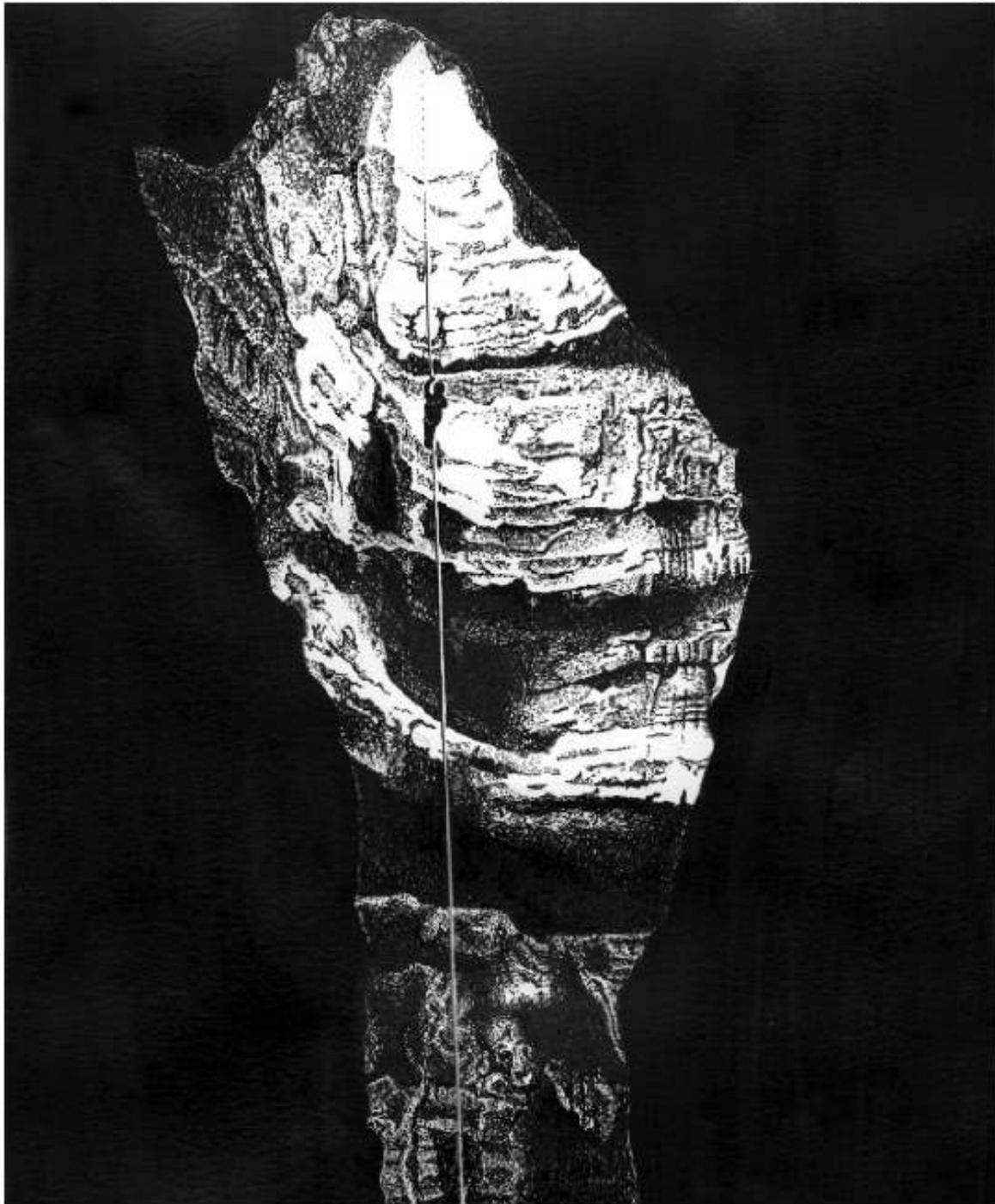


# *Nylon Highway* Issue #49



... especially for the Vertical Caver



**#49**

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**Nylon Highway** Issue #49



... especially for the Vertical Cover

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# Nylon Highway

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# Rack Safety

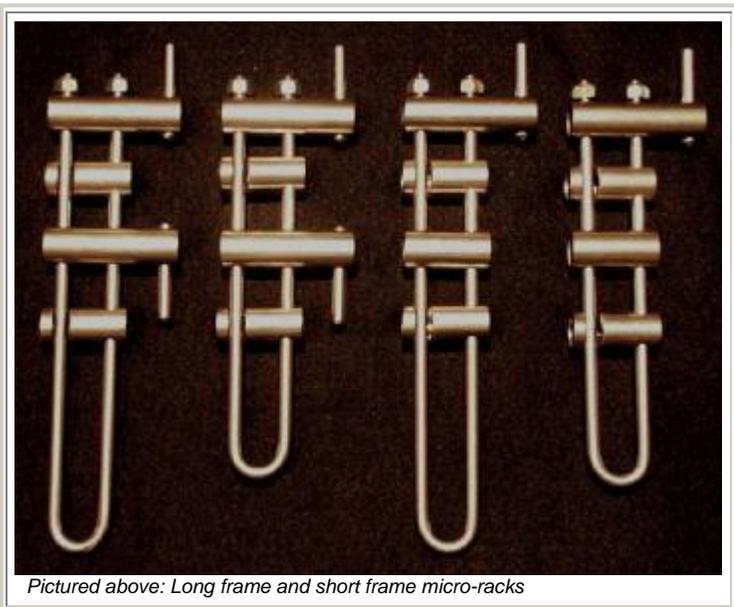
*By Carroll Bassett*

[Editors Note: This is a follow-up to the article titled: "**Danger! Don't Feed the Micro-rack!**", by Scott McCrea, that appeared in **NYLON HIGHWAY NO. 48 - 2003**]

Scott's point is well taken and his advice to use your other hand (aka balance hand, not your brake hand ) to not only spread the bars but to hold the fourth bar closed when feeding stiff rope makes good sense. If you routinely find yourself feeding rope (either because your rope is very stiff, you are a light person, or the rope weight acts to create too much friction) we strongly suggest that you switch frames to the longer version (BMS will be happy to switch your frame for \$20US plus \$6US shipping). This adds only about an ounce and just over an inch in length to your Micro-Rack and seems to solve most feeding issues our customers have had in the past.

If your problem persists and you are still uncomfortable with either a minirack or Micro-Rack a bobbin type device or a full sized rack may well suit your needs better.

Another approach to solving this possible problem is to make the fourth bar latch harder. This will increase the force that it takes to open and close the fourth bar with you find after tapping the bar it is too hard to engage with the frame properly you have probably closed the slot a bit too much and will need to open it a little. A rod slightly larger than the slot can be lightly tapped



*Pictured above: Long frame and short frame micro-racks*

into it with the effect of opening the slot slightly. Check the latching action after each adjustment to make sure of the bar's proper functioning. Older racks should be checked periodically as wear from use can lessen this latching force. Anyone who feels uncomfortable with making these adjustments themselves is welcome to return their Micro-Racks to BMS along with the return shipping (see above) for a free tune up.

Mini-racks made by other manufacturers with aluminum bars may have some issues with cracking so the manufacturers should be consulted first before any adjustments are made. Using a QAS (quick attachment safety) is highly recommended when approaching an edge especially before one has fully loaded the rope. For those of you unfamiliar with this technique I will briefly describe its components and their use. A QAS generally consists of a personal ascender or rope grab which has the ability to be attached to a rope quickly with one hand and a tether that securely connects it to the users harness.

The length of the tether should allow attachment above your descender but not be so long as to not allow easy reach when fully loaded on rope. It is generally clipped to the balance hand side of the rappellers harness to make it easy and fast to attach to the rope when on rappel. As one moves down the rope towards the lip the cam is held slightly open with the balance hand to allow progress. To stop progress the cam is allowed to engage the rope. This adds somewhat to the complexity of a system and can be taught on steep slopes for gaining experience before a real drop.

The auto-block is another rappel safety technique worth knowing and simply puts the ascender below the rappel device. Rather than a mechanical ascender a small prussik (6-7mm acc. cord) is tied onto the rope below the descender and then attached to the leg loop on the rappellers brakehand side usually with an oval or triangular quick link . Be sure to tie your prussik carefully and dress it properly. This should be rigged as short as possible so not to allow the prussik to ride up into your descender when loaded. To move down the rope the prussik is broken with the brakehand and rope allowed to slide through. To stop simply let go of the prussik and it will grab the rope stopping progress. Since the prussik only receives a small proportion of the users total weight (most of the users weight is on the descender above) it is relatively easy to continue a rappel after stopping by breaking the grip of the prussik. Again, practice with this technique on a steep slope to gain expertise and confidence. This is especially useful for the first person into a pit to use as there will be no one to bottom belay you in the event of an emergency.

Readers should be careful to understand these concepts fully before using them and always practice the highest standards of safety when on rope. Whenever in doubt seek out competent training and advice. Be safe and enjoy.

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# Will Your Safety Harness Kill You?

**Workers and emergency response personnel must be trained to recognize the risks of suspension trauma.**

*by Bill Weems and Phil Bishop*

I was surprisingly comfortable with my legs dangling relaxed beneath me, and my arms outstretched in a posture that must have resembled a crucifixion. I had no feeling of stress and mused as to why this was considered dangerous. I felt I could stay in this position for a long time. Three minutes later, maybe less, I wondered why I suddenly felt so hot. The next thing I knew, they were reviving me from unconsciousness.

I had just experienced what could be deadly for your workers who use safety harnesses. Fortunately for me, my suspension trauma occurred in the safe environment of the research ward of University of Texas Medical Branch Hospital at Galveston, Texas, where I was the first subject in a NASA experiment studying orthostatic intolerance in astronauts. Your workers won't be so lucky.

## **Harness-Induced Death**

Wide ranges of situations require safety harnesses of various types. Workers requiring fall protection, workers entering many confined spaces, mountain climbers, deer hunters in elevated stands, and cave explorers all try to protect themselves through the use of safety harnesses, belts, and seats. What is little known however, is that these harnesses can also kill.

