equipment might degrade with age and use, and gives advice on when to retire the equipment.

The remaining chapters of the booklet look in more detail at the mechanics and science of equipment failure.

An important note on equipment lifetime

Because of all the variables that affect an item of equipment when it is used, it is almost never possible to give a definitive lifetime for equipment in use. In all cases, the owner needs to take into account everything they know regarding:

- the history of the equipment – has it been involved in any long falls etc?
- the way in which it has been used – eg. top-rope, lead rope?
- the general advice given in this booklet;
- the manufacturers' advice;
- most importantly, the results of a visual and physical check – which you should always carry out – every time the equipment is used.

This may seem like a complex process, but in reality, much of the calculation is done subconsciously, leading to the general maxim:

If you think it may be time to replace an item of equipment then it probably is!

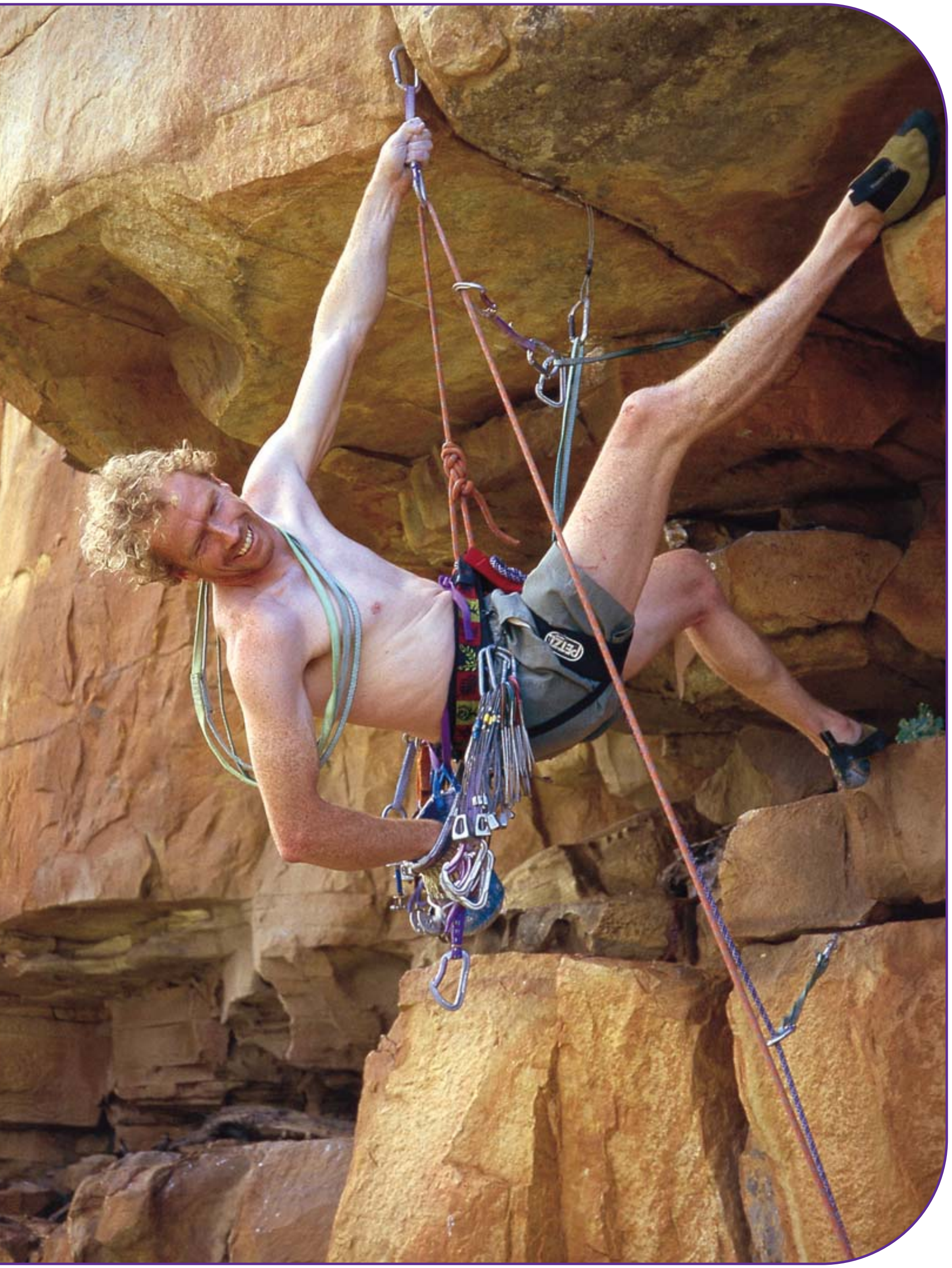
Standards

Almost all climbing hardware is categorised under the European Personal Protective Equipment (PPE) Directive. This applies to all equipment carried on the person to be used for protecting against falls from a height (ie. harnesses, ropes, nuts, karabiners etc.), or to protect against slippage (crampons & ice axe) or head protection (helmets). To be allowed to sell an item of PPE in Europe, a manufacturer must go to an independent 'notified body' and have their equipment tested against an appropriate standard and their quality control procedures verified. Once approval is given, the equipment can carry the CE mark and go on sale.

Prior to 1995, the international standards to which some equipment (mostly ropes and helmets) was manufactured were those published by the UIAA* Safety Commission. Manufacturers could effectively *choose* whether to manufacture to the UIAA standard, and whether to apply for a UIAA label for their equipment. However, since 1 July 1995 manufacturers have been required by law to meet the requirements of the PPE Directive. The easiest way to do this is to meet the requirements of the EN standards for mountaineering equipment produced by Working Group 5 of CEN/TC 136. Much of the active input into Working Group 5 came from members of the UIAA Safety Commission, and as a result the EN standards are largely based on the old UIAA standards, but are more rigorous with considerable revision and update. Since the publication of the EN standards, the UIAA Safety Commission has revised its own standards to be based on the new EN standards, but with a few additional requirements.

Although the PPE Directive came into force in 1995, work on the EN standards has progressed at a somewhat variable pace. Most of the standards have now been completed and published, but a few are still being worked on (eg. descenders, belaying devices).

* UIAA – *Union Internationale d'Associations de Alpinisme* – the world body for mountaineering



Nick Hancock hanging out in South Africa **Photo:** Andy MacNae

Karabiners

by Neville McMillan

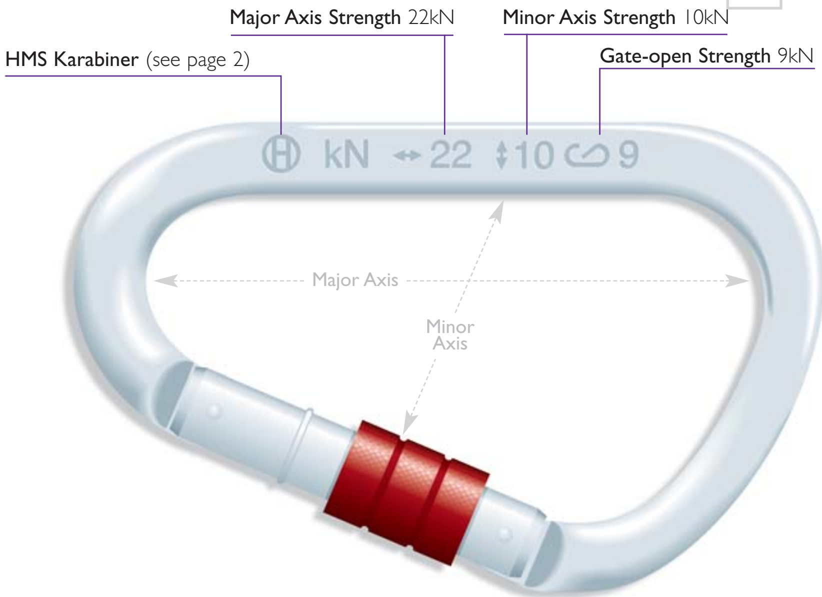


Figure 1.1 Karabiner strength markings

Introduction

Historically, karabiner was the German word for an early type of gun (in English a *carbine*, though both words derive from the French *carabine*). A bandolier or sling was used for carrying this gun, and the soldiers found that if the gun were attached by a hook it could be detached from the bandolier and brought into use much more quickly and effectively. The pear-shaped hook with a spring closure developed for the purpose was in German: *Karabinerhaken* (in English: *carbine hook*, a term still in use in the US army). Over many years, the '*haken*' was dropped, and the sprung hook became known as a karabiner. In due course, early alpinists saw the advantages of using a similar device for rapid attachment to a piton – this occurred around 1900. Subsequently, its uses were extended and its size modified accordingly. English alpinists incorporated the word karabiner into the UK climbers vocabulary, and similarly in America, although the US spelling *carabiner* is more faithful to the original French: *carabine*.

Parallel developments took place in France and Italy, but were related to a different gun, the *mousquet* (or English musket), thus the French for karabiner is *mousqueton* (and the Italian: *moschettone*), both of which can be Anglicised as 'musket hook'. Thus, by whatever route, and in at least four languages, the climbers 'karabiner' was originally a gun hook with a sprung closure used to assist in carrying a gun.

Relevant standards

The first standard for karabiners for use in climbing and mountaineering was produced by the UIAA Safety Commission in 1965. This standard and its revisions form the basis for the current, much more comprehensive European Standard for Connectors (EN 12275) published in 1998. The standard specifies 'safety requirements and test methods for connectors for use in mountaineering, including climbing'. The descriptive generic word *connector* has been used in the standard to allow the emergence of innovative designs that may not look like traditional karabiners, and also to include items, which do a similar job but are not normally considered to be a karabiner – eg. the quicklink or Maillon Rapide. In this booklet the word karabiner is used as it is the accepted norm, but it is intended to apply to all types of connectors which comply with EN 12275.

Types D, A and Q are easily recognised by their appearance, and are not required to be marked as such. Types H, K, and X have different strength requirements, and types H and K different gate requirements, and must be marked with the appropriate letter surrounded by a circle. There is no requirement to mark basic connectors with the type letter B – any karabiner not marked H, K, or X will be a basic connector.

The standard also requires that the appropriate strengths be marked on the body of the connector using the symbols shown in Figure 1.1. For the climber, the most important figure is the major axis gate-open strength, and it is worth becoming familiar with the symbol indicating this particular strength marking, as shown in Figure 1.2.

The standard requires the major axis gate-open strength for a basic connector to be at least 7kN. The previous standard only required 6kN, and gate-open failures then were more frequent (see below). Oval connectors are a special case and are used principally for aid climbing where the shape has several advantages. However, this shape makes them inherently weaker when the gate is open. The standard allows a gate-open strength as low as 5kN, but it is accepted that they will not give full protection in the event of a leader fall. Their use in UK (free) climbing is generally not necessary, and is undesirable because they are not strong enough for use on running belays.

In 1998, the relevant UIAA standard was revised to take into account the work done on the EN standard, and the title was changed from 'Karabiners' to 'Connectors'. The current EN and UIAA standards are essentially the same.

Table 1.1 The standard defines several types of connector as follows:

Type	Connector Name	Brief Information
B	Basic	General purpose eg. for running belays, at a stance, etc.
H	HMS	For dynamic belaying eg. using 'Italian hitch' or brake plate
K	*Klettersteig*	Higher strength, large gate opening, for via ferrata use
D	Directional	For unidirectional loading ie. with a captive or semi captive sling (eg. DMM Mamba) used for quickdraws
A	Specific Anchor	For use with a specific bolt hanger
Q	Screwed-closure	Quicklink or Maillon Rapide
X	Oval	For aid climbing use

Figure 1.2 Gate-open markings

Observed faults and failures

Like all equipment, karabiners can develop faults – most of which should be apparent to the user on inspection before use. These are quite rare, and such faults reported to the EIP have been (one instance of each in the last 20 years)

- Displaced spring-pusher in the gate (causing the gate not to close)
- Loose hinge pin
- Loose latch pin

There have also been some instances of seawater corrosion due to lack of care and maintenance by the owner (see appendix on seawater corrosion). In addition, it is known that screwgates and autolocking gates (or twistlocks) can become worn over time and fail to function correctly.

The majority of karabiner reports issued by the Equipment Investigation Panel (EIP) involve failures under load (with fatal or potentially fatal consequences), and were due to (most frequent first):

- Loading of the karabiner when the gate was open
- Abnormal loading of the karabiner, forcing the gate to open under load
- Loading with a sling/quickdraw (ie. no rope involved) – only one instance

How to prevent failure in use

Karabiner gates can open momentarily when loaded dynamically during a fall. Normally this is not a problem, because either the karabiner is not actually loaded whilst the gate is open, or the force applied is less than the gate-open strength of the karabiner. The 1998 standard increased the minimum gate-open strength from 6kN to 7kN to make this type of failure less likely, but a gate-open strength of 7kN does not guarantee that a gate open failure will never occur. If you are a heavier than average climber or you carry a lot of gear or a rucksack (or all of these), it makes sense to choose karabiners with a gate-open strength of 8 or 9kN to increase your margin of safety.

If you have karabiners manufactured before 1998, it is worth checking to see if a gate-open strength is marked on them. If it is below 7kN or not marked (as with nearly all karabiners made before 1990), there is a potential problem. If the karabiner is especially lightweight or made from round bar of less than 10mm diameter, it may have inadequate gate-open strength – seek expert advice or contact the manufacturer. ***If in doubt, replace the karabiner.*** *(It can still be used for carrying bunches of wired chocks, or your nut extractor; just don't use it where your life depends on it.)*

Use of a screwgate or autolocking karabiner avoids the gate-opening problem, and is recommended where

- high reliance is being placed on a karabiner, ie. at a belay, lower-off or vital runner;
- the chance of the gate becoming open is increased, eg. a karabiner on the end of a long sling, or which may hit the rock with force when loaded.

Even with a screwgate karabiner, the gate may be forced open in certain situations, particularly when using a figure-of-8. In this case it is possible for the figure-of-8 to lever open the gate if the system is loaded under an 'abnormal configuration' as shown in Figure 1.3. When abseiling or belaying with a figure-of-8, you must be vigilant at all times to ensure that the figure-of-8 does not come into contact with the gate.

Figure 1.3 A figure-of-8 forcing open a screwgate karabiner. ***Photo:*** *BMC Collection*

In practice, other abnormal loadings may arise (for example if a karabiner is loaded over a rock edge, or scraped along a horizontal break) that could cause the gate to open. When placing runners, take care to try to avoid these possibilities by anticipating the position of the karabiner in the event of loading, and extending the runners accordingly. If in doubt, it is best to use a strong screwgate karabiner.

Another way to reduce the chance of the karabiner being loaded with the gate open is to use wiregate karabiners. A wiregate has much less mass than an alloy bar gate, which very significantly reduces the chance of opening due to whiplash or inertial effects. But on rough, knobbly, or crystalline rock some wiregates may be more prone than a round bar to being opened when scraped along a rock edge under load. Wiregates solve some but not all problems.

In addition, care should be taken to ensure that the karabiner is loaded in the correct way. Karabiners are designed to be loaded along their length (a two-way load along the major axis), and in this mode basic karabiners will withstand a force of at least 20kN with the gate closed. They are very much weaker (typically 7kN) when loaded along the minor axis ie. on the gate, and for this reason three-way loading should be avoided as this increases the probability of loading the gate. In some cases, a three-way load is inevitable (such as when clipping both ends of a threaded sling), and in these cases take care to ensure that the angle between the slings does not exceed 60º. This will significantly reduce the chances of loading the gate – see Figure 1.4.

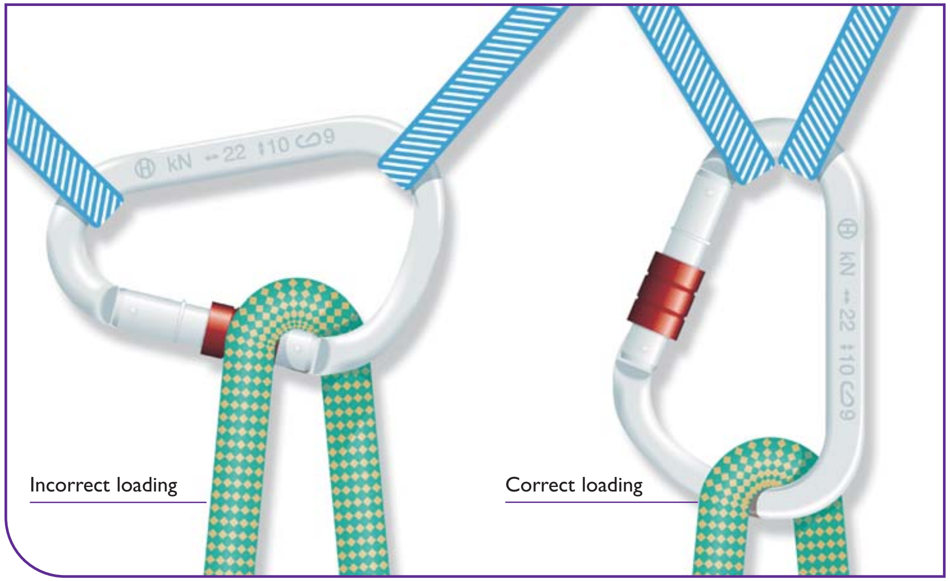


Figure 1.4 Three-way loading of screwgate karabiner

Figure 1.5 Badly-positioned karabiner ***Photo:*** *George Steele*

When clipping bolts or pegs with quickdraws, make sure that the rope is running in the correct direction through the karabiner ie. that the karabiner gate faces away from the direction of travel. Also, on slab routes it is possible for the quickdraw to move such that the karabiner gate will be loaded and open in a fall (see Figure 1.5). For a similar reason, do not clip two karabiners together directly; in a fall the body of one can lever open the gate of the other, and disconnect them.

