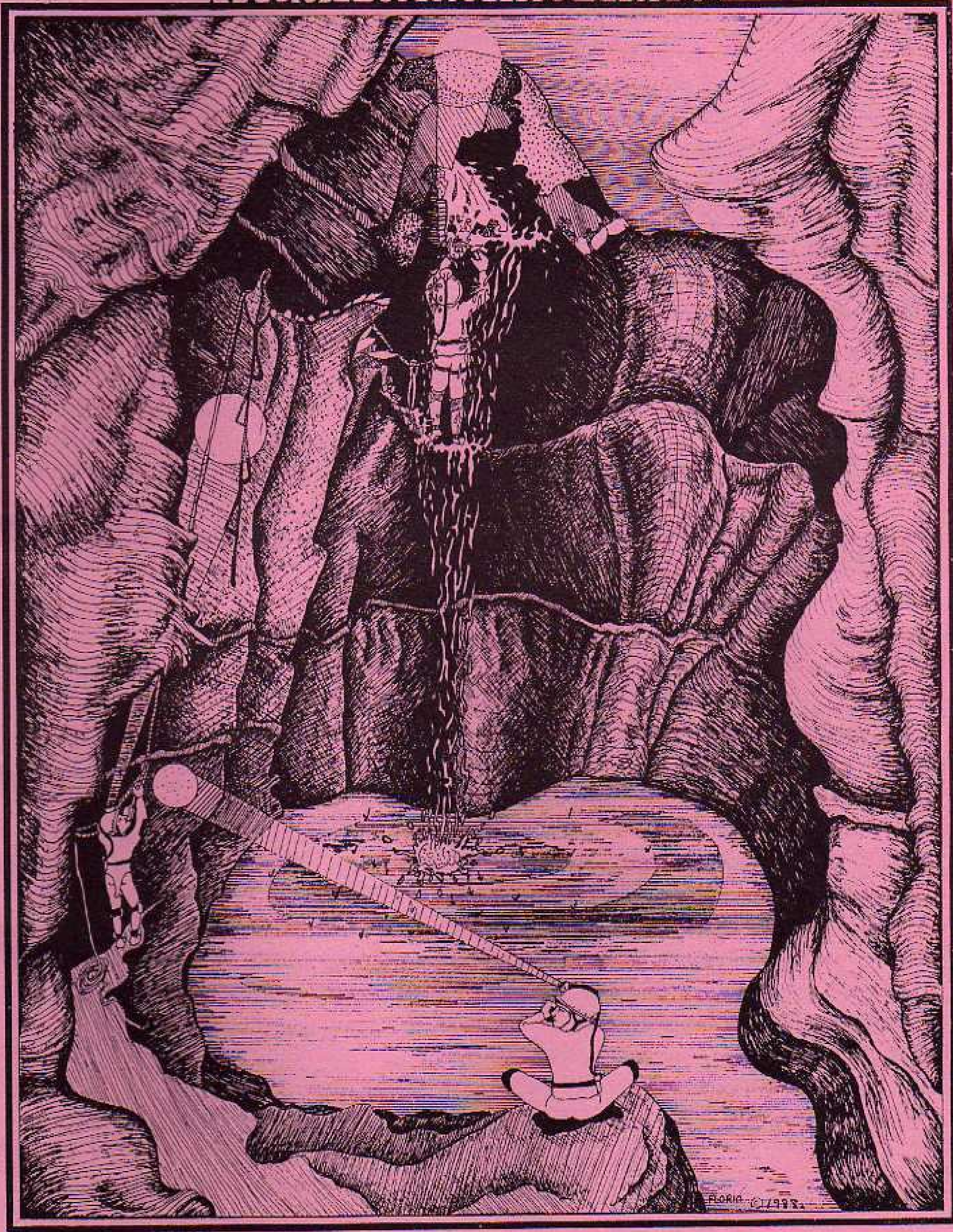
# NYLON HIGHWAY NO. 32



...ESPECIALLY FOR THE VERTICAL CAVER

# NYLON HIGHWAY

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# JUNE 1991

# NO. 32

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### FEATURE ARTICLES



## THE NYLON HIGHWAY

The **Nylon Highway** is published on a Semi-annual basis pending sufficient material. It is the intent of this publication to provide a vehicle for papers on vertical work. All submitted articles containing unsafe practices will be returned to the author. With this issue the section is over 900 members strong with a mail out of over 1000 copies. I hope to continue the fine tradition of the Section having one of the best publications of any NSS Internal Organization.

**COVER:** Lichen Cave Dome, by Joanna Florio Jeffreys

**Editor:** And so completes another issue of the Nylon Highway. These issues have become a labor of love, but the editor's IN box has been drained dry. Only one of the larger articles was written by cavers and the caver article arrived from the Soviet Union. We need your input to continue to have a fine publication.

Look for an article on the Vertical Section participation in the 1991 Soviet/US exchange trip. Ed Sira, Allen Padgett and your editor will be representing the Section and the NSS this year.

On another note, the Section is looking for a new Secretary/Treasurer. Bill Bussey has held this position since 1984 and is looking to pass the hat. Anyone thinking about getting involved in the section should consider running for the office.

Also, Bill Cuddington has reported that two ropes will once again be used at the VS contests at the NSS Convention in Cobbleskill, New York. One rope will be for short climbs only and both a spool and rack will be available to the climbers as a friction device. Look forward to an article by Bill on the development of the rack in the next issue of the Highway.

# ARE YOU REALLY ON BELAY?

## BY JOHN DILL

### PART I OF A TWO PART SERIES

### BACKGROUND

Rope rescue systems commonly rely on two ropes for safety. One, the main line, is used to raise or lower the load (rescuers, patients and/or equipment). While the other, the belay line, is kept ready to catch the falling load should the main line fail.

