CHAPTER NINE

Belay Anchors

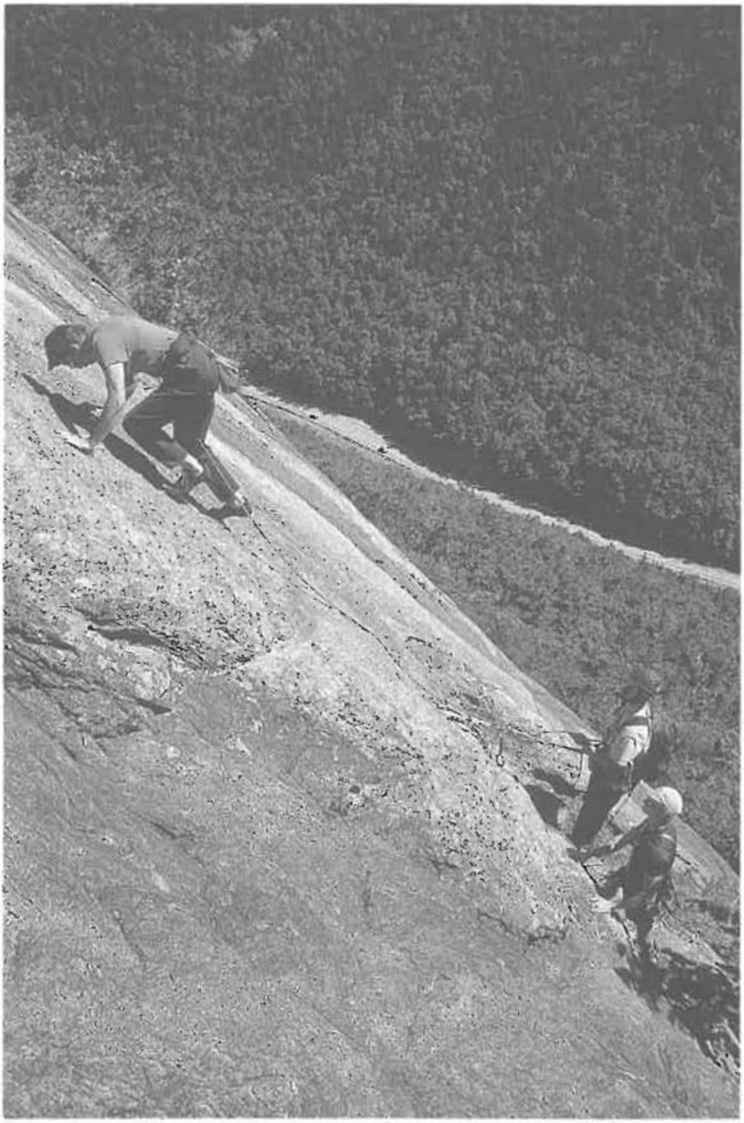
A handful of basic rigging methods cover most anchoring demands, providing you understand a few general principles and learn to improvise on a theme with a variety of instruments (gear). In the past the basic rigging methods included the cordelette, the sliding X and the crafty use of slings and clove hitches. Recent tests, however, have determined that the cordelette is dependable only when the arms of the system are of perfect length. The equalette, a new variation of the cordelette, is showing promise as a viable replacement and has thus far received solid reviews following extensive field testing. No doubt other systems will evolve over time as more climbers try to solve the longstanding problem of achieving redundancy and good equalization with limited extension.

The photos in this chapter show examples of typical anchoring setups. Memorizing the rigging on a given belay anchor doesn't mean you'll be able to (or want to) use the exact same method at a different location. The photos simply allow you to study various setups and develop a working understanding of general principles. When studying the photos, try to quickly recognize what basic technique is used, then consider options and mentally formulate ways you might do things differently.

When building any belay anchor, you'll always face limitations. A leader can take only so much gear on her rack, and it's impossible to predict what gear she will place to protect a given pitch. Whatever gear remains on your rack at the end of the pitch is what you have to efficiently and securely fashion a belay. If you don't thoroughly understand the basic principles, you will struggle to build anchors with limited gear.

BUILDING BELAY ANCHORS—A STEP-BY-STEP PROCESS

Aside from the ability to place sound nuts, cams, etc., adaptability and innovation are keys to rigging stout and convenient setups. Belay anchors can be subjected to



Matt Peer sets out *Across the Universe*, Crawford Notch, New Hampshire.
PHOTO BY STEWART M. GREEN.

high-impact loads, so arranging bombproof belay anchors is absolutely crucial.

Experienced climbers go through a step-by-step process when rigging a belay anchor. First is to determine, so far as you can, the directions of pull that the anchor must resist—for both the climber following the pitch and the leader casting off on the next lead. The directions of pull will influence your rigging choices per building a statically equalized or dynamically equalized anchor system.

After determining the possible directions of pull, locate where you want to belay—what physical location is best for tending the line, what affords the most secure and ergonomic stance, what allows use of the remaining gear on your rack, etc. If adequate primary placements aren't available, consider moving the station higher if possible, or lower if necessary. Often you won't have a choice. There will be only a small shelf or one crack.

Most belay anchors are built around one atomic bombproof nut or SLCD, and that's task number one: setting the strongest, most obvious big nut or camming device you can arrange. If extra stout placements abound, go with the one most handily located, ideally about chest level, where you can remain standing, can hang the rack and can keep an eye on the whole works.

STEP-BY-STEP BELAY ANCHOR

- On popular routes the belay stances/ledges are usually well established (though not always ideal). Belay there.
- Further narrow your belay site down to the most secure, ergonomic and practical position.
- Locate suitable cracks or rock features to fashion a "good enough" belay anchor.
- Set the most bombproof, primary big nut or camming device you can find—preferably a multidirectional placement—and tie yourself off before yelling "off belay."
- Determine the direction(s) of pull for both the climber following the pitch and the leader casting off on the next lead.
- Simply and efficiently shore up the primary placement with secondary anchors.
- Try to set the secondary placements in close, but not cramped, proximity.
- If the rock is less than perfect in quality, spread the anchors out, using several features, to preserve redundancy.
- Using modern rigging techniques, connect the various components of the system together so they function as one unit to safeguard against all possible directions of pull.
- Consider tying into the most bombproof anchor with a clove hitch (to aid adjustability).
- When bringing up a second after leading a pitch, if possible situate your body in line between the anchors and the anticipated direction of pull. Remember ABC: Anchor ⟶ Belayer ⟶ Climber.
- Also remember KISS: Keep It Simple, Stupid. Avoid overbuilding.

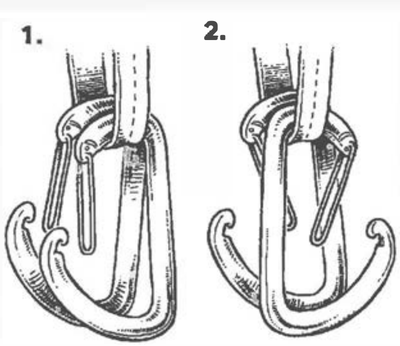
Sometimes you'll have to rig the anchor at your feet, or off to one side, or wherever you can get good placements. Whatever the situation, the priority is to sink that first, bombproof placement. No matter if you're standing on a 10- by 10-foot terrace, clip into this piece before you finish rigging the belay anchor and before you go off belay.

Next, shore up the primary placement with secondary placements, striving to keep the grouping close by, but not so close that they are crowding each other. If the rock quality is less than perfect, spread the anchors out, using several features, to preserve redundancy. Don't put all your eggs in one basket. Try to make the placement closest to you (first to be loaded in event of an upward pull) multidirectional by using an SLCD if possible.

Remember you want an efficient anchor, not simply one that will bear the most impact. The placements should be straightforward to place and remove and should be as centrally located as possible—a nice, tight grouping, as opposed to an entangling web of tackle crisscrossing the station.

Personally, I like to place a minimum of four pieces: three in the downward direction and if the situation requires, one upward placement opposing the primary anchor. Sometimes three are enough, and sometimes that's all you'll get. Anything less is a crapshoot. And accept that sometimes you'll be shooting craps. The rock will not always afford instant and bomber belay anchors. You sometimes have to work at getting anything approaching "good enough."

Once the primary placements are set, you must connect the various components together so they function as one unit. This is often the most critical, and difficult, part of the whole procedure. Several possibilities exist for connecting the



Doubled carabiners should always have the gates opposite and opposed.

1. The wrong way. Even if one of the carabiners is flipped over so the gates are on opposite sides, the gates are still not technically opposed.

2. The right way. Even if one of the biners flipped over and the gates were on the same side, the direction they open would still be in opposition.

anchors, a topic we'll exhaust shortly. For now remember that, if possible, the belayer's body should remain in line between the anchors and the anticipated direction of pull.

Those are the basics. Let's dig into the particulars.

TYING INTO THE BELAY ANCHOR

The standard method of tying into the anchor is via a figure eight on a bight clipped into the *power point* (see upcoming text) with a locking biner, or two biners with the gates opposed. Once a team gets established on a multipitch climb, however, the method of tying in depends on at least two factors: (1) the number of climbers on the team, and (2) whether or not more than one person is doing the leading.

Out in the field you'll see folks tying into the power point with a single clove hitch, two clove hitches, a clove hitch and a figure eight (to multiple power points), a daisy chain, a sling or two or three, an adjustable link of rope and a Ropeman ascender, and countless other methods. Many of these techniques are as sketchy as a felon on bail, none so much as attaching yourself with a daisy chain, which creates a static connection that sacrifices the considerable strength, give and flex offered by tying in with the dynamic climbing rope.

The aim of establishing a protocol on tying in is to facilitate the smooth and secure transition from climbing to belaying to climbing again. If, for instance, a two-person party is swinging leads, the process is fairly straightforward. If you are a three-person party with one person doing the leading, or if the leading and the following is done in no particular order, the belay can quickly become a hateful mess if you don't have a simple and reliable system for tying into the anchor. There are no hard and fast, standardized methods in this work because the configuration of belays is so varied. It will take practice to come up with your own efficient system. There are, however, some basic strategies that work in most instances.

One good strategy is to back up your connection. If you tie into the power point with a clove hitch, tie into another point of the anchor with a figure eight on a bight. The most bomber piece is a good choice for this backup. If you're using a cordelette to connect the anchor pieces, another potential backup point is the "shelf" of the cordelette, which is the point right *above* the power point. This "shelf" also offers an alternative clip-in spot for whoever is leading the next pitch in a group of three or more. The practice results in one less tie-in at the power point, thereby opening it up for others to clip in, and it allows the leader to quickly unclip and take off on the next pitch.

The Enigma of Factor 2 Falls

As we've learned, lab drop tests determined that a factor 2 fall creates the greatest force that can ever be put on a roped safety system. Though we've seen that a real world factor 2 fall generates forces that are less than those registered in the lab drop test, the party line remains the same: If a belay cannot sustain a factor 2 fall, it is not "good enough." And yet the *vast* majority of the most experienced climbers on the planet have little direct experience with a worst-case scenario, factor 2 fall.

American climber and mathematics professor Richard Goldstone puts it this way: "My sense is that circumstances severe enough to result in total anchor failure have happened in the field to no more than a handful of climbers during the nearly forty-nine years I've been climbing." Craig Connally says the same thing another way: "The reason there's so much screwy advice about falls and anchor building is that the roped safety system hardly ever gets stressed to its limits."

If traditional wisdom insists that we build belay anchors to sustain a factor 2 fall, and precious few of our anchors have ever sustained anything close to such loading, on what real world experiences and on what hard information are we basing our recommendations?

While there is a glaring lack of definitive information about real world anchors, this lack is somewhat countered by field testing carried out by millions of climbers annually. Unfortunately for our discussion, but fortunately for climbers, the bulk of this field testing entails fall forces in the factor .3 to .5 range. Better to have a large, controlled database on factor 2 falls that could tell us what techniques worked and what did not so we could base our recommendations on that data. As it stands, we must draw our information from a different, and admittedly, shallower well. That said, we were able to initiate an extensive series of lab tests specifically for this book, and the test results yielded invaluable information about rigging systems. This is only a start, however. Many more tests by many more people are required to wrestle with this very slippery subject.

Spreading the Load

A fall generates forces, and you want the impact of those forces equalized over and absorbed throughout the entire anchor matrix. A wise stockbroker has a broad portfolio. He doesn't toss all his dough into a single fund, no matter how blue the chip. Same thing with belay anchors. We spread the load over several sound primary placements and reduce the possibility that the whole matrix will fail. And that is, and always will be, the primary function of a belay anchor—to hold no matter what.

We've all had pro rip out; some of us have had two points of pro rip out. But it's unlikely you will ever read about a failed anchor that was set in good rock, well-equalized, redundant and fashioned to absorb loading in the direction of the pull. Three or four bomber nuts and SLCDs, judiciously equalized and set in good rock, simply are not going to fail no matter how far a leader might fall on them. Let's make no mistake about it: A leader can generate only so much impact force, and a viable anchor can readily sustain it.

By using oppositional elements in the anchor (if required) and properly equalizing them to the primary, bombproof anchors, the anchor becomes **multidirectional.** You can yank and tug and fall on it from many angles and that baby will still hold. Again, that's the bottom line with a belay anchor—it must hold, no matter what.

While we have stressed the critical importance of getting a secure placement just off the belay—the Jesus Nut—and have clarified that the top placement always sustains the highest loading during a fall, we nevertheless strive to build our anchors to sustain that worst-case scenario fall because if all our pro rips out, we still have a strong and secure anchor to save the day.

But it's a plain fact: No matter how superb the rigging, we almost never attain uniform equalization between primary placements in the anchor matrix. At best we achieve a somewhat even distribution of loading. Knowing that equalization is a relative term does not keep us from striving to build belay anchors with the following features:

- Distributes the load as evenly as possible between the component parts of the anchor system
- Has a minimum of slack between the various tie-in points
- Uses a rigging method and/or multidirectional components capable of self-adjusting, or automatically redistributing the load as the loading direction changes (say, as the belayer shifts position, or the belayed climber pitches off and swings, or if the belayer gets yanked upward)
- Can withstand the greatest load a leader can place upon it

STATIC AND AUTOMATIC EQUALIZATION SYSTEMS

There are two kinds of equalizing systems: static, pseudo-equalizing systems (also called pre-equalized systems) and automatic (dynamic or self-adjusting) systems. The following pages, photos and commentary explore these systems in detail, but to start out, understand these short definitions:

- A **static** equalizing system refers to a grouping of nuts, pitons, bolts, etc., which are tied off together with no slack or adjustability in the system. For example, if we have four nuts in a line and tie them all off with a cordelette, the impact force will, to some degree, get distributed over all four nuts. Realistically, this system provides imperfect equalization, so one of the anchors—the anchor connected to the shortest arm of the rigging system—is inevitably sustaining most of the load.
- An **automatic** equalizing (dynamic/self-adjusting) system employs various sling configurations between the anchors so all pieces share, to greater or lesser degrees, any applied load, even if the loading direction changes. The use of

limiter knots to reduce extension on sliding X configurations creates something of a hybrid anchor between automatic and static equalization, but for the purposes of this book, we will consider those anchors to be part of this category. Sometimes belay anchors feature a combination of automatic and static equalizing constructs. For instance, you might end up with several pairings of nuts equalized with the sliding X, these being lashed together with a cordelette or an equalette to create a complete system.

