

Life on a line

Part Two



A manual of modern cave rescue ropework techniques

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The book is published in three parts, as divided below. This is part 2. It should not be read or republished in isolation from the other parts, to which important references are made.

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IMPORTANT NOTE

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7. Basic hauling

We have defined ‘hauling’ as a process of raising a load under controlled conditions, using ropework, winches and manpower. This chapter introduces the basic ideas, and simple techniques to follow before Chapter 8 deals with the specific systems and equipment used.

7a. Introduction

Hauling has to follow a few ground rules in order for us to deal with it predictably. The prime rule, which I shall mention over and over, is that a hauling system is not intended to receive any significant shock loading. The lines should be in tension at all times the load is present, therefore apart from equipment failure the load simply has no ability to fall any distance while still fixed to the lines. This rule allows us to design systems that are efficient, rapid and simple to operate and yet may not be capable of dealing with a full 200kg shock-loading incident. It then becomes the responsibility of the pitch rigger to ensure that a shock loading cannot occur and that safety backups are used wherever a single equipment failure incident could lead to one. It could be argued that for ultimate safety all hauling systems must be capable of surviving our full 200kg / FF0.3 rescue fall, but unfortunately the vast majority of available ropework equipment used in hauling systems cannot meet this. We instead take the philosophy of forbidding a fall, then designing out the risk of one by using backup devices. There naturally remains a very small risk of a double- or triple-failure allowing a fall to escape through our designs, but the same applies to every other aspect of ropework. There are those that argue we should battle on to remove any risk, no matter how miraculous the chain of events needed to cause it – but then they probably don’t use passenger planes either!

In sections 5g/5h we discuss belay systems, and I should stress that a hauling system and a belay system are separate creatures for separate tasks. Belay systems are designed to react to and survive a shock loading, plus offer the ability to perform a ‘routine’ controlled lower. Hauling systems allow controlled raising of a load with some possibility of a controlled lower, but shock loading is not an option. The equipment, rigging and operation of belay and hauling systems is different and in many cases it is not even that easy to convert one into another. Having said that, at a pitch head you will probably end up with a hauling system and belay system side-by-side as belay systems are used in backup – so those operating them must know the differences – which lines should be in tension more than others, which lines are released first and so on.

7b. Backups and safety lines

To ensure that our system designs out the possibility of a shock load it must allow for the failure of any one item of equipment without introducing such a load. This is a protocol called single-redundancy and is the usual standard of safety applied to underground rescue. Double-redundancy (where any two unrelated failures could occur without causing a shock load) is possible to apply in high-risk situations but for the general cave rescue scenario the complexity, rigging time and operator skill issues overrule it. A single-redundancy system requires two failures before catastrophe, and so far in UK cave rescue this has never occurred.

This section is titled ‘backups and safety lines’ as there is a distinction between them. A ‘backup’ is an additional set of equipment (ropes, pulleys, etc.) designed to immediately and automatically replace a failed primary system and it *should leave the hauling system fully operational*. A ‘safety line’ is designed to prevent catastrophe (holding a falling load, etc) but does *not* have to preserve the operation of the system.

As an example of this subtle difference, a double anchor for a pulley is a backup, as failure of one anchor would not significantly affect the pulley and what it was used for. A belay line on a caver ascending a ladder is a safety line, as if the ladder (the primary system) fails then the caver is saved from injury but is not able to proceed upwards.

In an ideal world we would therefore like backups in preference to safety lines, but the underground rescue environment is far from ideal. In many cases (such as the ladder example above) then there is a theoretical way of creating a backup (caver wears full SRT kit so can climb the safety line, or there are two ladders fitted side-by-side) but the complexity outweighs the (small) risks. This argument is making a strong point: if something is *likely* to fail it should be a fully operational backup. Safety lines are for situations where failure is rare.

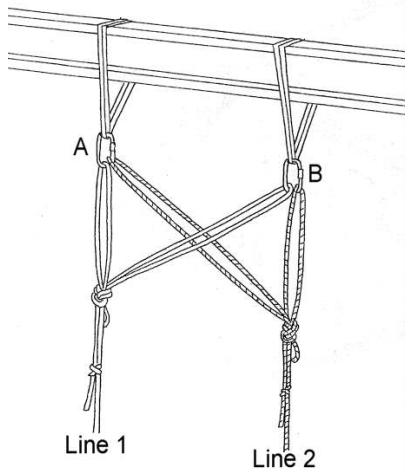
In industrial access work, the use of redundancy is strictly controlled and always required. Rules are laid down over the use of anchors, which types of ropes to use and how to arrange rescue systems in the event of a primary failure. Underground rescue demands a more flexible system, yet safety cannot be compromised by flexibility. One or two ‘industrial’ rules can therefore be kept:

1. When a load reverts to a backup after a primary failure, the fall factor and shock loading must be minimised.
2. Backups must not use the same anchors as the primary system they are protecting, but may share the primary anchors of an independent system.
3. Backups must be designed so that the load can be transferred to a place of safety without alteration of the rigging should the primary system be inoperable

(1) requires us to make sure that backup lines are always taken in or paid out with minimal slack, that anchor backups and slings are the correct length and not lying about in coils, and that a change of load from primary to backup will not swing the load across a pitch and into the wall like a bottle against a ship.

(2) can cause problems underground, where anchors are sometimes limited. Industrially you can always spend time adding anchors, underground you cannot. Your backup system must *never* share the same anchors as the system it protects (otherwise what would happen if those anchors were the point of failure?) but usually underground you can use primary anchors from an unrelated system (a technique called cross-loading, as introduced in section 5f). For example, you have a hauling system in a shaft, and a ladder-and-lifeline system alongside it for rescuers. You are allowed to connect the lifeline to the same anchors as the hauling system, or to connect the hauling system backup line to the same anchors as either the ladder or the lifeline. Failure of any one of the 4 systems will not cause total failure of the other 3. There is a problem when you are using a full twin-rope system (double-redundancy, with two main lines and two backups) as it is *permissible* to cross-load the 4 systems onto two anchors but if the 4-rope system is being used because failure is very likely, then you may wish to have as many independent anchors as you can get for the same reason!

(3) is important in rescue as more often than not your ‘load’ is an injured casualty and leaving them hanging on a backup line is not an option. If a failure leads to the primary system not



being operational (example: ladder and lifeline scenario, ladder fails) then whatever belay equipment you use on the lifeline must allow you to (at the very least) lower the load to the foot of the pitch safely and quickly. This, by the way, is one argument against using prusik knots for belays as opposed to mechanical devices – they can lock onto the rope and prevent subsequent lowering to safety.

The diagram to the left shows a typical arrangement of ‘cross-loading’. Two main lines are rigged from two anchor points. For line 1, anchor A is the main load-bearing point and anchor B is the backup. For line 2, B is the main point and A is the backup. With this arrangement, loss of one anchor will not fail either of the ropes, though of course the obvious question in this diagram should be ‘why not put 4 slings on that damn great RSJ and just make it properly redundant?’

7b1. Primary lines as backups

Using the definition of ‘backup’ as a way of recovering an operational system in the event of a primary failure, then there is no reason why the backup system cannot simply be a redundant part of the primary system. The best example is the traverse – if you use two ropes to rig the traverse, each under identical tension, then both are acting as primary lines but also both are backups in the event of one rope snapping. Industrially this is common practice but underground the use of a full twinned system (two identical primary systems acting in tandem) is not very common, despite advantages. Putting it simply, if your backup system must preserve an operational system then it must be (in most cases) a copy of the primary system in all but name. In that case, why not use it to reduce the load in the primary equipment and thus maybe prevent the failure in the first place?

The only problem with a fully twinned system (apart from the extra kit and time to rig it) is communication. At the casualty end of the rope it can be difficult to tell which line is from which system, so giving orders to rope handling teams can be tricky. The only reliable way around this is to use lines of two different colours (everyone understands ‘take in on yellow’) but getting coloured SRT rope is not easy in the UK. The other option is to label each system. I have worked quite successfully with teams by carrying a set of numbered plastic tags (a set of ‘1’s and a set of ‘2’s, which you slap onto the end of each rope and onto the hauling rig (plus anywhere else you’d need to know) so that ‘take in on 2’ makes sense to everyone.

7b2. Recovering redundancy

This is not a section on employer relations, but an important and often overlooked problem with all redundant safety systems. Once your primary system has failed and you are hanging on your backup you may well be able to continue the haul, but you are now out of options. Another failure will result in catastrophe. Once a primary system has failed the rigger must make a snap decision on the best option:

1. Continue the haul using the backup line and hope another failure doesn't happen
2. Stop all movement while another backup is rigged or the primary system is fixed
3. Lower the casualty back down to safety while the system is fixed

Which option you choose cannot be predicted in a book – it depends on the length of time it would take to complete the haul, how far up the casualty has got, where the dangerous points are and so on. The decision must also take account of the medical condition of the casualty and how quickly they must be extricated. The rigger is faced with a 'best of the worst' list of options but getting it wrong can be disastrous.

A final point that should, after all my nagging so far, not be needed: A backup is not an excuse for rigging a crappy primary system that is likely to shrivel and die when you breathe on it!

7c. Lowering

'Lowering' is often said, by those surface team types, to be something we never bother with as we haul casualties upwards. It's surprising, however, how much lowering can be needed on a rescue, even if the overall effect is getting them out and up! We do have the advantage that when you lower anything, gravity is on your side. However, the attraction between the planet and a casualty encased in medical equipment is surprisingly strong, so it's not just a case of letting them slither down through your fingers!

Before leaping off into lowering, I want to avoid backing myself into a literary loop by making this point – in almost all cave rescue work you may have to include the ability to lift a load while you are lowering it, and that demands a hauling system instead of a lowering one. So, a simple 'down-only' system is often quite rare. Rarity don't make it less useful though ☺

A bare-bones lowering system allows control over the movement of the line through a friction device, a safety line or twin main lines for redundancy and suitable anchors for everything. Most of this has been dealt with in the previous chapters with the exception of the friction device. In Section 5g we looked at devices for belaying, but made the point that a **belay device** is not the same as a **lowering device**. In belaying, the equipment should not be under load unless something goes awry, however in lowering it always is (unless something goes equally wrong, in which case you'll be glad of your safety line!). This means that certain devices are unsuitable for one application. Examples include:



The **Grigri** is ideal for belaying, but less suited to lowering as the friction control is too insensitive, making control of the load difficult. We will be using it to create Z-rigs in chapter 8, since it has become a common use in UK teams and has advantages that outweigh the problems in many cases. Remember however that Petzl certify the Grigri for single-man loading only, so any application to rescue brings in the great CE/PPE legal question.

Descenders such as the **Petzl Stop** and **rack** can be suited to lowering, but are difficult to use in dynamic belaying. The **Stop** can fail if rescue-loaded dynamically but has proven reliable in steady-force lowering despite weights being outside the approval envelope. As it is a mainstay of UK caving, teams often carry them simply for cost and familiarity reasons. I would suggest

that those are not the best reasons for selecting kit – better to train teams to use stronger equipment than give them something recognisable and flimsy! The **rack** falls foul of our failsafe rules unless a Shunt or prusik loop are used as a backup, but the prime issue over a rack is that there are no CE/EN/PPE standards relating to them. Whilst that does not mean they aren't suitable for their intended use, we are using them for something else that the manufacturer will be guaranteed to say is outside their test envelope, and without even a hint of a CE stamp your team are treading on a legal false floor. Many team members in the UK use a rack as part of their personal caving gear, and in the USA special rescue racks are in common use. Personally, some of these rescue racks are extremely well designed and work far better with extreme loads than some of the autolocking systems, however the CE marking issue creeps in.



