

# Cave Science

*The Transactions of the British Cave Research Association*

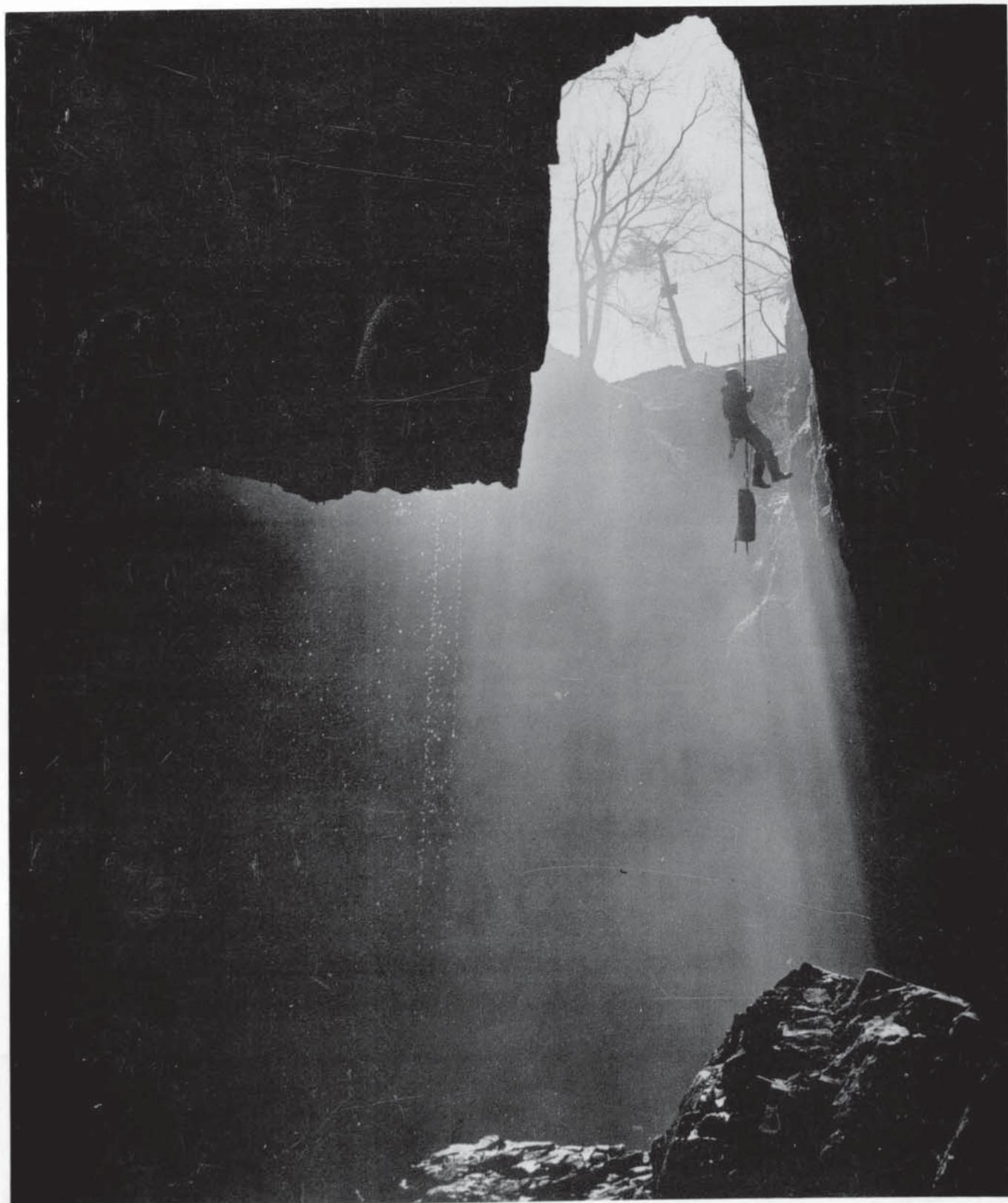


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Techniques and Equipment

## BRITISH CAVE RESEARCH ASSOCIATION

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CAVE SCIENCE  
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CONTENTS

Techniques and Equipment

Caving Gear - Habit, Addiction or Necessity?	
Ben Lyon .....	227-229
Ladders & Lifelines - a biased viewpoint	
Dave Elliot .....	230-239
Pitch Rigging	
Dave Checkley .....	238-240
Practical pitch rigging for SRT	
Dave Elliot .....	241-247
Self-Locking Descenders	
K. Lewis .....	248-254
The Multiscender design & concept	
Dick Lawson .....	255-257
An analysis of Prusik systems	
John Forder .....	258-260
Prusiking systems	
Dave Elliot .....	261-268
8mm Bolt belays	
Dick Lawson .....	269-276
Rock-drills	
J.S. Davis .....	277-279
Scaling Poles	
J.S. Davis .....	280-282
Scaling techniques	
Geoff Barber .....	283-286
The Weak Link	
Andrew Eavis .....	287-289
Do-it-yourself equipment testing	
Paul Ramsden .....	290-299
Solo caving	
Dave Elliot .....	300-302
SRT accidents & incidents	
John Forder .....	303-305
Index to Volume 9 .....	306-309
Cover photo: Alum Pot, by John Forder	

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## CAVING GEAR - HABIT, ADDICTION OR NECESSITY ?

Ben Lyon

## ABSTRACT

The technical aspects of vertical caving are becoming increasingly sophisticated. This paper attempts to explore the relationship between the caver and his tools.

Having already torn up four drafts of this paper because the subject matter had become too obtuse for even the author to follow, this fifth attempt must positively be the last, though I am acutely conscious that it is far from perfect. Unfortunately, the subject has inexorably drifted into areas I had sought not to touch, and in so doing ended up as a bad case of verbal diarrhoea, which in simple terms means that a self-evident proposition is examined until it becomes too complicated for anyone to understand any more. Well, lets start with the simple proposition that a caver has to add certain skills to the intrinsic properties and capabilities of his gear. It does not operate itself.

Let us look at the caver's relationship with his equipment. This can be split into three components, which I will term passive, caring, and dynamic. The pure passive relationship exists when an item of gear is bought and used without any additional input from the user. A helmet or sit-harness might fall into this category. However, few of the caver's tools fall into the totally passive category - all but the most feckless inject some element of caring into virtually every item of their gear. However, there is a trend in the modern world to try to reduce one's relationship with artifacts to a totally passive one - doors open at one's approach, no need to open windows to control temperature, etc. The list is endless, and the frightening thing is that this passive reliance on a robot world is seen as progress .....

Well at least we still have to care for our gear. Typical of a caring/passive relationship is the caver and his electric lamp. Before the trip he has to see that it is charged, the bulbs work, etc., i.e. he has to care for it. Underground it is expected to perform without further skill or work. If we move to a carbide lamp however, the relationship has a very definite dynamic element to it. The lamp demands fills of water, adjustment of drip, refilling, disposal of waste, clearing blocked jets, etc. If the user has the right skills, the lamp will probably perform well, and the user will like it. If not, it won't work properly and he'll hate the bloody thing. We can see here two divergent aspects of the dynamic relationship with gear. If the user has the right skills for a harmonious symbiosis he will enjoy using the equipment, and gain positive satisfaction from overcoming the difficulties associated with it. However, the pure gear freak will look at the tool on isolation, and decide that its use could be simplified, so that less skill is needed to use it. This makes the next generation of equipment usable by less skilled people, and reduced the exhilaration of mastering it. The passive relationship draws nearer ....

The reason I agreed to write this paper was a worry that gear was being examined in isolation, by the NCA Equipment Committee and others, and a feeling I have that it is very important to link equipment and its intended use very carefully together before pronouncing on its suitability. Take ropes, for instance: because of the possibility of abrasion it is safer to use a thicker rather than a thinner rope. General considerations of loss of strength in knots by wear and ageing lead towards a requirement of a minimum breaking load of 2 tons. These and other factors end up suggesting that a standard caving rope should have a diameter of 10.5 to 11 mm. This is all very sensible, but if a very small team are to do a deep 'pushing trip' on an expedition, the weight of such rope might make progress impossible. In these circumstances an 8mm/1 ton rope may be desirable. Its use will require new skills - not a whisper of abrasion and coping with far more than the optimum 'bounce' for instance, but if the cavers concerned have the right skills they can compensate for potential deficiencies in the gear itself.

This is far safer than inexperienced cavers buying recommended gear - perhaps endorsed by some big name - and assuming that they are also buying the skills to use it. In fact there is a lot to be said for the idea that British cavers are so good because their gear and techniques are so atrocious that they have to get used to coping with crises almost as a matter of course.

The well-equipped caver with a set of gear he knows how to use - but nothing else - will be stuck if he loses a vital part of his system, whereas someone who can cope with something less than a proper system in the first place will probably adapt.

What all this points towards I am far from certain, so I will proceed by taking a series of independent points. Firstly, equipment testing: an item of gear will have specific properties and functions. There can be no argument but that it is good to know what these are. If it is a rope its construction, size, material, abrasion resistance, elasticity etc., can and should be tested. Likewise an ascender or descender has certain physical parameters that can be checked. The tricky part is in selecting the right parameters to test, and having tested, to decide how important they are. Importance will tend to be ascribed to properties which are significant in the context of techniques known to the tester. Thus handles are essential for the classical 'Jumaring' technique, the Clog ascender boasts a fail-safe method of locking the rope into the jammer, and a certain sort of American rope is so stiff it is magic to ascend. For someone wanting to haul themselves up a rope, with no chance of the secondary ascender accidentally unclipping itself from the rope, and no chance of the rope riding up with the bottom ascender the combination may be considered perfect. However, for other techniques the Jumar handle may be unnecessary, the fail-safe Clog may make changeover manoeuvres positively dangerous, and the rope in question is so stiff there is no way it can be stuffed into a rope-bag.

I met this problem of tester bias myself some years ago when Sam Heath asked us to test his wire-walking system. The whole concept was so different to rope climbing techniques that it was almost impossible to remove tester-bias. Instead of aiming for abrasion-free hangs obtained by rebelaying, it was necessary to avoid all kinking or knotting of the wire, with abrasion being unimportant. The descending device simply trapped the wire between straight grooves, the two halves of which were simply compressed or relaxed to allow braking or descent. No comparison could be made with 'conventional' techniques, and I wonder to this day if the new system was tested fairly.

The designer of equipment is likely to be most biased of all. Having invented his marvellous invention and spent hours using it, he may, unconsciously, learn to compensate for deficiencies by developing compensatory skills, thus blinding himself to the difficulties others will have with his products. Hence testing by others is essential.

My next point is to comment on the debate about the relative merits of SRT versus ladder and line techniques. There is no way that a committed exponent of ladder and line techniques can condone the use of a single rope: it goes against the basic tenet that there must be two separate systems for safety. You have to abandon this before embracing SRT as a thinking person. To do so leads me to remember a conversation with Tom Brown - the leading cave-diver in the north some years ago. I asked him why he only used one demand valve. Simple, he said, "if I had one in reserve I would not worry too much about maintaining the first valve. With only one I know my life depends on it, and maintain it with that clearly in mind".

Let's apply this thinking to our vertical techniques - how safe is each of the links in the ladder/line system? The ladder is relatively weak - it can break - due to shock loading, corrosion, etc., and if the caver lets go - whether a momentary slip or due to tiredness is immaterial - he falls off. The lifeline is held - or not held - by a person who may be well removed from the person at risk. Even in good circumstances it is difficult for a caver to hold a line if someone falls off, but if communications are difficult due to length of pitch or noise of water - the very conditions when a lifeline is most necessary, it is most likely that the lifelining will be least efficient. Two good independent means of safety are safer than one, but one is safer than two defective systems. The fact is that ladders alone are potentially dangerous, and safe lifelining is difficult to achieve. There is a 'window of vulnerability'; many have fallen through it.

What about SRT then? If, and it is an 'if', the caver is capable of good rigging and has a good 'system', the chance of accident during much of the descent/ascent cycle is removed. Put another way, if the caver runs out of steam, or screams and lets go, he simply dangles, sitting in his harness. The exception is in the course of an abseil - as was tragically illustrated in a recent accident at Gaping Ghyll. The conventional descender demands the ultimate skill of the caver - varying the friction of a running rope. Penalty for failure - death.

To bend a line or two from Geoffrey Winthrop Young:

Within this trembling hand,  
these tense fingers,  
clamped to the sliding line,  
I hold the life of man.

Exhilaration meets success, extinction those who fail ...

Perhaps there is no argument against the introduction of self-lock descenders. I could mourn them as another step towards automated caving, with yet another skill element removed. However, practice shows that coping with a locking component tends to make self-lock descenders more difficult to control rather than less, so it passes muster.

For some cavers the difficulty of using their equipment is an end in itself. They mourn the passing of ladders and lifelines and say that SRT has made potholing too easy. Their challenge was inextricably linked to the gear they had to master. A trip to the end of say, Penyghent Pot or Lost Johns, was the ultimate in tweed jackets with rope and wood ladders. Advances in gearsmanship now means that the ultimate must be sought much deeper and further away.

And so to my conclusion. Cavers will always seek to push to the limit - better gear means further limits. For the 'pushers' it really is essential to have the best that technology and money can produce. Meanwhile, back in the mainstream of caving, gear freakery will flourish. Buffoons will buy all the latest gadgets. If all they do is clank around the pub in it, no harm is done and perhaps some good by raising a laugh. But beware of the Walter Mitty Arthur who believes that he can purchase Excalibur from Whernside, Inglesport or wherever. Caving gear does not work by magic - it needs a trained operator.

June 1982

Ben Lyon  
Whernside Cave & Fell Centre  
Dent, Sedbergh, Cumbria.

LADDERS AND LIFELINES - A BIASED VIEWPOINT

Dave Elliot

ABSTRACT

Various methods of lifelining a ladder climber are examined with regard to their inherent safety. It is the author's opinion that the 'traditional' techniques of British cavers are outdated and dangerous. Alternative techniques of remote lifelining are described and 'self-lining' suggested as a safer option.

My reasons for presenting this paper might best be illustrated by the drawing we chose for the front cover of the programme for this meeting. It was first published over 40 years ago and depicts the 20m pitch below the 'Bridge' in Alum Pot, with the ropes and ladders fastened to a metal stake driven into a crack at the rear of the ledge. The metal stake is still there, and each weekend one can still see cavers descending the pitch using the same crude and dangerous techniques as their predecessors did almost half a century earlier. Nowadays the tackle is a little different and wire ladders and synthetic ropes have replaced their wood and grass counterparts. The equipment has greatly improved, sadly, the cavers have not. The cartoon (Fig.1) illustrates the point again!

Lately, of course, SRT has rather undermined the use of ladders and lifelines, even to the extent that minor isolated pitches are often seen rigged for SRT, when a ladder and line would be more efficient. There are many involved aspects to consider, but for now rather than advocate exclusive use of one or the other, let's regard both SRT and ladders simply as different but complementary techniques for negotiating the vertical bits of caves, each with a specific application (Marbach & Rocourt, 1980; Dressler & Minvielle, 1979). This is after all a biased viewpoint, but I certainly don't aim to give the impression that ladders are no use underground; it's rather that I regard the associated techniques as outdated and inadequate.

I recall with some cynicism now the arguments of a few years ago when it seemed quite apparent that dangling from a single rope was obviously suicidal - a ladder and lifeline must be far safer. The air was heavy with dire predictions about the spate of fatal accidents that were certain to result from misguided dabbling in these strange, foreign techniques .... However, we learnt a thing or two, and nowadays many cavers, myself included, look on home-grown ladder and lifeline techniques with the same morbid anticipation. Not without some justification as a great many accidents have indeed resulted from the continued misuse of these techniques.

So let's examine safety on ladders; with the traditional approach to lifelining let's see if we can't do a little better. Take as a starting point the inherent strength of the ladder itself; two sturdy steel wires with a breaking load of perhaps 750 kg each, although these are generally attached by c-links which probably fail at nearer 300kg. Still fairly strong, as the ladder system is normally only subject to little more than straight bodyweight, say a maximum of around 150kg? But consider that the climber isn't in any way fastened to the ladder, but merely gripping the rungs with his cold, muddy hands, barely capable of supporting even his own bodyweight. It now becomes apparent that the bond between ladder and climber is a very tenuous one indeed, even without outside interference from water, falling rocks or acute exhaustion.

But, of course, there's always the lifeline; this magical talisman against the powers of evil that all cavers use on every pitch ... This is good, thick rope, often hairy and obviously very strong, in fact it says so on the reel - more than 2000kg. This is tied securely to the climber with the lifeline operator taking it in from above as he climbs. So that should the climber by some vague mischance fall off the ladder, he simply hangs there and either gets back on or is lowered to the bottom of the pitch. Couldn't be simpler - perhaps it's just coincidence that misuse of this technique results in more accidents underground than anything else?

Let's now look at the inherent strength of the lifeline system, and here again the 2 tonne breaking load of the rope doesn't count for much, because instead of being solidly attached to the rock it is simply wrapped around the weakest link in the whole system - the lifeliner. An important point to make

here is that the ladder climber using these traditional methods, entirely delegates responsibility for his safety to the lifeliner, who may or may not be doing the job properly and all too often is not.

The climber has no control at all over the safety system protecting him. Only too familiar to most of us is the 'experienced' lifeliner who considers attaching himself to the rock superfluous, being more than strong enough to hold a fall unaided ... All I can say is, avoid this bloke altogether - he is stupid! Even a metre or so of slack rope in the system can result in a fall producing forces of 3 or 400 kg, and his chances of holding this are non-existent. He will in fact, either let go of the rope to save himself or get pulled over the edge and land on someone's head; in neither case is he of any use at all to the falling climber. But simple as safe lifelining could be, this guy will be hard to convince, having got away with atrocious techniques for a number of years he presumes he always will. Nevertheless, either convince him or leave him behind, he is a distinct liability.

I don't intend to go into details of the traditional methods of lifelining correctly; this is a complicated, skilled technique already described by many experts in the field over a number of years (Cullingford, 1969), with remarkably little effect on general practice underground. Moreover, these techniques are outdated, they are clumsy and inefficient, and most important, the security afforded is largely illusory.

As a safety system these techniques suffer from a fundamental defect, they are not safe; instead of the rope being fastened to something solid, it is in fact just held by another caver interposed between the climber and the belay. This is nothing other than a very weak link in the chain, capable of supporting no more than a few hundred kg at best. At worst, if the lifeliner is tired, cold, confused, distracted or just plain incompetent, the lifeline is completely ornamental.

Far better are the direct belay methods where the lifeline is attached to the belay by some mechanical device and the caver simply stands alongside and controls the rope passing through it. There are two main advantages:

- 1) Such devices are far stronger than any caver; they do not get cold or become distracted, and any load is transmitted directly to the belay with no strain on the operator. The lifeline system is therefore very strong.
- 2) The operator is not trapped within the system; he can lower the fallen climber or anchor him securely to the belay and then be free to go to his aid in some other way.

There are many different possibilities. Mountaineers have used simple mechanical belay devices for years and there are various gadgets designed specifically for this purpose (Fig. 2). More practical is the use of conventional hardware such as a descender or karabiner, which is basic equipment carried by every caver. Simply running the rope through a descender anchored to the belay upside down is an effective means of lifelining (Figs. 3 & 4). A fallen climber is easily held, lowered, or the descender 'locked off' so the lifeliner can leave the rope and try to organise some means of rescue. Some descenders are better than others, certain 'self-lock' descenders function very well and may also form the basis of a simple hauling system should this prove necessary (Fig. 5). One disadvantage of descenders however, is that they are all designed to create friction along the path of the rope. The amount varies with different devices, but it means there is inevitably a certain drag when taking up the slack rope. Also, direct hauling through the device, say to assist a tired climber, is not so easy.

An alternative method using a pulley and reversed jammer arrangements (Fig. 6) avoids this friction and works extremely well, but with a couple of disadvantages. Firstly, it is comparatively weak (perhaps 500kg), and secondly, a jammer only works in one direction: it will not function as a lowering device. Indeed, once loaded it is necessary to find some way of lifting the load momentarily before the jammer can be released. There are of course ways and means but if you are alone at the pitch-head when the ladder breaks, with neither the strength nor the skill to lift the fallen climber, then he's stuck in a fairly unenviable position.

What is, in my opinion, the best lifelining method of all, requires no special equipment - just a very simple knot tied around a karabiner. The 'Italian Hitch' is, in effect, half of a Clove-hitch, easily recognised by its distinctive rope across rope friction contact. There are a few ways of tying

it but the easiest to remember is that shown in Fig. 7. As you can imagine from the configuration of the hitch, the rope can only run in one direction and the ease with which it does this is controlled by the friction created by tension in the non-loaded rope. The braking action is extremely effective: it is quite easy to arrest even a very severe fall with just one hand. While unloaded, the hitch is reversible; by pulling on the non-loaded side the hitch will rotate through 180° around the krab and thus inverted the rope will now slip in the opposite direction. It is thus a simple matter to take in the slack rope as the climber ascends, using one hand to lift the load rope and the other to pull it through the hitch (Fig. 8). Should the climber fall, the knot will automatically reverse and the fall can be arrested with very little effort. Subsequently, either the climb can be resumed, the hitch locked-off (Fig. 9), or by releasing rope into the hitch the climber can be lowered. Simple and effective, but there are a couple of points to bear in mind:

- 1) The reversing action of the Italian Hitch is essential to its operation and the krab must be wide enough to allow this; there are in fact krabs made specifically for this purpose.
- 2) Ensure that the running rope does not undo the locking sleeve of the krab.

Even though these latter techniques are a vast improvement on the traditional method, the basic concept of lifelining from the top of the pitch is suspect in itself. The simple fact of the rope moving up and down the pitch with each climber creates problems of communication, with retrieval of the rope, and the need for at least two cavers to operate the system at all. Far better if the rope is fixed in the pitch alongside the ladder, and each climber protects himself by trailing a jammer attached to his harness along the rope as he climbs - this is the technique of 'self-lining'.

Self-lining is a fine exploration technique. The rope is fixed in the pitch parallel to the ladder, used for abseiling during the descent and to safeguard the ascent by trailing a jammer along the rope attached to the climber's harness. To stop for a rest or to make some adjustment, the climber simply clips himself to the ladder and sits comfortably in his harness. Self-lining has many advantages:

- 1) Overall the technique is much faster than conventional lifelining and also requires less rope.
- 2) Manoeuvres with the rope are eliminated and communications reduced to a minimum.
- 3) The climber no longer depends on the expertise of a lifeliner; he looks after himself and because both the ladder and rope are solidly anchored, he is above all safe.

Should the climber lose his grip or the ladder fail, he will hang from the jammer. Here however, it is essential that the caver wears a sit-harness, carries a descender while climbing and is capable of using this to abseil back down to the foot of the pitch. There are various 'release' techniques which make this possible, all fairly simple, but without this option the caver might find himself dangling in mid-pitch, possibly under a waterfall, in an extremely dangerous situation.

Unfortunately, I don't recall ever seeing an adequate description of self-lining techniques in British caving literature, even though the technique is a particularly relevant one. Therefore, below is a fairly brief description of the main points, taken from a section on vertical techniques written by the author for a forthcoming BCRA publication.

#### SELF-LINING

Equipment. Basic self-lining equipment consists of a sit-harness, long and short cows-tails, descender and jammer, and a few krabs (Fig. 10). A chest harness is unnecessary, except with certain types of jammer used where both SRT and ladders are used in the same cave (Fig. 11).

Rigging. The rope is rigged in much the same fashion as for SRT (Fig. 12). The main features being the use of double belays at each pitch, provision of a traverse-line where necessary and the use of bolts and intermediate anchors to arrange a safe hang and avoid abrasion. The ladder is rigged to one of the anchors supporting the rope. Wire tethers and slings are rarely used, the ladder being attached to the same karabiner as the rope.

Descent. The pitch is approached with the long cows-tail clipped into the traverse line for safety or, where the pitch is very easy of access, into the

karabiner holding the rope. The descender is installed on the rope and locked-off, the caver then hangs from this, unclips the cows-tail and begins the descent. Intermediate anchors are passed in the normal manner by hanging from the short cows-tail while the descender is transferred to the lower rope (Fig.13). Here, having the ladder to stand on makes releasing the cows-tail particularly easy. Very tight vertical sections where the descender creates problems by digging into the chest, are more easily passed by abseiling with the descender attached to the short cows-tail (Fig.14). But remember that with the descender at about head height, long hair and unkempt beards are liable to be painfully shortened.

Ascent. The jammer is installed on the rope then attached to the waist of the harness, either by a karabiner and D-ring or two karabiners (Fig.10). The jammer should not be clipped directly to the belt with a single krab, as this causes it to twist on the rope and prevents it operating correctly. Trailing the jammer on a sling is also dangerous, since you risk a fall-factor 2 fall (albeit a small one) should you come off the ladder. An ovoid or pear-shaped krab makes clipping in and out of the jammer very much easier.

The best position for the jammer is at the side: in front it catches on the ladder rungs and the rope constantly gets in the way, while round the back you can't see what is happening and also end up in an awkward position following a fall.

Before climbing check that the jammer is running freely and locking correctly, and that you have a descender clipped to your harness in case it becomes necessary to get down again. Initially, with a slack rope, you may be obliged to stop every few metres and pull the rope through until it runs of its own accord.

It is extremely important not to accumulate slack rope as you climb, because of the large shock-load that would result should you fall. You can avoid this by weighting the rope with either a tackle-sack, a coil of rope, or a suitable rock (Fig.15).

Tackle is carried at the side, clipped to the waistbelt of the harness where it does not catch on the ladder. In tight sections it can be dangled beneath on a hauling cord. To rest during the climb, simply clip the short cows-tail around one of the ladder cables and sit back in your harness, rest your feet on the ladder and let your arms dangle to restore the circulation (Fig.16).

At the top of the pitch, attach the long cows-tail to either the belay or the traverse line before releasing the jammer from the rope. On a steeply sloping traverse line, attach yourself first with the short cows-tail, transfer the jammer to the traverse line and clip into this with the long cows-tail. Transfer the short cows-tail to the traverse line. You can now self-line yourself along the traverse line by sliding the jammer ahead. Where the traverse line is anchored mid-way, always use both cows-tails on the rope and transfer one past the anchor before unclipping the other.

Muddy ropes. With very muddy ropes there is a danger that a sprung-cam jammer might slip and not grip the rope. Cleaning the cam is ineffective and under these conditions only certain cam-loaded jammers attached to the harness as illustrated are safe (Fig. 17).

'Release' technique. Should the ladder break or the caver fall off it, he will dangle from the rope held by the jammer. In a good harness under favourable conditions he can sit there relatively happy for a while and figure out his next move. He could wait for his mates to replace the ladder with another, or have some SRT gear slid down the rope. Under a waterfall however, things are a little different and survival time may be very limited. To be safe, he must in fact be able to redescend to the foot of the pitch without delay. Self-lining without this ability to abseil back down, is roughly equivalent to committing suicide.

The basic 'release' technique is a simple one, but like anything involving a certain amount of skill, its value in an emergency is in direct ratio to previous practice. Swinging on a rope deep underground is the wrong place to make mistakes. Proceed as follows:

- 1) While hanging from the jammer, connect the descender to the front of the harness (if not already in place).
- 2) Improvise a stirrup by wrapping the rope around your boot three or four times on the opposite side to the jammer. It helps to pass the rope behind the calf first and to cover the first wraps with the subsequent ones to prevent them slipping (Fig.18).
- 3) Lift this boot a little and install the descender on the rope just beneath the jammer.
- 4) Place the free boot on top of the other, stand up and release the cam of the jammer, securing the safety catch in the open position.

Detach the jammer from your harness by unclipping the karabiner from the D-ring (Fig.18).

- 5) Lower your weight onto the descender (easier with a self-lock descender) clip the rope into an extra friction krab if necessary, undo the stirrup and begin the descent. The jammer (which is locked open) is left to slide down the rope on top of the descender.

A few general points: releasing the jammer from the rope is often made easier by attaching the descender with two krabs instead of one. The same 'release' technique is also possible without a descender, using 'crossed karabiners', or an Italian hitch (Elliot, 1982).

From the foot of the pitch, provided there is someone at the top, you can recover the ladders and have them hauled back up. If not you'll need to either improvise an SRT rig, or find somewhere comfortable and wait.

Self-rescue. Although much safer than the traditional methods of protecting a ladder climber, self-lining techniques are obviously not infallible. As always, things do go wrong, and here exactly as in SRT, safety is inextricably linked to mastery of self-rescue techniques (Marbach & Rocourt, 1980; Dressler & Minvielle, 1979).

In essence, self-rescue techniques enable you to recover the helpless victim of an accident from mid-rope, where he would certainly die. Or enable somewhat fitter cavers to get out of the cave unaided instead of sitting on their arses literally dying of cold.

The most important thing to realise is that the value of any such technical exercise depends heavily on having previously practised it, preferably on the surface in a safe situation. Vertical caving is an extremely practical skill and as such cannot be learnt entirely from a book. Incorrectly carried out, such 'rescue' techniques could well kill someone. Yet if hours and hours of patient experiment practising such manoeuvres only once allow a single successful escape from a dangerous situation - then all these hours will have proved well worthwhile.

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June 1982

Dave Elliot  
1 Millthrop,  
Sedbergh, Cumbria,  
LA10 5SP



Fig.1. As it used to be!



Fig.2. Sticht Plate.

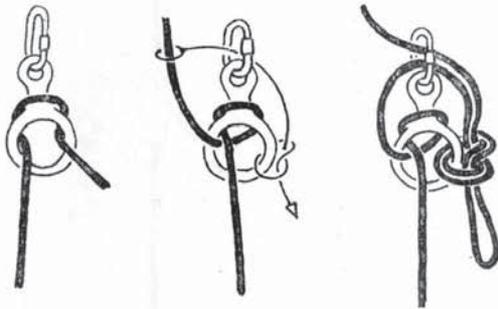


Fig.3. Inverted figure-of-eight descender as dynamic belay device.

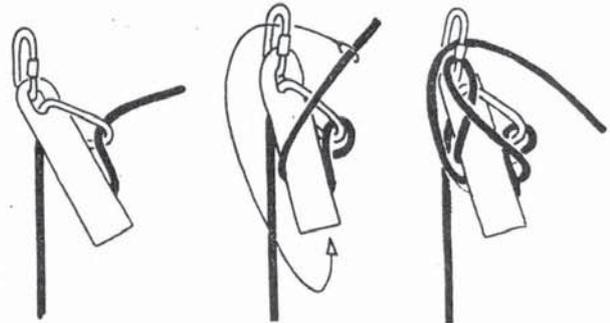


Fig.4. Inverted standard Petzl descender as a dynamic belay device.

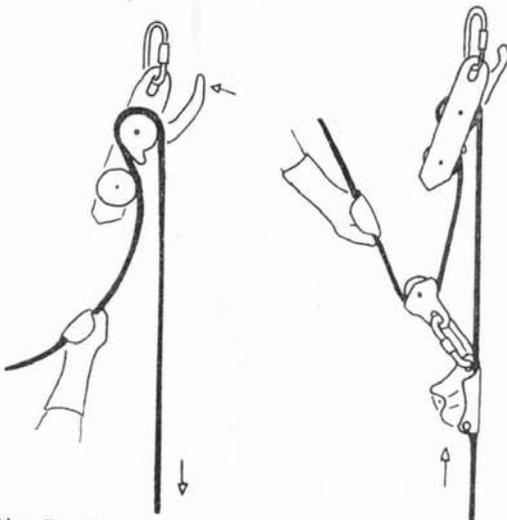


Fig.5. Inverted Petzl "Stop" descender as a belay device (note the modified rope path) and conversion to a simple haul system

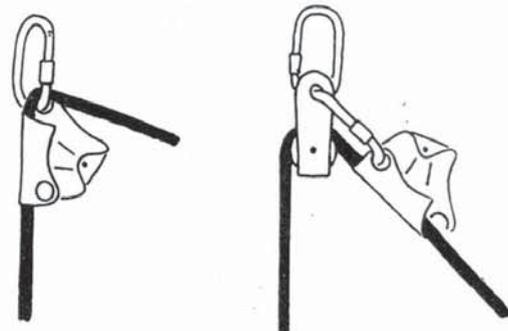


Fig.6. Petzl jammer as a belay device.

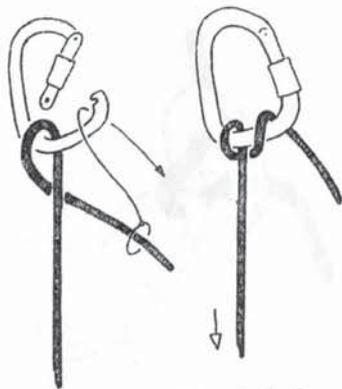


Fig.7. Italian hitch tying sequence.