A variety of belay devices are used to connect the belay line to its anchor (i.e., belay plates, camming devices and Prusik hitches). These devices must allow the belayer to control the slack or tension in the belay line by taking line in or letting it out as the load is moved, but they must also securely stop a fall. The entire process of controlling the line and stopping - or "arresting" - the fall is called belaying.

Instructions for rigging and operating most of these belays are found in rescue literature and courses. What is missing is proof these systems actually work. One reason for this deficiency may be the infrequency of main line failures in the field. There have, in fact, been several close calls, and the forces involved in hauling, even in short falls, may come close to the danger point for some system components. The more we can learn from these experiences, the better.

At the 1986 North American Technical Rescue Symposium, Zan Mautner and Arnor Larson described "drop tests" conducted since 1982 by the British Columbia Council of Technical Rescue (BCCTR). These tests lacked force measurements and other sophistications, but focused on the primary question: Can the belay catch a rescue fall? The results suggested that some common devices might fail this task, while others might work better than expected, at least under the conditions of the BCCTR tests.

Since then, other sessions have been conducted, including ones in 1897 in Denver, Colorado and 1989 in Sedona, Arizona. The U.S. tests, carried out primarily by Larson, Hal Murray, Reed Thorne and me, extended the BCCTR tests in detail and rigor and included measurement of the dynamic forces occurring during the fall arrest.

This report covers the Denver and Sedona test series. Although based on 230 individual tests, there are so many significant variables that our tests are far from complete. Many questions remain unanswered, new ones have appeared and we are still digesting our results. In fact, we are still learning how to test.

At present, there is no standard test method for rescue belay systems. There have been some slow pull tests of rescue equipment, but the behavior of the gear and the forces involved, may change during the high-speed impact of a fall arrest. Or emphasis, therefore, has been on drop tests of the unloaded belay line, and we tried to rig the system as closely as possible to how it might be in the field. This article is not a scientific report. With this information alone, another investigator will not be able to duplicate our claims.

Despite these limitations, we believe we should share a summary of what we have discovered so far. We hope this article will warn rescuers of possible limitations in their systems, suggest directions for their own test programs and stimulate a more informed and energetic public debate regarding methods and standards for rescue belays.

Warning to readers: Reviewers have suggested that many rescuers do not read to the end of a page and do not want to think about their procedures, but simply want to be told what to do. In case that is true, I have inserted this warning: **THIS ARTICLE IS NOT AN INSTRUCTION TEXT! IT IS DANGEROUS UNLESS YOU TAKE THE TIME TO CAREFULLY READ ALL OF IT, THINK ABOUT IT CRITICALLY, AND THEN, IF YOU DECIDE TO ADOPT ANY OF THESE SYSTEMS, SEEK COMPETENT INSTRUCTION.**

### THE BELAY

What must the belay accomplish? First, and obviously, it must catch the falling load. Second, the belay rope and system must survive the event sufficiently undamaged to allow the rescue of those hanging on the rope. Third, the Maximum Arrest Force (MAF) (i.e., the highest force occurring during the catch) must not cause injury to rescuer or patient, nor may it cause system failure, such as pulling out an anchor or cutting the rope over an edge. Fourth, the stopping distance must be short to prevent the load from striking obstructions during the arrest. Fifth, the system must work i any environment you may encounter - wet, icy, etc. - and with the other equipment you use. Finally, it must be user friendly. That is, you must be able to operate it properly when you are cold, wet, bored and out of practice, since most accidents are due not to gear failure but to improper rigging or handling.

### BELAY SPECIFICATIONS

Just as there is no standard test method, there is no widely accepted set of performance criteria for the belay. Again, the BCCTR has developed its own: For a belay device to be acceptable, it must arrest a 200 kg (440 lb) load, free-falling 100 cm (3' 3") on an initial rope length of 3 m (9' 9"). The load represents two 80 kg (176 lb) people plus equipment. The rope and fall lengths are intended to simulate a fall that, in the BCCTR's opinion, could occur if the main line failed while the litter attendant was negotiating a lip near the belay. This is a severe fall for several reasons: (1) the mass is more than twice that of a falling rock climber; (2) the rope is usually the low stretchy type and (3) the rope available to absorb the falling energy is relatively short. The BCCTR feels the resulting MAF must be less than 15 kN (3300 lbf), and the stopping distance must be less than 100 cm.

(**Note:** A word about units. This report uses the International System of Units (SI, or metric units). The unit of distance is the meter or centimeter. 1 meter (m) = 100 centimeters (cm) = about 3 ft 3 in. (3 ft is close enough for this report.) The unit of mass is the kilogram (kg). 1 kg = 2.2 lb-mass.[1] The unit of force is the kiloNewton (kN). 1 kN = 220 lbf, or the weight of a big person. Therefore, when you read that the MAF was, say 12 kN, just imagine twelve big firefighters all hanging on the end of your line at the same time.)

[1] The term kilogram is often used incorrectly to indicate force, such as the breaking strength of a carabiner.