Harnesses can become deadly whenever a worker is suspended for durations over five minutes in an upright posture, with the legs relaxed straight beneath the body. This can occur in many different situations in industry. A carpenter working alone is caught in mid-fall by his safety harness, only to die 15 minutes later from suspension trauma. An electrical worker is lowered into a shaft after testing for toxic gases. He is lowered on a cable and is positioned at the right level to repair a junction box. After five minutes he is unconscious--but his buddies tending the line don't realize it, and 15 minutes later a dead body is hauled out.

The cause of this problem is called "suspension trauma." Fall protection researchers have recognized this phenomenon for decades. Despite this, data have not been collected on the extent of the problem; most users of fall protection equipment, rescue personnel, and safety and health professionals remain unaware of the hazard.

## **Suspension Trauma**

Suspension trauma death is caused by orthostatic incompetence (also called orthostatic intolerance). Orthostatic incompetence can occur any time a person is required to stand quietly for prolonged periods and may be worsened by heat and dehydration. It is most commonly encountered in military parades where soldiers must stand at attention for

prolonged periods. Supervisors can prevent it by training soldiers to keep their knees slightly bent so the leg muscles are engaged in maintaining posture.

What happens in orthostatic incompetence is that the legs are immobile with a worker in an upright posture. Gravity pulls blood into the lower legs, which have a very large storage capacity. Enough blood eventually accumulates so that return blood flow to the right chamber of the heart is reduced. The heart can only pump the blood available, so the heart's output begins to fall. The heart speeds up to maintain sufficient blood flow to the brain, but if the blood supply to the heart is restricted enough, beating faster is ineffective, and the body abruptly slows the heart.

In most instances this solves the problem by causing the worker to faint, which typically results in slumping to the ground where the legs, the heart, and the brain are on the same level. Blood is now returned to the heart and the worker typically recovers quickly. In a harness, however, the worker can't fall into a horizontal posture, so the reduced heart rate causes the brain's blood supply to fall below the critical level.

Orthostatic incompetence doesn't occur to us very often because it requires that the legs remain relaxed, straight, and below heart level. If the leg muscles are contracting in order to maintain balance and support the body, the muscles press against the leg veins. This compression, together with well-placed one-way valves, helps pump blood back to the heart. If the upper-legs are horizontal, as when we sit quietly, the vertical pumping distance is greatly reduced, so there are no problems.

In suspension trauma, several unfortunate things occur that aggravate the problem. First, the worker is suspended in an upright posture with legs dangling. Second, the safety harness straps exert pressure on leg veins, compressing them and reducing blood flow back to the heart. Third, the harness keeps the worker in an upright position, regardless of loss of consciousness, which is what kills workers.

### **Phases of Fall Protection**

There are four phases of fall protection: Before the fall, at fall arrest, suspension, and post-fall rescue. Each phase presents unique safety challenges. Suspension trauma can be influenced by all aspects of the fall, so they are all important. As with many aspects of safety, increasing the safety in one phase can compromise the safety of the others. Whatever training workers have received will determine how they respond to different phases. Here is a brief discussion of each aspect of fall protection.

#### *Before the fall*

The key issue of fall protection before the fall is compliance. If a harness is too uncomfortable, too inconvenient, or interferes too much with task completion, workers may not use the equipment or may modify it (illegally) to make it more tolerable. A second major point is the length of the attachment lanyard, or, how far can a worker fall before his fall is arrested? The longer the fall, the greater the stress on the body will be when the fall is arrested. The shorter the lanyard, the more often it will have to be repositioned when workers are mobile. A moveable safe anchor is one solution, but this situation is only occasionally available.

#### *Fall arrest*

The whole concept of fall protection is that workers who fall will be stopped by the tethering system. The longer the attachment lanyard, the greater the acceleration time during the fall and the greater the stress on the body at arrest. Unfortunately, the posture of the falling worker is unpredictable.

Depending on the harness attachment point and the position of the worker's body at arrest, different harness attachments offer different advantages. An attachment near the shoulders means that any drag from the lanyard will serve to position the worker's body in an upright position so the forces are distributed from head to foot. The head is somewhat protected if the legs and body precede it in the fall, but this offers some disadvantages after the fall arrest is completed.

### *Suspension*

Many safety professionals naturally assume that, once a fall has been arrested, the fall protection system has successfully completed its job. Unfortunately, this is not the case. A worker suspended in an upright position with the legs dangling in a harness of any type is subject to suspension trauma.

Fall victims can slow the onset of suspension trauma by pushing down vigorously with the legs, by positioning their body in a horizontal or slight leg-high position, or by standing up. Harness design and fall injuries may prevent these actions, however.

### *Rescue*

Rescue must come rapidly to minimize the dangers of suspension trauma. The circumstances together with the lanyard attachment point will determine the possibilities of self-rescue. In situations where self-rescue is not likely to be possible, workers must be supervised at all times. Regardless of whether a worker can self-rescue or must rely upon others, time is of the essence because a worker may lose consciousness in only a few minutes.

If a worker is suspended long enough to lose consciousness, rescue personnel must be careful in handling such a person or the rescued worker may die anyway. This post-rescue death is apparently caused by the heart's inability to tolerate the abrupt increase in blood flow to the right heart after removal from the harness. Current recommended procedures are to take from 30 to 40 minutes to move the victim from kneeling to a sitting to a supine position.

### **Interference Among Phases**

An arrest harness attachment on the front of the body facilitates self-rescue after a fall. However, a front attachment means the arresting lanyard may be in the way for many work tasks. An attachment point near the center of gravity (CG) makes post-fall body positioning much easier and increases the likelihood that a fallen worker will not be suspended in an upright vertical position.

Yet a front near-CG attachment point can greatly increase the bending stress on the spine at the instant of arrest, raising the possibility that the arrest itself results in serious injury. The most protective harnesses for suspension can be the least comfortable.

### **Recommendations**

Safety harnesses save many lives and injuries. However, continual vigilance is needed to train and supervise workers to ensure harnesses are used safely. All phases of fall protection need to be examined for each particular application. Workers and emergency

response personnel must be trained to recognize the risks of suspension trauma.

*Before the potential fall:*

1. Workers should never be permitted to work alone in a harness.
2. Rope/cable tenders must make *certain* the harness user is conscious at all times.
3. Time in suspension should be limited to under five minutes. Longer suspensions must have foothold straps or means for putting weight on the legs.
4. Harnesses should be selected for specific applications and must consider: compliance (convenience), potential arrest injury, and suspension trauma.
5. Tie-off lanyards should be anchored as high and tight as work permits.

*After a fall:*

1. Workers should be trained to try to move their legs in the harness and try to push against any footholds.
2. Workers hanging in a harness should be trained to try to get their legs as high as possible and their heads as close to horizontal as possible (this is nearly impossible with many commercial harnesses in use today).
3. If the worker is suspended upright, emergency measures must be taken to remove the worker from suspension or move the fallen worker into a horizontal posture, or at least to a sitting position.
4. All personnel should be trained that suspension in an upright condition for longer than five minutes can be fatal.

*For harness rescues:*

1. The victim should not be suspended in a vertical (upright) posture with the legs dangling straight. Victims should be kept as nearly horizontal as possible, or at least in a sitting position.
2. Rescuers should be trained that victims who are suspended vertically before rescue are in a potentially fatal situation.
3. Rescuers must be aware that post-rescue death may occur if victims are moved to a horizontal position too rapidly.

*Recommendations on harnesses:*

1. It may be advantageous in some circumstances to locate the lanyard or tie-off attachment of the harness as near to the body's center of gravity as possible to reduce the whiplash and other trauma when a fall is arrested. This also facilitates moving legs upward and head downward while suspended.
2. Front (stomach or chest) rather than rear (back) harness lanyard attachment points will aid uninjured workers in self-rescue. This is crucial if workers are not closely supervised.
3. Any time a worker must spend time hanging in a harness, a harness with a seat rather than straps alone should be used to help position the upper legs horizontally.
4. A gradual arrest device should be employed to lessen deceleration injuries.
5. Workers should get supervised (because this is dangerous) experience at hanging

in the harness they will be using. [OHS endbug]

### **Authors**

*Bill Weems (bweems@ccs.ua.edu) and Phil Bishop are at the University of Alabama, in Tuscaloosa, Ala.*

*Dr. Weems is an industrial hygienist. He directs Safe State, the OSHA consultation agency for small business in Alabama.*

*Dr. Bishop is an ergonomist. He teaches and conducts research in the physiology of human performance.*

### **Reference**

Seddon, Paul. *Harness Suspension: review and evaluation of existing information*. Health and Safety Executive. Research Report 451/2002. 104 pp.

#### **Pull quotes:**

All personnel should be trained that suspension in an upright condition for longer than five minutes can be fatal.

Depending on the harness attachment point and the position of the worker's body at arrest, different harness attachments offer different advantages.

Fall victims can slow the onset of suspension trauma by pushing down vigorously with the legs, by positioning their body in a horizontal or slight leg-high position, or by standing up.

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# Comparative Testing of High Strength Cord

by Tom Moyer, Paul Tusting, and Chris Harmston

Complete test data for the results presented in this paper can be found at:  
<http://www.xmission.com/~tmoyer/testing>

Chris Harmston and Paul Tusting are employees of Black Diamond Equipment, the manufacturer of a product evaluated in this paper. All effort has been made to present the information here impartially. This paper presents the results of testing of many products. It does not represent the official position of Black Diamond Equipment.

## Abstract

Many climbers carry an 18-foot length of accessory cord called a cordelette for rigging anchors and as a tool for self-rescue situations. In the past, this cord was usually 7mm Nylon. In recent years, many climbers have changed to using one of a number of high-strength materials in smaller diameters. Vectran, Technora, Spectra, Kevlar, Kevlar/Spectra blends and Spectra/Nylon webbing are all used for these purposes along with Nylon cord and Nylon webbing. These materials all have different properties, and in some applications, dramatically different performance. This study tests and compares the strength of different knots in these materials, in both static and dynamic loading, along with their resistance to cyclic flexing, in order to judge their suitability as tools for climbers and rescuers.