Modern Rigging Trends

For many years most climbers tied directly into a belay anchor with the lead rope. The rope tie-in was considered the quickest, simplest and least gear-intensive method, and was used ten to one over all other setups. About fifteen years ago the cordelette was invented to spread the load quickly and somewhat evenly between two bomber bolts on sport-climb belay anchors. Over time the cordelette became a popular rigging technique for trad climbing. The notion was to maximize the overall strength of the anchor system, while reducing the belay switch-over time if one climber was leading all of the pitches, or if the party had three or more climbers.

As popular as the cordelette is, recent testing has shown that it does not achieve an acceptable level of equalization when the arms of the system are of unequal lengths. While the cordelette remains a viable rigging system in the equal-arm configuration (connecting two—and only two—placements), the equalette is looking good in both the lab and the field, and it appears to be a logical option when the arms of the rigging system are of unequal length, and even when they are not.

Another rigging method, built on the sliding X, is also a primary rigging strategy. More recently, climbers have started integrating both the cordelette and the sliding X into an anchor matrix. For example, you might equalize several placements with the sliding X, then use the cordelette to statically equalize the power point.

Because the cordelette, sliding X and equalette are primary rigging techniques, it's essential to understand the pros and cons of each. It is here, in this critical discussion, that the SRENE criteria jump to full life, for only when applied can the concepts be made clear. The reason for having started with a discussion of climbing forces (and direction of pull) is to help you make these what-if analyses more concrete. And it's pretty much what-if from here on out.

When to Use What

Trying to establish when to use the equalette, sliding X or cordelette is a slippery business. Recent lab testing has helped establish performance parameters of these

This photo shows decent technique for tying into an anchor the old fashioned way, directly with a rope, which might be necessary if you're short on gear or in some sort of emergency situation. An SLCD and hexentric are tied off tight with clove hitches to a backup SLCD above. The lower SLCD is set as an oppositional piece to hold an upward pull. The belayer is tied into the strand of the rope coming down on the left side of the photo, which will minimize extension if the lowest piece fails. Note that the load strands of the clove hitches are cinched nice and tight, with no strands on the gate of the biner. You might consider belaying the second through a biner connected to one of the upper pieces, especially if you're expecting someone to struggle and hang on the rope.

systems, as opposed to the "traditional wisdom" (oftentimes wrong) that guided our choices in the past. Let's first look at the cordelette, the mother of all rigging methods for more than a decade.

CORDELETTES

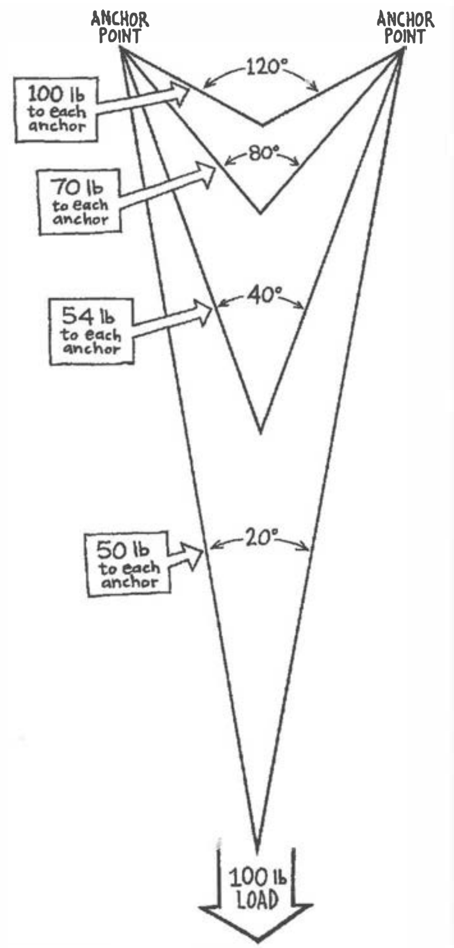
Until recent testing showed its shortcomings, a cordelette was generally used to distribute the load between two, three or four (rare) primary placements in a belay anchor. The cordelette minimizes the number of carabiners, slings and quickdraws required to connect the placements in an anchor matrix (unless you just use the rope), thereby justifying its size and weight. A standard cordelette consists of an 18-foot piece of 5.5mm high-tensile cord or 7mm nylon and has been commonly used by guides to create a single point for connecting clients to all the individual anchors of a belay or as a toprope anchor system.

The cordelette is tied into a loop with a triple fisherman's knot (if using high-tensile cord) or a double fisherman's knot (if using nylon cord) and clipped into each of the primary anchors. A loop of the cord is then pulled down between each of the primary pieces. If you have three pieces in your belay anchor, you'll get three loops that must then be pulled tight toward the anticipated loading direction (direction of pull). As a statically equalized system, the cordelette is designed to withstand forces in a specific direction of pull, and that direction must remain constant or the effectiveness of the cordelette is greatly compromised. In short, rigging the cordelette in the direction of anticipated loading is absolutely vital.

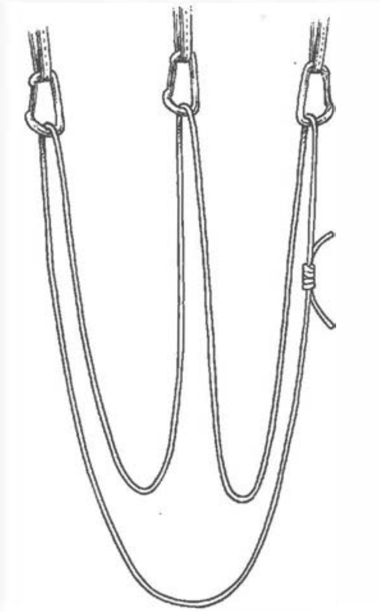
Align the fisherman's knot in the cordelette so it is below the highest piece in the matrix, which keeps the bulky fisherman's knot from interfering with the power point knot—a common mistake for beginners. Next, tie an overhand knot, or if you have enough cord, a figure eight knot, near the tie-in point. Clipping a biner in at this point greatly facilitates tying the knot with nice, equal loops. Tie the power point loop about 4 inches in diameter, roughly the same size as the belay loop on your harness. The cordelette has now formed three separate, redundant loops that offer no extension if one of the primary placements fails.

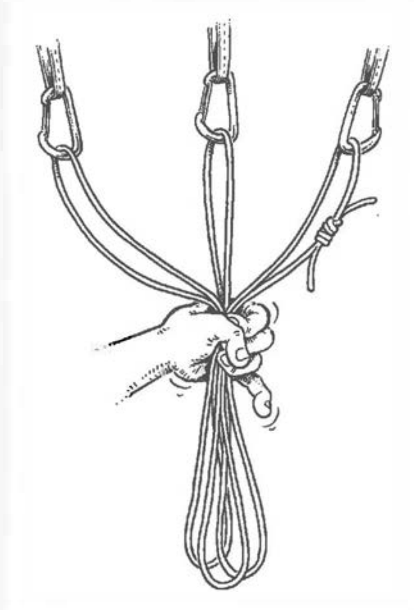
The problem with this configuration is the issue of equalization. Lab tests clearly show that unless the cordelette is configured with perfectly equal-length arms it does not achieve a remotely adequate degree of equalization between the primary placements. Instead the bulk of any loading is absorbed by the shortest arm in the system. Hence the cordelette works best in those situations where it can be configured with equal-length arms and connected to side-by-side placements (such as bolts atop a sport climb), and also where the direction of pull remains a constant—straight up and straight down.

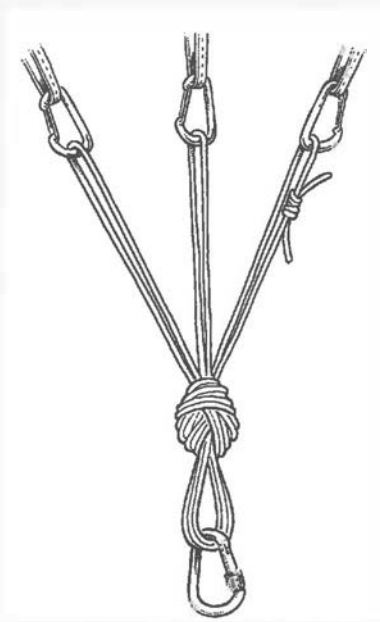
Always connect yourself to the rigging system with a small



How a 100-pound load is distributed between two anchors rigged at various angles. Whether rigging with a cordelette, equalette or sliding X, the forces on the primary placements increase significantly at greater angles.







The cordelette attaches multiple anchor points with a single, mostly static tie-in point. Remember to keep the fisherman's knot up out of the way like this. With equal-length arms and a predictable direction of pull (straight up or down), a cordelette like this is a viable anchor choice.

amount of climbing rope. This provides a more dynamic system and allows quick escape if need be. Always make sure the rope remains the primary attachment, owing to it's dynamic (stretch) properties. One disturbing, recent trend (and probably 90 percent of novice trad climbers do this) is to use a daisy chain for your attachment. This static connection—which daisy chain manufacturers warn against—precludes the climbing rope from acting as a shock absorber. In the double fatality on *The Step* at Tahquitz Rock, the belayer was attached to the cordelette with a small length of high-tensile cord, rather than with the main rope. Never do so.

In summary, when the primary placements of the belay anchor are of equal distance from the power point and bomber, and the direction of possible loading (pull) remains constant, a statically equalized setup like the cordelette is a viable choice.

Again, the biggest shortcoming of the cordelette—one that keeps some climbers from using the cordelette at all—is that it loses almost all, if not all, of its equalization properties if the loading direction changes. In short, a cordelette sacrifices equalization properties if it is impacted in a direction for which it is not rigged, and to a lesser degree, in the direction for which it was rigged. On most

A STANDARD CORDELETTE:

- Is a statically equalized system that is most effective when its arms are of equal length.
- Normally consists of an 18-foot piece of 7mm nylon cord (tied into a loop with a double fisherman's knot) or 5.5mm high-tensile cord (connected with a triple fisherman's knot).

TO RIG A CORDELETTE:

- Clip the cordelette into the primary anchors, then pull the loops of cord down between each of the pieces.
- Pull the arms of the cordelette tight toward the anticipated loading direction (direction of pull).
- Align the fisherman's knot so it is below the highest primary placement in the system, free and clear of the power point knot.
- Secure the power point with an overhand knot, or if you have enough cord, a figure eight knot. Tie the power point loop about 4 inches in diameter, roughly the same size as the belay loop on your harness.
- Clip into the power point with a section of the climbing rope, not with a daisy chain or other device made of high-tensile cord.

Belay anchor with three SLCDs tied off with a cordelette. The granite is sound, and all three cams are bomber, well retracted (over 50 percent), with all the cams nicely contacting the walls of the crack. The rope is attached to the power point with two carabiners opposed and reversed (including one locking). Clean, simple and strong. The bottom cam means this anchor could also withstand an upward force.

As our cordelette discussion points out, load equalization over placements set in a vertical crack is much more a concept than a fact. Here the bulk of direct, downward loading will fall on the middle SLCD.

climbs, however, the possible directions of loading are obvious and constant—most often they are pretty much up and down. So to safeguard against a lateral direction of pull when ascending a soaring crack, where lateral forces cannot occur, is to account for theoretical concerns, not real ones.

Limitations? Absolutely. But so long as you understand and work with them, the cordelette works well enough to remain popular. With practice, rigging anchors with cordelettes becomes quick and straightforward.

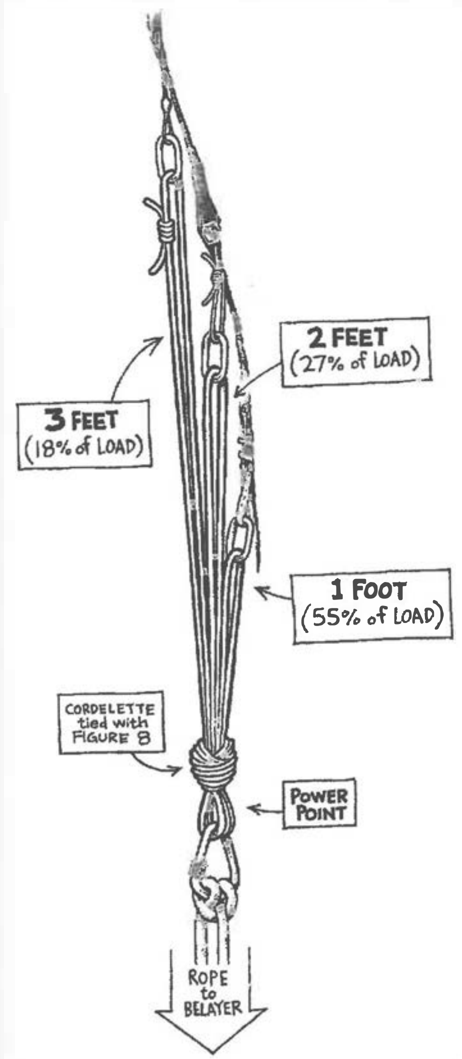
Cordelettes and Equalization—an Example

Because the cordelette was for many years a favored rigging strategy and because we are now suggesting otherwise in many situations, it is worthwhile to understand the entire picture. You will certainly hear strong recommendations for using the cordelette in all circumstances, especially from those not privy to recent test results and the theoretical discussion that follows.

Professor Richard Goldstone has over the years taken a studied look at some basic assumptions per anchoring mechanics. In the following paraphrased abstract, he presents a theoretical analysis (which testing later confirmed) from which the cordelette may never recover it's reputation for equalization. He wrote:

Imagine three primary placements in a vertical crack connected and "equalized" by a cordelette. In this common setup, providing the three arms of the cordelette are equally tensioned, many climbers assume that any loading is distributed equally between the three placements. However, this assumption is not true in general and may not even be approximately true in simple cases.

Consider the mechanism by which the cordelette transmits forces to the anchor points. When the power point is loaded, the arms of the cordelette stretch a little and the power point lowers relative to the amount of stretch. The tension in each cordelette arm is proportional to the relative stretch of the arms, and the relative stretch of different arms will, in general, be different.



Using a cordelette to connect anchors in a vertical crack results in an anchor that does not come close to truly equalizing the forces.