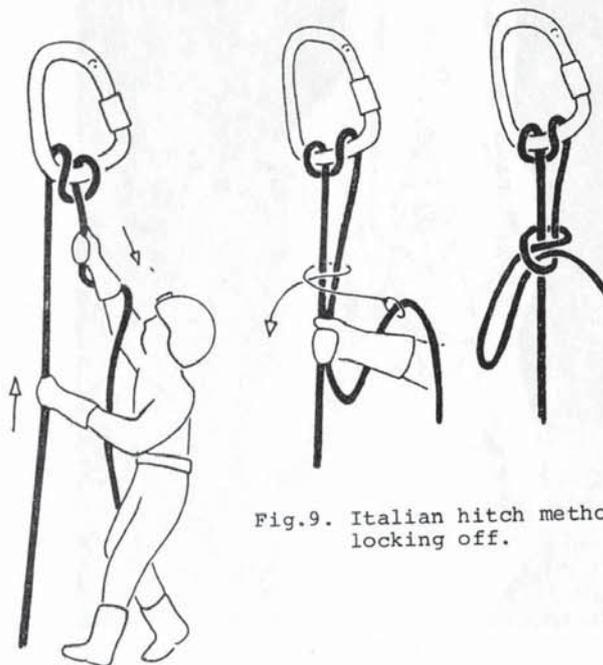


Fig.9. Italian hitch method of locking off.

Fig.8. Lifeline operation with Italian hitch.



Fig.12. Pitch rigged for self lifelining technique.

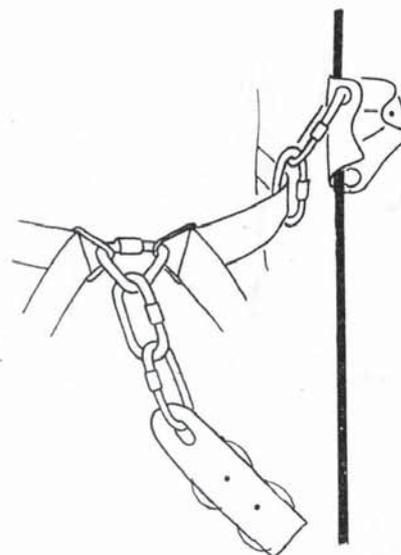


Fig.10. Basic self-lifeline equipment.

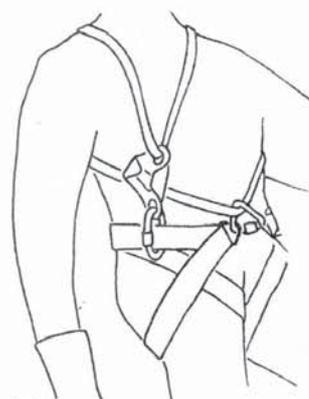


Fig.11. Optional use of chest harness for self-lifeline with certain jammers.

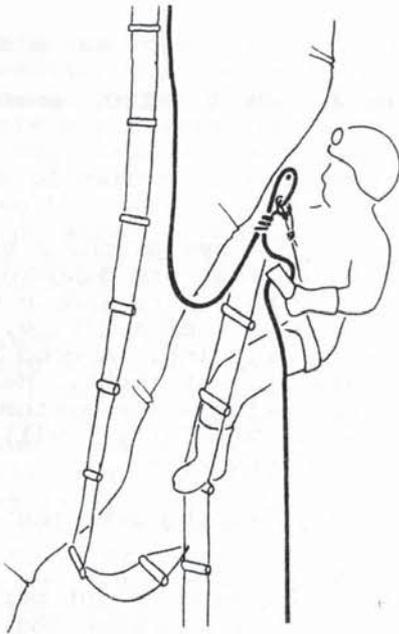


Fig.13. Passing a mid-pitch anchor during descent.



Fig.14. Technique of abseiling in a constricted pitch.

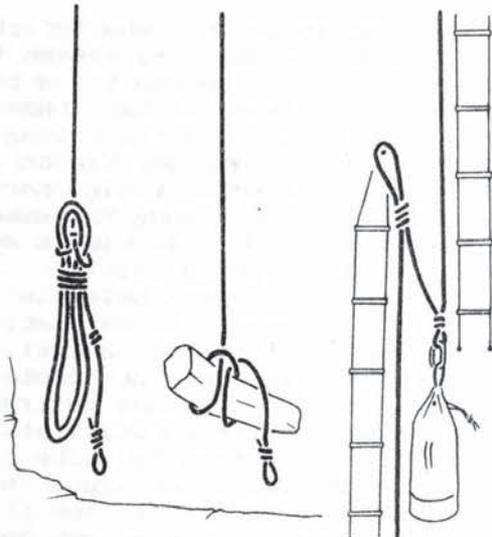


Fig.15. Means of weighting the rope.



Fig.16. Method of resting on the ladder.

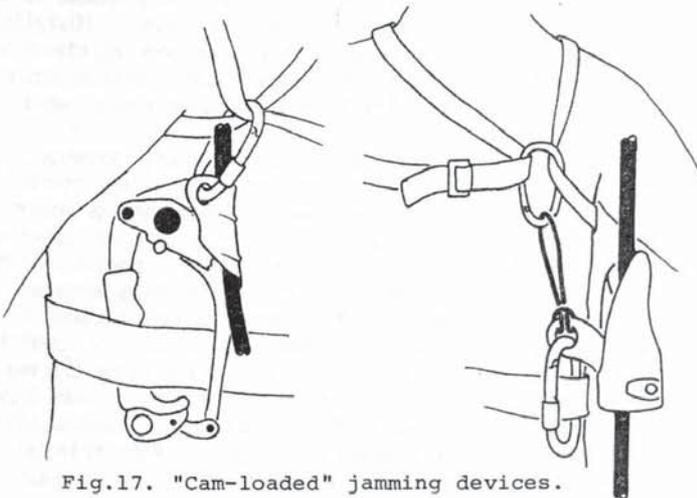


Fig.17. "Cam-loaded" jamming devices.



Fig.18. Improved foot stirrup.

## CAVE SCIENCE

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### PITCH RIGGING

Dave Checkley

There is nothing so exciting as arriving at the top of a new pitch, a big black abyss just crying out for you to descend it. Pitch tops are dangerous places and good pitch rigging difficult to achieve. The rules are simple enough, in fact they are pretty obvious once you have thought about them a little. However, there's a mile between good rigging and correct rigging. A good rig, once seen, leaves you with nothing to add, it's so clearly just right. Here I will only deal with ways of getting it right when exploring a new system, since that is where I have gained most of my experience. Hopefully I will provide a few useful tips to help you rig your future discoveries.

The basic rules are straightforward:

1. Take it easy and get roped up before enthusiastically leaping over the edge looking for a belay point.
2. Watch out for loose rocks and if in doubt hit it or kick it.
3. Try and imagine an exhausted caver coming back up and trying to get off the rope. A little more time and effort in the rigging could save the next twenty people a real struggle.
4. Get two good belay points and not one good one and a psychological one half a mile back up the passage.

So we have plenty of rope, bolts, tapes, krabs, maillons etc., and before us a beautiful black hole. We ease up to the edge, throw a rock over, listen to the distant rumble and fired with enthusiasm start a frantic search for a belay. It is at this stage that a little calm reflection is required, perhaps best provided by the second man in the team. The hole has been there for a long time and will probably wait for him to find a belay back up the passage, tie on and line the enthusiast at the edge whilst he risks life and limb searching for a good belay. A traverse up into the roof often pays off, but a long traverse way out over the hole will make the return "interesting" and it is always worth remembering that an SRT rope is not designed for a long climbing fall.

An unfortunate fact of the cavers' life is that the ideal rock belay is just out of reach or not quite right for a good hang. This normally means placing a bolt for the primary belay point, but the back up can sometimes be natural. There is a tendency for people to forget about natural belays and go completely over to bolts. This goes hand in hand with an unjustified and absolute trust in the bolt. Once you have seen a few come out, often with the rock still attached, then the appeal of big stalagmites or flakes increases dramatically. The other attractions of natural belays are that they are free and don't require a tortuous exercise in bolt-placing. However, it is worth looking carefully at the flake if an abraded rope is to be avoided. A rope protector or wire belay can be very useful here.

The choice of the primary belay point is difficult and can often take some time and discussion. A good electric light beam is useful for a long look down the pitch, so that your reasoning can be based on a good long descent. Holding a loop of rope at the proposed point is invaluable, since a few inches either way can make all the difference. Often in a shaft or rift one wall is convex and the other concave so a short traverse might take you to the concave wall and save multiple rebelaying on the way down.

Having placed the primary belay then the secondary, if not already known, must be sought: natural, if possible; not too close, just in case the rock fails, and not too far horizontally from the primary, or you will have a surprise when the primary goes. There is a temptation to use the secondary as an anchor for the traverse line leading to the pitch top. If you can do it - great, but invariably that means a nearly horizontal line between the two and the secondary being back over the lip of the pitch and we all know what happens to ropes taking shock loads and running over sharp lips. The traverse line belay can be sorted out by the life-liner back up the passage. It will give him something to do beside shiver and moan whilst you sort out the pitch. So a traverse line for a good pull and protection for the moves onto and off the rope. It is easy to fix up and uses a natural belay. It is connected to primary or secondary pitch head belays, the latter being as near to directly above the primary as

possible and hopefully natural. The primary is the one the rope hangs from and its position must be perfect. That really is the problem - what constitutes a good hang for the rope.

There are several obvious points, like easy access and keeping out of the water and clear of loose rubble walls, some of which are so crumbly that no amount of gardening will improve them. The other objective is to get a free hang so that all thoughts of nasty abrasion can be forgotten. It is the abrasion animal which SRT people have bad dreams about. Fifty metres up and ten to go, moving well until you notice a bulge 5 metres up the rope and then see the rope strands spin out one at a time - horrible, and even worse in real life. A free hang will amongst other things get rid of your bad dreams and help you sleep at night. However, it is worth remembering that 'free' means not touching the wall when there is a man on the rope. An even slope is always 'free' : it is the broken ones and the bumps that you have to worry about. Don't forget that people swing around on the rope and that in deep systems big unbroken pitches are best avoided since they really slow the group down and necessitate recourse to tandeming. One very important point in favour of a completely free hang is that it often keeps the man and consequently the rope from getting too muddy. Going down a muddy rope when you should be going up is the sort of experience you don't forget and I would recommend an extra rope walker or shunt as standard gear, since prussik knots do slip.

Getting nearer to the descent now and just a few details to consider. There might be a little wear on the rope at the belay, particularly if you haven't got a thimble. The odd rope protector could be useful, although as far as I am concerned, in any sizeable system the rope protector has no other use. The joke protection they afford part way down a pitch, especially on a bouncy rope, added to the time they take to place make a bolt or natural rebelay a must. Too much slack between the primary and secondary is worth checking. Is getting off going to be easy even when you are totally shattered? That nice high belay will help you swing in to a good safe position and will be welcome on the way back.

Now to the descent: nervous and checking for a knot in the end of the rope, full prussik gear on and the rope hangs down between your legs, but don't rush - a steady descent kicking the wall - gardening it clean and safe otherwise your partner will have something off onto your head when he follows you. Will that bulge below rub on the rope? Try lying flat against the wall and dangling a loop down. Don't go past it to find out that the rope will catch and you have got the only bolt kit! Yes, you're delayed again looking for a belay point, but this time half-hanging on the rope. My sit harness does not give me too long to think about it, but that's my problem. The same criteria hold, but the choice of primary is even more vital since there will be only one belay point. Don't forget the dubious pleasure of the pendulum, look around even if you are in trouble and think about the other wall - the one behind your back.

A useful tip here is that a bolt just below the lip of a ledge often gives a good hang. It may even be worth going below the lip of a ledge with standing room to get a good free hang.

Exactly how to go about placing an intermediate anchor is up to you, but my recommended procedure is: place the bolt low, tie the rope below you into it; transfer to the bolt maillon and then move onto the lower rope. This has the considerable disadvantage of requiring a guess at the amount of slack required for your mate to get his descender on to the unloaded rope at the top. It's easy to leave too big a loop and make the back-up potential of the pitch-head belays negligible and also it is possible to leave too small a loop to get on at the top or to pass the bolt on the way up. The alternative is to place the bolt, move onto it keeping your descender on the rope; unload the rope; calculate an acceptable loop; tie a knot and connect it to the bolt, then move on to the lower rope. This method makes the loop easy to judge, but means putting the rope onto the bolt whilst it is still bearing your weight. This is a risky move, particularly if using maillons, which can easily bend with the gate open. If anyone has a method without any drawbacks then I'd be interested in hearing. Of course if there is a good ledge nearby, then go for it and belay from there. In this, the rather more common situation, the second method is the better choice. It is only when you are hanging on the rope that setting the size of the rebelay loop is tricky, but just how big you make it is another problem.

The obvious answer to the loop size question is that it should be as small as possible. Possible means as small as the teams can manage to get their descenders on at the pitch head; pass the bolt going down and pass it easily when shattered, on the way up. Different bits of SRT equipment need different

loop sizes. Generally a loop of rope hanging down one metre below the bolt is plenty in the unloaded rope. If it is too big unloaded then it will be even bigger loaded, and two people may fall as a result of the failure of the intermediate belay. It is almost ironic that failure of an intermediate belay well down a big pitch is less risky than one just a few metres down. Fall factors again - in other words it is not so much how far you fall but how far relative to the length of nice stretchy rope between you and the belay. It is for this reason that a back up belay besides a primary and not above it, is so dangerous. You get to the top of the pitch and start feeling nice and safe again, the primary goes, you only fall a few feet, (largely due to slack between the belay points) but its far enough to overload the shock bearing potential of that none too stretchy rope and we wave you goodbye. Watch out for loop lengths and unnecessary slack in the system, particularly when there are several short pitch sections. Wet pitches in SRT systems demand special comment. If it is anything like humanly possible, get out of the water. A long traverse with three or four bolts is better than a wet, cold pitch with its added bonus of a chance to get trapped. However, if you cannot avoid the water it is vital to pull the rope up on the way out. Waterfalls cause very rapid rope wear by continually rubbing the rope against the rock.

One final point which I have never seen any discussion on before and that is on re-rigging. I don't know if everyone thinks he is perfect, but the people I have caved with haven't always been and I have made plenty of rigging mistakes myself. If you are working in a deep system then it is probably well worth correcting a few of the worst jobs. You can always tell where people have trouble by them either going quiet or swearing violently. It is often easy to get volunteers for alterations near the entrance, particularly as the cave gets to be deep and hard work. So take them up on it and give them an easier trip, it is just in the entrance region that people will appreciate good rigging and good rigging means more pleasurable caving - which is what it's all about.

Dave Checkley,  
17 Ash Grove,  
Heaton Chapel,  
Stockport,  
Cheshire.

The above article is based on a talk given at  
the symposium on SRT at Buxton, 1980.

## PRACTICAL PITCH RIGGING FOR SRT

Dave Elliot

## ABSTRACT

Recent developments in vertical techniques have revolutionised British caving of late. Single Rope Techniques open up many new prospects for the skilled, but contain dangers for the unwary. Rigging pitches for SRT involves some of the most crucial decisions a caver must make on a normal trip. This paper attempts to outline the basic principles of safe pitch rigging and how these are related to common situations underground.

SRT simply describes the passage of vertical bits of cave by means of a single fixed rope. Compared with traditional ways and means such techniques are relatively recent, but the effect of SRT has been to alter fundamentally the methods by which equipment is used to overcome such obstacles (Montgomery, 1977; Meredith, 1979; Marbach & Rocourt, 1980). Young cavers will doubtless smile to learn that only 5 or 6 years ago such techniques were generally regarded as suicidal. The advancement of SRT has been a radical one with the result that currently these techniques with minor variations are used exclusively for the exploration of deep caves throughout the world.

The obvious advantages of SRT are sufficient justification in themselves; the tackle required for a given cave is greatly reduced, making exploration possible for small teams of two or three cavers, which in turn implies greater speed and freedom of action. Less obvious though far more important is the inherent safety of these techniques. Now, as everybody present is perfectly aware, British cavers are amongst the best in the world. However, what they actually do here is open to question as many of the techniques in common use are probably amongst the world's worst. Nowhere is this more apparent than when it comes to rigging pitches.

Firstly, let's define rigging simply as the means of installing the equipment necessary to progress safely through the cave. There is no great skill involved - just the common-sense application of a few simple principles. Given suitable equipment (another story) the style of rigging largely determines:

- 1) The safety of the caving team, which is always of prime importance.
- 2) The speed and ease with which the pitches are climbed.
- 3) The wear and tear the gear receives.

In the first case it isn't difficult to see that depending entirely on a single, rather thin rope, it's a good idea to attach it to something very solid, positioned so that the rope is not damaged by abrasion. Likewise, hanging the rope so that it is easily climbed and got on and off at the top, without either rupturing yourself or prusiking along the floor, tends to make climbing the pitch a much more pleasant experience. I'm sure that many caves with a reputation of difficulty are only so when badly rigged. Avoiding water on pitches is always a good idea and adds significantly to the safety and comfort of a trip. For example, with a little thought for the position of the rope, it is possible to descend a cave such as Stream Passage Pot under very wet conditions, and with a little more thought, get up and down Diccan Pot without so much as getting your feet wet. As for wear and tear, a rope rigged so that it gets covered with mud and grit, very quickly wears away at both descender and rope so they soon need replacing. There were reports last year of wearing out a set of rack bars on a single trip (Elliot, 1982). It is all too easy to position the rope so that it glances against the rock in a few places. Provided that the rock is smooth there is little danger of the rope wearing through and failing. It will, however, suffer some damage, as limestone is harder than nylon and wherever the two meet the rope invariably comes off worst. With the price of certain ropes now over £1 per metre, caving becomes an expensive business if you knacker a rope on each trip. Not being involved with selling ropes, I can say that almost any current SRT rope will give many years of good use if properly cared for.

One last consideration before looking at how the rope is rigged in the cave. Consider the rope rigged in the pitch as a succession of different

elements, starting with the rock, then the anchor, bolt, hanger, and karabiner, and fastened to them by certain knots is the rope itself. Farther down the pitch, struggling fitfully on the rope, is the caver, a weak link in the system, attached by a couple of jammers or a descender and any amount of karabiners and bits of tape. Each of these different elements has its particular characteristics and strengths and weaknesses depending on how it is actually used. Just about all the papers this weekend are concerned with one aspect or another of this equipment and all have the same underlying principles. It's no use at all just buying the best equipment, you also need to know how to use it. Some understanding of the function and capabilities of a bit of gear is necessary to be able to use it appropriately. In fact the whole basis of rope rigging is simply ensuring that you stay within the very specific limits imposed by the equipment, stray outside these limits and you're in danger.

In arranging the anchor for the rope, there are four main requirements:

- 1) The rig must be strong and secure enough to withstand the forces involved in a shock load (that is as strong as the rope itself).
- 2) Provide a free hang to eliminate abrasion.
- 3) Allow easy rope access at the pitch head.
- 4) As far as possible, avoid objective hazards such as water and stonefall.

Rarely will a single anchor of any type fulfil all of these requirements - if this belay fails, you've had it ... So the First Rule of rigging is AT LEAST TWO SEPARATE ANCHORS AT THE TOP OF EACH PITCH. Natural rock belays are one greatly overrated possibility: either they exist or they don't and generally they don't. I can't think of more than a couple of good natural rope belays in the whole of the Yorkshire Dales. To avoid abrasion we need to be able to hang the rope exactly where we want it, which means alternative forms of anchor. There are occasional cracks where a peg or chock might be placed, but these are often suspect and it is almost always better to rig the rope from bolts - specifically the 8mm self-drilling types.

There are a few "one foot in the grave" traditionalists still muttering that current bolting techniques result in caves littered with rusty bolt anchors. There is perhaps some slight degree of truth in this, but these tiny anchors buried in the rock are certainly less offensive than the bloody great stakes and beams of the last decade, and fortunately in caving safety is an overriding consideration in any case. Caving is not generally fraught with the high-minded ego-ethical problems that beset rock climbers, and while doubtless very nice to rig a cave using natural rock features, it is obviously far more important to stay alive. With his life at stake the caver has every right to arrange an absolutely safe belay, and at least as far as I'm concerned, the conservationists can shove it. Do not under any circumstances be tempted to risk your life for anybody's ethics but your own, and even then think about it very carefully first.

When reaching the main rope involves climbing out over the pitch, a traverse line should be provided for safety. This is rigged at about head height, linking a safe back-up belay (often a natural anchor) to the main belay (Fig.1). This provides both a back-up for the main belay and a safeguard for getting on and off the rope. Considering the consequences of a single slip, it is amazing how many cavers take temporary leave of their senses at this point, scrambling about like spiderman looking for belays without thought for the drop beneath, and almost always with a mate stood by holding a rope which could be used for protection. The technique is very simple - the rope is fastened to the back-up belay and used by the first caver to protect himself while installing the main belay (Fig.2). He can do this with a jammer, an auto-lock descender, or an ordinary descender by tying a knot in the rope below it (Fig.3), or even simpler, by attaching a cow's tail to a knot in the rope. Should he then fall the force on the belay is not very great because of the pendulum nature of the fall; however, the caver might get bashed about a bit on the way. Obviously the back-up belay must be strong enough to support the rope should the main belay fail, which is not to say that the main belay is less important; the main anchor is just that and as such must not fail. Here unless a really perfect anchor can be found, two separate anchors are used and the chances of both these failing simultaneously is very low.

A common arrangement is to place two anchors one above the other, with the connecting rope tied with little slack (Fig.4). The upper anchor will take a shock load should the other fail, but this will be minimal. There is, however, little point in having two anchors available and loading only one.

Often a better arrangement is to load both anchors so that each takes less than the full load. Together they are less likely to fail and won't cause a shock load in any case (Fig.5). Perhaps the best arrangement of all is a Y-anchor, where both anchors are loaded about equally, generally on opposing walls, with the actual hang point somewhere in between (Fig.6). This technique is particularly useful in many northern caves with narrow, twisting stream canyons cutting down into the pitch where it may be impossible to obtain a free hang from either wall. So that each arm of the belay is under no more strain than the main rope, the angle between the two must never exceed  $120^{\circ}$ . Also, since generally most bolt hangers are not designed to work at more than  $45^{\circ}$  to the rock, an angle of  $90^{\circ}$  between the two anchors is the working rule (Fig.7). This is easy to recognise and in this case each element of the belay is subject to about 70% of the load on the main rope.

Having constructed the main belay, the caver descends and at each point where the rope touches rock he installs an intermediate anchor (or rebelay) at or immediately beneath the rub point, so that the rope again hangs free below it (Fig. 8/9).

Second rule: ELIMINATE ABRASION. No amount of abrasion, however slight, is acceptable. A single bolt is usually sufficient, as the rebelay is very effectively backed up by the main belay. Here it is necessary to leave a loop of rope so that those following can install their descendents (Fig. 9). The length of this loop is important, for should the intermediate anchor fail, a shock load will be transmitted to the belay above. About one metre is sufficient, but the elasticity of the rope must be taken into account or the loop may disappear when unloaded. This technique of rebelaying is continued to the foot of the pitch, whether the rope is simply touching the rock or there is a series of pitches close together (Fig. 10). Where a very large ledge or a traverse requires more than a small amount of slack to be left in the rope, the continuing pitch must be rigged with a double belay to avoid the shock load which would result from the failure of a single anchor. Third rule: MINIMISE ANY POSSIBLE SHOCK LOADS. The intermediate anchor technique has other advantages apart from avoiding abrasion and water. Splitting the pitch into sections reduces bounce in the rope and because the rope is attached to several anchors the overall safety is increased. Speed is substantially increased because now several of the team can descend or climb simultaneously, provided that each is hanging from a separate anchor.

A useful alternative method of redirecting the rope on a pitch is the technique of deviation. Here some vague anchor (perhaps on the opposite wall) is used to pull the rope away from the rub point by means of a length of cord and a krab clipped around the rope (Fig. 11). The force on this belay is not very great as the rope is not directly fixed into it and would not cause a shock load should it fail. Thus many belays are suitable for deviations which would be extremely dangerous if used for rebelays - for instance a small stalagmite, a knot jammed in a crack, or a partially inserted piton.

One further, far less satisfactory technique, is that of padding the rope at rub points, either with a mat or a tough sheath fastened around the rope (Fig. 12). Passing a rope protector is straightforward if a little tedious, but each caver must take the utmost care to replace it in the correct position after he has passed. If the rub point is a severe one, failure to do so could well kill the next caver to climb the rope. In practice padding is only really acceptable directly beneath an anchor point and often an empty tackle sack can be used (Fig.13).

The basic techniques outlined above will serve for most caves, but there are situations where more ingenuity is called for, and there is generally plenty of scope for this. The pitch head might be particularly awkward or you may need to install a long traverse line to reach some distant objective, or even a tyrolean traverse to overcome some obstacle or other. This is generally fine provided that a small amount of slack is left to avoid overtensioning the rope, and that one simple guideline is strictly adhered to. Because the rope is of low-stretch construction it has only a limited capacity to absorb energy. It must therefore never be subject to the shock load arising from a fall - factor of any significance. Apart from the likelihood of damaging the caver, many used caving ropes would break under a fall-factor of only one, in which case it's all over!

A fall-factor is a simple concept used to describe the relationship between the length of a fall and the length of rope available to intercept it (Fig.14). There is a danger here of getting involved in a lot of scientific discussion, but, briefly, the energy of a falling body is proportional to the distance fallen, where the rope's capacity to absorb this energy is proportional to it's length.

By dividing the one by the other we get a fall-factor which varies between 0 and 2. Bear in mind that it is the relationship between these two factors which is most important, not their value. Take the case of a fall-factor 1 fall, that is where the distance fallen and the length of rope are equal (say someone falling from the head of a pitch onto a slack rope), the shock will be substantial, but a 2 metre fall onto 2 metres of rope produces the same shock load in the rope as a 10 metre fall onto 10 metres of rope - the fall-factor being the same in both cases. With most SRT ropes this shock load is likely to be somewhere around 1 tonne, which is coming uncomfortably close to the limitations of both the equipment and the force a caver might withstand without major damage.

However, once aware of this absolute limitation of a low-stretch rope there is scope for improvisation. It is almost always possible to avoid dangerous situations arising by simply ensuring that the main belay is always positioned below the back up belay. This being so even a fall-factor 1 fall becomes impossible and in most cases no more than a violent swing will result (Fig. 15). Don't forget however, that as a result of this swing the rope could be cut against a sharp edge or the caver smashed against the walls. But even this rule is not inviolate, look at the situation in (Fig. 16); here, in order to ensure a free hang, the main anchor is placed well above the previous one. This is potentially a very dangerous situation; should the upper anchor fail with the caver close to it, a fall-factor of around 2 would result. This would almost certainly break the rope. But even here we can make things safe by tying the belay loop knot at a point below the level of the previous anchor (Fig. 17). This ensures that the descender is installed at a low enough level, reduces the fall-factor to almost nothing, and saves the CRO yet another messy job.

There are still certain situations where in spite of all that can be done to reduce the fall-factor, a considerable shock load will still be placed on the rope should the main belay fail (Fig. 18). However, all is not lost, even here we can take steps to minimise the resultant shock load by the use of "shock-absorbing" knots (Fig. 19). These are just certain loop knots tied in the unloaded section of rope (traverse line), which if loaded, will slip a little and in doing so both absorb a certain amount of energy and also release additional rope to help minimise the shock (Fig. 20). This is a sensible precaution to take with worn or thin ropes.

I think most cavers would agree that the basis of good pitch rigging is only commonsense application of a few simple concepts. It is, however, sometimes difficult to reconcile this with the marked tendency for the standard of rigging to decrease along with the length of the pitch. At a big pitch the rope is very understandably tied to everything in sight, and while "it'll be reet, it's only a little un" might sound comforting to some, there is obviously no reason at all to suppose that a belay at the top of a 15 metre pitch should be any less likely to fail than one at the top of a 50 metre pitch. Exactly the same forces are involved and the result of failure may well be identical.

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Dave Elliot,  
1 Millthrop,  
Sedbergh,  
Cumbria LE10 5SP



Fig.1. Back-up belay, traverse line and main belay arrangement



Fig.2. Self-protection while rigging the main belay.



Fig.3. Self-protection while rigging a traverse line.

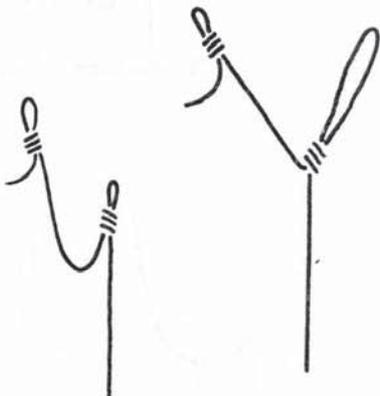


Fig.4 Fig.5.  
Double belays.

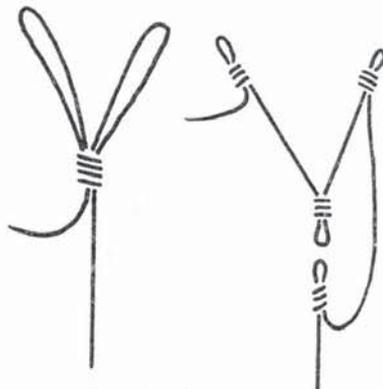


Fig.6. "Y" anchors.

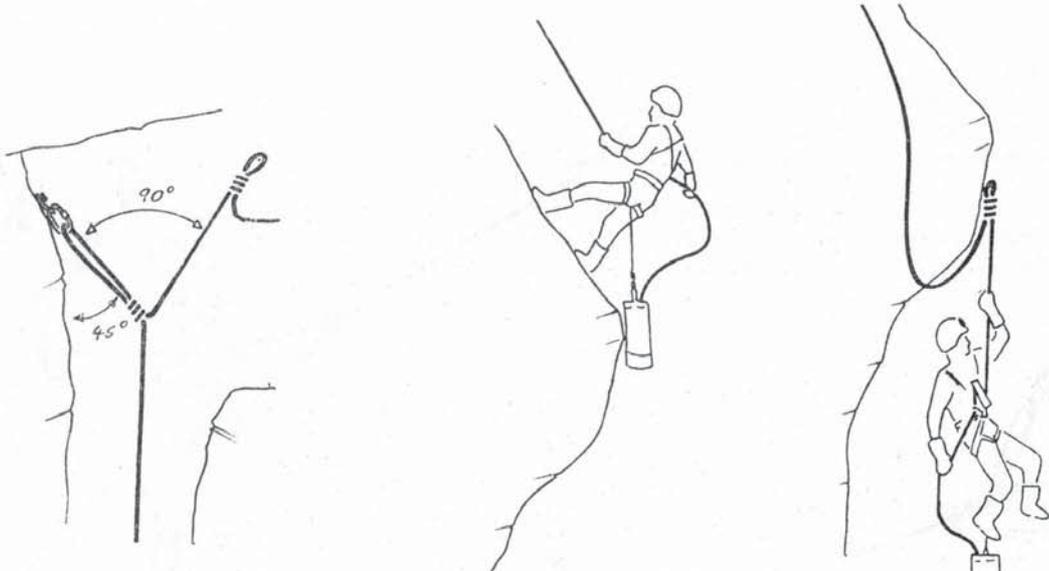


Fig.7. Safe loading angles. Figs. 8 & 9. Installation of intermediate anchor or belay.

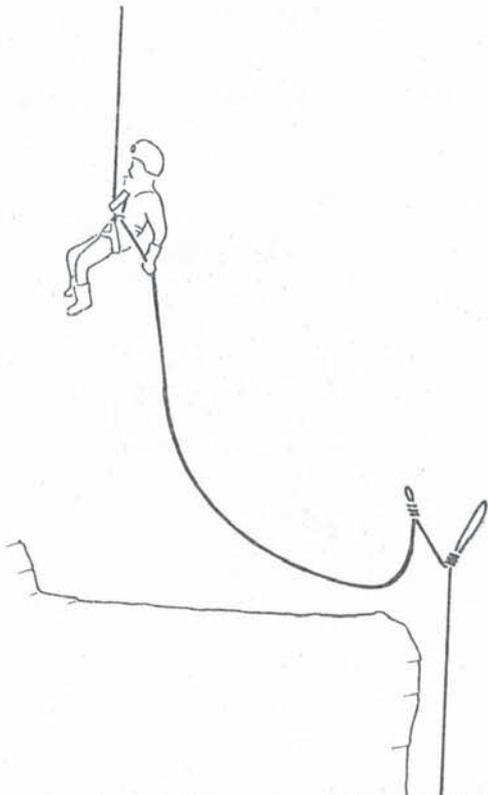


Fig.10. Continuous pitch-rigging.

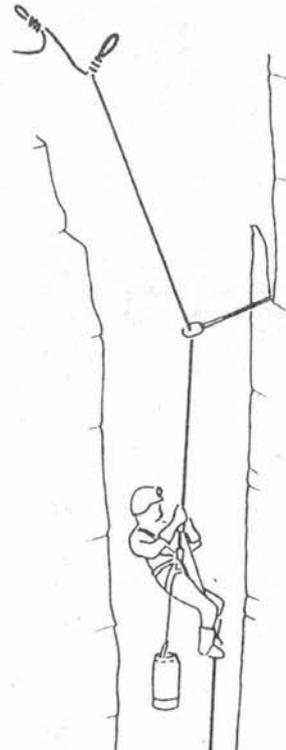


Fig.11. "Deviation" technique.