## Background

The use of Kevlar, Spectra and Vectran fibers to make high-strength rope was pioneered by the sailing industry, to take advantage of their high tensile strength, low elongation, and low moisture absorption. These materials gradually moved into climbing applications, first as chock cord and more recently as cordelette material, prusik cord, and emergency rappel line. In the climbing world they have been surrounded by a lot of mythology and little hard data. It has been said that tying and untying chock cord weakens it severely, that double fisherman's knots are not secure, triple fisherman's are needed, that Kevlar-based cords will self-abrade and eventually weaken, and that knots will not hold in Spectra/Nylon webbing. In recent years, manufacturers have been combining and improving materials, and climbers have been expanding their applications. Have the materials improved? Are the myths true? And most importantly, are these materials strong enough to use in these applications? This testing will provide some answers to these questions.

## Materials

### ***Kevlar:***

Kevlar was one of the first high-strength fibers to be used in rope. It still offers high tensile strength and very low elongation, but has poor fatigue properties. The fibers inside the rope abrade each other, offering little indication of the reduced strength until the rope breaks. Kevlar has a very high melting point, 500 °C or 932 °F. Kevlar-core

ropes are sold as escape lines for firefighters - to be used once and discarded. Manufacturers have had some success at solving the self-abrasion problem by combining Kevlar with Spectra.

**Technora:**

Technora, like Kevlar, is an aramid, but with vastly improved fatigue properties. It shares Kevlar's high tensile strength and high melting point.

**Spectra:**

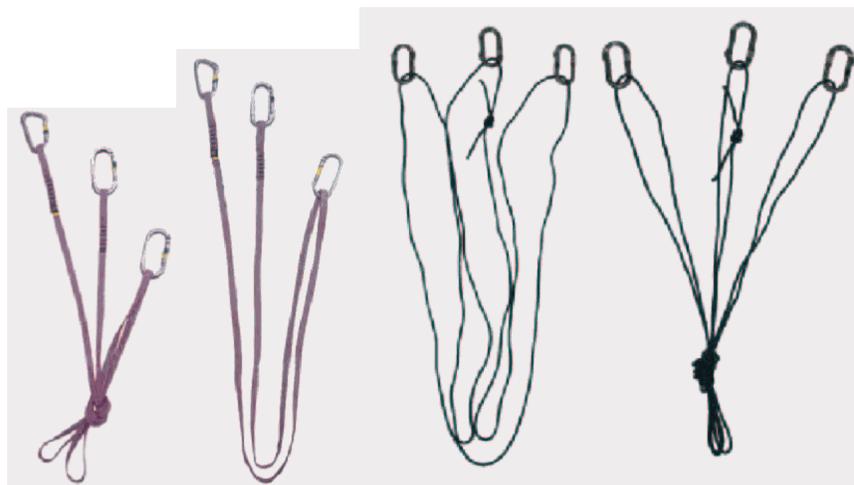
Spectra is a very high molecular density form of polyethylene - the same thing used to make grocery bags, six-pack carriers and milk jugs. The manufacturing process aligns the molecules, which vastly increases the strength of the material. It is twice as strong as hardened steel (per unit area) and one-tenth the density. Spectra has several difficult issues. The melting point is very low, 147 °C or 297 °F, not much warmer than boiling water. The material is unbelievably slippery, which makes it difficult for manufacturers to form into a workable rope. And, while the modulus of the fibers is comparable to steel, they slowly elongate under a continuous load. This process is called "creep." It is mostly irrelevant to climbers, but annoying to sailors. Spectra/Nylon is also known as Dyneema (a trade name of Beal Ropes) in Europe.

**Vectran:**

Vectran is a liquid crystal polymer - its properties are between those of crystalline solids and liquids. It has similar strength to Spectra, but without the creep problems. It has poor UV resistance, which is not a problem when used as the core in kernmantel rope construction.

Seven products were tested for this project. Sterling Vectran, Blue Water Titan, Black Diamond Gemini2, Maxim Spectra A, Mountain Tools Ultratape, Sterling 7mm Nylon accessory cord, and Liberty Mountain 1 inch Nylon Tubular Webbing.

Sterling Vectran has a Vectran core and a Nylon sheath - it is sold in precut lengths labeled "cordelette" in addition to spools. Blue Water Titan has a braided Spectra/Nylon core and a Nylon sheath. Black Diamond Gemini2 has a Technora core and a polyester sheath. It is identical to the product sold as "Tech Cord" by Maxim (New England Rope). The original Black Diamond Gemini was a different product, similar to Maxim's Spectra-A, and has not been sold in several years. Spectra-A has a braided Spectra/Kevlar core and a polyester sheath. It has largely been replaced by Tech Cord, but is still sold, usually at cheaper prices. Ultratape is a Spectra/Nylon webbing, constructed to minimize the amount of Spectra on the outside surface. This helps protect the Spectra from UV damage, and lets knots hold better, since more Nylon is in contact.



**Cordelette Anchor**

**Webbolette Anchor**

(Karl Lew photo)

## Test Methods

### **Slow Pull Tests:**

Slow pull tests were done on the 11,000-lb SATEC Apex 11 EMF universal test machine at Black Diamond. These were done on unknotted material over 4" diameter drums, on figure-eight knots, on loops tied with double fisherman's, triple fisherman's and water knots, and on a cordelette loaded on a single arm. Pull rates and fixtures were consistent with CEN standards. The material was not temperature and humidity conditioned, but all tests were done at 29% humidity +/-4% and at 71°F +/-6°. Five samples were tested in each material for each configuration and the results were averaged. One sample of various friction knots was also tested in each material on Black Diamond 10.5mm Cirrus dry-coated rope.

Keep in mind that an *average* breaking strength (the arithmetic mean) is not a good quantity to use to determine whether a component is strong enough. A *minimum* breaking strength - three standard deviations below the mean - is much more appropriate. However, five samples are not sufficient to determine a meaningful statistical minimum, so average strength is presented here.

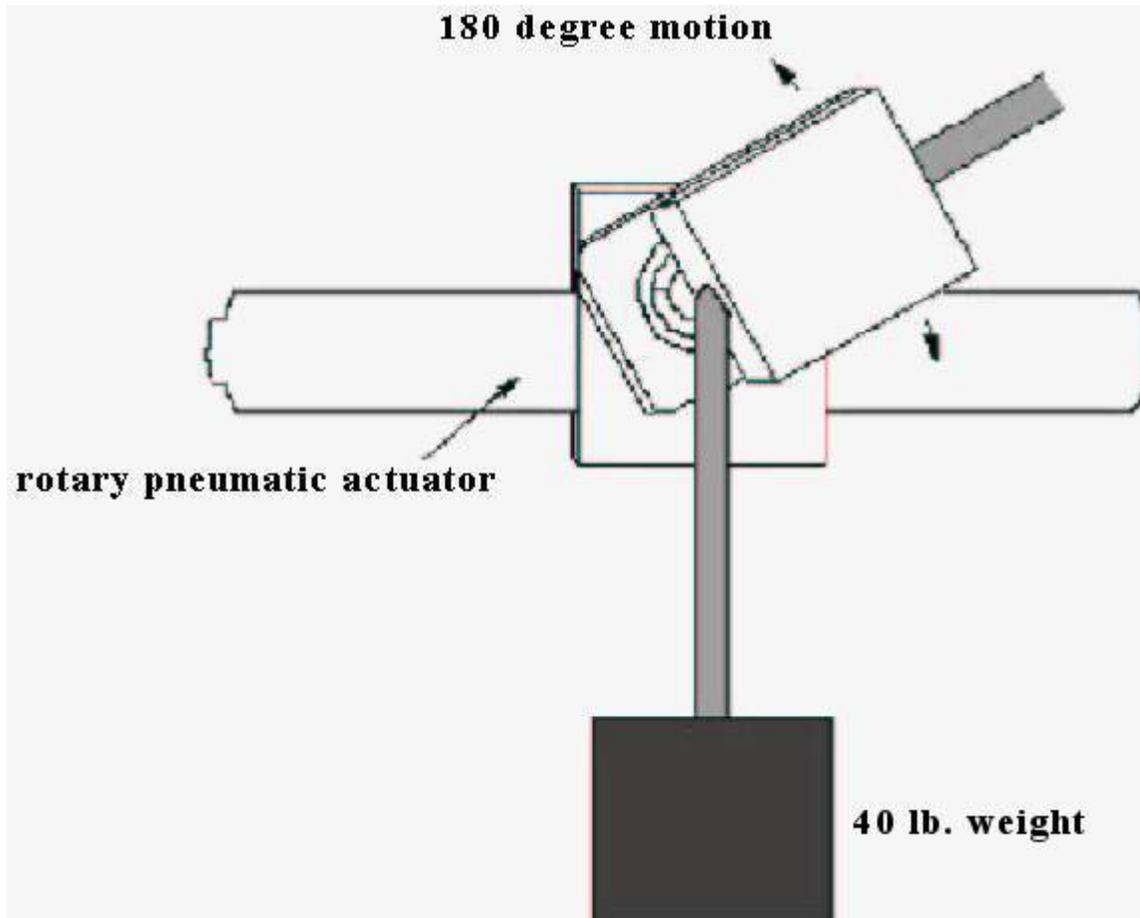
### **Drop Tests**

Drop Tests were conducted at the Rocky Mountain Rescue Group drop tower in Boulder Colorado. The configuration modeled the UIAA and CEN drop test - a fall factor 1.71 fall on 2.8 meters of rope. A new section of 10.5mm Black Diamond Cirrus (nondry) rope was used for each test. This rope carries a UIAA rated impact force of 8.4 kN (1888 lb). The cordelette to be tested was placed at the location of the "pivot edge", or the direction change anchor. The force at this point should theoretically be twice the rope tension because of the direction change. In reality, carabiner friction reduces this to around 170%. The load was applied to the cordelette with carabiners, as it would be in a climbing fall. As in the slow pull tests, only one arm of the cordelette was clipped. In accordance with the CEN specifications, the weight was dropped once every five minutes

until the cordelette had broken or sustained five falls without breaking.