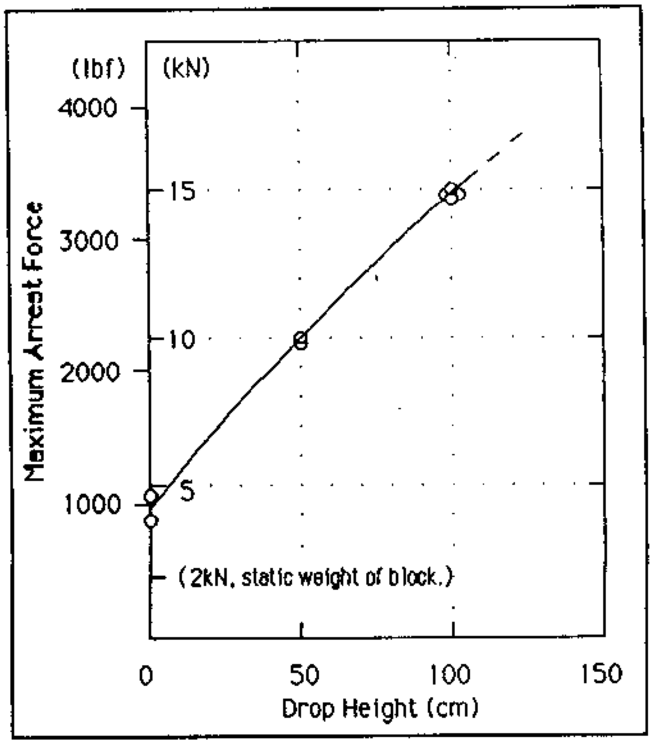



Fig. 1. Maximum Arrest Force (MAF) vs Drop Height, for a 200 kg block caught by 300 cm of PMI 7/16" E-Z Bend rope anchored with a Figure 8 knot..

We used the same mass (a 200kg, rigid iron test block) and rope length (3 m) as the BCCTR, and most of our drop heights were 100 cm. We chose these values not as an endorsement of the BCCTR, but to enable us to compare our respective results. We also sought the maximum drop length a device could hand, and in some cases, its performance had a 0 cm drop.

A 0 cm drop starts at the origin. There is no initial slack or tension in the line, so it represents the top-rope belay you would want when climbing. Although there is no initial free-fall in this case, the block will still fall some distance due to the rope stretch (imagine the 0 cm fall you would take on a Slinky). This fall is of interest because: (1) it seems as likely in the field as a longer fall; (2) the MAF on a 0 cm fall can be over twice the static weight of the load (exactly twice, if the rope were to act like a linear spring); and (3) a belay device might react differently to the relatively low speed of this fall compared to the higher speed of a longer one.

To avoid the impact of a 0 cm fall, some teams advocate that the belayer maintain some tension in the belay line, even to the point of trying to share the load equally between both lines. Others insist on an unloaded belay line, on the theory that this offers more protection against the line being cut if it is hit by rockfall and with the assumption that the belay can handle a 0 cm impact.

## REALITY

The real world if full of variables we did not examine in our tests. First, we chose a rigid block and anchor so our tests would be reproducible. Real loads and systems, being floppy, stretchy and deformable, may absorb enough energy to significantly reduce the MAF. Second, in most of our tests, no belayer tended the device after setting it up initially. This was both for safety and to see how the device worked by itself. A real belayer, alert or asleep at the switch, any either help or hinder its function. Third, we had no directional carabiners or rock edges in the system for additional friction. Depending on the particular variable(s), therefore, our tests may be more or less severe than your own rescue environment.

All of the devices we tested are either in common use for rescue belays or have been considered for this purpose. Top the best of my knowledge, however, none of the manufacturers of these devices advertise them for that use, and some specifically warn against using them for this application. The single exception is noted in the test.

Most of our tests used PMI E-Z Bend[tm] rope, with a few quick looks at other brands and types. Because our focus was on testing the belay devices, we used primarily one type of rope for consistency. Do not assume, however, that a success or failure with one combination of rope and device predicts the same result with a "similar" combination that we did not try or have not yet reported. Also, do not place too much confidence in what may appear to be successful results. We chose five drops as a sufficient test for consistency. However, in many cases, we had neither time or materials to do more than two or three - quick looks only. And, it is sobering to watch four similar drops perform successfully and identically, only to have the fifth one fail. Obviously, more testing needs to be done.

## TIED-OFF ROPE

No belay device was used in this test. In order to establish a benchmark for the MAF in our system, we simply connected specimens of new PMI 7/16" E-Z Bend[tm] directly to the anchor with hand-tight figure-eight knots and made drops of 0, 50 and 100 cm. **Figure 1** relates MAF to drop height. Any belay system that absorbs more energy than this knot - by slippage and friction between the rope and the belay device, or within the device itself - will reduce the force further. There,a this cure is close to the maximum force you can expect for this rope under these circumstances. (A device that allows less slippage than this knot - perhaps a camming unit - may produce a higher force.)

## MANUAL BELAY DEVICES

If a belay device is to react properly to a fall, it must often be "tended" in anticipation of the fall. That is, the belayer must keep it in an appropriate position while the rope is being let out or taken in. "Manual" belay devices require additional tending during and after a fall. The belayer must hold the rope in a particular position with respect to the device (the arrest position), while pulling on the rope. The Munter Hitch and the Sticht Plate are two examples of manual devices.

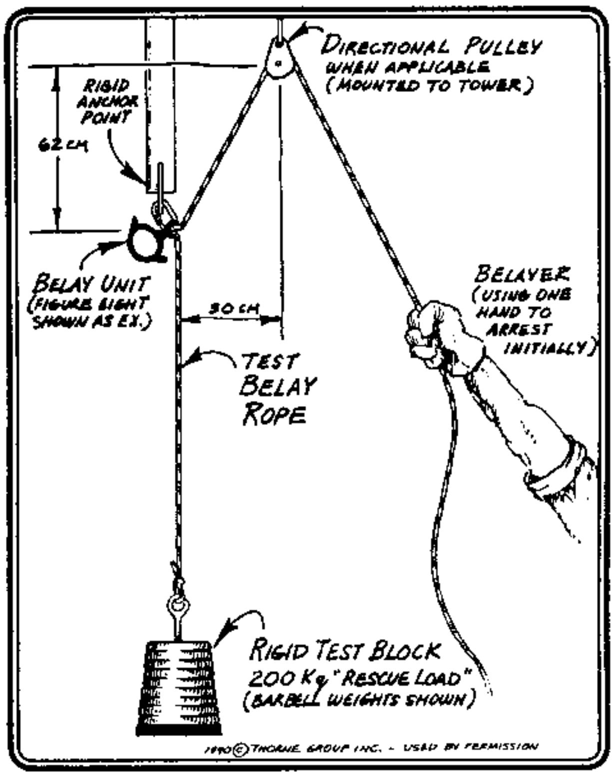



Fig. 2. Static test apparatus for manual abelay devices, using a directional pulley. Note: To test Munter hitch in maximum friction position, pulley is removed and belayer pulls directly from hitch.

