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Climbing Anchors

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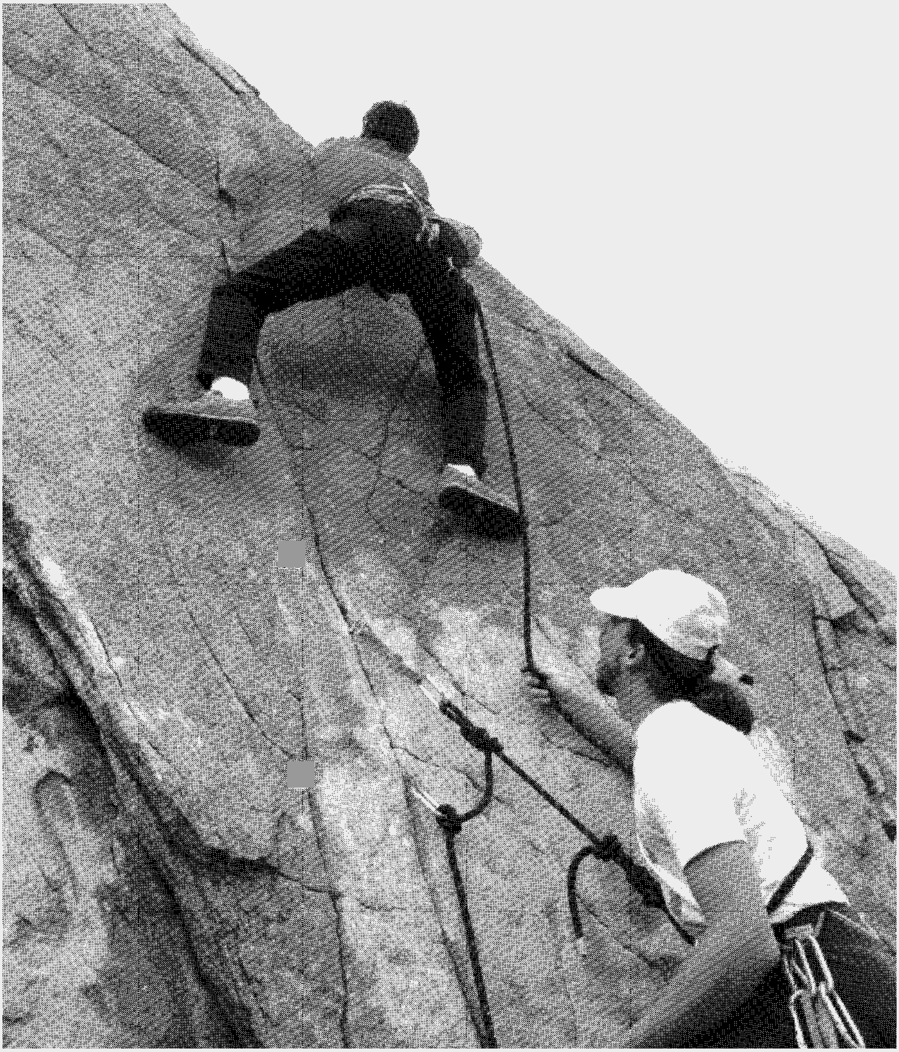
CHAPTER FIVE

Fall Forces and the Jesus Nut

Gear manufacturers are required to have their equipment independently tested and certified before releasing their product to the climbing public, at least in Europe, the biggest market. Manufacturers also test their own and everyone else's product in the hopes of gaining a competitive edge in the market. The bulk of these tests establish the strength of this carabiner or that sling. For better or worse, such testing has provided much of our statistical knowledge about the static and dynamic forces involved in climbing's roped safety system.

In terms of influencing rigging and anchor-building strategies, the lab-simulated factor 2 fall has for decades been the most important and definitive test. The test was originally devised to measure the number of severe falls a climbing rope would hold and the maximum force it would impart to a falling climber. To that end, an 80-kilo iron block (about 175 pounds, the weight of an average climber) is lashed to the end of a 2.8-meter (9-foot) length of rope. The other end of the rope is tied off to a fixed anchor (usually an inflexible iron bolt). The tie-offs for both the iron block and the anchor use .3 meters of rope. The iron climber is hoisted 2.5 meters above the anchor point and dropped through midair for a total free fall of 5 meters.