It is however worth mentioning the **BMS nanobelay** at this point. Shown to the right, this has a handles and non-handled version, and looks basically like a 3-bar rack. It is however specifically designed as a lowering/belaying device and not for personal descent. The handled version allows the load to be released in a controlled manner. Despite not being CE marked (the device is produced for the US market) it has to be mentioned due to it's amazing performance. It will arrest a fall factor 1.0 drop of a 300kg load with a slip of less than a metre, and has a frame failure loading of 89 kN. This makes it far exceed any other commercial belay device in the world. With a failsafe backup on the tail line (such as a prusik loop) and CE approval, this device could be unbeatable.



The I'D



By far the best device for lowering in rescue is the Petzl I'D. It is failsafe, relatively easy to use and most importantly it has been tested at rescue loadings and proven to work, so far the only descender to do so. Given the questionable issues of liability, PPE and CE approvals rescue teams have to face (see Chapter 11) it should be part of every team kit as a matter of course, at least until someone else makes a cheaper, stronger and lighter version! However, it is relatively rare in UK teams at the moment and takes a bit of thought for those who've never used one. You can use the I'D for belaying and lowering, but I will reserve it from incorporation into hauling systems such as the Z-rig, since by design it has very high friction on take-in under load. In fact, the friction generated by an I'D is enough to make the mechanical advantage of the Z-rig less than 1! This is unfortunately an example of a piece of kit that is approved, strong, reliable but not good at everything – nothing new there then!

This is said without commercial bias – it is simply that the I'D passes the tests and very little else does. Maybe it's a point for other manufacturers to note! If the nanobelay had CE approval it would be a hard act to follow, but it doesn't, so the I'D seems to have things covered.

I'm going to sidestep here (hence the box) and deal with the notion of non-failsafe devices again. In Belaying we ruled out any device that failed to meet our Sudden Death Rule and needed attention to prevent uncontrolled release. In lowering, especially of equipment, it is often common practice to use friction knots (such as the HMS or a simple multi-turn wrap) which we suggested are unsuited to belaying. This is a clear exemption to the previous rule **provided that they include a backup** such as a prusik knot or rope clamp to lock the device should the attendant lose control. Lowering a live load on friction knots (or a non-failsafe device such as a rack) is permissible if:

- (a) there are no failsafe devices easily available to use instead
- (b) a backup prusik knot or clamp is used
- (c) There is equipment available to release the backup (such as a jigger, see Section 8e) if it becomes locked.

The most common friction knot seen in lowering, especially by surface teams, is the HMS. With a full rescue load a single HMS does not offer enough friction to control the lower using one man, so one useful trick is to run the tail rope from the first HMS knot into a second one, thus doubling the applied friction. This technique does however make it almost impossible to pull any line back in should the need arise, as the high friction works both ways!

Now, back to lowering rigs. Everyone should be thinking at this stage 'Ah, but it's easy – just clip a descender into an anchor and run the rope through it'. True, that bit IS the easy part. What your rescue-head should be thinking is how we include redundancy and deal with a descender that's liable to be very frisky with such a large load on it.

7c1. Basic lowering

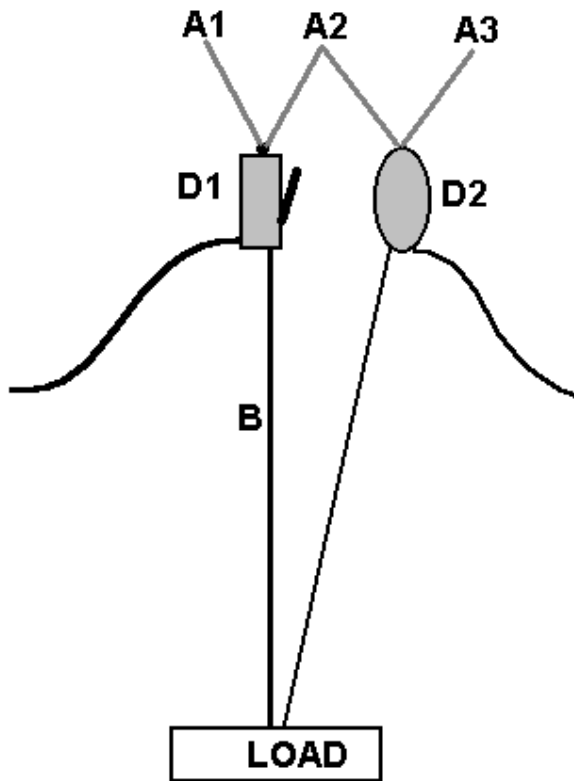
A schematic lowering rig is shown to the right. Here the main line connects the load to descender D1, and a backup line connects it to D2, both of which I shall insist are I'D descenders. The three anchors are cross-loaded on A2 as permitted by our anchoring rules of chapter 5.

It could be suggested that we could add some kind of backup device to the main line at position B to protect against D1 blowing up, but (a) that is why we have the line and D2 rigged up next to it, and (b) any automatic rope-clamp device used at B will have to be manually held open during the lowering operation, consuming another rescuer.

During lowering, the line to D1 supports the load and the line to D2 should just be taut. It is very difficult to achieve this during a lower, as with two operators on D1 and D2 it is almost impossible to keep pace with each other. As a result, the load will shift between the lines, so at any one time either can be the 'main' line. This is not too critical provided that both D1 and D2 can operate as belay-safe lowering devices. After our discussions in chapter 5 we decided that only the I'D allows full lowering *and* the ability to survive small dynamic falls.

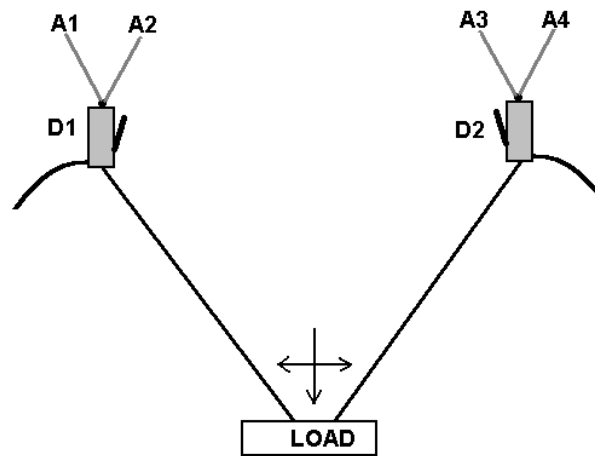
This is a major issue with lowering rescue loads – you cannot afford your backup line to develop any slack or you risk a dynamic loading situation your equipment may not be able to handle, and yet if you try to juggle the two lines in synch you risk passing the 'dynamic risk' to the other device. Motto? Both descenders and anchors must be the same! No good thinking 'Ah – I'll use an I'D on the backup and a Stop on the main line' if the exact moment of failure is the same exact moment when the load is held by the backup – remember the line under load is going to be the one to fail, so which one gets the weak descender then?

Some teams argue that by using a **dynamic** line for the backup you can control the load-sharing better (since it's easier to absorb distance inequalities if one line stretches) but we have ruled out dynamic lines on the grounds they extend too much under load. For a pitch where this is no problem, dynamic backups are fine. Find me such a pitch and I'll eat my hat – 'cos you can always fail the main line 2 feet above the floor with 3ft of dynamic bounce! Drop a spinal patient 2 feet and he will hurt you more than you hurt him. Having made this point there will be legions of riggers who will counter-attack saying that using a static line means you may be taking dynamic loads on a system that cannot absorb them, to which I reply that if you have a system with slack in it you're not looking after it properly ☺



7c2. V-lowering

One exception to this issue of load-synchronising (there is always an exception) is when you want it to occur. The only ‘common’ situation is a V-lower, where the load is suspended between two lines running to two control points some distance apart. This, as shown in the diagram, is a useful tool for landing a load onto a predetermined point between the control points when access directly above that point is not possible, and could perhaps be used to land someone on flat ground



at the foot of a gorge, or onto a safe area within a rift or stope. In this situation carefully-controlled synchronised lowering by each station can control the horizontal *and* vertical position of the load within the limits of each station. The drawback is that you must treat the rig as a full V-rig (see Section 8b for a full discussion of V-rigs) and two backup lines need to be used, one to each station. If you rely on the two load-bearing lines, then failure of one will result in the painful ‘champagne bottle and ship’ procedure. Motto? Whenever there looks like there’s a simple elegant fiddle, you can bet you’re missing something complex and important.

Now that we have addressed lowering (which as we have said is rare in isolation) we shall move on to the rigs needed to *raise* a load. Most of these can also be used to lower it back down again, and in 99% of cases the initial motion desired is upwards in cave rescue, so what follows is the best place to start!

7d. 1:1 Armstrong hauling

‘Armstrong’ is an American term, but it’s nicely apt, as to lift anything sensible by brute force, your arms had better be! In a vast series of tests it has been generally accepted that a fit adult male, given nothing but a rope over a cliff-edge and the power of his body (in any way he can think of using it) can only lift 50kg or less. Strong types may be able to raise 80kg by a few inches, but hauling a load up 30ft and you are strictly in the below-body-weight category. In the underground environment it gets even worse, as more often than not the direction of pull is sideways at a pitch head, limiting the force from each rescuer to only a few tens of kilos.

As with all seemingly-useless methods, 1:1 hauling does have a few applications. For a start, if you are lifting anything of 50kg or less (i.e. equipment) then it’s far quicker to put a few people on the rope and pull than rig a mechanical advantage system so that one man can do it instead. The other useful situation is an assisted ascent of a surface shaft, where it is often a distinct advantage to use a large group of people walking backwards across the fields than a local group of people with a pulley rig. The 1:1 system does not need to be reset, allowing one unbroken pull of the entire rope length, plus the movement imparted to the load is far smoother. The difficulty arises from communication between the pitch and the hauling party as they move off

from the shaft – it can often take a few seconds for the ‘stop pulling’ message to ripple down the team, so you must allow for that in your instructions.

The notion of a ‘mass party’ pulling team only works if there is either room for the team to walk backwards for the full rope distance or room to loop (where each team member reaches the limit of movement, lets go and runs back to the front). Using hand-over-hand pulling where the team members stay stationary is far less efficient (with only one hand on the rope for most of the time the force exerted is smaller) and imparts far more jerks to the load.

All hauling systems need a safety component, as discussed in section 7b. The 1:1 system is no exception, and some device must be included to prevent the rope from running back should the hauling team lose grip, get tired or suchlike. Basically, the rope must run through something that only allows passage in one direction, such as a rope clamp, descender, etc. Where this is used depends subtly on what the device is, and the layout of the pitch. If you are using a rope clamp (ascender, rescuender-derivative or similar) then on the intake there is no friction to deal with, but the rope must run straight through the device. It makes sense to place this between the pitch head and the hauling party, as this deals with the danger of the rope being damaged somewhere within the group of haulers. A descender (Stop, etc) on the other hand has high friction on the intake, and so it is far easier to use on a slack rope. If it is placed between the pitch and hauling party, a lot of their effort will be wasted dragging the rope through the descender. If you place it *after* the hauling party then it requires another rescuer to feed the rope through the device, but he will be working with slack rope. The issue of rope damage within the hauling area is slightly worse, but at least you aren’t wasting half your strength. One thing to remember if the distance between your pitch and your safety device is long is that when the hauling party transfer the load to the device, rope stretch can lower the load by quite a bit. Also, it helps to dedicate one man to managing the rope as it passes through the hauling party (if you are not just walking the full length) as it can rapidly build up into an unholy mess at the end of the working space.

Of course, as you will be waiting for me to say, you need to be able to access your device at all times as you never know when you may have to lower the load by a few inches. Having to climb out above a shaft to open the gate of an ascender is not best practice!