To picture this in action, return to our simple and quite prevalent case of three primary placements in a vertical line. Suppose that there is 1 foot from the power point to the lowest anchor, and that each of the two higher anchors is 1 foot above its predecessor. This means that the arms from

> the power point to the anchors are 1, 2 and 3 feet respectively. When loaded, the power point experiences a downward displacement of e feet (e will typically be a small fraction). The relative displacements are thus e, e/2, and e/3, which means the tension in the 2-foot arm is half the tension in the 1-foot arm, and the tension in the 3-foot arm is one-third the tension in the 1-foot arm. Put another way, the lowest placement takes about 55 percent of the load, the middle placement takes about 27 percent of the load, and the top placement takes about 18 percent of the load. Obviously this contradicts conventional wisdom about so-called anchor equalization, which holds that each anchor takes one-third of the load.

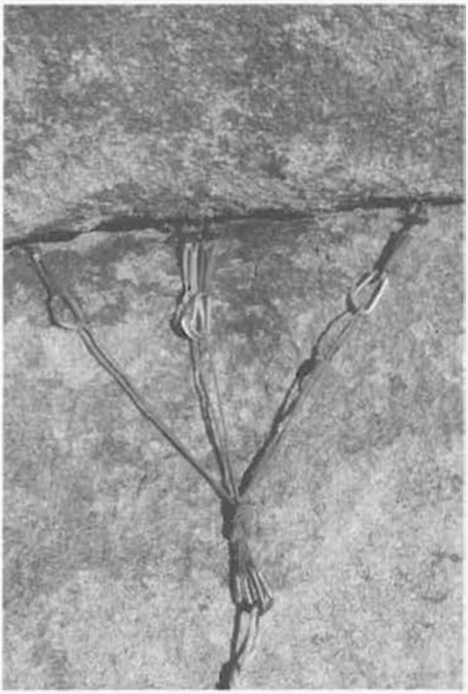
To summarize, Professor Goldstone is pointing out that when the arms of the cordelette are of different length, equalization is compromised by stretch in the arms, with the arm that stretches least in this case bearing better than half (55 percent) of the load. When tested, the cordelette proved to equalize less proficiently than even Professor Goldstone surmised, which is why the cordelette can no longer be recommended for its equalization properties when the arms are of unequal length.

Off-Axis Loading on Cordelettes

So far our examples assume that loading will come from directly below the power point, which gives the cordelette its best chance of equalizing the load evenly between the arms. What happens, then, with load angle changes, when the direction of pull comes from 5 or 10 degrees off the vertical axis? To visualize the vectors involved, consider this paraphrased explanation of Dr. D. F. Merchant, from his excellent cave rescue treatise, *Life on a Line*.

> Whenever you combine two anchors to a single power point (as you do with a cordelette) there will be an angle between them. The smaller this angle, the smaller the load on each anchor when a direct download is applied to the power point. If your load pulls outside the angle of your anchors, at least one connection (arm of the cordelette) will be slack, bearing little to no load, with the other connection taut to the load-bearing placement. If your load comes from a fixed direction, minimizing the angle between your anchors is the main aim. If you need a range of motion, then making sure your anchors stay loaded is a compromise against minimizing the angles.

This underscores the fact that with the cordelette, there is only one load angle where force is distributed—in varying percentages—to the anchor pieces. When



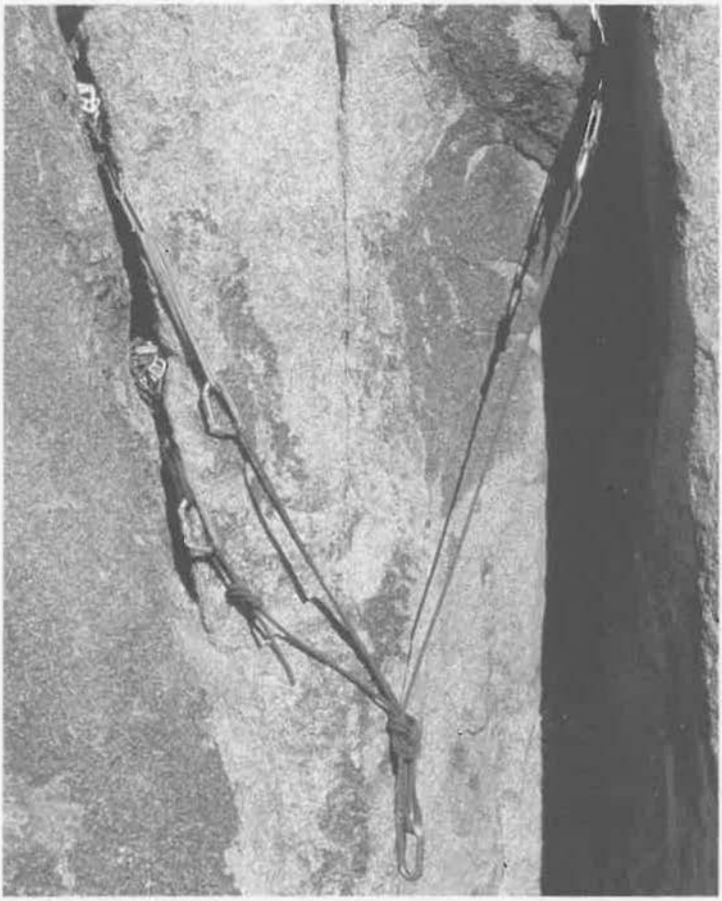
Four camming devices in a horizontal crack connected with a cordelette. Note how the fisherman's knot (on the cordelette) is rigged well out of the way. As with all statically equalized anchors, the setup is set for a single direction of pull. Even the slightest oblique angle of pull will load one side of the triangle while the other side will bear little if any load. Stretchy nylon cord is more forgiving in this regard, but off-axis loading will still weight one of the placements over the others. However, because the arms of the cordelette are of equal length here, climbers can expect to achieve some equalization as long as the direction of pull is straight down.

we stray even a few degrees off the loading axis, meaning the direction of pull impacts the cordelette from a different angle than that for which it was rigged, the off-axis loading will tension the left or right arm of the cordelette, which will then bear the brunt, if not all, of the load.

In *The Mountaineering Handbook*, Craig Connally gives a simple numerical example: "Consider a two-placement setup where the legs join at a 30-degree angle. If the load is off the precise balancing direction by 10 degrees, one anchor will take three times the force of the other."

If this off-axis load exceeds the max load of each primary protection point, the pieces will fail in succession—the ghastly cascade failure—as the force shock loads from one arm to the next. If the off-axis loading does not exceed the max strength of the primary protection points, redundancy here applies only as a backup since the load will be held by one piece, not the two or three for which the cordelette was rigged in the first place. (This is not meant to discount the importance of redundancy, which would obviously be critical if the primary load-bearing piece were to fail.)

This brings us back to the matter of stretch in the arms of the cordelette. Specifically, can the stretch of the arms provide some off-axis load sharing? And if



This cordelette has been unknotted and used in the "Web-o-lette" mode. This is a trick adopted by many professional guides to add greater utility to their cordelette. When untied, the cord works well for connecting three points when a standard cordelette, describing a single loop, would be too short. Simply tie the ends with figure eights, clip into the two outside anchor points in a V configuration, take the middle bight and clip it into a third point. Then gather the two bights together and tie a two-loop power point with a figure eight.

In this particular setup, all three camming devices are bomber, and the granite sound. Notice the upper left camming device has a sling looped through in the "basket" mode, to prevent the carabiner from grinding on the edge of the crack. The lower left camming device has a locking carabiner to prevent the gate opening on the crack edge, and a slight improvement here would be to do the same at the upper right cam. While there is some loss of strength in those arms of the cordelette with a single strand, this rig—based on bomber primary placements—is a trade off most climbers can live with.

As is always the case with such setups, this is rigged for a downward pull, and any oblique loading will put the load on one of the other three primary placements. Also, because the arms of the cordelette are of unequal length, true equalization is not achieved.

so, to what extent would the stretch increase the ability of the cordelette to more evenly distribute the load over three pieces placed in a vertical axis as well as increase the loading axis when the primary placements are on a horizontal or slanting axis?

So far we've see that the random changes in the cordelette's arm length may well result in limited initial loading on at least one primary placement as the anchor matrix is loaded and the stretching process begins. If high-tensile cord (an almost static material) is used, then it is possible that at least one anchor will never be loaded unless there is a failure in the others.

This means that Professor Goldstone's example (three placements in a vertical crack), where the long arm of a cordelette absorbs 18 percent of the load, could be a high estimate. "In fact," writes Goldstone, "my suspicion is that for many anchors with three or more pieces in any configuration, it is quite possible that nearly all the load will be imparted to a single anchor, even if the load comes from the expected direction."

The fact is that any static equalization setup is more realistically an example of redundancy than an example of equalization. We should always keep that in mind when we're building an anchor with a cordelette. Other valuable feedback comes from Jim Ewing, the quality control manager for Sterling Ropes, who noted during testing that low-stretch high-tensile cord always weighted one leg first, which failed, then the next leg, which failed, then finally the last leg, which failed.

Bottom line:

1. A no-extension anchor (including the cordelette) is a distributed anchor, not an equalized one, and it is possible that at least one of the anchor pieces will experience little or no load (unless others fail).
2. The ability to distribute forces to all anchors is increased by the use of stretchier material, a strong endorsement for using a 7mm nylon (nylon) for any rigging system.

Point 2 is commonly trotted out by those recommending the cordelette for all anchoring setups. They claim that cord stretch provides off-axis load sharing, and it might somewhat, but the question becomes this: What available material provides the ratio of stretch best suited to promote load sharing on a shock-loaded cordelette? An answer comes again from Jim Ewing at Sterling Ropes, who tested two cordelette setups (hand tied), one with high-tensile cord, the other with low-tech nylon (nylon). In these tests the nylon always won. The stretchy nylon not only won, it provided a much more dynamic system, something mostly lost on a cordelette rigged with comparatively static high-tensile cord.

HIGH-TENSILE CORD VS. NYLON

For those interested in the actual figures of the Sterling tests, the high-tensile cord failed at 5,000+ pounds, with nylon holding strong to roughly 7,000 pounds, even though it's rated to only 2,500 pounds. Note that the 7,000-pound mark was attained because loops of nylon have a doubling effect in their capacity (a looped leg of 2,500-pound test fails close to 5,000 pounds, while a looped leg of high-tensile cord still fails at 5,000 pounds, not 10,000 as you would expect). In the widely reviewed Moyer study (see below), the high-tensile cord in both the weak and strong arm failed at just over 4,000 pounds.

This article is definitely worth reviewing:

2000 International Technical Rescue Symposium: "Comparative Strength of High-Strength Cord" by Tom Moyer, Paul Tusting and Chris Harmston

(Chris Harmston was quality assurance manager at Black Diamond)

www.xmission.com/~tmoyer/testing

THE SLIDING X

With the advent of the sliding X (aka crossed sling, magic X), the concept of dynamic equalization was born. To most every trad climber's relief, the sliding X apparently resolved two long-standing concerns: (1) how to achieve maximum equalization between two primary pieces of protection, and (2) how to safeguard against changes in the direction of loading. Functionally effective within a wide axis, the sliding X can be loaded from various directions, and the "X" will dynamically shift to help distribute the force between two pieces.

Rigging the Sliding X

The sliding X is simple to construct, but a proper twist in the sliding X sling is essential. When you bungle twisting the X into the sling, the sliding X is totally useless if one placement fails. To confirm proper rigging after connecting the sliding X to the placements, simply clip a biner into the X, weight the placements and slide the biner back and forth along the sling to ensure fluid and stately functioning.

The sliding X provides true automatic equalization; the drawback is that it can allow extension in the system if the slings are long and one of the anchors fails. To minimize the potential extension in longer slings, tie an overhand "limiter" knot in the long leg of the sling, just above the tie-in point. (Keep in mind that this limiter knot, while it reduces the possibility for extension, also by its very nature limits the equalization properties of the sliding X.) Make sure the angle between the two legs of the sling is not too large. If the angle is larger than about 45 degrees, use a longer sling to decrease the angle and avoid load multiplication. An angle of about 25 degrees, as shown in the sliding X drawing, works well.

While it's an ingenious, simple and effective rigging method, the main concern is that the sliding X violates the No Extension criteria of SRENE. Put simply, the sliding X is used to connect two primary placements. If one of the two primary anchors should blow when loaded, the force would "extend" or drop onto the remaining placement equidistant to the slack in the sling. The concern is that the force dumping onto the second piece might possibly produce cascade zippering of the remaining pieces of the anchor. The possibility of this has always remained a black mark against the sliding X, but Craig Connally (along with recent testing) largely disproved the prevailing paranoia about the minimal extension (with the limiter knots) possibilities with the sliding X.

Basically Connally explains that true shock loading cannot occur. Mirroring recent testing done by Duane Raleigh at *Rock & Ice* magazine, he provides the example of a climber who clips to an anchor with a Spectra daisy chain, climbs a few feet past the anchor, then falls. The Spectra daisy means there's no energy-

The sliding X equalizes an anchor dynamically when the load changes directions

absorbing rope in the system, Connally says, "and forces rise incalculably high. In real-life situations where this has happened, hardware has broken and climbers have fallen to their deaths." That's true shock loading. But in the case of moderate extension found in the failed arm of a sliding X anchor, the aforementioned shock loading does not occur if there's dynamic rope in the system. An example would be to picture a climber hanging on 10 feet of rope. A placement blows and drops him a foot. Disaster? Unlikely, since that amounts to a fall factor 0.1, which is less than the average of around 0.3 for most climbing falls. Granted, you avoid building anchors that could result in really long extension, but there's little cause to fear ordinary setups.

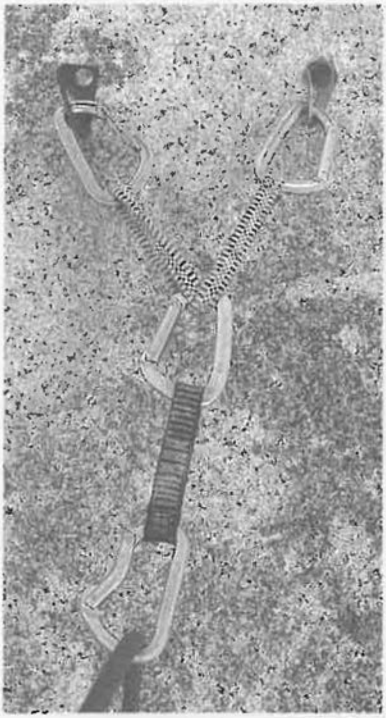
SLIDING X BASICS:

- The sliding X is an automatic equalizing system.
- It is normally rigged on standard length and/or double-length sewn slings.
- A proper twist in the sliding X sling is essential to prevent failure of the complete system if one piece pulls. Always double-check to be sure that this twist is in place.
- After connecting the sliding X to the placements, clip a biner into the X, weight the placements and slide the biner back and forth along the sling to ensure fluid functioning.
- To minimize potential extension in longer equalizing slings, tie an overhand limiter knot in the long leg of the sling, just above the tie-in point.
- To avoid load multiplication, keep the angle between the two legs around 25 degrees (or less). If the angle is larger than about 45 degrees, use a longer sling to decrease the angle.