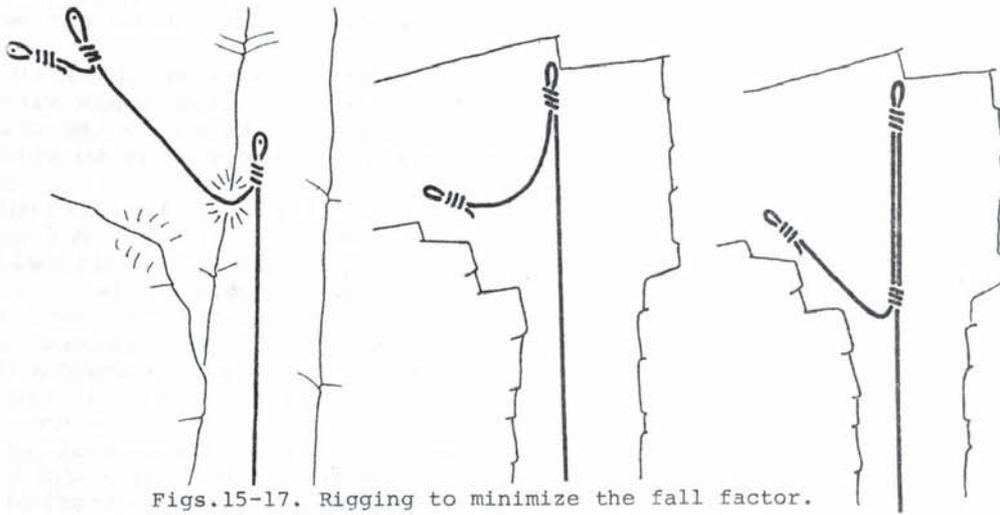
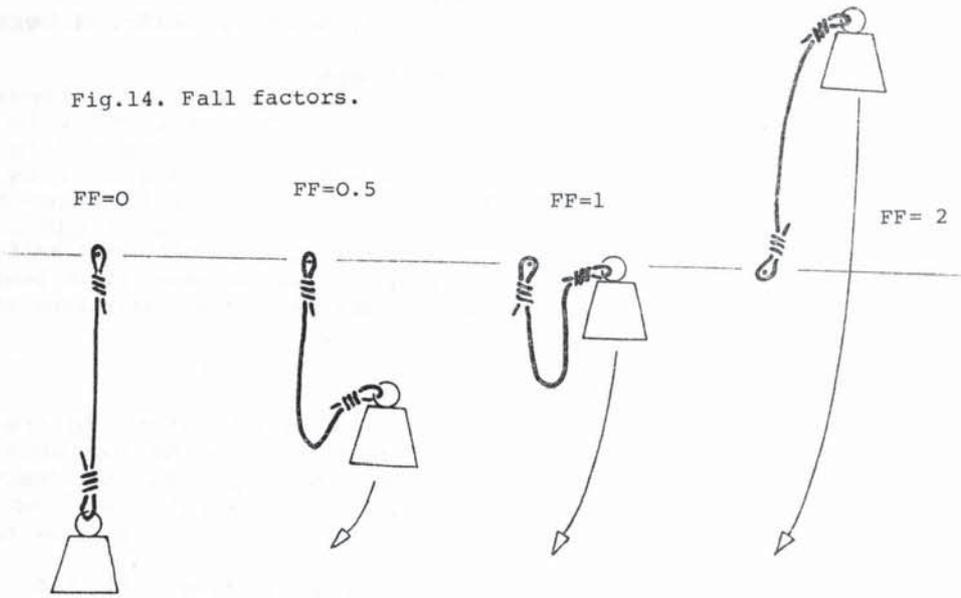


Fig.12. Rope padding with sheath.



Fig.13. Rope padding with empty tackle bag.

Fig.14. Fall factors.



Figs.15-17. Rigging to minimize the fall factor.

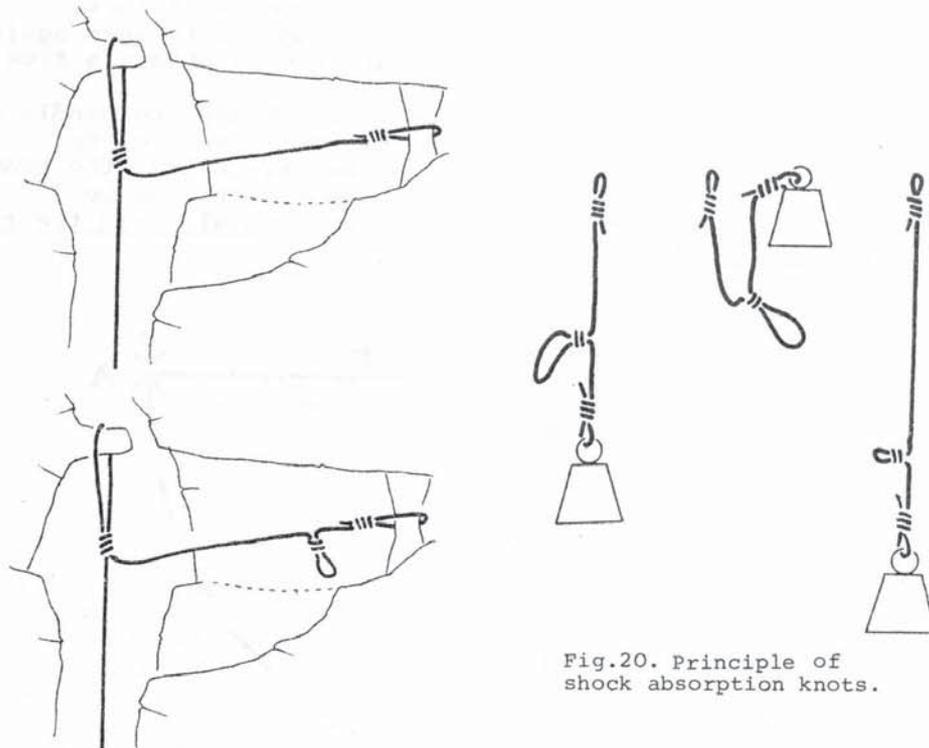


Fig.20. Principle of shock absorption knots.

Figs.18 & 19. Use of shock absorption knot.

## SELF-LOCKING DESCENDERS

K. Lewis

## ABSTRACT

Techniques using self-locking descenders are described. Seven different self-locking descenders are tested on three different types of rope, four on different pitch lengths, by two cavers of different weights and their performance compared. Wide variations in performance were found.

Modern single rope techniques owe their high level of safety to the virtual impossibility of the caver becoming detached from the rope on his ascent, making a fall unlikely, except by an act of gross negligence. On descent, however, using conventional descenders, it is easily possible to lose control since a positive action on the part of the caver is required to slow or prevent descent.

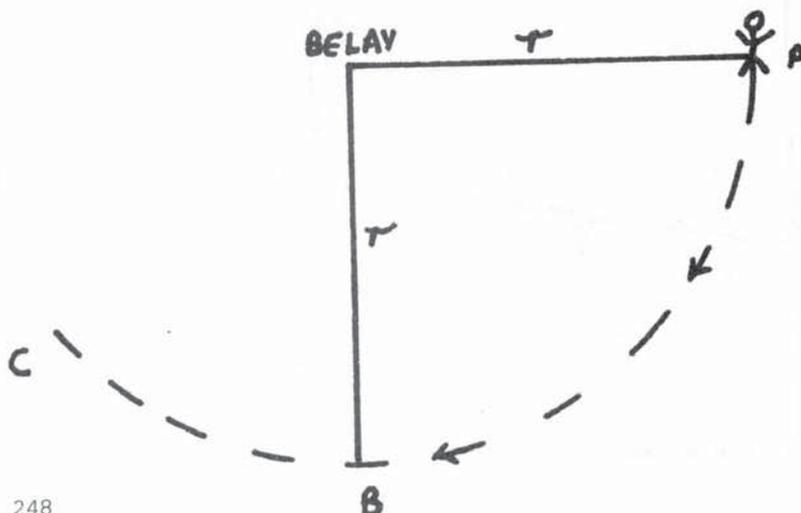
Various self-locking descenders have been introduced over the last few years, all of which incorporate a handle which has to be moved in order to descend; inaction prevents descent. This has presented the vertical caver with a means of substantially increasing his safety margin which he has so far largely ignored.

An efficient self-locking descender makes mid-rope manoeuvres, such as passing intermediate belays and changeovers from abseil to prusik and vice versa much easier and safer. The caver is therefore encouraged to improve the standard of his pitch-rigging techniques when he no longer has to worry about locking off a conventional descender.

Some self-locking descenders are of considerable value in self-lifelineing a caver across pitch-head traverses when trying to obtain a free hang for the rope. A sprung cam jammer may be used for this purpose but difficulty will be experienced when trying to move smoothly along the traverse without introducing slack into the rope and many are rather weak at around 4,000 to 5,000 N. The manoeuvre may be lifelined by a companion but this places responsibility for surviving a fall with someone else with whom communication may be difficult and unless two ropes are used, makes rigging very difficult.

The procedure for self-lifelineing a traverse with a self-locking descender is to clip a tackle bag containing sufficient rope (not forgetting a knot in the bottom end) to the sit harness via a cow's tail, tie the rope to a sound belay at the beginning of the traverse and fit the descender, which is attached to the sit harness, onto the rope. As long as the handle is held in it will be possible to move along but if it is released the descender will lock, protecting the caver if he should fall and also allowing him to lean against the tension of the rope to place bolts, if necessary and so obtain a free hang for the rope.

If the caver should fall from the traverse he will release the handle and pendulum along a circular arc with his belay as centre. Assuming, for simplicity, an inelastic rope and no contact with the cave walls, the tension in the rope and therefore the load on the self-lifelineing device, can be considered as below but this assumes also that there is no slack in the rope and that the caver has not climbed above his belay.



If the caver, having mass(m), falls from point A the maximum tension (t) in the rope will occur when he reaches a point B vertically below his belay at which point his velocity (v) along arc ABC will be at a maximum. The tension (t) will be the sum of the force required to produce the centripetal acceleration constraining him to follow arc ABC and that required to support his weight on the rope,

$$t = \frac{mv^2}{r} + mg \dots\dots\dots(1)$$

His potential energy at point A relative to point B must equal his kinetic energy at point B,

$$mgr = \frac{mv^2}{2}$$

$$\therefore v^2 = 2gr \dots\dots\dots(2)$$

combining (1) and (2),

$$t = \frac{m(2gr)}{r} + mg$$

$$\therefore t = 3mg$$

So the tension in the rope will be independent of the distance traversed and equal to that produced by three times the caver's total weight. However, the kinetic energy of the falling caver will be directly proportional to the distance traversed and since this will almost certainly be dissipated by collisions with the cave walls, intermediate belays are obviously to be recommended for long traverses.

A heavy caver carrying a bag of rope and other equipment may therefore exert a tension in the rope, through his self-lining device, in excess of 3,000N. This may leave a rather inadequate safety margin with some sprung cam jammers which may be destroyed by forces of 4,000 to 5,000N. The self-locking descenders, however, are probably all able to withstand loads in excess of 8,000N (Courbis 1982; Elliot, 1980).

TABLE 1

DESCENDER	WEIGHT (GM)	PHYSICAL SIZE	ARE INSTRUCTIONS SUPPLIED	ARE SPARES AVAILABLE	ROPE SIZES	USE OF DOUBLE ROPE	CAN ROPE BE LACED INCORRECTLY	CAN DEVICE BE FITTED WHILE ATTACHED TO HARNESS	USE AS PLAIN DESCENDER
LEWIS	330	6	YES	YES	9-11mm	YES	YES BUT LOCKS	YES	YES BUT FAST
PETZL	325	3	NO	YES	UP TO 10mm	NO	YES PLAIN DESCENDER	YES	YES
LAWSON	340	5	YES	NO	10-11mm	NO	YES BUT LOCKS	YES	YES
DIABOLO	350	4	NO	NO	10mm	NO	YES PLAIN DESCENDER	YES	YES ALSO INADVERTENTLY
KONG	415	7	NO	NO	10mm	NO	YES PLAIN DESCENDER	NO	NO
D.A.D.	280	1	YES (IN FRENCH)	NO	10mm	NO	YES PLAIN DESCENDER	NO	YES
GRIVEL	300	2	NO	NO	Over 9mm	YES	POTENTIAL DANGER	NO	NO

TESTS

Various tests have been performed on the seven self-locking descenders available from the Whernside Cave and Fell Centre equipment loan service to examine their suitability for use as mentioned above and their performance when abseiling. General information on them is presented in Table 1, some observations on which are:

Instructions, an advantage with a completely new concept in descender design and use.

Spares, if unavailable the descender is useless when worn out and therefore very expensive.

Rope sizes, a descender which will not accept all commonly used sizes of caving rope is an embarrassment when a cave is rigged with an assortment of rope.

Double rope, useful for through trips and in scaling.

Incorrect lacing, ideally should firmly lock the descender rather than give a very fast descent (Grivel particularly susceptible).

Attachment to harness, should allow device to be fitted onto rope without removal, all too easy to drop under stress.

Use as plain descender, may be of advantage in tight caves, should not be possible to lock as plain descender inadvertently (as with Diabolo).

Abseiling on a self-locking descender

A commonly held misconception among newcomers to self-locking descenders is that the descent can be controlled with the handle alone. In fact, on any known self-locking descender, it is still essential to brake the descent with a hand on the rope below the device as, once the handle is moved to descend, the descender behaves just like a conventional one until the handle is released to lock it again. If the handle is held in without braking with the lower hand a very fast descent will result, just as though abseiling on a conventional descender and letting go of the rope. If a stop is required during the course of a descent, or if anything goes wrong, the best advice that can be given is to let go of the handle; this soon becomes instinctive.

TABLE 2

PERFORMANCE ON SHORT ROPE (MARKS OUT OF TEN)

DESCENDER	55kg CAVER			89kg CAVER			COMMENTS
	9mm JOANNY CLIMBING ROPE	10mm EDELDRID SPELEO ROPE	11mm BLUEWATER III	9mm JOANNY CLIMBING ROPE	10mm EDELDRID SPELEO ROPE	11mm BLUEWATER III	
LEWIS	8	9	9	8	10	10	Handle awkward for very small hand but locks well
PETZL	10	10	10	9	10	10	Possible to beat self-locking action at top of short pitch. Good handle for small hand.
LAWSON	5	8	8	3	6	8	Wont lock on 9mm for heavy caver. Poor locking action at top of pitch on all ropes.
DIABOLO	6	7	7	1	5	6	Slips at top of pitch. Very fast jerky descent for heavy caver.
KONG	4	5	5	2	4	4	Slips at top of pitch. Very bad handle position. Very difficult to control.
D.A.D.	5	10	9	6	8	7	Slips at top of pitch on 11mm rather fast on 9mm. Good handle for small hand.
GRIVEL	4	7	7	4	7	8	Unkind to rope. Rope rubs against hand.

Tests on short rope (Table 2)

The results in this table are two testers' opinions of the performance of each descender. Both testers are very experienced in the use of self-locking descenders and the results are based upon that experience. A complete newcomer to these devices would possibly disagree with the results, tending to prefer

the descender with the most friction which would initially give an impression of more controllability due to the lower "contrast" between go and stop. It must also be stated that one of the testers manufactured one of the descenders concerned but that he has attempted to be objective.

For these tests three ropes were hung from a platform in a tree giving a pitch length of approximately 10m. The ropes used were:

9mm Joanny climbing rope  
10mm Edelrid Super-Speleo  
11mm Bluewater 111

Bluewater 11 would also have been an obvious choice due to its widespread use in British caves but experience suggests that the continental descenders which are designed for 10mm rope perform very badly on this rope when it becomes still with age. Matt polyester rope was also avoided since it has different friction properties to nylon and all self-locking descenders give a much jerkier descent on it although the newer smooth polyester ropes are slightly better in this respect.

The ropes were in all cases "dry" on a warm sunny day. Wet rope tests would be useful but insufficient time was available for them and accurate control of the degree of wetting would be difficult.

The two tests were of different weights (89 kg and 55 kg) and used every descender on every rope and awarded points out of ten on the basis of controllability and the locking capability of each descender. This procedure has been followed in Table 2 to illustrate the wide spread of efficiency encountered. Simple listing in order of merit would not illustrate this.

Further observations on individual descenders are:

- Lewis: the most certain self-locking action on all the ropes tested; controllable descent on all ropes but handle found a little awkward by 55 kg caver who also has a very small hand.
- Petzl: Most controllable descent on short pitch. On a smooth rope it is occasionally possible to beat the self-locking action making it necessary to check that the handle moves out as weight is transferred onto the device but most of the time it locks very well.
- Lawson: Provides a reasonably controllable descent on 11mm rope but has poor locking action at head of pitch on all ropes. Would not lock in the course of a descent for the heavy caver on 9mm rope. Can also be used in a variety of other modes, e.g. as a ropewalker for ascending the rope.
- Diabolo: Slips at the top of the pitch on all ropes. The heavy caver had to take a turn of rope around his leg on 9mm in order to make a safe descent. Can be locked as a plain descender inadvertently.
- Kong: Slips at the top of the pitch on all ropes. Has an exceptionally badly placed handle giving the least controllable descent of any of the descenders tested. Has to be removed from the harness in order to insert the rope.
- Dad: the best handle for a small hand. Would seem to be designed for 10 mm rope only as it slips at the top of the pitch on 11 mm and is rather fast on 9 mm but provides a controllable descent on 10 mm. The rope has a tendency to slip off the top "bobbin" which seems to be more disconcerting than dangerous. Has to be removed from harness to insert the rope.
- Grivel: Provides a controllable descent on 10 mm and 11 mm but rather fast on 9 mm. A steel device which bends the rope round rather small radii, tending to fluff it. The rope rubs against the hand. Has to be removed from the harness to insert the rope.

The above comments are only one side of the picture and should be considered together with each descender's performance on a longer rope as this is a more accurate comparison with caving use. Three descenders were eliminated from the tests at this point as they could not be recommended for use on a long pitch. They were Kong, Diabolo and Grivel.

#### Use on longer ropes

Longer ropes were simulated by hanging appropriate weights on the bottom of two of the ropes used in the previous tests to determine the friction characteristic of each descender. The ropes used were 10 mm Edelrid Super Speleo and Bluewater 111.

TABLE 3  
USE ON LONGER ROPES

ROPE	60M	BWIII	100M	EDELRID	106M	BWIII
Weight of caver	89kg	55kg	89kg	55kg	89kg	55kg
Petzl	OK		OK			
Dād	OK	OK	OK	OK		
Lewis	OK	OK	OK	OK	OK	
Lawson			OK			

X indicates excessive friction

The results are presented in Table 3 in a different form to Table 2 since all the descenders, as a result of increased friction, were very controllable so it was only necessary to indicate excessive friction within the device. The criterion by which the friction was judged was that it should be possible to pull in the handle on the descender and abseil down the rope. If the rope had to be lifted with the lower hand and fed through the descender the friction was considered to be excessive.

#### Heating

Accurate tests of heat dissipation would be very difficult, would vary with rope type, rope humidity and weight of caver and have not been undertaken. Practical caving experience over a long period of time and in different conditions is probably the best guide. The author has extensive experience of only one of the descenders under consideration, the Lewis, and has found its heat dissipation to be adequate on any pitch on which it can be used. Slight experience of other descenders in which there is a very short conduction path from the friction components to the handle (Lawson, Petzl) suggests that the handle tends to become rather hot in the course of a descent. This is borne out by the experience of others (Anon, 1981). The problem is not important if abseiling on a wet rope and its effects are reduced by wearing gloves.

#### Pulling along a traverse

Each of the four descenders used in the last test were fitted onto an unweighted rope, the handle pulled in and the descender pulled along the rope. The Lawson, Lewis and Dad moved easily but the Petzl was difficult to move due to its greater friction.

#### ACKNOWLEDGEMENTS

Pete Seed assisted with the practical tests and provided valuable criticism. Whernside Cave and fell Centre loaned the descenders tested and allowed the use of their facilities. Dave Elliot and Ben Lyon supplied much information.

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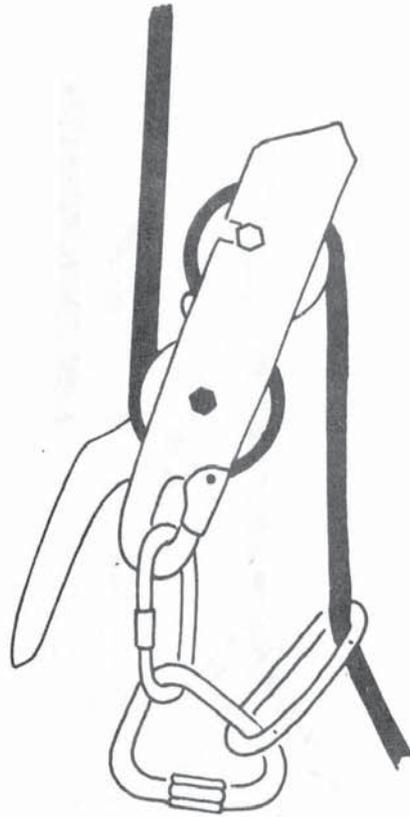
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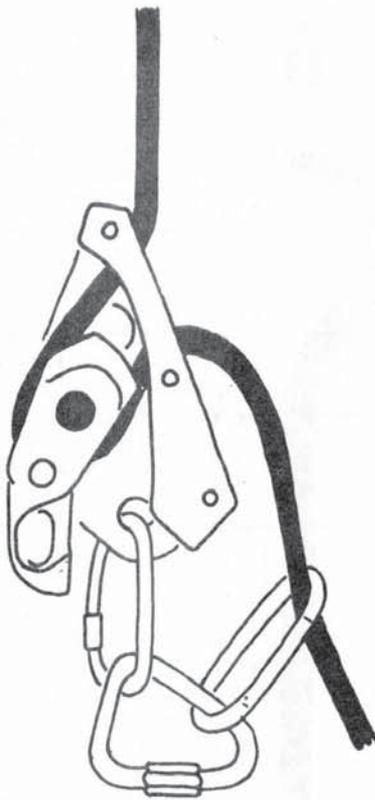
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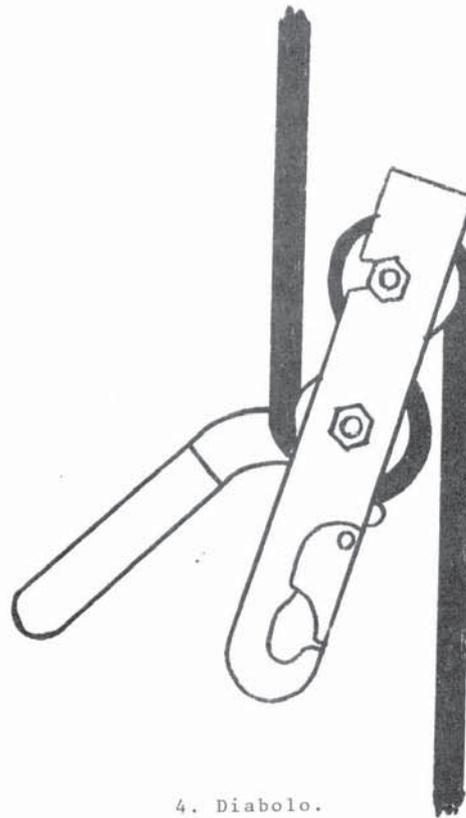
1. The "Lewis".



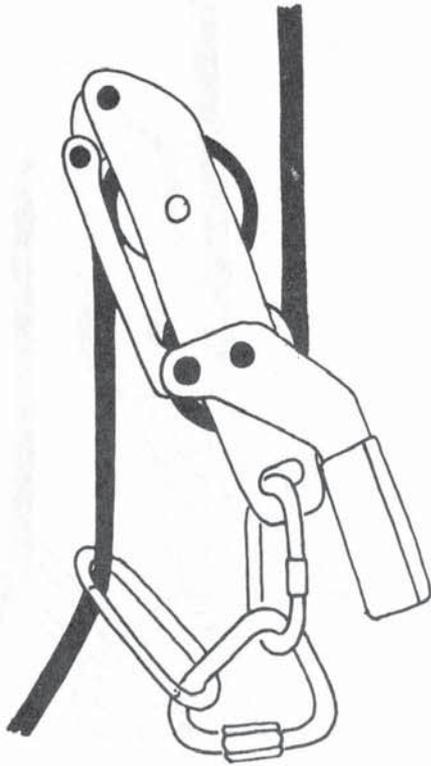
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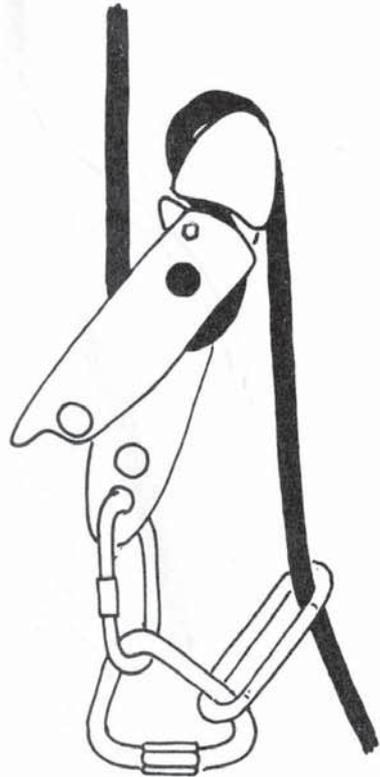
3. Lawson Multiscender.



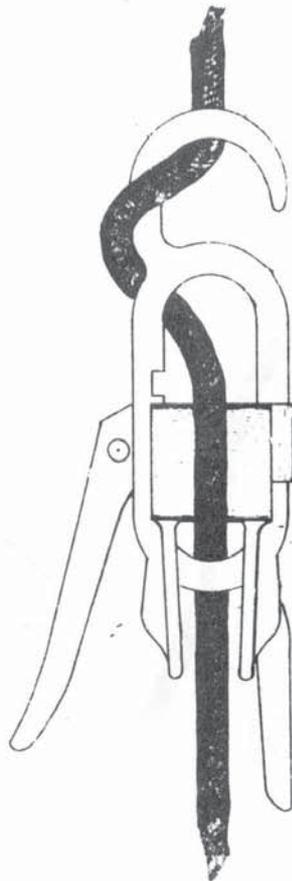
4. Diabolo.



5. Boniati "Kong".



6. D.A.D.



7. Grivel.

## MULTISCENDER - DESIGN AND CONCEPT

Dick Lawson

S.R.T. has developed in Britain over the past decade. Initially the new rope technique was not taken seriously as a real alternative to ladder climbing and was reserved only for longer descents. Little attention was paid to safety aspects of pitch rigging and the label 'kamikaze caving' was indeed justified. However, techniques developed; the upholstering of pitch heads lost favour to the bolt belay as the British caver became wise to the merits of 'alpine' techniques. Today he is better educated in the 'safe system'.

For want of a better 'home grown' alternative, the rappel rack reigns supreme even though it is not ideally suited to British caving. The ascending rig most favoured is the Frog sit/stand system because not only is it considered most efficient, but it is also most capable of coping with short split pitches and emergency crises. Although more reliable in greasy conditions, 'Gibbs' ascenders are more awkward to instal on the rope than the open frame 'Jumar' type, and so spring-loaded jammers are generally preferred by the British caver. However, to equip himself for the event of malfunction, the wary caver carries an additional cam-loaded device which will grip a muddy rope where sprung-cam ascenders are prone to slip. This third jammer can also be used for the occasional conversion of the Frog system into a rope-walking rig for longer drops.

The Design Project:

The task I set myself was the design for an auto-lock descender which could also function effectively as an 'auxiliary' jammer. A formidable list of design considerations was drawn, foremost in my thinking being that one function should not compromise the other. As a descender, the device should be 'fool-proof' or 'fail-safe' in respect of operator error. It should for example, be virtually impossible accidentally to thread rope incorrectly in a dangerous manner. So as to ease manoeuvres such as the placing of rope protection and changing of ropes at intermediate belays, the device itself should lock onto the rope without the need to lock-off manually. In the event of a panic when the caver loses control of an abseil, the instinctive reaction of holding tightly onto the device should have a braking effect. As an ascending ratchet, the device should incorporate the virtues of both rope-walking and spring-loaded jammers; that is, it should have an open frame for ease and speed of installation, and a cam to which the load is attached to ensure positive locking.

Numerous ideas were considered but the simplest mechanism common to both functions was that of the eccentric cam. For the climbing ratchet, a cam and lever would turn under direct loading to trap the rope against an open wrap-around' frame. The variable friction for the descender would be gained by threading rope around the back of the cam. Adhesion between the rope and cam would rotate the cam so as to trap the rope against a fixed bobbin so positioned that it would impinge on the locus of movement of the cam. Manipulation of a lever attached to the cam would release the lock.

Various prototype designs were built and tested, and after a further period of development and evaluation, the Multiscender was born. Multiscender 2DL comprises an open frame onto which an eccentric cam and attached cranked lever is integrally mounted. The frame is fabricated and consists of a mounting plate onto which three bobbins and an enclosing bridge piece are fastened with M6 button head screws. The cam and lever are of cast construction, and is pivoted with an M10 shouldered bolt threaded into the frame and doubly secured by a self-locking nut. With the handle folded away, the Multiscender measures 150mm x 70mm and is approximately 30mm thick and 350 grammes in weight.

The Abseil Mode

Attachment is made with a carabiner clipped through the frame. Rope is threaded as illustrated and can be done without first removing the Multiscender from the harness. Speed of descent is controlled in the usual way - that is by varying the degree of tension applied to the 'dead rope'. The lock is released by grasping the carabiner with the fingers and manipulating the handle with the base of the thumb. Depressing the handle progressively reduces static friction whilst introducing the other side of the cam into the rope. In a panic situation, depressing the handle to its fullest extent has, in theory if not in practice! a slight braking effect.

In the worst abrasive conditions or when the rope is excessively heavy, a smoother descent can be made by feeding rope through a descender with both hands. To enable the Multiscender to be used as a 'fixed-friction' descender (albeit without the

auto-lock) the attachment carabiner is passed through both the frame and handle. To compensate for the progressive reduction in tension whilst descending, additional friction can be applied if the rope is threaded through a 'breaking carabiner fastened to the harness and positioned between the Multiscender and the controlling hand. Unfortunately, without the addition of a second braking carabiner there is no simple or effective way of locking off the Multiscender in the 'fixed-friction' mode.

Used on very gritty ropes, the sliding surfaces of any descender soon become deeply scored. The locking efficiency of some auto-lock descenders is reduced by the effects of wear. Multiscender 2DL however, is equipped with a self-compensating cam and its blocking effect is not impaired until worn excessively. When the bobbins become severely abraded, they can be turned over or interchanged. Experimental ceramic bobbins have been used successfully on 'expedition models'. Even in the most abrasive conditions, ceramic bobbins exhibit no tendency to wear, and caged in the Multiscender frame they are not susceptible to embrittlement.

By its very nature, friction in abseil generates heat in any descender. This severely limits the use of auto-lock descenders because they can soon become too hot to handle. The large surface area of the Multiscender is intended to function as a sink to dissipate heat quickly. In practice though, it is advisable to soak ropes before use so as to inhibit the generation of heat. Moistening ropes of kernmantle construction has the effect of tightening the sheath onto the core and prevents the damaging intrusion of grit. In the long term this also prolongs the useful life of both ropes and descenders.

Underground, rope soon reaches an equilibrium with the cave environment; since most caves contain almost 100% humidity, ropes can be regarded as always being wet. However, rigged on surface pitches, rope tends to be both dry and grit-free. In this condition a rope has little frictional adhesion with a descender and auto-locks are prone to slip. Multiscender 2DL is designed so that it might lock positively even onto these 'fast' ropes. To prevent slipping, an inclined protruding edge is positioned across the cam just beyond the point where rope is trapped against the locking bobbin. When the handle is released, any slippage should be arrested as the 'tooth' is caught by the rope as it passes over the bobbin. As the tooth bites, the cam is drawn further into the rope so increasing its grip.

Some concern has been expressed over the effects of a fall onto auto-lock descenders and in particular, the Multiscender. The energy developed by a dynamic force must be safely arrested by all the components in the load bearing chain without failure of any one unit. There are no ill effects to equipment of a fall onto conventional descenders that have not been locked off - rope slippage safely dissipates the energy of the fall. Unfortunately, because the actual height fallen is likely to be greater than the slack developed in the rope, the resultant damage to the caver is largely a matter of luck!

Descenders that have been locked off prior to a fall can be subjected to high peak loads when arresting a falling caver. With a rope correctly installed on a pitch, the worst fall likely to be encountered is in the magnitude of factor one - that is, a free fall on to an equal length of rope. In tests which simulate a fall of factor one, the Multiscender slides a short distance down the rope. Results vary according to the condition of the rope, but this slippage superficially melts the sheath and at worst plucks the rope fibres. If this appears undesirable, the question must be asked of the caver whether he would rather risk damage to rope or self!

#### The Prusik Mode

In common with conventional rope-walkers, the efficiency of the Multiscender is impaired by the slight loss in height gain as the device tilts when loaded. For this reason, if for no other, the Multiscender is only intended as an auxiliary jammer. If used as both descender and primary foot ascender, change from abseil to prusik is somewhat problematic. However, with a little thought, no manoeuvre cannot be undertaken in safety.