In normal fall situations using a dynamic climbing rope, the forces on the karabiners and anchor system are limited by the stretch within the rope, and the slippage of the rope through the belay device (dynamic belaying). The force on the top runner is very unlikely to exceed 10kN, and will generally be significantly lower than this and well within the gate-closed strength of a karabiner. However, if a climber is linked to an anchor point only by karabiners, quickdraws and tape/accessory cord, there is no energy absorption in the chain of connection. In the event of a fall or other shock loading, forces in excess of 25kN are quite possible – sufficient to break a karabiner even with the gate closed! So when clipping to a belay point using only slings, quickdraws, and karabiners, adjust the length of the sling to eliminate any slack, thus eliminating any shock loading in the event of a fall. This also applies to protecting yourself on *via ferrata* scrambling routes, which have fixed metal cables to clip to. Never clip yourself to these cables with just a tape sling and karabiner – if you fall, the karabiner could easily break because slings do not stretch like rope! Instead, use one of the several energy absorbing lanyards now commercially available, which are made specifically for this task.

Routine care and maintenance

Provided karabiners are kept away from sea cliffs and salt water (see appendix on saltwater corrosion), they require little maintenance. However, if any irregularity in the gate action is observed in use, the karabiner should be carefully inspected as soon as possible. In any case, it makes sense to inspect all your karabiners methodically from time to time (say, once a year) to ensure their performance is satisfactory.

The following procedure is recommended:

- Check that the gate opens and closes easily and smoothly. If not, lubricate the hinge with a suitable aerosol lubricant such as GT85 or WD40. Wipe away any surplus, and check the movement again – if this does not cure the problem, discard the karabiner.
- Check that the gate closes completely from any open position. If the gate catches on the latch or does not close fully under its own spring, the karabiner should be discarded. ***Bending the gate to rectify this is not recommended as it weakens the hinge and does not constitute a reliable repair!***
- Very carefully, inspect by eye and using the fingers, the inner surface of the karabiner, particularly where the rope will run in use. Any karabiner with burrs, grooves or sharp edges on its inside radius should not be used for clipping ropes (it could be reserved for clipping bolt hangers or pegs – you should have dedicated rope-end and gear-end karabiners to your quickdraws in any case!). Do not think that the problem can be solved by filing down any sharp edges on the karabiner, since even the grooves left by a fine-cut file could significantly damage the nylon filaments of the rope sheath.
- Check the screw action of the sleeve on screwgates to ensure that it is smooth and will keep the sleeve locked in the closed position.

Examine the edge of the sleeve which provides the locking action; usually the edge which covers the nose, but in some cases the edge which covers the hinge. If there is any sign of cracking or distortion, the karabiner should be discarded.

- Inspect autolocking and twistlock karabiners very carefully – open the karabiner several times and release the gate from different open positions. Check that the gate closes fully every time, and that the locking sleeve closes of its own accord. If the karabiner is reluctant to lock even after lubrication, it should be discarded. Again, check the edges of the sleeve – any signs of cracking or distortion are criteria for discarding.
- If a directional karabiner (eg. DMM Mamba) includes a tape sling, inspect and maintain the sling as described in the section on slings. If the sling cannot be removed but needs replacing or re-stitching, the whole device should be returned to the manufacturer.
- Karabiners should be stored in a dry, airy place. For quickdraws, or other connectors that have textile elements, there is an additional requirement that it should be cool and dark.

Degradation and discard criteria

If properly looked after, there is no reason why a karabiner should not have a lifetime of at least 20 years. Most of the discard criteria have been covered in the routine care & maintenance section above, however if the karabiner is more than ten years old, or shows signs of corrosion or local discolouration, the following test should be added to the inspection routine:

- Remove as much surface corrosion as possible using a domestic pan scrubber or wire wool. Carefully inspect any discoloured regions for signs of cracking or an etched appearance on the surface. A magnifying glass will be needed to distinguish between cracks and surface scratches. If cracks can be seen, or if the corrosion or discolouring are such that cracking cannot be ruled out, discard the karabiner (see also the discussion of corrosion mechanisms on page 33 in the Appendix on seawater corrosion).

Provided that karabiners are properly used and looked after, it is much more likely that they will be replaced with new models for reasons of cosmetics, handling or strength/weight ratios than they will be discarded over concerns about their failing strength. Nevertheless, it is important that they receive methodical inspection and maintenance.

Crampons

by Alan Huyton

*Figure 2.1 Different types of crampon: **a** – Walking Crampon, **b** – General Mountaineering Crampon & **c** – Technical Climbing Crampon* ***Photos:** DMM/Ben Lyon*

Introduction

Hunters in the European Alps used a simple type of heel crampon as early as the sixteenth century, but the first mountaineers preferred to use their nailed boots alone. Whymper wrote that he only felt comfortable wearing crampons where there was no possibility of slipping – and he would not use them on an ice slope for any consideration whatever! It was not until the twentieth century that this opinion changed but crampons then quickly became standard issue for serious alpinists. In 1932 the 12-point crampon was introduced and over time this revolutionised snow and ice climbing, the forward facing front points allowing climbers to ascend very steep ice with reasonable security (Figure 2.1a). Since then improvements in strength and design have made crampons lighter, stronger and more suited to different types of climbing such that they are now an essential part of any winter climber's or mountaineer's equipment.

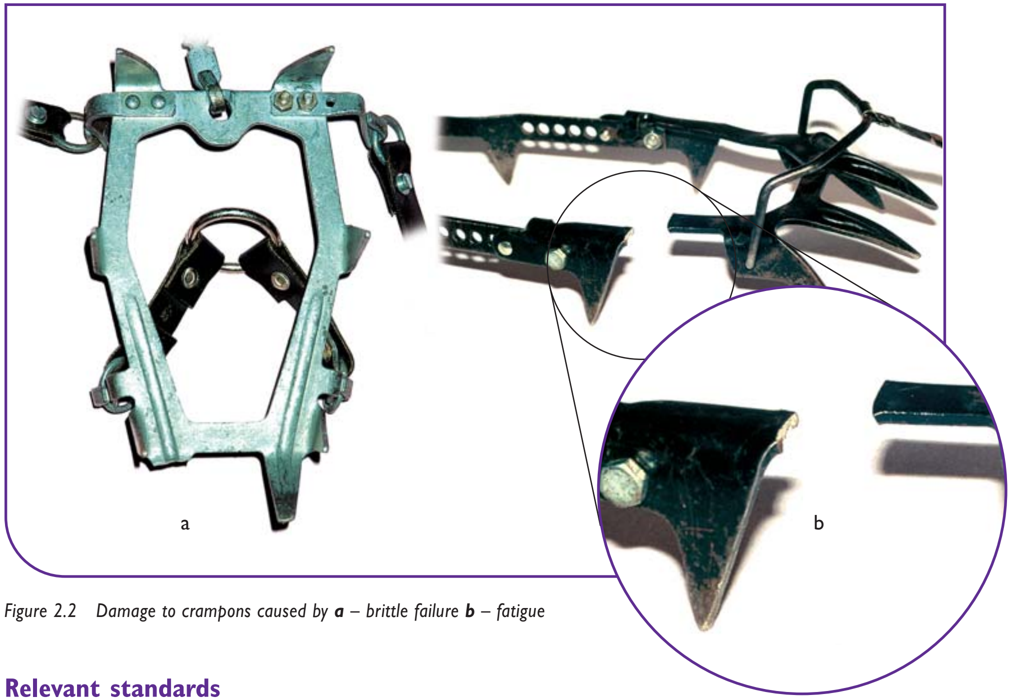


Figure 2.2 Damage to crampons caused by ***a*** *– brittle failure* ***b*** *– fatigue*

Relevant standards

The European Standard for crampons is EN 893. This specifies safety requirements and test methods for crampons for use in mountaineering on snow and ice including climbing mixed terrain. For the purpose of the standard a crampon is defined as a device fitted with spikes, which covers the sole and heel of a boot so as to provide grip on snow, ice and mixed terrain and which has a system of attachment to the boot. The standard does not cover instep crampons.

The standard gives requirements for the shape and design of crampons. The main ones are that each crampon must have an effective system of attachment to the boot and have at least eight spikes, six of which should point downward. Also included are various requirements for the strength of the crampon. These include the hardness of the metal, the strength of the spikes, frame, attachments and other parts. Detailed test procedures are then given by which these properties are to be measured.

It is worth noting that the strengths specified for the various parts have been decided as reasonable values for normal use and that crampons meeting the standard may fail if subjected to high or abnormal loads. It would be a mistake to assume that just because a crampon is made to the standard it will never break.

Observed faults and failures

In the period from 1985 to 1999 the BMC Technical Committee has investigated 31 incidents involving broken crampons. In four cases the attachment system failed whilst in the remainder the actual crampon itself broke. All the incidents can be attributed to one or more of the following:

Figure 2.3 A well-fitting crampon **Photo:** *BMC Collection*

- **Brittle fracture or fatigue** (19 cases)
  Crampons take an incredible amount of punishment – a climber carrying a heavy rucksack and walking over rock or boulders transfers a large force onto the points of the crampon. (For the technically minded the impact force can be around 3kN, which on rough terrain might be shared by only two or three of the points!). Also the crampon bends slightly, even on the stiffest boot, and this happens on every step. On a ten-mile walk a crampon could experience 10,000 bending cycles. Metal will break if cold enough and either bent with sufficient force (brittle fracture) or flexed back and forward enough times (fatigue failure). The surprising thing is not that some crampons break but rather that most crampons don't break – a testament to our equipment manufacturers – see Figure 2.2.

- **Poor fitting of crampon to boot**
  It would be unreasonable to expect that all crampons will fit all boots, so a number of the failures were due to inappropriate boot/crampon combination leading to the crampon becoming detached. It is essential to take your boots to the shop when buying a pair of crampons to ensure that they are compatible and fit together properly. Advice on choosing the correct type of crampon for your boots and intended use can be found in the BMC companion booklet on crampons and also in various books and magazine articles covering equipment.

- **Poor design or manufacture**
  The remaining failures were due either to poor design or manufacturing defects. The design problems have been identified and these models have either been withdrawn or modified. The manufacturing faults have tended to be isolated incidents that were reported back to the manufacturer.

How to prevent failure in use

There is no sure method to avoid crampon failure. By the very nature of the treatment given to crampons it is possible they may break eventually. However there are some simple guidelines you can follow to reduce the likelihood of a failure:

i) Choose a crampon suitable for your boot type – putting fully rigid crampons on flexible boots may damage the boots, the crampons and possibly your feet into the bargain.
ii) Choose a crampon appropriate for your intended use – using highly technical crampons for walking on mixed terrain will increase the likelihood of fatigue failure. Similarly, using crampons with long front points for climbing on rock will probably result in broken front points very quickly!
iii) Regular inspection – be aware that your crampons take the most abuse of any of your mountaineering equipment so be extra vigilant with frequent inspections as below.

Routine care and maintenance

Crampons require very little maintenance to keep them in working order but they should be inspected before every use for signs of damage and wear. The following procedures are recommended:

- Clean off any mud and remove any small stones from the hinge (on hinged crampons).
- Carefully examine the corners where the points join the frame for any signs of cracks. A magnifying glass will be useful for this. Discard the crampons if any cracks are visible.
- Check for loose nuts on the adjustment bars and tighten if necessary. A glue such as Loctite may be useful if the nuts frequently work loose.
- Check the straps for damage. Neoprene straps will tend to fray along the edges but passing a flame along the edge to melt the loose fibres can easily rectify this.
- Check the rivets in the straps (if applicable) and insert new ones if they become loose or damaged.
- The heel lever on step-in crampons should move freely, if not a spot of oil may help.
- When sharpening the crampons, sharpen the front points on the top like a chisel so that the cutting edge is at the bottom. Downward points should be sharpened along their narrow edges, not their sides. Sharpen with a hand file as a power tool can heat the metal too much and ruin its temper. Remember that points do not need to be razor sharp!
- Finally, it is well worth getting a crampon bag or a set of rubber spike protectors – these help to prevent damage to your rucksack and its contents by the spikes. After use the crampons should be wiped dry and stored in a warm, dry place. Do not store crampons in the rubber protectors or crampon bag if there is any chance of dampness or condensation.

Degradation and discard criteria

Degradation is not a problem with crampons – if looked after properly there is no reason why a pair should not last 15 to 20 years of normal use. It is much more likely that crampons will need discarding after some sort of damage or breakage and the criteria for this have been discussed above.

3

Ice Tools

by Trevor Hellen

Introduction

The basic ice axe was well developed by the classical climbing era of the last century. The shafts were quite long and made of wood. In Whymper's time, the pick and adze head were already popular for snow and ice work, the pick being slightly curved after it was realised that a 'swung' axe entered the ice in a more accurate manner. The design has not changed fundamentally since then, except that shafts have become shorter (walking stick length or less) and the materials have been improved – wood has been replaced by hollow shafts made from quality alloys of steel or aluminium (and more recently carbon fibre). The head is now made of a suitable steel alloy, whereas Whymper's was wrought iron!

Technical tools for climbing steep ice are an invention of the last few decades, with characteristic short shafts and a head comprising a pick (originally fairly straight as in Whymper's axes) opposite an adze or hammer. Often these are manufactured from alloys of a slightly higher specification than more basic tools like walking axes. The main innovation in this area came about when Chouinard in the US developed a curved pick with the same radius as the arc that the head of the axe makes when swung at arms length. This allowed the pick to penetrate and be removed from ice much more easily. About the same time Hamish MacInnes in Scotland manufactured the drooped pick of his 'Terrordactyl' axe, which was very effective for hooking on the mixed ground of Scottish winter climbs. Since then, other improvements have included refinement of the drooped pick design to reduce sticking; thicker, thinner and shorter picks for specialist uses such as torquing and brittle waterfall ice; and curved (or cranked) shafts to improve the swing and handling of the tool. Lightweight tools intended for ski mountaineering have been developed, and materials for construction of ice tools are continually improving.

Figure 3.1 George Mallory (left), Teddy Norton and Howard Somervell (photographer) climbed without oxygen equipment to just below 27,000ft on Everest on 21st May, 1922.
Photo: *T. Howard Somervell*

Technical tools are used in pairs for steep modern ice routes (in conjunction with front-pointed crampons) and so are designed to withstand a certain force due to the impact of the pick hitting

Figure 3.2 Modular tool components

the ice. To aid adhesion when the pick has been struck into the ice, its lower edge usually has a saw-tooth pattern, and the pick itself is quite thin. Opposite the pick is either an adze for digging purposes, or a hammer used for inserting ice screws and pitons (the pick can also be used to tighten and extract ice screws). Many tools are ***modular***, in that the pick, hammer and adze are detachable and interchangeable, being held in place by nuts and bolts – this design has the advantage that broken components are easily replaceable. Otherwise, the whole tool is ***integral***, with the advantage of being lighter in weight and having fewer modes of failure.

Relevant standards

The safety requirements and test methods for ice tools for use in mountaineering and climbing are defined in European Standard EN 13089. The standard UIAA 152 encompasses this, plus an extra requirement concerning the means of attachment of the climber to the axe shaft (the leash). The term 'ice tool' is used to describe both ice axes and ice hammers.

Two recognised types of tools exist, although there are multiple uses for both: a ***technical ice tool*** (type **T** – used when climbing steep ice) and a ***basic ice tool*** (type **B** – for other use, typically when crossing glaciers and for standard snow climbs). A technical ice tool is required to have a stronger shaft, head and pick than a standard ice tool, and in addition there is a fatigue performance test on the pick of a technical ice tool.

Observed faults and failures

The BMC's Technical Committee has investigated almost 30 cases of failures relating to ice tools, most of which have occurred to tools used for steep ice/mixed climbing, whilst under heavy use. As with crampons, ice tools receive hard treatment during use (especially in modern mixed climbing), and some kind of failure is a possibility that should be borne in mind. The common modes of failure that have been found are:

- Picks can bend a short distance from the tip due to very high impact forces – this commonly occurs when rock (rather than ice) is accidentally hit.
- Picks can twist, bend and even snap (again, usually a short distance from the tip) due to very high leverages incurred when using the tool for hooking and torquing. This is currently the most common mode of failure. It must be stressed that these forces are not specified in the standards covering ice tools. The standards assume that ice-tools will be used on snow or ice, not rock!
- Modular hammer heads can crack or fracture, usually around the bolt hole attachment, as a result of being hit.

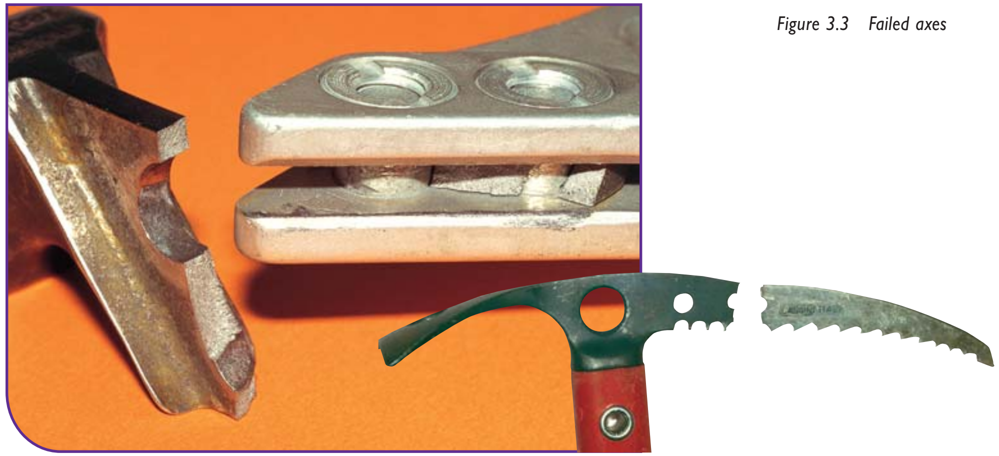


Figure 3.3 Failed axes

- Some modular heads can allow the pick to rotate and become useless due to breakage of the bolts (holding the component in place).
- On basic ice tools, wooden shafts are quite liable to break, although using linseed-type oils to condition the wood will help prevent this.

Users of ice axes with wooden shafts should be aware that such shafts are unlikely to meet the strength requirements of the standards. Such tools cannot be relied on for belaying, as the shaft may break.

How to prevent failure in use

Provided that routine care and maintenance is carried out, and the tool is used in the way recommended by the manufacturers, the chances of failure in use will be minimised. Some models are more likely to break than others, especially if misused, and some climbers are more likely to break their tools than others (eg. those who climb hard mixed routes in Scotland all winter). To reiterate: most manufacturers consider torquing to be beyond the design specification for an ice tool, and that such use makes a failure far more likely. Some manufacturers now produce extra-strong, thicker picks designed for this use that are less likely to break or bend, but will give reduced performance on ice.