Sliding X: Normal Usage

Let's look closely at how the sliding X is normally engaged and draw some rules of thumb for general usage.

With solid, two-bolt anchors on multipitch sport climbs (where the issue of extension is diminished and the scale tips toward equalization or redundancy), setup is quick and easy. Plus, the sliding X saves having to leave two draws at the anchor. And for anchors placed in non-horizontal orientations—say, two cams in a slanting crack—the sliding X can connect the pair so they are largely equalized while providing vastly more multidirectional capacities than if you were to tie the same two pieces together with either a cordelette or with knots tensioned in a sling. In fact, whenever you wish to dynamically distribute the load between two pieces, the sliding X is both effective and the best-known method.



A sliding X connecting two bolts. This self-equalizing technique can be used when leading if the need arises to spread potential loading over two sketchy bolts placed close together, or two marginal pieces of gear

A three-piece anchor equalized with sliding X's. The lower sling has been doubled to adjust the location of the power point.

The sliding X is also effective for equalizing pieces on lead, especially when doubling up small or sketchy nuts, when it is desirable to get load distribution over both pieces. Likewise when arranging protection before a traverse, or after a traverse, when the route goes abruptly up, the sliding X is a blessing, equalizing marginal pieces so they reinforce each other across a multidirectional range. The possibility of extension (small with limiter knots) here is eclipsed for ease of setup when out on the sharp end.

A leader will also find the sliding X useful as a power point on multipitch routes. For instance, at the end of a lead, if you gain a ledge and need to move around, the sliding X will always keep tension on the anchor and retain equalization.

Occasionally the "X" in the configuration can bind on itself (the so-called "clutch effect"). A simple and test-proven solution is to rig the power point with one or two

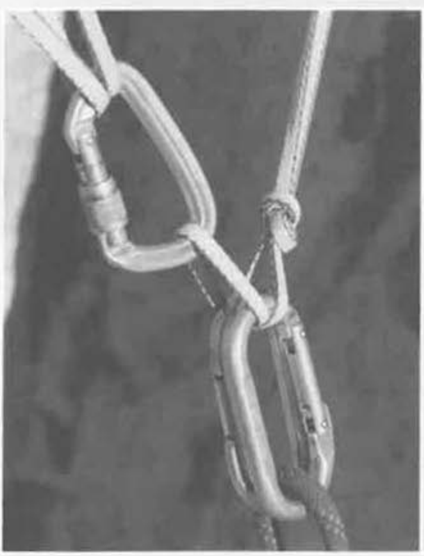
Here we have a pre-equalized anchor. meaning no self-equalizing sliding X is used. The primary placements are tied with Dyneema slings, shortened and pre-equalized by tying limiter knots. This anchor is rigged for a downward pull only. The equalization looks tight, and even though it's impossible to achieve the best equalization with such a static system, this anchor could easily hold two tons. Once loaded, however, even under body weight, those thin slings will be *very* difficult to unknot, particularly at the overhand knots.

pear-shaped anodized biners. This eliminates the clutch effect and allows the X to slide freely on the sling, enhancing equalization.

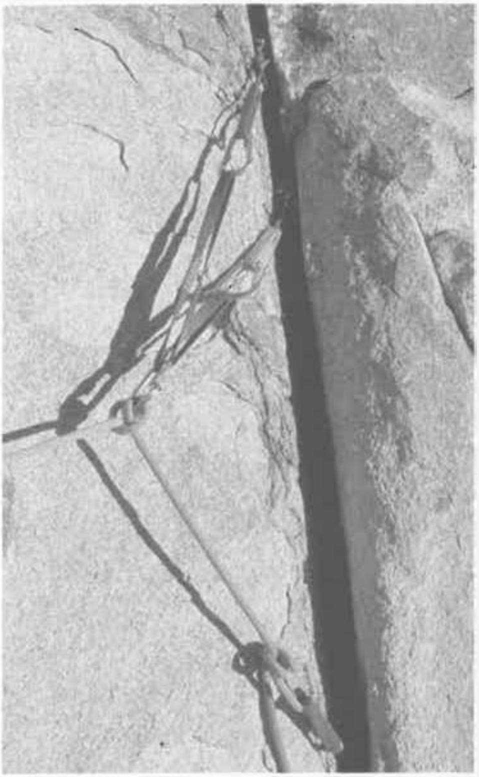
Good, Bad and Both

What pairs of placements are best exploited by the sliding X, and which placements, if any, call for a different rigging strategy? Placement quality spans a wide spectrum, but there are three basic pairings: (1) two good primary placements,

Here we have the same anchor as shown on the previous page, except now the three pieces are self-equalized with two sliding X knots. Unlike the previous anchor, if the load angle changes on this set up, the anchor will remain equalized. The limiter knot tied into the right-hand sling just above the power point will limit extension if the right piece should fail. However, the knot also serves to limit the equalization potential of this anchor—as with every set up, compromises are part of the deal.



Close-up of previous photo. An overhand limiter knot is tied on the right side of the sliding knot to check extension if the piece should fail.



Three camming devices equalized with a sliding X and clove hitches. This is a good belay anchor rig for a multipitch climb, providing the two climbers are swinging leads. Since there is no power point, climbers swapping leads at this belay stance will require the arriving climber to also rig his rope in this fashion. No big deal, but a bit more time consuming, and a real cluster if there were a third climber at this stance. If one of the two CDs on top were to blow out, there would be sudden loading on the remaining anchor, but judging by the placements (A-1), this would be nearly impossible, even in a factor 2 fall situation, as the downward force would be shared by the two cams, and the force required to break the sling would be astronomical.

(2) two bad placements, and (3) one good and one bad placement.

With poor (i.e., weak) placements, the concern is that a fall could blow out the anchor point, so equalization becomes a priority. The aim is to reduce the initial loading on the stacked (doubled up), weak placements by distributing the load as equally as possible over both pieces. Here, extension is of less concern than maximizing the potential holding strength of the anchor point to the extent that it will actually hold. Clearly two sketchy placements are better than one. And since the sliding X is the best thing going for equalizing two placements—especially with the use of limiter knots—it remains for many the strategy of choice when rigging together stacked, sketchy placements.

Most climbers in the no-extension camp avoid the sliding X unless the primary placements are bomber. When the placements are mediocre to poor, many will statically equalize using overhand knots on a sling, a method that testing has shown to yield little—if any—equalization between pieces. It should be noted that the general anchor preference for those in the no-extension camp is Redundancy

Same anchor as previous page, now rigged to be entirely self-equalizing. An overhand limiter knot tied on the left side of the upper sling (configured in a sliding X) would limit extension if the top cam failed. This rig, in turn, is equalized with two slings paired up and attached (via a sliding X) to the lower piece, to safeguard against an upward/outward pull on the anchor.

Deceptively clean, simple and effective, it normally takes a leader some time to A) survey a given belay and quickly decide upon such a system, and B) quickly and efficiently rig same. While its utility has been proven over several decades, initial work with the sliding X is sometimes confusing. Ultimately there are but a few tricks to using the sliding X, including the limiter knots to reduce extension. Much of the process is simplified once you can quickly determine what sized slings are needed for a given setup, as well as your ability to shorten the slings as needed. Using, or trying to use, oversize slings—which adds needless slack in the system—is a common error when first employing the sliding X. As with all anchor building, confidence and efficiency comes with practice.

and Approximate Equalization with No Extension. For those less concerned about extension, it's better to dynamically equalize the load on the gear (using the sliding X) in an effort to prevent failure than to anticipate failure and mitigate the consequence of extension. Using limiter knots to minimize extension in a sliding X is a solution that could possibly appease both camps, but as yet, it has not.

Changes in the Direction of Pull

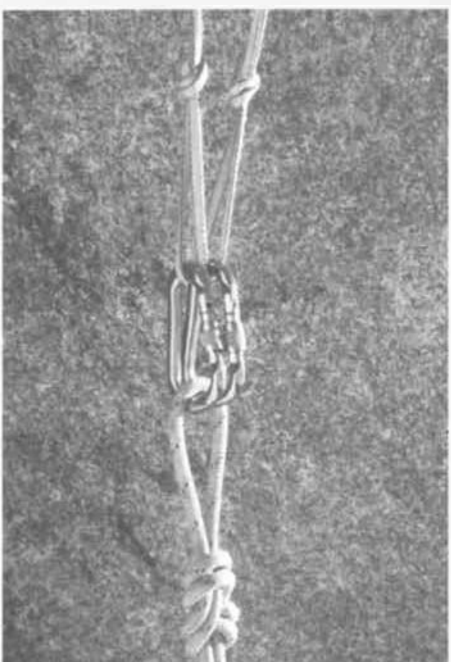
Although this was covered in earlier chapters, it's worth repeating: Every climber having to hand build a belay anchor on a route that traverses left or right directly off the belay faces a particularly challenging situation. Pitons, fixed pins and (to a lesser degree) SLCDs are all multidirectional, but everything else is unidirectional, so any multidirectional capacities must be provided by the rigging.

Consider, for example, a belay anchor where the leader traverses 10 feet right, places a nut and falls. Providing the protection holds, the direction of pull will come directly from the right. If the protection fails, or if the leader falls before placing the initial pro, the direction of pull will describe an arc. Much of the load comes when the leader's straight-down fall begins to be pulled into the arc, and it continues until he is in the fall line.

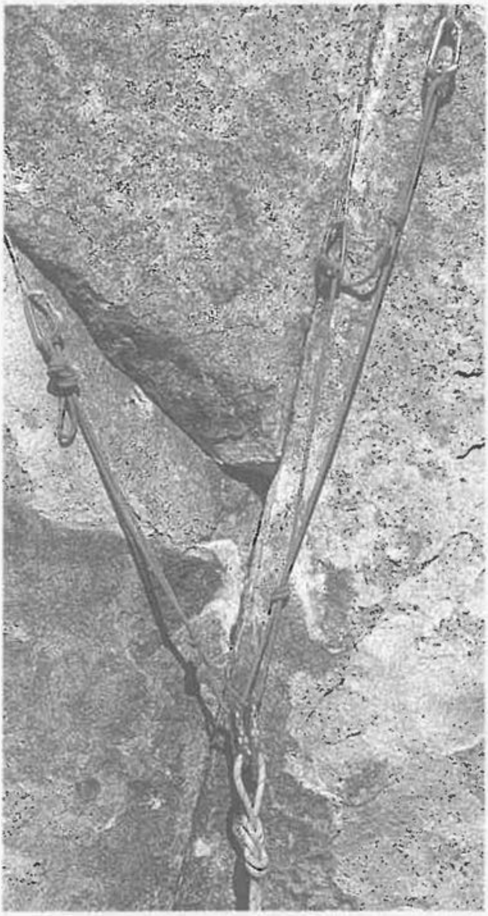
Here the challenge is to build an anchor that will safeguard dead lateral pull, the arc of the swing and the straight down loading once the leader's full weight slams onto the end of the rope. A statically equalized anchor can only cover this 90-degree arc at various points. At best the load will fall variously onto individual placements as the climber swings through the arc. A dynamically equalized anchor like the sliding X—alone, or as a component within a larger anchor matrix—can cover the entire arc insofar as the X slides as the vectors change.

THE EQUALETTE

The equalette was born out of lab tests conducted by Jim Ewing at Sterling Ropes. The system was rigorously field tested by professional guides Bob Gaines, Tom Cecil and others, who reported very favorable results. While only time can render the verdict on a rigging system, the equalette and quad (explained shortly) performed well in both the lab tests and in the field, and they are worth consideration as primary rigging tools.



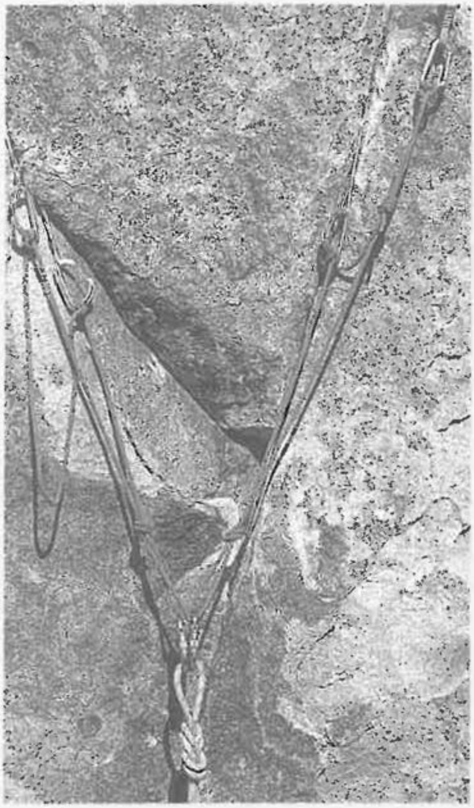
This close up of an equalette power point (tied using slings rather than cord) clearly shows how to rig two locking biners through the strands between the limiter knots. The belayer is tied into the power point with a figure eight knot. This set up will remain equalized if the load swings right or left, but if one anchor should fail, the limiter knots will minimize extension in the system.



Three-piece anchor rigged with an equalette. Not only solidly equalized but able to adjust to changes in loading direction

Three-piece anchor rigged with an equalette.

Basically an equalette is built on a cordelette, and field testing has suggested a 20-foot piece of 7mm nylon cord works well in situations ranging from multipitch ice climbs to trad multipitch setups to short sport routes. After the cord is connected with a double fisherman's knot, the loop is then formed into a U shape. At the bottom of the U, two limiter knots are tied approximately 10 inches apart, with the fisherman's knot situated just above one of the limiter knots. This keeps the fisherman's knot clear of the two-strand arms of the equalette that are used to tie off primary placements. For speed and efficiency the limiter knots are best left tied into the sling between usage.



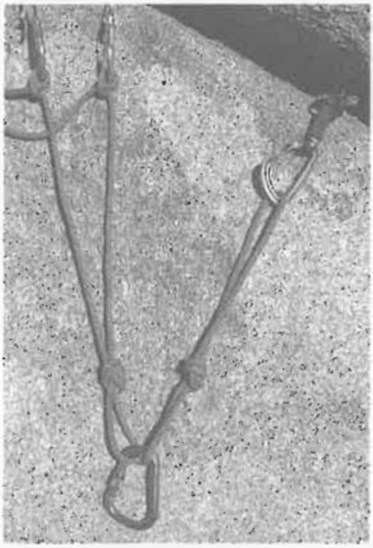
Four-piece equalette rig. Very simple and very stout.

A four-piece equalette rig. Four placements in a vertical crack usually result in a complicated and messy rigging system. Here everything is simple and clean, with good equalization between the two arms and some load sharing between the strands of each arm. While it is unrealistic to think any rigging system can equally load four placements, this equalette comes as close as you will likely get when using a single sling to connect four placements.

Between the two limiter knots are two strands; the power point is rigged by clipping two locking biners into the individual strands—one locker for each strand (see photos).