**Flex Cycle Test:**

A cyclic flex test was run to check the fatigue performance of the different materials. A sample of cord passed through a horizontal hole in the fixture, flexed 90 degrees over a steel edge, and was loaded with a 40 lb weight. The fixture was rotated back and forth 180 degrees by a pneumatic actuator for a specified number of cycles, with all the flexing happening at the same point on the sample. The sample was then pull-tested over drums with the fatigued point in the free section to measure any reduction in tensile strength at that point.



**Results**

**Slow Pull Tests**

The Technora and Kevlar/Spectra cords live up to their billing as having extraordinary tensile strength, but the story changes immediately when the cord is knotted. Knot efficiencies for a figure-eight knot ranged from 40% on the Gemini to 92% on the Nylon. For a double fisherman's knot, Gemini and Titan share an interesting failure mode. The sheath breaks at the knot and the slippery core unties, pulling through the sheath. When a triple fisherman's knot is tied, this does not happen. The strength gain for the triple fisherman's is not large, but it is enough to change the mechanism. The Ultratape - a

Spectra/Nylon webbing - shows excellent strength in all of the knots, contradicting the popular belief that knots will not hold in this type of material. Testing is needed on webbing with a more conventional Spectra/Nylon weave to see if that conclusion can be extended to other products.

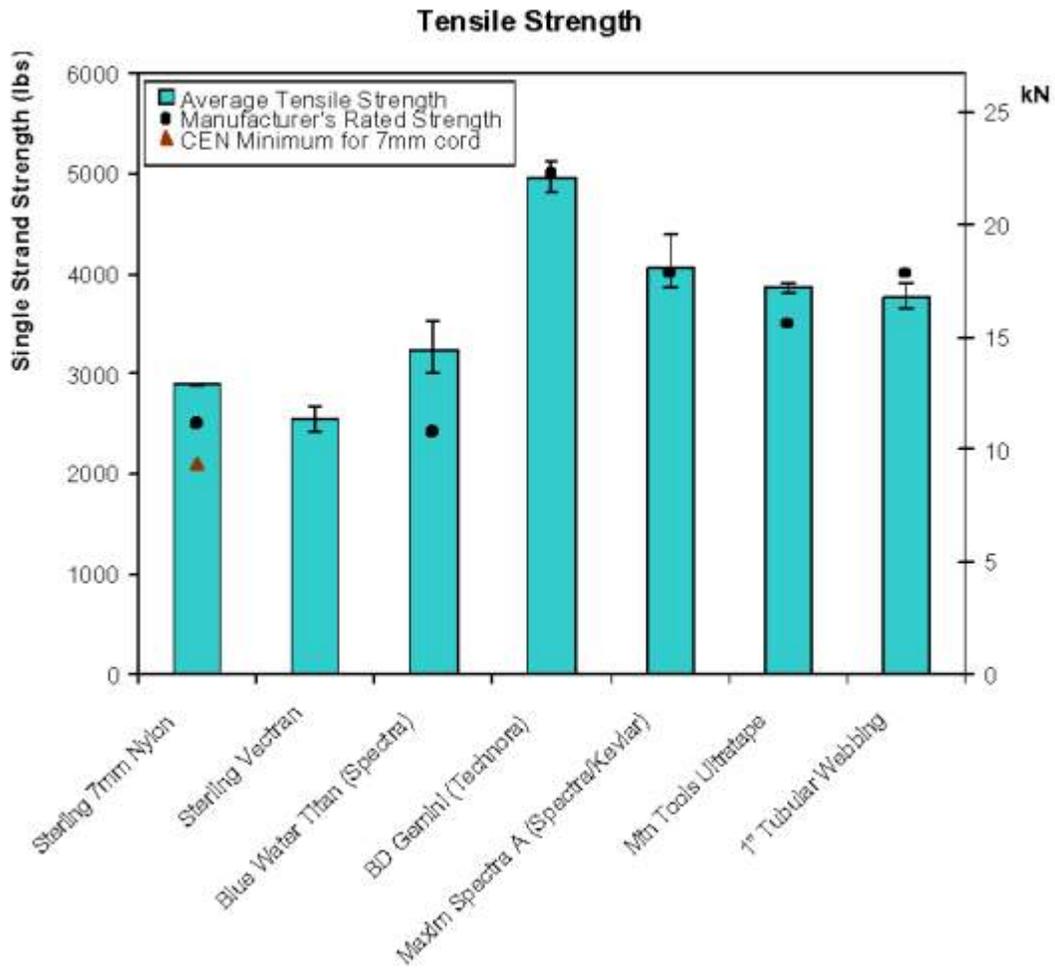
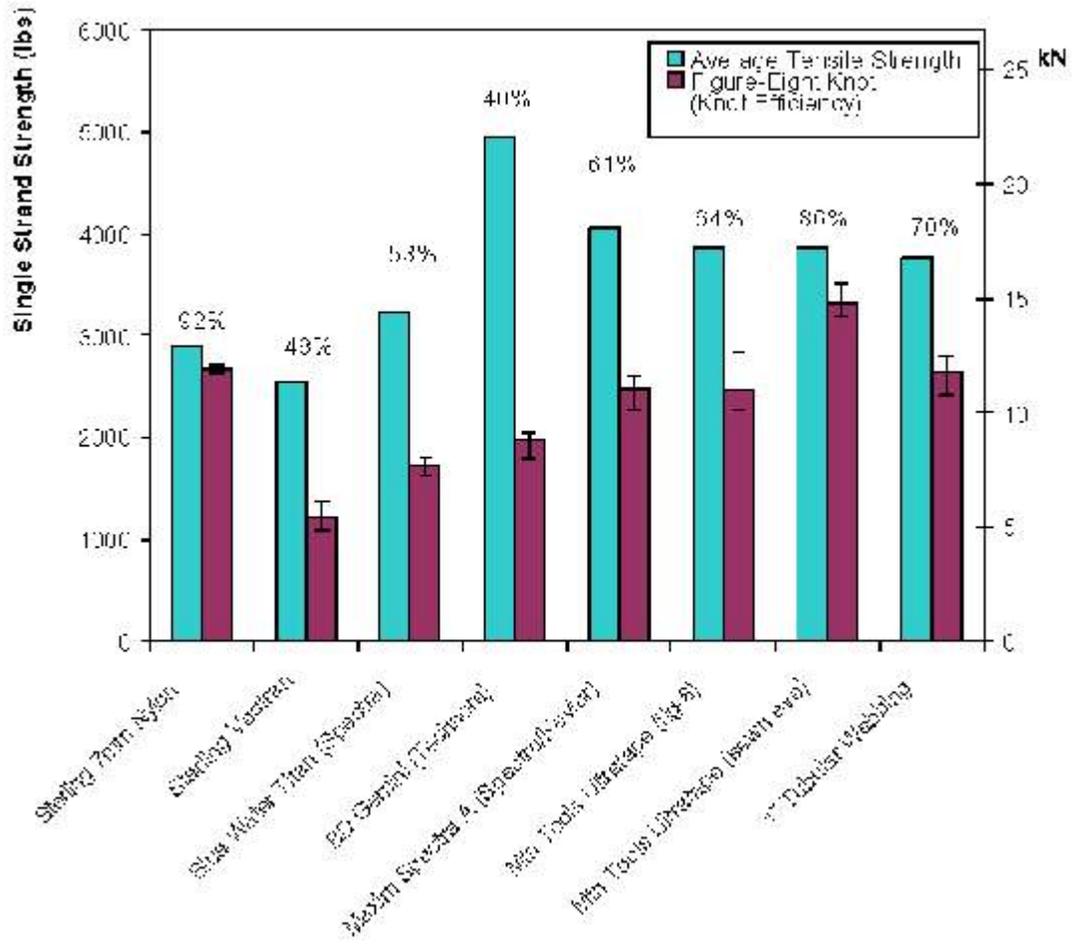
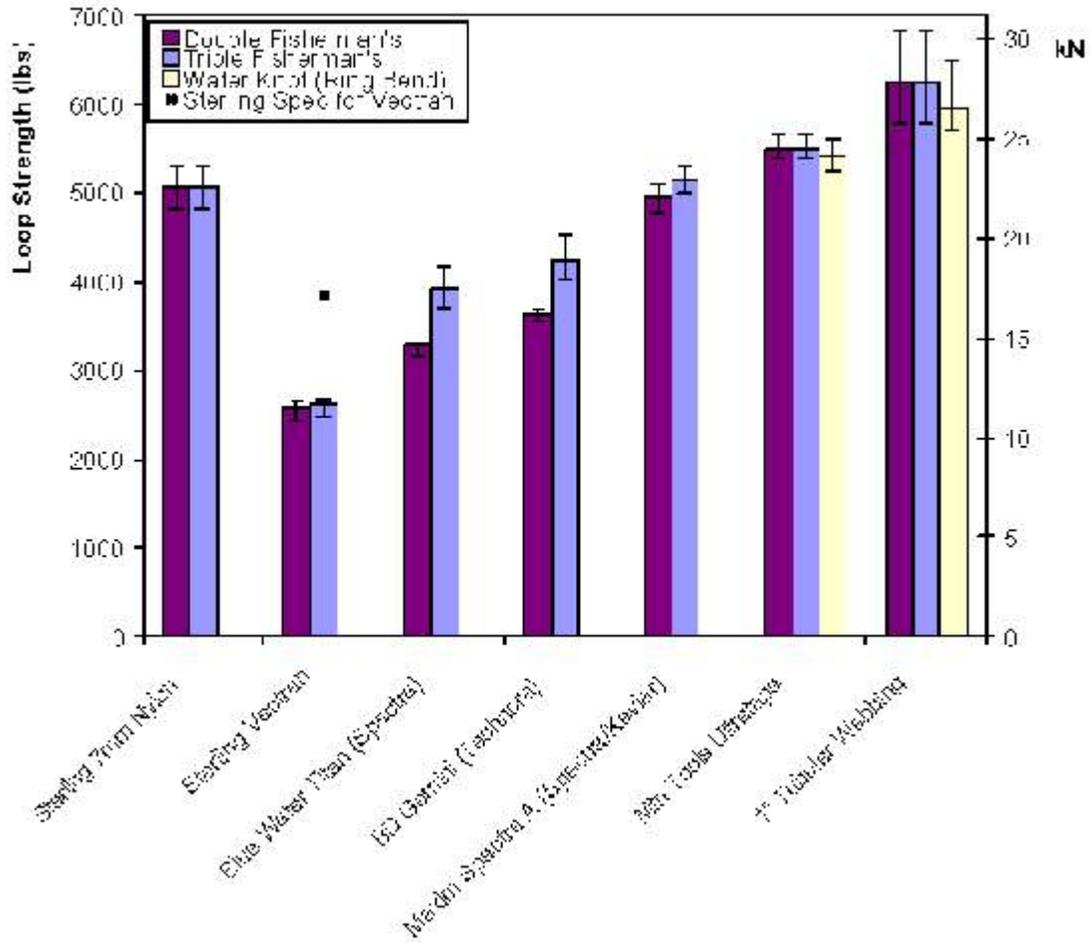