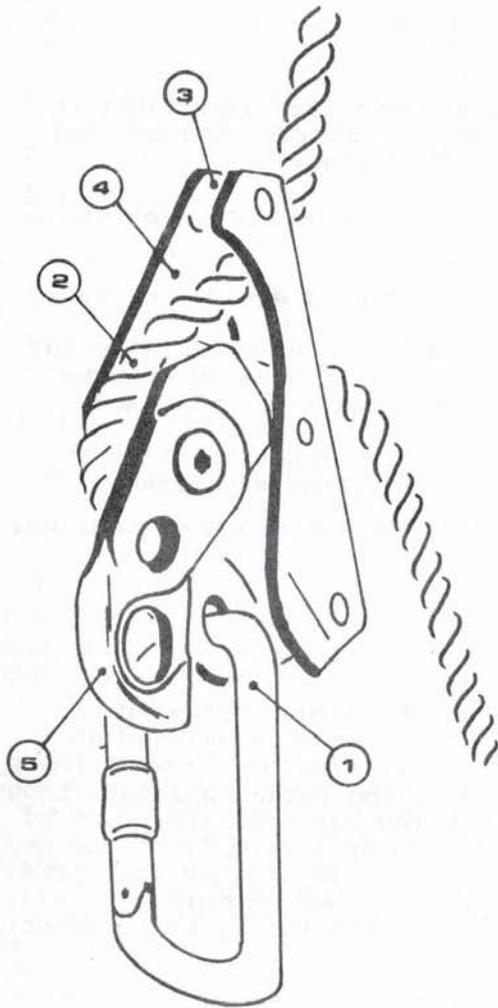
In the prusik mode, attachment slings are secured to the inner hole in the handle. Despite the fact that the rope has to be slightly flexed in order to slot it into place, Multiscender 2DL can easily be installed even onto heavily tensioned ropes. Because the rope has to be flexed, it is highly unlikely that the Multiscender will accidentally unthread itself if the rope passing through it is in tension. Should the device be installed on a slack rope, however, the rope must be further secured in position by passing it through a carabiner clipped through the small hole in the frame. This precautionary measure guides the rope through the Multiscender and prevents all but the smallest diameter ropes from extracting themselves since the slot between the cam and bridge is restricted.

Conclusion

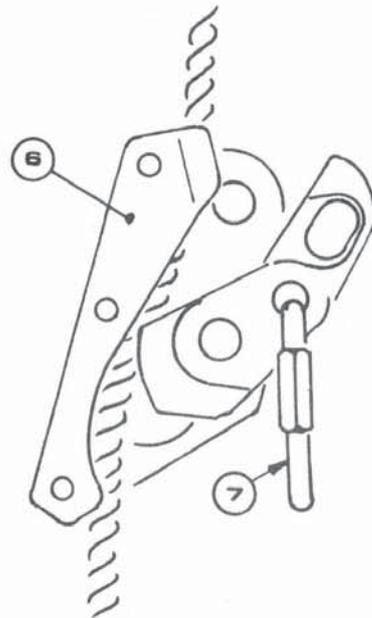
The Multiscender has been specifically designed for British vertical caving though it has proved itself on small European expeditions. It is intended to make rope manoeuvres safer, but like any other piece of climbing equipment, in the hands of the fool-hardy or unwary, the Multiscender is potentially a dangerous device. Perhaps it is not surprising that cavers who have become accustomed to the convenience of a self-locking descender are loth to resort to using devices without the additional security afforded by the auto-lock. Considering that only a relatively few cavers take the precaution of carrying with them a third jammer, there can be little doubt about the merit of a descender which is specifically designed to replace a failed jammer. Although the Multiscender has to be removed from the rope and inverted in order to change its function, it is nevertheless a significant step forward toward the concept of a 'universal', omnidirectional rope climbing device that is both simple in design and marketable - if indeed such a device is desirable!

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Dick Lawson,  
41/3 Station Road,  
Oakworth,  
Keighley,  
West Yorkshire BD22 0DU



Abseil Mode



Prusik Mode

## AN ANALYSIS OF PRUSIK SYSTEMS

John Forder

## ABSTRACT

The commonly-used prusik systems are examined from various points of view; for the typical British cave, the author claims that the best all-round method is likely to be the "Frog" system.

The most commonly used prusik systems can be examined from the following points of view:

- 1) Comfort
- 2) Safety
- 3) Simplicity
- 4) Versatility
- 5) Speed
- 6) Rescue possibilities.

Comfort and safety, along with simplicity, hardly need any justification for their inclusion here. Versatility is, perhaps, a bit less obvious, but any prusik system should be able to cope with the following:

- a) Variable pitch lengths.
- b) Variable pitch characteristics - e.g. constricted or wide open, wet or dry, free-hanging or wall-hugging.
- c) Awkward access at pitch head.
- d) Mid-rope manoeuvres, e.g. change-overs from up to down and vice-versa, knot-crossing, passing rebelay, 'reverse-prusiking'.
- e) Though not the be all and end all, speed is of importance, especially for large parties and/or long drops; having once waited for some 40 minutes for one person to climb 125 feet, I can personally vouch for the fact that slowness can be a nuisance.
- f) The increasing tendency to go caving in small parties makes it all the more necessary to be able to cope with any emergency that may arise.

The common prusik systems have been divided into the following categories, which are not, in fact, mutually exclusive:

- A) Systems using knots only
- B) 'Sit-Stand' systems
- C) 'Step' systems
- D) Hybrid systems

A) Knots. As a general rule, prusik knots have about as much relevance to caving as Ben Hur's chariot does to Le Mans; they can be dismissed on grounds of safety, versatility, speed, rescue possibilities or, lack of these. The classic 3-knot prusik is, at best, uncomfortable and rather painful, though a Texas-style prussik with a proper harness is not too bad from the point of view of comfort. This leaves only simplicity - which applies only to the gear used, not to its actual mode of use. In mitigation, it is alleged that prusik knots can be made to grip on dirty, muddy ropes where other jammers may fail, and that they make useful, light, spares against the possibility of equipment failure.

B) Sit-Stand systems.

1. The simplest way to climb a rope is, in all probability, the Texas-prusik' in which two jammers (or, indeed, knots) are used - one fastened to a sit-harness, the other having a footloop/s attached. The two jammers are then moved alternately up the rope, the climber adopting a sit-stand motion. This means it satisfies the third criterion - simplicity - but not the others (with the possible exception of the first - comfort). As regards safety, the point is to guard against failure of one of the jammers, particularly the chest one. If the foot one fails, you're left hanging off the rope - if the chest one fails, you might not be ... I have details of two incidents in which people using this system had accidents; in one, the caver ended up hanging upside-down from his feet, in the other he tipped over and plunged head-first down the shaft he was climbing (and lived, in spite of falling over 60 feet).

To safeguard oneself, the footloop jammer can be tied into the harness so

that at least you don't fall if the sit-harness jammer fails. Surprisingly enough, a party was seen by the author struggling mightily to get out of Alum Pot using the Texas-prusik in June 1982 - perhaps they drove up to the Dales in a Model-T Ford!

2. The 'Inchworm-system' uses a jammer fastened to the sit-harness and to a chest one, with the feet resting on a bar tied to a second jammer. It's reasonably simple and comfortable, and quite fast - but fails to satisfy the other criteria.

3. The 'Frog-system' is, in essence, a development of the Texas Prusik in which a jammer is slung between the sit-harness and chest-harness, and a second jammer is used for the feet. It is possible to have the foot-jammer above or below the chest one; if below, the chest one will move more readily as the caver stands up, but it has three drawbacks. If the chest-jammer fails, or the caver messes up some manoeuvre, so that the safety-cord to the foot-jammer sustains a shock-load, the caver will fall twice the length of his safety-cord. Secondly, it is possible - if unlikely - that the caver may fall onto his chest jammer in such a fashion that the device rips through the rope; in which case, if the foot-jammer is fastened to the rope below, no safety-cord will be of any assistance whatsoever. The third drawback is that it is harder to operate the foot-jammer below the chest one. For these reasons, the Frog-system utilizes a foot-jammer with a long foot-loop (or loops), and a safety-cord to the harness. Such a system satisfies all the criteria set out above, with the possible exception of no 5 - speed. This is only likely to become important on long free-hanging drops where rope-walking has the edge; but as soon as bolt rebelayes are introduced, the speed advantage of rope-walking a big pit is likely to be negated.

C) 'Step-systems' Step systems differ from the sit-stand ones in that the legs are moved alternately, so that one 'walks' as it were, up the rope.

1. In the 'Mitchell' method, one jammer is used for each foot, the jammers being held one in each hand and moved alternately. A sit-harness is tied into one of the jammers, and something is needed to hold the climber upright. This latter function can be achieved by the very simple expedient of having a chest-harness with attached karabiner into which the rope is clipped; better, but more complicated, is a purpose built 'chest-box', a device fitted with rollers which allows the rope to slide very easily through it. Most chest-boxes incorporate a second channel for the longer footloop cord.

Such systems are quite comfortable, safe, and reasonably simple; they can also enable one to prusik very quickly, at least on a free-hang, but they tend to fall down somewhat on versatility, while rescue attempts would be very difficult indeed. (Wandering through a cave with a box on one's chest can also pose problems).

2. 'Rope-walking' systems can be seen as a logical development of the Mitchell method, but instead of using the arms to move the jammers, these are fastened to the legs or feet. The original rope-walking systems had one jammer tied to one foot, with a second jammer tied to the other knee, the foot being inserted into a stirrup. A third jammer/krab/pulley or somesuch device is needed high up on the body to keep it upright and close to the rope.

The spur to the development of 'rope-walking' seems to have been the desire to devise a fast and efficient way of getting up the deep pits of parts of America, in particular Mexico, additional impetus being provided by the NSS's 'prusik races'. Thus speed is their main claim to fame. They tend, however, to fall down on grounds of simplicity and versatility, owing to having to fiddle with bits and pieces fastened to ones feet - making change-overs, etc., rather awkward.

Many variations on the basic rig are possible, for instance a 'floating-cam' system employs a jammer (normally of the Gibbs type, incidentally) held at knee-height not being fastened to the knee, but, being held on shock-cord tied into the harness, its function being to tow the jammer up the rope automatically through its stretching and contracting. One of the best systems is, probably, the 'Howie-belt' one; in this, a Gibbs-type jammer is mounted on a wide belt fastened to the front of the harness. The belt has a quickly-adjusted buckle which enables its length to be easily varied, so that for climbing, it comes under the armpit and round to the opposite shoulder to keep one upright and close to the rope, while for resting and manoeuvring the strap can be shortened to enable one to hang in safety and comfort.

D) Hybrid systems. It is possible to devise dozens of different ways to climb a rope - some good, some bad, some crazy - and many attempts have been made to combine the best features of the 'sit-stand' and the 'step' systems - i.e. the safety, simplicity and versatility of the 'frog' with the speed of 'rope-walking'.

The obvious way, perhaps, to do this is to have one foot in a standard 'frog' type foot-loop with a third jammer 'floated' at knee height for the other foot. So, on a trip involving a mixture of pitch sizes and characteristics, the Frog can be used for short and/or awkward ones, the third jammer staying in ones tackle bag and only being used on long free-hanging pits.

Conclusion.

When it comes down to it, the choice of a prusik system must be up to the individual caver. But the decision should be based on the pros and cons of the various methods rather than "well, I read it in a book" or "my mate showed us how to do it " or .....

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June 1982

John Forder,  
Whernside Cave & Fell Centre,  
Dent, Sedbergh,  
Cumbria.

## CAVE SCIENCE

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### PRUSIKING SYSTEMS

Dave Elliot

Simply put, prusiking describes the ascent of a fixed rope by any method more sophisticated than shinning up it, that is those methods employing either special friction knots or mechanical rope-clamps. All the basic methods of prusiking require the use of at least two jamming devices attached to both climber and rope. So that by the artfull transference of bodyweight from one to the other as they are alternately slid up the rope, some attempt at upward progress can be made. Somewhere round about here is where it stops being simple, for in fact there are a great many variations possible on this basic theme. Whole books have been written on the subject and (probably) millions of man-hours devoted to studying the ergonomics involved in gaining the fastest ascent for the minimum amount of effort. Even after ignoring the sillier ones, there are still about fifteen or more methods of climbing a rope reasonably safely. However, it is possible to recognise certain basic similarities amongst many of them, and for our purposes these systems can be broadly divided into just two groups according to the type of leg-movement involved. Namely those with an alternate "stepping" action, and those requiring a "sit/stand" type of motion.

#### Step systems

- Fig. 1 Ropewalking
- 2 "Floated" ropewalking
- 3 Howie Rig
- 4 Jumar System
- 5 Gossett Rig
- 6 Mitchell System
- 7 Third-Phase System
- 8 Pygmy System
- 9 Another prusiking system

#### Sit/Stand systems

- Fig.10 Texas Rig
- 11 Plummer system
- 12 Inchworm Rig
- 13 Frog System
- 14 Wisconsin Rig
- 15 Italian pulley system

Each of these individual systems has both good and bad points to it in varying ratios and consequently it is difficult to recommend one particular system over all others. Suffice it to say at this point that all the systems considered work, although to some extent their overall efficiency is dictated by personal expertise and fitness. Not surprisingly, after working with one particular system for a while and becoming expert at it, it is then extremely difficult to fairly evaluate a method you are relatively unfamiliar with. As a result I suspect there are many sworn disciples of a particular system who have never seriously tried anything else. What I intend to do here is briefly describe each of the various systems in turn and make some very general (and inevitably biased) comments on their relative merits, dealing with the "step" systems first as there are rather more of them.

#### Step Systems

Perhaps the best known of all the step systems is the basic "Ropewalking Rig" (Fig. 1). The method generally employs three jammers; one mounted directly to the foot, one on the knee of the opposite leg, with a third at either shoulder or chest level. The upper jammer serves to keep the climber upright against the rope and is used to hang from while resting. Climbing is simply a matter of taking alternate short steps while pulling on the rope at about head height. Largely due to its success in surface prusik races (?), ropewalking has gained widespread popularity in America and inevitably there are far too many minor variations on the theme to mention them all. However, two particular adaptations that might justifiably be considered improvements are: a method developed by Kirk McGregor of "floating" the knee-jammer by suspending it from a length of elastic shock-cord which automatically pulls it up the rope as each step is taken (Fig. 2). Also the "Howie" shoulder-strap (after Will Howie) as a more versatile means of attaching the upper jammer (Fig. 3).

One of the original methods of rope-climbing, devised by "Jusy and Marti" makers of the Swiss "Jumar", has since (not surprisingly) become known as the "Jumar System" (Fig. 4). This method consists simply of two jammers attached by long footloops one to each foot with both cords running behind a makeshift

chest-harness. Climbing is a matter of taking short steps while alternately moving the jammers up the rope. I understand the system was first developed for collecting birds-eggs, and might add that nobody in their right mind would use this method in a cave (or anywhere else for that matter). There are many reasons why not, but mainly because it is very tiring for the arms and there is no safe rest position, in fact I have mentioned the system only because it forms the basis of so many other systems. One useful modification is to run the footloops through a roller-box at chest level, and these should also be linked to a sit-harness for safety. Lowering the roller-box to waist-level converts the system into a "Gossett Rig" (Fig.5), which apart from anything else is a splendid method of knacking yourself extremely quickly.

Yet another adaptation of the basic Jumar rig is the much maligned "Mitchell System" (Fig.6), which comprises of one jammer above and one below a chest mounted roller-box or karabiner, with the main rope also running through the box. This is considered necessary in order to maintain an upright position on the rope but makes any mid-rope manouvres that much more difficult. A short cord between the top jammer and the sit harness allows a safe rest position, or with certain roller-boxes a knot in the footloop cord is sufficient. As with the ropewalking rig it is possible to "float" the lower jammer from a length of shock-cord and thereby leave one hand free. One of the main disadvantages of a Mitchell system is its poor performance against a wall, which "Vertical Bill" Cuddington reckons to have sorted out with his "Third-Phase System" (Fig. 7)

which is vertical bullshit for a straightforward Mitchell rig with the addition of a third jammer slung from the sit-harness. This permits mid-rope conversion to a fairly strenuous "Texas System" (Fig.10), using the seat and lower jammer for balance and presents a really sporting challenge when it comes to passing an intermediate belay.

Last but by no means least there is always the "A.P.S. System" (Fig.9) (i.e. another Prusiking System), a hybrid Mitchell/ropewalking set up, with a few very strong points and most of the disadvantages of both systems.

That more or less covers the main "step" systems, apart from a short cautionary note. With these systems the sit-harness is generally used only for resting and chest-harnesses used mainly to keep the cave upright. However, it is essential that a decent sit-harness is worn, and any chest-harness linked to this in such a way that the main part of the load is taken on the thigh and buttock region. Anybody left dangling from a waistbelt or chest-harness alone can probably count their survival time in minutes.

#### Sit/Stand Systems

The original sit/stand system, or in this case squat/stand system, was more than likely a "Three-knot" method using "Prusik" knots tied in cord slings. Three slings are used, one for each foot and one around the chest, and by moving each of them in turn it is possible to climb a rope. The method is slow, strenuous and has a very low safety margin, it has no place at all in modern caving apart from certain adaptations used in improvised rescue situations.

One of the simplest prusiking rigs of all is the "Texas System" (Fig.10), which basically consists of just two jammers (or knots) slung from short slings, one to the sit-harness and one to the feet, with a safety cord also connecting the lower jammer to the sit-harness. Progress is a matter of hanging in the sit-harness while the lower jammer is slid up the rope, then standing up in this sling while the upper jammer is moved.

A fairly duff adaptation of the previous method is the "Plummer System" (Fig.11), with a jammer slung from each foot and an adjustable connection from the upper jammer sling to a chest-harness, intended to prevent the climber from turning upside down. The sling lengths are critical and the system is only worth trying provided that: (a) you want to get fit in a hurry, or (b) you don't want to die of old age...

Eliminating the need to move jammers up the rope by hand, another joke technique known as the "Inchworm" (Fig.12) uses one jammer fixed between sit and chest harnesses and another bolted to a metal bar at the feet. Climbing is largely a matter of sitting down and standing up, with the arms used on the rope above for balance. Obviously having your feet tied together does tend to make sloping pitches a bit sporting, and one proposed solution is to use the footbar arrangement above the chest jammer like a "chinning bar" to drag yourself up.

The best known and most widely used sit-stand system in the world is without doubt the "Frog System" (Fig.13). The method uses two jammers, one mounted between the sit and chest-harnesses. The second higher up the rope

carries a footloop/s for either one or both feet. Climbing again is largely a matter of standing up and sitting down, with the arms used to lift the upper jammer and help stay upright. The Frog system is a simple and practical one that for sheer versatility is probably unbeatable.

A modification to the Frog method, the "Wisconsin Rig" (Fig.14), uses twin footloops run through a karabiner above the chest-jammer to help keep the body upright and close to the rope.

That cursorily covers most of the sit/stand methods, but before going any further I must make a fairly obvious point. As far as I am aware there are no effortless prusiking systems (apart from motor-driven ones), and simple rope-clamps are by no means anti-gravity devices (which is one reason why I dislike the term "ascender"). To raise 60 or 70 kg many metres up a rope requires a certain amount of work, and all we can do about this is to make the most of it by directing the necessary effort in more or less the right direction. As the desired direction is usually up, then maximum effort should be directed straight down and effort expended in any other direction, i.e. sideways, is less effective. This is particularly relevant with sit/stand systems where there is a general tendency to lean back. If you are going to get anywhere at all then it is no good lying back and enjoying it. It is necessary to tuck the legs underneath and pull into the rope with the arms in order to stay reasonably upright while climbing (Fig.16). Wrapping the footloop around one leg helps (Fig. 17), but this is rather less comfortable.

Without delving into the realms of fantasy or worse still the depths of "Nylon Highway", these are the systems available, and all of them are suitable for climbing a straightforward pitch. The differences in performance become most apparent when mid-rope manoeuvres are necessary, when emergency situations arise, and when the safety aspects of the rig are examined. As far as comparison goes, it is obviously impossible for me to fairly present the pros and cons of all these different systems when I don't normally use them. What I intend to do is describe in detail the system I prefer, which is a fairly conventional Frog rig, and make a few observations in order to draw your attention to the safety and versatility of this system. You can satisfy yourself with regard to your own system by direct comparison of the two (Fig.18).

Fundamental to the Frog system is a comfortable sit-harness which allows relatively free and independent movement of the legs while suspended. "Leg-loop" type harnesses are perhaps the most readily available designs, made even more suitable with the addition of a "bum-strap", a simple modification which prevents the loops slipping down the legs between pitches. The harness is linked at the front by a strong (10 mm) Maillon Rapide, which unlike a karabiner may be loaded in any direction without a significant loss of strength. The "body-mounted" jammer is fastened directly to the main Maillon and supported by a simple Fig-8 type chest-harness. This is simply a 3 m length of tape with a quick-adjustment buckle at one end, wound around the upper body and threaded through both the chest jammer and main Maillon. The function of this type of harness is mainly to tow the chest-jammer, consequently it need be neither loadbearing nor particularly restrictive. By locating the buckle in a convenient place, the harness may be easily adjusted while climbing and loosened between pitches. The upper jammer carries a footloop and is also securely linked to the sit-harness for safety purposes, so that if the chest-jammer slips or fails you may hang safely from the footloop jammer. Almost any type of jammer is suitable for the footloop according to which of their various characteristics are considered most important. The footloop is tied from a single length of 7-8 mm dia, preferably low-stretch cord. A large, single loop takes either one or both feet, dependent on climbing against a wall or free-hanging, and also makes possible trapping a slack rope between the feet while climbing the initial few metres so that no one is needed to hold it (Fig.19). The footloop is attached to the jammer by a screwgate karabiner and the length adjusted (while hanging on the rope) so that the two jammers almost touch when the legs are fully straightened. The remaining safety cord from the jammer to the sit-harness should be long enough to permit the maximum gain with each climbing cycle, but not so long that the jammer is out of reach while hanging from it. Also attached to the main Maillon are two safety cords or "cows-tails", one short and the other somewhat longer, each with a karabiner at its end. These are used for attachment at anchor points or traverse lines as protection while making a manoeuvre, such as gaining the rope at a pitch head or passing intermediate anchor points in the pitch. The shorter cows-tail is about 40-45 cms long including the karabiner, and the longer one should not be so long that the krap is out of reach while hanging from it, say 65 cms. Cow's-tails are tied from sturdy 10 mm dia climbing rope

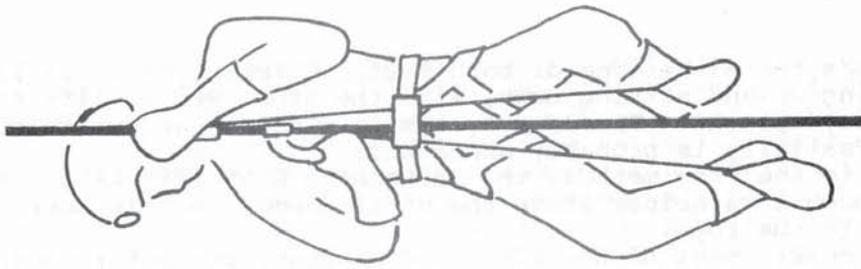


Fig. 5. Gossett Rig.

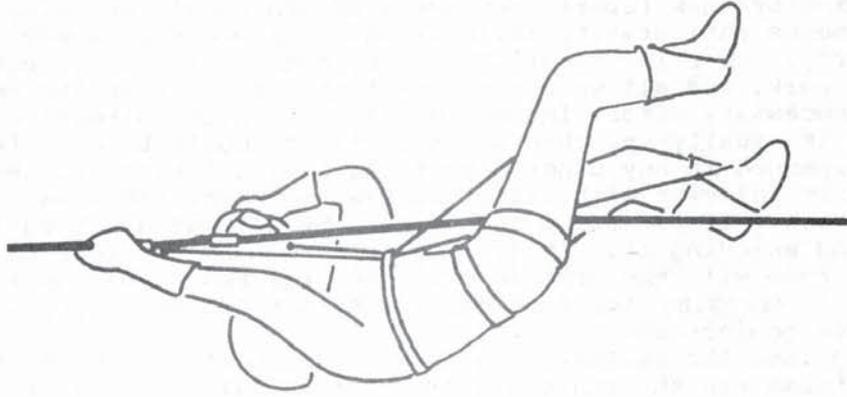


Fig. 4. Jumar system.

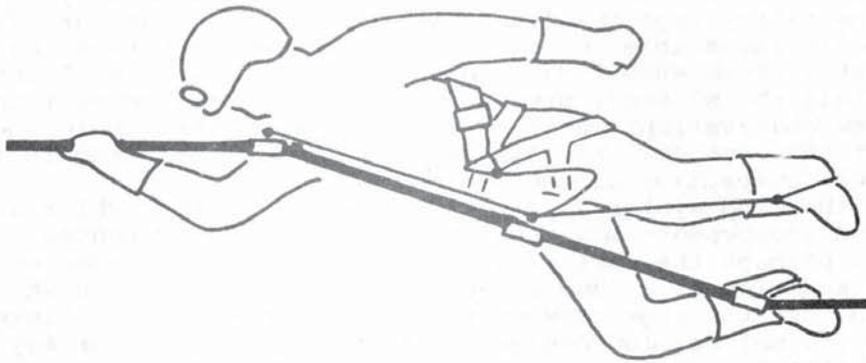


Fig. 3. Howie Rig.

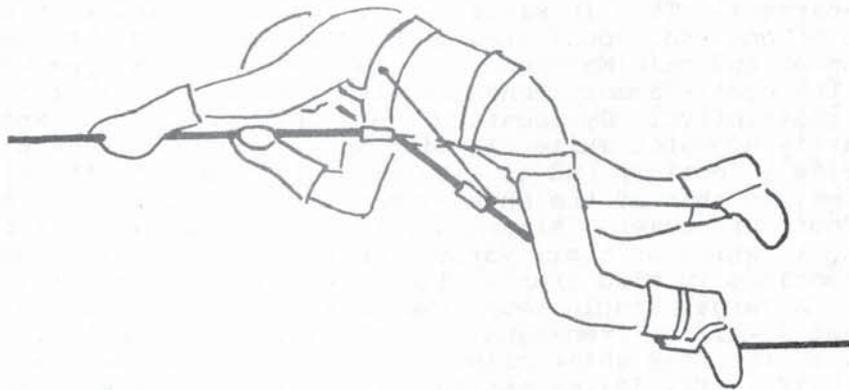


Fig. 2. "Floated" rope-walking.

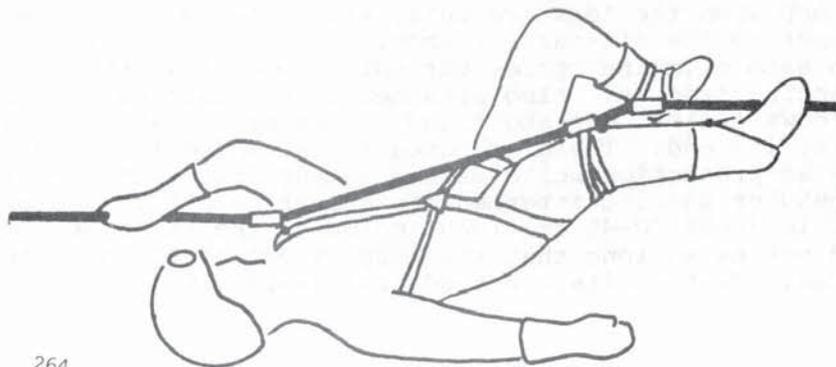


Fig. 1. Rope-walking.



Fig.9.

Fig.6. Mitchell system. Fig.7. Third phase system.

Fig.8. Pygmy system. 'Another prusiking system' Fig.10. Texas Rig.

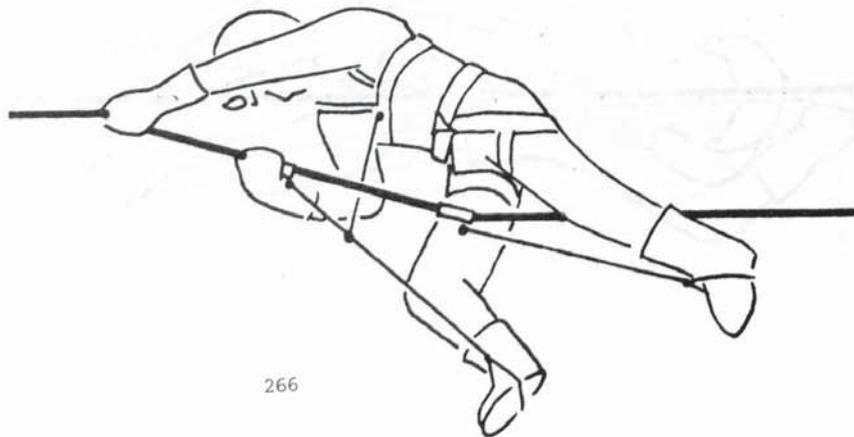


Fig.11. Plummer system.



Fig.12. Inchworm Rig.

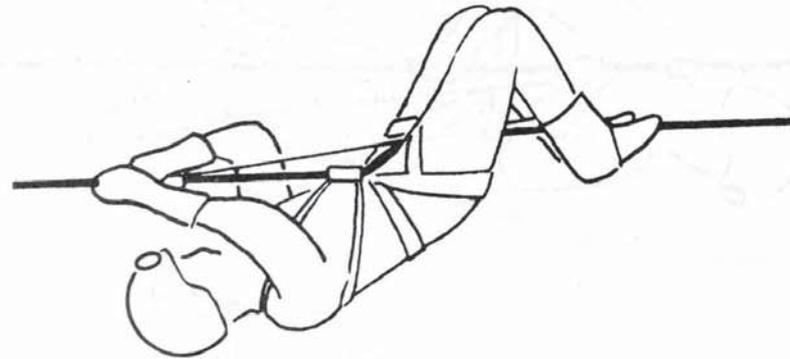


Fig.13. Frog Rig.

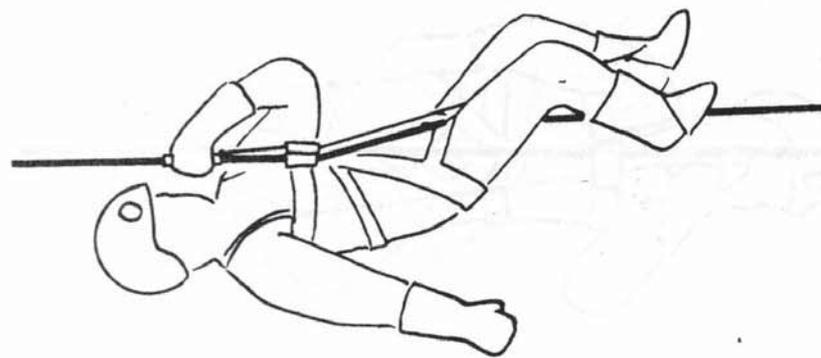


Fig.14. Wisconsin Rig.

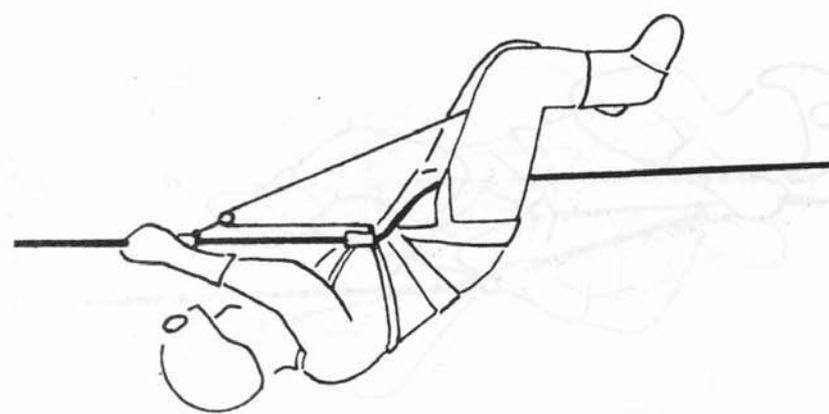


Fig.15. Italian pulley system.



Fig.16. Keeping the body close to the rope.

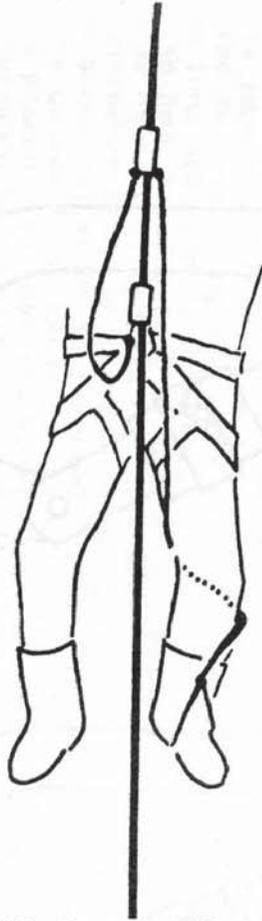


Fig.17. Wrapping the rope round the leg.



Fig.19. Guiding the rope between the feet.