7e. Rebelays and deviations

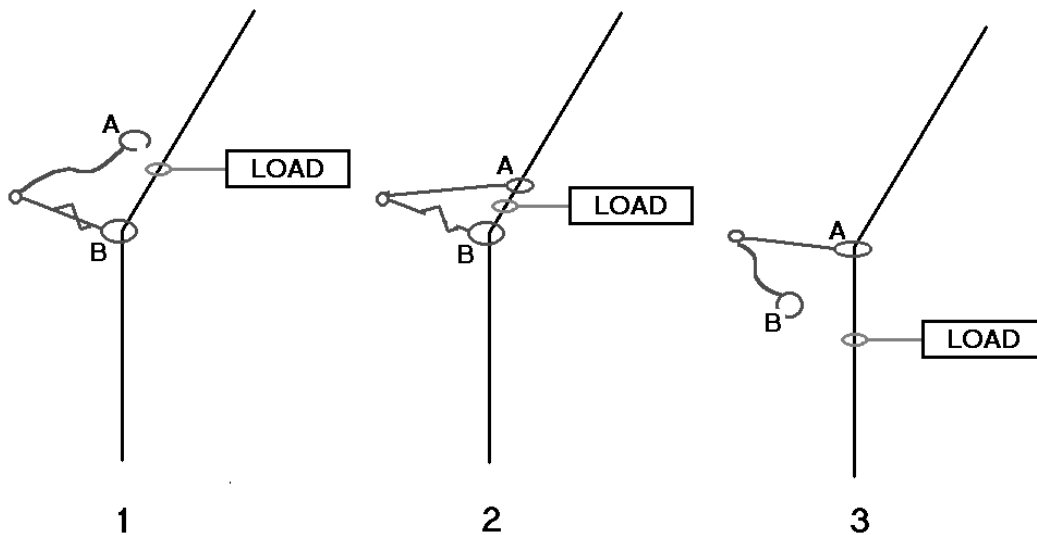
In SRT caving the rebelay and deviation are common, in hauling they are a positive nightmare and every effort must be made to avoid them. Deviations are not too terrible in comparison, but for both rigs you will lose time and effort passing them, plus need rescuers local to the load and the rig to engineer the system past the problem.

Rebelays are points where a line is fixed to an anchor in such a way that the anchor supports the full load on the line below that point. Clearly in hauling a rebelay is impossible, as the line will be moving. However, when we address advanced rigs in Section 10a we will introduce the idea of the hauled object following a course controlled by other lines (usually at an angle). In this situation, it is possible for these guide lines to be rebelayed. It is also possible to encounter a rebelay if you are performing SRT self-rescue, which is addressed on the next page.

Deviations are anchors that change the route of a line without being attached to it in a fixed position – usually the line simply runs through a karabiner or pulley. They can be applied to

hauling lines and indeed often are, however passing them with a rescue load is slightly different from the method used by an SRT caver. The difficulty is that with a higher load it is often impossible to unclip the deviation and then retain the load in position while the deviation is re-clipped. Quite unexpected things can happen if you treat a hauling system like an SRT caver!

Passing a deviation is the same no matter which direction your load is travelling, so let us take the example of lowering past a deviation. Here, the load is being lowered and must at some point be pulled sideways (maybe to avoid the walls of a shaft). Now, it is a very bad idea to try and deviate the load by running a long tail rope below the load, through a deviation anchor and then trying to pull the load across from the foot of the pitch. Apart from the problems of judging distance, it is almost impossible to pull a full rescue load sideways by more than a few feet using this method, and by applying even more tension to the upper hauling lines you are stressing your lowering rig. The usual approach is therefore to fix one or two tensioned guidelines through the deviation, fixed off at the top and bottom of the pitch and to which the load is secured by short slings and karabiners. The load then swings sideways as it is lowered, without needing effort from below or extra tension on the main lines. The problem is that when these slings hit the deviation you must unclip them and move them below the anchor before the lower can continue. Here is where the problem can arise, as a rescuer mid-pitch trying to juggle the weight of a stretcher and unclip karabs is not in a position to exert much force! The most elegant solution to this requires a bit of forethought and a few more bits of rope. The idea is to change the deviation, not the rigging on the stretcher.

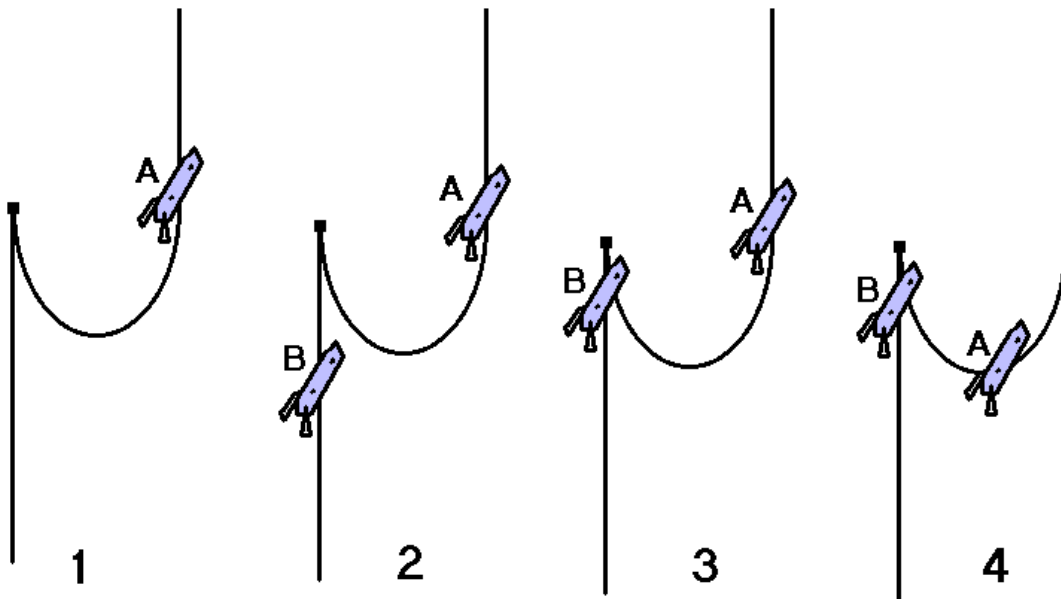


A normal SRT deviation is a fixed sling or rope with a karabiner on the end, through which your tensioned guideline passes. For our rescue deviation, we have two instead of one (as shown in step 1 above). If the deviation is large (and so the weight will be large on the guideline) then one (marked B) should be a releasable belay, as introduced in Section 5i. The other is fixed, but slightly LONGER than the releaseable one and is marked A above. The shorter sling takes the load until the deviation needs to be passed, at which point the stretcher handler clips the second longer deviation onto the guideline *above the stretcher slings* and slowly releases the shorter deviation (step 2 above). The force transfers onto this sling, and the first can be unclipped (step 3) – resulting in the stretcher passing below the deviation without ever being removed from the guideline. The same applies in reverse if ascending the pitch, with the longer deviation being attached below the stretcher slings instead of above them.

Passing a rebelay for assisted or SRT self-rescue

If you are forced to recover a casualty from a single SRT rope by attaching them directly to your SRT equipment and climbing or descending without help, then passing a deviation or rebelay in ascent is identical to normal SRT practice, however it is unlikely that you would have the strength to perform the body-jammer swap with another 100kg hanging from your harness. The solution is to ascend to the knot, attach the casualty to the anchor using one of their cowstails and then reverse-prusik to remove their weight from your harness. You can then unclip them, pass the knot in the normal manner and then re-attach to them using your cowstails. By continuing to climb you can relieve the tension on the anchor and unclip them from it. It must be stressed that assisted SRT ascent is unbelievably hard work and if at all possible the casualty should be taken down rather than up!

To pass a deviation on descent (e.g. on a guidewire) you can usually treat it as a normal SRT operation, taking note of the increased tension when releasing the line. To pass a rebelay needs a little trick to avoid having to lift the combined weight from the anchor, as shown in the pics below. Here the initial rescuer is on descender A. He descends to level with the anchor and clips in for safety, then attaches the casualty's descender B (or any other spare one you can get hold of) onto the rope below the knot – step 2. He pushes it up as far as possible, and clips this into his harness – step 3. Removing his safety from the anchor and descending into the loop of the rebelay – step 4, and eventually the weight is transferred onto descender B, allowing him to release descender A and continue down without ever having to support the weight of the casualty.



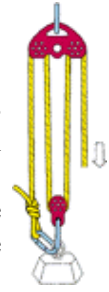
The next chapter deals with the rigging needed to introduce mechanical advantage. Lifting a rescue load (or even a 100kg body mass) without some sort of pulley ratio is beyond many otherwise-fit rescuers, and the simple 1:1 techniques described above should only be applied to lifting equipment less than bodyweight (such as tackle bags or an empty stretcher).

8. Compound hauling

The term ‘compound’ means that there is a mechanical advantage greater than one, as discussed in section 7a. There are multitudes of ways of obtaining this advantage but all boil down to either a geared mechanical device or a combination of pulleys and ropes. For cave rescue the option of a geared device (a winch or capstan) is only valid for the surface pitch. If your team is commonly called to sites with large entrance pitches (mine shafts, etc.) then arranging a wire or rope winch is worthwhile.



Winches are touched upon in chapter 10 but here we assume that you are underground and without access to anything with gears in it. What is needed therefore is a compound pulley block that will allow reduced force on the haul at the expense of increased rope length. The problem in 99% of cases is that there are physical and practical limits on the length of rope used, so you often have to raise the load in stages. This of course demands some method of holding the load whilst the pulley system is reset for the next pull. The solution, again in 99% of cases, is the A-block.



8a. The A-block

The heart of almost all hauling systems is a pulley and rope clamp in combination, designed to allow free pulling of rope in one direction and secure locking in the other. This combination is called an ‘A-block’, a cannibalisation of the terms ‘autobloc’ and ‘pulley block’. There are an increasing number of purpose-designed products on the market, however creating one from standard components can be somewhat of a black art.

I must introduce one more term at this point, before it leads to much head-scratching as you read on. Any system that allows one-way rope movement has a property called ‘runback’ – this is the length of rope that pulls back out of the device before the locking action occurs, and is important for two reasons. Firstly it limits the smallest movement possible whilst actually gaining position, and secondly if a shock load is applied to the system whilst hauling in, the runback distance becomes the effective fall distance. Long runback means a higher fall factor and more load on everything else.

A perfect A-block should therefore pass the rope without friction (β close to 1.0) and yet grip the rope instantly and securely on the release (minimal runback). In addition of course it must be able to cope with the loading being placed upon it, be reliable in operation and simple to release. Being able to perform a controlled lowering of the line is an ability of descender-based systems only, though for our intended applications an A-block that cannot be lowered under load is not a significant disadvantage.

One final important point: A-blocks are intended for hauling and line tensioning only. Their gripping action is ‘instant’ and ideally they should have minimal runback. As such they are not suitable for use as dynamic belay devices. Belaying a load should always be carried out using a suitable belay device as discussed in section 5g and NOT an A-block. Because of this we will assume in this section that there will never be a significant shock loading onto an A-block. If one should occur then it is likely that the device will fail and the load then be transferred onto the backup lines or minder slings. This is an important point as some of the manufactured devices we will discuss are not capable of surviving a shock load from a 200kg mass but are perfectly suitable for raising one in a well-behaved hauling system. In almost every case the point of failure for a shock load will be the severing of the rope at the clamp (normally a toothed cam) though in other cases where the rope survives then the mounting karabiner or

anchor points will undoubtedly fail. This distinction between belay devices and A-blocks is another argument why controlled lowering is not a vital performance requirement, since controlled lowering is far more likely to be requested of a belay system than a hauling system.

The restriction on shock loading at an A-block is critical in that it allows us to use components that would not survive such large peak forces, but which are ideally suited to the task in every other respect. The Petzl Fixe pulley is one such item.

8a1. Choosing an A-block

When planning your team kit there are three options available to you, either purchasing a dedicated device, allocating standard components ready to make up an A-block on scene or using a descender. Clearly once underground you are limited to the gear available on site, and so it is worth spending some time planning what that gear will be before needing to install it. It is not a simple argument as each option has points for and against...