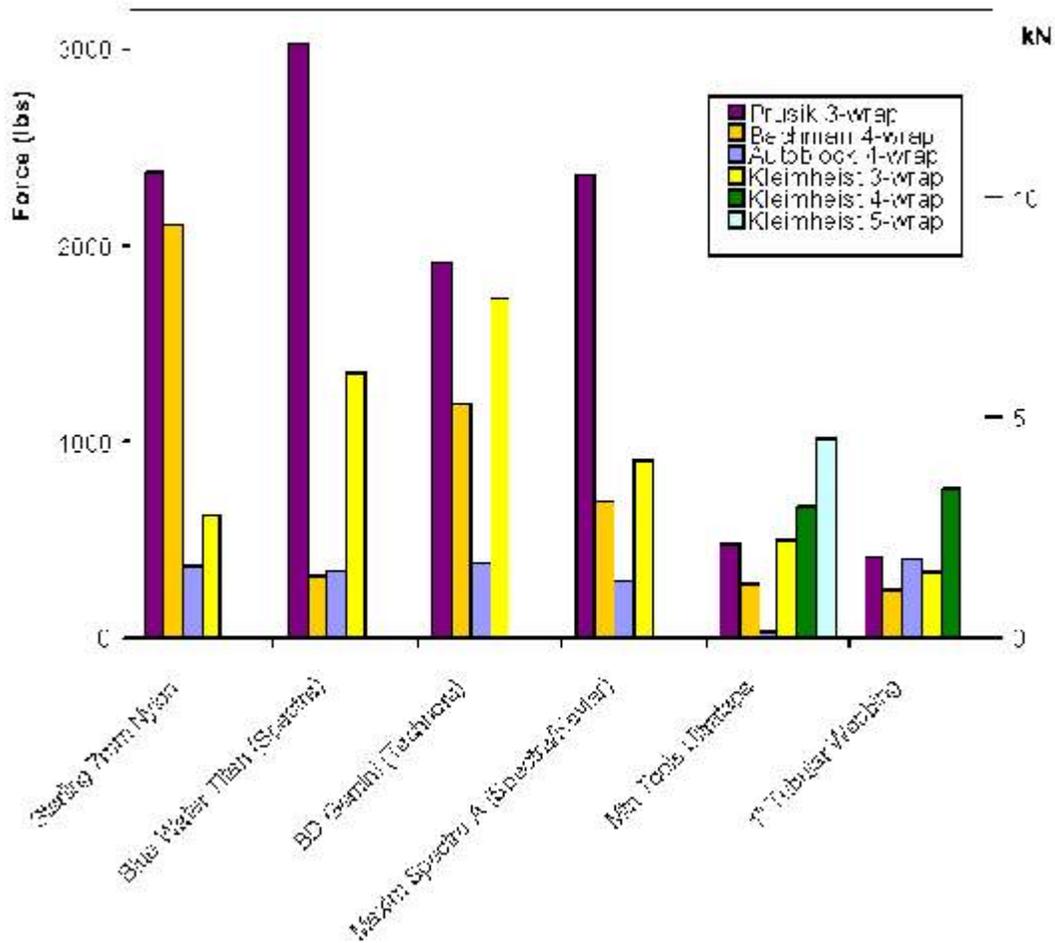
Figure Eight Knot Comparison



### Loop Knots (Bends) Comparison



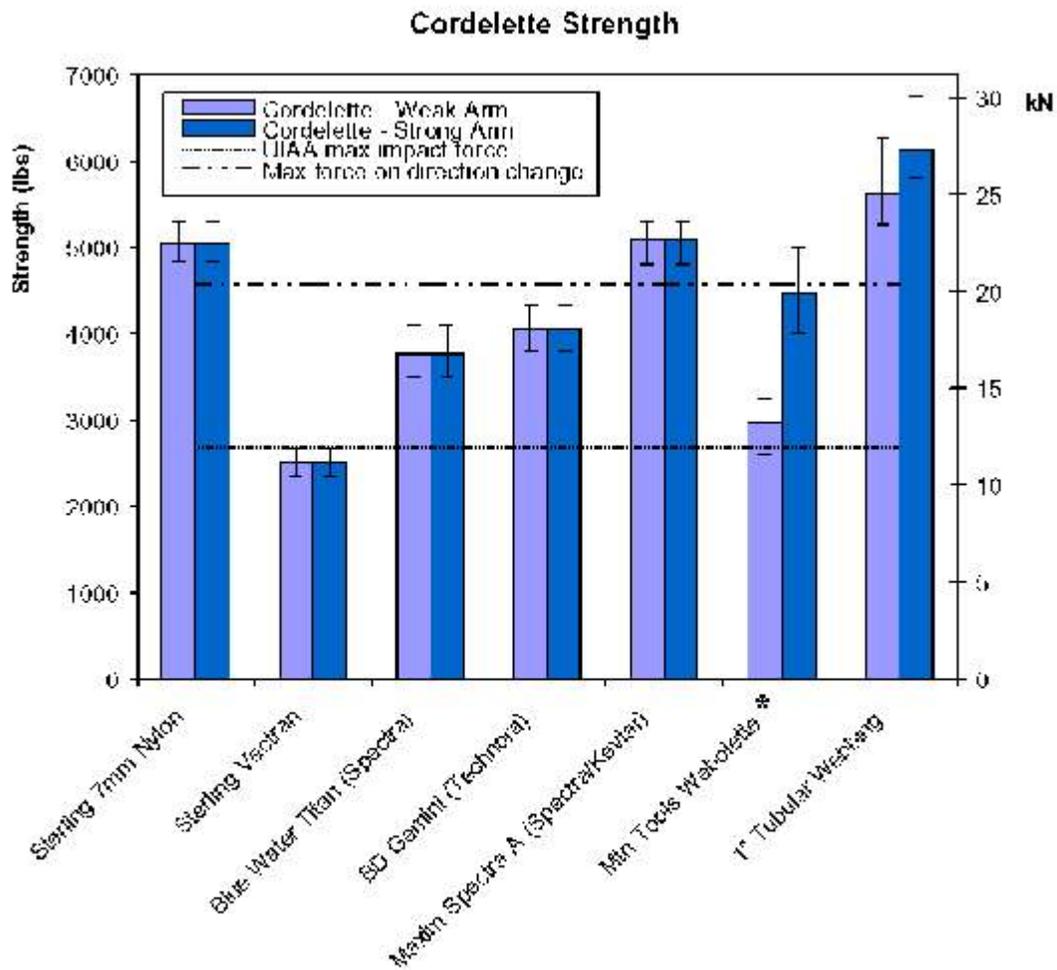
## Friction Knots



Friction knots were tested to determine whether there were any obvious reasons why any of these materials could not be used for ascending or as a self-rescue rope-grab. For all the cord materials, any of several friction knots work fine and the choice would be based simply on ease of tying and loosening in use. For the two webbing materials, it is tougher to get sufficient holding power. A climber can easily generate forces of 500 lb when ascending. If a hitch will not reliably hold that load, slipping will happen. For the webbing, adding wraps is the only way to get the holding power. The most convenient hitch to do this with is the Kleimheist. The fact that the Spectra/Nylon Ultratape can be used at all for friction knots also contradicts the conventional wisdom.

For the cordelette strength, both the strength of the weak arm (knotted or single-strand sewn) and the strength of the stronger arms are plotted. For most of the materials there is no difference. The material breaks at the pin or in the overhand cordelette knot. For the webolette, the weak arm is a single strand, so the double-strand leg is considerably stronger. Since these are used as anchors, the UIAA spec for maximum dynamic-rope impact force is shown for comparison. This represents a typical worst-case force on the rope. However, if the belay is run through the anchor, force on the anchor is multiplied. A level 170% of the UIAA spec - an assumed maximum - is also shown for comparison. It is apparent from this chart that at least some of these cordelettes would be expected to

fail a UIAA drop test.

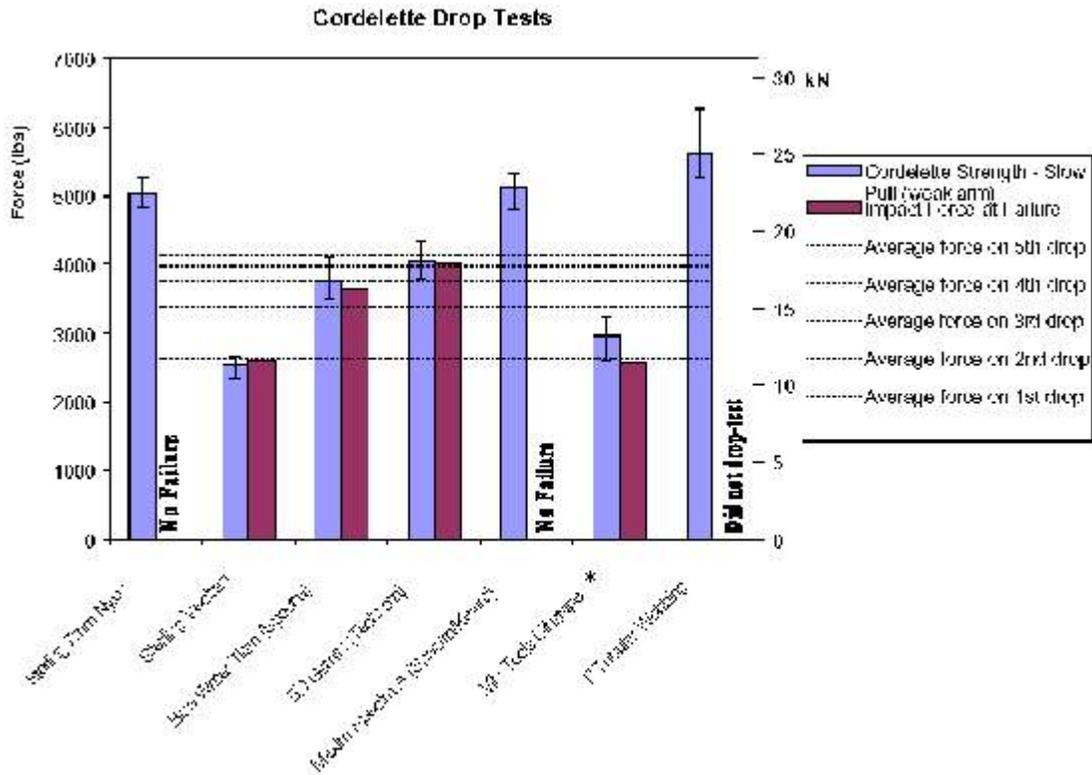


\* For the webolette, the weak arm is a single strand with a sewn eye. The strong arm is a double strand.