There is a wide range of tools available on the market. An intelligent choice of model needs to be made, bearing in mind the intended use, the weight of the climber, and the degree of (mis-) use to which the user will subject the tool.

Routine care and maintenance

The procedures below should be followed:

- Read and follow the manufacturer's instructions and specifications.
- With modular tools, ensure that the nuts and bolts are tightened properly according to the manufacturers instructions, and check frequently for loosening.
- Take care with the tool when it is not in use – eg. do not drop or stand heavy loads on it.
- Keep the tool clean and free from dirt, using water and a little mild detergent and drying it quickly – particularly if it has been exposed to a corrosive or salty environment.
- When not in use, clean and store in a dry environment.
- When transporting ice tools, the sharp components should be protected by rubber covers that will prevent damage to other equipment and people, as well as the tools themselves.

- Regular inspection of the whole tool is important, particularly during periods of heavy use. Check for burrs, knocks or signs of bending on the shaft. Look for any signs of out-of-plane bending in the pick, and for any tiny cracks in the saw-teeth or around any of the holes using a magnifying glass. With modular tools, check the bolt area for undue wear and cracks around the attachment holes. Discard the component or seek the manufacturer's advice if any of the above is found.

Degradation and discard criteria

Degradation should not normally be a problem with ice tools, in the same way as with crampons. If corrosion appears, clean and dry thoroughly, and check that the underlying surfaces are not affected. This advice should generally only apply to older tools, since modern tools are constructed of alloys that should not rust.

Discard criteria are covered in the above section, but good general advice is that if any components become bent or have visible cracks, however small, they should be retired immediately and replaced.

Figure 3.4 Hooking on steep mixed ground
Photo: *Tim Glasby*

Chocks

4

by Dick Peart

Introduction

A chock is a piece of metal (usually aluminium alloy) threaded on a rope or wire sling which can be hand placed in a crack in the rock, and thus form running or static belays to protect the climber. Chocks have evolved slowly and only relatively recently reached their current sophisticated form and variety. During the early twentieth century, climbers began to use loops of rope (slings) on flakes, rock spikes and around trees to give some protection to the climbing party where previously there was none. In the 1930's climbers began to jam the actual knot tied in the sling into cracks, which allowed them to place protection much more frequently, and in the fifties this evolved into the practice of placing chock stones into cracks (a supply of different sized pebbles was carried in the pockets) by hand or hammer, which were then threaded. During the sixties, leading activists in North Wales and members of the Rock and Ice club started threading hexagonal metal machine nuts of various sizes on slings, which could then be jammed in cracks for protection and sometimes a little aid! By the turn of the seventies, the first nuts manufactured specifically for climbing protection were in use – namely the wedge by MOAC and the hex from Clog. The strength of the slings used on small nuts was limited by the size of the threaded rope that could fit the nut – on very small chocks, this was of the bootlace nylon variety! The advent of swaged wires in the mid-70s was an important improvement in the strength of climbing chocks, and around the same time Wild Country modified the previously straight sided wedge with concave-convex facets, and Chouinard made a hex nut that was eccentric (ie. non-parallel sides) giving the now synonymous hexcentric. These important modifications enabled nuts to 'cam' in parallel-sided cracks, increasing their versatility. The 80's saw the introduction of micro wires, offset designs and small brass wedges such as the RP.

Figure 4.1 Different types of nuts

Relevant standards

The appropriate standards are EN 12270 and UIAA 124, which are essentially the same. They are very simple, specifying a minimum strength and the method of test. To ensure that the smallest micro-chocks of any real use could still be marketed, the minimum strength requirement was set at only 2kN when larger sized chocks are obviously much stronger than this. Thus it is the responsibility of the user to purchase chocks of adequate strength, and for the larger sizes you should expect to see strength of at least 10kN.

Observed faults and failures

The few chocks that have been presented to the EIP for investigation, were due to suspected cracks caused by manufacturing defects in the alloy. Upon inspection these have proved to be scratches sustained during normal use or cosmetic manufacturing flaws – neither of which reduces the strength of the unit below its stated value. The wires on chocks do degrade and become damaged with age and use, but in a progressive way such that it becomes obvious that broken ends of individual wires are protruding before failure occurs.

Although the EIP has not investigated many cases of chock failure, this can and does happen. To the knowledge of the Technical Committee, there has never been a case where a chock has been known to fail below its stated strength. However, remember that small sized chocks do fail in normal use, as larger falls can and do produce forces well in excess of their design strengths. The only wire failure submitted for investigation was on just such a micronut, and due to overload. Where the reported failures have been of the chock pulling out of the rock, the main cause has been poor placement by the climber, as in Figure 4.2.

Figure 4.2 A damaged nut which pulled out due to bad placement ***Photo:*** *BMC Collection*

Figure 4.3 An example of poor placement in rock – the nut is not 'seated' with all of its edges in contact with the rock ***Photo:*** *Alex Messenger*

How to prevent failure in use

The first important thing is to look for the strength rating when buying. This is generally printed on the plastic sleeve covering the wire swaging. The EN/UIAA standard only requires that a chock is able to withstand a force of 2kN – this low requirement allows the manufacture of small chocks for very thin cracks, but has little relevance to the bigger sizes. With this in mind, the buyer should check the strength of each individual size of chock to ensure it is adequate. For the larger sizes, you should expect to see a strength of at least 10kN and ideally up to 14kN – such a chock (if correctly placed) will withstand the forces generated in the most severe of fall situations. For smaller sizes look for a strength of 7kN if possible. Chocks with less than 7kN rating should be classed as micro-nuts, to be used when nothing else will fit, but not to be relied on alone to protect against a significant fall.

The primary cause of failure of chocks in use is when they do not remain in their placement – either through poor placement by the climber, or failure of the rock placement itself. Therefore, training and experience in nut placement is of paramount importance. Simple checks can be made whilst climbing such as tugging the nut to seat it securely, or pulling outward to check stability in a horizontal direction.

Routine care and maintenance

The most important care-in-use advice is not to try to remove well-seated runners by a violent upward tug on the wire. This distorts the wires, making the chock difficult to place in future, and stresses the wires where they leave the chock, leading to premature failure of the wire. Otherwise, with these mechanically very simple devices care and maintenance is minimal, apart from the usual recommendations to wash thoroughly if there has been contact with seawater, see the Appendix on page 33.

- Cord or tape used to thread nuts should be shifted through the nut at regular intervals to spread the wear, and replaced when it becomes discoloured or shows signs of wear, or after a particularly serious fall. Check any knots frequently for slippage.
- 'Slide' nuts on swaged wires so that the wire normally hidden by the body of the chock may be visually checked.
- Chocks should be stored in a dry airy place. If they are on cord or tape, it should also be cool and dark.

Degradation and discard criteria

Apart from corrosion, damage to the chock itself will only occur either by excessive hammering to remove it from the rock, or damage if the chock is pulled out of the rock during a fall. Both are likely to be more serious for a small chock. Any significant change in the shape of the chock is an obvious discard criterion.

A more likely area of concern is the wire – these should be inspected regularly, particularly around the areas where the wire emerges from the nut. If there is any sign of corrosion, damage or breakage of wire strands, the nut should be discarded.

Camming Devices

by Alan Huyton

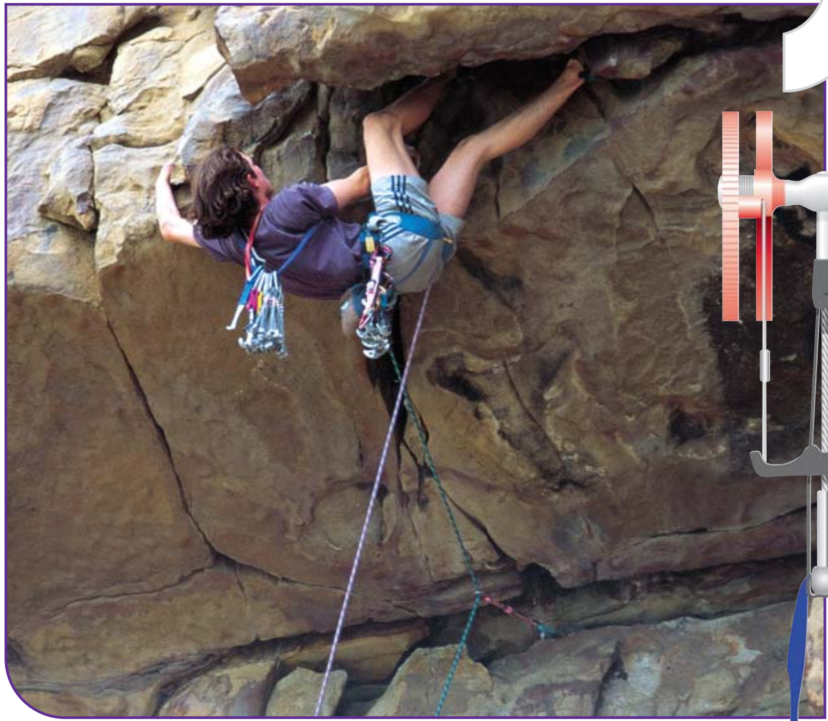


Figure 5.1 Peter Robbins in South Africa **Photo:** *Andy MacNae*

Introduction

Camming devices for climbing were first developed in the early seventies by Greg Lowe as a method of protecting the long, mildly flaring cracks of Yosemite Valley. They subsequently revolutionised climbing the world over by enabling many previously unprotectable climbs to be ascended safely. The early devices had to be removed by reaching a hand into the crack to rotate the cams, but a few years later Ray Jardine made a four-cam unit with a trigger bar, which is the basis of the designs used today. The most significant refinement of this design was the introduction of flexible stemmed units, allowing camming devices to be placed in horizontal breaks without the need to tie off the rigid stem, or risking its breakage. More recent developments include offset or different-sized cams, and extra small units to fit very thin cracks.

Relevant standards

The European Standard for spring loaded camming devices (SLCDs) is EN 12276 and this covers all types of adjustable chocks that rely on friction and will therefore work in parallel-sided cracks. Hence the standard applies to sliding nuts as well as the various types of SLCDs. The standard specifies a test rig consisting of two parallel steel plates to hold the cams and a loading bar. The force required to cause the unit to break or slip through the test apparatus should be at least 5kN. In addition the standard specifies the information which must be provided with the device, which includes a minimum guaranteed holding force (equal to or greater than 5kN). There are two important points to note about this standard:

1. The reason the tests are carried out using steel plates rather than rock is because this can be made repeatable between the various test laboratories. SLCDs rely on friction to keep them in place during a fall and there are certain situations when the friction available will be less than in the test, for example – wet, icy or sandy rock, lichen covered rock and rock with a soft surface layer. Most camming devices have teeth on the cams so they will hopefully bite through any surface layer to the solid rock underneath.
2. The strength quoted is in an ideal situation where the unit is loaded along its axis with the cams open equally on each side. In some real falls this is not the case and so the strength of the unit will be less than quoted. The 5kN specified in the standard is a minimum for the smaller units and it is known that this can be exceeded in long falls. Therefore it is recommended that larger units with strengths of 10kN or more should be used wherever possible.

There is also a UIAA standard No.125 which is closely based on EN 12276 but which has additional requirements concerning the stitching of the textile sling.

Observed faults and failures

Since 1988 the BMC Technical Committee has investigated 8 incidents involving frictional anchors, 7 of which were SLCDs. In all cases where the device broke it was concluded that the cause was due to poor placement. The BMC Technical Committee believes that if placed correctly and if the device does not rip out of the crack (which is just another form of poor placement) then camming devices are quite strong enough to hold most falls.

How to prevent failure in use

The most common cause of failure of camming devices is due to misalignment of the cams. In order to operate correctly the cams should be positioned so as to be symmetrical about the stem when loaded, as shown in Figure 5.2a. This means that the user has to estimate the direction the stem will take under load. In deep vertical cracks this is not a problem because the unit will swivel to line up with the direction of the load. However in horizontal cracks or pockets it is important that the device is placed with the stem in contact with the lower edge of the rock with the cams open equally both sides (Figure 5.2b). The temptation is to place the unit with the stem horizontal, but this is not correct as the cams will no longer be symmetrical when loaded.

The following hints may prove useful when using camming devices.

- Choose a size of unit such that the cams are between a quarter and three quarters open when placed, ie. do not use them either fully open or fully closed.
- Do not allow the cams on one side to become inverted (as shown in Figure 5.2c/d).
- Do not place the device so that the cams are in contact with the bottom of the crack or pocket (bottoming). In the case of a fall this will prevent the unit from rotating into the direction of the load. Even without a fall it will make removal difficult.

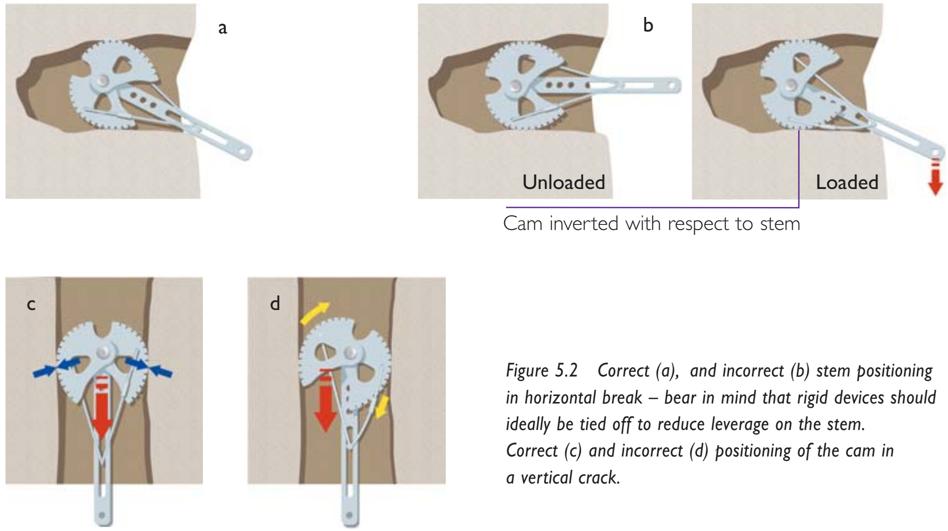


Figure 5.2 Correct (a), and incorrect (b) stem positioning in horizontal break – bear in mind that rigid devices should ideally be tied off to reduce leverage on the stem. Correct (c) and incorrect (d) positioning of the cam in a vertical crack.

- In horizontal placements ensure the stem touches the lower rock edge as mentioned above.
- Try to avoid using devices with rigid stems in horizontal cracks; flexible stem units are more suited to these placements. If a rigid device must be used consider tying off the stem close to the rock to reduce the leverage on the stem.
- Excessive movement of the rope can cause these devices to move about in the crack (walking). Be aware of this and try to choose a placement where the crack does not get wider or the unit may move and fall out. A longer extension sling can sometimes help to prevent this or another runner close by can have the same effect.
- Some camming devices have strong cam stops which are designed to hold a fall if the cams are fully open (in which case the device behaves as a chock, and camming action ceases), but many of the older models do not. Make sure you know the difference and if in doubt do not rely on them holding if fully open.
- Try not to place them deeply in cracks or in awkward positions as your second will have trouble removing them and they are too expensive to abandon!
- Ensure that the unit operates smoothly and the axle is lubricated (see section on Care and Maintenance). This is essential for correct operation in the event of a fall as well as ease of placement and removal.

Routine care and maintenance

Camming devices are fairly complex mechanisms and as such are not easily maintained. In the event of damage due to a serious fall or general wear and tear they should be returned to the manufacturer for maintenance. Most manufacturers offer this service but it should be realised that they may not be able to maintain the older models since they may no longer make the parts or the unit may be so worn or damaged that they cannot bring it back to the standard they set for their equipment. The user should regularly inspect and service the unit as detailed below:

- Ensure that the unit is clean and free from dirt or grit, particularly around the axle and between the cams. Remove with a soft brush (an old toothbrush, for example) using clean warm water and mild detergent. Rinse in clean water and allow to dry in a warm room.
- Check that the cams and trigger operate smoothly through their full range of movement and that the cams return to the fully open position when the trigger is released. Lubricate periodically and also after any cleaning with an aerosol lubricant such as GT85 or WD40, which should be sprayed between the cams and on the axle. Wipe off any surplus and avoid allowing it to contaminate the textile sling.

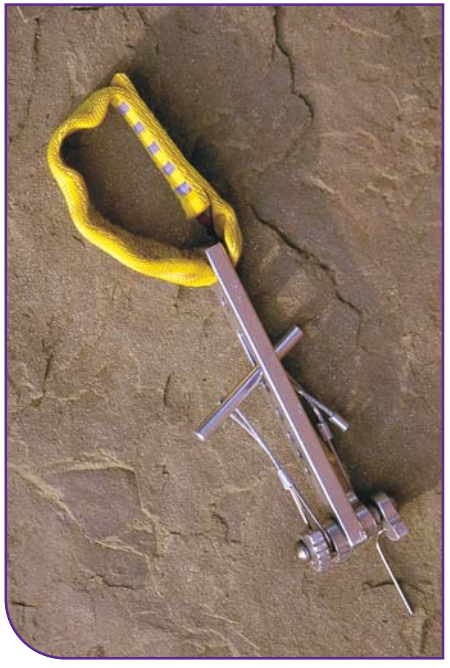


Figure 5.3 Example of a camming unit with a failed trigger wire. It is important to check the trigger wires for broken strands. Manufacturers will repair damaged trigger wires, which helps to avoid the situation shown left.
Photo: *BMC Collection*

- Examine the metal parts for any cracks or deformation and the wires for any broken strands. If any of these are found the unit should either be discarded or repaired by the manufacturer. Bent wires or flexible stems can sometimes be carefully straightened by hand or replaced by the manufacturer.
- Textile slings should be checked for wear and broken stitching and replaced if necessary. When cleaning and drying make sure slings are kept below 50°C.

Seawater

See separate section on seawater corrosion of metallic climbing equipment.

Transport and Storage

When carrying cams in a rucksack it is worth packing them carefully to avoid bending the trigger wires. For prolonged storage they should be kept somewhere dry.