Purpose-manufactured device:

Advantages

- Ready-to-use without ‘building time’
- Reliable and predictable operation and performance

Disadvantages

- Comparatively expensive compared to subcomponents
- Dedicated to one use – parts cannot be ‘diverted’ to other locations
- More training required in operation



On-site built device:

Advantages

- Can be produced from spare equipment to hand on scene
- Can be varied to suit circumstances
- Parts can be re-used elsewhere as required

Disadvantages

- Operation and performance less predictable and reliable
- Training in assembly required

Using a descender

Advantages

- Minimal training required for setup and use
- Reliable and predictable operation and performance
- Can be used for other purposes

Disadvantages

- This application is usually outside manufacturers approvals
- High friction compared to pulley-based systems leads to high anchor loads
- Can easily exceed the rated loadings of some descenders



As with all rescue applications it is rare to find any type of device that is rated by the manufacturer for a full 200kg load. Pulleys in isolation are of course available in suitable strengths but dedicated devices and descenders are often rated only for 100kg operation. The distinct disadvantage of using a descender is that the lack of a true pulley sheave means that the friction within the device is very large. This increases tension in the rope during hauling and can increase the load on the anchor point by several times.

In premature summary I suggest that where resources allow every kit should include a suitable dedicated device, when these are used or not available then constructing an A-block from standard pulleys and jammers is the next best option. Use of a descender should remain the last resort.

8a2. Purpose-designed devices

These are growing in diversity and popularity, driven more often than not by the needs of industrial rope access. Historically there have been ‘haulers’ produced for climbing where raising of tackle for big wall routes was intended. These devices were lightweight and low strength, as the intended uses were equally minimal. Gradually as the use of hauling systems in industry has increased people have come to realise just how awkward A-blocks can be if not handled correctly, and so manufacturers have leapt at the chance to fill a gap in the market.



There are two categories of A-block currently on offer:

Follower clamps



Wall Hauler

Here, as in the self-build devices we discuss later, a rope clamp and pulley are mounted together in such a way that the clamp acts on the rope after it leaves the pulley or before it enters. In either case the rope is gripped while it is still straight and before contact with the pulley sheave. Examples include the Kong BlockRoll, Wall Hauler and USHBA Hogwauler.



USHBA Hogwauler

Sheave clamps

Here a toothed cam engages on the rope as it passes over the top of the pulley sheave, and clamps it between this cam and the sheave itself. The rope is therefore gripped at the point it is being bent. Examples include the Petzl Traxion and Pro Traxion.

All designs incorporate a pulley sheave that can be used as a pulley in isolation, by opening or releasing the clamp component. None are intended for use as replacements for personal SRT jammers.



PETZL Pro Traxion

The jury remains out on the exact relative merits of these designs, though for discussion I have some **personal** observations to consider:

Sheave clamps are more compact, though follower clamps can be more intuitive to operate due to the 'open' design and similarity to conventional SRT jammers.

The Petzl Pro Traxion has a 'bucket' hole that is used to secure the swing sides into position and must be fitted with a spare karabiner. This obviously allows simple connection to a rope for compound pulley systems that is not always possible on follower clamps.

The major point of contention is the cam position. Whilst not arguing against the performance and design of either device there is a clear difference in the operation under load. Follower clamps grip the rope between a toothed cam and a fixed metal plate, as is the manner of generic jammers. Under loading therefore there is both the positive grip of the teeth in the rope sheath and the friction of the rope against this fixed plate. In addition the rope is straight at the point of contact, so there is no preferential tension in any part of the sheath or core. In contrast shave clamps grip the rope between a toothed cam and the moving pulley sheave, so the only holding effect is from the teeth - there is no additional friction effect. Also, the rope is gripped at a point where it is wrapped over the sheave, so the outer radius of the rope is under increased tension compared to the inner. This outer radius is also the part gripped by the cam, therefore there is a question of how this 'gripping the part most under stress' can influence the failure process. Devices such as the Pro Traxion are tested and fully approved and this discussion is not intended to criticise their performance or suggest faults, however there is obviously an argument that any device working to the optimal design should not apply stress to a point on the rope that is already under increased stress in the first place. In conclusion a follower clamp is probably more rope-friendly and may cause less damage or failures when subjected to high shock loading or extreme static loads. This is reflected in the fact that the working load limit of the Pro Traxion is 2.5kN whereas that of a site-built follower clamp A-block using a Fixe pulley and Basic ascender is 4kN.

Sheave cam devices are however a lot more compact than any other design, and have advantages in applications where size is critical (such as jiggers, as discussed in Section 8f).

This book does not seek to show commercial bias so I will stop short of giving recommendations on which types to buy. What is important is that the device is rated for rescue work and not personal (e.g. the Petzl Pro Traxion is a rescue-rated version of the Traxion) and that the design is intuitive to operate, reliable and suitable for your working practices.

Even if your team includes these devices in kits, riggers must still be able to construct A-blocks from component parts. There is always a need underground for one more system than the kit bags contain, and reliance on specific devices is not an option if there are none left. Aside from this, being able to build an A-block and understand the reasons behind the choice of components and mechanisms of failure helps to predict how a purpose-made device will perform when pushed beyond the rated limits.

8a3. Building an A-block on scene

There are many ways to correctly assemble an A-block and twice as many ways to get it wrong. Of all rigging systems it is probably the one that is rigged wrong most often, and in some cases the consequences can be dire.

The main failing of an assembled device is that the component parts are linked together with flexibility (usually by karabiners). The device is then able to deform under changes in tension, increasing runback. The most serious problem is that if the karabiners are free to move they can on occasion rotate to a position where the load is applied across the gate – a situation leading to failure for the forces involved in rescue. Assembly of an A-block is therefore a battle to ensure that this cannot happen, but even with the best design and careful assembly it remains a problem that must be watched for at all times.

Not all pulleys, jammers and karabiners are suitable for building A-blocks, and even those that are need to be used in the correct combinations. What follows is mainly based on Petzl equipment, as this is by far the most common in use by UK cave rescue teams. If your team uses equipment from other manufacturers you must think carefully about the combinations possible. The pages that follow will show you what needs to be considered.

It is surprisingly difficult to find manufacturer data on how to turn pulleys and rope clamps into A-blocks. Petzl show diagrams in their manuals that relate only to their 'Fixe' P05 pulley. The method of rigging for this device is different to any other, so it is not possible to copy the instructions for other purposes. Before embarking on the methods for swingcheek pulleys I will first discuss the use of the Fixe (which we all know by now would not be suitable for a full-load rescue hauling system).

The Fixe has, as the name suggests, fixed cheeks with a gap between them. The attachment hole will only accept one karabiner, and that must be oval. To create an A-block it is therefore an issue of getting two karabiners where only one will fit. Petzl's solution is to cross-load the karabiners.

The first karabiner must be oval or this simply does not work. For strength the second karabiner (which connects the pulley to the anchor) should be a D-pattern as shown. Following the photograph you can see that the krab through the pulley holes links to the ascender (in this case a Petzl Basic). The correct attachment point for any Petzl-type ascender in a hauling system is through the two top holes, NOT through the bottom hole.

This arrangement works well, with only a small runback. There are however two problems, one of which is serious.

First (and least dangerous) if the jammer is fully opened to pay out, as may happen during initial setup, it can hang against the tail rope as shown in the photo. As the rope is pulled through it can catch the teeth of the ascender and snap it closed. Annoying, but not too dangerous.

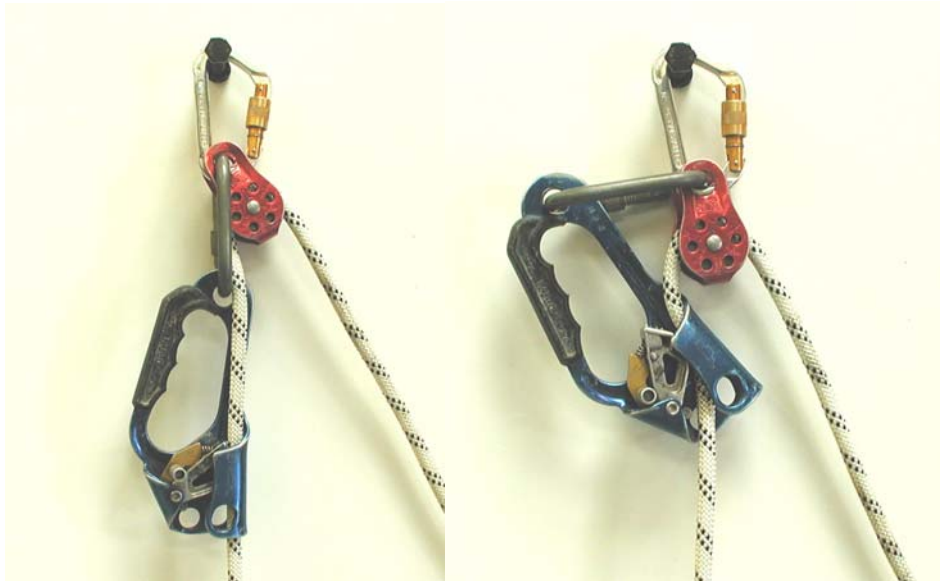


My solution to this problem relies on the spare hole in the base of the Basic ascender (which Petzl have yet to find a use for, or reason behind...) By fixing a 30mm length of aluminium bar into this hole (using an M5 bolt) you can provide a riding surface to keep the rope away from the teeth. It does not interfere with the operation, strength or connection points of the Basic and is well worth doing. In the photograph the aluminium rod is tipped with a nylon ball, simply to cover any sharp corners.

The second issue with this cross-karabiner rig is potentially serious, and is the result of the oval karabiner rotating under a snatch load on the main line. As you can see from the photos on the previous page, this oval krab is in compression and therefore unstable. It is possible, either by sudden loading or when the tail rope is moved upwards (anticlockwise in the photographs), that the oval krab will suddenly rotate by 90 degrees, loading across the gate. Obviously this results in an incredibly weak system that is likely to fail under a shock load. The problem with the Fixe is that this is difficult to prevent, by the nature of the design of the crossed karabiners there is little warning of a twist and little that can be done to stop it, other than careful tending.

Runback...

I have seen people (often who should know better) rigging an A-block using what is called a 'follower clamp pattern' – where the rope clamp grips the rope on the load side and acts in tension rather than the tail-side compression version above. This is often argued as a solution to the krab-twist problem but can be fatal for whoever is being hauled. Follower clamp pattern A-blocks that are constructed with movement (as you will get when you use krabs to clip things together) can suffer from huge runback and can even take themselves apart. Looking at the pictures below on load and take-in, you can see the problem...



Under take-in the clamp can ride upwards (as the krab acts as a nice hinge). It will either stop at the pulley, or in the worst case it can rotate so that the rope is being pulled outwards through the gate. This can damage the rope, risk pulling it clear or even cause the cam finger lever to become hitched into the pulley. The result of that would be that when the load is returned and the clamp pulls downwards the cam could be opened all by itself!

The solution, which we will use in the next section, is simple enough. The clamp is moving upwards as there is nothing pulling it down, so you can simply pull the clamp downwards by using a small weight or bungee cord. If the rig is vertical then a short sling and tackle bag of rocks will do the trick, for horizontal hauls you will need to use bungee cord, attached to something downline of the A-block.

One final point, a minor one but worth a mention. The bottom hole of the Basic is only rated for 17kN rather than 20kN for the 'twin' top holes. Clipping through these twin holes also fixes the rope into the clamp, preventing it coming free even if the cam is opened. The Ascension has a full-strength bottom hole but there is still the issue of a positive capture using the top holes, so if you use an Ascension to rig a follower-clamp, it is worth throwing a spare karabiner through the top holes to act as a safety and the point to tie your weight or bungee cord to.