### Drop Tests

One might guess that some of the materials, particularly those with Spectra in the core, would be weaker when loaded dynamically than statically because of heat produced by energy dissipation in the knot. In fact, that turned out not to be the case. Every material failed at very close to the static failure load. The one that appears to be an exception, the Ultratape, was drop-tested in a non-standard configuration - with a tied eye rather than a sewn eye in the single strand. Horizontal lines in the chart show the average impact forces on the anchor for each drop. On each successive drop, the rope's modulus increases (it gets stiffer) and the impact force increases. Other than knot tightening, there was no evidence of any change to the cordelette with successive impacts. The Sterling Vectran failed on the first drop, raising some serious questions about its suitability as a cordelette material. Keep in mind that the rope used in the testing has a relatively low impact force rating of 8.4 kN, nowhere close to the UIAA limit. In addition, rope modulus increases with age and use, so older ropes would be expected to place a higher impact

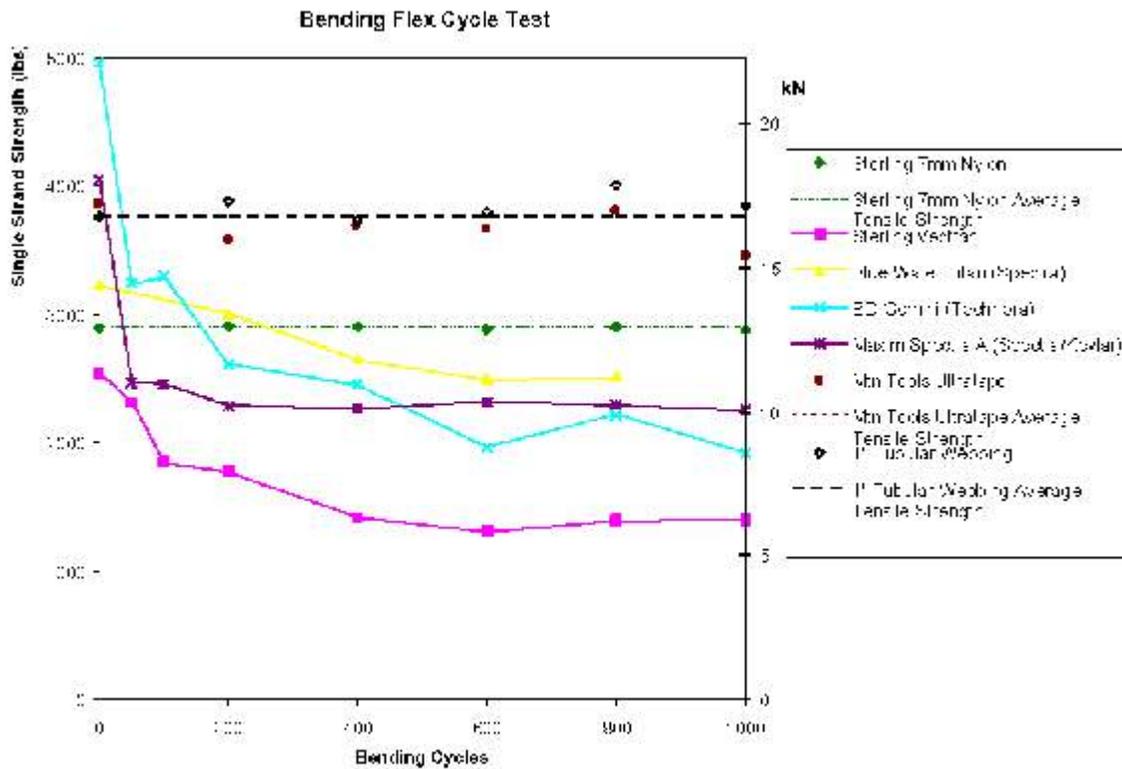
force on the anchor. 7mm Nylon and Maxim Spectra-A did not fail in five drops. Tubular Nylon webbing was not tested, but it is assumed from its slow-pull strength that it would not have failed in drop testing.



\* Ultrape was tested with a sewn eye in the pull-tests and a tied eye in the drop-tests.

### Flex Cycle Test

The results of this test were a surprise. One might expect to see linearly descending strengths, with different slopes for different materials. Instead, Nylon and the Spectra/Nylon webbing show *no* drop in strength over the test, and Technora, Spectra-A, and Vectran all show an immediate and dramatic reduction in strength, but at higher cycles, the curve flattens and little further strength appears to be lost. Since the effect happens so quickly, a used piece might show this strength loss everywhere along its length. The knot efficiencies for these materials, which are very low in new material, may be higher when the cord is used and more flexible, but further testing is needed to determine this.



## Conclusions

How strong should your anchor be? One arm of a Vectran cordelette, for example, fails at only 2600 lb (11.5 kN). This is little stronger than a good carabiner in the open-gate mode - and the material gets weaker with use. Is this strong enough? One can easily argue that the drop test we performed is unduly harsh. First, it uses a completely static belay. A sticht-plate or tube belay-device can reduce the peak impact forces significantly. Second, the lead rope is run through the central anchor point. This practice increases the load at the anchor. Third, the test loaded only one arm of a cordelette. While the cordelette anchor does not equalize when the belayer shifts position, there is typically enough stretch in each arm that all three will be loaded to varying degrees in a major impact. Fourth, Chris Harmston, Black Diamond's Quality Assurance Manager, has reviewed field failures of climbing gear for eight years. He has never seen a stopper rated at over 10 kN fail, and has seen only a few carabiners fail in closed-gate mode. He believes that forces exceeding 10kN rarely happen in climbing falls.

All that said, we do not think it is unreasonable to expect one arm of the anchor to hold at least *one* UIAA fall on a soft rope when both the rope and the cordelette material are new! The decrease in strength with use is a worry for any of the Technora, Kevlar or Vectran materials. The Gemini and the Spectra-A are also extremely stiff and difficult to tie and untie. An 18-foot piece makes a bulky object hanging from the harness. They make excellent chock cord (where a stiff cord is desirable), but would make a poor cordelette. Among the high-strength cords, Titan seems to be the most suitable material for cordelettes. The Ultratape is even better, and the webollette is an elegant solution to

multi-point anchors, although we'd prefer to see slightly higher strength on the single-strand arms. Last, Nylon cord and webbing may be the best of all. Although heavier, they are cheap, strong, universally available, and seem to have a virtually unlimited flex life.

## **Acknowledgements**

Black Diamond provided test material and made their test lab available for this project. Sterling Rope, Blue Water Rope, New England Rope, and Mountain Tools all provided material for testing. Karl Lew asked these same questions a year ago and provided samples for earlier testing in the BD test lab on this subject. Bill May, Lewis Dahm, John Snyder, Jim Gallo, Scott Whitehead, Dave Hibl and others from the Rocky Mountain Rescue Group in Boulder worked hard to get their new drop tower up and running in time for it to be used for this project. Sensotec provided the load cell used to measure forces at the drop-tower.

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# THE EFFECTIVENESS OF A BOTTOM BELAY ON LONG DROPS

*by Jim Kovach*



This article is on the effectiveness of a bottom belay on long rappels. We had been wondering about this for quite a few years and had even done a few surveys to try and gauge the response of people who would be likely to use a bottom belay. In 1997 we handed out 150 surveys at the International Technical Rescue Symposium (ITRS) but only 22 people responded. The question we posed was "How effective would a bottom belay be on an 800 foot rappel?"

7 people said it would be effective  
6 said it would not be effective  
4 said it depends  
4 said they don't use one  
and 1 didn't answer.

Those were mixed results from a very small sampling of rescuers. So, in 1998 we handed out a survey at Bridge Day. Bridge Day offers the opportunity to rappel from the catwalk of an 876 ft bridge. We asked the question "How effective will your bottom belay be if it is

needed on Bridge Day?"

114 said it would be effective

37 said it would not be effective

36 said it would be somewhat effective.

Bridge Day is an event that is held once a year on the third Saturday in October in Fayetteville West Virginia. Fayetteville has a population of 2,200 that swells to 100,000 for this festival that is rated as one of the best in North America. This event celebrates the completion of the New River Gorge Bridge. This bridge is the second longest steel arch span in the world and is three thousand thirty feet in length with a main span of 1700 feet. It is the highest bridge east of the Mississippi and second highest in the United States. The bridge was opened in 1977 and the West Virginia Legislature established the New River Gorge Bridge Day Commission to "sanction, coordinate and promulgate rules and regulations for this event." Bridge Day began in 1980. BASE-jumping from the bridge began in 1981 and rappelling in the mid 80's.

Benjy Simpson, the Bridge Day Rappel Coordinator, began keeping statistics on rappellers in 1992. From then until 2002 there were 1,783 rappellers who did 3,499 rappels. The rappellers rig their ropes from the catwalk, 25 feet below the bridge deck. Their rappels range in height from 650 feet to approximately 850 feet depending on where their landing spot is located in the valley below. Everyone at Bridge Day uses single rope techniques and many rely on their bottom belay should anything go wrong. These rappellers have ranged in age from 14 years old to 75 years of age and until the year 2002 there had never been a rappel accident.