Degradation and discard criteria

Of all the metallic gear on a climbers rack the camming devices are likely to wear out first. This seems particularly unfair since they are also the most expensive! The reason is simple – complex mechanisms with lots of moving parts are expensive to make and moving parts wear out. With average use, without serious falls and provided the routine care and maintenance described earlier is carried out most camming devices should last 10 years. They should be discarded if they no longer operate smoothly or if they are cracked or damaged as described in the section on care and maintenance.

6 Ascenders

by Ben Lyon

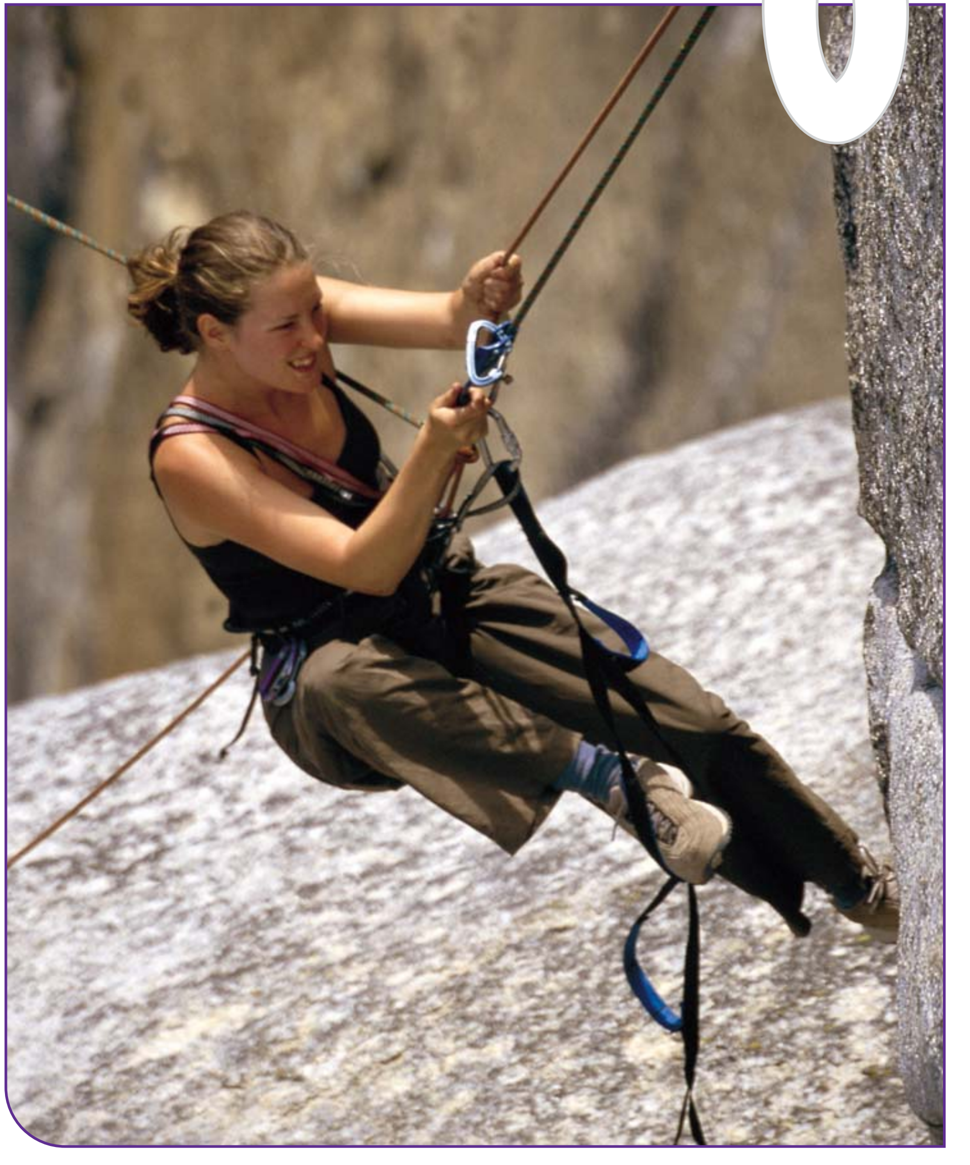


Figure 6.1 Ascender in use on the Lost Arrow Spire Tyrolean Traverse, *Yosemite Valley* **Photo:** *Alex Messenger*

Introduction

Ascenders are described as devices that when affixed to a rope, will slide or lock as required. Most (but not all) will lock in one direction only. The first ascenders were effectively the human hand and foot, but straightforward gripping is difficult on ropes of climbing diameter! The first mechanical device employed as an ascender was the Prusik knot – a closed loop of lesser diameter cord is wrapped at least twice around the rope and tucked through itself. The knot so formed will slide if pushed upwards by hand, but lock if pulled downward by the main loop. Derivatives of the Prusik knot such as the Bachmann knot incorporate a karabiner, and slide more easily whilst providing a handle (the karabiner) for ease of use. This type of knot is generally used in improvised situations, and has become less common with the advent of mechanical ascenders, which are commonly used in climbing and mountaineering situations where climbing of the rope is intended.

Most mechanical ascenders are quite large (sometimes handled) devices as in Figure 6.3, and work by trapping the rope between a cam (an eccentrically mounted rotating body) and a housing body. These can be subdivided into ascenders which are loaded via the body (most of which have toothed cams to grip the rope) and those that are loaded via the cam itself by a lever extension. The latter usually have a less aggressive cam surface presented to the rope. The latest ascender on the market (and the third type available) is a lightweight 'emergency' type clamp with no moving parts at all, that removes much of the bulk generally associated with ascending devices.

Since most failures associated with ascenders are due to inappropriate usage the various types of ascender and their intended uses are now discussed:

For individuals climbing clean ropes, ***body-loaded ascenders*** are usually more efficient. They tend to be easier to put onto the rope, and allow all the climber's effort to be translated into upward movement. There are handled, non-handled and chest-mounting body-loaded ascenders available; so make sure you buy the right type for the technique you will be using. Be aware that body-loaded ascenders require aggressively toothed cams to grip the rope, so that sheath damage will occur if they are overloaded, and this type of ascender will wear your rope more quickly than a cam loaded type. Also, the open channel construction required for rope entry means that the ascender itself may begin to open under excessive load.

If using an ascender in a situation where high loads may occur (eg. tensioning ropes in rescue situations), a ***cam-loaded ascender*** may be preferred. These are usually more fiddly to attach to the rope, but complete mechanical enclosure of the rope gives added strength and security. The lever effect that they exert distorts the passage of the rope, but this means that they exert less pressure on the rope whilst giving the same level of grip, and that wearing of the rope is less than with body-loaded ascenders. Thus, they are less likely to slip on icy or muddy ropes, but the action of the lever means that there is less height gain for each reach/step upwards.

Thirdly, very small 'emergency' ascenders with no moving parts at all are now available. These are invaluable in emergency situations or for occasional use, but must be used with care and should not be regarded as suitable for regular and repeated use.

Relevant standards

The European Standard is EN 567: Mountaineering Equipment – Rope Clamps, and the technical requirement of the UIAA standard is identical. Key requirements of the standards are:

- marking of the clamp with the range of rope diameters which may be used;
- requiring the clamp to hold to 4kN without significant visible deformation to the rope and without it breaking;
- that the clamp should have a locking device to prevent the rope becoming detached.

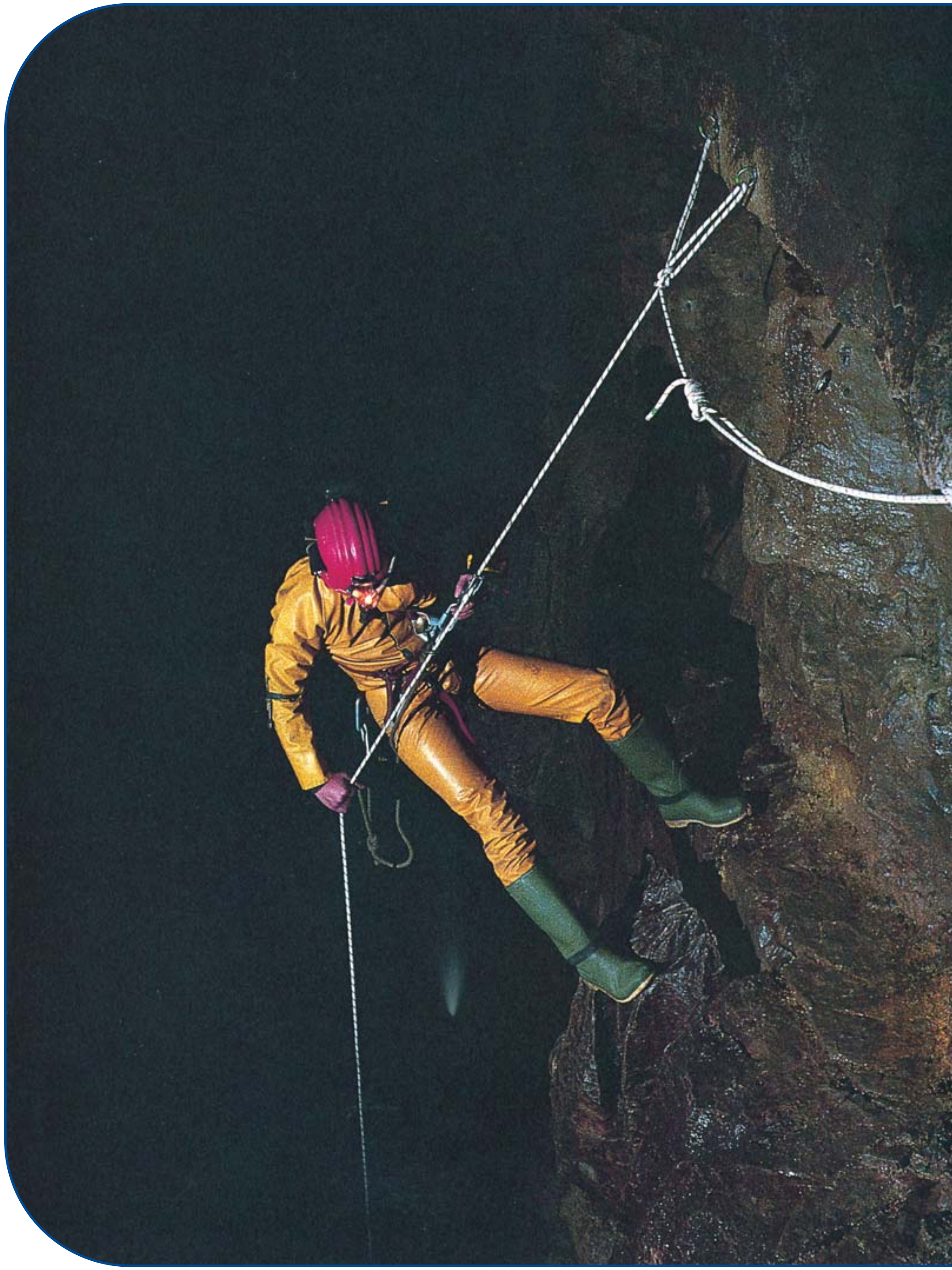
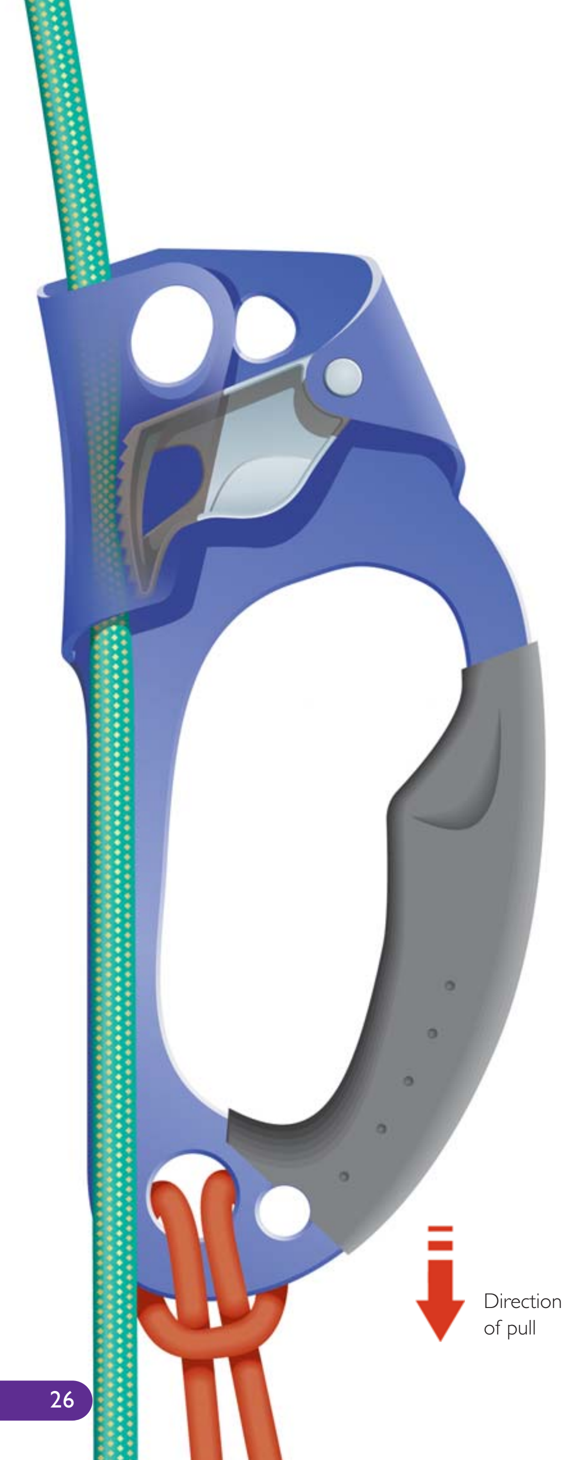


Figure 6.2 Caving in Juniper Gulf **Photo:** *John Forder*

Figure 6.3 A body-loaded ascender



Observed faults and failures

The EIP has only received one broken ascender for investigation over 20 years ago, and the cause of failure was established as fracture of the (relatively brittle) cast alloy body, probably after the ascender had been dropped or crushed. However it is possible for ascenders to fail in the following ways:

- Failure of the body of cast alloy (as in the case above).
- Failure of the cam springs, or of the cam-retaining (locking device) springs.
- Slippage due to wear to the toothed cam.
- Slippage due to mud or ice on the rope.
- Breakage of the rope by the ascender under high load.

How to prevent failure in use

The most important action you can take to prevent the failure of an ascender is to choose one that is fit for your purpose in the first instance. Use it only according to the manufacturer's instructions and inspect it frequently for signs of damage and wear. The following specific points give more guidance:

- Be aware that if the ascender has a cast metal body, it will be relatively brittle, and in particular may be susceptible to damage from impact – **do not drop**! This applies in particular to the thin handle sections.
- Test the spring actions before and after use, both on the cam and the locking device.
- Discard an ascender when the teeth are appreciably worn down.
- Try to avoid contact with mud and ice as much as possible – if this is impossible, then the cam can be assisted to 'bite ' by pushing it up the rope before putting your weight onto the ascender.

It is important to realise that all ascenders exert a very high pinching load on the rope, and some more than others – in general, ascenders loaded via the retaining body exert a higher force than those loaded via the cam.

As a general rule, ascenders should only be used to hold the static load of one person. They should never be relied upon to hold the fully loaded section of a tyrolean traverse, nor be relied upon to hold any kind of dynamic fall.

Routine care and maintenance

Ascenders will benefit from regular care and maintenance from the user. The following actions are recommended:

- Read and follow the manufacturer's instructions, and only use the ascender according to these.
- In general, care for as for any other metallic climbing equipment, so:
  - do not drop, or allow heavy loads to be dropped on the ascender;
  - after use, clean with water if necessary and dry ASAP – use an old toothbrush on dirty cams and locking mechanisms (this should be done as soon as is practical after exposure to salt water – see Appendix Section 1);
  - disinfect following the manufacturer's instructions.
- Inspect before and after each use, checking particularly:
  - that any spring actions are working correctly;
  - that the cam surface and teeth are not worn out or corroded;
  - that the body of the ascender is not appreciably worn or corroded;
  - that all axles are secure;
  - that the locking mechanism is working properly, and its action is smooth;
  - check the whole piece for cracks and wear.

Figure 6.4 Ascender with worn and damaged teeth

- Store in a dry place.
- There are no special transport requirements.

Degradation and discard criteria

The ascender should be discarded if any of the following is found:

- Any wear to the cam and teeth which begins to cause slippage in use (see Figure 6.4).
- Any visible removal of metal from the groove which the cam presses the rope against.
- Any distortion, bending, cracking or other visible damage.
- Any other reason listed in the manufacturer's instructions.

The ascender may be returned to the manufacturer for replacement of springs if these break or fail, but carefully check the remainder of the unit for wear and damage before deciding to keep it in service.

Good safety practice in action on the gritstone **Photo:** BMC Collection

7

Belaying & Abseiling devices

by Ben Lyon

Introduction

Belaying and abseiling devices both work by bending the rope around a radius to give friction, which is then used to arrest a fall or control a climber's rate of descent. They may also pinch or squeeze the rope to give additional holding power. The first incarnation of the belay device was a rock spike or boulder around or behind which the belayer held the rope – this is known as a ***direct belay***. The performance of this system ranged from the devastatingly abrupt, in which the falling climber suffered a sudden, total arrest (sometimes causing the rope to snap) to the spectacularly ineffective 'we'll-all-go-together' variety experienced all too often in the early days of alpinism.

Then came the human or ***indirect belay***, in which the climber secured himself to the rock with a loop of rope, and wrapping the live rope around his body, used himself as a capstan-type friction brake. Abseiling was carried out in the same (rather painful) way – the descender was the descender, so to speak! The human belay had the important advantage over the direct belay that it allowed the climber to vary the amount of friction used, thus fall arrest and descending could be carried out in a more controlled manner.