We tested several manual devices, each rigged with a single carabiner (Stubai steel locking, #9850) as is commonly seen in the field. Since it provides less friction, this is a more severe test than rigging with double carabiners. We otherwise biased the test in favor of the device (see **Fig. 2**). The rope ran from the belayer up to a pulley and then down to the device. This kept the rope properly oriented at the device, while allowing the belayer to pull down on the rope with his own weight assisting him. (For the Munter Hitch in the maximum friction position, the pulley was removed so the belayer could pull down directly from the hitch, as required.)

A belayer unavoidably introduces variability and subjective impressions into the test. We tried to minimize this by using the same belayer throughout. He was a skilled climber and rescuer, stronger than average and experienced with the belay devices being tested. Additionally, the belayer wore gloves, got the best grip on the rope he could, was braced and forewarned.

We tried new 7/16" and 1/2" PMI E-Z Bend^tm rope and an old 7/16" Bluewater II^tm rope (used 3 years and with a lightly fuzzed sheath). The new ropes probably provided the most severe tests of the three cases, because the belayer felt they were noticeably slipperier than the old rope.

Although our goal was to try catching falls with each device, safety dictated that it first pass a static test, in which the block was lowered slowly by the winch until the belay system bore its weight. For the device to pass this test, the belayer had to easily hold and lower the static load with one hand. (Only one hand may be on the rope when a fall occurs in the field, and the other hand may subsequently be needed to secure the rope.)

The Munter Hitch, in the low friction configuration, failed the static test with all three ropes. The high friction variation passed with the old rope but failed with both new ones.

The Sticht Plate (for an 11 mm rope, no spring) failed the static test with old Bluewater II. We did not try either of the new ropes, because of time constraints and they were more slippery.

The CMI Rescue Belay Brake has been advertised for belaying two- person loads with a single locking carabiner, and with 7/16" climbing and 1/2" low-stretch ropes. (See 1989 CMI catalogue, p. 6.) It failed the static test with all three of our ropes.

The carabiner hole in the Russ Anderson/SMC Figure Eight (the standard aluminum model), rigged as a belay slot, failed the static test with 7/16" and 1/2" E-Z Bend^tm.

The CMI Standard '8' Ring, rigged as a single-wrap rappel through the big ring, failed the static test with the old rope. Our belayer could barely hold the load with two hands. We did not try new rope, again due to time constraints and it would have been more slippery.

In summary, none of these devices passed our static test. In many cases, the belayer could not restrain the load with two hands, let alone remove one. Other rescuers have related success with some of the devices we tried, so it is possible we missed some important variable in designing our test. However, a comparison must wait until the details of their experiences are available.

There are many combinations of manual devices, ropes and rigging we did not try. Some may work in the lab, at least with a specific rope. The performance of such devices might change, however, when the rope is worn or wet. Finally, the success of any manual device ultimately depends on a surprised belayer, hands in an awkward position, instinctively making the right move.

## AUTOMATIC DEVICES

These belay devices may also require tending prior to a fall, and in some cases, action during the fall such as letting go. But, they will grab the rope automatically in most situations with no furgther action by the belayer.

## THE SALEWA ANTZ[tm]

Like most manual devices, the Antz[tm] bends the rope around a carabiner. Yet, it's designed to activate automatically with the impact of the fall, by flipping from a low- to a high-friction position. It requires a symmetrical carabiner such as the HMS type (the type commonly used with the Munter Hitch) for an effective grip on the rope. We used a Chouinard Pearabiner[tm]. Although intended for climbing falls, and therefore high-stretch rope, the Antz[tm] has been suggested as a possibility for rescue belays. (See "Rescue Forum," May/June 1988 Response.

In 0 cm falls with new 7/16" E-Z Bend[tm], the Antz[tm] flipped into what appeared top be the correct position, but the rope slid through it with little resistance until the block hit the ground. Apparently, the device did not receive quite the kick it needed to fully engage the rope. It did stop 100 cm falls with this rope. However, our rigging may have been biased in its favor, in a way that does not occur in the field. Confirmation must await further tests.

## THE GIBBS ASCENDER

In our tests, new 7/16" E-Z Bend[tm] survived drop of 25 cm (10")- the only visible damage being light sheath abrasion. More often than not, at 50 cm and above, this rope was completely severed by the cam. New 7/16" Wellington Puritan Rhino-Kote[tm] rescue rope was cut through in one of three 100 cm falls, and we did not try shorter drops. 1/2" E-Z Bend[tm] stopped a single 100 cm fall, but the sheath and half of the core strands were severed, and the remaining strands were not uniformly sharing the load.

After our test drops, the rope occasionally remained centered under the cam, but most often it had slipped toward the side. Sometimes it had fallen completely into the space between the cam and the side of the housing. Slipping farther into that space seemed to cause less rope damage and allow more rope slippage through the Gibbs during the arrest. In some of these drops, the rope failed at forces roughly 30% of the advertised breaking strength of the rope.

Are Gibbs Ascenders safe for rescue belays? Some rescuers think so, believing they can control the slack in the belay line to within safe limits and their rigging provides additional shock absorption not present in the test lab. They also point to a history of no known failures in the field. Others disagree on all counts. Regardless of who is correct, our results underscore the importance of control over the system. If you cannot demonstrate that control, you should consider the manufacturer's warning (printed on the price list): "Gibbs ascenders are intended for the use of a single person with an overhead line."