The accident in 2002 prompted us to approach Benjy Simpson, the Bridge Day Coordinator, with a request to do some testing. Our stated objective was to determine the effectiveness of a bottom belay on long drops if the rappeller is using a standard length stainless steel brake bar rack and loses control. Our test mass would be 150-225 lbs. of steel weights rigged on a standard SMC stainless steel 6 bar open leg rack with 4 or 5 bars rigged and spread apart. This would simulate a rappeller who lost control.



For our testing we removed the 6<sup>th</sup> bar completely from the rack, so it could not interfere in any way with the test. We would release the test mass from varying heights, which would give different lengths of rope between the belayer and the rappeller and different lengths of rope between the rappeller and the anchor.

Benjy Simpson, owner and operator of PASSAGES TO ADVENTURE, took our request to the Bridge Day Commission and once it was approved we began to prepare for the testing.

To accomplish this we needed to overcome some obstacles. How do we safely release our test mass that may be 400 to 600 feet from the catwalk or the ground? How do we safely perform a bottom belay without subjecting our belayer to potential harm? These were 2 big concerns we had. Fortunately, one of our instructors, Steve Bellamy, is an electronics wizard. He spent countless hours developing a radio controlled release device that would work up to approximately 700 feet.

To protect our belayer we realized we had to remove him from the drop zone. To do this we decided to use a change of direction at the belayer's location, which would move him away from the area. Next we had to come up with the equipment to perform the testing. We submitted a proposal to PMI asking for their support. PMI has a strong history of supporting research that benefits users of rope. With their background in caving and cave rescue, their involvement in industry standards and their commitment to safety, PMI offered to supply the rope needed for the testing, and we would like to acknowledge PMI

and thank them for their support.

Protecting our belayer was easy. Just move him out of the drop zone. But by doing that we altered the physical mechanics of an actual belay. Now our belayer would be pulling horizontally instead of pulling down vertically to affect the belay. Also by placing a change of direction in the system we were adding friction and changing the forces involved in the belay.

To determine how this would affect our testing we needed to do some further research. We had rescuers pull vertically and then horizontally on PMI 11mm rope and then we compared the two.

We did in excess of 60 vertical tests and 110 horizontal tests to determine how our change of direction would impact the effectiveness of our bottom belayer. What we learned was that most rescuers could pull with more force vertically than horizontally. This concurs with a U.S. Dept. of Army Technical Manual on Rigging published in 1968 that states "On a vertical pull, men of average weight can pull approximately 100 pounds per man, and on a horizontal pull approximately 60 pounds per man."

A study published in 1994 conducted by Kirk and Katie Mauthner of the British Columbia Council of Technical Rescue that was titled Gripping Ability On Rope In Motion, showed that "the average gripping ability of the sample population was 47 lbf with a standard deviation of 16.6 lbf." This was for a rescuer gripping a moving rope with one gloved hand in a horizontal orientation. It should be noted that all their tests were performed with the rescuer wearing rescue gloves and the testing was done on 11mm low stretch nylon Kernmantle rope.

When we discuss belaying it may be considered that a bottom belay is an extension of your brake hand. Excluding all other factors a rappeller will always be able to brake or stop if they have enough friction rigged. And a bottom belayer will always be able to perform a bottom belay if there is enough friction in the system. If a rappeller can't stop or a bottom belayer can't stop them, then there is not enough friction in the system.

For the purposes of this article a "system" is comprised of a rope, a brake bar rack, the person on rappel and a bottom belayer. The manufacturer of the rope, the diameter of the rope, the construction of the rope, whether the rope is new or old, clean or dirty, wet or dry are factors to consider. The rack length, the diameter of the brake bars, the material the bars are made of, and the number of bars used, are all factors to consider. The strength and weight of the rappeller, the gripping ability of the rappeller, the health and competence of the rappeller are all factors to consider. The strength and weight of the belayer, the gripping ability of the belayer, the health and competence of the belayer and the attentiveness of the belayer are all factors to consider. Together these factors determine the system. And the system determines the effectiveness of the rappeller or bottom belayer to control the situation.

One way a person on rappel can stop is by pulling down on the rope with his or her brake hand. This is the same thing a bottom belayer does. Only a bottom belayer has the advantage of using two hands and his or her body weight if necessary and can pull from above the waist not at or below the waist. So traditionally, we like our bottom belayers to

be big. Big meaning large in mass, and strong. The bigger and stronger they are the more reliable we believe they will be. Through the course of our testing we found that this is not always true. Size matters but only in weight, not in strength or gripping ability.

The Mauthner's define "gripping ability" in their study Gripping Ability On Rope In Motion as "The resultant holding force exerted on an object after taking into account grip strength, surface friction, and the shape and size of the object being gripped. In belaying, it is the useful grip actually applied to the rope." What they found through observation in their study was, and I quote "that there is no correlation between height and/or mass and gripping ability." Our testing also bore this out.



As an example, in one series of tests we did, we had 1 male firefighter and 2 female firefighters perform the same tests. If you were to see them standing together it's pretty obvious which rescuer most of us would pick to be our bottom belayer. The man is 6 foot 6 inches tall and weighs 240 lbs. He has a master's degree in human physiology. He understands the mechanics of belaying. He was also a world-class athlete. He was a tight end for the Super Bowl Champion New York Giants in 1991. His glove size is extra, extra large. The two young women are also career firefighters. One weighs 125 pounds and wears a medium rescue glove. The other weighs 140 pounds and wears a small rescue glove.

All three of these rescuers participated in vertical and horizontal pull testing. The forces that were recorded were very similar with the male slightly out performing the females on the vertical pull testing. In the horizontal pull testing the women recorded forces that were

equal to or greater than what the male was able to pull.

We then compared the difference in hand size of these three rescuers. Imagine the large male hand trying to grip a small 11 mm rope, but how easy it would be for the smaller female hand to grip that same size rope.

Later we performed a series of pull tests on 7/16 inch, 3/4 inch and 1-1/4inch rope and compared the results of these same three rescuers. As the diameter of the ropes increased, so did the force exerted by the male as compared to the force exerted by the females. The larger the diameter of the rope, the better the grip the male was able to achieve and the higher the forces he recorded.

In another series of tests we had firefighters pull on an 11 mm PMI low stretch rescue rope at a distance of 15 feet and then repeat the test on the same rope at 140 feet.

Of the 12 that were tested, 8 pulled with greater force 15 feet from the anchor and with less force 140 feet from the anchor.

1 pulled with the same force

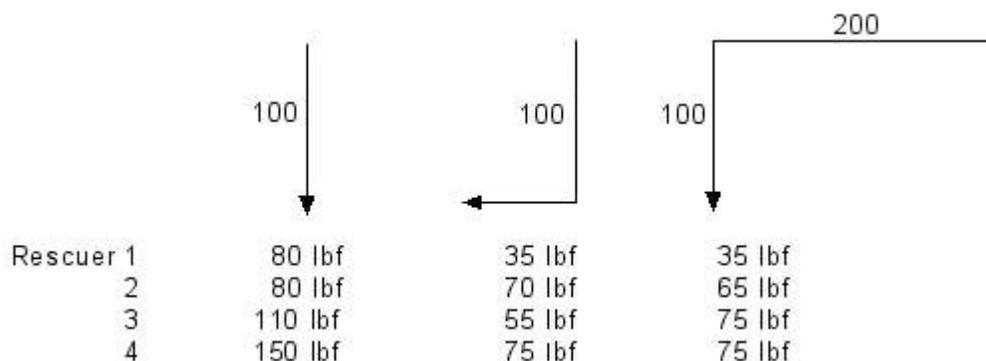
3 pulled with slightly higher force at 140 feet from the anchor.

How does this relate to the following questions?

Does the amount of rope in the system make a difference or is it the amount of rope between the belayer and the rappeller or the amount of rope between the rappeller and their anchor?

In another test we had 4 rescuers pull vertically on a rope that was anchored at 100 feet. Then we added 50 feet and a pulley at the bottom for a change of direction and pulled horizontally. We followed that up by adding another 150 feet of rope and moved the change of direction to an upper anchor so that our rescuers were pulling vertically.

So our test and results looked like this:



The 1<sup>st</sup> test is a vertical pull on 100 foot of rope and no change of direction.

The difference in the 2<sup>nd</sup> pull is the change of direction, an additional 50 ft of rope and the

fact that it is a horizontal pull. Notice that the forces exerted by the rescuers decreased in this second test.

The last one also has a change of direction, a total rope length of 300 ft, but it is a vertical pull.

From previous testing it appears that most rescuers are able to pull with greater force vertically than horizontally. So even though there is more rope in the system in the 3<sup>rd</sup> test, it may have been overcome by the fact that it was a vertical pull and not a horizontal pull.

So the change of direction and a horizontal pull or a change of direction and greater rope length or a combination of these factors was cause for less force to be recorded at the anchor.

Obviously this testing needs further study.

So far this article has focused on the ability of rescuers to exert force on an anchor by pulling an 11 mm rope in a vertical or a horizontal orientation. It was our hope that you would come to the same conclusion that we reached. That conclusion is that most rescuers can pull with greater force vertically than horizontally.

Because of our concern for our belayer's safety during the testing at the New River Gorge Bridge, we installed a change of direction at the bottom of the drop, which allowed us to move our belayer to a safer location. Realizing that our belayer would not be as effective pulling horizontally, and having to overcome friction in the change of direction, we chose a much stronger than average belayer for our testing at Bridge Day. Our belayer is 6 ft 1 and weighs 260 pounds. He's 46 years old and bench-presses 300 pounds. His glove size is extra large. He's an instructor and has been teaching rope rescue for over 20 years.