A-blocks and swingcheek pulleys

As by now you will be bored of hearing, any full rescue loading required full rescue pulleys. Here we use Petzl P50s and Basic or Ascension rope clamps, as they are almost standard for UK cave rescue teams. Most other pulley manufacturers are poorly-represented in UK suppliers, so teams often never bother looking past the P50 for anything better.



Petzl keep very quiet about how to rig a P50 into an A-block, as there isn't a single straightforward solution. SMC never mention A-blocks and Kong simply advise users to buy a dedicated hauler device. Useful if you're down a cave and all you have left is a P50, one jammer and a bag of krabs!

Let us start with the most common (and probably the best) variation – the follower clamp. Although we ruled it out for the specific application to the P05 Fixe, it was beaten by a very specific rig for which the Fixe was designed. To make an A-block with a swingcheek pulley demands care and a few extra bits of kit. The runback problem on the previous page, and the solution with bungee cord or a small weight, is vital for all swingcheek-based A-blocks.



Here we have the same follower pattern as we abused in the Fixe section, and it will not surprise you to learn that it does the same things if left in this basic state. Even worse for this photograph we are using the weaker bottom hole of a Basic clamp, so switching to an Ascension clamp would give us a full-strength bottom hole if one were spare. The Basic's bottom hole is still strong enough if there are no other options, but there's no point in skimping for the sake if it.

As you can see, without the bungee cord pulling the Basic downwards it will ride up on the take-in and can capsize the oval linking karabiner. Putting some kind of restraint on this movement is absolutely vital for this pattern of A-block. The same applies if you

use a becketed pulley and attach the clamp to the becket (which we've done in the photo to prove the point!)

This horrible result not only has about 15cm of runback, it is forcing the gate of the krab against the pulley wheel, a nice metal-on-metal grinding process that does all manner of damage to both parties... as good an excuse for tying it down with bungee as you will ever need.

Back to the compression pattern – copying the Fixe solution but clipping both krabs into the large eyehole of the P50. You can probably imagine the problem with this one – it has very low runback (3cm) but that oval krab is very free to twist – even more so than in the tighter holes of the Fixe.



And so it does. In the photograph you can see that the larger hole size of the P50 has allowed the oval krab to rotate to the point where the top of the Basic is pressing against the pulley, the oval krab is in fact loose. Whilst 'safe' since the Basic will not fit through the cheeks of the P50, it is hardly elegant.

The solution I use is simply to attach a third krab between the base of the Basic and the main line. This forces the clamp to stay 'upright' and whilst the oval krab is still loose in this picture, there is very little runback. You could also use the bungee cord / weight idea from before, but this is a solution designed for those situations where you've lost your bungee and nothing heavy is available!

This third krab method does not work as well for the Fixe pulley, as there is insufficient room within the pulley hole for the oval krab to move. As a result the krab remains under compression when the tail rope is not being pulled, and the probability that it will rotate remains. Having said that it would not do any harm, and anything that is not bad in ropework is by definition worth it if you have the bits to spare.



So what have we learnt? Well, the most reliable A-block for swingcheek pulleys is a follower clamp with some bungee-cord-based tension on the jammer, or a compression pattern with a third tie-in krab. Either will work equally well and is equally safe, so the decision is down to the availability of something to tie the bungee cord to. Learn both patterns and make the decision on site.

The Fixe pulley, on the other hand, works reliably in compression mode as it was specifically designed for it. There are similar methods of rigging in follower pattern but this is defeating the design. All that matters is attention to detail, use of a third tie-in krab and the possible addition of a metal peg to hold the rope clear of the open teeth.

In terms of strength there is no difference in using the apparently weaker Fixe, as the critical failure point is the rope clamp and this is far weaker than the pulleys themselves. The only issue with including Fixe pulleys in kitbags is that they must not be used for rope deviation – that is a high-load application only suited to swingcheek designs.

Help! My pulley has a tiny hole!



Many swingcheek pulleys have holes only capable of taking one karabiner (such as the good old SMC pulley to the right in the photo, as compared to the huge hole in the Petzl P50 next to it). How do you rig an A-block with one of them? Well firstly, going by our rules in section 6a you shouldn't really have this type of pulley in your kitbags as it limits the uses. Sidestepping that issue and assuming you are there and that is what you've got, there is a solution – albeit a rather dodgy one...

If you clip another karabiner into the main pulley karabiner, alongside the swingcheeks, it will push the pulley to one side and create problems of unequal stress and rope friction on the cheeks. What you need to do is support a jammer in the follower clamp position without being able to attach it to the main karabiner. The solution is to clip a second karabiner between the pulley and the anchor, then clip a chain of 3 more karabiners (or a short sling which would be better) from this to the jammer. The inclusion of a bungee-cord tensioning system is vital this time, as without it the chain of equipment will wrap itself in knots when the rope is taken in. If you are using a sling to separate the jammer and anchor krab then a medium length (1 metre loop or thereabouts) is best as it makes sure the jammer and pulley are well clear. Provided the jammer is tensioned back using bungee cord there is no real limit to the length of the sling, but obviously if the A-block is elongated it limits the amount of movement possible in hauling systems as you cannot go past the jammer!

The next section combines the A-block into the most popular compound hauling system, the Z-rig. A-blocks are also used in chapter 9 to construct counterbalance hauls. Of course if you are raising a light enough load then an A-block in isolation (with no mechanical advantage) may well suffice. Even raising tackle bags and equipment it is good practice to use an A-block

rather than just lift hand-over-hand, as if something happens to the hauler (encounter with a falling rock or untimely natural death...) the object being raised does not plummet back to the waiting cavers below.

8a4. Using descenders to create an A-block

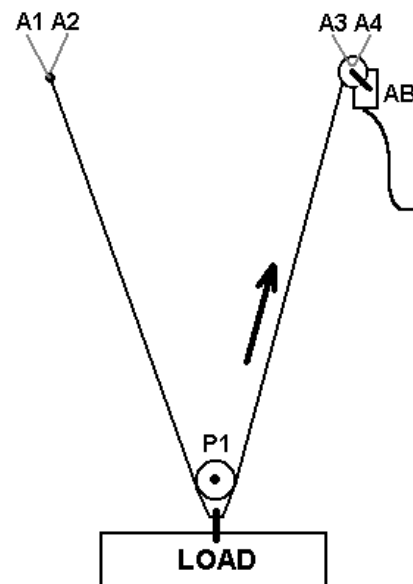
The last option is to use some kind of descender as an A-block. On first thought, any autolocking descender seems ideal to use as an A-block, as it takes in rope in one direction, locks on the other and 99% of the time it does a nice 180-degree bend for you as well.

As with everything in the world, there is a fly in this otherwise-pleasant coffee, and it is friction. Almost every descender is designed around a cam system, with the rope passing around a semi-fixed metal sheave. Whilst it is this contact that provides your controlled descent, it imparts the exact same friction when trying to pull the rope backwards under load. Some devices such as the Stop and I'D impart so much friction that they remove the mechanical advantage of a compound hauling rig built around them! Apart from making it hard work for the rescuers, **there is a more important and subtle problem** – since you are rigging your a-block as effectively a 180-degree pulley, the sum of the forces in each side of the rope are applied to the anchor point and karabiner. Whilst a descender such as the I'D may be rated safely for lowering a 200kg mass (where the anchor load will be just that – 200kg), if you have to pull 500kg on the tail rope to draw the 200kg mass up in a hauling system, your anchor is now seeing 700kg! This is the sole reason why Petzl expressly forbid the use of some descenders (Stop, I'D etc) in compound hauling systems.

To this end, I will stick to self-assembled devices in the rest of this chapter and only include one descender – the Grigri. Whilst it does indeed suffer from the friction problem, and using it in a compound system is outside the approval envelope, several years of use by teams across the world have shown it works reliably and the advantages in being able to lower under control can outweigh the loss in mechanical advantage. It is however a team call – if you don't like the idea of using a Grigri then stick to pulleys and jammers!

8b. The V-rig

Beyond a simple 1:1 straight haul, the V-rig is the next simplest system to employ and gives the rescuers an almost 2:1 ratio. All that limits the V-rig is the need for a rope that is at least twice the length of the pitch. Now, before launching into this and at the risk of confusing you, I must make a point concerning the terms 'V-rig' and 'Z-rig'. The difference is that for a V-rig your hauling lines have some sort of pulley that reaches the casualty/load and stays there. With a Z-rig, the pulley does not. I say this to stop any smart types picking holes in my description of a V-rig in the next section!



8b1. Setting up a V-rig

Setting up a V-rig is simplicity itself. First, one end of the hauling line is tied off at the top of the pitch (to two separate anchors A1 and A2 if we are playing by the rescue rules) and an A-block (AB) set up alongside it to receive the other end of the line. Between these two, a pulley (P1) and karabiner is attached to the line, and the pulley lowered down the pitch on the resulting 'doubled' rope. Once at the bottom, the pulley is attached to the load, the A-block is engaged and the system is ready for hauling. There are a few points to note:

1. It is the weight of the pulley and karabiner that help the rope loop to reach the bottom of the pitch – so it can help to clip something heavy to the line if the rope is stiff and doesn't want to play. A few more krabs, a tackle bag of stones or something will help a lot.
2. If you are sending a V-rig line down to a casualty who has a single line in place (e.g. to haul a tired SRT caver mid-pitch) then you can clip the pulley karabiner around his single line to make sure the V-rig reaches him.
3. It is very important with V-rigs that the two halves of the hauling line do not twist together, as they need to move past each other. On long pitches it is therefore important to keep some horizontal distance between the fixed tie-off and the A-block so that the line does indeed form an open 'V' and cannot twist.

A rescuer can be lowered to a casualty on a V-rig, can be sent an empty V-rig after arriving, can take an empty V-rig down with him or the pulley can be lowered to a helpful casualty without a rescuer moving from the pitch head. One temptation that **must be resisted** is the idea of clipping a jammer to the casualty's line, attaching the V-rig pulley to it and letting it slide all the way down. Rescuers can argue that this will let the V-rig reach the casualty without them having to grab it, clip it on and close the krab. My argument against this is on two points:

1. A casualty that cannot perform such a simple task reliably and without help should not be left alone on the rope. Get a rescuer down to them.
2. If for some reason you need to retrieve the Z-rig partway down (such as if the ropes get tangled) then neither you nor the casualty can reach the jammer to open it. You'll have to send someone down, so you should have predicted that and sent someone down in the first place.

The only caveat to my hatred of the 'travelling jammer V-rig' is if you are alone at the pitch-head and have to recover an unconscious caver from an SRT rope or safety line. In that situation the normal priority of rules changes, so sending down a jammer is the only option. Remember though – if your casualty is conscious they can deal with clipping on a karabiner!

Using a pulley at the bottom of a V-rig and a pulley-based A-block at the top, then a force ratio of almost 2:1 is possible. This will allow one fit rescuer (or two normal ones) to raise the unsupported weight of one casualty (without stretcher or other additional weight). It is a very quick technique to recover someone on a normal caving trip who is just too tired to prusik up the final pitch, and in this situation the casualty should remain attached to the SRT rope by at least their chest jammer whilst being pulled upwards by the V-rig. Their SRT rope then acts as a safety backup, and if they get their will to live back they can assist by prusiking at the same time.

A V-rig without a rescuer 'local' to the casualty must never be used where the casualty has a medical condition requiring monitoring, or where the casualty is out of sight of the rescuers at

any point during the raise. The final limit on the use of the V-rig is of course the length of rope required. For hauls of greater than 50m then you may be limited by available rope to using a single hauling line and a local advantage system at the pitch head, such as a Z-rig.

8b2. The V-rig in gorge rescue

Cave rescue teams can often be faced with a situation, underground or on the surface, where a 'gorge' rescue is required. This is defined as a rescue from the bottom of some shaft, opening or rift of an appreciable width where the rescuers must work from both sides to keep the casualty from being scraped up one wall. The classic surface scenario is rescue from a deep river valley where unstable rock or trees make access along the side walls impossible. Underground the situation usually arises in mine chambers.