## THE RESCUCENDER[tm]

This new device from Rock Exotica, Inc. resembles a heavy duty Gibbs Ascender. The most significant difference is the curved rope-channel machined into the housing. This allows the cam to contact the rope along a greater length, reducing the pressure, and therefore the wear and tear on the rope. It is intended as a personal hauling cam, and its designer, Rock Thompson, advises against using it for belays.

Never the less, in tests done by Rock Exotica, Inc. at the factory, following the BCCTR specifications, it caught 150 cm falls without significant rope damage.

On our first drop - 100 cm with the 7/16" E-Z Bend[tm] - the rope slid continuously through the Rescucender[tm], the block hit the ground, and the MAF (2.4 kN) was only slightly greater than the static weight of the block. A 0 cm drop gave the same result, We subjected all the 7/16" ropes in our inventory to 100 cm drops, and were surprised when a used climbing rope and new PMI Max Wear[tm] (the less flexible companion to E-Z Bend[tm]) stopped the fall, whole E-Z Bend[tm] and several other ropes did not.

It turned out that Rock had done all his factory tests with climbing rope and Max Wear[tm], not foreseeing (nor had we) the Rescucender's apparent sensitivity to rope construction. When we tried a cam with larger teeth, it did catch a 100 cm fall with 7/16" E-Z Bend[tm]. There was little apparent damage, but slippage was 120 cm. Rock had originally rejected this cam as being too rough on the rope, as he tried to achieve acceptable performance with several rope diameters. The force as which rope slips through the device depends on diameter.) He now uses this cam design instead of the gentler one.

This story has lessons for all of us, and Rock Exotica's interest in thorough and independent testing is commendable. To my knowledge, the new model has not been thoroughly drop tested by an independent group, and the advisory against belays still stands. The concept has potential as a belay device, but it will be interesting to see how the performance of such a sensitive design changes as the shapes of the channel and the cam are altered by wear.

In part II, I will discuss the Prusik hitch and some possibilities for additional energy absorption. Save Part I, read all the caveats in the introduction again before you review Part II, and wait until you have thoroughly digested both parts I and II before drawing your own conclusions.

Reprinted from Response Magazine, Summer 1990, Official Publication of NASAR.

# Bridge Day

## by Adrian (Ed) Sira

Once in a while, we vertical cavers get a chance to perform some extra activity. Not in a cave, but vertical none the less and this was one of those days. A day I will remember for a long time. I will never forget that first look off the top of the bridge. HOLY SH__ this is high! But I'm getting ahead of the story. It all began when Gene Harrison and I had some Cave Rescue related business to take care of. He asked if I would be interested in going to the New River Gorge Bridge on Bridge Day. He had an opening on his rope and asked if I would like to fill in. Was he kidding? I almost fell to my knees to say thank you. I thought better of it and decided to play it cool. I think I said something like, sure - I guess so - sounds interesting. Boy did I hold my composure.

I should explain. Bridge Day is one day a year set aside by the powers in charge, (that day being the third Saturday in October, the anniversary day of the opening of the bridge). They close the bridge to vehicular traffic, and allow Base Jumpers and Cavers to do their thing. Of course our thing is to rappel and if time allows, climb. You don't just go there on Bridge Day and expect to drop a rope. You have to apply in advance for a rope slot, and hope your name is drawn in the lottery to find who gets a slot or not. Gene had a slot and was nice enough to invite me to participate.

I had heard enough about the New River Gorge Bridge, and believe me, I began immediately to make arrangements. My wife Jerry was going so I decided to stay in a motel for Friday and Saturday nights instead of camping with the others. I had to be there Friday night for an orientation anyway. I called a few motels in Fayetteville, the nearest town to the bridge, would you believe they laughed at me. You have got to be kidding; Don't you know what this weekend is? They were still laughing when I hung up the phone and decided to try for accommodations a little further away. The Comfort Inn in Beckley was the only place that had an opening.

The Comfort Inn was only 30 minutes from the bride, no problem. I took that Friday off from work to make the nine hour trip so we could get there with plenty of daylight left to look the area over. Jerry and I left our home in Raritan at 6:00 AM and arrived in Beckley approximately 4:00 PM. The drive down wasn't bad at all. Take I-78 west to I-81 south. From Lexington, VA. go west on I-64, or west on Rt. 60, they will both take you to Beckley. I-64 being more direct, while Rt. 60 the more scenic with a lot of switch backs. First thing we did was register at the motel. I wasn't taking any chances of losing my room.

We registered and started the 30 min. trip to the bridge. I wanted to see this monster in good daylight. From Beckley, Rt. 19 takes you to the bridge. All you hear about the bridge will not do it justice. There is nothing you can conjure up in your mind that will compare to being there. It is awesome! No words can describe it. You have to see it for yourself. The Rt. 19 bridge that spans the New River Gorge is the world's longest single steel arch bridge of 1,700 feet and a total length of 3,030 feet. It rises 876 feet above the New River, the second highest bridge in the United State.

When we got to the bridge, the first thing I wanted to do was take some pictures while the sun was still in a good position and there was enough light. We drove down the old road, narrow with a few switch backs, to get to the rover. I took a few slides of the bridge from almost every angle. The sun was going down so we headed for the area north of the bridge where everyone was to register and camp. Not bad! Closer to the bridge than I thought, walking distance actually. That made it very helpful the next day when we had to walk to the bridge with all our equipment. The only vehicle we were allowed to bring on Saturday was Gene's van will all the ropes in it.