Experts always agreed that this drop test produced the greatest peak force that could ever be encountered in any fall on a rope, because the fall distance is twice (factor 2) the length of the rope available to absorb energy. Possibly because it was called a *simulated* drop test, the common understanding was that the test replicated a real life, on-the-rock, factor 2 fall and provided legitimate evaluations of forces on that account. Consequently a factor 2 fall, and the forces measured in the lab drop test, became the Gold Standard by which all anchors were measured.



This climber needs to set a Jesus Nut—fast. Even with that, this anchor is sketchy. The idea that two wee nuts in a seam constitute a viable anchor is an idea that will make you dead. Even if the belayer had equalized the nuts with a sliding X, they are still not nearly enough. And since there is no oppositional nut, this anchor is worthless for an upward pull, which is the only direction the pull will come from once the first nut is in place. If the leader were to fall here—which he looks close to doing—the impact would rip the anchor right out (provided the belayer's hip belay could hold such a fall, which is questionable), and the two dupes would shortly find themselves in the Golden City, harps in hand, wondering what went wrong.
PHOTO BY KEVIN POWELL.

From Chamonix to Katmandu, a belay was not "good enough" if it couldn't withstand the forces that the drop test said were generated during a factor 2 test fall.

To appreciate those forces, and what they mean to a climber placing protection and building anchors, you need to know the system used in the lab tests to measure those forces. This is a bit confusing for Americans (who are still using their own private measuring systems) because the lab testing is conducted using the metric system. Here mass is expressed in kilograms, and force (the consequence of mass accelerating or decelerating) is expressed in units called Newtons. Weight, mass and force are all different things; Americans express forces encountered in climbing's roped safety system in terms of pounds of force (lbf). One pound-force is about 4.44 Newtons. One thousand Newtons equals one kiloNewton (kN), a common value in climbing testing and product specifications. *To get a quick conversion, simply remember that 1 kN is basically 225 lbf.*

While a physicist might chuckle at this simplification of a complex and nuanced subject, we need only understand things in terms of simple values since it's the roped safety system, not the derived figures, that is our mortal concern.

FORCES FACTS

- Essential peak (dynamic) force load-limiter qualities in the belay system depend on flex and give in the components.
- Flex and give in the belay system keep dynamic forces of a real world factor 2 fall lower than forces recorded in the lab during a "simulated factor 2 fall drop test."
- The top piece always absorbs the greatest force during a fall, therefore *the top piece is the most important component in the entire belay chain*—be it a point of protection, or the belay anchor itself.
- Make certain, so far as humanly possible, that the top piece of pro, and not the belay anchor, arrests any and all leader falls.
- The main task of the belay is to limit loading on the topmost protection.
- The most critical time is when a leader is first leaving the belay and has yet to place the first piece of protection (the Jesus Nut).
- The belay anchor is not completed, and the roped safety system is not truly online, till a secure Jesus Nut is placed.

STATIC AND DYNAMIC FORCES

Imagine a leader hanging off a bolt on an overhanging sport climb. The force on the bolt will equal the climber's weight, and that weight is a static force because all the objects in the overall system are at rest. Static force loading is what you have all over your house. That nail in the wall on which your Picasso hangs is sustaining the weight, or static force, of Pablo's painting. Your desk sustains the static force of your computer. Your chair sustains the static force of your body.

In climbing, dynamic force occurs when a climber's body speeds up during a fall and slows down when she is arrested by the belay. Dynamic forces quickly build to a peak and then taper off to static forces once things stop moving. It is critical to understand how peak forces are created, because when slings snap and anchors blow out, it is the consequence of peak forces. This is such a fundamental point that climbing's entire safety system should be viewed in terms of peak force management.