The equalette can be used to connect two, three or four primary placements and is especially effective in rigging vertically oriented placements, as found in a vertical crack. When rigging, keep the power point centered at the bottom by clipping the lowest placement first then working up the placements from there.

To start, hold the right-hand limiter knot 2 to 6 inches below your lowest piece. (When rigged, an equalette will always feature a right- and left-side orientation). Imagine you are starting by tying into the "right side" of the anchor. After clipping



Three-piece anchor connected with an equalette. This system is clean, simple and well equalized. When only using one locking biner at the power point, clip it through one strand, then twist the other strand 180 degrees and clip into it. The technique is the same as clipping into a sling to form a Sliding X.

into the piece or set of pieces on the right, hold the left-side limiter knot even with the first knot, and clip into the piece or pieces on the left. Adjust the strands so your knots end up evenly tensioned (clove hitches are very helpful there, if not required).

For a two-placement setup, connect each arm of the equalette to the placements via the loops in the cord, clove hitches or overhand knots on a bight. For three placements, one arm will accommodate two placements (usually with clove hitches tied into individual strands of the arms), and the other arm will connect to one placement (via the loop in the cord, a clove hitch or overhand on a bight). For connecting four placements, each strand (four total) of the two arms will connect the placements via the loop in the cord, clove hitches. Be sure the load-bearing strands align with the spine of the biner.

The equalette can also be rigged using a double-length sling, though you'll find the 7mm cordelette easier and more versatile to work with, especially when tying clove hitches. Plus you have the added benefit of the stretch in the nylon cord to reduce peak loading on the anchor system.

Tests show that the equalette allows nearly perfect equalization between the two arms, and it allows a ratio of equalization between both strands on each arm. While it is impossible (in a practical sense) to achieve perfect equalization between all four placements, the equalette achieves a degree of equalization—along with solid redundancy and very inconsequential extension—to a higher degree than any system tested.

Because the power point biners can slip side to side on the strands between the limiter knots, the system, when weighted, will dynamically equalize to accommodate a limited degree of off-axis loading. In those rare cases where horizontal forces can impact the belay, oppositional anchors are needed.

As with any new rigging system, it takes a few times working through a variety of anchors before you can rig the equalette quickly and efficiently. The hardest part of the system is getting used to feathering the knots to achieve equal tension in the arms and/or strands. But this is mastered quickly, making the equalette as fast to rig as the cordelette. And because you don't use as many knots with the equalette, breaking down the system is much faster than breaking down a cordelette.

Advantages of the Equalette

- It provides vastly superior equalization over the cordelette.
- If you pull considerably off-axis on an equalette, two arms remain equalized. With the cordelette, any off-axis loading results in only one strand or arm being loaded.
- It has increased versatility. Given the same length of cord (20 feet), an equalette

TYING THE EQUALETTE:

- Use 20 feet of 7mm nylon cord tied into a loop with a double fisherman's knot, or 5mm high-tensile cord tied with a triple fisherman's knot.
- Form a U shape and grab the cordelette at the bottom of the U.
- Position the fisherman's knot about 18 inches above the bottom of the U.
- Tie an overhand knot on each side of your palm where you have grabbed the cord, about 10 inches apart.

USING THE EQUALETTE:

- At the power point, always use two locking biners, with one locker connected into each separate strand of the power point (between the limiter knots). If you are forced to use one biner, clip one strand, twist the other 180 degrees, then clip the other strand to maintain redundancy. This is the same technique used to clip into a sliding X.
- Before using the equalette, make sure you have mastered the clove hitch.
- On multipitch climbs (with a two-climber team) where the first climber to the stance is going to lead the next pitch, each climber can clip into the power point with his own two locking biners. If the second climber to the stance is going to lead the next pitch, he can clip a locking biner directly into the two-locking-biner power point (biner to biner). This greatly facilitates secure and speedy turnover at the belay.

allows you to clip off four primary placements, whereas with the cordelette you can usually only clip off three.

- It is fast and easy to rig—and faster to break down—than a cordelette.
- The dual power point facilitates a fast and easy clip-in, even when weighted, resulting in smoother belay transitions.
- Clove hitches are faster and easier to untie than the overhand and figure eights used in other rigging systems
- By leaving the limiter knots fixed in the sling, you gain all the function without the tedious and time-consuming repetition of tying multiple overhand knots at each belay.

Limitations of the Equalette

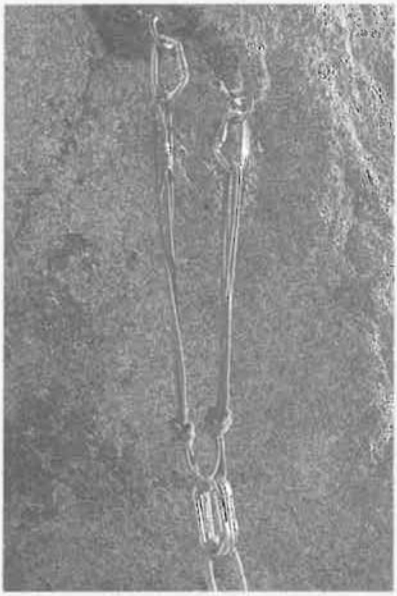
No rigging method is without its limitations, and one size, or one system, does not fit all circumstances. Initial experiences suggest that the equalette is quite versatile and user friendly, but several things should be kept in mind. While the two arms of the equalette achieve a remarkable degree of equalization, the equalization between the individual strands is less than the almost perfect equalization between the arms when the system is rigged to three or four placements. Also, too many clove hitches tied into small-diameter cord can twist the rope, so consider using a combination of knots when rigging three or more placements.

The Quad

The quad is simply a doubled equalette, resulting in a four-strand "super sling" that has proved peerless for use when belaying and/or toproping from two horizontally oriented (side-by-side) bolts. The quad is a specialty item that has limited practical use, but for those who toprope or belay off bolts, having a quad pre-rigged on a sling means you have a virtually indestructible, ready-made rigging system that almost perfectly equalizes two placements and is rigged as quickly as you can clip off four biners.

The quad is best rigged with 5.5mm high-tensile cord (for durability and compactness). First, form a loop by connecting a 20-foot piece of high-tensile cord with a triple fisherman's knot. Double that loop and form the doubled loop into a U. Tie permanent limiter knots, roughly 10 inches apart, in the bottom of the U (giving you four strands of cord between the two overhand limiter knots). Clip off the doubled ends of each arm to each bolt respectively, and arrange the power point via two lockers clipped into two or three strands between the limiter knots.

The quad is mega-strong and durable, and it provides great equalization, accommodates some off-axis loading and is almost instantaneous to rig. For connecting two side-by-side bolts, the quad is hard to beat.



Two-bolt "quad" rig for toprope setup. Lab testing suggests that for two horizontally oriented anchor points (as shown here), the quad setup is basically indestructible. Field testing suggests that for those who frequently belay from, or toprope off, two horizontally oriented bolts (as found on top of countless sport and toprope climbs), a quad rig is your best friend. Simply keep it rigged (with the limiter knots tied) on a piece of 7mm nylon, like this, or 5mm high-strength cord, and break it out for use in these situations. Brute strength and fantastic equalization are achieved just as quickly as you can clip off the bolts and the power point.

Quad rig close-up. At 5,000-pound test for each strand, clipping just two strands at the power point gives you twice the strength ever needed. Clip three and have a submarine anchor.

COMPOSITE ANCHORS: CORDELETTE, SLIDING X AND EQUALETTE

Before the Sterling Ropes tests (described later in this chapter), which redefined our use of the traditional cordelette rigging system, many climbers believed that the sliding X was best considered as a component and that the cordelette was the Whole Ball Game. In any event, because it is fast and requires nothing beyond a sling, the sliding X is the most efficient and flexible method of combining two primary placements to a cordelette, or better yet, an equalette.

In the traversing scenario mentioned earlier, a cordelette or knotted slings would be oriented for a vertical/downward pull. As has been shown, horizontal loading would variously fall on single placements, introducing greater loading/cascade failure potential. In the past it was here that we might have combined a sliding X with a cordelette so that if the leader fell from above the belay with no gear in, the whole anchor was equalized for a downward pull, but if the leader fell on the traverse, the two pieces connected by the sliding X would share the load. Now it seems that we have even more options, including an equalette, or an equalette combined with a sliding X, the latter configuration shorn up with one or more oppositionals set for upward forces, thus forming a super multidirectional anchor. Whatever system or combination you choose, safeguarding the full range of the arc is the goal.

Multi-pitch anchor with cordelette and sliding X combo. While this setup—and ones like it—have been a mainstay for many years, incorporating new techniques such as the equalette will allow climbers to achieve even greater equalization.

Another common composite-anchor situation occurs when a cordelette or equalette isn't long enough to equalize three pieces and remain pointed in the anticipated direction of pull. To fix this, simply equalize two of the pieces with a sliding X, then rig this with the cordelette or equalette to the third piece. In this situation it makes sense to use an equalette in place of a cordelette to achieve superior equalization.

WHAT'S BEST FOR BEGINNERS?

What, by and large, is the most appropriate system for beginners? Every instructor knows that beginners are sure to place sketchy gear (primary placements) and misjudge the direction of pull. For this reason we suggest a self-equalizing system that will adapt to changes in load direction and that will exploit the collective strength of less than textbook placements.

SRENE Anchors

- Solid
- Redundant
- Equalized
- No Extension

Guide Tom Cecil says, "It is more protective to teach self-equalization to beginners. Using self-equalization as a strategy is like using training wheels on a bike. They allow the beginner to lean in any direction and still be held. Over time they learn to anticipate these forces."

Bob Gaines, co-author and owner of Vertical Adventures guide service, sees it this way: "The key in teaching novices is to stress the absolute importance of avoiding factor 2 fall situations. They must be taught to recognize the forces and place pro (the Jesus Nut) soon and often above a belay. This helps ensure that the peak forces that novices encounter will occur at the highest piece of pro, not at the anchor. In most situations, when belayers are catching a leader fall, it is a good thing if the force generated by the falling leader is great enough to pull the belayer slightly upward, as the counterweight effect greatly reduces the force on the piece the leader has fallen on. *Therefore, the best belay strategy is to be anchored against the upward pull with a bit of slack in the system, which provides some counterbalance shock-absorbing, but not so much so that the belayer is pummeled into the wall or extruded through the Jesus Nut.*

"As far as toprope setups go, the direction of pull is basically straight down—easy to judge even by the novice. The biggest and most common mistake I see with novice riggers (aside from poor primary placements) is usually major extension potential and lack of redundancy."

UPWARD OPPOSITIONAL ANCHORS

As shown in various photos, for an anchor to sustain upward loading, we often place a nut or cam set for an upward pull, below and in opposition to the other primary placements in the anchor matrix. While upward forces at a belay are generally small compared to downward forces, I've repeatedly seen this opera play out in the gym: A belayer is grossly outweighed by some lug climbing on a toprope. From neglect or sloth the svelte belayer has foregone a ground anchor. Jumbo pitches off and the belayer is directly wrenched 5 to 20 feet into the air. I've witnessed belayers hoisted all the way to the top anchor, 30 feet up. Jumbo, who is now on the ground, acts as a counterweight/anchor, and the belayer returns to the deck by rappelling down the rope via their belay device, through which the rope runs.

This scenario is particular to the gym, where the routes are vertical to overhanging and the toprope usually runs over a chubby pipe on the top of the route. On a cliff the rope runs through carabiners, at radically tighter angles that won't allow such a meteoric hoist as found in the gym fiasco. Nevertheless, this extravagant hoisting of the belayer often took place during drop tests conducted by the Sierra Club and other outfits during the 1960s and early 1970s.

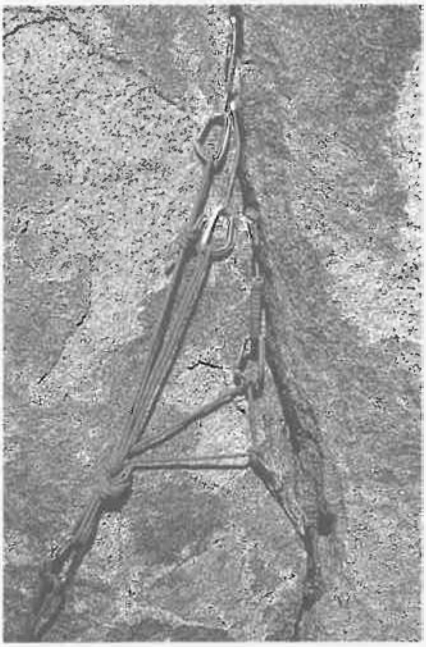
In the Sierra Club version, one end of some goldline rope was attached to a bucket of concrete weighing roughly 120 pounds. The rope ran up an overhanging wall to an anchor on top—or was connected to a cross-beam in a gymnasium, as the case may have been—then back down to a belayer on the ground. By means of another line, the bucket was heaved 10 to 20 feet into the air—according to the sadistic leanings of the instructor—then cut loose, leaving the belayer to arrest the 10- to 20-foot "fall" via a hip belay. More than one corn-fed male was launched as if shot from a catapult, and it was even money that a wispy female could get extruded halfway through the anchor biner. Such was the examination to become a certified rock climber in years past.

The tubby/svelte toprope hoist job and the antique drop test are goofball examples but nonetheless demonstrate the power of upward forces, and the need to safeguard against them if and when they are significant factors. The question is: What are the circumstances in which upward forces are great enough to warrant oppositional placements in the belay anchor? Let's place ourselves back on the rock and see what questions arise.

Consider a leader climbing above a hanging belay. If she falls off and is arrested by the Jesus Nut, for instance, or pro she has placed higher, the belayer will be pulled upward, or directly toward the first piece of protection off the belay—which is generally upward since most climbs go up. But what is the actual power of this upward force on a belayer? Most of us have held leader falls that have jerked us skyward hard and fast, but even on steep sport routes, if the belayer and the leader weigh roughly the same, when have you ever seen a belayer, following a leader fall, left in midair, stretched taut against an anchor straining against the upward force?

UPWARD FORCE OPPOSITIONALS ARE REQUIRED:

- When a belayer is significantly lighter than the active climber
- Whenever belaying below an overhang and the initial protection off the belay anchor (the Jesus Nut) is directly above or even behind (such as with a roof crack) the anchor
- Where the rock is steep or overhanging and the forces generated by a leader fall can create significant (say, more than 18 inches) "lift" of the belayer



This rig shows a cordelette used to equalize the load on two tapers with another SLCD placed to provide opposition. A belayer tied tight to these anchors isn't going to be lifted any more than 18 inches—enough to provide some "give" in the system, but not enough to be dangerous.

Consequently, in real world climbing, nuts placed in opposition to safeguard against upward forces are never expected to sustain the same loading as those placed for downward forces. In fact one of the ongoing debates in the climbing community is whether or not upward-oppositional placements are necessary at all. Some people favor forgoing upward force oppositionals because they think oppositionals waste time, energy and gear while "needlessly" complicating the system.