In gorge rescue, the V-rig is used more as a tyrolean traverse that can be lowered to the casualty (See chapter 10). With one end fixed to the top of one bank of the 'gorge', the rope is thrown across the gorge and a hauling system (A-block, Z-rig or something similar) used to attach the rope to the other bank. The V-rig casualty pulley is allowed to run out into the middle of the rope and the rope lowered until it reaches the casualty. The problem with this scenario is that you can raise the casualty to a mid-air point between the two banks, but you need to ferry them sideways to one bank for recovery. To do this, a separate line must be connected from the casualty pulley to one bank before the V-rig is lowered. Once pulled up to the safe tyrolean limit (120°, as we will discuss in chapter 10) then the casualty can be pulled across to the bank using this separate line. It does not matter which bank receives the casualty in technical terms, so the decision is one of space, manpower, access and anchors. Depending on the situation and relative heights of the banks (they are always the wrong way round) then you may have to physically 'tow' the rescuer out to the casualty and/or tow them back to safety, thus requiring a positioning line to each bank. One thing that is often overlooked when rigging a V-rig gorge system is that the weight of the rescuer and casualty are significant. When they are suspended in the centre of the raised 'tyrolean' and you are trying to tow them up a 30° angle to safety, it requires considerable effort and either a good bank of strong people or a local advantage system such as a Z-rig. Mid-rescue is not the point to find out that you haven't got the strength to get them out of thin air, so plan for something heavy. That way your only surprises will be pleasant ones.

At the risk of stating the obvious, if you are using a V-rig for gorge rescue then the safety lines for the casualty must also be rigged to both banks and the two lines taken in carefully. A safety line going to only one bank will lead to a painful recreation of 'bottle of bubbly launching an ocean liner' should the V-rig fail.

A point worth some consideration, but with limits, is the view of the casualty. Often gorge rescue (above ground) is for a casualty who has no experience of being in mid-air suspended on ropes. They are likely to be more frightened by being literally in the middle of nowhere on a V-rig than being raised against one wall, so where the casualty is obviously frightened and there are NO safety or technical reasons for avoiding the side walls, then using a mid-air V-rig for the sake of it is not the best practice. Teams do not carry Diazepam to permit scary procedures to be used 'cos the rescuers think they look like fun!

The V-rig gives, at best, a 2:1 ratio of hauling. To get more than this needs a bit more complexity, and the next stage up in the ladder of pulley ratio is the Z-rig, which we will see in

the next section. Naturally, the Z-rig can be used in conjunction with the V-rig if you need the extra pulling-power, and if your casualty is in a stretcher or is accompanied by a rescuer on the same lines, you will. Always keep in the back of your mind the thought that stacking pulley systems onto each other to gain Biblical amounts of force is only effective to the point when your rope breaks! As the pulley ratio increases above 3:1 you must watch for tension on ropes and anchors, as it is entirely possible to overload equipment without realising it.

8c. The Z-rig

The Z-rig is the basis of almost all UK cave rescue hauling when the load is too great for a simple 1:1 pull. The use of a pair of pulleys and a travelling clamp result in a 3:1 mechanical advantage and a flexible system that is quick to reset.

8c1. The basic layout

A typical ‘bare bones’ Z-rig is shown to the right. An A-block is secured to a suitable set of anchors and a travelling clamp and pulley (a B-block) is placed on the main line. Pulling on the emerging tail line moves the rope through both pulleys and moves the B-block and A-block closer together. The basic operating principle is 100% simple – pull until the two blocks are close, then push the travelling clamp back along the main line (whilst paying out some tail rope) and start all over again.

In the photograph I have used the P50/Basic A-block design with third krab as discussed in section 8a. The travelling B-block is another P50 pulley and Ascension connected by an oval krab, simply to show that handled ascenders can be used. With either type the oval krab must connect through the top twin holes rather than the bottom hole, as the tail rope can be pulled at any angle and it is important not to impart any leverage onto the B-block.



This bare-bones Z-rig is ideal for deadweight hauling of equipment, or as a line tensioner for tyroleans. When lifting live loads (casualties) it is important to protect against failure of the A-block. Even with multiple anchors it is obvious that if the A-block pulley should fail then the load will drop by at least twice the length of the Z-rig. As the tail ropes are not usually belayed, it would be unlikely that the hauling party could arrest a fall even when the Z-rig slack has gone.

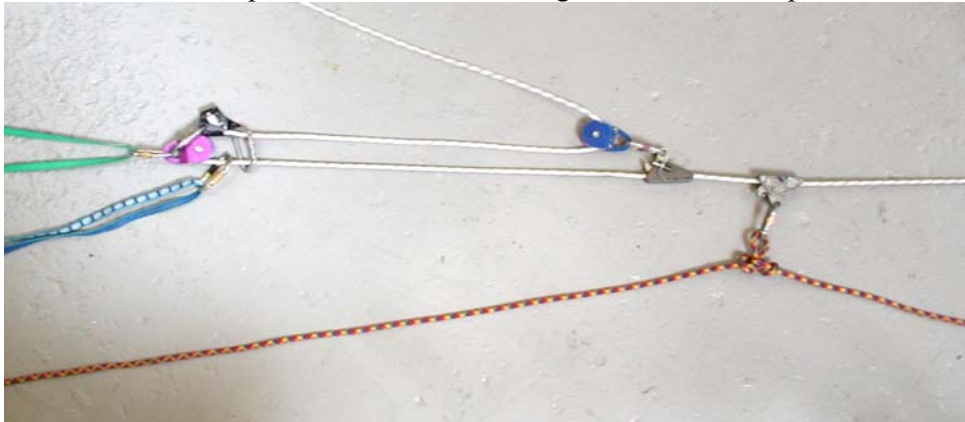
There are various solutions for A-block protection. Some teams attach a minder sling (See chapter 6) to the main line just as it enters the A-block pulley, this running to separate anchors. If the A-block fails the load moves to this new anchor point with very little runback. Assuming the A-block clamp survives intact and thus cannot pass through this now-loaded krab, the rope will not free-run and with increased friction the Z-rig would probably remain in working order, at least until emergency repairs can be done.

A second option is to put a downstream clamp on the main line, to deal with any possible failure of the Z-rig including rope break at the A-block. This should be as far away from the Z-rig as possible to allow for slipping, and is often fitted at the point where the main lines divert over the pitch-head pulleys. The problem with this approach is that in the event of an increase in loading on the main line (such as from connection of the stretcher) the rope between the downstream clamp and the Z-rig now cannot stretch. The single downstream clamp takes the entire load, with the Z-rig drawing tension back onto the main anchors only after the haul has begun. The same applies to any shock loading on the main lines (for example from deviation

failure). Clearly this downstream clamp was intended as a safety backup, not a main anchor. It is not simply a case of adding slack into the downstream clamp by using a webbing sling or similar, as now there will be a larger runback if the Z-rig fails. The only option is to choose a clamp that is as rope-friendly as possible, and make sure it is more than capable of supporting the full rescue load on it's own. In the photo to the right we achieve this using a Rescucender. Note that it is fixed to the anchors using dynamic rope – we expect it to receive a small shock-load if our main system fails, so a direct connection with slings is not possible.



A Petzl Shunt can be used though as we have discussed earlier, it must be expected to slide a long way. A positive-action compression clamp such as a Rescucender is ideal as slipping is minimised yet the gripping action is still 'friendly'. Toothed clamps (Basic, Ascension etc.) are suitable but less rope-friendly in the event of a full-load shock incident. Personally, my suggestion is to stick with the A-block minder sling and assume that rope failure within the Z-rig is not as likely as A-block anchor or connector failure. Adding a downstream Rescucender for very high load hauls is worthwhile but only as a method of reducing the peak shock loading on the A-block anchors in the event of a problem on the pitch. A Shunt on its own will not be able to support a full 200kg load with a shock start but would be worth putting on if there are no Rescucenders spare, as it will, if nothing else, reduce the peak shock load on the Z-rig.



The photo above shows a full belt-and-braces Z-rig with a minder sling and downstream clamp.

8c2. The Grigri Z-rig

As discussed, a Petzl Grigri offers an alternative to a pulley/clamp A-block but at the cost of far more friction, since there is no rotating bearing. The same rules for the rest of the system apply, and the Grigri is rigged as normal. It offers the ability to lower through the Z-rig with ease, but at the cost of reduced mechanical advantage. The main difficulty in using this system in UK cave rescue is that the Grigri is specifically intended for use on dynamic ropes only, and as a belay device for climbing. Use with static ropes and as part of a hauling system is plainly beyond the purpose specification and also the limits of the CE approvals. Whilst practical tests show it can work, legally it could be an issue of negligence through intentional misuse of

equipment. The decision is therefore one of liability not suitability and I will not suggest a course of action in either direction.

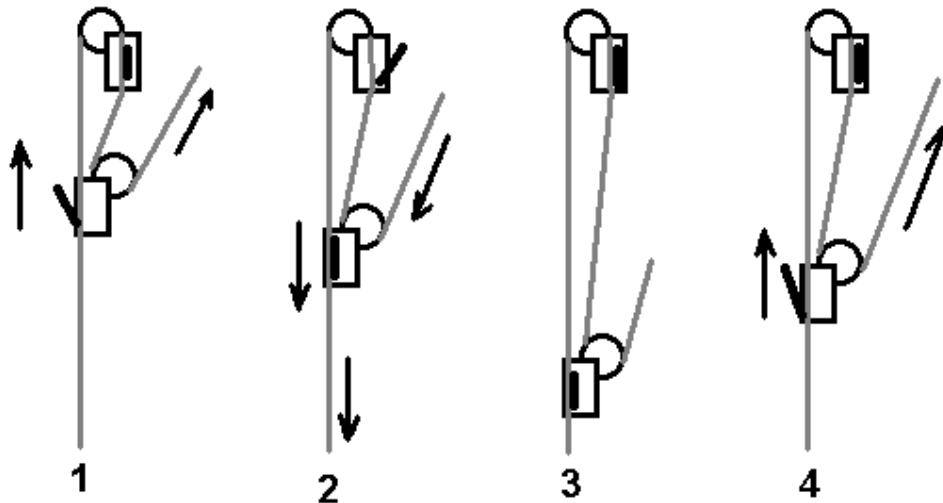
Many teams use the Grigri in Z-rigs without thinking of the friction losses, suitability for use or strength simply because they have seen others do it, and thought it must be a cool thing to do. It's a classical example of a piece of kit being adopted widely on an initial assumption rather than being thought about on merit. If you see another team using a rig you are unfamiliar with, think (and ask) why they are doing it, if it is any better and **then** decide if you want to copy them!