DYNAMIC FORCES IN A FALL

In his outstanding book, *The Mountaineering Handbook,* alpinist and scientist Craig Connally presents a new take on the forces involved in a real world factor 2 fall. His findings, conclusions and words, which are the principal source of this discussion (we collaborated on this chapter), differ substantially from the common understanding extrapolated from lab tests, and for one basic reason: The simulated drop test does not employ the safety system used by actual climbers on actual climbs.

Basically the drop test is an exercise in shock-loading a system that is entirely static save for the 2.8 meters of dynamic climbing rope. In real world climbing, flex and give are present in many components of the safety system, and when that flex and give is accounted for, along with rope slip in the belay device, the force numbers (and the implications of same) are substantially lower than those provided by a UIAA factor 2 drop test.

According to Connally, the lower forces are primarily due to the fact that in a real life factor 2 fall, normal tube or plate belay devices function far differently than the inflexible anchor tie-off in the lab tests. It can be no other way since, Connally says, the maximum force a modern belay device can put on the rope without slipping is 2 or 3 kN. That means the maximum force that any fall can put on the belayer is south of 675 lbf.

In those rare cases where the climber falls directly onto the belay anchor, Connally figures that forces on the climber and belay anchor in a factor 2 fall are relatively low (about 2 to 3 kN), which is only slightly more than a hanging climber could create by thrashing around. He says during a factor 1 fall, rope slip in the belay device would again limit peak force on the belayer to a couple of kN (this time upward rather than downward), and that the force on the climber would be only slightly higher (about 3 kN), due to friction through the top carabiner. However the force on the highest anchor between them (in a simple system) would be the sum of the force on the climber and the force on the belayer. Overall Connally figures that the highest real world force on the top anchor would be in the range of 5.5 to 8.5 kN—roughly 1,900 pounds at the top end, and possibly lower than 1,250 lbf (he talks about things that would increase or decrease these forces). That's much less than the 12 kN maximum that the UIAA allows in the drop test, a test in which the rope is tied off. Of course, in a real world fall, the rope is not tied off. It's belayed, and the belay slips.

Again, during high-factor falls energy absorption at the belay (due to rope slippage) soaks up considerable fall energy, keeping forces lower than those of the lab drop test or even the impact force rating of most ropes. When all energy-absorbing factors are taken into account, it's likely that peak forces on the climber and belayer will be lower still. According to Connally:

> "The previous calculations assumed that the climber is an iron weight tied directly to the rope. A real climber is a flexible object attached to the rope by a conforming harness. Distortion of the falling climber's body will reduce forces about 5 percent, and harness distortion will absorb another 5 percent during typical falls. Lifting of the belayer's body may also reduce peak forces by a significant amount, maybe 10 to as much as 20 percent, if design of the belay permits. The overall consequence is that fall forces for short falls are less than those calculated (in the lab drop test) because of all these various factors that absorb energy and reduce peak forces."

Connally is not alone in believing that the forces suggested by lab drop tests are greater than those sustained in the field. Chris Harmston, Black Diamond's quality assurance manager, reviewed field failures of climbing gear for eight years. He never saw a Stopper rated at over 10 kN fail, and only saw a few carabiners fail in closed-gate mode. He concluded that forces exceeding 10 kN rarely happen in climbing falls.

This is telling because a BD Stopper is among the most commonly used protection device in all trad climbing. It's certain that Stoppers have held countless worst-case scenario falls. They are rated at 10 kN, so if not one has ever failed, it's a sure bet that forces of 10 kN have never been logged on any rock climb. The lack of even a single 10 kN rated stopper failing, in the entire history of the sport, suggests that the 10 kN rating (2,250 lbf) has never been seriously challenged, and that actual forces of factor 2 falls are likely to be less than even Connally's high-end figure of 8.5 kN (roughly 1,900 lbf).

This shows a climber running the lead rope through the anchor points as he takes off on lead. If he should fall, his full weight will come onto the anchor, not the belayer, which is a mixed blessing. It might mean less force directly on the belayer, but it will double the forces on the anchor. Better for this climber to forego running the rope through the anchor and instead place a bomber Jesus Nut as soon as possible, probably from his current stance, where the crack looks willing to accept a good piece.