Proponents of oppositional anchors raise the possibility of the anchor being uprooted when the belayer is dragged upward in the course of holding a fall. For this to ever happen, the belay anchor would have to be set in vertical cracks and consist of nuts and, less likely, cams—pro that might conceivably be plucked clean if the belayer were yanked a sufficient distance above the anchor. I've never read of an instance where a belayer actually got dragged above the anchor and where the primary placements in the belay anchor itself were plucked from the crack like cloves from a holiday ham.

We know that during a leader fall (held by pro above the belay), slight lift of the belayer's body and flex and give in the system act as peak force reducers, absorbing much of the fall's kinetic energy before the anchor is ever loaded. If nothing else, rope slip/stretch will likely preclude a meteoric hoist, even when little rope is out.

But that's with a belayer who weighs roughly the same as the leader. Get a leader who weighs twice as much as the belayer, and the lift factor becomes significant no matter the angle. Here the peak force reduction enjoyed by the body of a large climber is null and void. And so is the main argument against setting nuts for an upward pull: No matter the fall scenario, the belayer is not likely to be lifted far enough to threaten the anchor. My counter to this claim is that I (210 pounds) once fell at Tahquitz and pulled belayer Lynn Hill (105 pounds) 10 feet into the air.

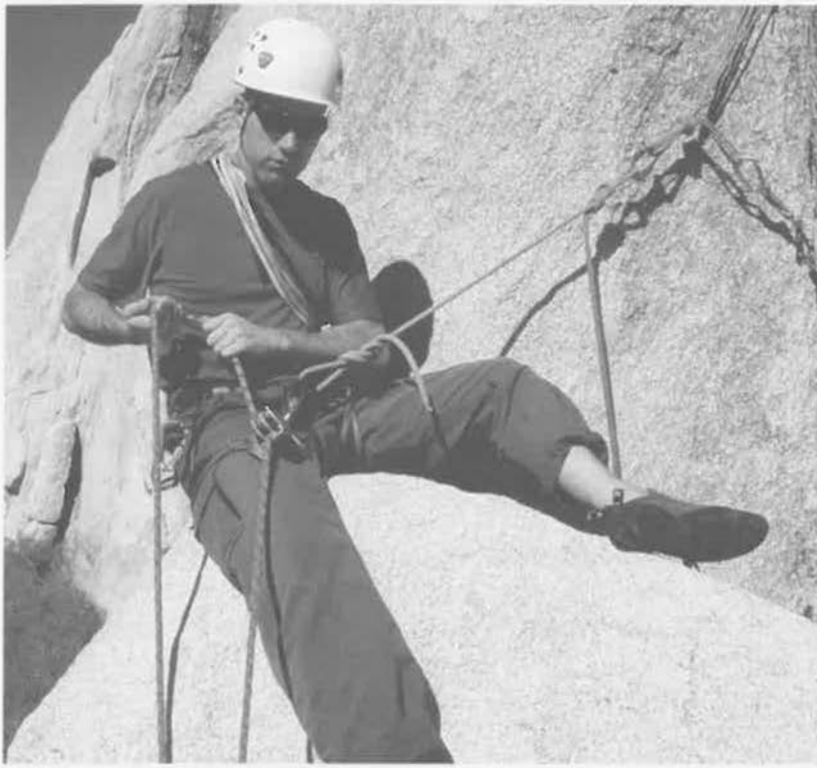
When Oppositionals Are Required

While there are instances—primarily on low-angled climbs—that climbers can argue against setting nuts to safeguard against upward pull, there are other instances where upward oppositionals are compulsory. These include A) steep hanging belays built from hand-placed gear, B) whenever you are belaying below an overhang and the initial protection off the belay anchor (Jesus Nut) is directly above or even behind (such as with a roof crack) the anchor, and C) when a belayer is significantly lighter than the active climber. All three of these examples are where the rock is near, at or past vertical, where a falling climber will basically be airborne and where forces generated by a leader fall are great enough to start replicating the mega-hoist seen in our first two examples—the toprope scenario in the gym and in the Sierra Club drop test.

Bottom line: Some little "lift" at the belay is usually a good thing, acting as a counterweight and load limiter to the forces generated by a leader falling above. But whenever the potential of that lift exceeds a foot or so (the A, B and C in our examples above), oppositional placements should always be incorporated into the belay anchor.

BELAY POSITIONS

No matter what system you use to connect your primary placements to a power point, the techniques used to arrange various types of belays (direct, semi-direct and re-directed) remain much the same. Although a cordelette is used in these examples, it just as easily could be another type of system or a combination of systems.



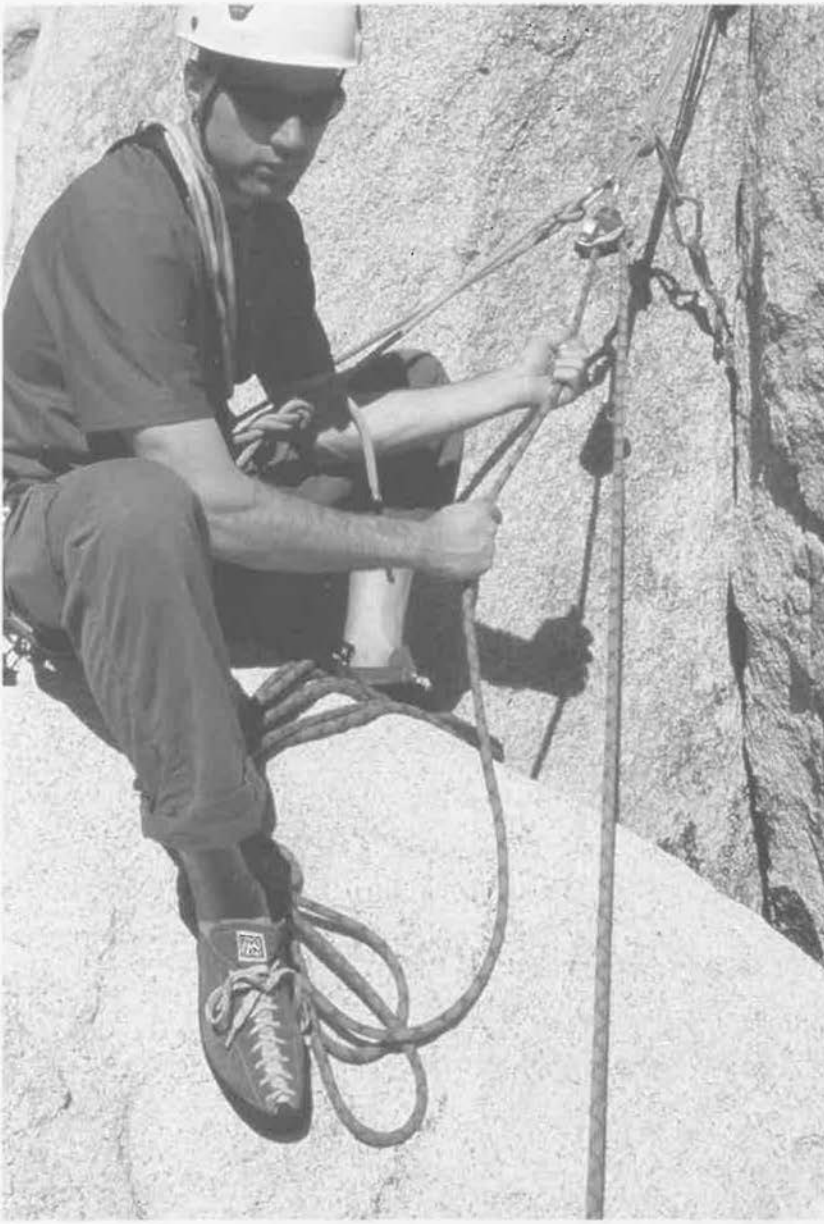
Here the belay device is clipped into the belay loop on the climber's harness—an **indirect belay**. Providing the belayer has a solid stance to brace against downward loading, the indirect belay is the technique of choice if the anchor is less than superb. In holding a fall, the belayer bears the brunt of the fall force, which can be uncomfortable and awkward when the falling climber hangs on the rope for a long period of time.

Though this setup is adequate for the low-angled slab it is servicing, if the terrain below was vertical (meaning higher loading), the belayer's backside might get dragged down to a position directly below the anchor. Remember that when the system is loaded, gravity pulls every object on the rope into the fall line, into a position directly below the anchor. Here we have a classic trade-off: In terms of managing forces, the best position for the belayer is directly below the anchor, where downward loading can only pull him straight down. But here the best body position is slightly to the left of the anchor—meaning his arse and brisket will have to bear the bulk of the loading. If the loading becomes greater than what he can maintain (very unlikely on this slab toprope setup), downward loading will pull him down and across to where he is directly beneath the anchor.

Though not always possible, the ideal is: With any indirect belay, the belayer should try to get into a position directly beneath the belay anchor to avoid getting dragged there by downward loading. Remember ABC positioning for bringing up the second: Anchor ⟶ Belayer ⟶ Climber.

Here the belay device is clipped into both the harness's belay loop *and* the loop in the figure eight tie-in knot. If the climber falls, most of his weight goes onto the anchor, *not* on the belayer—providing that the belayer is situated directly beneath the anchor. To the extent that the belayer is to one side or the other of the anchor is the extent that his body, not the anchor, will bear the load.

This shows how a **re-directed belay** is set up. Always remember that a re-direct basically doubles the loading on the anchor—no problem with premium anchors (like bolts on a sport climb), but with sketchy anchors, a re-directed belay is a little dicey.



This effectively illustrates a clean and simple rigging of a **direct belay**. Whenever the primary placements in the anchor matrix are stout, many climbers find this setup the most user friendly, especially when the second is slip-sliding and hanging all over the route. Under these circumstances, it's almost always better that the anchor (providing it is bomber) bears the loading, not the belayer's corpus.

A three-bolt anchor rigged for a **direct belay** (direct belay = belaying directly off the belay anchor) via a Petzl Grigri clipped into the power point. Note how the power point is at an ergonomically friendly chest level, ideal for managing a direct belay. Beyond the Grigri, other popular auto-locking devices are the Petzl Reverso, and the Trango Cinch. Here, another direct belay option would include the Munter hitch on a large, pear-shaped locking carabiner.

Remember this: a direct belay is an easy and efficient means to belay the second or follower, but never should be used to belay the leader. Also, understand that with all direct belays, when the anchors are less than ideal, any loading bypasses the shock-absorbing qualities of the belayer's body, and places the entire load directly onto the anchors. Granted, toprope forces are generally moderate, but any force is a concern if you've wandered off route and get stuck belaying from mank. When the anchors are rock solid, however, a direct belay is a quick, efficient and comfortable way to bring up a second.

Also note how the leader has clipped directly into the bolt hangers, bypassing the trashy, hardware store quick-links.

Three bolt anchor rigged as a **re-directed** belay. Understand that with every re-directed belay, the load is almost doubled where the rope is re-directed through the anchor. Always a sketchy choice when the follower considerably outweighs the belayer; if not well braced for the loading, a sudden force greater than their body weight can slam the belayer into the wall. Re-directed belays add friction to the system, and when the belayer is equal to or bigger than the follower and the anchors are mint, this technique makes for smooth and fluid lowering if the second is climbing up to, then getting lowered off, an anchor.

Guides frequently use a rope-direct when the anchor is set back from the edge and they want to position themselves near the edge to eyeball their client. In this setup you run the rope through two biners at the anchor's power point, climb back down to the edge, then tie an overhand loop on the doubled bight of rope. This now serves as an extended power point, and the belayer is secured where he wants to be. Here a Grigri is used for a direct belay from the new power point.

This is an easy technique that is especially useful at one-pitch crags where you belay from the top and the anchors are often set back from the edge. The end of the rope is clipped to the power point of the anchor system with a figure eight on a bight. Find your belay position and tie another figure eight (which becomes an extended power point), then simply secure yourself with a locking biner to your belay loop, and rig a direct belay (with a separate locking biner) off the extended power point.

As always, downward forces will try to drag the belayer into a direct line beneath the anchor—which is exactly where you might end up if your stance is not adequate and the anchor is not directly behind you.

Anchor Test Results

The previous discussion of the cordelette, sliding X and equalette was invaluable, but yielded only theoretical results about the relative merits of these systems. To answer the fundamental questions raised in that discussion, we needed to generate some hard data. The aim of testing was to determine performance differences between the sliding X and the cordelette when both systems were subjected to the same dynamic load (as found in a real world fall). Since hundreds of thousands of climbers literally hang their lives off these systems on a weekly basis, such testing was clearly indispensable to both this manual and the climbing community at large.

On the recommendation of Kolin Powick, quality assurance manager at Black Diamond, the physical testing was conducted by Jim Ewing, research and development manager at Sterling Ropes. Ewing is both a world-class climber and an engineer with years of experience testing on Sterling's UIAA drop towers and computer assist gear, and he is widely considered the leading tester in the United States. The tests took weeks and many late nights to complete (upwards of 200 drop tests were performed) and went far in answering many long-standing questions about rigging systems.

Very much an ongoing team effort, Ewing's raw data was worked up by nationally recognized statistical experts (and climbers) Dr. Lawrence Hamilton and Dr. Callie Rennison. Lastly, the tests led to a discovery phase involving several new rigging strategies that were field tested and refined by professional guides Bob Gaines and Tom Cecil and others.

Test Parameters

In order to devise the most significant tests, we first had to determine what factors were most crucial to a team building and belaying off a real world anchor. This involved examining the following elements of the anchor chain.

1) The primary placements. Hundreds of such tests already exist on the strength of "this" bolt and "that" camming device. Further analyses could tell us little about the applied function of either the sliding X or the cordelette.

2) The connecting points. In other words, the biners that connect the cordelette and the sliding X to both the primary anchor placements and the power point. Again, we initially believed such testing would divulge little about performance differences per either rigging system—a belief we later revised.

3) Materials. Because previous testing indicated performance differences between old-style nylon and high-tensile-strength cord and webbing (Dyneema, Spectra, etc.), we decided to use a variety of commonly used materials for all testing.

4) Knots. Tests have shown the holding power of high-tensile cord is reduced once it is knotted (less so in nylon). However there is little if any real world evidence to suggest that the holding strength of a use-appropriate, properly tied knot—tied in any material—has ever caused anchor failure. Hence the issue of knots and knot strength was ruled out as being relevant to our testing.

5) Extension. Not an issue with the cordelette. And with limiter knots (always advised), the extension possibilities of the sliding X are reduced to mere inches. As Craig Connally has shown, providing there is flex and give in the system—as there normally is in a real world belay and a real world leader fall—it seemed unlikely that extension of mere inches can ever cause the "shock loading" we so frequently read about.