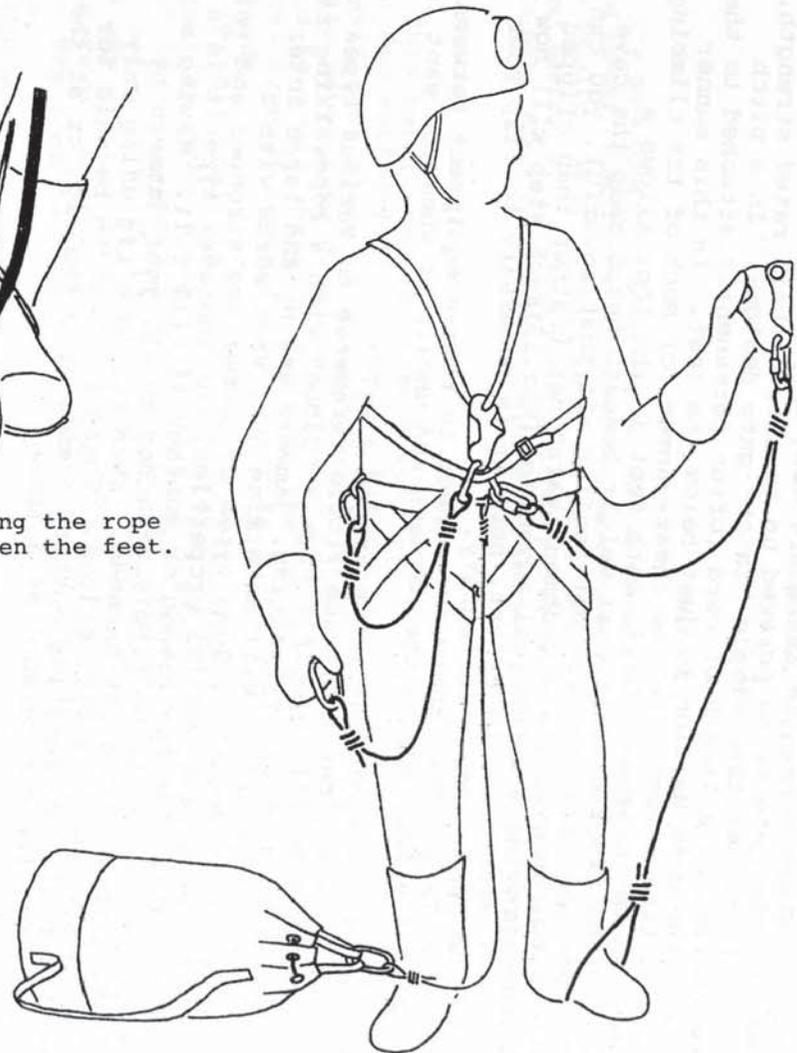


Fig.18. 'Whernside Frog' Rig.

and generally fitted with asymmetric form krabs rather than oval ones. Because such krabs are rarely attached for very long, strong, non-screwgate snaplinks are often preferred. Where screwgate krabs are used they should be of the type that do not depend on the gate being screwed up to attain their rated strength, that is "pin and slot" rather than simple "latch" gate designs. In a pitch tackle-sacks are carried on a length of cord (often permanently attached to the sack) reaching from the main Maillon to just below the feet. In this manner the weight is transmitted directly to the chest-jammer for much of the climbing cycle with no pull on the climber. Using both feet in the loop allows a powerful lifting action and the additional weight beneath helps keep the cave vertical on the rope. Any time you are not feeling all that powerful, you can adjust the footloop to run over its attachment karabiner (rather than clipped into it) and thereby provide a mechanical advantage (Fig.15). Each step will now gain half the distance but with half the effort, here it is necessary to clip your long cows-tail to the upper jammer for safety.

Generally with the Frog system there is no need to remove equipment between pitches, simply clip the footloop to the harness and unclip it when you want to climb.

The total weight of the whole outfit is around 2 kg.

In this review I have deliberately made little reference to various types of jammers being commonly used with specific rigs - "Gibbs" with a ropewalking rig for example. This is unnecessarily limiting, jammers are by and large interchangeable and a few simple trials will determine just what works with a particular set up and what doesn't. Some types of jammer are stronger and more reliable than others, some have special properties, but whatever type it is a fact that sooner or later, for one reason or another it will fail. Having said that it obviously makes sense to be firmly attached to all your jammers by strong cords linking them to the sit-harness. Even so, in a rig using only two jammers, failure of one is a bit serious. There is a lot to be said for the simple precaution of incorporating a third jammer into the rig, or at the very least carrying one (on the person) as a spare.

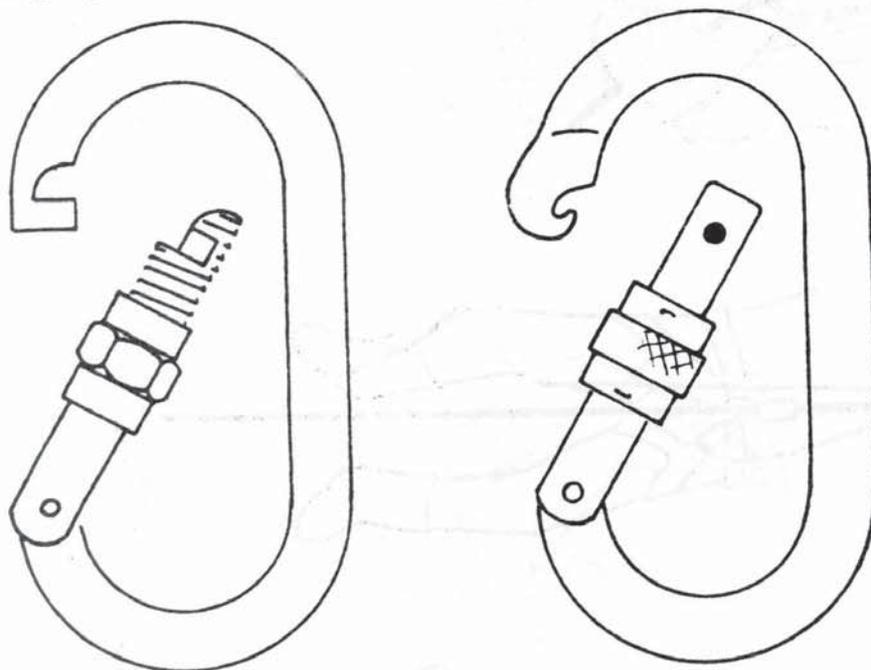


Fig.20. Karabiners: (a) cross-type catch; (b) pin and slot type catch.

Dave Elliott,  
1, Millthrop,  
Sedbergh, Cumbria.  
LALO 5SP

(presented at the Buxton SRT symposium, 1980)

## 8mm BOLT BELAYS

Dick Lawson

## ABSTRACT

The development of modern, safer caving technique is synonymous with a reduction in the bulk and number of different pieces of equipment necessary to negotiate common manoeuvres. This is equally true of the bolt belay and it is implied that 'sturdy' components are not necessarily most desirable. Various patterns of hanger brackets are described as are other components of the bolt belay, consideration being given to the safe performance of the assembled anchorage.

This paper concerns itself with artificial rock anchors as provided by the 8mm self-drilling sleeve. Without the introduction of this small but significant piece of equipment, modern techniques of static rope rigging could never have developed as they have over the past decade. The implicit need to avoid abrasion dictates the use of bolt belays positioned to hang ropes free of contact with the rock surface and away from other potential hazards.

'Traditionalists' have expressed concern that modern bolting techniques result in caves being littered with unsightly bolt holes and rusty anchors; this is an exaggeration of the truth. The key-note of modern caving technique of which the bolt belay is an integral part, is 'safety first' and any ethical questions have essentially more to do with self preservation than cave conservation. It may also be said in defence of the bolt belay that 8mm rock anchors are very much less obtrusive than traditional fixed aids.

The modern bolt belay consists of an assembly comprising the anchor - that is the threaded sleeve which is permanently implanted in the rock - and a hanger bracket, generally taken out of the cave when not in use, which is bolted to the anchor to provide the means of attaching ropes or ladders to it. The following columns examine the various components of the bolt belay and beg the question: how safe are they?

Potentially the weakest link in the bolt belay is the anchorage point itself. Both the rock and the sleeve embedded into it are very hard and brittle components and either can crack if incorrectly stressed. It is therefore essential that the anchor is inspected before use; for this amongst other reasons, hanger brackets should not be left in situ because it is impossible to examine the anchor if this is concealed behind the hanger.

The self-drilling sleeve is a hardened tubular steel sheath measuring 30mm long and 12mm in diameter. It is provided with cutting teeth at one end and an 8mm threaded hole at the other. Machined along part of its length and spaced equally around its circumference are four grooves; these are designed to introduce areas of stress concentration and encourage fracture along them when a conical wedge is inserted into the sleeve. Driving the cone into the sleeve causes it to expand so that it grips the sides of the hole into which it is placed. So that the sleeve does not split along its entire length, the threaded section is tempered to give it a degree of toughness.

Once the sleeve is expanded into the hole, the rock immediately surrounding the anchor is severely stressed even before any additional load is applied to it through the hanger. Before drilling therefore, it is vital to position the anchor correctly having regard to the quality and configuration of the rock. The anchor must be placed a good distance from any possible weaknesses. Wherever possible, both fractured and thinly-bedded limestones and calcite deposits should be avoided. In order to achieve maximum strength, the rock should be hard and homogeneous, free of micro-fissures and calcite veins. An anchor placed in a concave surface is likely to be stronger than one placed in a convex surface because the stress is distributed over a larger mass of rock. For the same reason, the sleeve must be drilled at right angles to the rock surface.

The hole is drilled by screwing the sleeve onto a 'driver' so that it can be used as a percussion tool. By rotating the driver and striking it sharply with a hammer, the hole is drilled into the rock. At frequent intervals it is necessary to withdraw the sleeve from the hole so that the powdered rock which collects in the centre of the sleeve can be removed. Tapping the end of the driver clears the spoil from the sleeve, and dust can

be blown from the drilling by means of a short length of plastic tubing. To ensure the sleeve will be correctly embedded when finally set into the rock, when drilling the hole, the sleeve must be sunk about 2mm below the rock surface. To fix the sleeve permanently into the rock, the drilling is cleared of any spoil, the cone is lightly pressed into the sleeve which is then offered to the hole. Slight pressure in the direction of the anticipated load is applied to the driver, and the sleeve can be hammered home so that it is flush with the rock surface.

Having set the sleeve, the security of the anchor must then be checked. A close visual inspection should reveal any hairline fractures, and the expansion of the sleeve can be verified by measuring the depth of the threaded hole with the tubing previously used for blowing away the powdered rock. A sleeve that protrudes from the rock surface or one that is placed in too large a hole that is cone-shaped at its entrance will stress the sleeve incorrectly and the anchor will be considerably weakened.

Immediately after installation, the anchor should be greased to combat corrosion. Once fixed into the rock, the sleeve cannot be removed and each caver has a responsibility to ensure its long-lasting security. Sleeves should not be allowed to rust or become clogged with mud or grit. To prevent the intrusion of water and grit, ideally the threaded hole should be sealed when not in use - perhaps with a spare set screw. However, careful selection of the drilling site should reduce the hazard; generally sleeves should not be installed vertically into the rock or positioned where they are likely to become blocked with mud.

Blockages can often be cleared by poking the sleeve with a length of wire. Even rusted sleeves can sometimes be reconditioned if they are considered structurally sound. Moisture can be driven out with an aerosol water repellent (WD40), and threads can be trimmed with an 8mm screw-cutting tap. Such measures may be preferred to placing another anchor whose positioning might be compromised if the original anchor provided the best possible hang.

It is difficult to quantify the strength of an anchor, its security being dependant upon the solidity of the rock and the fixation of the sleeve. Unlike the anchor, other components of the bolt belay are made of relatively elastic materials which are better able to withstand tensile loads. Materials used for the fixing bolt and the hanger bracket are specially heat treated so that they can resist the forces to which they are likely to be subjected.

A component common to all hangers is the bolt itself. Although most hangers today have some method of holding the screw captive with the hanger, bolts are often lost and/or need replacing. It is important that the bolt is of the correct specification. The length of the bolt varies according to the hanger with which it is to be used; the protruding portion to be screwed into the sleeve should be between 11 and 12mm in length. The screw should have a diameter of 8mm and a pitch length of 1.25mm. The distance across the flats of a hexagonal headed bolt or set screw is 13mm, and socket-headed screws usually require a key of 6mm. Contrary to popular belief, socket screws are quite suitable and indeed have certain advantages over hexagons. It is vital, however, that such fasteners are forged from high tensile steel. To indicate the material from which they are made, bolts are marked on the head with a two number code, the first figure denoting the 'yield stress' - that is, the elastic limit or the load at which the material is permanently distorted, and the second number refers to the breaking resistance. Only bolts marked 8.8 should be used; these have an ultimate tensile strength of  $80\text{kg} / \text{mm}^2$  which should enable them to support loads of up to 1800kg - a figure far in excess of any load likely to be generated in even the worst falls underground.

However, a bolt breaks when the total load applied to it - that is, the weight of the (falling!) caver plus the tightening force exceeds its ultimate tensile strength. It is dangerous therefore to overtighten the bolt since doing so can drastically reduce the load that it can support. The bolt should be finger tight with an additional half turn with a spanner. Wrenches for socket screws are shorter and less rigid than spanners for hexagon heads and so there is less likelihood of overtightening socket-headed screws. It is a good idea to shorten spanners by sawing them in half so as to reduce the leverage that can be applied to the bolt.

The bolt serves to fix to the anchor a bracket to which in turn ropes or ladders are attached. A variety of hanger brackets are available and these can be divided into two basic types: those which require the addition of a carabiner, and those which do not.

'Conventional' hangers are those which are used in conjunction with

carabiners. Shapes differ, but those which are commercially available are made from tempered duraluminium and have two drillings, one to accept the bolt to secure the hanger to the anchorage point, and another to which the attachment carabiner is fastened. These brackets can be subdivided into two groups determined by the relative position of the holes: those in which the holes are positioned so that the attachment carabiner lies perpendicular with the rock surface, and those where the carabiner lies parallel with the rock.

Of the first category, the 'simple cantilever' is most common. Petzl and T.S.A. manufacture hangers of this type. Although of slightly different shape, both are simple plate hangers folded in the horizontal plane with a straight bend. These hangers are designed to be used with certain oval shaped carabiners, the intention being that the knob lies firmly against the rock in such a way that it helps support the load (Fig. 1).

The Pierre Alain hanger is a larger bracket, made of thinner material than the simple cantilever, the main difference being that the folded sides of its box-like construction brace the attachment point away from the rock surface. Because it hangs freely from the bracket, any shape of carabiner can be used to attach equipment.

Petzl manufacture a twisted hanger which is an identical pressing to the simple cantilever but is twisted in the vertical plane so the attachment carabiner lies closer and parallel to the rock surface. British hangers of this type manufactured by Troll and previously sold under the name of Parba, are machined from extruded section of thicker material than bent forms (Figs. 3 & 4). The latest Troll bracket is considerably thicker and the hanger itself substantially stronger than bent designs made from thinner sheet material.

When comparing different hangers, simply placing them in order according to their relative strengths does not list them in an order of merit. For example, a 'flimsey' hanger that is able to flex under high loads and reshape itself to suit the contours of the rock is probably safer in certain situations than a rigid hanger which might otherwise produce dangerous bending moments in the bolt.

Conventional hangers must lie firmly against the rock; to ensure that they do so, the rock around the anchor must be dressed so that it is flat and square to the axis of the sleeve. The attachment point for the rope or ladder is cantilevered away from the rock surface by the hanger bracing itself against the wall. In effect the hanger transfers the load through a lever which actually increases the load applied to the anchor. Some hanger designs are better than others in this respect and a brief examination of the geometry of each should establish which model might best be selected for a given situation.

A hanger can be regarded as a lever with its fulcrum positioned at the point where the bracket is braced against the rock. For the lever to be in equilibrium, the turning moment at one side of the fulcrum must be equal to the other. From this simple equation it is possible to calculate the value of the resultant load applied to the anchor and its direction. Although the example illustrated in Figure 2, is an extreme one chosen to demonstrate the principle, all 'rigid' hangers that bear against the rock transfer the attached load so that the anchor is partially stressed in tension. Furthermore, the resultant load is always greater in magnitude than that applied to the hanger.

The 'simple cantilever' hanger illustrated is in fact designed to be used with an oval carabiner; in the example the load is attached with a smaller Maillon Rapide which effectively changes the intended geometry of the hanger. A carabiner touches the rock below the attachment point (Fig. 1) and serves to strut the hanger, whereas a Maillon hangs free from the bracket. Using a Maillon to attach the load to this particular hanger flexes the bracket unnecessarily and fatigues the metal. This is clearly undesirable even though, being somewhat flexible, the hanger will straighten itself under higher loads until it is properly supported.

The way in which different hangers transfer their loads to the anchor is compared in Table 1. The first column refers to loads applied at right angles to the anchor, and the higher figure indicates the hanger which is best in this respect - that is, that which stresses the bolt least harshly. This figure is determined by dividing the dimension measured between the centre of the bolt hole and the fulcrum point where the hanger braces itself against the rock, into the perpendicular distance between the point of attachment and the anchor.

Table 1

Hanger: make / type	Leverage	Optimum angle
Petzl twist	36	17°
Troll (Mk II)	26	42°
Parba	25	35°
Petzl 'cantilever' with krab	25	30°
Pierre Alain	25	20°
Troll (Mk I)	21	40°
Petzl 'cantilever' with Maillon	13	30°

If the load is applied to the hanger so that its direction forms a straight line drawn between the centre of the fixing bolt and the point of attachment (Fig. 3), the resultant load in the anchor is the same in both direction and magnitude as that applied to the hanger. This is called the 'optimum loading angle' and it is different for each hanger. The second column of Table 1 tabulates the optimum angle as measured from the rock surface for each hanger. If this angle is exceeded, resultant loads will increase considerably since the lever action is greater, the fulcrum point being transferred to a position closer to the bolt.

It has been suggested that a very strong and rigid hanger is not necessarily most desirable. The ability for a hanger to reshape itself so as to minimize the leverage applied to the bolt when loads are excessively high is a deliberately designed safety feature. In destruction tests however, unlike other hangers, the new Troll bracket is so unyielding that the bolt breaks first with only slight deformation of the hanger. This is perhaps only of academic interest since ropes or ladders are most likely to fail before the belay. As can be seen from Table 1, compared with less rigid hangers, the geometry of the Troll hanger is such that over the range of angles at which loads can be safely applied, the leverage of the bracket is minimal. Correctly seated against the rock and properly orientated so that the 'mitred' edge of the bracket - so shaped to minimize the area of rock that needs to be trimmed to ensure a perfect seating - lies in the vertical plane (Fig. 4) the new Troll hanger provides the strongest and most versatile belay of all 'conventional' brackets.

Maillon Rapides offer an alternative to carabiners as the method of attachment to conventional hangers. Preferred for their competitive price, Maillons also have the advantage that properly screwed up, they are more secure than carabiners; krabs are potentially weaker, there being a possibility of keeper failure since a proportion of the load is transmitted through a tiny hinge pin. This weak link is eliminated with Maillons, but some cavers are concerned that the smaller radius of a Maillon stresses the rope excessively. To reduce flexion in the rope, the knot loop can be formed over a 'rope thimble'. For pitch rigging there is in fact little to be gained from this precautionary measure: providing Maillons of smaller diameter than 7mm are not used, ropes will always suffer greater distortion within the knot itself.

When krabs or Maillons are in short supply, there is a temptation to fasten ropes directly to conventional hangers. A tensioned rope that has been threaded through the carabiner hole of a hanger is considerably weakened. For several reasons, hangers that do not require krabs or Maillons for attachment are becoming increasingly popular. These specialist hangers are specifically designed for static belays in caving where speed of attachment is of little importance. Generally these 'carabiner-less' hangers are less expensive than conventional assemblies and are lighter in weight and less bulky - very important factors considering the trend toward more efficient caving in small groups, and the numbers of hangers required to rig 'technical' caves safely.

Although not available in this country, the 'channel hanger' is included in this study because it is an obvious development of the conventional hanger bracket. Made from relatively thin sheet material folded into a 'U' shaped section, the channel hanger is a rather cumbersome bracket. It is screwed to the anchor through one of two holes drilled into its rear, ropes or ladders being hung over a bolt fastened through its two sides. The channel hanger has little to recommend itself, there being a risk of losing its various components, and its size eliminating it for consideration as an 'expedition' hanger.

With the following carabiner-less hangers, ropes are tied to them before the bolt is screwed into the anchor. This is regarded as an added advantage because cavers are obliged to make a preliminary inspection of all the components of the belay before trusting their lives to them.

Both T.S.A. and Petzl manufacture 'ring' hangers. Both are formed into a ring from 7mm diameter steel welded with a scarf joint to the sides of a bolt hole, the two makes having slightly different shapes. Ropes are attached either by larks-footing a knot loop over the ring, by tying a bowline-on-the-bight through it, or alternatively krabbing the rope to the ring in the conventional manner. Although it is more expensive on rope, a bowline is generally preferred, a larks foot being awkward to form with a stiff rope.

The ring hanger is primarily designed for situations where the load is applied at angles between  $45^{\circ}$  and  $90^{\circ}$  to the rock. However, it is vital that the ring lies in the vertical plane to avoid dangerous bending moments in the bolt. One advantage of the assymetric design of the Petzl ring over the circular shape of the T.S.A. version, is that the attached rope is likely to occupy a position where the curve of the ring is tightest thereby encouraging the safe orientation of the hanger.

The ring hanger is normally used as a 'universal' belay where the attached load is applied closer to the rock at an angle around right angles to the axis of the bolt. In this situation a considerable bending moment is applied to the bolt. However, under extreme loads which might threaten the integrity of the bolt, the ring distorts and assumes 'optimum geometry' (Fig. 5). If the rock is sufficiently hard, ring hangers should perform quite safely.

Another hanger of French manufacture and known as the CAT (cable amarrage T.S.A.) consists of a swaged loop of wire to which ropes can be larks-footed to form an assembly which resembles a reef knot - one side of which is wire and the other rope. This configuration holds the sides of the rope loop closely together and with the normal figure-of-eight or nine knots usually used for attachment to hangers, the krabbing of cows-tails into the rope is particularly awkward if the rope is held in tension. This problem can be overcome by tying a bowline-on-the-bight and fastening either one or both loops into the CAT - the form of a bowline knot separates the attachment loop thereby facilitating the krabbing of cows-tails.

To reduce harsh flexion in the rope where it is formed over the cable, the CAT wires are sheathed with a plastic tube. Threaded over the wire loop is a plastic disc, the function of which is intended to protect the rope from harsh contact with the rock face. As such, the CAT is particularly suited for hanging ropes from poorly positioned anchors placed above abrasion points, its limitation being the strength of the crimping at the join of the loop (Fig. 6).

A function of bolt hangers is to transfer the load applied by the caver to the rope or ladder, to the rock without unduly stressing any of the components of the belay. The thinking behind the latest idea in hanger design is that the strongest bolt belay is likely to be that in which the number of components under load is reduced to an absolute minimum. Such a hanger is potentially the smallest and lightest it is possible to have. The 'bollard' hanger is a Lizard prototype design of which only the bolt itself is normally stressed.

The bollard hanger consists of a high tensile bolt to which a 'rope cage' is held in place by an integral threaded sleeve. Ropes or ladders, or both, are attached to the hanger by passing a loop of rope or wire through the cage and hooking it over the bollard. The hanger is then screwed into the anchor, the rope being firmly held against the rock around the bolt, and the cage lifting the rope away from the rock surface below the anchor (Fig. 7).

The bollard is best suited to situations where the load is applied at a slight angle to the rock. When loaded at other angles, forces are not transferred directly to the bolt since the cage serves to deviate the line of force. However, since the rope itself is flexible, resultant loads applied to the anchor are not significantly greater than the tension in the rope. Under normal static loads, components of the bollard resist any tendency to bend, but when subjected to high peak forces when shock loaded, the cage distorts so that loads are safely transmitted directly to the anchor, the bolt being of superior strength that it remains intact. In common with all other hangers with the exception of the 'ring', loads should not be applied to the bollard at angles greater than  $45^{\circ}$  to the rock surface.

## CONCLUSION

An analysis of all the factors discussed above suggests that the ideal position for an anchor is in a rock wall that is slightly overhanging. This ensures that sleeves are least likely to be inundated with water and grit; that loads will be applied close to the optimum angle for any hanger so that the anchor is stressed least harshly, and, perhaps most important of all, ropes belayed to the anchor will hang free of contact with the abrasive rock surface.

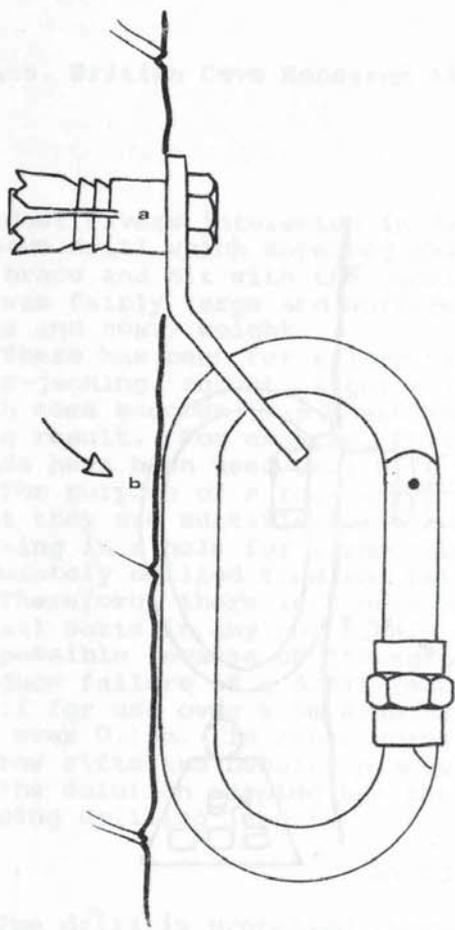
One of the most important factors in deciding which hanger to use for a given situation is the question of protecting ropes from damage. If the rock is particularly smooth, a certain amount of contact might be tolerated in the immediate vicinity of the anchor, but the worst hazard is that of knot abrasion caused by protrusions in the knot oscillating against the rock; this is to be avoided at all costs. Some hangers are better than others in this respect. If the loop of rope is parallel to the rock, protrusions in the knot are of smaller dimensions and so abrasion is less likely. Quite often the threat of rope abrasion can be avoided simply by elongating the attachment loop, or by adding extra carabiners to extend the attachment or to turn the knot through right angles. In situations where harsh contact cannot be avoided using these methods, the rope must be padded. The most effective way of padding ropes is to 'bolt' a mat to the wall - that is, securing the mat beneath the hanger bracket. Such mats can be simply made from defunct tackle sacks, the draw cord being used to enclose the rope to ensure the two cannot separate. Intelligent pitch rigging can overcome any problem.

All things considered, bolt belays are as safe as the caver chooses to make them. There are but a few golden rules that should always be observed: hangers should be firmly bolted to the anchor so that they cannot invert, and bolts should be properly tightened so that they cannot accidentally unscrew themselves. Finally, because the possibility of stress fracture in the rock can never be eliminated, NEVER TRUST YOUR LIFE TO A SINGLE BOLT BELAY.

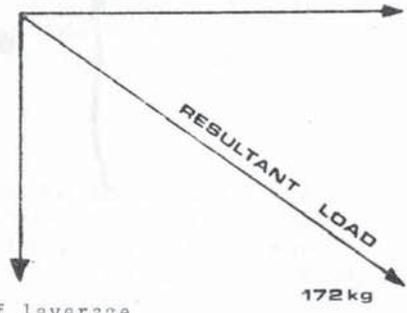
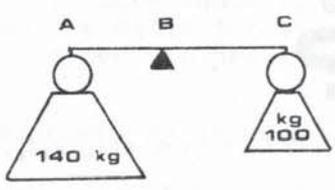
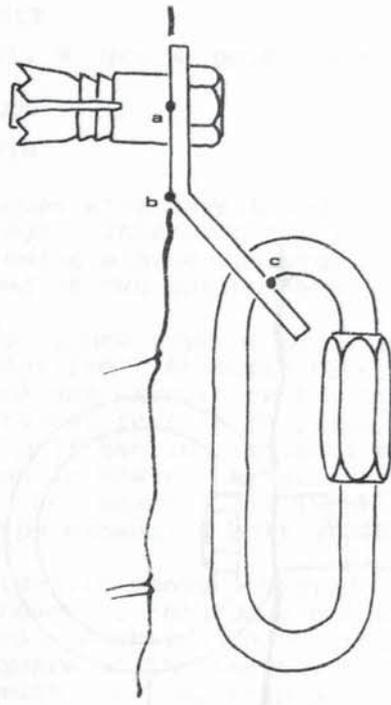
June 1982

Dick Lawson  
41 / 3 Station Road  
Oakworth  
Keighley  
West Yorkshire  
BD22 0DU

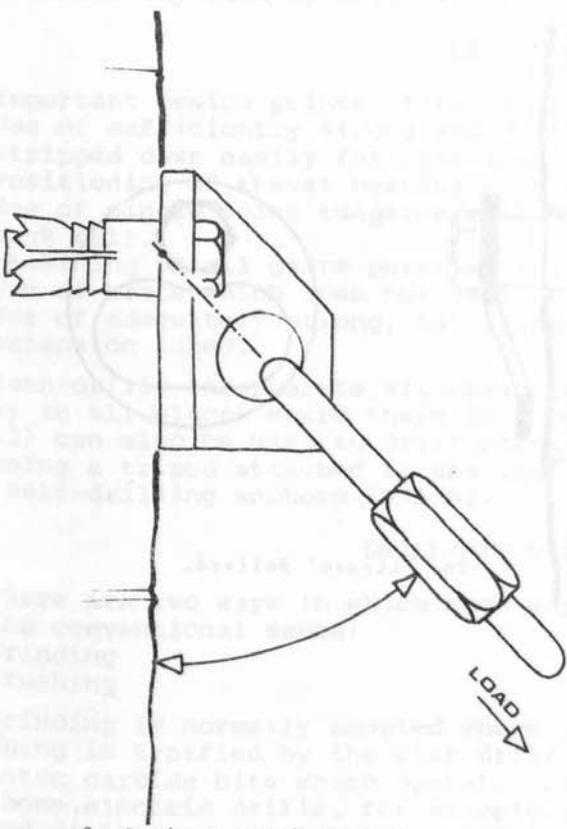
For recommendations on the placing of bolts readers are referred to the article by Paul Seddon on "Bolt belays for SRT" in Caves & Caving, no.12, May, 1981.



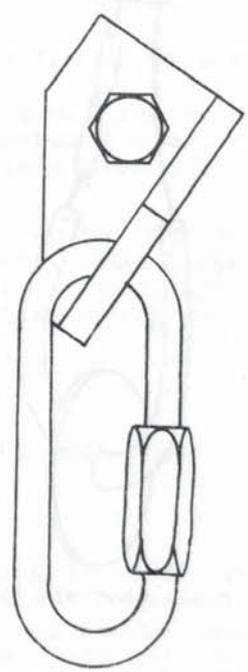
1. The 'simple cantilever' hanger.