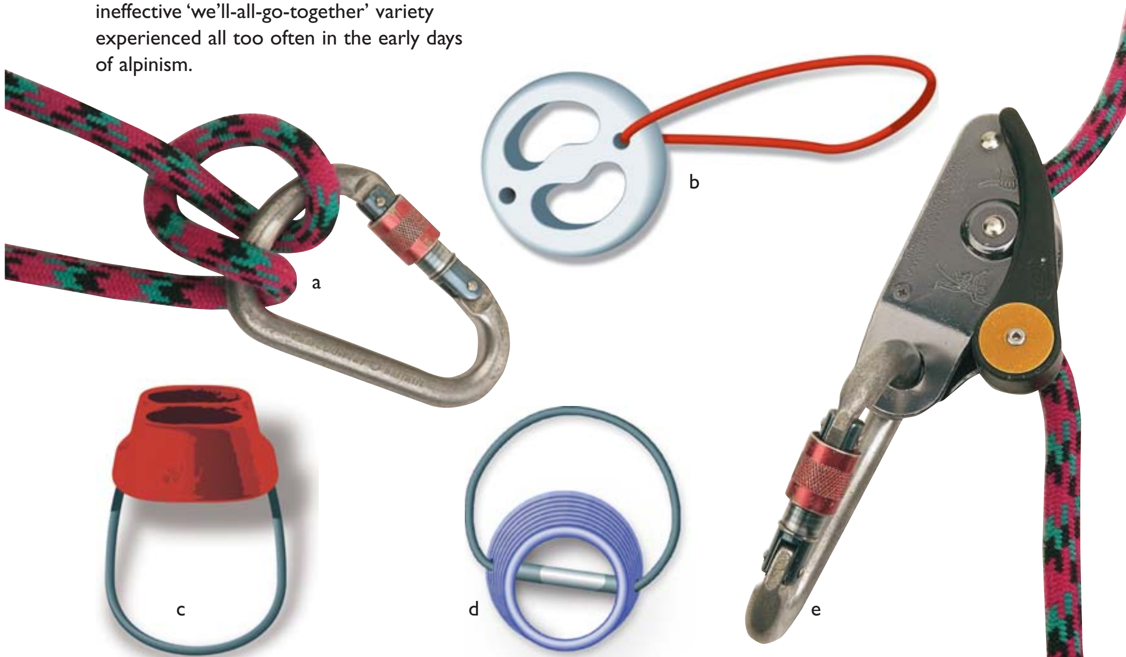


Figure 7.1 Belay and abseil methods and devices ***a:*** *Italian Hitch,* ***b:*** *Sticht Plate,* ***c:*** *ATC,* ***d:*** *Latok Tuber,* ***e:*** *Grigri*

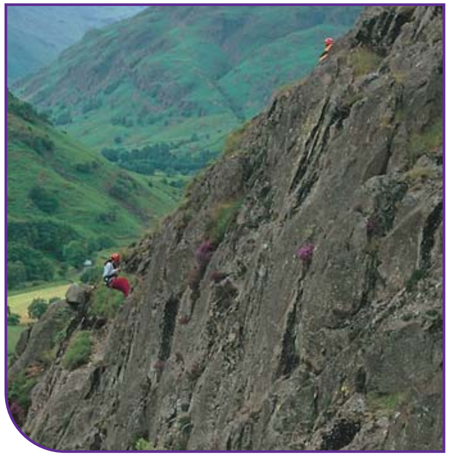


Figure 7.2 Abseiling under instruction
Photo: *BMC Collection*

The first modern belay device was probably constructed from two (or four) karabiners placed at 90º to each other, with the rope forming a loop over and under the bar of one of the karabiners. Another common early form of this dynamic belay was the use of an Italian hitch tied on a karabiner with a wide nose profile (pear-shaped). Both of these methods can still be usefully employed today.

Nowadays, belay and abseil devices come in many shapes and sizes (Figure 7.1), but are all basically metal devices through which the rope runs, with a varying amount of friction and/or pinching, allowing a high force on the exit side to be controlled by exerting a lower force on the entry side. The only fundamental difference between a belay and abseil device is the way in which they are used – a belay device is held static whilst the rope runs through it, whereas an abseil device slides down a static line. Thus, as far as the bit of metal forming the device is concerned, the distinction is rather academic – abseil devices can in theory (and often in practice) be used as belay devices and *vice versa*. Currently available designs fall into one of four categories.

- **Flat plate (such as sticht plate)**
  A basic circular plate with holes through which the rope is fed; when used in conjunction with a karabiner this bends the rope through two dimensions. When actioned by the belayer, it provides both frictional and pinching effects and 'grabs' the rope. This tendency can be both a help and a hindrance. There are many design variations, providing various relative degrees of friction and pinching, and hence differing ease of use. In all cases the principle is the same.
- **Tube devices (such as ATC or Tuber)**
  A short tube through which the rope is fed. As with the flat plate, it is used with a karabiner and bends the rope in two dimensions. Unlike the flat plate, it does not pinch the rope, but relies instead on friction. These devices are characterised by relative ease of use and 'slick' feed, but the lack of a pinching action increases reliance on the strength and skill of the belayer.
- **Figure-of-8**
  This design bends the rope through 3 dimensions to create friction, and with these devices the karabiner is required only to provide attachment to the climber's harness, not to provide friction. Again, many variations exist, but all are characterised by a high degree of 'slickness' in use.
- **Locking devices**
  These have the advantage that a climber can be held on the rope for long periods of time without the belayer needing to maintain tension on the live rope, and most will lock quickly in the event of a fall. However, they are not infallible and require skill and vigilance from the user to perform correctly. They are often of a more complicated design and may contain moving parts, so their care and maintenance becomes more of an issue.

Relevant standards

There are no current standards for belaying and abseiling devices for mountaineering and climbing – at present the UIAA Safety Commission is working to produce one. There is a European Standard (EN 341) for descenders, which defines these units as 'rescue devices', and is intended to describe parameters for lowering people to safety via a rope and descender. Unlike most other items of metallic climbing equipment, belay and abseil devices have not been classified as Personal Protective Equipment (PPE), and hence do not carry a CE mark. This situation may well change in the near future. A few abseil devices used for climbing have been certified to EN 341, but when looking for the right buy, you should not be influenced for or against on the basis of conformity to this standard.

The important consideration when selecting a device is that it is fit for purpose: ask yourself the following questions:

- Does it need to work on one rope or two?
- Is it suitable for the diameter of rope to be used?
- Does it provide enough friction for you to control it effectively? Does it operate smoothly or tend to 'grab' and lock under sudden load?
- Will you use it for both belaying and abseiling?
- Do you have the necessary skills for its safe use?

Observed faults and failures

The Technical Committee is aware of numerous cases of failures within belaying or abseiling systems, but be aware that the system includes the user and that very few, if any of these failures can be attributed to the actual device in use. Belay and abseil devices are very much a part of a system and do not work by themselves, but in conjunction with karabiners, ropes and most importantly climbers. Common causes of system failure include:

- misusing locking devices, preventing their proper action;
- inserting the rope/s wrongly into the device;
- using the wrong diameter of rope;
- using double ropes of differing diameters in double rope devices (resulting in differing amounts of friction between the two ropes);
- incorrect alignment of the device and connecting karabiner;
- insufficient strength/skill or care and attention of the belayer/abseiler (may be due to tiredness, cold or distraction);
- poor or inattentive holding technique;
- allowing the device to provide too little friction, resulting in the rope travelling through the device too quickly (or even freely), possibly resulting in burned hands and releasing of the rope;
- clothing or hair becoming jammed in the device;
- relying totally on a locking mechanism, or using it as a 'hands-free' device;
- adopting a poor belaying stance (eg. standing precariously balanced, sitting or lying down or standing too far away from the rock), resulting in stumbling or slipping in the event of a fall and releasing the device.

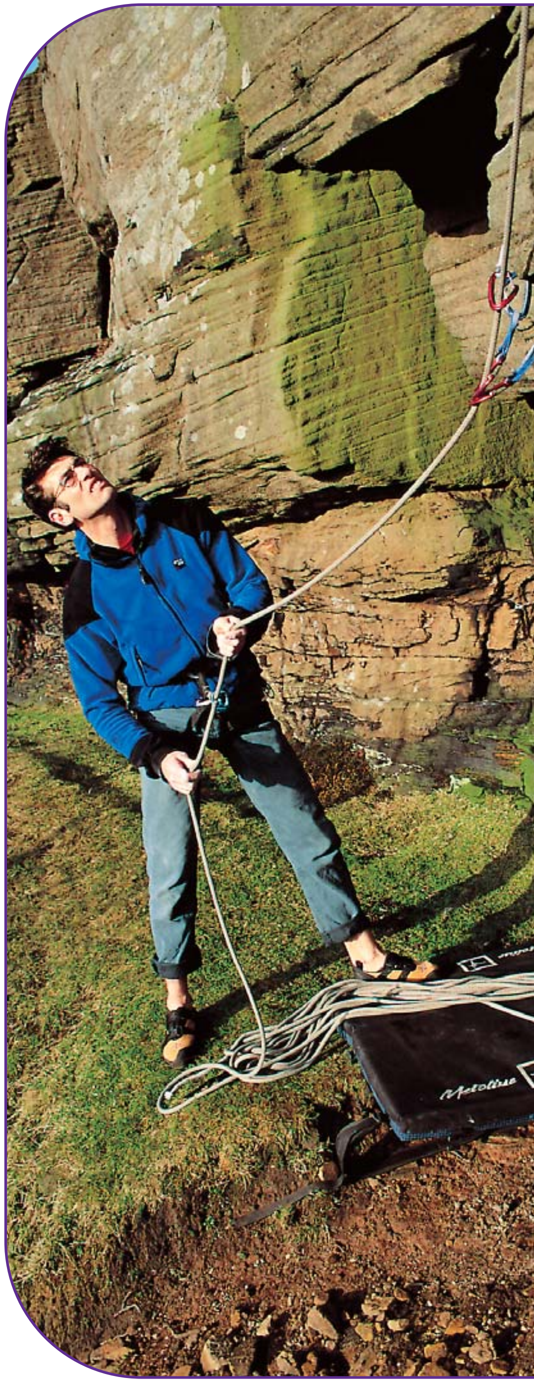


Figure 7.3 Attentive belaying **Photo:** *David Simmonite*

How to prevent failure in use

The above points can be summarised by recognising that ***abseiling and belaying require skills from the user, which need to be properly taught and practised***. Every device has different performance characteristics, and may require specific rigging and handling to perform effectively. Even if you are completely familiar with a type of device and do not need to learn new user skills, constant attention must be paid to the device and your handling of it to prevent possible failures. Smoothly operating (or 'slick') devices tend to require more physical hand strength from the belayer, whilst the most efficient locking devices can allow a light climber to hold a much heavier one very effectively. However, this increases the peak force applied to the whole safety system – ropes, runners, climbers, harness etc. Slick devices generate lower forces in belaying, thereby allowing more rope slippage through the device in the event of a fall. Anyone using this type of device must be aware of this!

For further information and advice, consult the BMC/MLTB belaying leaflet and poster, or any good instructional handbook.

Routine care and maintenance

Simple devices of the sticht plate variety require very little in the way of maintenance, but must be periodically checked for damage and wear. More complex locking devices will require more attention. In general:

- read and follow the manufacturer's instructions;
- care for as with other metallic climbing equipment as discussed in previous sections;
- inspect before and after each use for rough edges or burrs on the path where the rope will run, excessive wear of the device and any corrosion and/or cracks (use a magnifying glass);
- with locking devices, check that all mechanisms and springs are operating correctly and smoothly, and are properly lubricated;
- check that any attachment wires or cords are secure and in good condition;
- after use, clean in water paying attention to any moving parts and dry thoroughly – particularly if there has been exposure to salt water – see Appendix Section 1.

Degradation and discard criteria

With care and proper usage, a belay/abseil device (particularly the simple one-piece designs) may have a lifetime exceeding that of the user! However you should discard the unit immediately if there is an appreciable removal of metal due to wear and tear from normal use.

With locking devices pay particular attention to the moving mechanism, and discard if this has become worn in any way, or fails to generate enough friction for safe use. If the device is dropped or otherwise damaged, check it very carefully for ill effects before continuing to use it.

8

Appendix – Principal degradation mechanisms

by Neville McMillan, Rob Allen & Trevor Hellen

1. Seawater Corrosion

Seawater and airborne sea spray present a number of corrosion problems of varying severity to all metallic climbing equipment. ***In all cases, the corrosion is electrolytic with the chloride ions in the seawater acting as the electrolyte. In climbing equipment electrolytic corrosion can take one or more of the following forms:***

General corrosion
This occurs in the form of uniform chemical attack, and is the most easily detectable form of damage as it is visually obvious on the outer surfaces of equipment. ***This corrosion does not usually cause a problem with PPE, (as items are usually retired when they acquire a thin surface layer of corrosion products), but its presence is a useful indicator that other, more serious forms of corrosion may be active elsewhere on the component. This form of attack is however an issue with in-situ pegs as shown in Fig 8.2 (see also the section on localised corrosion).***

Galvanic corrosion
Galvanic corrosion occurs when two dissimilar metals are in contact in the presence of an electrolyte (ie. in this case seawater). These conditions are met (for example) in the hinges of karabiners and on the axles of camming devices where aluminium alloy and steel are in contact with each other. Such small gaps provide ideal sites for water to collect, and corrosion in these locations can lead to a much stiffer action of the moving parts, or even complete sticking. This could result in the gate of a karabiner not opening or closing properly, or the cams of a camming device failing to operate.

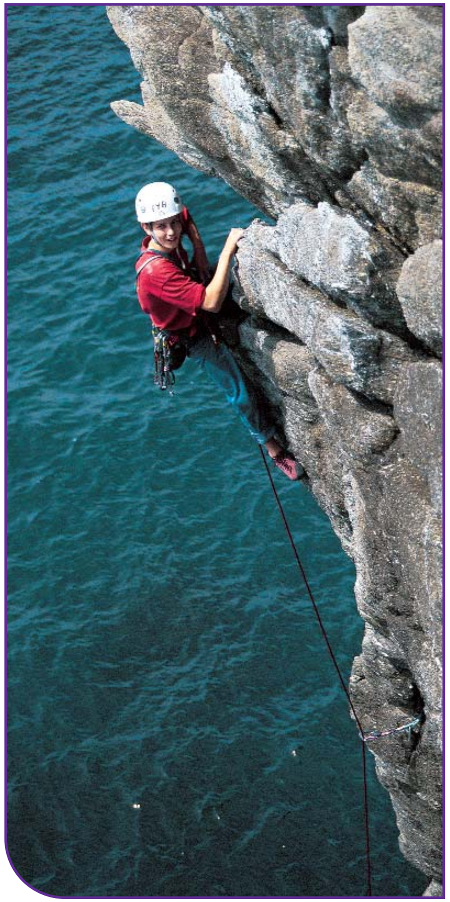


Figure 8.1 Sea-cliff climbing can be outstanding – but what is happening to your gear? ***Photo:*** *BMC Collection*

Figure 8.2 Badly-corroded piton ***Photo:*** *David Hillebrandt*

Localised corrosion
This can occur as pitting corrosion (which is confined to a small point or area, and takes the form of small cavities), or crevice corrosion (associated with sites such as small gaps and crevices). Both forms of attack can locally thin the metal, making it more prone to stress-related failure, and in addition crevice corrosion can lead to exfoliation of the metal ie. cumulative degradation propagating outwards from the crevice site.

The most severe forms of attack are ***intergranular corrosion*** and ***stress corrosion cracking*** (SCC). These can occur in several alloys when exposed to aqueous chloride ions and oxygen (in combination with tensile stress in the case of SCC). They manifest themselves as fine, potentially deep cracks, which can be exceedingly difficult to detect and can result in catastrophic failure of metallic climbing equipment. Fortunately, only one instance of this type of failure has been known to occur to climbers' Personal Protective Equipment (15 years ago), and this was attributed to a quality control problem with the alloy, which was rectified. ***However, a number of failures attributed to SCC have been reported in stainless steel bolts in Thailand, The Cayman Islands and the Calanques sea-cliffs of Southern France. No such failures of bolts in the UK have yet been reported to the BMC, but this issue is currently under investigation by the UIAA.***

In storage, it is essential to keep metallic equipment dry!

After every use of metallic climbing gear on sea cliffs, and anywhere within the region of sea spray (which may extend well over and around the actual sea cliff in rough weather), it is recommended that the following procedure be carried out:

- After finishing climbing for the day, keep the dry gear separate from the wet, and make sure it is kept away from any damp ropes, slings and clothing etc – even to the point of carrying a drybag to store dry equipment. Any wet metallic equipment should be washed thoroughly in tap water or a freshwater stream to remove all traces of salt, then after removal of surface water it should be hung out to dry. This should be done even if the plan is to climb again the following day.
- If you are travelling home, do not leave any metal equipment that may have been contaminated with salt water in a rucksack or other carry bag where it may come into contact with slings or ropes – especially in a warm environment – as this will induce corrosion. If karabiners or camming devices are left like this for, say, a week, they will at the very least become discoloured and suffer surface corrosion. Within a few weeks, they could be so badly affected as to be unfit for further use – a costly mistake!
- As soon as possible after returning home, all metallic equipment that has been contaminated with salt water should be thoroughly washed in tap water, preferably with a little mild detergent. Then remove all surface water and put in a warm, dry, airy place (such as a rack in an airing cupboard) to dry off the remaining moisture. With chocks and camming devices, take special care that the wire cables have been thoroughly washed and dried.
- When dry, any hinges, movable joints, wires and cables etc. should be treated with a suitable aerosol lubricant, any surplus wiped away, and the movement checked before storage.

2. Stress degradation

Any piece of equipment that operates under applied loads becomes subject to the effects of the stresses that result from those loads. Thus, any structure or component used in an engineering application becomes stressed during the normal course of their intended operation, and metallic climbing equipment is no exception to this. For instance, when a climber falls, the rope takes the climber's weight along with the harness, karabiners, slings and protection placed – all become stressed to a degree. The manufacturers design their equipment to withstand these stresses, but in conjunction with wear & tear and time, continued stressing sometimes leads to a failure. For example, crampon points and ice tools are subjected to continual and sometimes abnormal loading (as in torquing when mixed climbing), which can sometimes be above and beyond the intended design load. In some cases, this load is greater than the equipment can sustain and failure results.

3. The effects of overload

All items of metallic climbing equipment are designed to be able to withstand a certain amount of applied load, which translates to a certain amount of internal stress. The maximum load of the design is known as the ***failure load***, or internally as the ***failure stress***. Obviously equipment that is required to be lightweight (such as a micro nut) cannot sustain a very high load otherwise it would cease to be light. Hence the standards for mountaineering PPE require the manufacturer to state the failure load *on each piece of equipment*.