While the limited extension (as found in a sliding X with limiter knots) was considered a minor factor in determining performance differences between rigging systems, we had no lab data to determine the forces involved during this extension. Wrestling with this long-standing question, Jim conducted a battery of tests that strongly suggest short extension does not cause any increase in forces (load multiplication) beyond the initial load on the system prior to the failure of one primary anchor placement. This is a fascinating, involved and important subject that warrants further research.

6) Redundancy. In terms of a belay anchor, a redundant anchor is different than an anchor that is merely backed up. A redundant belay anchor implies that the forces generated in a leader fall will never fall on one piece of gear. With a backed up anchor, the force falls on a single primary anchor placement, and if that fails, the force then falls on a second placement, and if that fails, the force impacts a third placement—the dreaded "cascade" anchor failure. To avoid this cascade scenario and to enjoy functional redundancy in a belay anchor (to avoid loading on one piece of gear), impact forces must be spread or equalized over at least two primary placements. To determine how well any rigging system accomplishes such functional redundancy would therefore involve the issue of equalization.

7) Equalization. Equalization is the very quality for which the sliding X and the cordelette were designed, and are employed, to achieve. After the previous analysis it became clear that the most meaningful testing would determine how well or how poorly the sliding X (dynamically equalized system) and the cordelette (statically equalized system) delivered on their promise of equalization.

To contrast the functional equalization of the sliding X and the cordelette, we decided on the following test parameters:

- "Slow pull," static loading tests have limited bearing on real world sport and adventure climbing. Only drop tests, using actual climbing rope, could replicate the dynamic forces of a real world leader fall.

- A drop test equaling a real world factor 1 fall would be used during each and every test. Factor 1 forces represent a significant but not shattering fall. Such forces would plainly illustrate how well both the sliding X and the cordelette distributed the dynamic load (in our case) over two primary placements of an anchor. It is almost certain that a greater or lesser dynamic force (than that of a factor 1 fall) would not change the actual load-sharing ratios, and that from the ratios provided by the factor 1 tests, we could reliably extrapolate up or down.

Metric Conversion Chart

1 mm = 0.039 inch
1 cm = 0.393 inch
1 dm = 3.937 inch
1 m = 39.37 inch = 3.28 feet

1 kg = 2.2046 pounds
1 kN ≈ 220 pounds

The test rigging was set up as follows:

1. Pieces of cord and webbing tied in 140cm to 150cm loops were used as opposed to the more typical 600cm. This length of cord was used to simplify setup.
2. The dynamic load ("mass") was dropped on 10.2mm Sterling Kosmos lead rope.
3. All drops = fall factor 1 on 0.5m of rope (starting length) between figure eight knots.
4. Mass = 100 kg

Summary: Simply put, the first tests answered the following question: If we rigged a cordelette and a sliding X off the same anchors (in both vertical and horizontal configurations) and subjected the anchors to a controlled, dynamic fall of exactly the same length and force, what might the test data disclose in terms of how well the two rigging systems distributed the forces between the two anchor points? Here is what we found.

These tests provided two distinct pieces of information about the sliding X and the cordelette rigging systems. First, the results offer the average absolute "difference in force" or "difference in load" between the two legs of the anchor generated due to a factor 1 fall. In some cases, these differences are close to zero, meaning that each leg of the anchor receives about half of the force. In others, the differences are quite high, suggesting that one leg is experiencing a disproportionate amount of the force generated. Ideally we would like to see the force distributed equally between the two arms of the anchor.

Second, test results indicate how consistent or inconsistent these measured "differences in load/force" are across multiple tests. In some cases, repeated measures will produce very consistent results. In other cases, great variation in measurements of these differences will be noted, suggesting that the difference in load

HORIZONTAL ANCHOR SCENARIO—EQUAL LEGS

Distance between anchor attachment points = 30cm ± 1cm

Cordelette configuration	Sliding X configuration
Length of legs = 70cm ± 1cm	Length of legs = 70cm ± 1cm
Angle between legs ≈ 24°	Angle between legs ≈ 24°

VERTICAL CRACK SCENARIO—UNEQUAL LEGS

Distance between top and bottom anchor points = 45cm

Cordelette configuration	Sliding X configuration
Length of long leg = 55cm ± 3cm	Length of long leg = 100cm ± 3cm
Length of short leg = 12cm ± 3cm	Length of short leg = 45cm ± 3cm
Angle between legs = 0°	Angle between legs = 0°

created will vary greatly from fall to fall. It is preferable that a rigging system generate little variation, or consistent differences in load measured, from fall to fall.

Systems Tested

A. Cordelette equal length: Tests simulating a factor 1 fall demonstrate that on average, a cordelette with equal-length arms configuration generated an absolute difference in load that was almost 1 kN (220 pounds), a significant amount. Repeated measurements of the difference in the forces generated varied somewhat across multiple tests. Contrary to conventional wisdom and popular usage, the cordelette, even with equal-length arms, is not a very effective system to achieve equalization.

B. Sliding X equal length: Testing of this anchor configuration shows that on average, the absolute difference in force transferred to each equal-length arm due to a factor 1 fall was very close to zero (i.e., about 0.2 kN difference). In other words, on average, there is almost no difference in load measured using a sliding X equal-length rigging configuration. This configuration equalizes very well. In addition, repeated testing demonstrates that the difference in force generated between the arms was very consistent across multiple tests. In fact, the consistency in equalization from drop to drop did not get better than this configuration. When compared to the cordelette equal rig, it is clear that the sliding X equal-length performs far better. Not only does the sliding X equal-length system equalize much better than the cordelette in a similar situation, it equalizes much more consistently from fall to fall.

How do these configurations compare in a situation in which one must build an anchor with unequal-length arms?

C. Cordelette unequal length: This clearly-the-worst-configuration tested produces an absolute average difference in force between the anchor arms of almost 3.5 kN, or roughly 780 pounds of force. Aside from generating the largest difference in force of the riggings measured, the cordelette unequal-length rigging was the most inconsistent when repeated measures of this difference were taken. In some cases, the difference in load measured was greater than 5 kN. To put it bluntly, the cordelette unequal-length configuration is the poorest performing anchor considered in all the testing conducted. Not only is equalization very poor, the degree of equalization varies wildly from fall to fall. This configuration is very unpredictable, except that the difference in the forces generated from a fall will be high. The cordelette unequal length is simply to be avoided.

D. Sliding X unequal length: The fourth configuration examined is the sliding X unequal-length anchor. This rigging produces, on average, an absolute difference in force between anchor arms of approximately 1 kN as a result of a factor 1 fall, putting it on par with the equalization obtained using a cordelette with equal arm lengths. Though the equalization offered by the sliding X unequal is on par with the cordelette equal, both are inferior to the sliding X equal. Of the two unequal-arm configurations examined, however, it is very clear that the sliding X unequal is the way to go.

In terms of consistency in equalization from test to test, the sliding X unequal-length configuration was as consistent in the absolute differences in load generated across repeated falls. Interestingly, though, while it tended to be very consistent across repeated measures, this anchor was also the most likely of all configurations to produce an occasional *extreme* difference in load. In other words, although tests showed this configuration to be generally consistent, it generated some unpredictably dreadful equalization.

Summary: This initial series of testing firmly establishes the sliding X as superior in terms of load distribution, while at the same time suggesting that the materials used played only a minor role. While the equal-armed cordelette distributes a dynamic load to an acceptable degree (barely), and will no doubt remain a viable option in that configuration, a cordelette rigged with unequal arms is an inferior—and likely hazardous—choice when contrasted with the more efficient load distribution of the sliding X.

The Sliding X—Why Unpredictable?

The sliding X with unequal arms showed acceptable but sometimes unpredictable loading. While still far superior to the cordelette with unequal arms, we wondered if switching out a gear component—mainly the power point biner—might produce more equal loading. This idea came from other tests that suggested the X was prone to binding on itself (the "clutch effect"), and that a wide-mouth, anodized biner could greatly reduce, if not eliminate, the clutch effect.

During testing Jim Ewing noticed that the X, or crossing of the cord or webbing, naturally wanted to settle right on the biner. In rigging the sliding X for this round of tests, he manually forced the crossing to occur on one or the other side of the biner in order to avoid the clutching effect (i.e., separated strands). He also used an anodized, wide-mouth (pear-shaped) biner for this set series of drops. To investigate the role of the clutch effect, additional tests were conducted. Pieces of cord and webbing tied in 140cm to 150cm loops were used, the dynamic load (100 kg) was dropped on 10.2 Sterling Kosmos lead rope and the drops equaled fall factor 1 on 0.5m of rope (starting length) between figure eight knots. In addition, the long leg equaled 100cm +/- 3cm, the short leg equaled 45cm +/- 3cm and the angle between legs equaled 0 degrees. Again, during tests, the strands of the anchor were manually separated on the biner. Here is what we found.

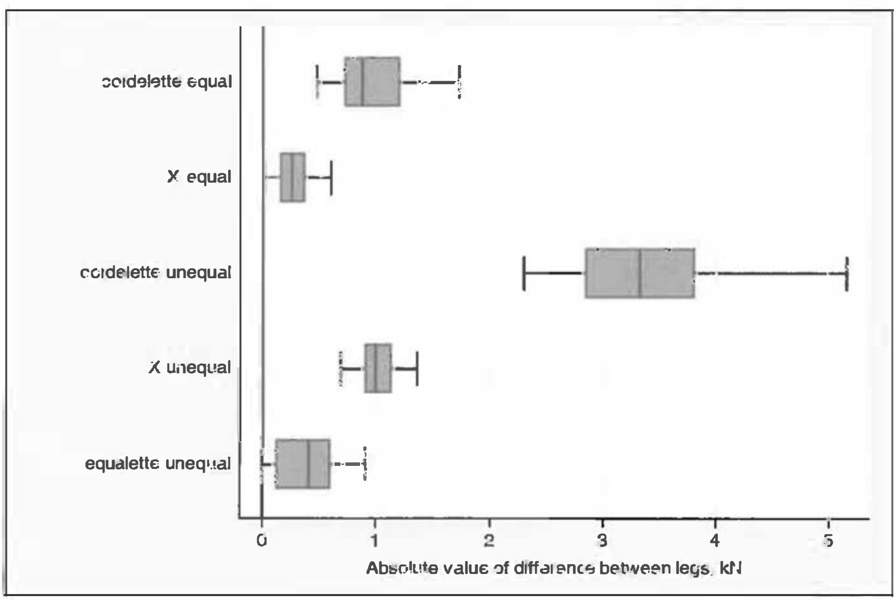
The sliding X unequal with an anodized wide-mouth biner produces, on average, a difference in force between anchor arms of approximately 0.5 kN as a result of a factor 1 fall. In other words, the equalization achieved using this configuration is better than that achieved using the sliding X unequal length (about 1 KN), and a bit worse than that obtained for the sliding X equal length (about 0.2 kN). Over repeated tests, differences in kN generated by this configuration varied at about the same degree produced by the sliding X equal-length configuration. This demonstrates that by removing the clutch effect, one can achieve equalization superior to that obtained using the sliding X unequal and remove the chance of an occasional lack of equalization.

While it's impractical in the field to separate the strands of the sliding X, doing so while adding a wide-mouth, anodized biner did result in near ideal equalization (basically 125 pounds of difference for a 1,500- to 2,000-pound dynamic load). This begged for yet another round of tests using the anodized biner, but not separating the strands of the sliding X. Yet in the process of reviewing the data and looking closely at the sliding X itself, it became obvious that the sticking point was the cross in the sling/cord, the actual X in the system. So long as limiter knots were used—as they always should be to limit extension—another option presented itself: Eliminate the X and simply clip two locking biners (with both "mouths" facing down and out) into the individual strands of the sling between the limiter knots. This rigging system was coined the "equalette."

To determine how the equalette compares to the sliding X and the cordelette unequal, a new round of testing was conducted. (Note: Because it is much more difficult to achieve equalization with an unequal-length arm configuration, testing focused on that mode.) Again, to maintain consistency, tests on the equalette were performed using pieces of cord and webbing tied in 140cm to 150cm loops, the dynamic load (100 kg) was dropped on 10.2 Sterling Kosmos lead rope and the drops equaled fall factor 1 on 0.5m of rope (starting length) between figure eight knots. In addition, the long leg equaled 100cm +/- 3cm, the short leg equaled 45cm +/- 3cm and the angle between legs equaled 0 degrees.

E. Equalette unequal length: The equalette unequal-length configuration outperforms the sliding X unequal-length configuration, and it performs as well as the sliding X unequal with a wide-mouth biner. Of course, unlike the sliding X unequal wide-mouth configuration, the equalette has the distinct advantage of being practical to use in the field. Equalization with unequal legs is difficult, and though the equalette did not equalize as well as the best-case scenario (sliding X with equal legs), it performs very well. In fact, the equalette offers the best equalization among the unequal-arm riggings considered.

Though the variation from test to test is greater for the equalette unequal compared to the sliding X unequal with a wide-mouth biner, the actual ability to equalize by the equalette is so far superior to the sliding X that it continues to be the best choice. In sum, this round of results shows that the equalette with unequal arms provides equalization equivalent to that seen in the sliding X equal-length rigging, and in instances when one requires an anchor with unequal arm lengths, the equalette performs significantly better than the traditional sliding X and vastly better than the unequal-length cordelette.



Note about the Quad

Extensive testing was also carried out on the "quad" system already described in this chapter. Since the quad is essentially a doubled equalette, and since tests on the quad revealed numbers virtually identical to the equalette, an illustrated argument about the quad was considered superfluous to this discussion.

Shock Loading

One of the longest ongoing debates (and one that largely, if not entirely, has been devoid of any test data) is the subject of "shock loading." Because this term has no meaningful definition, it usually is more confusing and misleading than informative. The conventional definition implies a force so sudden and terrific it could break biners and snap slings. The issue of extension in an anchor has always been a paramount concern to climbers, who feared such extension could cause this shock loading. When we looked to see what data had been generated to support this claim, we found none, and so we set out to conduct some preliminary tests.

Relevant to our discussion of rigging strategies, the key issue was what happens when one leg of a dynamically equalized system fails and the load falls to the remaining leg. Some have speculated that the load somehow multiplies between the time of the initial loading/arm failure, creating shock loading on the remaining leg.

As covered earlier in this book, all dynamically equalized anchors are only viable if they use limiter knots to limit possible extension. Given that these are in place, we wondered what the testing might divulge when one arm is allowed to fail and a dynamic load is sustained by the remaining arm. Here is how we went about the testing.

Leg-Failure Test of Equalette

This test used the same setup as previous unequal-leg tests but with the short leg connected with a "fuse." The fuse is meant to break before the long leg. We reused a sample of rope from earlier drop tests since a dynamic rope changes very little after multiple factor 1 drops, making the total force generated fairly consistent. Also, using the same piece of climbing rope greatly increased the chances of observing potential shock loading since after repeated drop testing the rope is only a little more dynamic than a piece of static line. If a shock load were ever going to happen, it would happen now.