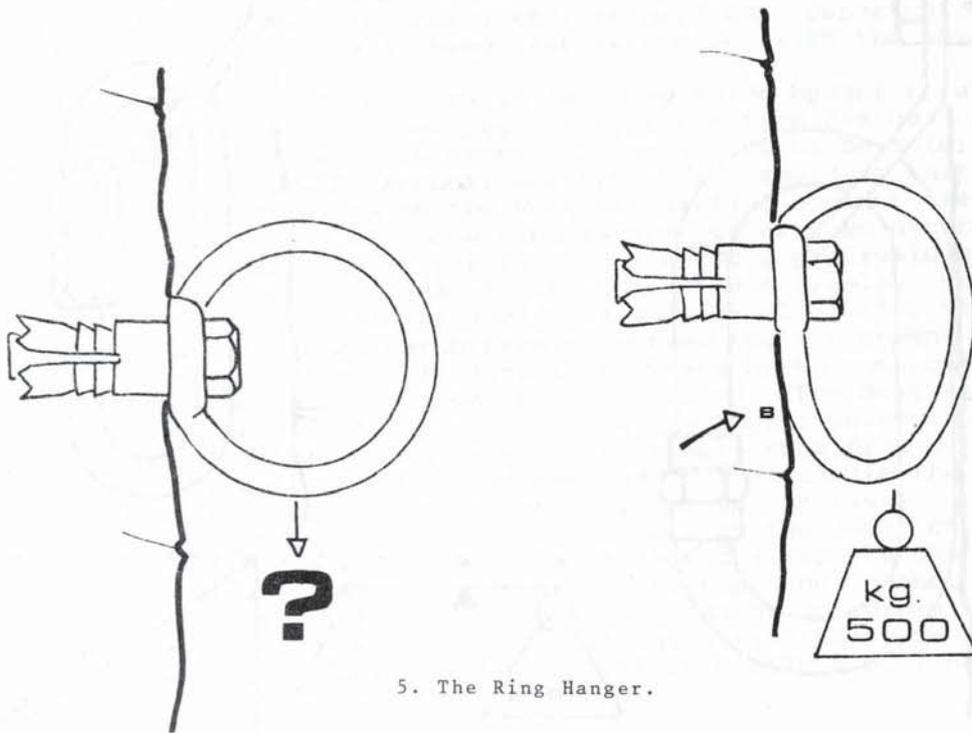
2. The effect of leverage



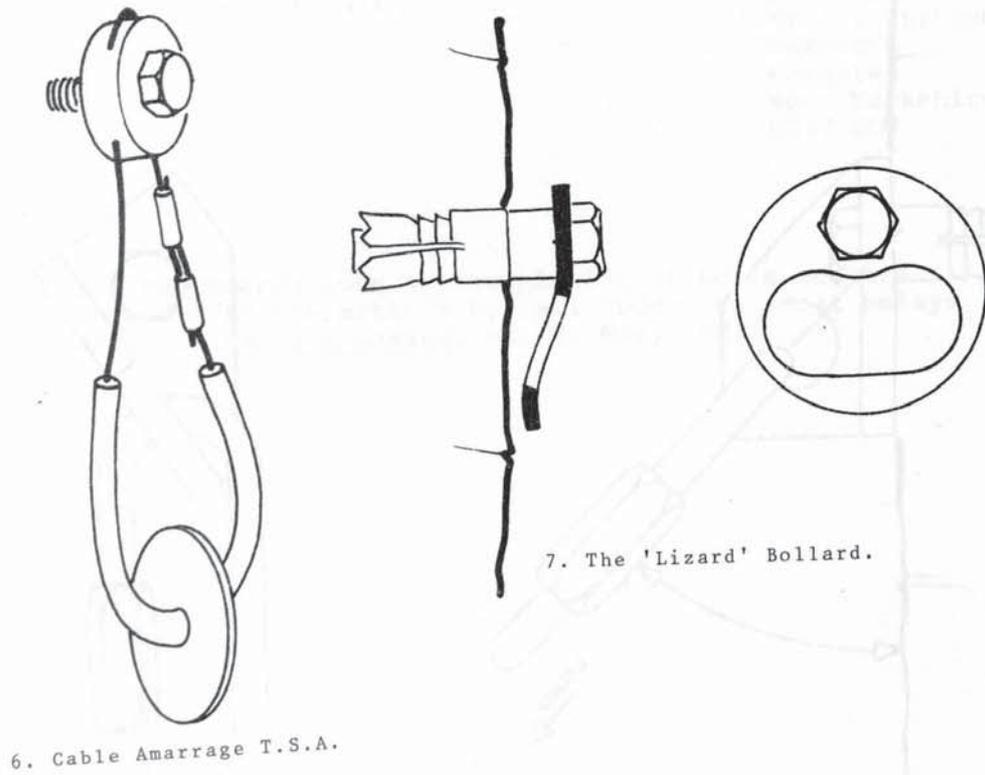
3. Optimum loading angle.



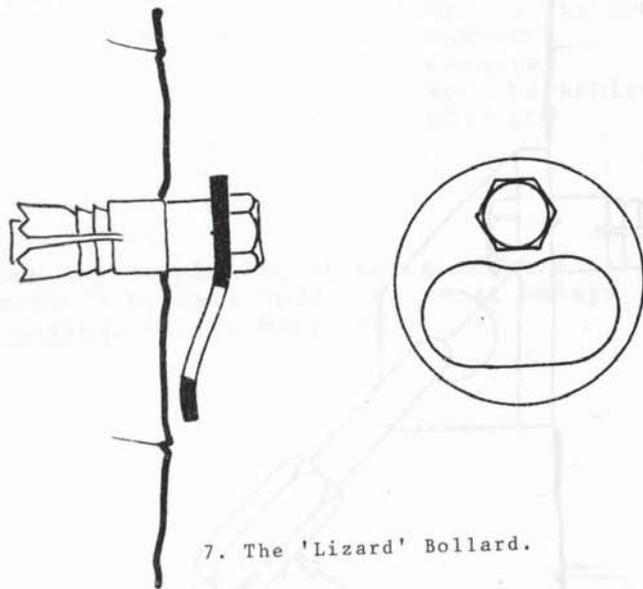
4. Correct orientation (Troll MkII).



5. The Ring Hanger.



6. Cable Amarrage T.S.A.



7. The 'Lizard' Bollard.

## CAVE SCIENCE

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### ROCK DRILLS

J. S. Davis

Most cavers interested in drilling techniques will have heard of the Russum drill which appeared about ten years ago. This used the principle of brace and bit with the jacking mechanism being a hand-operated screw jack. It was fairly large and suffered from the need of two active hands, large size and heavy weight.

There has been for a long time the need for a new type of drill which was self-jacking, robust, light weight and trouble-free. Attempts have been made with some success (Sam Heath and Phil Pappard) and experience has been gained as a result. For example, thrust bearings pre-set to slip at predetermined loads have been used, but have failed due to grit getting inside the bearings.

The purpose of a rock drill is to put holes in where they are needed so that they are suitable for the intended use. For example, it is no use putting in a hole for a removable Rawlplug-type expansion bolt if it is not accurately drilled true and parallel.

Therefore, there is a need for a drill versatile enough to produce holes of all sorts in any position. In practice, however, this does not seem to be possible because of strength considerations. Buckling forces required to produce failure of a drill reduce with the square of the length, so that a drill for use over a 5m span has to be made much stronger than a drill for use over 0.15m. In other words, it is more sense to have one small drill for narrow rifts and bedding planes and one drill for everything else.

The solution adopted has therefore been to have two drills with an overlapping drilling length.

### BASIC PRINCIPLE OF JACKING

The drill is propelled forward when the tangential brake applied to the outside of the jack overcomes the friction between the threads of the screw-jack, thus extending the jack until the drilling pressure in turn reverses the situation and causes the brake to slip. Use of a simple adjustable brake thus allows any size of drill to be used.

### DESIGN POINTS

Important design points of the drills are:

1. Use of sufficiently strong and durable thrust bearings which can be stripped down easily for cleaning.
2. Positioning of thrust bearing at rear of drill.
3. Use of single point tungsten carbide tip for location of jack base on back wall.
4. Machining of all parts parallel to ensure drilling of true holes.
5. Use of brace which does not deflect under the pressures used.
6. Use of adequately strong, but light-weight materials especially for extension tubes.

Both drills incorporate all these points so they can be used successfully in all places where there is a point to jack off. The larger drill (Mk.3) can also be used to drill holes where there isn't any jacking point by using a tripod attached to the item needing drilling using wire belays and self-drilling anchors (SDA's).

### DRILL BIT DESIGN AND CHOICE

There are two ways in which rock may be removed by mechanical drilling in the conventional sense:

1. Grinding
2. Crushing

Grinding is normally adopted where diamond drilling is used, whereas crushing is typified by the star drill. In the middle, there are the tungsten carbide bits which operate best under crushing conditions. Most DIY home electric drills, for example, operate at too high a speed for 'WC' tipped drills and are only successful in burning out the tip by grinding it

away, unless a speed reducer is used.

Speed of rotation of drills and pressure of drilling are the two controlling factors on rate of drilling. Low pressure plus high speed is used for diamond drilling whereas high pressure plus low speed is used for 'WC' tipped drills.

Diamond core drills of 50mm. and 110mm. has been adapted for use with the Mk.3 drill which allows water to pass through the drill and flush out rock waste. However, the diamond drills can only be used with the brace, because insufficient speed is obtainable if the ratchet is used.

'WC' tipped drills may be solid or core type. Core drills are only a real advantage at large diameters because a large wall thickness is necessary to hold the 'WC' tips. Solid drills suffer from having to remove the centre of the hole which is the most difficult part. Use of a chuck is not recommended because large drills simply spin round in them. Direct threading into the drill or hexagon bar is suggested in order to prevent slipping.

A modification of the solid drill has been suggested by offsetting the two halves of the drill tip in such a way that a small gap is left in the middle. The theory behind this is that the small piece of rock left in the middle will be insufficiently strong to remain, and will simply shear off. This should result in a faster drilling rate and in practice this has been reported by Phil Pappard.

Resharpener of drills only applies to 'WC' type. The angle of tip and throw are critical and resharpener should only be done by a skilled person. Core drills are even more difficult to resharpen, particularly since the inner faces need resharpener, and if they are expected to drill straight afterwards.

The angle of tip has obviously been researched by the manufacturers, but it must be borne in mind that the drills in a caving context are being used outside the range for which they were intended. There is therefore, room for practical work and a literature survey in this area.

Sizes of drill depend on the use of the hole. Small diameter drills less than 10mm. are not suitable because they tend to buckle under the pressures used. In practice, it is easier and safer, if the hole is intended for an anchor, to put in larger anchors 12-15 mm. and larger. An attempt has been made to standardise on drill sizes of 12, 15, 24 and 32 mm. since these have been adopted by most of the anchor manufacturers.

#### USES OF THE Mk.2 AND Mk.3 DRILLS

The Mk.2 and Mk.3 drills can be used for the following purposes:

1. Permanent anchors.
2. Artificial hand-holds.
3. Peg holes for use with a "Cheating stick" and sling.
4. Holes for plugs and feathers or destructive expansion bolts.
5. Shot holes.
6. Drain holes, e.g. for sumps.

The requirements for anchors have been covered by a NCA report, but to reiterate, they must have holes drilled parallel, straight and be of correct diameter and depth in order to ensure optimum strength. Holes for plugs and feathers also need to be drilled accurately in order for them to be effective. However, plugs and feathers are not available now unless made to special order, so alternatives have been looked at. The technical information supplied by anchor manufacturers, especially Hilti, is very useful because, in general, large anchors tend to cause material failure rather than anchor failure. Consequently, the obvious move of using a large anchor intentionally to cause rock failure has been tried with success.

The Hilti data relates failure load to bolt diameter, depth and distance from the edge of the test block. In practice, holes should not be drilled more than 2.4x hole depth from an edge, and in order to encourage breakage should be less than 1.5x hole depth from an edge. The implication of this is that holes of 32mm. diameter should be adequate to produce cavable passage, and in the case of not being able to get the bolt in the hole (e.g., in a narrow rift) use of 24 mm. bolts would work.

Bolts suitable for this type of use are those which have a high bolt diam. to hole diam. ratio, but which can still be removed in the event that failure doesn't occur.

Cost of plugs and feathers are £26 per set whereas bolts are between £3 - £5 each.

At the moment work is being done on expanding cements which are commercially available for use as non-explosive demolition agents, but no information has been published in a caving context.

#### RATES OF DRILLING

Test drilling to date has been mostly qualitative rather than quantitative, but a programme of tests is in progress.

Qualitatively, drilling rates of mm. per minute are attainable using a 24mm. solid 'WC' drill using the Mk.3 drill with brace. Ratchet operation on both Mk.2 and Mk.3 drills using 15 mm., using 24 mm and 29 mm solid 'WC' drills produce rates of 25 mm per minute; however, these are under ideal conditions. Realistically, 29 mm holes 150 mm deep have been drilled consistently in very restricted bedding planes in less than half an hour.

To conclude, the basic designs of the Mk.2 and Mk.3 drills and their flexible application provide a successful method for drilling holes in a caving context.

This is intended as the first of a series of articles on the drilling of holes and their uses. Planned experimental work will be published and any comments or information from other interested people is welcome.

Ideas which are also worthy of investigation are:

1. Development of a tangential drive for drills.
2. Efficient pneumatic drills.
3. Butane powered internal combustion engine with a carbon monoxide adsorber.
4. Hydraulic drills have definite advantages over compressed air because of the higher pressures available - 2000 psi compared to 100 psi for compressed air.
5. Chemical methods for dilling holes such as acid-etching, plasma blasting and heating methods (thermite, oxy-acetylene, thermic lance).

J. S. Davis  
The Old Reading Room  
Selside, Settle,  
N. Yorkshire, BD 24 OHZ

## SCALING POLES

J. S. Davis

Scaling high caverns may be accomplished by free climbing or by using various aids. These aids may be removable, e.g. pegs or chocks, or fixed anchors, e.g. self-drilling anchors or recoverable anchors from drilled holes.

In conjunction with the method of attachment to the rock, there are other aids which can be used - etriers, bolting platforms, scaling poles and stemples.

Scaling poles have been used for a long time, but rather crudely and with a "Hope for the best" attitude as far as their strengths were concerned. No theoretical evaluation of their strengths was available until my articles in BCRA Trans. Vol. 7, No. 4, pp.200-204, (December, 1980) and in Trans. Vol. 9, No. 3, (September, 1982). However, this has had to be amended because of theoretical errors which produced a much lower allowable loading than now permitted. A condensed data sheet is included at the end of this article containing correct values and suggested sizes for scaling poles.

In practical terms, the following requirements should be considered:

1. Safe working load
2. Operating length
3. Weight
4. Manoeuvrability.

Safe working loads for ropes, anchors, and SRT equipment in general seem to be standardizing around 1000 kg. To achieve this for scaling poles would make them too heavy as a practical caving item, and, in any case, they do not need such a large safety factor as implied by the 1000 kg. figure. The reasons for adopting this attitude are that shock-loading should not occur unless cavers are unbelievably stupid or fall of rock occurs. A safety factor has obviously got to be adopted and a 4x factor has been chosen. This allows for weakness of joints and an educated guess. It is realized that these statements may be criticised and any comments or discussion will be welcome.

Operating length must be long enough to be worth taking it underground in view of the availability of bolting platforms. However, a pole should not be too long for safety reasons because it is necessary to be able to see the end of the pole clearly, otherwise there is a great danger from loose rock falling. The pole should also reduce to easily carryable proportions and be made of a material strong enough to take normal caving wear and tear.

The weight of the pole should be such that, when assembled, it is easily lifted and positioned by one person.

Manoeuvrability covers easy carrying and positioning.

The techniques of using scaling poles has not been very refined to date although some have been used to leap-frog up avens. When considering techniques, simplicity should be foremost as it is very easy to get in a muddle when too much gear is literally hanging around.

Firstly, self-lining is advised because of the strength reduction of the pole if life-lining through a pulley by another caver is adopted. This is because the effective load on the pole is doubled and hence, the strength of the pole halved.

A refinement designed to reduce shock-loading on the pole and the caver is the use of a pulley at the end of the pole and an anchorage for the rope about a third of the way down, thus reducing risk of both rope and pole failure.

A second point to consider is whether ladders or SRT should be used. The answer to this is that if you have SRT sorted out properly then use it, otherwise use ladders. (Don't use a scaling pole for your first SRT trip!). The reasons for favouring SRT are that it reduces the tackle required, the load on the pole and the gear to carry. However, ladders are probably easier for scales of two pole lengths or less.

A "Frog" technique is recommended for use with 2 SRT ropes. The ropes need to be 10 metres longer than the scale.

## SCALING TECHNIQUE

1. The pole is assembled and raised.
2. The caver ascends rope and uses drill or SDA (self-drilling anchor) to place 2 anchors - one for caver and one for pole. Anchors should be vertically spaced about one third of a metre apart.

3. The caver attaches a cow's tail to krab to bottom anchor hanger and then attaches pulley to krab on top bolt.
4. A second SRT rope attached to the bottom of the pole is used for hauling by passing it through the pulley on the top bolt.
5. A hauling party then raises the pole whilst the caver at the top guides the pole into it's next position. In the event of there not being a hauling party, the caver can raise the pole alone by using his ascending gear.
6. The bottom of the pole is then attached to the top bolt, and the caver removes hauling rope and attaches it to himself.
7. A wire belay can be used to connect the two bolts together.
8. The caver then swings across to opposite wall (if there is one) using the bottom rope for a slow swing, and then ascends to top of pole.
9. The caver then places two more anchors and repeats process.
10. At any time, the caver can be relieved.
11. At the tope of the scale, a natural belay is preferred for de-rigging, with the objective of recovering as many bolts as possible if 15 mm. removable bolts are used.

The pole in present use has been designed for use in avens or rifts with a maximum of 5m width so that a minimum of 5m height is gained on each leg. The maximum height in avens less than 2m height is about 8m. The pole has been designed for use with a self-jacking rock drill which is covered by the accompanying article.

It is proposed to extend the pole by two sections to make use of the 4x safety factor, therefore increasing the maximum height scalable from 8m to 11m.

Two special hangers were originally made in order to remove the risk of incorrect loading on the anchors, but these were very heavy for what they were and have since been declared obsolete and replaced by improved 'pin' ends.

J. S. Davis  
 The Old Reading Room  
 Selside, Settle,  
 N. Yorkshire, BD24 OHZ

Appendix                      Scaling Pole Strength Calculations

$$F_{\max} = \frac{33913 \times (d_2^4 - d_1^4)}{2L \text{ (ft)}}$$

Values for  $d_2^4 - d_1^4$  for different diameter scaling poles.

- 3"  $(3^4 - 2.744^4) = 24.31$
- 4"  $(4^4 - 3.744^4) = 59.51$
- 5"  $(5^4 - 4.744^4) = 118.50$
- 6"  $(6^4 - 5.744^4) = 207.43$

By substituting in rearranged equation for HT 30 aluminium tube:

$$L(\text{ft}) = \{30.83 \times (d_2^4 - d_1^4)\}^{1/2}$$

For 5x safety factor & 100 Kg load			For 4x safety factor & 100 Kg load		
Diam. Ins.	Length ft.	Weight lbs.	Diam. Ins.	Length ft.	Weight lbs.
3	27.4	38.6	3	30.61	43.2
4	42.83	80.5	4	47.89	90.0
5	60.44	142.6	5	67.57	159.5
6	79.97	226.3	6	89.41	253.0

However, because of overlap the following % need to be added:

3" - 18.75%		3" - 51.3 lbs	
4" - 25.0%	Giving	4" - 112.5 lbs	Total weights
5" - 31.25%		5" - 209.3 lbs	
6" - 37. %		6" - 347.9 lbs	

It is recommended that the 3" pole is adopted for rescue use because it incorporates an easily erected pole with light weight, and capability of use in the 'Zig-Zag' technique where one caver should be able to lift and reposition the pole by himself.

Suggested accessories based on SRT frog technique are:

- 2 x scaled height of SRT rope
- 4 x oval screw gate carabiners,
- 5 mm Rawbolts or 14.3 mm Philips Redheads - 2 x per leg,
- 2 x pulleys - Petzl type.

## SCALING TECHNIQUES

Geoff Barber

### ABSTRACT

A review of scaling methods used underground is presented with special emphasis on bolting. Three basic bolting techniques are discussed. Foot loop and etrier methods being covered briefly. Platform bolting is covered in more detail with a step by step account of self-lining whilst solo-bolting.

Much has been written over the years about rigging pitches for descent by ladder and line or SRT but scant attention has been paid to rigging routes to ascend pitches from the base.

On exploration of new caves the caver is sometimes required to scale vertical rock faces. Usually this occurs when following streams back towards their source, either inlets to a cave or exploration from the resurgence. Less frequently attempts are made to overcome 'terminal' sumps by looking for older high level passages heading downstream. In Britain the lure of inlets and avens is strong with lots of extensions to caves having been found over the years and Langstroth Pot, for example, having been fully explored from the resurgence.

In this article I shall talk about three methods of ascent, free-climbing, maypoling and bolting. Only bolting will be covered in any detail, three methods being discussed.

### FREE CLIMBING

Because of the dark and claustrophobic nature of caves people often comment on their lack of fear of heights underground. Cavers chimney out over huge drops to rig pitches which would make them cringe with fear on the surface. This advantage of cave drops usually injects cavers with a bravado which works contrary to their instincts for self preservation.

Although limestone is looked on as a sound, hard rock, normally very clean for climbing on underground, often in new passages just the opposite is found. In spray-washed shafts the walls become etched and fretted leaving flakes and spikes which are far weaker than expected. Cavers are more used to rigging the tops of pitches away from the effects of this spray and only when it comes to scaling is the full effect of etching appreciated.

Once aware of the dubious nature of the rock the climber can sometimes choose a route between close walls affording the chance to lean back and rest. The danger of under-estimating the height and dispensing with protection should be avoided. The difficulty of rescue must always be borne in mind.

Cavers not used to rock climbing should remember that the majority of caving ropes are not designed to take the sort of shock load liable to be met with should the climber fall any distance. If a climbing rope is used much of the shock from a fall will be absorbed by the stretch in the rope. If an SRT rope were to be used the shock will be transmitted to the ends of the rope. Not only will this hurt or injure the climber but the chances are that the life-liner (belayer) will be unable to arrest the fall - it is not his life after all.

On underground shafts natural protection is scarce. Good threads are few and far between and loops over spikes will pull off if dragged upward by the climber. The limestone dissolves from the outer surface giving cracks and beddings which become narrower as they deepen making the placing of chocks difficult.

Pitons can be used but bolts are safer which takes us on to bolting later in this article.

Snow and ice techniques have been used to good effect on mud walls underground and only in this case can climbing be considered a safer option to bolting - after all you cannot trust bolts placed in mud!

### MAYPOLING

This technique has been put to good use over many years and a lot of cave has been explored thanks to the stalwart men and their maypoles. The

discussion of poles and their use is covered in the paper by Jim Davis so little will be said here.

The idea is to take lengths of pole down to the aven and then join them together as you push them up the aven. A rope or ladder and double lifeline are fastened to the end. Once erect the pole is positioned leaning against the wall and the base secured by some means, the brave explorer then prussiks up the rope (or climbs the ladder).

The problems of the system are ones of weight versus strength and safety. The pole and its couplings should be strong enough so as not to buckle and bend under their own weight plus that of the climber. The advantage over bolting is speed but the carry into the cave must be considered as a major factor.

It must be borne in mind that protection for the climber comes only from the pole itself and should that fail the climber will fall the distance scaled. Ascents of over 40 feet have been achieved by this method. The limiting factor being the weight of pole to be heaved erect.

Stabilizing the pole can be a problem and to this end stays or guys can be held either side of the pole if the morphology of the aven permits this. Once at the top it is possible for the climber to place bolts in the wall both for protection and also to give a base for a second ascent. If the aven is of the right dimensions by drawing up the pole and securing it to the wall with the top leaning back to the opposite wall or into an alcove it is possible to make further ascents.

#### BOLTING

With the advent of the self-drilling rock anchor a safe, quick and fairly efficient means of placing belays became available to cavers. By purely artificial means of scaling, sheer, blank walls of rock can be mounted. The climber hanging from one bolt to place the next and by leaving the bolts in place as runners can protect himself against falling.

With judicious use of a climbing rope the bolting can be done solo, doing away with the need to have someone shivering at the base of the pitch whilst belaying. The use of a safety line complicates the process but should NEVER be dispensed with. When choosing a place to bolt the route should be carefully inspected. The objective, if visible, should not overrule other problems. It is always better to take a line of ascent away from falling water even if this should mean having to traverse sideways into the passage once at the top. Areas of loose and shattered rock and overhangs should be avoided. A diagonal line may take one through beds of sound rock where a vertical line would be unsafe. Ledges often afford traverses at height to alter the line of ascent.

Three methods of bolting are described with their advantages and drawbacks. The method of self-lining is common to all three and is only described under platform bolting.

#### FOOT-LOOP BOLTING

1. An anchor is placed at a convenient height and a hanger is bolted to it.
2. A long cow's tail and an adjustable foot-loop are clipped into the bolt.
3. The foot-loop is adjusted and by standing in it the climber clips in his short cow's tail.
4. Hanging by his short cow's tail the foot-loop is adjusted and the climber stands to clip into the bolt with a karabiner clipped directly to his sit harness.
5. Hanging by his sit harness, steadied by bracing knees against the rock, the climber places the next bolt.

The gain between bolts is one metre, the stance is uncomfortable to maintain and the only point in favour of this method is that it requires no special equipment. Protection is as for platform bolting.

#### ETRIER BOLTING

1. An anchor is placed at a convenient height and a hanger is bolted to it.
2. Two entriers are hung from the bolt.
3. The climber climbs an etrier and clips in his short cow's tail.
4. With one foot in each etrier a good stance can be maintained to place the second bolt.

5. By hanging from the second bolt by his long cow's tail the etriers are moved up and the sequence begins again.

This is the conventional bolting method. The stance using etriers is far more comfortable than that using a foot-loop. By using a knee brace as on the bolting platform more height can be gained, up to 1.2 metres. Protection is as for platform bolting.

#### PLATFORM BOLTING

Various designs of platform have been developed over the years. The basic principle is to enable the climber to stand at, or just below, the bolt. With the previous two methods the climber hangs bodily from the bolt and balancing has been of little difficulty. Once the centre of gravity is moved above the bolt, as it is with the platform, stability becomes a major problem. The design of the platform must combat this instability.

The author uses a platform as designed by Rocourt (Fig. 1); the downward load is transferred to the bolt as an almost tensile pull and necessitates the use of ring hangers to avoid the levering action one would get from conventional hangers. In conjunction with the platform two short etriers are also used and two long cow's tails.

The sequence described ensures that the climber is at all times safeguarded by the rope. It is necessary to use climbing rope as it is possible that the climber could fall four metres should a bolt fail.

1. The rope is tied off to a suitable belay at the base of the pitch for an UPWARD pull, e.g. a thread, around a large block or to two bolts with hangers inverted.
2. Place first anchor at a convenient height and insert a ring hanger and karabiner.
3. Take rope and clip figure of eight knot into krab as in Fig. 2.
4. Clip long etrier to bolt and attach platform.
5. Clip into bolt with cow's tail.
6. Climb long etrier, steady platform and transfer weight to short etrier which hangs from it. Climb onto platform.
7. Clip waist karabiner to top of upright of platform and put brace behind knees. These two attachments enable the climber to lean back in a comfortable stance.
8. Place second bolt as high as possible.
9. Clip second cow's tail to second bolt. Reach down and take bight of rope up to second bolt and tie figure of eight knot. Clip knot into krab at second bolt.
10. Untie figure of eight knot from first bolt then replace rope in the krab to act as a runner. Whilst doing this the climber is attached by cow's tails to two bolts. Feed the slack rope through the knot at the second bolt without untying the knot.
11. Hang from cow's tail and take long etrier from first bolt up to second.
12. Unclip platform and first cow's from bolt and move platform to second bolt. This manoeuvre is easier if the climber clips onto the second rung of the long etrier by a krab on his sit harness.
13. Once the platform is secured at the second bolt it is just a matter of starting again at stage 6 climbing onto the platform and clipping in ready to place bolt number three.

As the route progresses the picture becomes clear as in Fig. 3. The climber is always fastened to the rope at the top by his cow's tail. Should the top bolt fail he will fall up to four metres before the rope running up through the bolts begins to stretch and arrest his fall. With the rope running free down to the sac it is possible to abseil off and return later by prussiking back up. The platform method of bolting is very comfortable as the climber stands rather than hangs enabling bolts to be placed faster and a much larger area of rock is within reach. This itself makes things safer but also enables the bolts to be placed to one side moving the route diagonally up the face if necessary. When bolting from foot-loops or etriers the climber is held into the rock allowing little scope for sideways reach. The gain is good around 1.8 to 2 metres.

There are disadvantages to the platform method, the main one being the bulk of the equipment to carry into the cave and move from bolt to bolt. It is unlikely that a freshly placed bolt will fail but if it should whilst

the climber is stood on the platform not only will he fall but the platform will fall with him, attached to his waist ..... the consequences could be quite dangerous.

All the techniques mentioned in this paper are valid and have their place. If the route is free-climbable then the chances are that it has already been climbed, unless it is down a new cave. Scaling usually involves a combination of methods, climbing where one can, bolting for protection, and using the bolts for scaling when the holds run out. Maypoles can be used to overcome shattered sections halfway up a bolt route if the aven is of the right dimensions.

No matter which method you choose the most important point is that you do it safely.

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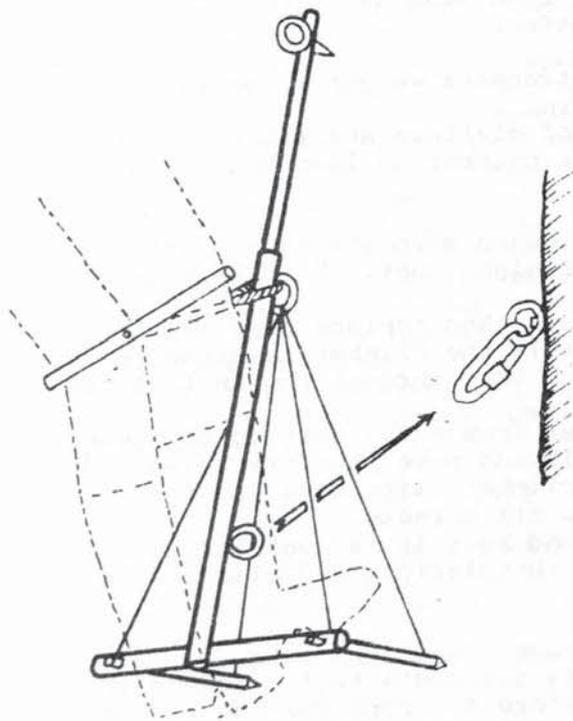


Fig.1. Attachment of Rocourt platform

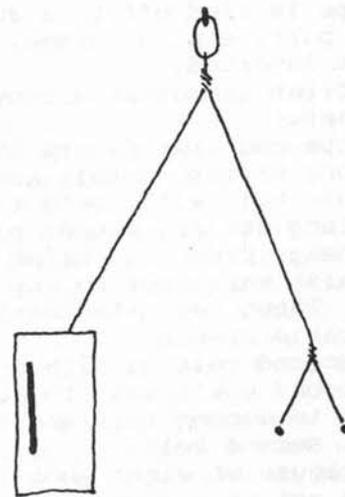


Fig.2. Fixing rope at the base of the pitch.

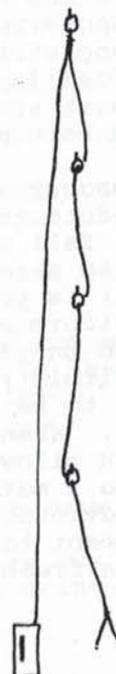


Fig.3. Rope running up through bolts.

Geoff Barber,  
 Wherside Cave & Fell Centre,  
 Dent, Sedbergh, Cumbria.

## THE WEAK LINK

A. Eavis

When considering the strength of an S.R.T. system you have to look at the strength of each individual component. There is little point in insisting on using karabiners with an operating strength of 3,500 Kgf if the actual usable strength of the rope is only 1,000 Kgf. To start with it is worth going through the system starting with the body and finishing with the belay.

## THE BODY

There have been many discussions over what force a human body can withstand in an S.R.T. situation without permanent damage. A figure for a person taking a dynamic load onto a good seat or body harness of 1,200 Kgf is often used as the point up to which only bruising occurs. This has been arrived at by looking at a lot of test data produced by the U.S.A. National Aeronautics and Space Administration and also actual drop tests performed by climbers. From personal experience 600 kgf in a good sit harness is painful and I would think that bones could start breaking at nearer 1,000 Kgf than 1,200 Kgf.

## THE HARNESS

Most modern harnesses when new are adequately strong, but after hard use they can soon suffer damage sufficient to reduce their strength very considerably. Caving must be most punishing and most climbing harnesses are not designed for continuous rubbing as in a tight cave situation. Most harnesses fail in a progressive manner and are fairly elastic so they have reasonable energy dissipating characteristics. In a dynamic load situation on an S.R.T. system one would not expect the harness to fail unless it had been damaged by abrasion, etc.

## THE KARABINER

There are a lot of popular fallacies connected with karabiners. People have tended to think of them as being so strong there is no chance of them ever failing; this has now been shown to be totally untrue. Karabiners are normally very strong when the gate is closed and they are loaded along their long axis (typically 2,000 kgf), if the gate is not closed this drops dramatically to say 1,000 kgf or less, and if loaded across the long axis this strength is typically below 500 kgf. This means that in practice that if a caver takes a fall, if in the moment before the rope goes tight the karabiner twists or the gate opens, it could easily fail. The most common reason for this happening are the use of badly designed karabiners, not closing the screw-gate and carrying gear on load-bearing karabiners.

## THE DESCENDERS

It is possible that a dynamic load could be applied to an S.R.T. system while the participant is descending, so it is worth considering the strength of descenders.

The weakest common descender will be the rapel rack: destruction tests have unrolled a simple pig-tail at less than 500 kgf and snapped rack bars at forces only slightly higher. It must be remembered, however, that, unless the falling caver has his rope locked off to his rack, slip must occur to dissipate energy. The rack itself fails progressively again dissipating energy so it is fairly unlikely to fail totally. The same is not true of self-locking descenders where rope slippage is unlikely as a falling caver would probably release the operating handle thus locking-off the device.

## THE ASCENDERS

The philosophy of the strength of a prusiker/rope system is an interesting one. It is no real advantage if the device is very strong but cuts through the rope at a low force. In many situations it is going to be much more

serious if the rope is cut through than if the device fails. If the top device fails in a fall situation, the second or third prusiker will almost certainly hold, but if the top device cuts through the rope it is obviously a disastrous situation. Appendix 1 gives some idea of the strength of some devices. It is interesting to notice that the strongest sprung cam device has an ultimate tensile strength of 550 kgf, whereas the strongest rope walker is about 1000 kgf. If we consider a human body capable of taking 1,000 kgf there is obviously a good argument for the other components in the system taking the same force or dissipating energy in a way that prevents this force being produced. Since with a fall onto an ascender there will be little or no slip it would be ideal if they would fail at a force between 1,000 and 1,200 kgf without cutting through the rope.