Orientation was Friday night around the campfire. All participants were required to sign a waiver of liability for any injury, death or damage to or loss of equipment. All the do's and don'ts were clearly spelled out by the Bridge Day Committee Chairman, Bob Frostick. One of the don'ts was not to give the authorities a hard time, to cooperate with them 100%. Bruce Banner said to just agree with them and wave your hand. And when you wave to use all your fingers. Rope slots were picked from a hat and Gene drew slot #4. He put Bill Bussey and I in charge of the rigging. Bridge passes were also handed out to everyone that was going to be on the catwalk beneath the bridge. Gene and Bruce Bannerman were in charge of safety, and they did one great job and were busy all day long.

Everything had to go like clockwork. The schedule that day was as follows:

6:30-Riggers breakfast

7:00-Bottom crew and riggers to bridge

7:00-Breakfast for others

8:00-Equipment van leaves

8:15-Weather notice posted

8:30-Group leaves for bridge

9:00-Bridge closes to traffic.

9:30-Rigging starts

3:00-Last rappel & derigging

4:00-Bridge open to traffic

After the orientation meeting around midnight, Jerry and I started back for our motel. Would you believe, we took a wrong turn and got lost. Not for long though, we got to the motel about 12:45 AM. Needless to say, I didn't get a very good night's sleep. Thinking about that rappel, the bridge, getting up early. I just got to sleep when the alarm went off, or so it seems. We got up, did what we had to do and got to the campground in time for breakfast.

Bill Bussey and I got our crew together and headed for the bridge. In our group was Bill Bussey, Steve Luke, Patty Luke, Chuck Frostick, Bob Frostick, Bruce Bannerman, Gene Harrison, a couple of members of Charleston Grotto and myself.

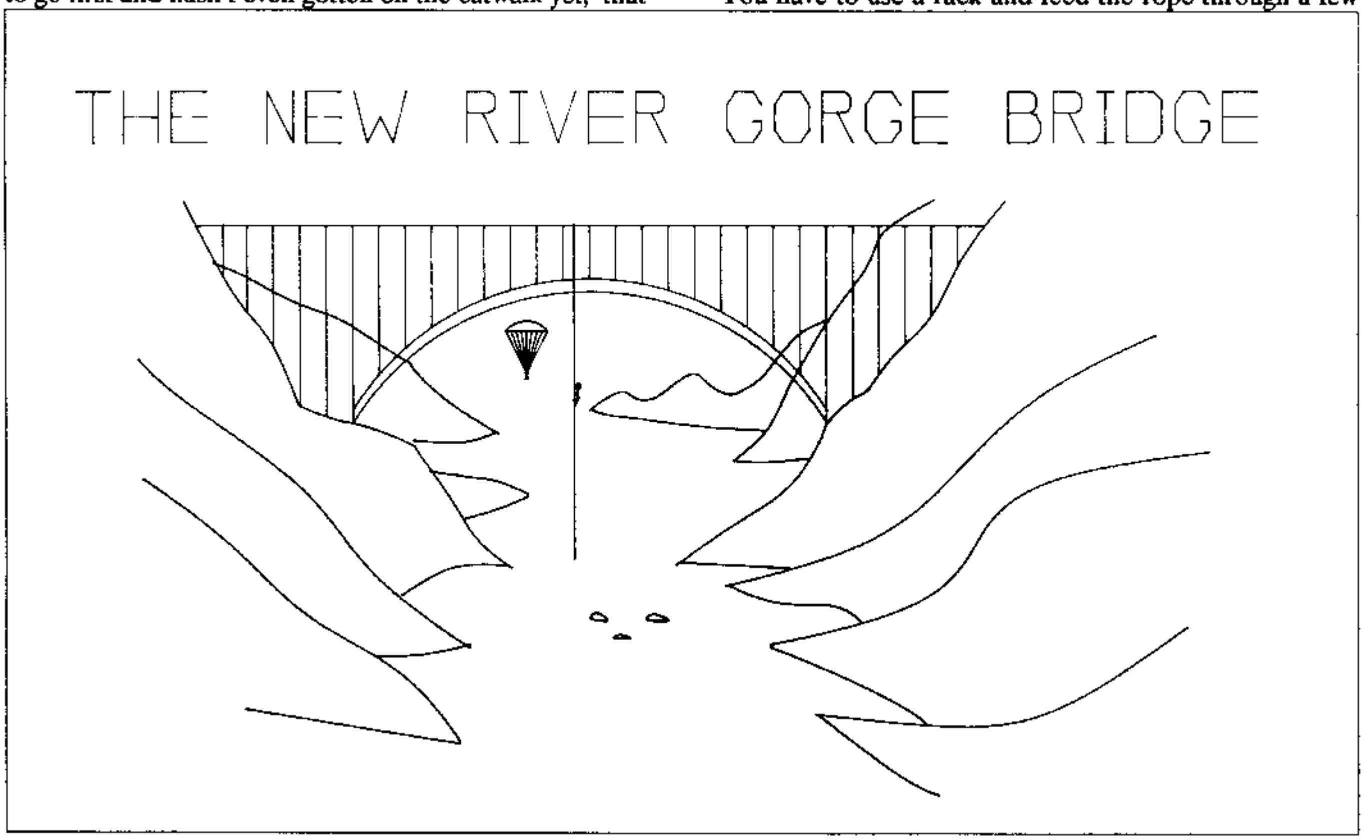
When we arrived at the bridge, I was not prepared for the sight before my eyes. Where the hell did all these people come from. Vendors and people for as far as my eyes could see. The local paper the next day, estimated it to be approximately one hundred thousand spectators. Base Jumpers were arriving and getting ready in the center of the bridge. They go off the top. The cavers rappel off a catwalk in the center of the bridge about 15 feet below the road surface. State Police, Local Police, and National Park Police were in control of everything.