Clearly a single application of a large enough load will cause an instant failure (Figure 8.3) or breakage, thus removing that piece of equipment from the load chain. This load is termed an ***overload***, and obviously should be avoided wherever possible by careful usage. If an overload does occur, then it is to be hoped that there will be another piece of equipment in the chain that can absorb the new load, such as when a climber falls and his top runner fails due to overload, then the next runner down will hopefully not experience its own failure load, and therefore will hold.

Overload can also arise when a piece of equipment is dropped onto hard ground, for example. If brittle enough (eg. the cast body of an ascender), the unit will fail by sudden cracking. As explained later, this is more likely to happen in steel alloys under low-temperature conditions.

4. Fatigue

Whilst the maximum failure load is a concept central to all engineering applications and their designs, another aspect of equal concern is ***fatigue***. Fatigue is well recognised by professional engineers in nearly all materials, but especially in metallic alloys since it affects the life span of a product. If a load is applied that is lower than the stipulated failure load of a particular piece of equipment, but is done so repeatedly, then the piece may eventually fail. This process is known as fatigue failure. Each load application is known as a cycle, and the less the load, the more cycles are required to cause a failure (if the load is small enough then a failure will never happen). However in reality for climbing equipment, the load level over a sequence of cycles is not constant, and a sudden big load equalling the failure load will cause the piece to fail.

The importance of fatigue effects implies the need to keep the amount of load to a reasonable level – well below the failure load – and to avoid sudden large loads, thus prolonging the fatigue life of the item. The design of a piece of equipment should take fatigue into account in the following way:

The usual loads expected should be such that many thousands of cycles are required before fatigue failure, and this should be beyond the expected usable lifetime of the product.

However, if through exceptionally heavy or abnormal use too many cycles have been accumulated and failure is near, then cracks in the highest stressed areas will be forming and growing. Hence, a close examination with a magnifying glass on well-used equipment will be very worthwhile – a common example is cracking at the base of the front points of well-used crampons.

In climbing terms, this means that reasonable use should attempt to avoid any chance of fatigue failure by limiting the number and/or severity of the load cycles. Examples of equipment use that go against this are:

- excessive torquing, or repeated hitting of hidden rocks under ice, will shorten the life of an ice tool;
- hard, awkward walking or scrambling over rocks in crampons will shorten their useful life (especially that of the front points).

5. Wear

Wear is a phenomenon that occurs when metallic surfaces are rubbed by other surfaces under pressure, and local shear stresses arise. Because of these, particles on the surface are eroded, and the physical volume of material locally decreases – see Figure 8.4. The higher the contact pressure and the softer the material, the greater the rate of wear. Sharp surface features (like edges and corners) will also erode quicker than smoother parts, because the stresses in those features are higher under a rubbing force.

For climbing equipment, any contacting surfaces are liable to wear since most alloys in common use are relatively soft. The most usual high-pressure situation encountered in practice is that of ropes passing through karabiners, abseiling and belay devices etc. Grooves can appear in these items of metallic equipment, and since a noticeable groove represents a new surface geometry with some material removed, the performance of these items will alter over time. This has the further implication that the failure load and other design parameters of the item are changed, and a safe course of action is to retire the piece of equipment once such a groove has become noticeable.

Karabiners that have been used on *via ferrata* wire cables are also prone to accelerated wear.

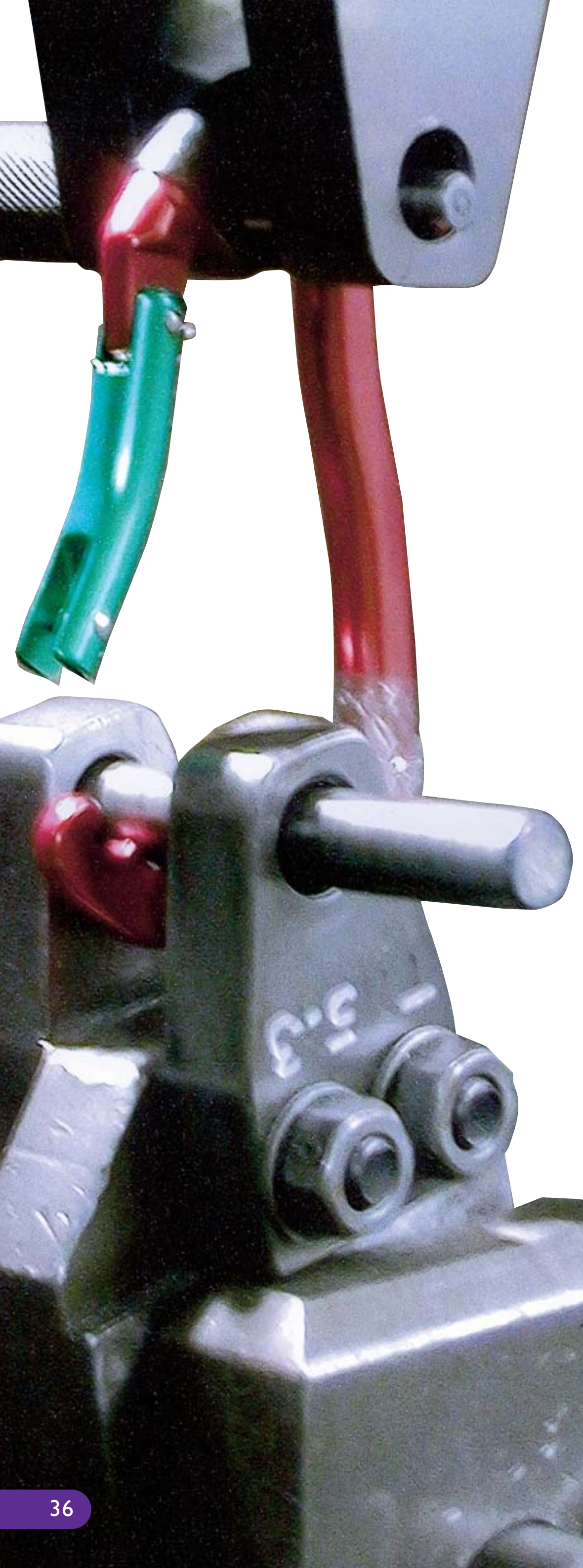


Figure 8.3 Testing the failure load of a karabiner
Photo: *DMM*

6. Cracks

The presence of cracks in any structure that is designed to carry load is potentially dangerous, but obviously so where metallic climbing equipment is involved. Cracks can arise for several reasons:

- During manufacture or heat-treatment of the equipment, commonly during welding processes – these are invariably detected at an early stage, or not critical to the intended performance of the equipment.
- During a sudden overload when the failure load is exceeded and the item breaks – this is effectively the sudden initiation and catastrophic growth of a crack through the weakest part of the equipment.
- Due to corrosion – see Section 1 above.
- By fatigue as explained above. Such a crack starts at a microscopically small size, growing as the fatigue life progresses until it is big enough to be noticed by the naked eye. In climbing equipment, this usually means that the fatigue life is nearly at an end, and that a failure is imminent. This is the reason for recommending ***regular inspections of equipment both with the naked eye and with a magnifying glass***, and when such a crack is detected to retire the item immediately.

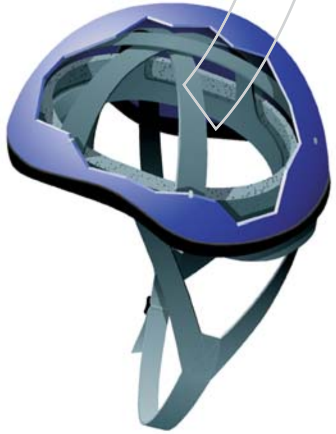
Continued use of a cracked item will almost certainly lead rapidly to sudden failure – a very dangerous situation.

Another relevant consideration when considering cracks is the influence of temperature. If the temperature is low enough, the brittleness of a material can increase significantly and any small cracks are liable to sudden and catastrophic breaking, like shattering glass. At higher temperatures, materials exhibit a more ductile characteristic making sudden cracking much less likely. For the alloys used in climbing equipment, the transition temperature between this brittle and ductile behaviour occurs somewhere in the range –50°C to +50°C. The important factor for climbing equipment is that at cold extremes, it is more liable to brittle fracture, and prolonged use in these conditions increases the likelihood of this occurring (for example, during an expedition). Although a lot of care is taken to consider this during design and material choice, it is prudent to check regularly for cracks in equipment that is used at cold temperatures for extended periods of time.

Figure 8.4 Grooved, worn karabiner

Helmets

by Dave Brook



Introduction

The helmet is a very important (and vastly underused) piece of safety equipment in the world of mountaineering and climbing. There are many instances of accident reports containing phrases like 'serious injury/death could have been avoided had the climber been wearing a helmet'. Obviously it is a matter of personal judgement and choice whether to wear a helmet or not, but prudence and common sense would suggest the former.

*Video stills from the film **Equilibrium** courtesy Mark Turnbull, **Intrepid Film**.*

Figure 9.2 Shell/cradle helmet

The first helmet designed specifically for mountaineering appeared in the 1960s, but industrial helmets or cycle caps had been pressed into use well before this. Alternatively, climbers improvised with whatever was to hand – Don Whillans famously using (and losing) his flat cap stuffed with money and cigarettes! Nowadays, helmets come in three basic types, each more suited to a slightly different end use.

Fibreglass/resin composite shell
This was the material first used to manufacture helmets, and offers longevity and durability at the expense of being generally heavy (though there are exceptions), and poorly ventilated and therefore can be hot to wear (good in winter!).
Many outdoor centres and group users choose this type of helmet.

Plastic shell
(Injection-moulded or vacuum-formed)
Advances in material technology allowed the production of these lighter and better ventilated helmets but this type of helmet will almost certainly not maintain an acceptable level of protection for as long as a fibreglass/resin shell.

Both the above types can be categorised as the more usual style of mountaineering helmet consisting of a hard outer shell and an interior cradle to secure it on the head in conjunction with a chinstrap. For many years these were the only types of mountaineering helmet available, primarily designed to protect the wearer's head against stonefall from above. Recent years have seen the rise of a third type, more geared to pure rock climbing, ie. protecting against impact with the rock rather than falling rocks themselves.

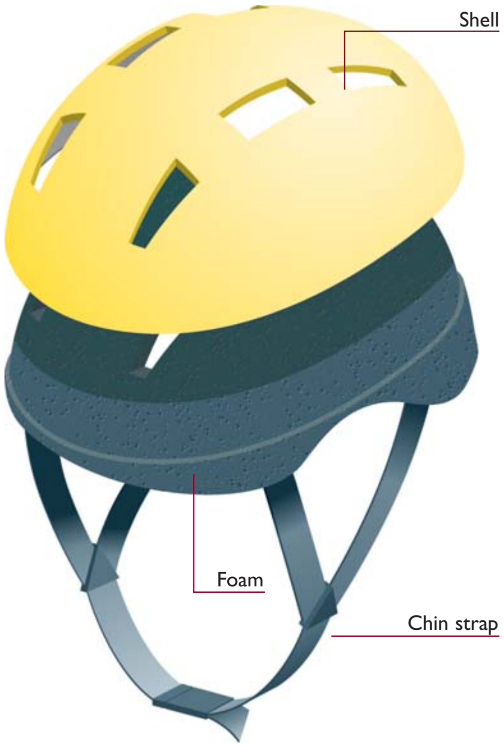


Figure 9.3 Expanded polymer foam helmet

Expanded polymer foam helmets
Akin to a cycling helmet, this type uses a thickness of foam in conjunction with a thin plastic skin as the energy absorber, rather than the traditional shell and cradle system. This allows the helmet to be lighter and more comfortable (thus making the user more likely to wear it) at the penalty of a higher peak transmitted force. Helmets of this type with a fairly uniform thickness of foam have been shown to give good protection to the front, side and rear of the head and are thus well-suited to protecting against head injuries during rock-climbing falls.

Relevant standards

When considering helmet design, manufacturers must give thought to two main criteria – the peak force transferred via the helmet to the climber's neck (this must not exceed 10kN), and the penetration of the helmet (and head!) by sharp objects. These form the basis of the tests that a helmet must pass to gain the standard specified by EN 12492. In addition, the retention system (ie. cradle and chinstrap) and front, side and rear impact forces are subject to testing. The UIAA standard is similar but more stringent; for example, the peak force transmitted must not exceed 8kN rather than the 10kN allowed in the EN standard.

Observed faults and failures

In the last ten years, six incidents involving helmets have been reported to the EIP – in five of the six cases, the helmet did its job and prevented injury or death. The sixth case involved use of a helmet, manufactured to the industrial standard but used in a climbing situation, where the chinstrap released itself on impact (as industrial helmets are designed to do), leaving the wearer helmetless and exposed to further impacts, from which he died.

How to prevent failure in use

There is a clear message from the case of the industrial helmet incident noted above –

Ensure that the helmet is a good secure fit on your head and check that your chinstrap is secure and holds the helmet tightly on your head!

It is worth spending some time adjusting the retention straps, side buckles, and chinstrap, preferably in front of a mirror, to ensure that:

- the helmet cannot be pushed up in front and over the back of the head;
- the helmet cannot be pushed up at the back, over the face, and off the head.

Such adjustments are crucial to ensuring head protection in a sliding fall.

Routine care and maintenance

In addition to checking the chinstrap and overall fit frequently, the following actions are recommended:

- Do not expose your helmet to high temperatures (eg. on a car parcel shelf) or unnecessary UV light. This will accelerate degradation of the shell material.
- Don't sit on your helmet – sideways loads in particular are undesirable.
- Paint and stickers may degrade some types of plastic helmets. Always check before applying, or better still don't bother!
- Frequently inspect your helmet for any signs of damage, not just to the shell, but also the cradle, chinstrap and attachment points.
- Do not store wet, and always rinse thoroughly after exposure to salt water – any rivets can quickly corrode.
- Helmets are best stored in a cool dark place – as usual keep away from corrosives and solvents if stored in a garage or similar.

Degradation and discard criteria

In a similar manner to the way that the bonnet of a car crumples in a head-on crash in order to reduce injuries to the passengers, a helmet crumples, or suffers internal damage in protecting the wearer's head. Every impact degrades the helmet to some extent. A severe impact reduces a helmet's protection capability to such an extent that it should be discarded and replaced as quickly as reasonably possible.

The problem is that helmets do not necessarily show outward signs of serious damage. GRP or other composite shells do show obvious damage after severe impacts, but injection-moulded or vacuum-formed plastic shells may not. Some foam polymer helmets may not show any outward signs, but if cut in two it would become obvious where a severe impact had occurred. Hence the owner must take note of all impacts in use, and use judgement in deciding when to discard – contact the manufacturer for further guidance.

Even without major impacts, helmets deteriorate in performance over time due to degradation of the shell material. Again, composite and injection moulded models are different – the former can still perform well after 20 years of light use, but plastic helmets have been found to degrade to the point where they will no longer pass the standard tests after only 5 years. This should be considered as grounds for retirement. As a general rule, the larger the original energy absorption capacity of the helmet (in other words, the lower the stated value for transmitted force), the longer the usable lifetime of the helmet. Check the information supplied when purchasing a helmet, and follow the manufacturer's advice on lifetime.

Figure 9.4 Damaged helmets **Photos:** BMC Collection

Ropes

by Dave Brook

*The following section provides a summary of a very important area of equipment. See the BMC **Ropes** booklet for more comprehensive coverage.*

Introduction

The rope is the most vital piece of safety equipment for use in climbing and mountaineering, and was one of the first pieces of gear to be employed for safety in the sport. The earliest ropes used by the pioneers were made from natural fibres like manila or hemp, but their low energy-absorption capability and breaking strain meant that they offered more in the way of psychological rather than actual protection, very often breaking whilst in use!

The ropes were constructed by twisting three thick bundles of fibres together to form a cord of around 11mm thickness – a ***hawser-laid rope***. Immediately after WWII, improvements made in materials during the conflict allowed rope manufacturers to start using nylon cords, which provided much greater energy absorption, although ropes were still hawser-laid in construction.

"Roped together on the tricky descent, the hopelessly inexperienced Hadow slipped, pulling with him three of the others. The last in line, who were tied to the rest of the chain by a weak sash-cord which broke under the strain, could only gape aghast as one of the most famous guides in the Alps, an English Lord, an accomplished English climber and an unfortunate novice, plummeted to their deaths."

The description of Whymper's disastrous first ascent of the Matterhorn, taken from *A Brief History of British Mountaineering*

Figure 10.1 Doré's etching of Whymper's disaster on the Matterhorn in 1865

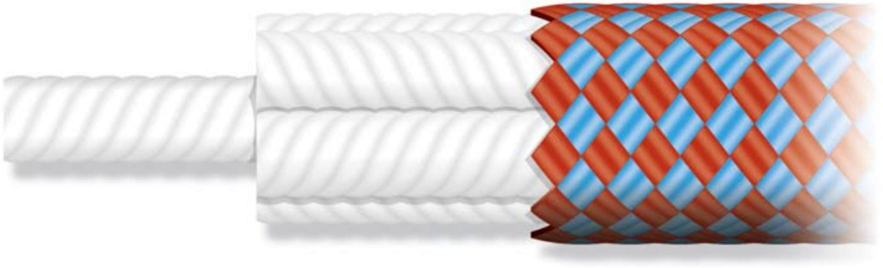


Figure 10.2 Kernmantle/core construction

These ropes were a vast improvement over the old fibres, allowing a fall to be stopped reliably without the rope breaking. The first modern climbing ropes were made in the early 50s in a ***kernmantle construction*** – a braided sheath (the ***mantle***) surrounding a load-bearing inner core (the ***kern***). All ropes manufactured today are of this design, which offers vastly superior handling, durability and energy absorption. However, ropes are manufactured to many different specifications for different uses, and an outline of the varieties available is given below (refer to the BMC Ropes booklet for a more in depth discussion):

Dynamic Ropes

- **Single (full) ropes –** Classically 11mm in diameter, but now varying from 9.2mm upwards, these ropes are used singly in situations where a leader fall is a possibility.
- **Half ropes –** Historically 9mm in diameter (now from 8.1mm), two half ropes are used simultaneously to protect against leader falls, and have the advantage of allowing more spaced protection to be placed without prohibitive rope drag. Having two ropes as opposed to one also allows climbers to abseil twice as far in one go.
- **Twin ropes –** These are of a smaller diameter than half ropes, and must be used in pairs with both ropes clipped into every piece of protection. Very rare in the UK, but common in the Alps.