8d. Lowering through a Z-rig

By the very nature of a Z-rig, lowering is not easy. Apart from the Grigri-adapted Z-rig, where lowering is simply a case of paying out through the Grigri whilst controlling the load on the tail rope, lowering on a conventional Z-rig is a slow and uneven affair:

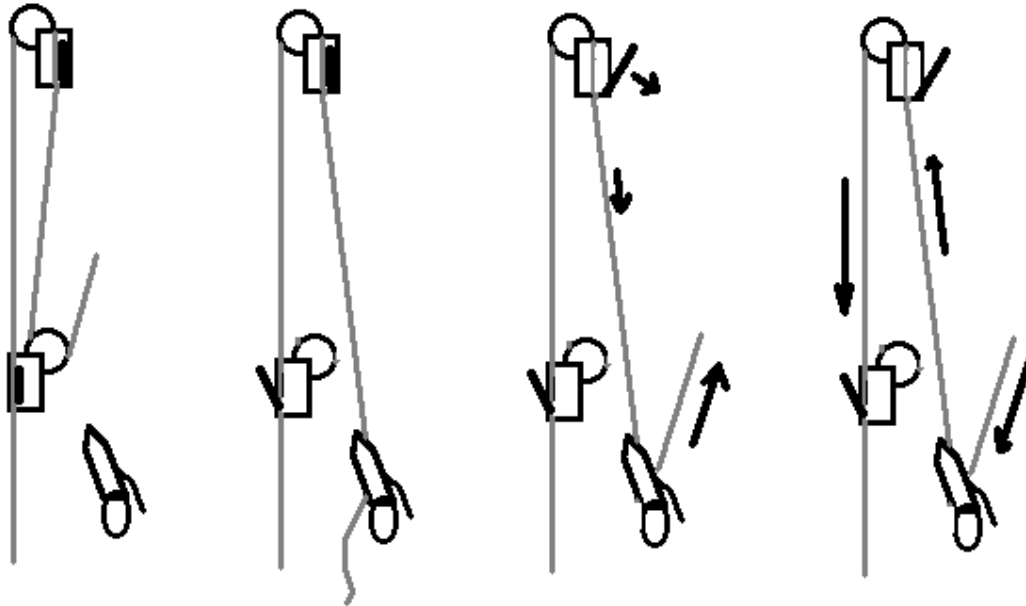
1. The travelling B-block is moved as close to the A-block as possible (but not into contact!) and the hauling party prepare to take the load on the tail rope.
2. As the load is taken, a rescuer releases the A-block clamp cam – using the finger method and most certainly not by opening the cam completely.
3. With this cam released, the tail rope is paid out until the travelling B-block has reached the limit of motion. The A-block cam is replaced.
4. The B-block is released and returned back to the A-block, the process is repeated as required.



For a long lower this is not practical and the technique can also impart a large bounce to the lines, creating problems of casualty care and extra loads on the anchors. It is suitable for small adjustments, for example if a load has been raised a few feet too high to enable access to a

rebelay or level in a shaft. For a lower of more than five cycles of the Z-rig it is easier and faster to convert the rig to one of the two lowering modes.

Mode 1: partial conversion



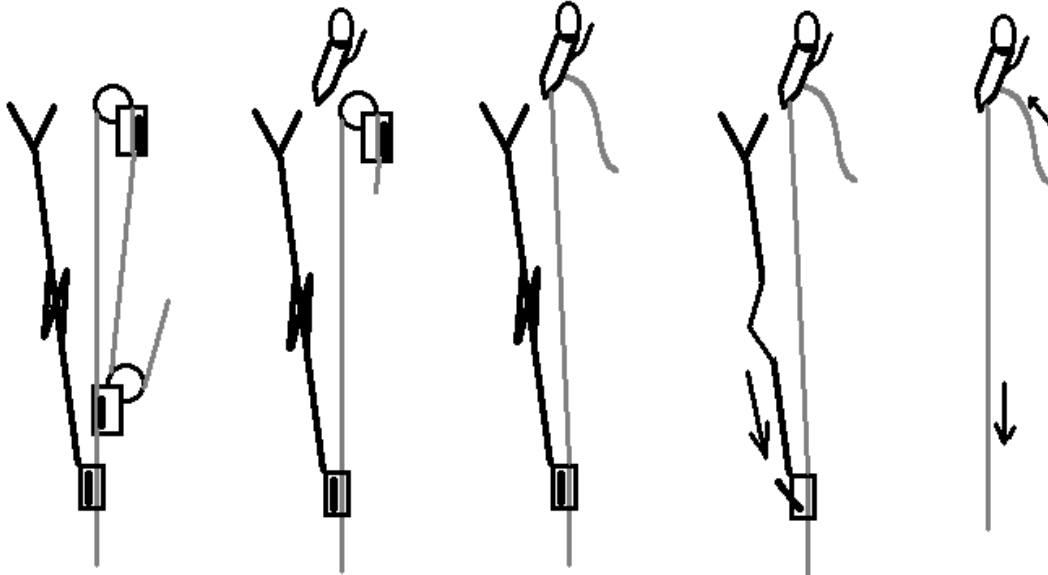
This is the fastest option and allows equally rapid return to the Z-rig, but requires an anchor point somewhere in the vicinity of the end travel of the B-block, and those anchors must be able to take load *towards* the A-block.

The idea is simple. With the A-block taking the load, the travelling B-block is moved up to these anchors where a descender is fixed to a sling or short rope, so that it can operate in ‘free air’. The tail rope is fed into the descender (removing it from the B-block pulley), leaving the B-block effectively unloaded and redundant on the main line. The cam on this clamp should be opened so that the B-block can slide freely. By pulling in on the tail rope again (this time through the descender) the load on the A-block can be released to the point where this clamp can also be opened. When the tail is paid out the load will be supported on the descender, via the pulley of the A-block. As the descender pays out the main line slides past the unloaded B-block. If at any point the Z-rig is required again, simply close the A-block cam, release the tension in the descender and put the tail back into the B-block.

The disadvantage of this mode is that to initially release the A-block cam, the rope must be pulled through the descender – a point of high friction. It would be possible to use a jigger (see section 8f) if these were available, applied upstream of the A-block to release tension on the entire system while the cams were opened and the descender fitted. If you used a Grigri for your A-block this isn’t a problem, as you can release under load without taking in any rope so wouldn’t need to go through this conversion process. However, as we’ve said a Grigri-based rig is high friction all the time.

Mode 2: full conversion

Where a long lower is needed and time is not critical, or where there are no suitable anchors for the partial conversion route, the entire Z-rig can be removed and converted to a lowering rig. This requires (as well as a descender device) a medium length sling, rope clamp and karabiner:



1. The sling and new clamp are connected to the same anchor(s) as the A-block, or two nearby, and the clamp applied to the main line downstream of the others.
2. Pushing this out to the point of tension, the Z-rig is paid out fractionally, transferring the load to this new clamp and sling. The entire Z-rig is then unloaded, so the B-block can be removed.
3. The A-block is removed and the descender fixed to these anchors and to the rope.
4. Using a spare rope (or the tail of the main line), a line is rigged from one A-block anchor, through the original B-block and out as a tail.
5. The B-block cam is closed and this spare rope used to pull in the line slightly, to allow the third clamp to be released and removed.
6. The spare rope is let out, leaving the load on the descender. The B-block is opened and lowering commences.

If the third clamp is attached using a releasable sling (see section 5i) then there is no need for the B-block to be used to release the tension. This has the advantage of being able to lower without needing to take in any distance on the main line whatsoever – useful if the main line is jammed or the load was too heavy to lift. The drawings above show this option.

Someone asked me why go into all this talk of converting Z-rigs when you could just hold the load on the second line, strip things down and put in a lowering device such as an I'D. The answer (or should that be the excuse?) is that if you have a casualty mid-pitch with two lines to him, and you remove one completely to rebuild a lowering system, you are leaving them on a single rope. We said that was a silly idea, and so the last two pages had to be written!

8e. Modifications and improvisations

Cave rescue rigging does not often get more complex than a Z-rig, which hopefully by now you will realise means it doesn't get complicated at all! However, the best-laid plans always die on the route to the callout, so you can expect to be faced with having to rig your Z-rig without all the kit, in an amazingly awkward place and without enough anchors. Remember that apart from two pulleys, an SRT-equipped caver carries everything needed to make and convert a Z-rig (two clamps, three karabiners and some short slings). If you have to resort to cannibalism, remember that the chest jammer (Croll) should only ever be used as the B-block device – it is not suited for incorporation into an A-block as the holes are twisted.

You can improvise a B-block using a prusik knot if need be, so the absolute bare minimum for a functional system with some nett mechanical advantage would be a prusik loop, three karabiners and one jammer (you could risk a prusik loop for the A-block as well, but controlling it on the uptake is much more fiddly). If you only have ONE pulley, adding it at the B-block makes a huge difference, adding one at the A-block makes less as the rope movement over this point is only half that at the B-block per pull.

There are some 'tips' worth noting about Z-rigs that I suppose I should mention:

1. The system is not only less efficient if the tail rope is pulled in a direction that is not parallel to the main lines, but it can make the line bend at the B-block and possible cause rub points on downstream passage walls. It also introduces more bounce.
2. The golden rule of hauling must be followed – make gradual smooth pulls to minimise bounce. This leads to increased system loads and motion sickness in the casualty.
3. The A-block is a pulley with a 180-degree turn, so the anchor load is twice that in the main line. Always use a minimum of two discrete anchors for the A-block, as well as separate anchors for any minder slings. The main krab in the A-block must also be a big, beefy steel affair capable of taking the high loads.
4. A long Z-rig slide means fewer cycles and less bounce, plus greater ability to lower without resorting to conversion. With very long Z-rigs (on the surface for example) watch that the three lines between A- and B-blocks don't wrap around each other.
5. Always make sure that someone can physically reach every clamp (including any downstream safeties) at all times. They will all need to be released at some point...
6. It is rare to rig a Z-rig in the vertical plane in the UK, but if it was to be rigged vertically then a small object (a chain of krabs or small bag of rocks) can be used as a pull-weight to make the B-block return under gravity after each cycle. If you do this, remember to satisfy rule 5!
7. Practice, and keep a jigger handy.

8f. Jiggers

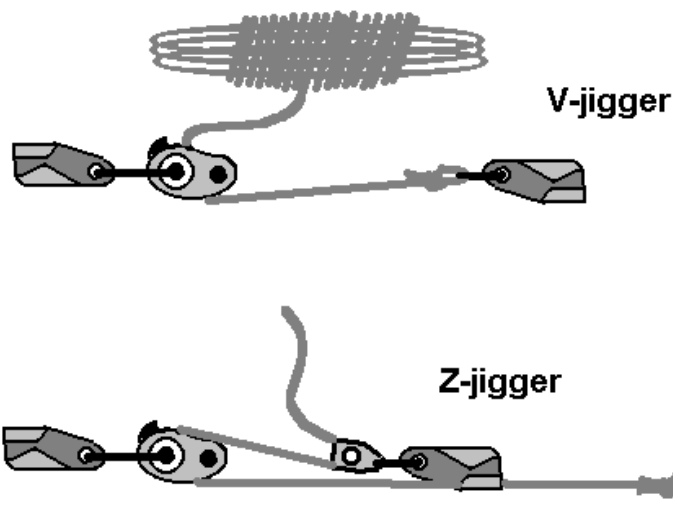
'Jigger' is an American term, as can be realised from the fact it means 'a device to jig'. Jigging, of course, means 'to pull like a madman because something isn't working right'. I will use the US term as the British phrases for such emergency measures are far more anatomically-related, as is the way for the tongue of the Brit under stress....

A jigger is basically the bare bones of a Z-rig plus some clamps to piggyback it onto a rope, pre-built and packed in a bag ready for use. It is designed to allow tension in a line to be

released locally, for example when converting a full-sized Z-rig to lower mode or to release a karabiner from an anchor when the line is still in tension. Jiggers must be able to take a full rescue load but are not expected to experience shock loads, as they are only temporary additions to the ropework. As such many teams in the US use smaller-diameter cord (e.g. 9mm static rope). This is chosen for physical size and weight, but as a typical jigger only uses 10m of rope, full 11mm line is pretty acceptable and abides by our earlier rules about never using less than 11mm rope underground. Although designed to stay in one piece it is always possible that at some point the rope from a jigger will be cannibalised for some other emergency use, and having stray bits of 9mm around is not a good idea. Dynamic rope is not suitable as the jigger must collect the tension quickly rather than spend time stretching itself. You can argue over the 9mm/11mm issue but do not say I didn't make the point!

There are several 'types' of jigger:

- 1) Z-jig: a full Z-rig with the A-block connected to another clamp. Self-locks, so can be used to raise in steps just like a full-size Z-rig.
- 2) V-jig: One A-block mid-rope with a connecting clamp, and one clamp at the end. Allows a 2:1 pulling ratio and self-locks, but can only be pulled in once.
- 3) Open jig: As above but just a pulley mid-rope – not self-locking and so can only be used to hold tension off the main line for a short while.