So far we've heard Connally assert that the belayer sustains less than 3 kN peak force. He goes on to show how the "top piece," be it a component of the belay anchor, the first piece of pro off the belay or the last piece high above, is subject to—at the very most—somewhere around 1,900 lbf. Moreover this calculation is based on the climber being an iron block. Swap out the iron block with a human body, and the forces might drop to as little as 1,520 lbf at the top end. This is far less than the force measured in lab drop tests, where there is no belayer, no belay device and no rope slip, and no give and flex from the climber's body and the rigging typically found in a real world belay anchor. The obvious implication of all this is that the top-most pro is the most important in the entire roped safety system, since it always sustains the greatest loading (and the leader and belayer might both end up hanging from it).

Conclusion: The main task of the belay is to limit loading on the top-most pro, a process that is highly facilitated by rope slippage in modern belay devices. Further force reduction is provided by the other flex and give in a normal belay setup, not the least of which is the belayer's body, providing a counterweight to cancel out much of the upward force. Clearly a belay and a belay anchor with these characteristics bears little resemblance to a lab drop test, where an iron weight (the climber) is not belayed at all.

THE TOP PIECE

Even though the forces in a real life factor 2 fall are less than those registered in the lab drop test, we never want to fall directly onto the belay anchor, no matter if the forces are 5 lbf or 5,000 lbf. The whole point of placing protection is for the pro, not the belay anchor, to arrest the fall. That is why we fashion the belay to function as a peak force load limiter to keep loading on the top piece as low as possible. And since we never want to fall directly onto the belay anchor, the most critical time is when we might possibly do so, when the leader is first leaving the belay and has yet to place that first piece of protection. After the first pro is placed, any fall force on the belayer will always be up (not down), potentially reducing the static force (the belayer's weight) on the anchor. Conversely, fall force on the top piece will always be down (and maybe out), and that dynamic force will be considerable.

This leads to a basic safety credo: What deserves our most critical attention is the first placement after the belay anchor, the so-called Jesus Nut (a term that generically applies to any and all protection devices, from pitons to bolts to nuts, etc.).

THE JESUS NUT

"Jesus Nut" is a term made infamous by helicopter mechanics during the Vietnam war. The then-ubiquitous Bell UH-1 "Huey" Iroquois helicopter had one and only one giant, stainless steel nut (the Jesus Nut) that screwed onto the top of the main rotor mast, keeping the main rotor blades attached to the copter. As the saying went, "If it fails, the next person you see will be Jesus."

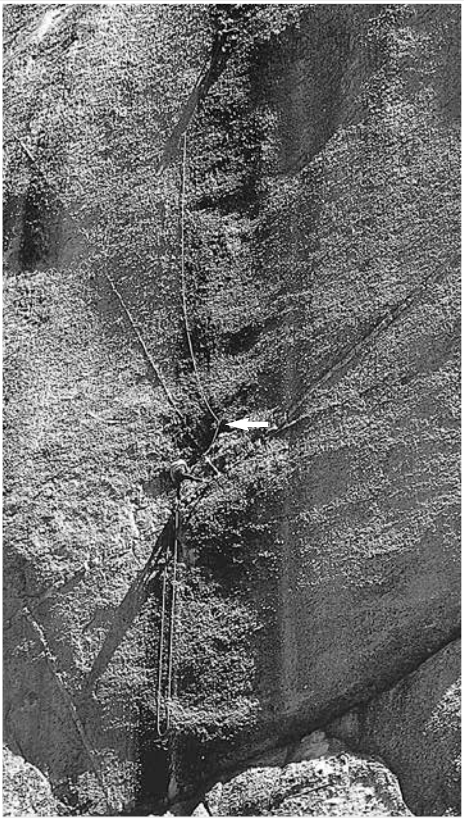
If a leader falls and the Jesus Nut fails, the belay anchor becomes the last line of defense by default and must be built with that worst-case scenario in mind. Anything less is not good enough. But in real life rock climbing, most any leader fall directly onto the belay anchor is almost always avoidable, and was generally preceded by significant errors in judgment.