Low-Stretch Ropes

Primarily used by climbers (and cavers) for abseiling or ascending, these ropes have very low stretch and have little energy absorbing capability and so ***must not be used for lead climbing!***

Accessory Cord

Smaller diameter rope, used for slings, Prusik loops, etc. It should be noted that accessory cord is not designed to have any energy absorption capability, and must never be used as climbing rope. See *Chapter 3 – Slings* for further information on standards, care and maintenance.

Relevant standards

Ropes of kernmantle construction for use in climbing and mountaineering (and that are designed to hold leader falls) are manufactured to standard EN 892. Low stretch ropes designed for uses other than holding leader falls (eg. abseiling or ascending) are made to EN 1891. The use of these ropes and their sub-types is fully covered in the BMC booklet on ropes, to which reference should be made.

Observed faults and failures

The Technical Committee has received 20 reports of failures and/or serious damage to ropes (both dynamic and static) over the last 15 years. Two failures were caused by contamination of the rope by corrosive substances, one (dynamic) rope was damaged – but did not fail – as a result of excessive jumaring, and the remainder were due to serious abrasion over rough or sharp rock edges. In a small number of cases, abrasion to the rope resulted in its failure during a fall with serious consequences, including one fatality.

How to prevent failure in use

The key to preventing failure during use is to minimise abrasion, or at least recognise serious abrasion to a rope before you use it through ***regular physical inspection of the entire length of the rope***. This is probably most easily done whilst coiling the rope after a climbing session, and should be practised without fail. Assuming that there is no visible damage to the rope when you begin using it, the overriding priority whilst in use is to ***avoid allowing the rope to drag over sharp edges and rough rock*** as in Figure 10.3. This necessitates constant attention to where the rope might run during a climb, and also to how and where it will be loaded over the rock in the event of a fall. This in turn requires some skill and knowledge on the part of the climbers whilst placing runners (look out for sharp edges and protrusions near your runner placements) and setting up top-rope or belay anchors (often the use of a rope protector or padding material is appropriate). In addition:

- Do not throw the rope down onto gritty or sandy ground if at all possible – small particles of dirt or grit can adhere to the nylon and then be ground into the sheath or core during normal use. Potentially this could cut some of the ropes fibres and cause it to fail with no visible evidence that it had been weakened.
- Avoid standing on your rope for the very same reason. It goes without saying that you should exercise extreme caution whilst using your rope with ice tools and crampons.
- It is advisable to avoid speedy abseils, which allow the abseil device to heat up very rapidly and can cause melting of the rope if the descender remains in contact with it at the end of the abseil – nylon has a low melting point!

Routine care and maintenance

The most important aspect of caring for your rope has already been mentioned above, but it is so vital that it is worth saying again:

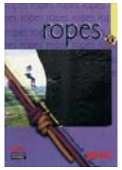
Inspect the rope frequently (ideally before and after every use) for signs of abrasion, damage and wear and tear.

Figure 10.3 Serious damage to a rope in use
Photo: *BMC Collection*

Most ropes are not user-maintainable, and the only task you should need to perform during its life is that of cleaning it. To do this use warm water and a very mild (pH neutral) detergent such as natural soap flakes (if any at all) or a proprietary cleaning product from one of the manufacturers. A rope can be cleaned and soaked in the bath, or pulled through a plastic tube with soft brushes on the inside, several versions of which are commercially available. Always follow cleaning with copious rinsing in fresh, clean water and never use a pressure washer as this can drive any grit or dirt deeper into the rope, where it may damage the nylon fibres and cause the rope to fail.

Ropes are best stored (long term) in a cool dark, dry place. Be especially careful to avoid contact with corrosive substances in places such as garages. It is sensible to avoid strong light and extended exposure to UV rays, although there are no known instances of a rope failing due to UV degradation, since the core is protected from UV by the sheath.

Degradation and discard criteria



The following is adapted from the BMC ropes booklet

The BMC receives literally hundreds of calls each year asking for advice on this subject. Ideally, it could be said that, after a given time or pattern of use, a rope should be retired, but in reality there are too many variables for such a simplistic answer to be given. The responsibility lies with the owner of the rope to make a judgement, based on his/her unique knowledge of how the rope has been used through its lifetime and of the factors that will degrade a rope.

To further confuse the situation, manufacturers are now required to give advice on when to retire ropes with their product user information supplied with each rope. This puts them in a difficult position and understandably, they will tend to play safe and give conservative figures for a ropes lifetime. This is usually quoted as 3 to 5 years, regardless of pattern of use. Such figures are not particularly helpful when deciding to retire a rope as an unlucky rockfall or severe abrasion can ruin a rope on its first outing, whilst another rope may have sustained no damage or leader falls over five years of light use (and may well be suitable for another five!)

Knowledge of a ropes history is vital when making decisions about when to retire or downgrade it, since every traumatic event suffered by the rope will cause some damage. As a general rule, you should consider downgrading any rope that has sustained a serious fall (fall factor greater than 1). Apart from knowing the number and severity of falls that a rope has sustained, a more general knowledge of its type and conditions of use is also important. You can check for localised internal damage or twisting by running it slowly through your fingers and feeling for any irregularities or unevenness – the existence of either could indicate serious internal damage. Unfortunately, the absence of either does not mean that a rope is not damaged – as mentioned above small particles of grit can work their way inside a rope and damage the core invisibly.

The general feel of a rope also gives a good indication as to its condition. For instance, a rope

Figure 10.4 *Furry, over-used ropes* **Photo:** BMC Collection

that was once soft, smooth and supple and has become stiff, furry and liable to kinking should perhaps be downgraded, as these characteristics indicate the onset of permanent damage.

As a very general figure then, with regular (every weekend and midweek) usage and no major incidents, you should not expect to get more than around three years out of a rope before downgrading it or retiring it outright. Heavy use (ie. most days) will greatly reduce this lifetime, and it is quite possible to wear out a rope in less than six months, whilst on a long holiday, for example. Obviously, if used less and well cared for, a rope will have a much longer lifetime.

There is some evidence to suggest that if a rope is 'broken in' gently – by alternating the lead end and avoiding hard loading – it will have a longer life than a rope that is used hard from new. However, the reasons for this are not fully understood.

Downgrading a rope – several times above, it has been suggested that certain criteria mean that you should downgrade your rope. Essentially, this means that a rope need not be considered unusable at the end of its life as a lead rope, but can still be used for top-roping, abseiling or as a glacier rope.

To summarise:

The decision on when to retire your rope is your own responsibility. The best you can do is base your decision on knowledge of how a rope has been used, and how it feels and looks. Keeping a log of its use, and regularly checking for damage is good practice, and if in doubt you can ask the advice of other experienced climbers.

11

Harnesses

by George Steele

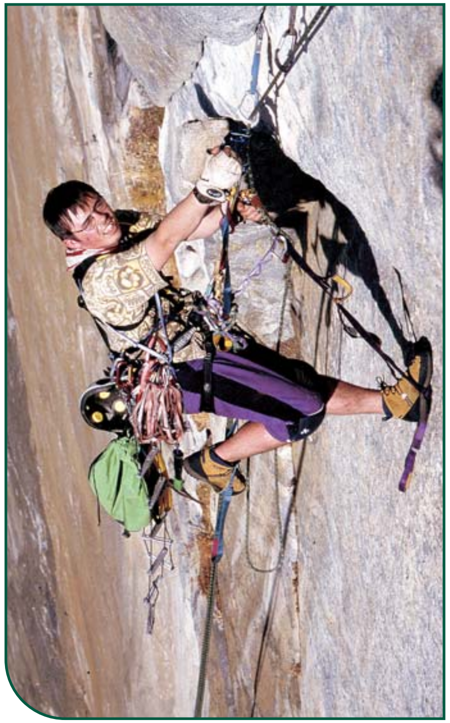


Figure 11.1 *Andy Kirkpatrick on Iron Hawk, Yosemite Valley* **Photo:** Andy Perkins

Introduction

The harness is an important piece of climbing equipment that performs the vital task of attaching the climber to the rope or belay anchors, and also gives a means of arranging your other equipment so as to be close at hand when needed. However, when climbers first began using ropes to safeguard their ascent, harnesses were a yet unheard of luxury – the early climbers simply whipped a few coils of rope around their waist tied with a bowline and made do! From this technique, the first rudimentary harness was developed in the mid war years – the ***swami belt***. This consisted of a few turns of wide tape webbing around the waist tied with a tape knot, to which the rope was then tied at the front. The swami was more comfortable than using the rope directly, and safer in the event of a fall, dissipating the force transmitted to the climber over a much wider area of the body. The now familiar ***sit harness*** added leg loops and a central tie in point to the swami belt, again increasing comfort and safety and the advent of adjustable metal buckles allowed the harness to be adjusted through a wide range of sizes enabling a precise fit. The sit harness can now be found in several different forms – sections of wide and narrow tape, 3D foam cushioning, ultralight materials etc. – but performs the same basic job. There are two basic types on the market today:

Adjustable size
Harnesses with adjustable leg loops enable changes in size to accommodate extra clothing and achieve a precise fit and will also allow you to don the harness without having to step through the leg loops. These are all major advantages when winter climbing or mountaineering, although of course the harness may still be used for regular rock climbing.

Fixed size
These harnesses are adjustable only at the waist, are lighter, more compact and quicker to don than the above, making them ideal for general rock climbing.

Relevant standards

The European standard for all types of climbing harnesses is EN 12277. It specifies suitable materials for use in harnesses and defines methods of test and performance criteria. The main requirement is a strength test designed to simulate the load placed on a harness in the event of a fall. The forces involved in the test deliberately greatly exceed any forces, which could occur in a fall, and harnesses have never been known to fail due to a lack of strength.

Meeting the standard does not guarantee a harness will be comfortable. Comfort is a very individual thing, and it is recommended that the purchaser should spend some time wearing a harness, and hanging in it in the shop. The best-padded harness may not be the most comfortable to hang in.

Observed faults and failures

The most common problems with harnesses seen by the BMC Technical Committee relate to buckle slippage. These instances arise either when the manufacturer's instructions are not properly followed and the buckle is mis-threaded, or when a design flaw allows slippage in a properly threaded buckle. Some manufacturers have reported problems with corroded buckles after immersion in seawater, but this could be avoided by thorough cleaning of the harness soon after immersion.

Figure 11.2 Check your harness buckle frequently for slippage (Anne Arran, Calanques) **Photo:** Alex Messenger

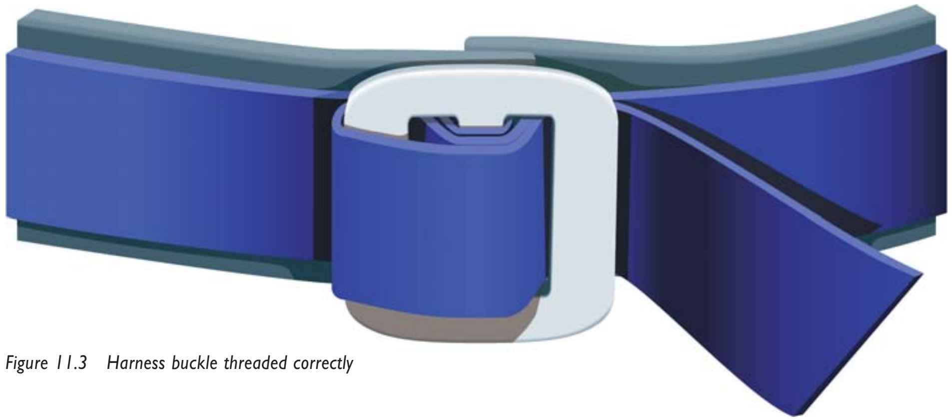


Figure 11.3 Harness buckle threaded correctly

There have also been instances where people have mistakenly clipped into gear loops instead of the main tie-in point, and also where climbers have failed to tie in correctly, but these cases are due to user error, and do not involve actual failure of a harness within the defined standards.

One report from Germany details dangerous abrasion damage to the tie-in loop of a harness, which was assumed to have been caused by continued rubbing of the rope against the harness during repeated falls. This problem has been observed in the UK, but only in the most extreme cases. It generally happens when long periods of hanging in the harness are combined with a dirty or gritty environment, leading to repeated abrasion of the harness material (eg when cleaning routes). Be aware of this potential situation if you do a lot of sport climbing and working of routes.

How to prevent failure in use

Always use the harness in strict accordance with the manufacturer's instructions, particularly with regard to threading the buckle and ensuring there is enough webbing left over to be safe (usually 50–75mm). Do not use the gear loops for any other purpose than carrying gear – they are not strong enough! – and try to avoid general abrasion when climbing or sitting down whilst wearing the harness. Be aware that gradual buckle slippage can occur in some harnesses, but that in general this is too slow to be of concern in general rock climbing situations. However, if the harness is to be worn for long periods, regular checks of the buckle should be made (Figure 11.3). Any slippage is accelerated by loading and unloading, for example whilst jumaring.

Routine care and maintenance

There is no doubt that careful use can avoid many potential problems. An important part of this is regular examination of the key parts of the harness, including all tape sections, stitched joints, buckles and other adjusting devices:

- **Tapes**
  Look for excessive fading, wear or cuts (Figure 11.4). Any of these could mean that the harness should be retired.
- **Stitched joints**
  Look for damaged, frayed or broken stitching as can occur if the harness becomes abraded (eg. scraped over rocks). Never attempt to re-sew a damaged section of stitching; retire the harness immediately.
- **Abrasion at tie-on points**
  Look for signs of abrasion, fraying, etc, where the abseil loop touches the rest of the harness, or where the rope is tied on to the harness.
- **Buckles and adjusting devices**
  Look for bending that could affect the operation of the buckle or adjusting device. Also, make regular checks for corrosion, especially if using the harness in a saltwater environment.

Figure 11.4 Frayed/damaged webbing

- If the harness gets covered in saltwater or seaspray, rinse it thoroughly in cold tap water as soon as possible, paying particular attention to the buckles. Then allow it to dry naturally.
- Avoid getting the harness covered in dust, grit or sand, as this can be ground into the webbing structure during normal use and may cause invisible weakening. The harness should be cleaned as above if this occurs.
- Store the harness in a cool dark place, and keep it away from acids, sharp edges and high temperatures. Storing the harness in the bag provided by the manufacturer will help keep it clean inside your rucksack.

Degradation and discard criteria

If an examination as detailed above reveals cuts, tears or serious abrasions in the webbing, buckles or adjusting devices appear damaged, then you should seriously consider discarding the harness straight away. If in doubt, compare your harness with a new one in a shop, or contact the manufacturer for advice – for a small charge they may be willing to assess its condition for you. Current advice from most manufacturers is that a harness has a maximum shelf life of around 10 years. With average use, (weekends, once during the week and a couple of holidays per year) a harness should generally last for 5 years, although as with ropes, this could be as little as a few months, or even a single use in extreme cases.

12

Slings

by Dave Brook

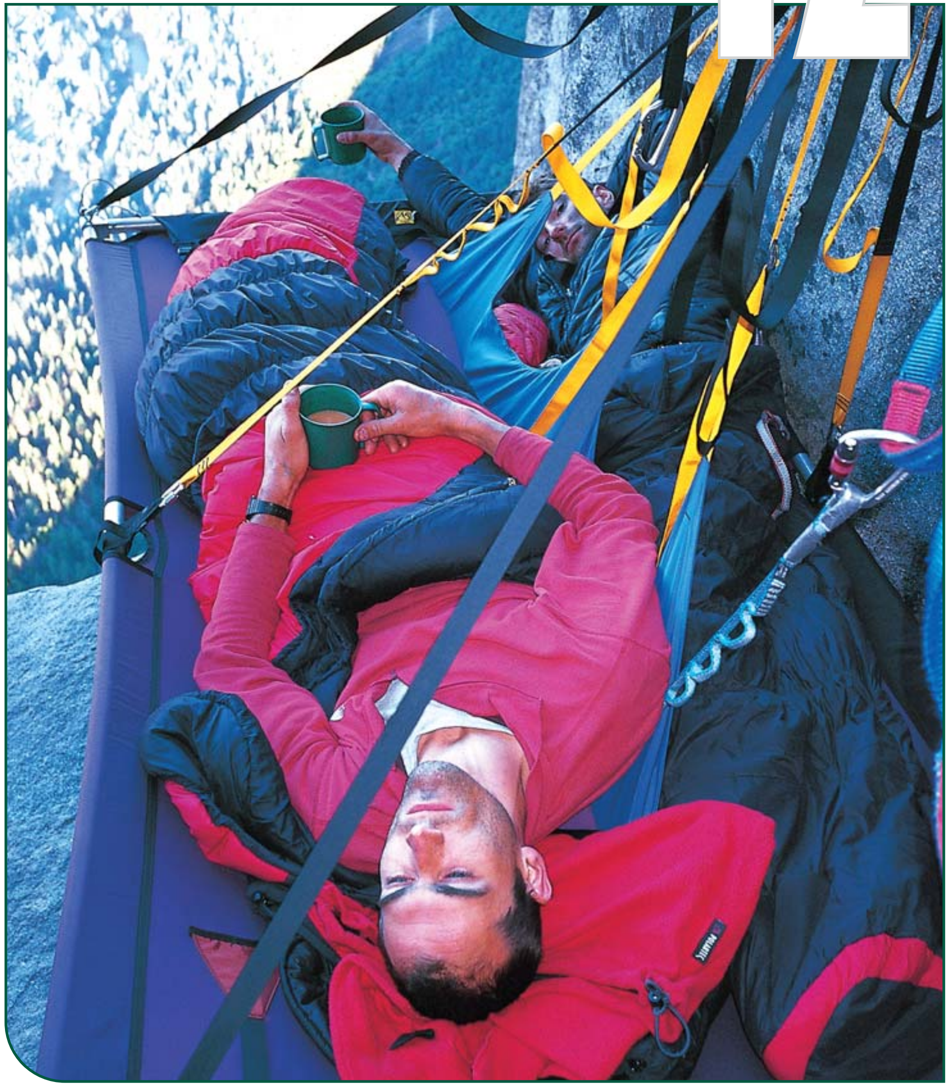


Figure 12.1 Neil Bentley and Richard Heap appreciating slings in Yosemite, USA **Photo:** Ben Pritchard

Introduction

Slings are the most versatile component in modern climbing and mountaineering, and have a whole multitude of uses – the most important of which is to provide a link between the climber and the belay and also to connect the rope to a protection point. The first slings used in climbing were no more than knotted loops of rope or cord that were employed to thread chockstones, rock spikes etc. to provide running and static belays. These were sometimes even carried loose, and threaded and tied one-handed whilst on route! Later in the inter-war years, climbers experimented with loops of hawser-laid rope to provide increased security, and began to jam the actual knots into cracks, opening up further protection possibilities (see previous section on chocks). As with ropes, the advent of nylon provided a much-needed advance in technology being stronger and lighter, and the first factory-stitched slings began to appear, having appreciably greater strength over the hand knotted variety. Nylon also allowed the safe use of thin loops of accessory cord (3–8mm in diameter) for everything from slinging chocks to ascending ropes and abseiling.