#### THE ROPE

Modern S.R.T. ropes should be carefully designed pieces of engineering. If the human body is fatally damaged by a certain force there is no real point in making the actual usable strength of the rope higher than this. Ideally an S.R.T. rope is not to be elastic when being used normally, and very elastic when having to arrest a falling body. This is difficult to achieve in practice. Some ropes have a very stiff core which actually fails at a load greater than that normally applied: the elastic sheath then holds the fall giving forces never greater than 1,000 kgf. If an absolute figure has to be given for the recommended strength you could say that a body would be very badly damaged at 1,500 kgf so to take into account the knots in the system, wear, degradation etc. this should be doubled to give say, 3,000 kgf. There seems little point in an S.R.T. rope being very much stronger than this.

#### THE BELAY

This is the first link in the chain where the rope is attached to the rock. If the rope is tied to a natural belay the attachment is as strong as the knot or the cutting action of any sharp rock etc. This is largely taken into account if a 3,000 kgf rope is used. If a second belay material is used (tape or wire rope for example) they must also be at least 3,000 kgf as must the karabiner. Many wire belays are not as strong as this and often badly placed tape slings would fail considerably below this force. If a bolt is used as a belay each component of this system must be examined. The shear strength of a 7mm bolt may not be as high as 3,000 kgf and if it has been over-tightened the actual tensile strength available could and often is very much lower than this figure. The bolt hanger is also a potential weak link with a strength often as low as 500 kgf. If the main bolt fails any back-up bolt will almost certainly then fail from the shock load.

The way in which the rope is attached to the rock is probably the most important factor in S.R.T. In all the previous discussions there have been references to the ultimate tensile strength of each component in an S.R.T. system, and certain figures have been quoted for some components. But, apart from the rope snagging on a pitch, the only way in which these forces can arise in a caving situation is from the failure of a part of the primary belay (if the back-up belay fails as well the only force encountered will be mg). Consequently the most important decision one has to make when using S.R.T. is the choice of the primary belay (or belays).

Direct attachments to solid natural belay points are hard to beat in any respect but these are not always present (or at least not obvious), but where they are present they should be used in preference to any bolt that is present, unless the use of that bolt gives a significantly better rig, though ideally both should be used, as, in most cases, a natural belay would be stronger and therefore safer than a bolt. It must be stressed though that not all natural belay points are satisfactory, and just because a belay point has wear marks showing that it has been used for many years does not make it safe; the failure of one such belay point almost caused the demise of the author!

Where there are no natural belay points an artificial one has to be used such as a bolt, beam, piton, climbing chock etc. The most commonly encountered artificial belay is the self-drilling bolt (usually 8mm), which when inserted correctly in sound rock is perfectly adequate provided the bolt is not overtightened - if you try hard enough it is possible to shear a bolt simply by tightening it up. The problem with this type of bolt is that it deteriorates due to corrosion and it is not possible to inspect it once this has happened. The rate of corrosion or its effect on strength in a cave

environment is not known, so maybe every time one uses an old bolt one should be prepared for the consequences. Unfortunately many inexperienced cavers tend to believe that bolts are the greatest thing ever invented and never use a back-up belay when there is a bolt present and as a result we shall lose a number of promising cavers.

In general, the ability of artificial belays to withstand the shock loads caused, for example, by someone slipping at the top of a pitch is not very good. This is especially true in the case of bolts and wire belays which do not absorb energy very well. Remember it's the fall factor that counts and not the distance, so take care at the top of pitches.

#### CONCLUSIONS

A human body is able to withstand a force of about 1,000 kgf in a good harness and dynamic fall situation. This means that the other components of the system should be at least as strong as this. At present many components are not this strong. Many descenders fail below this force as do all sprung-loaded ascenders. Ropewalker type devices often cut through the rope below this force any many types of artificial belays are not strong enough.

Manufacturers should be striving to increase the strength of the component parts of the S.R.T. system. Rope manufacturers should be trying to reduce the peak force produced in a fall but not at the expense of losing inelasticity at low loads.

#### APPENDIX 1

##### ASCENDERS

<u>Rope Walkers</u>	<u>Ultimate tensile Strength</u>	<u>Notes</u>
Gibbs	1,000 kgf	Elongation of holes in sheath allowed Cam to turn inside out. Rope damaged and probably close to breaking.
Lewis	775 kgf	Distortion of sheath holes and deformation of rope contact area on sheath allowed cam to turn inside out. Slight increase in sheath thickness would give much stronger device.
<u>Sprung Devices</u>		
Jumar	550 kgf	Distortion of cam which allowed device to turn inside out. New Jumar has stronger cam.
CMI 5000	530 kgf	The wrap around opened out allowing the cam to pull through. New device is stronger in this respect.
Petzl Jammer (Early)	500 kgf	The cam distorted and pulled through. Later devices have stronger cams.

N.B. The spring clamps are very much stronger if the cams are prevented from turning inside out. A karabiner in the top hole of most of them stops this and greatly increases the strength of the rope/device system. Typically the rope would fail by severe cutting by the cam at about 1,000 kgf.

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Andrew Eavis  
 "Tides Reach"  
 Redcliffe Road  
 Hessle  
 N. Humberside

## DO-IT-YOURSELF EQUIPMENT TESTING

Paul Ramsden

## ABSTRACT

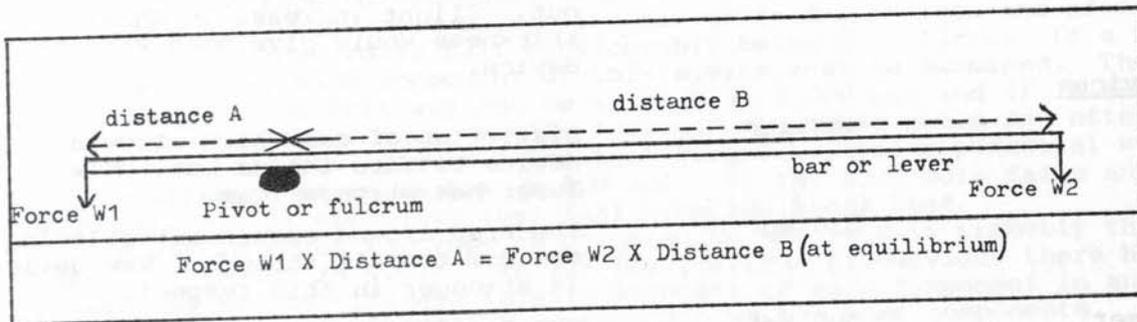
A lever system is described to produce static loads. Test results on ladder components are given.

A drop test is described to produce shock loads which can be used to test the safety of all sorts of equipment. The concept of Fall Factor is examined together with Peak Force (or Impact Force) to see how closely the test approaches reality. Test results on Cows Tails, showing the big difference between new and used tape are given, together with other tests on used rope.

A lever system for static testing

Many people will have heard frightening tales of tests done on ladders, which failed at just above bodyweight. If you have been around long enough you may have seen articles on strengths of ladders etc., but most of these are out of print. The caver of today may have no idea of the risk he faces, through lack of knowledge or misuse of equipment. The lever system is a simple method of producing static loads, which although not very accurate can be used for testing gear, in this case commercially made ladder.

Fig. 1 The Lever Principle

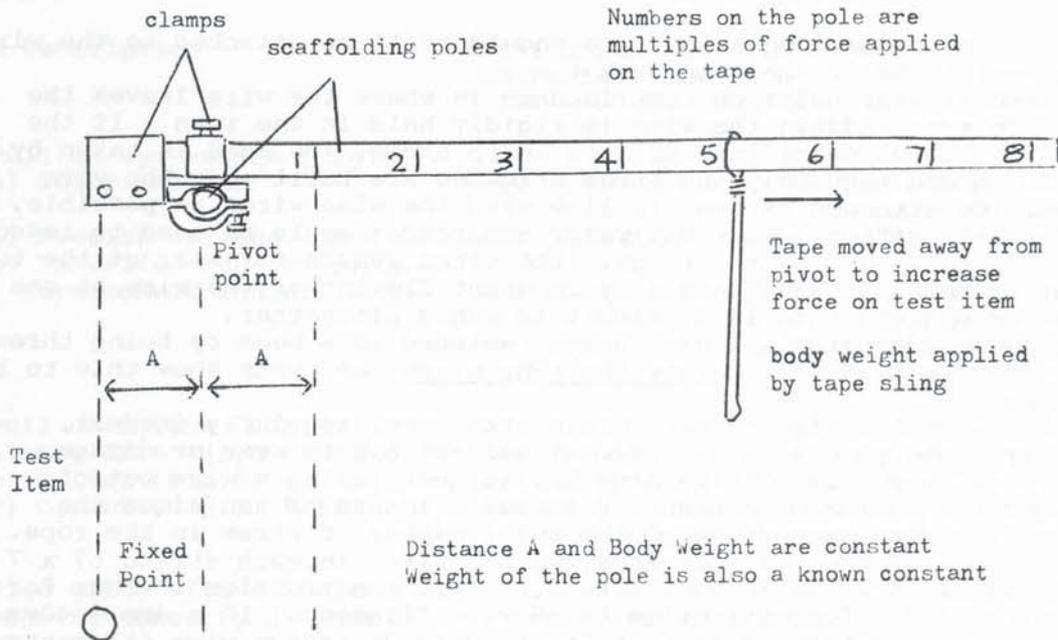


A test Rig was made from scaffolding poles. If distance A is a constant small value and the Force W2 is a known bodyweight, the Force W1 can be increased by increasing distance B.

The weight of the pole is a known constant value. On this rig the lever had marks with multiples of distance A, so that if for example the bodyweight is applied at 4 times distance A, then a force W1 of 4 X bodyweight is produced on the test item.

Alternatively: Force W1 (Load on Test item) =  $\frac{\text{Bodyweight} \times \text{Distance B}}{\text{Distance A}}$

Fig. 2 Test Rig



Ladders are designed to take relatively small loads, say 2 times bodyweight, any extra being a safety factor or to cover deterioration over time. Ladder wires are generally 3mm or 4mm diameter, with a strength of 650 Kgf to 1000 Kgf depending on size and construction. The end fastenings of the ladder should be as strong as the wire, if made correctly. The commonest two types being a Talurit Ferrule (Fig. 3) commercially pressed on or a Flemish Splice (Fig. 3), which has a ferrule solely to secure the end of the splice.

Most ladders and wire belays have C-links to join them together, which, though convenient, are generally very weak. The strength is quite low, but variable, depending on what chain is used. I have heard of some opening at one body weight, but in this test some opened at 200 Kgf, while similar looking ones did not fully open at 500 Kgf. (Figs. 4 & 5). Wire belays are often made of 4mm wire, (approx. 1000 Kgf) as they tend to get rougher treatment than ladders, but the c-links are probably only  $\frac{1}{4}$  to  $\frac{1}{3}$  of this strength. The normal use of ladders and belays involves loading two strands of wire more or less equally, so that half the load is taken on each wire (Fig. 6). Thus a wire sling in which individual C-links opened at 250 Kgf, should be good for approx. 500 Kgf. If you want to get the maximum strength out of the wires (e.g. for an SRT intermediate belay over a sharp edge) do not use C-links, but fasten directly into the eye splice with a karabiner or maillon. Pulleys taking the safety rope are unwisely often attached with a wire belay and C-links (Fig. 7). In the event of a fall, a force  $W$ , is produced. In order to hold the fall an equal force  $W/2$  has to be applied, this puts twice the force ( $2 \times W$ ) on the pulley and belay wire. Dangerous situations may arise on rescues, where a large number of people are heaving on a rope going over a pulley to a stretcher which is jammed. The best solution is to restrict use of wire belays to ladders only. Pulleys and all parts of the safety rope system, where shock loads are possible, should be anchored with suitable rope or tape slings.

Rungs and Rung Fixings in normal use (with a boot applied over a large area of the rung) do not have to take more than say two times bodyweight, (e.g. someone jumping on it). Probably the most dangerous way to use a ladder is to point load a rung, by hanging a karabiner on it (Fig. 9) to abseil from, or for a pulley, or to back up a doubtful belay. Using a 7mm maillon rapide in the centre, the rungs bent at 1.5 bodyweights and broke at 2 body weights. A karabiner in the centre of the rung will often slip so that it is pulling at one end of the rung (Fig. 10); this may cause rung slip instead of the rung breaking. Depending on the construction, rungs may slip along the wire at quite variable figures. Some homemade ladders have had rung slip at just over one bodyweight, but in other cases the fixing is so strong that the wire can break first. There was quite a variation within the three samples. If you must fasten onto a rung (e.g. when resting), it is safer to fasten around the wire and load the end of

the rung. Even if the rung slips, you should still be attached to the wire, which you wouldn't be if the rung broke!

The commonest wear point on most ladders is where the wire leaves the top rung. On most ladders the wire is rigidly held in the rung. If the wire is pulled outwards or inwards at a sharp angle, the load is taken by the strands on one side only and large stresses are built up. The wire belay should be attached as near in line with the side wires as possible, to minimise this effect. Alternatively, a spreader could be used to lessen the angle the tails are bent through. The other reason for wear at the top rung joint is metal fatigue caused by constant flexing of the wire at one point; unfortunately this is difficult to avoid altogether.

I have never advocated a ladder being fastened to a beam by being threaded through itself (Fig. 3 & 5) unless the rung slips the tests show this to be quite strong.

General advice for wire ropes: Clean after use, regularly inspect, particularly those points which are most susceptible to wear or damage. As general guidance Bristol Wire Rope Co. suggest taking a wire out of service when the number of broken wires over a length of ten times the diameter of the rope exceeds 5% of the total number of wires in the rope. Most wire in caving use has 7 strands, with 7 wires in each strand (7 x 7 construction) or 19 wires in each strand (7 x 19 construction). Thus for 4mm diameter wire of 7 x 7 construction (= 49 wire filaments) 10 x 4mm = 40mm length, there should be no more than 5% (roughly 2) broken wire filaments. (Though for 7 x 19 wire 5% = 6). This is probably more than most people would tolerate without getting worried.

As a final point to bear in mind with all gear: beware if you use anything in a way other than for which it was designed.

Figs. 3 - 10.

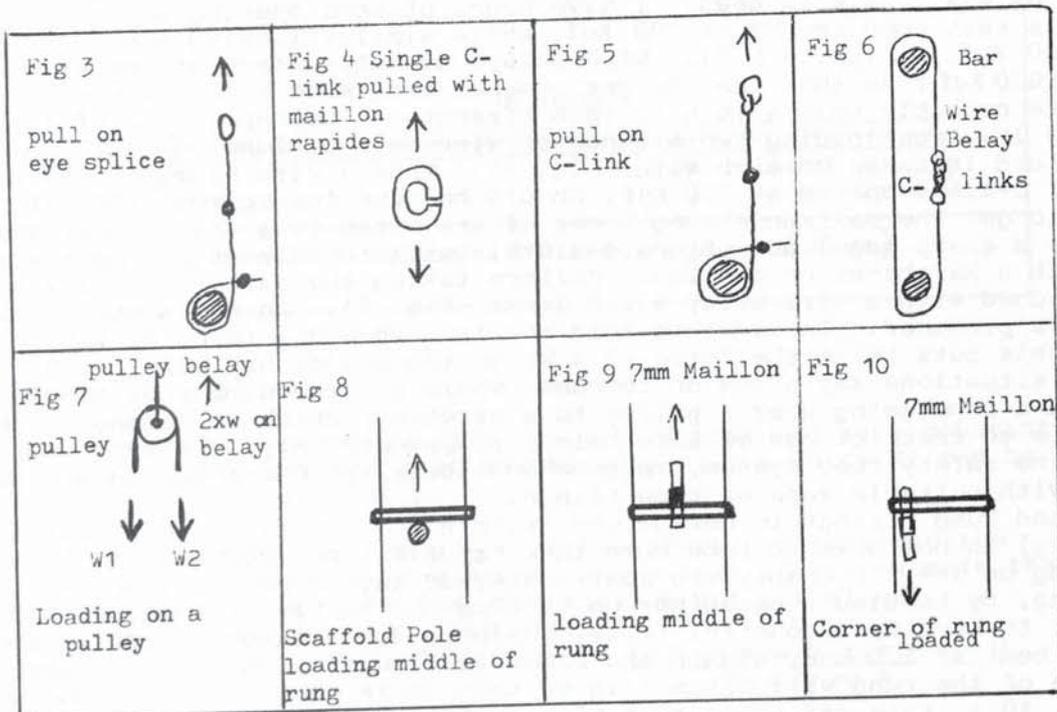


Table 1

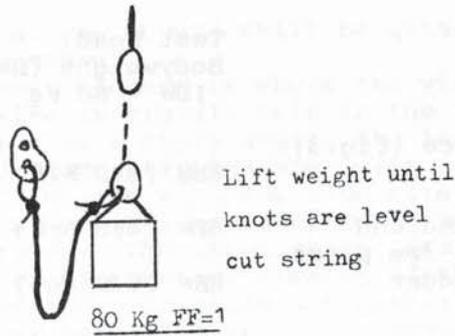
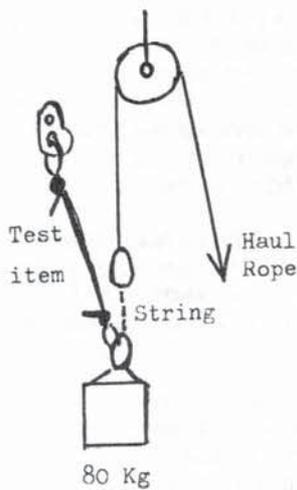
Test Description	Test Load Bodyweight (BW) 1BW = 80 Kg	Comment
1. Pull on eye splice (Fig.3)		
a) Talurited End	8BW (640 Kgf)	3mm wire broke half-way between rungs.
b) Flemish spliced end	6BW (480 Kgf)	No visible damage.
c) Talurited end-3mm pressure bonded ladder	8BW (640 Kgf)	3mm wire broke next to pressure bonded rungs. Splices seem as strong as the wire as expected.
2. Pull on C-link (Fig.4)		
a) New 5/16" High Tensile	3-4 BW (240-320Kgf)	opened at 4 BW
b) C-link (Fig.5)	3-4 BW (240-320Kgf)	opened at 4 BW
c) C-link (Fig.5) 5/16" Old	3-4 BW (240-320Kgf) 7 BW (560Kgf)	slightly opening wire broke at top rung.
3. Wire sling with talurited ends fastened by C-links (Fig. 6)	6 BW (480Kgf)	C-links damaged by hack-saw cuts - but no visible damage.
4. a) Centre of rung loaded with Scaffold pole (Fig. 8)	2 BW (160Kgf) 3 BW (240 Kgf)	Bent Broke
b) Centre of rung load with 7mm maillon (Fig. 9)	1.5 BW (120 Kgf) 2 BW (160 Kgf)	Bent Broke
c) as above (Fig. 9)	2 BW (160 Kgf) 3 BW (240 Kgf)	Bending Broke
d) Rung loaded in corner (Fig.10) 7mm Maillon Pressure bonded rung fixing	3-4 BW 5 BW (400 Kgf)	Slight movement Rung slip
e) As above (Fig.10)	7 BW (560 Kgf)	3mm wire broke next to rung Very strong fixing
f) Rung loaded in corner (Fig.10) pin and resin fixing	6 BW (480 Kgf)	pin broke inside rung rung slipped, several strands of wire broke

The Drop Test

If a piece of equipment fails, it is far more likely to do so as a result of a shock or dynamic load than in a static situation. The drop test is thus a more realistic method of testing equipment than with a slowly applied force, and is considerably simpler.

The Drop test involves lifting an 80kg weight (176lb/12 stone 8lb) by a piece of string to the appropriate height, then cutting the string to drop the weight onto the test item (Fig. 11).

Fig 11. DROP TEST RIG



The following section explains how the test can be applied to caving situations. In rope literature there is a concept known as FALL FACTOR which is the measure of the severity of a fall. Fall Factor is the ratio between the height or length of the fall and the length of rope available to hold the fall. Fall Factor does not depend on the length of the fall alone.

$$\text{Fall Factor (F.F.)} = \frac{\text{Length (Height) of the fall (H)}}{\text{Length of rope used to hold the fall (L)}} = \frac{H}{L}$$

The energy of the falling body is proportional to the height of the fall (H), while the rope's capacity to absorb energy is proportional to its length (L). Thus a 2m fall onto 2m of rope should produce the same forces in the rope as a 10m fall onto 10m of rope.

Fall Factor can vary from 0 up to 2. If someone falls from next to the rope belay and is held by the rope, he has fallen the full length of the rope used to hold the fall. This is Fall Factor 1 (FF1) (Fig. 12).

If someone has climbed 3m vertically above the rope belay and falls, he will fall 6m before being held by the rope. This is Fall Factor 2 (FF=2). Falling twice the rope length is the most severe fall possible. (Fig. 13).

Fig 12

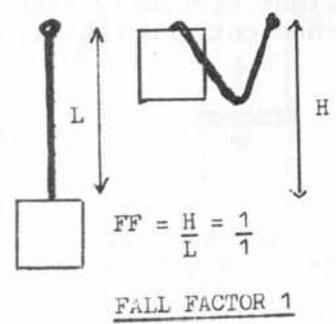
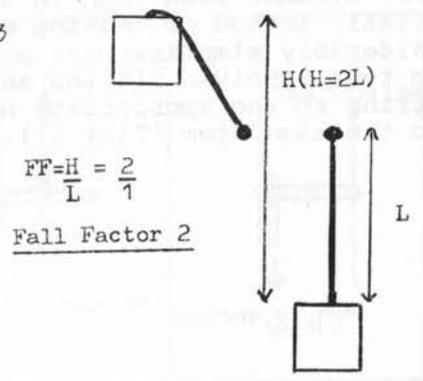


Fig 13



$$\text{FALL FACTOR} = \frac{\text{Height (length) of the Fall}}{\text{Length of rope used to hold the fall}} = \frac{H}{L}$$

Fig 14

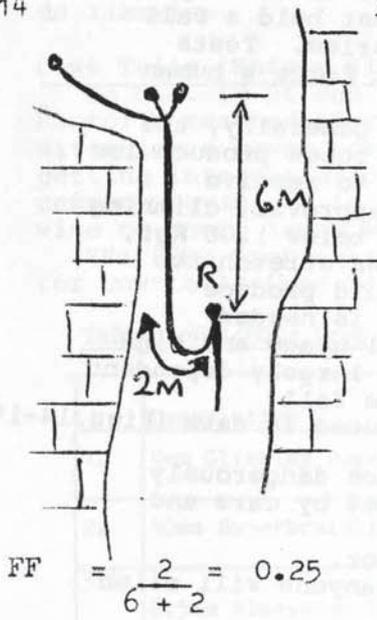


Fig 15

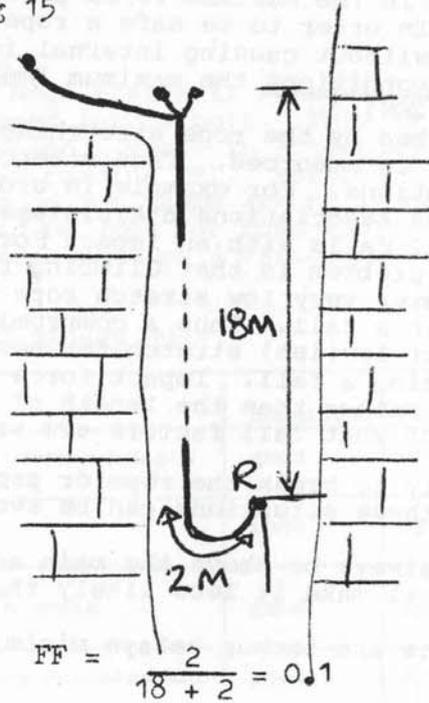


Fig 16

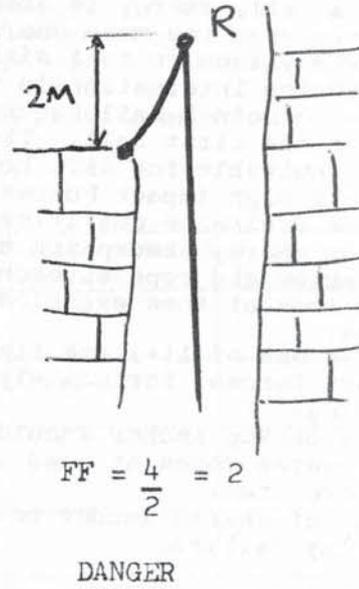
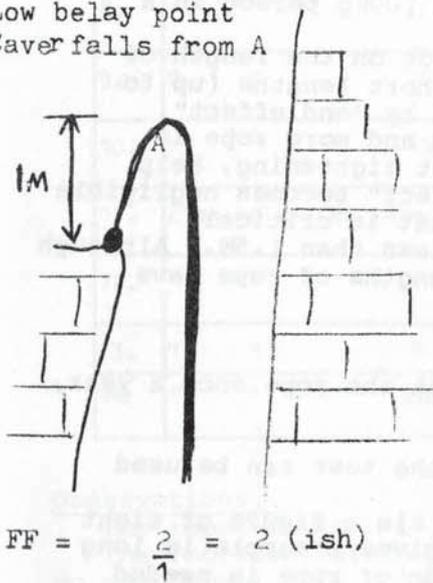


Fig 17

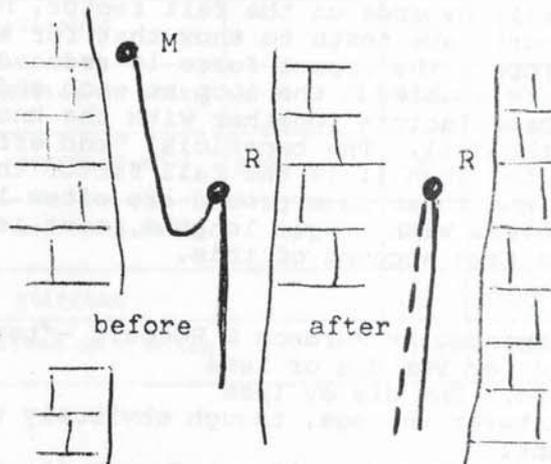
Low belay point  
Caver falls from A



DANGER

Fig 18

Main belay (M)  
fails - No backup

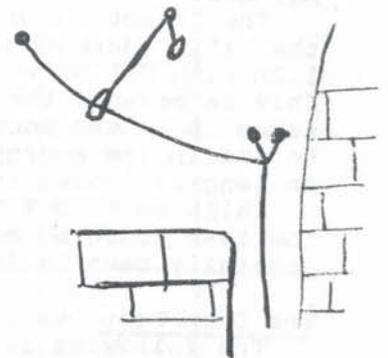


- (a) Rope upside down
- (b)  $FF = 2$
- (c) Hits floor !

Main belay must not fail

Fig 19

Cows tail



Do not climb  
above traverse rope  
possible  $FF = 1(+)$   
even  $FF = 2$

DANGER

## IMPACT FORCE or PEAK FORCE

The Impact Force or Peak Force is the maximum force produced in the rope or belay system in holding a fall. In order to be safe a rope must hold a fall without breaking, but must do so without causing internal injuries. Tests have shown that under favourable conditions the maximum Impact Force a human body can withstand is 1200 Kgf (12KN).

During a fall, energy is absorbed by the rope stretching; generally, the more it stretches the more energy is absorbed. Thus stretchy ropes produce low Impact Force values in fall situations. For example in order to receive U.I.A.A. (Union Internationale des Associations d'Alpinisme) approval, climbing ropes have to hold 5 Fall Factor 2 Falls with an Impact Force below 1200 Kgf, measured on the first fall. The problem is that Climbing ropes stretch too much to be suitable for SRT, however very low stretch rope could produce unacceptably high Impact Forces in a fall. Thus a compromise is needed between the desirable qualities of low(ish) stretch for normal usage and high stretch for energy absorption during a fall. Impact force is largely dependent on fall factor and rope stretch, rather than the length of the fall.

Let us look at some examples of what fall factors are produced in cave (Figs.14-19) situations.

Fall Factors of 1(+) are likely to break the rope or produce dangerously high Impact forces, fortunately these situations can be avoided by care and good rigging:

- (i) The backup anchor should always be above the main anchor.
- (ii) Traverse ropes at head level make it less likely that anyone will climb above them.
- (iii) Use of shared anchor points and backup belays minimises the risk of belay failure.

### How does the drop test approach reality?

Marbach & Rocourt in "Techniques de la Speleologie Alpine"(1980) using the drop test with a force-measuring device have attempted to ascertain the difference between an inert mass of 80Kg and a human body in a harness. They concluded that the muscles and harness absorbed energy, so that the Impact force was reduced by about 30% compared to the inert mass. The amount of energy absorbed by the body is more or less constant, so the effect will diminish on longer falls, with a constant fall factor. Another figure I have heard quoted is that a fall with the 80Kg inert mass is equivalent to a 100Kg person in a harness.

The Impact Force formally depends on the fall factor, not on the length of the fall. Marbach & Rocourt have tests to show that for short lengths (up to 1.5M with FF1 on static rope), the Impact force is reduced by "end effect". This is because the rope is doubled in the loop at each end and more rope is taken up in the knot. These factors together with the knot tightening, help to absorb the energy of the fall. The beneficial "end effect" becomes negligible on lengths longer than 1.5m, when it is the fall factor that is critical.

Falls onto cows tails and ropes underground are often less than 1.5M. Although the test would be more severe with longer lengths, test lengths of rope have generally been 1m long to take account of this.

### The Drop Test (Fig. 11).

The following is recommended by Marbach & Rocourt - 'test the rope once a year, - starting at 2 years old for 9mm dia or less - starting at 4 yrs old for 10mm dia or less Test any suspect rope whatever the age, though obviously the test can be used for all sorts of equipment.

They say take a sample of rope 1.5m long and soak it; tie a figure of eight knot in each end (figure of 9 knots for 9mm rope). This gives a sample 1m long corresponding to underground conditions (we found that 2.5m of rope is needed to give a 1m knotted sample).

The test rope is fastened to the 80Kg weight (beer barrel full of gravel). The haul rope is attached to the weight by several thicknesses of string. The pulley for the haul rope is vertically above the bolt or belay point for the test. As the weight is hauled up the test sample is fastened to the belay point; when the two knots are level (i.e. fall factor 1) the string is cut.

Any rope which holds two falls (FF1/80 Kg) under these conditions is good. If it only holds one, a second sample from the same rope is tested. If this also holds one fall the rope is good.

Edelrid are to be commended for supplying details of Impact force at FF1/80Kg with the latest caving rope leaflet - other manufacturers please do likewise.

Cows Tails (Safety Sling).

In Fig. 19 it can be seen that Fall Factor 1 can be exceeded and even Fall Factor 2 reached if clipped into a bolt. This is probably the most dangerous situation a caver could find himself in - although people are warned against getting into situations exceeding FF1. Marbach & Rocourt make a telling comment saying it is a good job there are no laces in cavers' wellies, otherwise no doubt laces would be used for cows tails!

FF1/80Kg Drop tests were done on a variety of materials commonly used for cowstails (see Table 2).

TABLE 2. FF1/80Kg Drop Test on Cows Tails

	Description	Condition	Age	quoted strength when new	No of falls held
1.	9mm Climbing rope - overhand knots	good	2yrs	?	3
2.	10mm Superbraidline " "	good	2yrs	2725 Kg	2
3.	8.5mm Bluewater Fig 8 knots	good	2yrs	?	2
4.	8mm Polyester Footloop overhand knot	good	2yrs	?	0
5.	8mm P/E " " "		New	?	2
6.	15mm superblue nylon tape "	good	1-2yr	1300kg	0(5tests)
7.	15mm " " stitched	V.good	6 mth	1300kg	0
8.	" " " overhand knot		New	1300Kg	(i)2 (ii)3
9.	" " " stitched		New	-	5
10.	" " "knotted as sling	good	6mths	1300Kg	2
11.	25mm Polyester tape overhand knot	good	2yrs	1500Kg	0(2 tests)
12.	" " " overhand knot		new	1500Kg	0
13.	" " " stitched		new	1500Kg	0
14.	" " knotted as a sling		almost new	1500Kg	2

Observations.

The ropes in Nos. 1-3 seemed reasonable.

The footloop safety rope in a "Frog" system is always above the chest ascender, so only small fall factors should be possible. The material for these is less critical than for cowstails - 7 or 8 mm rope is suitable.

A tape knot causes a loss of approximately 50% of the strength compared to the quoted figure. A sling is double thickness (tests 10 & 14) but knotted, so should be around the quoted strength of the unknotted tape.

In tests 11-13 all the 25mm polyester cowstails broke, even the new stitched one. The 15mm superblue tape broke in tests 6 and 7, even the 6 month old stitched one. However, the new knotted (test 8) and stitched (test 9) held several falls. The reason for the new nylon holding falls while the stronger new polyester broke, is presumably because of the higher impact force generated

in the lower stretch polyester. More disturbing, however, is that there appears to be quite a difference between new tape which is satisfactory and tape even 6 months old (test 7). The reasons for this are not clear, but warrant further investigation.

In tape all the load-bearing fibres are exposed, unlike ropes which have a protective sheath.