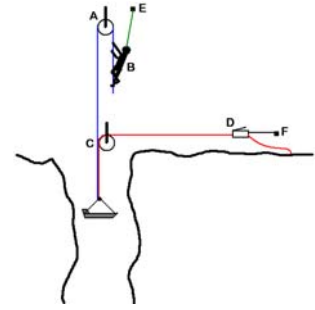
The A-block in a jigger needs to be physically small (so that the available movement per metre of rope is maximised) and so a sheave-clamp device such as the Pro Traxion is a better option than pulley/jammer constructions. It is not suggested to use a Grigri as the payoff in higher friction outweighs the benefits.

Note that since a jigger is permanently rigged, the knots should follow the rules of permanent rigging and be sealed. The tail end of the 10m rope should not be knotted to prevent the jigger being taken apart, as often you find you'll want to!

Jiggers have become very popular in the USA but are rarely used in the UK. Given the relatively little size, weight and cost of putting one into a bag and keeping it handy, I can see no reason why UK teams cannot find a place for them. Apart from the obvious advantages in their use for all manner of quick hauling system repair, they can be handy for other uses (shifting an annoying boulder, pulling a steel beam into position and so on). Added to that is that fact that to have a solution to an emergency is the best way to ensure that the Gods do not send one your way.

9. Counterbalance hauling

In the previous chapters we dealt with raising a load using force applied to the lines (via pulley systems and one-way devices) by members of a hauling party. An alternative method to this approach of having men standing around and pulling on ropes is to use the weight of something or somebody to counterbalance the weight of the load, thus making the effort of the hauling party far less. The basic premise goes back to our notes in Chapter 1 – that the average rescuer cannot apply more than his bodyweight to pulling on a rope. If you use him as a counterbalance you therefore get more out of him! There are of course advantages and disadvantages to this idea:



In its favour the load on the hauling line is reduced and the effort required by those hauling is reduced, possibly allowing less men or a less mechanically advantageous system. It therefore comes into it's own when rescuers are scarce.

Against it are the complexities of rigging (as you will see shortly) and the balancing of weights and distances.

This 'complexity of rigging' will raise eyebrows, as many times I have seen teams and text books treating a counterbalance hauling system as some kind of glorified balancing act over a pulley. **This is not how it works!** Please please take this part to heart, it is vital. You use a counterbalance weight to *assist the hauling party*, not to replace them. You still need the same twin-rope hauling system, anchored and controlled as usual, it's just that you can do away with some of the pulling team.

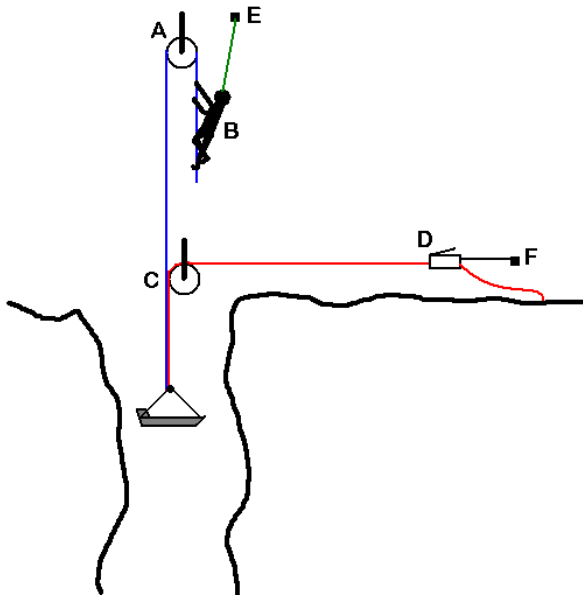
The idea is to reduce the load, not remove it!

The worst thing you can do is put too much weight into your counterbalance and turn an assisted haul into a runaway descent, where your casualty flits past three hurtling rescuers mid-pitch as they each head towards opposite ends of the planet. If in doubt use less weight – after all you were originally intending to haul the load up by other means anyway!

The result of this drum-bashing is that the ropes used in the counterbalance are separate from the hauling system and should never become part of it, even as some kind of safety line. Think while you are rigging – you should be able to remove the counterbalance completely without changing the hauling system at all.

9a. Top haul

The most common counterbalance is where the balance weight starts at the top of the pitch next to the hauling party and is allowed to descend (ish...) as the load rises. In the simplest sense we have the 'travelling balance' system, where a single rope equal to the pitch length runs from the load, up through a top pulley and down to the balance weight (which we shall assume is a rescuer in SRT gear). As the load is raised, he descends, passing the load mid-pitch. This works fine if there is physically enough room for this passing to take place but you need to judge the length of the rope carefully, as the idea is that the balance hits the floor as the load reaches the take-off point. More common is the steady-balance system where the team member climbs the rope and aims to stay still as the rope moves past him:



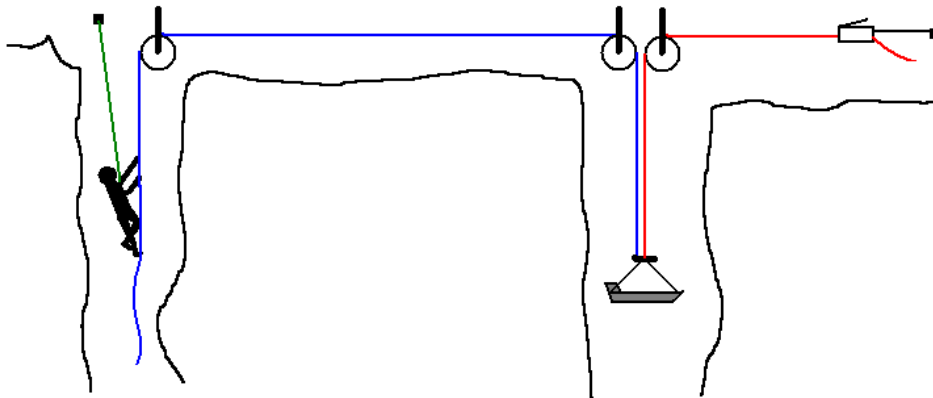
In the pic to the left I've shown this first variant on top-hauling. Here, the load is being raised using the red line and some conventional method of propulsion, probably a hauling party at D. The main pulley at C and jammer/anchor system D/F take the load, but for whatever reason some extra help is needed. Using a higher pulley at A (so it's out of the way), and a second balance line (in blue) we connect a team member B to the stretcher and as he climbs the blue line using SRT, he assists in the haul. A single safety line (green) links him in position; otherwise there would be no way to release him from the stretcher when it comes time to clear the pitch. If there is a need to temporarily lower the stretcher then the balance man needs simply to prusik down a bit.

NOTE: in the above diagram I have omitted the standard second safety line for the stretcher for clarity (as there are enough colours already!). The blue balance line is NOT a substitute for this safety line, since it will do very little to hold a fall, until the balance man is squeezed through the top pulley genitals-first.

As you can see, the issue with a static-balance rig is keeping the poor balance man out of the way! He needs to be either well above or well below the main pulley and pitch-head, so he doesn't interfere when the stretcher is unloaded. If you have the headroom, then placing him higher is better, as the stretcher never needs to pass him and (often) he is in a better position to observe progress and self-regulate his climbing.

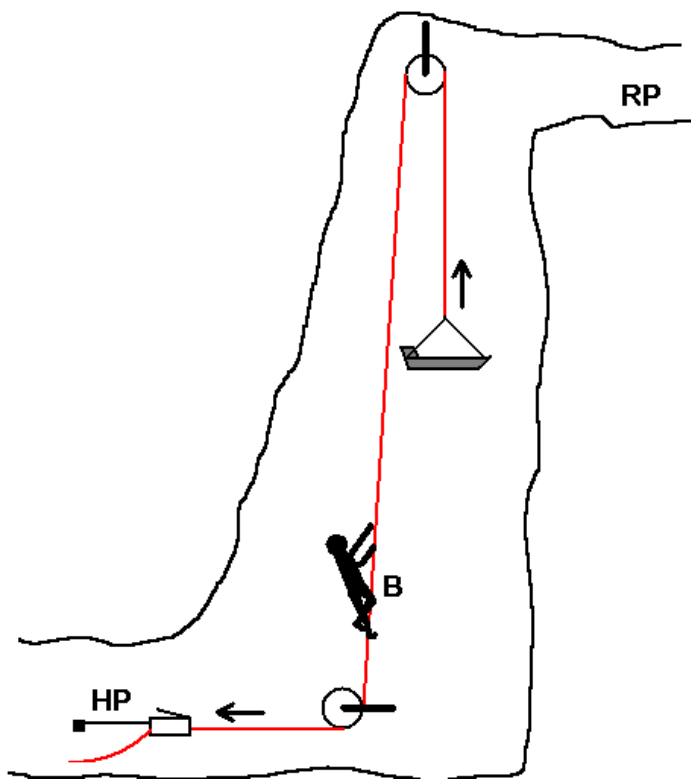
Looking at the above diagram you can also see that the balance man can remove himself from the rig at any time simply by letting his weight transfer onto the green line and disconnecting from the blue one.

A final point on top hauling – there is no rule anywhere that says the balance man has to be descending the same pitch as the load! If you have two pitches nearby (as with many mine shafts where the shaft is split into two halves) you can run the balance man down the 'empty' pitch to keep the hauling route clear:



9b. Bottom haul

Here, the hauling party are at the bottom of a pitch, raising the load to a waiting reception party using lines that pass over pulleys. This may be needed if the pitch head is very constricted and there are no suitable anchors for the hauling system, but should be quite rare in practice. There are two options in this case, the first being to use the same counterbalance ideas as in the previous section, with the balance man positioned wherever he can operate without getting in the way. The other option, and one **specifically permitted in this application only** is to place the balance man on the hauling line as shown below. He ascends the line using SRT as it is pulled down through the rig, therefore remaining a few metres above the ground at all times. It is permissible in the bottom hauling scenario as the balance man is never exposed to a large fall risk should anything happen to the main lines, and his presence will not interfere with the operation of the system at any stage.



To the left I show this idea (again omitting all the second lines). The hauling party HP are trying to deliver the stretcher to the reception party RP, and there's precious little space for any conventional counterbalance. Taking great care not to climb more than a few feet above the ground, our balance man B climbs against one of the main lines, adding his bodyweight to the hauling force.

He must be able to disconnect from the line (either by switching onto another rope or descending to ground) at the point when the load is being delivered to the reception party, as the line will need to be made slack at some point. There must also be a second line without a balance

man for safety of the load (i.e. do not use two balance men, one on each line!). The essence of this rig is of course that nobody can pull a horizontal rope with their full bodyweight, but can hang on a vertical one thus imparting more force for a set number of men at HP.

This method does increase the tension on the balanced line and the associated anchors, however it is a useful trick to keep in the back of your mind should you need to apply more force on a bottom haul for some reason, as you can quickly add a balance man to the lines without having to fit another pulley and a counterbalance rope to the system. The technique cannot be used in top hauling systems as it relies on an 'empty' section of line both vertical and moving downwards. Above all, NEVER put two balance men on the same line – that will increase the loading on the top pulley to a point over the acceptable rating.

9c. Inanimate balances

We have created the methods above using an SRT caver as the balance weight. There are no reasons why he cannot be supplemented by inanimate objects (tackle bags of rope, etc) but you should never use such objects as the sole form of balance. The essential aspect of using a caver is that they have the power to move along the balance rope and remove themselves from it if need be, whereas a bag of rocks remains there until it hits the floor. If you need for whatever reason to release the balance line and your weight hasn't reached the floor, you are in trouble! So by all means add to your balance man's bodyweight by covering him in coils of rope and bags of sand, but resist the temptation to make use of that tree trunk lying near the footpath, unless you think you can teach the woodworm to operate a descender!

This is the end of part two of the three-part edition

This part was last modified on 11 May 2003

Changes in this issue: Expanded the counterbalance section and added diagrams.