It should be noted that when using a 100 kg mass and low-stretch rope, the forces are somewhat higher than one would expect with a fall factor of 1.

The drop tower computer program produces a force/time curve that is quite jagged immediately after the leg failure, indicating lots of vibration. It is obvious on the curve at what point the fuse fails. Immediately after the fuse blows, there is a sharp drop in force followed by the vibration, which is then followed by a normal-looking curve. The peak force varied depending on the tenacity of the fuse. The stronger the fuse, the lower the peak force on the remaining leg; the weaker the fuse, the higher the peak force on the remaining leg. Another interesting finding from these tests is that the sum of the force experienced by each anchor leg decreased as the fuse load is increased. In short, there is no "load multiplication" between the initial leg failure and the mass slamming onto the remaining anchor point. In other words, this series of testing demonstrates conclusively that *no catastrophic shock loading* and *no "load multiplication"* occur as a result of the extension.

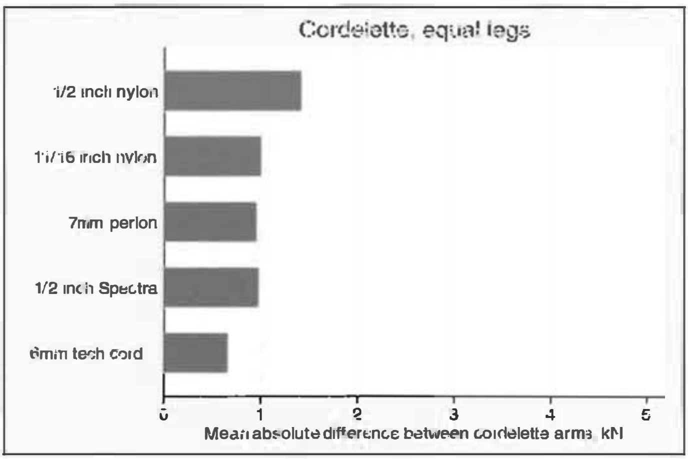
Shock-Loading Conclusion: In climbing systems, all the components have a degree of resiliency. These are by and large only maxed out when a section of unbelayed static line or high-tensile-strength cord sustains a dynamic load that is transmitted directly to the anchor, such as when a leader clips off to an anchor with a tech-cord daisy chain, climbs up 2 feet and slips, falling 4 feet directly onto the anchor. You can bust biners this way because the gear can't handle mass decelerating that quickly.

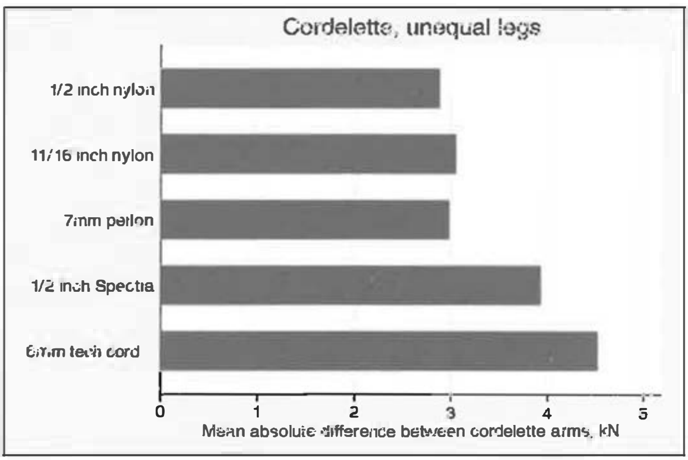
Stretch and give allow the mass to decelerate slower. In the daisy chain fall described above, you basically have the equivalent of a headon collision—something that's not going to happen when you're on a dynamic climbing rope that is running through a belay device, and when you're clipped into the anchor with the climbing rope. Here extension simply means that the next anchor that holds will be subjected to the initial load, minus what the first leg/piece absorbed. The load does not increase or multiply between the initial failure of a leg and the resultant loading on the remaining leg(s).

Materials

Testing so far has produced several important and some unexpected findings. Cordelettes by far do the poorest job of equalization. The sliding X equal and the equalette unequal are clearly the best configurations in terms of equalization. We wondered, however, what role was played by the sling materials used in the tests. We first looked at the cordelette. Here is what we learned.

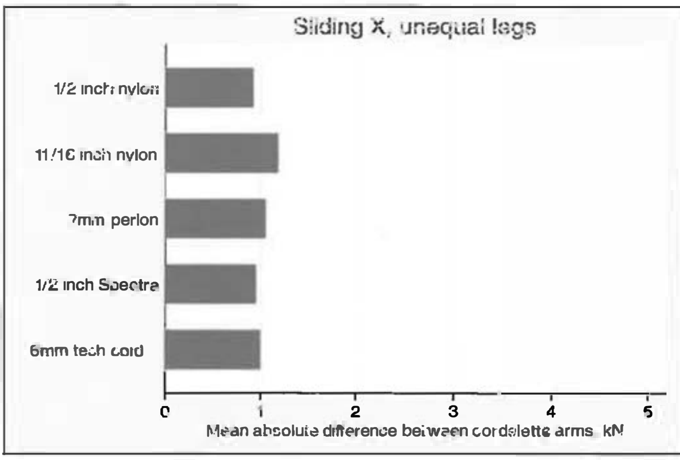
The bars in the graphs represent the mean of the absolute difference between forces generated between the two arms of the anchor. In some cases, these bars are very small—close to zero—meaning that each arm of the anchor receives about half of the force generated by the fall (i.e., equalization). In other instances, the difference in forces transmitted to each arm is quite large, suggesting that one arm of the anchor is experiencing a disproportionate amount of the force generated. As was the case in earlier tests, we ideally would like to see the force distributed equally between the two arms of the anchor.

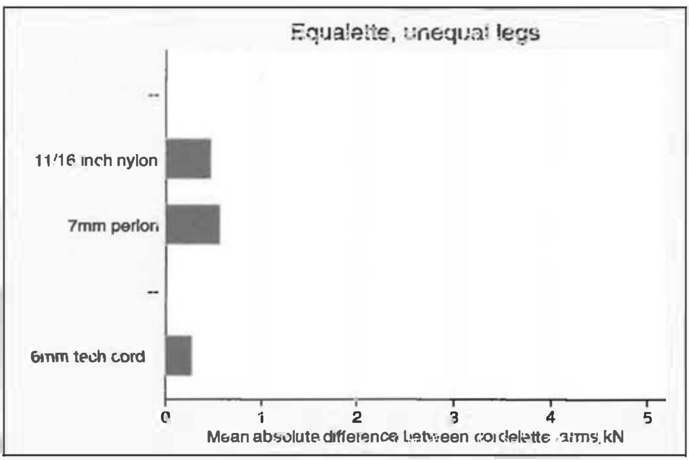




Considering the cordelette equal riggings, slight differences are noted among the sling materials, though substantively they appear to perform equally well. A different conclusion is reached when examining results from the cordelette unequal configuration. Findings show that nylon or Perlon provide better equalization than Spectra or high-tensile-strength cord, in the case of a cordelette with unequal legs. This suggests that for equalization purposes, nylon is the preferred material to make cordelettes. Though these results are based on limited data, it appears that for a cordelette unequal setup, *sling material does matter*.

Tests show much smaller differences in equalization across sling materials for the sliding X unequal and for the equalette unequal. In these configurations, sling material does not influence equalization greatly.





These findings reinforce what we concluded in the previous sections—that regardless of sling material, the cordelette is a terrible choice, the sliding X is a better choice and the equalette is the best choice of riggings tested for achieving equalization of two unequal legs. In addition, for use with two side-by-side primary anchors, the quad is also a handy system that provides easy use, brute strength and excellent equalization.

Summary

The Sterling tests were invaluable because they analyzed rigging systems, rather than equipment, and they applied dynamic loading (replicating the forces of a real world leader fall) on a dynamic rope, as opposed to "slow pull" or static loading on static ropes. Slow-pull, static-rope testing is a mode followed in many evaluations but one that has questionable relevance to real world climbing falls. Climbers do not lead on static ropes, and falls do not happen slowly.

Testing determined that unless a rigging system features perfectly equal-length arms and is used when the loading direction doesn't change so much as a single degree (and these are already imposing limitations), equalization and a fixed power point are mutually exclusive. The deduction is that future refinements in rigging systems will probably move away from fixed power points, with their big, beefy knots that, ironically, were long considered earmarks of security itself.

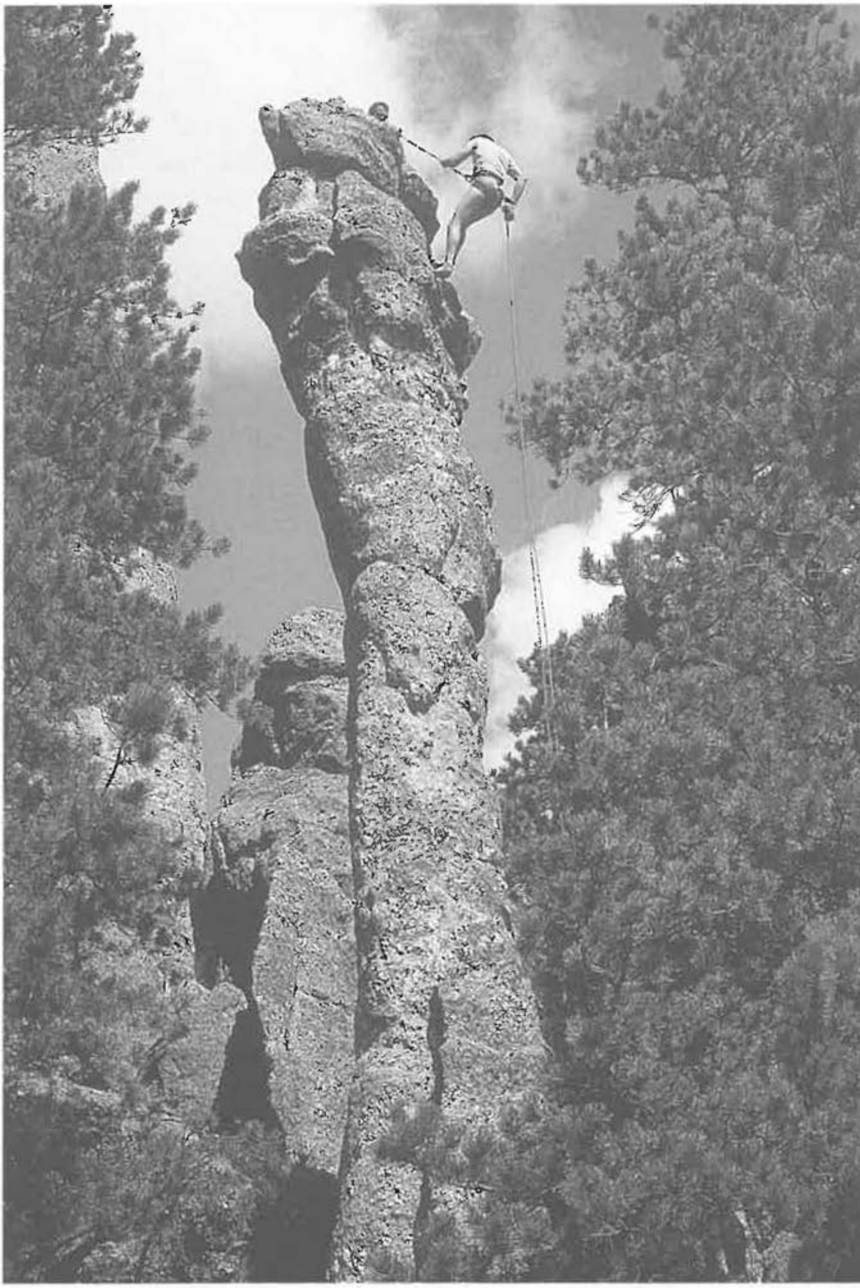
Some thirty years ago the sliding X introduced the concept of a sliding power point, and the refinements and tentative new systems spawned by the Sterling tests are the first baby step in taking the concept into the twenty-first century. Because this work is just beginning, I expect over the next few years to see many more options featuring a sliding power point. Simplified versions of the Trango Equalizer, as well as other "pulley" rigging systems, have already been presented and offer much hope for future innovation. No doubt others will devise new systems that feature strategies not yet imagined. A truly revolutionary method is yet to appear; we're basically still tweaking systems based on the cordelette and the sliding X. But no matter what the future turns up, it is doubtful that any single rigging strategy will prove "best" across the board. A combination of techniques will surely be required to cover the varied conditions found in real world rock climbing.

That much said, an obvious question remains unanswered: If the old systems—namely, the cordelette—tested so poorly in terms of equalization, why don't more cordelette-rigged anchors fail in the field? The answer is likely what we touched on earlier: Few belay anchors (no matter the rigging system employed) have ever failed because so few anchors ever experience a factor 2 fall. But for those very few teams that one day will experience such a fall—where the leader plunges directly onto the belay—we now have a much better idea of what actually works in terms of equalization.

It remains an engineering marvel that we can hand-place a collection of widgets into features in the rock and swiftly tie them off so the load gets somewhat evenly distributed throughout the matrix. No doubt we originally underestimated how tricky equalization was to achieve, largely settling for the cordelette on the strength of its apparent simplicity and utility. It came to pass that any other rigging strategy was judged by the simplicity of the cordelette (and other systems were generally found lacking), while all along the cordelette, if subjected to a dynamic load, was rarely performing as advertised.

Experience now shows that, in terms of rigging systems, the acronym KISS (Keep It Simple Stupid) is valuable only up to a point. We are free-soloing a slippery slope if we think the only rigging system worth using is one so facile that a rank beginner can arrange it with no training and no discrimination—a totally foolproof setup. In almost any potentially lethal endeavor, participants are required to learn the basic procedures to safeguard the adventure. Climbers simply have to master some essential protocols, and that's a fact. To expect rigging to be as simple as tying your shoes is to expect too much from the systems. Compared to what others learn—and must exercise—to fly a plane or scuba dive, climbers are obliged to know very little indeed. But it will never get to the point where climbers must know nothing at all.

All told, the Sterling tests are but one page in an ongoing investigation that will sire innovations as long as humankind is inclined to pull down on the Big Stone. A recent thread on rigging strategies featured on Rockclimbing.com received more than 35,000 views and generated 500-plus responses in fifteen days. Many ingenious rigging strategies were presented, and more are surely forthcoming. The bulk of these will come from grassroot sources for a simple reason: Rigging strategies are not products, and climbing companies only test what they sell. The gauntlet has been thrown down: Future rigging methods must be built on standard cord or webbing and cost no more than the cord or webbing itself. No doodads, widgets, rap rings or pricey sewing. Since there is little profit to a manufacturer in the simplified rigging methods most of us rely on, there's no motivation to develop or test such methods, even if the results are invaluable to real world climbers. It's up to us.



Climbers rappelling in the Needles, South Dakota. PHOTO BY BOB GAINES.