#### Conclusion.

The best material for cowstails is climbing rope to U.I.A.A. standard, as this will hold the fall and have a low impact force. Tapes, static mountaineering ropes (generally sold off reels up to 8mm diameter) and SRT ropes are generally low stretch and will not break if sufficiently strong, but will produce impact forces far higher than the climbing rope. Marbach & Rocourt have tests with force measurements and recommend 9-10mm dynamic rope, because thinner ropes wear quickly, even if satisfactory when new. Similarly thick tape though strong enough, produces high impact forces. Finally it should be noted that though these tests were done at Fall Factor 1, more severe falls are possible, though hopefully avoidable.

### ROPES

FF1/80kg drop tests were carried out on ropes to check their safety. All SRT ropes aged 4-5 years held one fall, with the exception of Marlow 10mm 16 plait matt polyester which always failed. This rope should be withdrawn from use, or only used where no possibility of a shock load exists.

Tests on 2-5 year old 12mm multifilament and staple-spun polypropylene ropes (quoted strength when new 2030kg) occasionally held 1 fall, but mostly failed on the first drop. After having discarded a 2½ year old rope which looked in good condition, further tests were done on lengths taken from the middle of the rope. Some of these samples held 2 or 3 falls, whereas the end of the rope would not hold 1 fall. Although little work has been done on this subject - it is reassuring to think that the end of the rope taken for the normal test, is the weakest part. If this is true, then if the end of the rope is good, the middle is probably better.

Because so many of the used ropes failed, samples of new rope were tested at FF1/80Kg. The new 12mm staple-spun polypropylene held 16 falls and the new 12mm multifilament polypropylene held 26 Falls. Again further investigation is necessary to establish why there is such a large difference between new and say 2½ year old rope in superficially good condition.

#### Conclusion.

The drop test is a good check on a rope's condition, as some rope which fails the test looks quite good.

### DROP TESTS ON HARDWARE

#### 7mm Maillon Rapides.

People often worry about a rope failing by bending over a small radius and sometimes use plastic thimbles to increase the radius. Our tests showed that the rope will always break at the knot rather than over the 7mm maillon; so 7mm Maillons are quite safe without thimbles.

The strength of a particular knot as a percentage of the unknotted rope varies with the rope thickness, rope stretch, and flexibility etc. We tested a 9mm flexible climbing rope, a 12mm stiff low stretch rope and 9mm stiff low stretch rope at Fall Factor 2/80Kg and in each case the rope broke at the knot.

#### Hangers.

A limited number of tests were done with hangers. A Petzl twisted hanger held a fall factor 1 fall/80Kg with a low stretch rope, which should have produced high impact forces. The rope broke at the knot. Similarly tests on the new bollard karabiner-less belays held Fall factor 2 falls, with Blue water rope breaking at the knot.

#### Wire belays.

1000Kg wire belays and a sling of 1000Kg wire, broke with a Fall Factor 1/80Kg Fall - presumably the tiny amount of stretch produced very high impact forces.

Ascenders and Descenders.

We have not tested these, partly because of the cost, but also because we hope to get some force measuring device built into the drop test. Marbach & Rocourt have limited tests and suggest that a Petzl descender locked off, is good for FF1/80Kg, but will disintegrate at FF2/80Kg. In a severe fall, spiked cam ascenders are likely to cut through the sheath of the rope, if not the core as well. The moral of this is - try not to have any sort of a fall onto ascenders.

REFERENCE

Marbach, G. & Rocourt, J.L. 1980. *Techniques de la Spélèologie Alpine*, F38680 Choranche, France.

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Paul Ramsden,  
Whernside Cave & Fell Centre,  
Dent, Sedbergh,  
Cumbria LA10 5RE.

## SOLO-CAVING

Dave Elliot

## ABSTRACT

Modern equipment and techniques make solo exploration of all but the deepest caves a possibility for the skilled caver. General motivation and safety precautions are discussed and some common sense solutions to practical problems suggested.

There are certain questions which always arise whenever solo-caving is discussed: firstly, "isn't it dangerous?"; secondly, "what if you have an accident?" and thirdly, "why go solo-caving at all when there are plenty of other cavers about?". Perhaps the best way of dealing with questions such as these is to simply ignore them and get on with it. Caving is a diverse activity where each caver takes part according to his own motivation in whatever discipline or aspect of it that appeals to him. There are as many variations as there are individual cavers, ranging from the leading hardmen of the time, to those that dig up old bones or catch bats, all following their own particular philosophy and approval from others is not required. However, we can try and at least partly deal with these questions, and in passing touch on some of the modern techniques and equipment that nowadays make solo-caving a far better proposition than it has ever been.

Firstly, "isn't it dangerous?" the answer to which is simply "no". As far as I'm aware there is no evidence at all to suggest that a solo-caver is more likely to have an accident. In fact there is good reason to suppose that someone caving alone would take a great deal more care of himself than he otherwise might in a group. Further, experience of caving with groups suggests that ideally we should all be solo-cavers, by which I mean completely self-contained as cavers regardless of whether we cave alone or not. Social fabrications such as "Team spirit" and "Group effort" have the net effect of weakening self-reliance, which in fact is a caver's only real safeguard. To be blunt about it: if your mates are not safe underground without you to look after them, then they need to think very seriously about what they are doing there in the first place, and you need to think twice about being with them. Solo-caving doubtless involves additional hazard, although the actual physical dangers are no greater and in fact may even be lessened for somebody caving alone. Increased speed is perhaps the greatest safety factor, but there are others. For example, there is nobody above to dislodge rocks that may damage you or the rope, and even a badly rigged rope is unlikely to abrade through with just one man climbing it. The real hazard lies in the more serious outcome of even a fairly minor accident when help is not readily available.

This leads directly to the second question: "what if you have an accident?" This is obviously a valid criticism of soloing, although in fact your chances of actually surviving the accident are little different whether you are alone or not. It is the consequences of such an accident that are likely to be more serious for a solo-caver. For instance, a slightly injured caver with, say, a broken wrist, could be helped out of a cave by a few mates with little difficulty, where a lone caver might experience considerable trouble in getting himself out. Or take another situation where the incident results from broken tackle on a pitch, even if the caver escapes serious injury, he probably has no means of re-rigging the pitch and can consider himself stuck. There are very many such situations possible, some that may be mitigated to an extent by forethought and lots that may not. But always, simply because a lone caver cannot send for help immediately it is required, there will be a longer delay before any such help arrives, which in itself is bad news. Basically all you can do about this sort of thing is to evaluate all the disadvantages, against whatever it is you get out of solo-caving and decide whether to accept the additional risk or not. It's purely a personal thing, nobody will ever make you go caving alone if you don't want to.

On the other hand, it is possible to counter these ill effects to some extent by carrying sufficient equipment to survive an enforced delay (that

is, reserve lighting, food and a light-weight survival bag) and by making careful contingency arrangements with somebody competent on the surface about what action to take if indeed you are not out at a pre-arranged time. Only in extreme cases need these arrangements include full scale rescue call-outs. Rescue teams are made up of ordinary cavers: they have no magic wand to wave, consequently there is no reason at all why a couple of handy lads should not rescue their own mate, causing the minimum amount of fuss and only resort to the organised rescue teams where specialised skills or equipment are required. No rescue team worth its salt will object to attending an incident where specialist help is needed, this is the whole point of a rescue team, but if your normal caving mates are incapable of effecting a simple self-help rescue then you are caving with the wrong blokes. Solo-cavers have in the past been labelled as irresponsible and not deserving the benefit of rescue services, but hopefully such narrow-minded attitudes will not survive the more widespread acceptance of minority interests. The plain fact of the matter is that there is no difference at all, either practically or ethically, between rescuing a solo-caver or a member of a "responsible" larger group. Both situations are best avoided altogether.

Third question: "how do you justify solo-caving when there are so many other cavers about?" The simple answer is don't bother. By its very nature there is no need to justify solo-caving to anyone apart from yourself. If you like caving alone for whatever reason, then go caving alone, and you need not accept criticism from anybody simply because their interest in caving is a little different from yours.

Every walk of life has its share of athletes and record breakers, and because caving ultimately has its roots in physical exploration, there is inevitably a slight bias towards the longest, deepest, or most difficult. There is also a profound solitude to be found in caves, which affords total escape from the everyday pressures of modern life. It is a harsh, alien, environment, but one in which wide experience cultures a perception of rare peace and beauty in some individuals, where others find only discomfort and hardship. We all have our own view of such matters, but my own attitude is not to arbitrarily label solo-caving as a means of making the same old trips harder, more dangerous, and therefore more exciting. For one thing I don't reckon it does, and in any case like many a tired, old caver, I've never seen much future in getting unduly frightened or knackered, so as soon as these situations arise I tend to give over. But doubtless plenty of others see it differently and that's entirely their problem.

Obviously, solo-caving demands that you look after yourself, and this process begins long before you go anywhere near a cave, with training in the necessary skills and the choice of suitable gear for the job. No special equipment has so far been developed for solo-caving. Sadly there are no items of powerful magic by which we can effortlessly transport ourselves into dark and secret places. We must therefore simply choose the best protective clothing, rope climbing equipment and techniques available. The days of stumbling around in rags and tatters by the feeble glimmer of an ancient miner's lamp are fortunately long gone. Specialised gear is now easily available and good equipment is a major step towards being safe and comfortable in what is after all a fairly hostile environment. Reliable lighting is obviously of great importance, cavers are no better adapted to seeing in the dark than flying. Each and every caver, solo or not, needs three separate sources of light - a main light, a standby light, and an emergency light.

For solo-caving, competent use of SRT is essential for the vertical bits, and although the finer points of what particular climbing system or which hardware to choose, is not appropriate here, bear firmly in mind that whatever gear is used, sooner or later for one reason or another, it will fail. For example, in a rig using only two jammers failure of one is a bit serious, so there is a great deal to be said for the obvious precaution of incorporating a third jammer into the rig, or at least carrying a spare. Practised familiarity with methods of improvising equipment in an emergency is also particularly valuable training (Elliot, 1982).

Even conventional Single Rope Techniques enable a lone caver to carry sufficient gear for any of the deeper caves in this contry without undue difficulty. Here the use of lightweight 8 or 9mm dia. ropes, and belays without karabiners (CAT, Bollard, etc) make this even more of a possibility. Another option is use of the "Cord technique" (Elliot, 1981) where all the tackle needed for a given cave is a rope equal to the longest pitch, a

selection of lightweight belays, and sufficient thin cord (approx. double the total length of pitches).

There are perfectly straight-forward techniques that make possible solo-photography, survey (Marbach & Rocourt, 1980) or aid-climbing (Barber, 1982), and where necessary it is possible to bivouac underground comfortably with comparatively little equipment (Marbach & Rocourt, 1980). Yet another possibility is cave-diving (Farr, 1980). With modern high-pressure air cylinders and compact equipment, certain unique trips beyond flooded sections of cave can be made by a single diver carrying his own gear. British cave-divers often dive alone.

In summary - solo-caving is not for everyone, as a minimum it requires sound judgment, wide experience of the factors involved underground and complete self-reliance. It is nevertheless certain that solo-caving will become commonplace over the next few years as lightweight equipment and fail-safe techniques are developed. Consider that even with current equipment and conventional techniques, it is perfectly feasible for a single caver to safely explore any cave in the U.K. within a few hours. Provided only that somewhere along the line he has picked up the basic skills of his craft, and of course wants to do so ....

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Dave Elliott,  
1 Millthrop,  
Sedbergh,  
Cumbria LA10 5SP.

(presented at the Buxton SRT symposium, 1980).

## CAVE SCIENCE

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### S.R.T.ACCIDENTS AND INCIDENTS

J.Forder

The present article is a follow-up to one published in the B.C.R.A. Transactions, Vol.4, No.3, August 1977, in which 32 incidents - the word is used advisedly - were examined. Of these, 19 related to prusiking, 13 to abseiling - on the face of it somewhat surprising, insofar as abseiling is probably more dangerous and is a more frequently used technique. Thus, one can go out of control; abseil off the end of a rope; put ones descender on wrongly, not to mention the possibility of equipment failure. While prusiking, it is impossible to go out of control (unless, of course, one's jammers pack up and one slides back down!); impossible to prusik off the (top) end of a rope; while if you put your devices on wrongly, you probably wouldn't get off the ground anyway. This apparent enigma is resolved by a consideration of the difficulties of the two techniques. To a certain, though limited, extent, "any fool can abseil", but prusiking is a far more complicated affair, and contains more traps for the unwary. Also, the very fact that one is bouncing on the rope while going up, for a much longer time than one is sliding smoothly (?) down, provides more scope for gross failure of the rope through abrasion.

I have adopted the same policy in this article as in the previous one - i.e. describing individual incidents, as opposed to attempting to categorize them statistically - many, in fact, are of a miscellaneous nature and not easily pigeon-holed.

In my previous article I considered first the possibility of equipment failure, pointing out that in most such cases, failure occurs as a result of misuse or incompetence. The most frightening possibility is, of course, the rope breaking, and I quoted four cases of this having happened. Encouragingly enough, no new cases of this occurring in the past four years have come to my notice.

In similar vein, I have come across one new case to parallel that of the "Dale Head Incident" when the sheath of a rope broke. Unfortunately, I do not have the full details, but it appears that the same thing happened to someone in Sell Gill Hole - presumably on the big pitch, as it seems unlikely that the short pitches would cause enough abrasion - and the sheath, along with the prusiking devices, started running down the core till brought up against the knot in the bottom of the rope.

Failure of the main belay is, of course, just as nasty as rope-failure and, I should say, there is even less excuse for it. Previously, I quoted three cases of this happening, and have come up with another three. Two of these appear to have been quite straight-forward; in the first, a caver fell 50 ft to his death in Pumpkin Cave, Texas, when the iron stake used as a belay broke. The second occurred at Echo Aven in Lancaster Hole, the only injury this time being a badly-bruised shoulder. The third such incident involved a much more complicated affair in Tumbling Rock Cave, Alabama, in 1975, when cavers were trying to scale an aven called the Topless Pit. The gist of the story seems to be that the team were pulling out for the day, having reached a height of 360 ft (which obviously suggests they were quite an experienced group) and the accident occurred when someone had just passed a ledge 174 ft above the floor. The line from that ledge was fastened to a "karabiner chock", backed up with a hexcentric nut. The caver abseiled off the ledge and as she did so, pulled out the belay and its back-up. The rope was also tied off at a lower ledge - at 134 ft, where her friend awaited her - and, fortunately, her fall was arrested, though she banged her head against the wall. She regained consciousness to find herself hanging upside down from a bent rack in a waterfall, about 20 ft from the ledge. Her friend helped her to the ledge, and she was evacuated from the cave some 9 hours later by a rescue team - as far as I am aware, she made a full recovery.

So, unless you've got a bomb-proof belay, always back up your anchor point with another one; and, if you use these fancy climbing nuts, remember that they work very well if they're properly placed, but it is very easy to put them in a crack which appears to be safe enough, but which may not be, if stressed from a funny angle.

Failure of equipment other than the rope can and does occur. For example, in March, 1978, a caver fell about 20 ft and broke his ankle on the 90 ft pitch in

Marble Steps Pot, when the karabiner fastening his rack came undone. The reasons for this are not altogether clear, but a contributory factor was, no doubt, the fact that he was using a non-screw-gate karabiner. At least two frighteningly near misses have occurred when cavers' racks failed. Again, without full details of the incidents concerned it is not possible to ascribe a cause unequivocally - but at least one of the racks was home-made. This one failed on a 60 m pit in the Grotte Emilio Comici, when the sides somehow contrived to splay apart - in this case, the caver was able to grab the ladder (as they were self-lining) and save himself. The other incident occurred on the 180 ft pit in Black Shiver Pot, when the bottom loop of the rack unwrapped itself as he set off down. It seems that he saved himself by grabbing the rope and putting a Jumar on ..... and then reverse prusiking to the bottom (!).

I have come across the odd incidence of Jumars failing under load; without knowing the full history of the equipment in question, it is impossible to ascribe a cause to such failure - it may be, for example, that the gear in question had previously been dropped down a pitch and had sustained one or more fractures. A bit of light relief is provided by the first such incident, when a caver was practicing his prusiking technique through a hole from his bathroom to the loft above. He fell into the bath when his ascender failed!

Another incident which had far more potential for disaster occurred when an American caver had got 15 ft from the top of a 105 ft pit, where he noticed a crack - alleged to be 1 inch wide - in the brace of his Jumar. He very slowly and carefully fastened on a prusik loop and got out safely.

In addition to one's mechanical bits and pieces, there is also the question of tapes, slings, harnesses and cords. Abrasion of such articles can easily occur, for example a caver found himself rather surprised and alarmed - but in no real difficulty or danger - when a fairly new piece of half-inch tape fastening his ankle "rope-walker" snapped. Similarly, a caver prusiking out of Alum Pot by the Mitchell method (see R.R.C.P.C. journal, No.7) had a rather desperate struggle when the fixing of his chest box came undone. He had to hang on with one hand while fixing a spare ascender with his other. As he himself points out, he would have had no problem if he had had a safety sling from his harness to his top Jumar.

A sad example of the failure of a connecting cord happened in Rio Camuy Cave (Puerto Rico) when an "experienced vertical caver" fell 23 m in a 50 m pit - and died three hours later. The case has one odd aspect, in that the bottom Jumar (of the Mitchell System) was off the rope; the suggested explanation is that - because the rope was wet and muddy, he had removed his Jumar to clean the cam, and by bad luck the cord (polypropylene ski rope) to his top Jumar snapped at a point where it had abraded in his chest-box.

Very few people in Britain seem to use Prusik knots as a routine technique, but knots appear to still be quite popular in the United States. A case of knot-failure which, in retrospect, has an amusing aspect, occurred when an American had climbed 30 ft up a 220 ft shaft on a 3-knot system. His seat knot broke, and he flipped upside-down to be held by the "chicken loops" round his ankles. Totally unable to help himself, he hung there upside down till his mates at the top fastened on another length of rope and lowered him head first to the bottom.

A mistake that is easily made is to ram a Jammer hard against a knot (or anything else) in such a way that it is impossible to release it. There was, for example, the caver who was rope-walking out of the rather constricted entrance pit in Bar Pot when his chest-ascender got jammed against a chock-stone. It seems that he was unable to get any higher because the rope was too tight, and was unable to go back down because he could not raise the ascender sufficiently to unlatch the cam. There was no-one at the top, nor could anyone get past owing to the constricted nature of the pitch-head. For two hours he struggled, eventually cutting his chest harness - but (inexplicably) to no avail. At last, he freed himself by the rather drastic measure of cutting the rope above him - only possible in a place like Bar Pot that is narrow, and well endowed with ledges to allow one to scramble to safety.

There have been a surprising number of "near misses" involving racks threaded back-to-front. I was on a trip down Juniper Gulf when the person in front suddenly pulled himself up and out of the top of the 80 ft pit, just as he was about to set off down. He had realised, just in time, that his rack was back to front; fortunately, the top of the pit is rather narrow, and he was clinging on to a flake as he pushed his way down. I have heard of similar incidents in Rowten Pot where "strong arms and a cool head averted a tragedy",

and Gaping Gill itself, where somebody almost went over the lip with a rack on back-to-front.

Closely associated with S.R.T. is the use of "abbing" in, and self-lifelining up on a ladder - a system which holds traps for the unwary, the most lethal being the use of a "safety" jammer fastened to one's belt only. If you simply fall off a ladder you may escape with a few uncomfortable moments; if, however, you swing away from the ladder (or, indeed, the ladder breaks) you could be in serious trouble. A sad example of this occurred in the Scialet de l'Appel, in the Vercors, when a young caver was self-lining up a mere 5 m pitch. He fell off the ladder and hung by his belt. Unfortunately, the ladder had been rigged at an angle to avoid a waterfall (the cave being in flood) and he eventually drowned while hanging under the waterfall. An equally sad accident whose details are not at all clear, involved two boys who went down Dead Deer Cave in Texas. The owners of the cave decided, on impulse, to check out the cave for trespassers, finding equipment near the entrance. Being quite used to this, they were not unduly worried, but later that night they found the equipment still there. So they contacted local cavers, who descended the hole to find a gruesome sight - one 16 year old lying injured in a pool of water, and another hanging dead in a tangled mass of rope. Gross inexperience seems to have been the chief factor in this accident.

Needless to say, there have been cases of people abseiling down and being unable to prusik out. For example, a youth on his second trip - Rowten Pot in flood - was unable to prusik back out owing to incipient exposure and general lack of expertise in the Mitchell-type method employed. He was pulled out by the C.R.O. in a "routine" rescue.

Going out of control while abseiling accounted for four of the incidents in the previous article, and two of the present ones. One fatality occurred in Wheal Jane Mine in Cornwall, but no details are available. The other, quoted by Brew in "Caves and Caving" involved a caver in an unspecified pot who bungled a change-over from ascending to descending, as a result of which a fast abseil/free fall ensued for 50 ft, the unfortunate individual receiving severe bruising.

No doubt many "near misses" go unreported, the people concerned learning from the experience. Perhaps if such incidents were reported somewhere, other people might learn as well? For instance, there was the caver whose ropes jammed up in his cams when prusiking Rowten Pot; he abseiled back down, and re-rigged his system with tape - which also jammed up, and caused him severe problems which he overcame unaided.

A climber using the Frog System at Malham Cove discovered an increasingly large amount of what appeared to be iron filings accumulating in the folds of his cagoule. A steel karabiner connected to an alloy karabiner had worn a deep groove right through the barrel and quarter way through the latch of the latter.

Then there was the team who abseiled into Turbary Pot, under the impression that it was Swinsto Hole; having pulled their rope down after them, they found themselves confronted by a choke!

Clearly, it is neither possible nor desirable to eliminate entirely the dangers of caving; nevertheless, it is probable that most cavers would agree that there is a difference between stupid risks and calculated risks, and that the former should be cut out.

There are, indeed, many possibilities for error when using Single Rope Techniques, most of which can be eliminated by practise and care. The most obvious thing is to sort out one's basic going-down and coming-back-up techniques - a point so obvious, in fact, that it is sometimes overlooked.

Practise on the surface, in a tree or on a crag, is not difficult to organise, and can be used to sort out a proficient prusiking system that fits one's personal requirements. In particular one can ensure that whatever system is used, one is not attached to the rope by a single jammer, so that one doesn't end up hanging upside-down (or not hanging at all!) in the event of failure of one escender. Proficiency in the use of one's gear includes carrying out change-over manoeuvres (down-to-up and up-to-down); knot crossing; passing re-belay points, etc. Thinking about what can go wrong may well provide the means to overcome problems, while it is common sense to try out one's techniques in easy (dry?) caves before tackling deeper, wetter ones. The final point - and one of the most difficult - is to rig pitches properly, in such a way as to avoid any chance of abrasion.

With care and practice, S.R.T. provides far more fun than ropes and ladders - which is, arguably, what it's all about.

(presented at the Buxton SRT symposium, 1980).



- Ockenden, A.C. See Walsh, P.T.
- Ramsden, P. Do-it-yourself equipment testing. (4) 290-299
- Rose, J. The Melinau River and its terraces. (2) 113-127
- Ryder, P.F. See Cooper, R.G. et al.
- Smart, P.L. and Friederich, H. An assessment of the methods and results of water-tracing experiments in the Gunung Mulu National Park, Sarawak. (2) 100-112
- Smart, P.L. See Friederich, H. et al.
- Solman, K.R. See Cooper, R.G. et al.
- Stanton, W.I. Mendip - pressures on its caves and karst. (3) 176-183
- Walsh, P.T. and Ockenden, A.C. Hydrogeological observations at Water End Swallow Hole Complex, North Mimms, Hertfordshire. (3) 185-194
- Webb, B. The geology of the Melinau Limestone of the Gunung Mulu National Park. (2) 94-99
- Willis, R.G. and Lyon, M.K. Introduction to the Mulu '80 Expedition. (2) 55-61
- Wilson, Jane. M. A review of world Troglopedetini (Insecta, Collembola Paronellidae) including an identification table and descriptions of new species. (3) 210-226
- Wooldridge, J. Mulu Expedition Report: Photography. (2) 67-70

#### TITLES

- Bolt belays Lawson D. 8mm bolt belays. (4) 269-276
- Cave Minerals Laverty, Cave minerals in the Gunung Mulu National Park, Sarawak. (2) 128-133
- Caves Champion. A study of the conceptual criteria held by caves for the perception of danger. (3) 200-209
- Chapman. The ecology of caves in the Gunung Mulu National Park, Sarawak. (2) 142-162
- Crabtree and Friederich. The caves of the Bau District, Sarawak. (2) 83-93
- Crowther. Temperature characteristics of seepages in four west Malaysian caves. (1) 38-46
- Gascoine. The formation of black deposits in some caves of Southeast Wales. (3) 165-177
- Stanton. Mendip - pressures on its caves and karst. (3) 176-183
- Caving Elliot, D. Solo caving. (4) 300-302
- Caving gear Lyon, B. Caving gear - habit, addiction or necessity? (4) 227-229
- Danger Champion. A study of the conceptual criteria held by caves for the perception of danger. (3) 200-209
- Deposits Gascoine. The formation of black deposits in some caves of Southeast Wales. (3) 165-177
- Descenders Lewis, K. Self-locking descenders. (4) 248-254
- Drills Davis, J.S. Rockdrills. (4) 277-279
- Ecology Chapman. The ecology of caves in the Gunung Mulu National Park, Sarawak. (2) 142-162
- Equipment Ramsden, P. Do-it-yourself equipment testing. (4) 290-299
- Expedition Boothroyd. Mulu Expedition Report.: Surveying (2) 65-67
- Buchan. Mulu Expedition Report.: Medical.: (2) 72-75
- Checkley. Mulu Expedition Report.: Food (2) 70-71
- Eavis. Mulu Expedition Report.: Finance and Organisation (2) 62-64
- Meredith. Mulu Expedition Report.: Underground Equipment. (2) 64-65
- Wooldridge. Mulu Expedition Report.: Photography. (2) 67-70
- Willis. and Lyon. Introduction to the Mulu '80 Expedition. (2) 55-61

- Geology Webb. The geology of the Melinau Limestone of the Gunung Mulu National Park. (2) 94-99
- Gunung Mulu Chapman. The ecology of caves in the Gunung Mulu National Park, Sarawak. (2) 142-162
- Lavery. Cave minerals in the Gunung Mulu National Park, Sarawak. (2) 128-133
- Smart and Friederich. As assessment of the methods and results of water-tracing experiments in the Gunung Mulu National Park, Sarawak. (2) 100-112
- Webb. The geology of the Melinau Limestone of the Gunung Mulu National Park, Sarawak. (2) 94-99
- Hertfordshire Walsh and Ockenden. Hydrogeological observations at Water End Swallow Hole complex, North Mimms, Hertfordshire. (3) 185-194
- Hydrogeology Walsh and Ockenden. Hydrogeological observations at Water End Swallow Hole complex, North Mimms, Hertfordshire. (3) 185-194
- Karst Day. The influence of some material properties on the development of tropical karst terrain. (1) 27-37
- Stanton. Mendip - pressures on its caves and karst. (3) 176-183
- Ladders Elloit D. Ladders and lifelines - a biased viewpoint. (4) 230-239
- Lifelines Elliot D. Ladders and lifelines - a biased viewpoint. (4) 230-239
- Limestone Friederich et al. The microflora of limestone percolation water and the implications for limestone springs. (1) 15-26
- Link Eavis, A. The weak link. (4) 287-289
- Malaysia Crowther. Temperature characteristics of seepages in four west Malaysian caves. (1) 38-46
- Microflora Friederich et al. The microflora of limestone percolation water and the implications for limestone springs. (1) 15-26
- Melinau Rose. The Melinau River and its terraces. (2) 113-127
- Webb. The geology of the Melinau Limestone of the Gunung Mulu National Park. (2) 94-99
- Multiscender Lawson, D. The Multiscender - design and concept. (4) 255-257
- Palaeomagnetism Noel and Bull. The Palaeomagnetism of sediments from Clearwater Cave, Mulu, Sarawak. (2) 134-141
- Percolation Friederich et al. The microflora of limestone percolation water and the implications for limestone springs. (1) 15-26
- Pitch Checkley, D. Pitch rigging. (4) 238-240
- Elliot, D. Practical Pitch rigging for SRT. (4) 241-247
- Prusik Elliot, D. Prusiking systems. (4) 261-168
- Forder, J. An analysis of prusiking systems. (4) 258-260
- Review Wilson. A review of world Troglodetini (Insecta, Collembola, Paronellidae) including an identification table and descriptions of new species. (3) 210-226
- Sarawak Chapman. The ecology of caves in the Gunung Mulu National Park, Sarawak. (2) 142-162
- Crabtree and Friederich. The caves of the Bau District, Sarawak. (2) 83-93
- Lavery. Cave minerals in the Gunung Mulu National Park, Sarawak. (2) 128-133
- Noel and Bull. The Palaeomagnetism of sediments from Clearwater Cave, Mulu, Sarawak. (2) 134-141
- Smart and Friederich. As assessment of the methods and results of water-tracing experiments in the Gunung Mulu National Park, Sarawak. (2) 100-112
- Scaling Poles Davis. The design of scaling poles - an amendment. (3) 195-199
- Scaling Poles Davis, J.S. Scaling Poles. (4) 280-282
- Scaling techniques Barber, G. Scaling techniques. (4) 183-186
- Sediments Noel and Bull. The Palaeomagnetism of sediments from Clearwater Cave, Mulu, Sarawak. (2) 134-141
- Seepages Crowther. Temperature characteristics of seepages in four west Malaysian caves. (1) 38-46
- SRT Elliot, D. Practical pitch rigging for SRT. (4) 241-247
- Forder, J. SRT accidents and incidents. (4) 303-305





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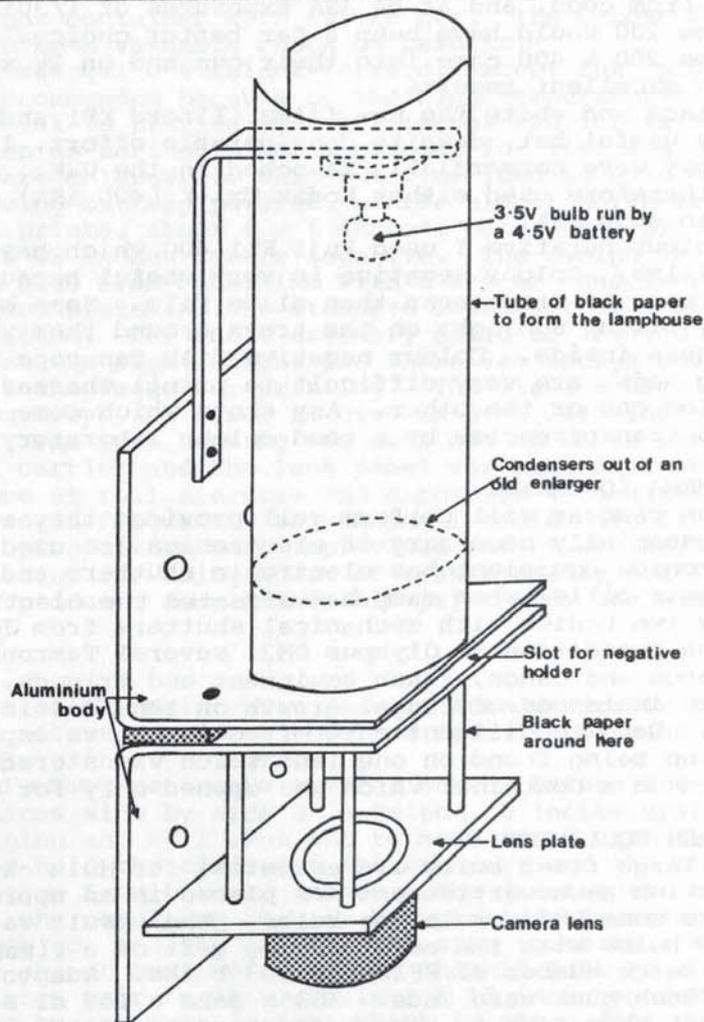
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## Notes on survey equipment

- (1) The 100 metre tape was generally found to be too clumsy. A 50 metre tape would have been ideal.
- (2) Paper Knives were included for sharpening wooden pencils underground, the use of clutch pencils made these knives superfluous.
- (3) These were not used as the parallel motion slide and graph paper made them redundant.
- (4) Liable to breakage in rucksacks in transit to sub camps. Six 180 degree protractors should have been included for sub-camp work.
- (5) These were only used once.
- (6) These had sealable ends and were used for storing paper and surveys. They were very useful.

Fig.4.  
Base-camp enlarger.



PHOTOGRAPHY - Jerry Wooldridge F.R.P.S.

### CARE OF EQUIPMENT

The environment of the tropical rain forest is one which is not suited to delicate photographic equipment or films. Airtight containers are essential for storing both film and cameras. Film will quickly absorb moisture from the very humid atmosphere and may then easily jam in the camera. 35 mm cameras are particularly prone to this problem because the film needs to be wound back into the cassette, the film will also easily scratch if at all damp and may well stick to itself, in which case it will probably be useless. Black and white films seem much more subject to these problems than colour films, probably because the latter are designed for much higher processing temperatures. Roll film cameras using 120 films are less troubled in this respect for several reasons, the film does not require rewinding, it has a paper back, so scratching and