For all of the tests the 11 mm PMI pit rope (Max Wear) was anchored 700 ft above at the catwalk, came down to the ground and was revved through a change of direction pulley that ran horizontally to our belayer 50 ft away. Our belayer was ready and wearing rescue gloves but did not apply any tension to the rope until the mass had been released and allowed to "get out of control". This would simulate a rappeller who had let go of the rope because of rock-fall, fatigue, a mental lapse or a medical reason. So the person in charge would release the test mass and count "one one thousand two one thousand" and then yell "BELAY" and our rescuer would attempt to slow or stop the falling mass.

The results of each test are as follows:

Test # 1 Our mass of 175 lbs. was attached to the SMC stainless steel rack that was rigged with 5 bars and raised to a height of 115 ft. After the release of the test mass the belayer was able to stop and control the lowering of the mass.

Test # 2 Our mass of 175 lbs. was attached to the SMC stainless steel rack that was rigged with 4 bars and raised to a height of 115 ft. After the release of the test mass the belayer was unable to stop or slow the mass and it impacted the ground.

Test # 3 Our mass of 175 lbs. was attached to the SMC stainless steel rack that was

rigged with 4 bars and raised to a height of 230 ft. After the release of the test mass the belayer was unable to stop or slow the mass and it impacted the ground.

Test # 4 Our mass of 175 lbs. was attached to the SMC stainless steel rack that was rigged with 4 bars and raised to a height of 300 ft. After the release of the test mass the belayer was unable to slow or stop the mass and it impacted the ground.

Test # 5 Our mass of 175 lbs. was attached to the SMC stainless steel rack that was rigged with 4 bars and raised to a height of 225 ft. After the release of the test mass the belayer was unable to stop or slow the mass and it impacted the ground.

Test # 6 Our mass of 150 lbs. was attached to the SMC stainless steel rack that was rigged with 4 bars and raised to a height of 200 ft. After the release of the test mass the belayer was unable to stop or slow the mass and it impacted the ground.

Test # 7 Our mass of 150 lbs. was attached to the SMC stainless steel rack that was rigged with 4 bars and raised to a height of 400 ft. After the release of the test mass the belayer was unable to stop or slow the mass and it impacted the ground.

Test # 8 Our mass of 175 lbs. was attached to the SMC stainless steel rack that was rigged with 5 bars and raised to a height of 395 ft. After the release of the test mass the belayer was unable to stop or slow the mass and it impacted the ground.

Test # 9 Our mass of 225 lbs. was attached to the SMC stainless steel rack that was rigged with 5 bars and raised to a height of 240 ft. After the release of the test mass the belayer was unable to stop or slow the mass and it impacted the ground.

Test # 10 Our mass of 200 lbs. was attached to the SMC stainless steel rack that was rigged with 5 bars and raised to a height of 240 ft. After the release of the test mass the belayer was able to stop and control the lowering of the mass.

TEST #	# BARS	MASS (lbs.)	HEIGHT (Ft.)	BELAY
1	5	175	115	CATCH
2	4	175	115	FAILURE
3	4	175	230	FAILURE
4	4	175	300	FAILURE
5	4	175	225	FAILURE
6	4	150	200	FAILURE
7	4	150	400	FAILURE
8	5	175	395	FAILURE
9	5	225	240	FAILURE
10	5	200	240	CATCH

In summary this testing suggests some points to consider for an out of control rappeller.

1. The length of the drop matters. The further the rappeller is from the bottom belayer, the less likely the bottom belayer is to notice an out of control rappeller.
2. The greater the rope length between the bottom belayer and the rappeller, the less effective the belay effort may be.
3. The slower the reaction time of the bottom belayer, the less likely he or she is to be successful in his or her belay effort.
4. The gripping ability of the belayer may be more important than the overall strength of the belayer.
5. The size of the belayer may be misleading.

This research would not have been possible without the help and support of the following individuals and organizations:

Benjy Simpson, Bridge Day Rappel Coordinator  
New River Gorge Bridge Day Commission  
Pigeon Mountain Industries

Stephen Bellamy, Barb Born, Russ Born, Marcus Chapman, Marie Cress, Dale Cubranich, Justin Cubranich, Billie Hall, Gary Hamilton, Jerry Hille, Ron James, Kevin Mohr, Daniel O'Brien, Tom Robinson, Brian Szuter, Ed Thomas, Judy Thomas, Gordon Thompson, Mike Warner, Phil Way, Chris Vatty, Mike Vatty

And all the students and team members that participated in our pull testing.

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**Minutes of the  
2004 NSS Vertical Section Meeting  
July 14, 2004**

The 2004 NSS Vertical Section meeting was held Wednesday, July 14, 2004 at the Northern Michigan University in Marquette, Michigan. Executive Board members present were Chair Miriam Cuddington, Kevin Smith (proxy for Editor Tim White), At-Large members Bart Rowlett and Ed Kehs, Jr., Vertical Techniques Workshop Coordinator Terry Clark, and Contest Coordinator Bill Cuddington. Approximately 20 Vertical Section members were in attendance.

- I. **Meeting opened at 9:30 AM by Chair Miriam Cuddington.**  
Announcements - Thank you to all who helped at the climbing contest on Monday and Tuesday. We would appreciate it if all contest participants would stay for a while before or after they climb to help out. If everyone would help a little, the work would be spread out more.
  
- II. **Minutes of the Last Meeting** - were published on the website. Minutes were accepted as published.
  
- III. **Officer Reports:**
  - o **Secretary/Treasurer:** Bill Bussey -  
Secretary's Report - Not present. No report given.  
Treasurer's Report - Not present. No report given.
  
  - o **Editor:** Kevin Smith for Tim White -  
Annual volume for NH #47-48 is printed and will be mailed before the end of July. NH #49 is available on the website. All articles are posted. More articles are needed.
  
- IV. **Committee Reports:**
  - o **Contest:** Bill Cuddington -  
Thanks to PMI for the 2 long ropes that make the climbing contest possible. Thanks to Aubrey Golden on the last minute help in finding a new location for the climbing contest. There is now a new climbing age category of 80 +. We had good participation with two 80 + climbers. We hope to have some new contest record boards made up to add the new category records and to provide one for the Sit-Stand category. These boards are popular with people who come in to watch the climbing competition. There was a question about the facilities provided by conventions for the climbing contest. Bill Cuddington replied that there is a requirements sheet given to convention planning staff. However, we did not have a good contact with the convention staff this year. It is important

to have a good liaison on the convention planning committee to make sure the gym is adequate for the climbing contest.

- **Vertical Workshop:** Terry Clark -  
There were about 35 students last year. There are 35 students registered for this year and several more are expected. The workshop will begin at 11:00 AM on Thursday. Terry still hasn't gotten the money from last years workshop. There was a problem with the check from the convention that went to Bill Bussey. We need to work this problem out this year and get caught up with the money that is owed to the Section. There was some discussion on why the Contest Awards are done on a separate day late in the week. The main reason is the time it takes to prepare all the certificates.
- **Education:** Bill Cuddington for Bruce Smith -  
The training manuals are being updated and will be ready for distribution later this summer.
- **Symbolic Device Sales:** Bill Boehle -  
A total of \$519.40 (net after postage costs) was collected for symbolic items, NH back issues, and membership dues.
- **Rebelay Course:** Bart Rowlett for Gary Bush -  
There was a low turnout this year of only three people. This was probably due to the location of the gym relative to the main convention sessions.

#### V. **Old Business:**

- Web Page - Gary Bush webmaster. Suggestions for improvements were requested last year. Any problems? None were reported. Updating of website content is ongoing. Miriam stated that the site looks good and recognizes the good job done by Gary. Additionally, more pictures of the symbolic device items are now posted on the website. This will allow members to better see the items that are available for sale.
- Other - No old business from the floor

#### VI. **New Business:**

- Changes to our By-Laws because of going electronic on our Nylon Highway (Gary Bush and Tim White). How is this working? There was little discussion, but the consensus seems to be that it is working as is.
- Reimbursement for expenses. Miriam noted that Terry Clark works hard on the Vertical Workshop and has to haul or ship about 500 lbs. of gear to convention. This is a significant expense and wear and tear on his

vehicle. Miriam raised the question of whether or not some compensation should be made for this effort. Dale Lofland also mentioned that others also hauled a lot of stuff for the contests and for symbolic items. He questioned if these should be compensated as well. More discussion followed and most of the affected parties said that it was not really a problem if they were going to drive to convention anyway. The problem would be if they were not going or were going to fly. In these cases equipment would have to be shipped and that tends to be expensive due to the weight and bulk. It was noted that if someone incurs an expense related to Section activities that they can be reimbursed by the Board under existing authorities. Bill Boehle noted that this is a volunteer organization and that only unusual expenses need to be reimbursed. There shouldn't be an expectation of compensation to do a volunteer job.

Also, the Section budget probably couldn't support a significant compensation proposal. Several potential motions were offered and discussed. Kevin Smith made a motion that the Executive Committee determine an appropriate reimbursement amount for individuals who transport equipment to convention for the Section. Much discussion followed and several substitutes and amendments were considered. The final motion with friendly amendment by Dale Lofland reads as follows:

"Resolved that the Executive Committee may determine a transportation reimbursement subsidy for Section material used at convention."  
Final motion passed (14 For, 0 Against, 1 Abstain).

## VII. **Elections:**

- **Secretary/Treasurer** (1-year term) - Bill Boehle was nominated and elected by acclamation.
- **Editor** (1-year term) - Tim White was nominated and elected by acclamation.
- **At-Large Board Members** (2-year term, 1 to be elected) - Barb Ritts and Ed Sira were nominated. A ballot of the section members present was taken and Ed Sira was elected. [Note: Current At-Large members Bart Rowlett and Ed Kehs, Jr. have 1 year remaining in their terms.]

[Note: Current At-Large members Barb Ritts and Miriam Cuddington have 1 year remaining in their terms.]

VIII. **Motion to Adjourn:**

Motion to adjourn was made and carried. Time of adjournment was approximately 11:00 AM.

[Additional note: Subsequent to the Meeting, the new Board Members elected Miriam Cuddington as Chair. The three appointed members were re-appointed to serve for another year. They are:

- Contest Committee - Bill Cuddington
- Vertical Techniques Workshop Committee - Terry Clark
- Education Committee - Bruce Smith]

Respectfully Submitted,  
Bill Boehle

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