We made our way to the fence enclosing the area beneath the bridge. The guard checked our bridge pass and let us through. All the cavers gathered beneath the structure waiting for the ok to climb the ladder that gave us access to the catwalk. I gotta go to the outhouse. Must be the breakfast, or maybe I'm nervous. Anyway, I gotta go. Let's see, I'm on rope slot #4 and slot #12 has to go first and hasn't even gotten on the catwalk yet, that gives me plenty of time to get to the porta john. The johns were way the hell down the road, and when I got there I had to stand in line. I made a mad dash for the first door that opened, I didn't care who said anything. Just act like a mad dog and everyone will get out of your way. It worked! One thing you want to remember when you go to one of those porta johns, TAKE YOUR HARNESS OFF FIRST! It was a bitch in those cramped quarter.

I got back to the bridge in time. It was our turn to climb the ladder to the catwalk. Bill, Chuck and I got the 1,000 ft. of rope and up we went. Only the riggers were allowed on the catwalk at this time. All the others had to wait for the signal to come to their rope one at a time. Once on the catwalk, we had to walk to our rope slot which was all the way on the other side of the bridge. Damn, this catwalk is narrow! Well it was 2 ft. wide, with a rail on either side, one about knee high and another rail about elbow high. After you got used to it, it wasn't bad at all. We got to our drop off point and was told to rig our rope, but no rope was to be lowered until the authorities gave the signal to do so.

Communication was by radio, and we waited for the signal to lower the ropes. And we waited. And we waited. What the hell are they waiting for. The weather was the best they had in years, a slight breeze, but warm. Bill was smart, he brought a gallon jug of water to tie to the end of the rope to make it easier to hit our drop zone when we lowered it.

Finally, about 10:00 AM, they gave the signal to lower the ropes and proceed with the days activities. You have to use a rack and feed the rope through a few



bars and let the weight of the rope carry it to the bottom. The rope weighs about 75 lbs. by the time it touches the bottom and would be unsafe to lower it any other way. Each team has a person on the bottom. Three of the bottom crew get together and give each rope a pull test, then we have our fun. Bill asked if I wanted to go first and did I ever jump at the chance. Chuck held the rope up to give me enough slack to rig my rack. Once that was done, I stepped through the rail onto a bridge beam, checked my rigging, made sure I had control of the rope and swung into open space, almost 900 ft. above the ground. I let out a big YAA HOO, spread the bottom two of the four bars I started with, and began my rappel. I looked around at the other ropes, so far I was the only one on rope. Well, for a short while I was. Soon, I had plenty of company. I spread the bars further apart and began moving at a steady pace. that steady rappel gave me plenty of time to look around and enjoy the sights.

The base jumpers were going off the bridge and every once in a while you could hear their chutes pop open. It sure was a pretty sight. As soon as one would land, another would dive off the top with a loud yell that would reverberate beneath the bridge. I didn't want to spend too much time sight seeing, so I continued my rappel. Half way down, I had to add a bar. Everything went great. As I got closer to the bottom, I could see that I was going to land in a tree. Nothing to worry about, my belay man pulled me to a small opening between the trees as I approached the drop zone. Nine minutes from the time I started my rappel, I was off rope. Now my job was to belay the next person on rope. One of the men with a radio was close enough to me to here the communication from the top. On rope four! I could hear over the radio. rope four on belay! I said, and the signal was repeated. I looked up to see if I could tell who was coming down. Was I kidding, all I could see was a speck in all the bridge girders. The sudden vibration of the rope was mo only indication that someone was on rappel. Chuck Frostick was on rope and as soon as he got to the bottom, I gathered all my gear and sought out the shuttle bus that was to take everyone back to the top. If I was to have any complaints about anything to do with Bridge Day, it would be the lack of transportation and the lime lost getting back to the top and eventually back to the catwalk. A van loaded with base jumpers asked if I was one of the cavers and would I like a ride to the top. Needless to say, I jumped at the chance. They let us all out at the top of this winding road, at Rt. 19. Now I had to walk a quarter of a mile to the other side of the bridge to get back on the catwalk. Try walking through a crowd of one hundred thousand people for a quarter of a mile and you can understand why the trip from the bottom to top took almost two hours.

At the catwalk, I was notified by Jackie Bannerman that Bill bussey was waiting for me back at the rope drop off slot, and I was to hustle my butt over there. You don't need to hustle on a two foot catwalk almost nine hundred feet above the ground, but I did get there in good time. Steve Luke was ready to make the drop and Bill was next, but couldn't go off until I got there. After Steve was off rope I helped Bill get rigged, checked him out, and over he went. Just before he started down, he asked me to come down next and he and I would tandem climb. that was an offer I couldn't refuse.

Bill made it to the bottom in good time. Now it was my turn but there was no one around from my team to assist. A radio call to Jackie at the ladder confirmed that no one was waiting there, so I had to go it alone. **Like hell I will!** Looking around I noticed slot five had four people standing around waiting their turn, so I enlisted one of them to assist me and check me out as I got rigged. This time down was a breeze and took me only eight minutes. Close to the bottom, I saw my wife Jerry with a camera taking pictures. The trouble Jerry went through getting around is another story we won't get into now, but is a testimony to why transportation has to be improved.

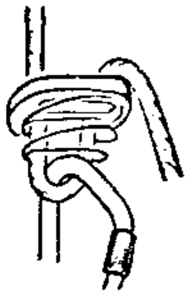
Bill and I rested a short while before our climb. Bill rigged on rope first, climbed about twenty feet and waited for me to get on rope. I put on my chest harness with a Simmons double roller. (I got the double roller from Ron at the California convention. One of my better vertical investments.) I slipped on my seat harness, connected the Gibbs to the rope, put the climbing rope through one roller and the double bungie through the other. Floating both Gibbs is the way to go on a long climb. The third Gibbs was connected to my seat harness and floated above the roller on the rope. Great for resting. Bill continued twenty feet above me for the first half of the climb then pulled ahead.