For example, a team cannot suffer catastrophic anchor failure unless the leader falls. If you misjudge the caliber of the Jesus Nut, climb on, fall off and the Jesus Nut rips, that's one error in judgment. If you cannot secure a reliable Jesus Nut, carry on anyhow and pitch off, you've either overestimated your ability to climb a section of rock without falling or trusted rock that failed. Finally, if the belay anchor itself fails, it was not "good enough"; you broke the Golden Rule and paid for it with your life.

On established rock climbs, the times that a team encounters a suspect belay anchor, above which a bombproof Jesus Nut is impossible to acquire, on rock too difficult or too loose to climb, and under conditions in which you must try and climb on anyway, are so rare they're hardly worth mentioning. Such dire conditions are infrequently encountered even on new routes, and when they are, the bolt gun usually comes out. Alpine climbers (Connally's targeted audience) regularly confront these circumstances, which might be why so many of them die. If you ever find yourself in such straits, either rap off, or if that's impossible, start yelling for a rescue. If you choose to carry on, understand that you're basically free soloing—and if one goes, you're both goners.

The Golden Rule

- **An anchor system is not good enough unless it can withstand the greatest force that can possibly be put to it, known as a factor 2 fall.**



Climbers on the extremely runout *Bachar-Yerian* route in Toulumne. Notice how the first bolt placed by the leader is only a few feet above the belay—this will help absorb the force of a fall rather than having all that force put directly on the anchor. The sooner you can put in that first bomber piece, the better. If you're placing natural gear, an SLCD works well because of its multidirectional capabilities.

CONCLUSION

Effective force management requires that we build a "good enough" belay anchor and set a secure Jesus Nut directly off the belay. This is preventative medicine that essentially backs up the belay anchor. The Jesus Nut is not some auxiliary component we add if convenient, rather it's a crucial element of the belay anchor itself, the redundant element that just might save your ass. Many climbers try to make Jesus, so to speak, an SLCD, which has some multidirectional qualities. People often double up and equalize this first piece, applying the same SRENE principles as those used for the belay anchor. If a leader fall directly onto the belay is even a remote possibility, the anchor must be built to serve as protection (much more on this later) with the understanding that if it fails, "the next person you see will be Jesus." No helicopter pilot in his right mind would take off if there were any chance at all of the Jesus Nut failing. Likewise, no one climbs above an anchor that might be fallen upon and that might fail.

While what you place can take many forms, the importance of the Jesus Nut cannot be overstated. When both the belay anchor and the Jesus Nut check out, the roped safety system is truly on line. If not, it's a gamble, and you're "all in" every time.

WHAT DOES THAT STANDARDS STAMP STAND FOR?

You may see standards abbreviations on ropes and other hardware. The CE mark (Communauté Européenne or Conformité Européenne or just an abstract logo, depending on whom you believe) isn't intended as a mark of quality; instead it indicates that the product's manufacturer claims compliance with applicable directives (Euro-speak for standards). These can include certain requirements for quality and performance and, in the case of "personal protective equipment to protect against falls from a height," safety. Climbing hardware products must have the CE mark to be sold in Europe. The number following the mark indicates the test facility, not the directives or standards that the product claims to meet; so you may find different products with the same number, or similar products with different numbers.

The CEN (Comité Européen de Normalisation or European Committee for Standards) issues EN (European Norm) standards specific to the type of product; these standards may have any number of safety, performance and testing requirements. The EN standard for dynamic climbing ropes, for example, is EN 892. The UIAA standard 101 is comparable. The UIAA mark is sometimes printed inside a little mountain-shaped logo. You may also encounter reference to ISO 9000. This is a paperwork standard that doesn't indicate quality or performance but signifies that the manufacturer's processes, including quality testing, are well documented. It suggests that the manufacturer has its act together overall. You'll increasingly see ISO 14000 certificates, indicating the manufacturer implements and documents an acceptable environmental management policy.

Source: *The Mountaineering Handbook* by Craig Connally. Used with permission.

Contents

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