Modern stitched slings are made of nylon, which gives softness and flexibility or spectra (dyneema), which is less bulky and more abrasion resistant than nylon – important in some situations. In particular, the production of very thin dyneema slings (12–15mm diameter) allows their use in places where nylon slings would not pass – for example, if threading thin rock spikes or small slots, being 20–25mm in diameter for comparable strength. Nylon slings are manufactured of 'flat' woven tape (cheap, light and flexible) or a tubular construction, which is stronger and more durable, but more expensive and bulky. Dyneema slings combine the advantages of both kinds of nylon tapes, with the additional benefit that it is easier to see when the fibres are damaged or cut, and are less susceptible to UV damage than nylon. However, the melting point of Dyneema is lower than nylon and it is less elastic and so does not absorb as much energy under a shock load.

Relevant standards

Cord for use in climbing and mountaineering must conform to EN 564; tape must conform to EN 565; and sewn slings, whether made from cord or tape, must conform to EN 566.

Since 1994 the European standard for sewn slings has specified a minimum strength of 22kN, which is more than adequate for every conceivable loading in climbing use. Sewn slings are amongst the strongest items of safety equipment, and given the light weight and small bulk of dyneema/spectra slings, they represent excellent value for money. There is really no longer any reason for carrying knotted tape slings, other than to use in an emergency and leave behind.

Observed faults and failures

No incidents involving the direct failure of a sling have been reported to the Equipment Investigation Panel – another component in the safety chain normally fails first, and seriously weakened slings are easily identified and discarded by the user. However, many incidents of sling failure have been observed worldwide, with the majority involving failure of badly weathered (abraded, frozen and thawed, UV degraded etc.) *in situ* slings – generally this occurs in regions with stronger UV than the UK! The other common mode of failure involves melting of a nylon sling resulting from a loaded rope being passed directly through a sling, the friction generated being enough to melt the sling (remember the low melting point of nylon and dyneema). The EIP has also been advised of one incident where a hand tied sling in use as a top-rope anchor came undone, with predictably disastrous consequences. In one instance in the Alps, it has been reported that the knot of a hand tied sling has caught on a rock edge and been pulled open.

How to prevent failure in use

Several important points arise from the modes of failure reported to the BMC. ***Never pass a rope directly through a sling for lowering off*** – the friction generated can easily become sufficient to melt a nylon sling, perhaps in as little as 3 metres of lowering. This is very different from abseiling with the rope through a sling, because the rope does not move under load. Nevertheless, ***when pulling rope through a sling after an abseil, do it slowly and without using a lot of force***, otherwise glazing damage can occur to the rope (in addition to the abandoned sling).

Do not use hand-tied slings except for emergency use. Modern sewn slings to EN 566 are stronger, there is no risk of them coming undone, and they are now relatively cheap.

As for ropes, when using slings to extend running belays, take care to position them such that they will not be dragged over sharp or rough rocks in the event of a fall. Read the manufacturer's instructions provided with the sling as part of the CE system, and understand how to arrange slings in the proper configurations at anchor points in order to obtain maximum strength.

Finally, and very importantly – ***always treat* in situ *tape slings with extreme caution! Never rely on them totally*** and always use a back-up anchor wherever possible. *In situ* cord or rope slings are more reliable – only the sheath is susceptible to UV damage and the core is usually unaffected.

Routine care and maintenance

The same general principles as care and maintenance of other textile equipment apply:

- Avoid contamination with any substances other than water – be especially careful of oils, cleaners and corrosives in places such as garages, car boots and kitchens.
- Slings are best stored in a cool, dark, dry place and in use it is advisable to avoid exposure to strong light and UV rays as much as possible – these will both affect the strength of a tape sling over time. Accessory cord is less susceptible to UV damage – see above.
- Frequently inspect webbing for signs of damage to the tape or stitching. The edges of flat (as opposed to tubular) tapes are particularly prone to cuts and abrasions, especially whilst under load. If there is a small nick in the side of the sling then not only is the number of yarns taking the strain reduced, but stress concentrations are set up on the damaged part of the tape – you should consider discarding any webbing in this state. Fortunately, it is generally very easy to spot this type of damage to slings and tapes – see Figure 12.2.
- Slings should be discarded following a severe fall, even if there is no visible damage – the sling may have been damaged internally. Tapes that have suffered shock loading may become elongated, and if over stretching has occurred it causes the individual fibres to break, forming small lumps within the weave and weakening the sling. This type of damage can be detected by inspecting the tape both with the fingertips and visually.
- If exposed to seawater or salt water spray, clean thoroughly in fresh water, and dry naturally in a cool dark place. (Dry salt crystals have a similar abrasive effect to fine grit.)

Figure 12.2 Cut, damaged yarn

Degradation and discard criteria

This has been mostly covered in the above section, but to re-iterate: discard slings that have become faded and/or furry and stiff due to deterioration in use. Any slings with obvious abrasions, cuts or broken yarns should be retired. You can be fairly rigorous when retiring webbing items, as they are inexpensive and simple to replace.

Appendix –

Principal degradation mechanisms

by Stuart Ingram

1. Chemical

Textile materials are extremely vulnerable to chemical attack, and any contact whatsoever with potent chemicals (eg. acids, bleaches etc.) should be strictly avoided. There is no recommended cleaning treatment to follow if webbing etc. becomes contaminated with such a chemical – the item should be destroyed and replaced immediately. Table 13.1 shows the effect of a variety of common chemicals that may conceivably come into contact with textile materials.

Table 13.1 The effect of common chemicals on textile materials *Table courtesy of Troll*

Chemical	Nylon			Dyneema	
	20°C	60°C	100°C	20°C	60°C
Acetic acid (vinegar)	B	B	B	A	A
Aviation fuel	A	A	■	C	■
Brine (seawater)	A	B	B	A	A
Castor oil	A	A	A	A	A
Chlorine water	A	B	C	C	C
Dettol	■	■	■	A	A
Kerosene	■	■	■	A	B
Lubricating oil	A	A	A	A	B
Motor oil	A	A	A	A	A
Silicone oil	A	A	A	B	C
Turpentine	A	A	■	A	B
Urine	A	B	C	A	A
White spirit	A	A	A	B	D

■ **No data** • A **Negligible effect** No need to discard: rinse in clean water • B **Limited effect** Consider discarding
C **Considerable effect** Discard • D **Dissolves or decomposes!**

One interesting fact to emerge from this table is that temperature has a bearing on the effect of a chemical on textiles. For instance, get seawater on your slings at ambient temperature (around 20°C) and the effect is negligible, but raise the temperature to 60°C or more and the effect is magnified and could be cause for retiring the item.

2. Ageing

All textile materials age as the complex molecules making up the material break down. This mainly occurs through oxidation or under the influence of UV radiation.

UV radiation

When an energetic photon hits a complex polymer it is likely to knock loose an electron which will go on to hit further molecules and knock loose further electrons. The loss of an electron destabilises the polymer and this electron 'cascade' means that one UV photon can cause damage to many molecules. This problem of UV degradation has been known for a long time and generally where a textile material is likely to be exposed to UV radiation then UV stabilising chemicals are added. These act by mopping up the loose electrons and preventing a damaging cascade. Textile equipment used in climbing has this protection against UV radiation and this means that damage only occurs in the thin surface layer. The practical upshot of this is that only where items are dependant on surface materials for their strength will UV exposure cause serious problems. This means that even with relatively prolonged exposure, ropes and helmets will not be significantly damaged by UV, but tape can lose much of its initial strength through exposure.

Manufacturers' figures suggest that a normal dyed nylon tape can lose 4% of its strength after 300 hours of 'English' summer sun – thus not normally causing a problem for the lifetime of the item in the UK! Such loss of strength is of course proportionate to the overall exposure time and intensity of the sunlight. In desert regions the loss can be as high as 70% after 18 months, and regular replacement of textile equipment should be considered in regions of strong and prolonged sunlight. Remember that the intensity of UV rays is increased dramatically by reflections from seawater, snow & ice cover and altitude.

Oxidation

This does not just affect metallic equipment as might be thought, but can also be a major contributor to degradation in textiles. Such ageing has been observed in older plastic boots, which have become brittle and in rare cases shattered at low temperatures (see BMC technical reports for further details). However, this only really affects older items, as modern climbing textiles (from the last 10–15 years or so) are manufactured from more oxidation resistant materials, and other factors are likely to cause retirement of the items before oxidation has a significant effect.

Moisture, temperature cycling and UV exposure all increase the effect of ageing on textile materials, but this can be minimised by storing the equipment in a cool, dark, and dry place when not in use.

Again, it's worth mentioning the general point that when textile items begin to appear 'fuzzy' around the edges, lose their handling and become stiff, or suffer significant abrasion or cutting, then they should be retired and replaced.

14

Appendix –

Forces, kN & dynamic loads

by Neville McMillan

If you are confused by kN, then read on…

Confusion, confusion

In the past there has always been a great deal of confusion between mass and weight, partly because the same unit (the pound or lb) was used to measure both. The ***mass*** of a body is the basic quantity of matter it contains. Thus a one kilogram (*kg*) bag of flour contains one kilogram of flour whether it is on the supermarket shelf, on the top of Everest, or on the Moon. Scientifically ***weight*** is defined as the force exerted by gravity on a body. So *weight* is a force, which is a quite different entity to *mass* (and hence varies between the three aforementioned places). But, as the same unit (*lb*) was used to measure both mass and weight is it any wonder there was confusion! In engineering calculations the units lbf and lbm were often used to try to differentiate between force and mass, but it was easy to get confused.

The confusion also existed in the original ***MKS*** system of metric units based on the **metre**, **kilogram** and **second**. But a major breakthrough occurred, in my opinion, in the 1950s when the *MKS* system was modified and extended to form a rationalised and coherent system of units. This was formally approved in 1960 by the *Conference Generale des Poids et Mesures* (CGPM) and given the title *Système International d'Unités*, now universally known as ***SI Units***.

In SI Units there is a new unit for the measurement of force – the newton.
This is based on Newton's second law of motion, and is defined as:

> *That force which, when applied to a body having a mass of one kilogram, gives it an acceleration of one metre per second per second.*

This is a relatively small force – the sort of force you can easily apply with one finger. The forces which ropes need to apply to climbers to arrest a fall, and which chocks and karabiners have to be able to withstand, are much greater and are quoted in ***kilonewtons*** (thousands of newtons, *kilo* stands for 1000), abbreviated to *kN*.

So what is 1kN in practical terms?

If you take a one kg mass and drop it, it will accelerate due to the force of gravity at approximately 9.81 m/s^2 (metres per second per second), so from the above definition the gravitational force on it must be 9.81 newtons. For approximate calculations (error less than 2%) this number is rounded to 10. So the gravitational force (on Earth) on a 1kg mass is approximately 10 newtons. Hence if you put a 1kg bag of anything on the palm of your hand you must be applying a 10 newton force to stop it falling.

Turning to bigger things, if you personally 'weigh' 15½ stone, this means you have a body mass of 100 kg. So the force of gravity on you will be (approximately) 10 × 100 newtons, or 1kN.
If you hang stationary on the end of a climbing rope, the force in the rope holding you up will be 1kN. If you jump up and down on the end of the rope (as in energetic jumaring), the force will fluctuate and could have a peak of say 2kN.
In arresting a fall the forces will be greater; even with a dynamic belay the peak force on the climber could be say 3kN in a simple fall. Due to the pulley-action of the karabiner, the force on the top runner could easily be 5 to 6kN. So there you have some practical examples – see also Figure 14.1.

For the pedantically minded, although the unit was named after Sir Isaac Newton, the ***newton*** (the unit) does not have a capital letter. But the abbreviated form ***N*** or ***kN*** has a capital letter. Similarly, the unit of power is the watt, named after James Watt, but a light bulb could be correctly designated 60W, and a heater 2kW (and similarly for other named SI units).

Further reading

Manufacturers' Catalogues
Beal, Petzl, Mammut and Edelrid all produce highly informative catalogues, which go into detail on the dynamics and forces involved in fall arrest.

Instructional manuals
Manuals such as *The Handbook of Climbing* (Fyffe & Peter) and *How to Rock Climb* (Long) have sections on this subject.

Manufacturers' Websites
www.petzl.com/sport/sportuktest/sport.html
Petzl website has lots of useful information on forces in climbing, and this URL has a fall simulator to help you understand where, why and to what degree the forces are distributed in a fall.

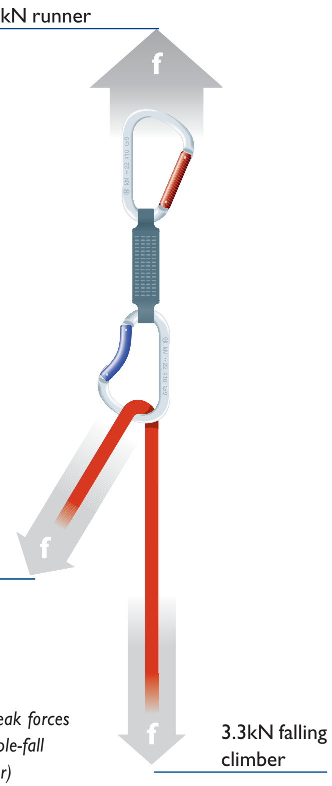


Figure 14.1 Peak forces in a typical simple-fall (with one runner)

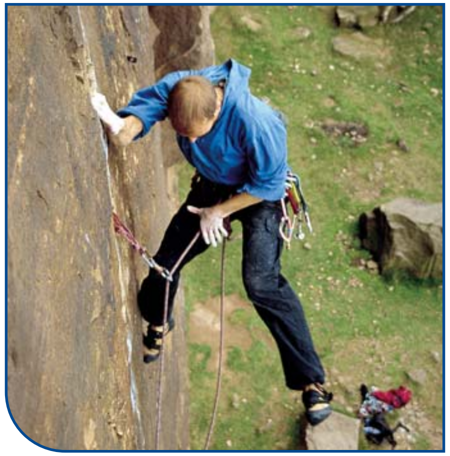


Figure 14.2 Dynamic loading about to occur
Photo: *Alex Messenger*

Further Reading and References

1. Useful Articles

There are many useful articles published each year on the technical aspects of mountaineering and climbing gear. They also offer good advice on what to consider when buying these items, and how to choose the models most suited to you. For clarity and up to date information, only articles from the last couple of years are included.

General
BMC Summit No 15 – *Technical Committee, PPE and CEN: What are they?*
BMC Summit No 17 – Technical Conference 1999: *Ropes, boots and crampons.*
BMC Summit No 18 – *Retiring Gear*
OTE No 108 (June 2001) – *Latest gear update*
OTE No 109 (July 2001) – *More latest gear*

Helmets
BMC Summit 19 – *Helmet testing programme Part 1*
BMC Summit 20 – *Helmet testing programme Part 2*
OTE No 102 (Nov 2000) – *Helmet review*
Climber (July 2000) – *Helmet review*
Rock & Ice No 94 (August 1999) – *Helmet review*
Climber (July 2001) – *Helmet testing and reviews*

Ropes
Climber (August 2000) – *Rope review*
Rock & Ice No 99 (April 2000) – *Rope review*

Camming devices
Climber (March 2000) – *Cams review*
Climbing (US) No 193 – *Cams review*
Rock & Ice (July 2001) – *Latest camming devices*

Crampons
Climber (January 2000) – *Review*

Harnesses
Climbing (US) No 199 – *Reviews and criteria*
Climber (May 2001) – *All-round Harnesses*

Chocks & nuts
Climbing (US) No 193 – *Reviews*
(Some models reviewed unavailable in the UK)

Belaying & ascending devices
Rock & Ice No 98 (February 2000) – *Reviews*
(Some models reviewed unavailable in the UK)

In addition to the above, ***On the Edge***, ***Climbing*** (US) and ***Rock+Ice*** all publish annual gear reviews, detailing the latest technology in each area. ***Climbing*** (US) has a 'technical tips' section in each issue illustrating the proper (and sometimes quite innovative) ways to use certain pieces of equipment. The BMC website (www.thebmc.co.uk) and ***Summit*** magazine feature regular technical articles and updates.

2. Useful books and publications

There are many textbooks available covering in-depth the techniques required to make safe use of climbing and mountaineering equipment. Much of what they say is relevant to care and maintenance of your equipment, mainly under the 'how to prevent failure during use' banner. Some of the better sources are:

The Handbook of Climbing (Fyffe & Peter)
Climbing Anchors: How to rock climb (Long)
Complete guide to rope techniques (Shepherd)
How to rock climb (Long)
Ice world (Lowe)
Mountaincraft & Leadership (Langmuir)
Extreme Alpinism (Twight)
Ice tools & techniques (Climbing magazine)

3. Other resources

BMC website – www.thebmc.co.uk
A full list of the reports held at the BMC on investigations into equipment failures can be obtained from the technical section of the website, or from the BMC office. You will also find regular updates on current research and important investigations here.

UIAA journal – available from www.uiaa.ch or +41 31.370.18.28
Regular technical articles are run in the journal of the world body for mountaineering. Copies are mailed direct to affiliated federations, and these articles will be reproduced in ***Summit*** magazine if relevant.

Manufacturers' Catalogues and Websites
These often go into a good amount of detail regarding the construction and testing of equipment. Particularly useful are catalogues from Beal, Petzl and DMM. Black Diamond occasionally produce information leaflets about new products and their own testing programmes.