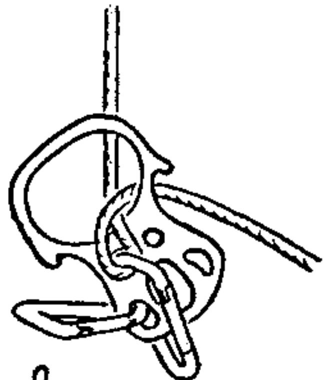
Watching the base jumpers go off and taking in all that beautiful scenery of the New River Gorge during the occasional rest periods, helped take my mind off how tiring the climb was. Bill made the clime in 25 to 30 minutes, it took me 40 minutes but I enjoyed every one of them. There was just enough time for Steve Luke to climb before we had to de-rig. Two men pulling and two men stuffing the rope in the duffel bag had the job done in a short time. When they want you off the bridge at 4:00 PM, they mean it, and we had all the ropes in Gene's van shortly after the 4:00 deadline.

We all met back at the camp ground where Jerry and I were invited to join the Bridge Day Committee and others to an all you can eat chicken barbecue pre-arranged by the committee. It was held at a nearby restaurant. The food was good and so was the company. We ate our fill of food and went over next year's Bridge Day plans.

My wife and I got up early Sunday for the long drive home. This time we took Rt. 60, the scenic way. It was indeed a long but enjoyable drive. We arrive home in the early evening. All the way home, I kept reflecting upon the activities of the past day. I've been doing vertical for almost 25 years and rappelling off that bridge, and the climb back up had to be one of the highlights of my vertical career. I made up my mind to put in for a rope slot for next year. I wouldn't miss it for the world.

A tip of my helmet to all those that had anything to do with putting it all together. They did one hell of a job.





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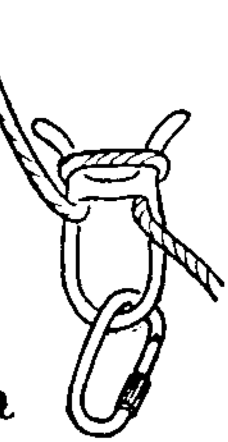

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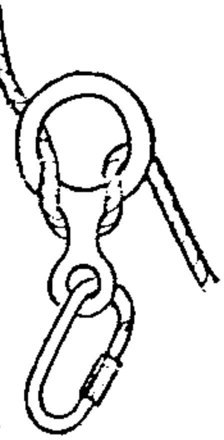

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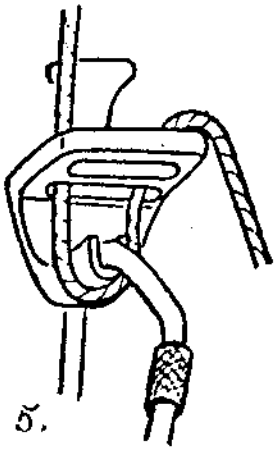

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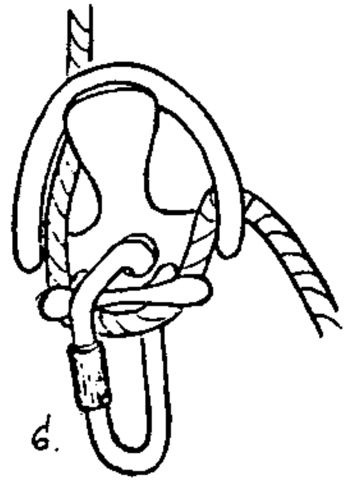

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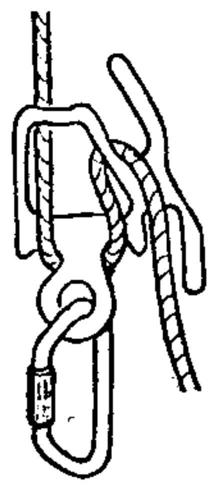

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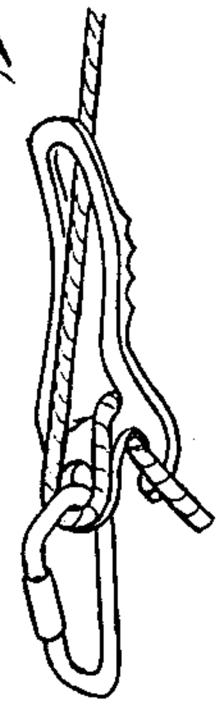

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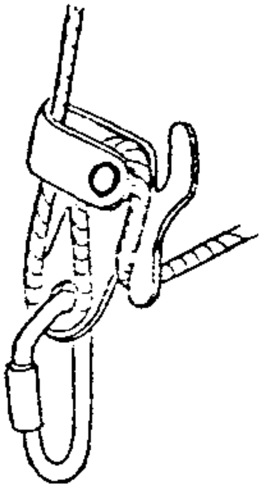

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1. Plate by Sticht
2. MSR Longhorn Ring
3. Buget by Munter
4. Figure 8 by Clog
5. Bukashka by Kashevnik
6. Bukashka-2 by Kashevnik
7. Bukashka-3 by Kashevnik
8. Horn Ring
9. Petal
10. KR by Duisekin

# An Analysis of SRT Descenders

by Konstantin B. Serafimov

National Association of Soviet Speleologists

In conformity with the program "Technique and Security of caving explorations by the Speleological Section of the Research Council in Engineering, Geology and Hydrogeology of AS of the USSR, the Security of East-Kazachstan Regional Club of speleology "Sumgan-SRT" - the Soviet Union's leading club using Single Rope Techniques, has examined all known descender constructions for their fitness of application in SRT.

Criteria for appraisal of fitness of the descenders was formulated. Let us look at the criteria in succession of reduction of their significance.

1. The descender must not twist the rope. In this case the rope must go through the descender in one plane. The twisting of rope, as a result of going through the descender, leads to the formation of "tangled ropes" at the intermediate anchor point. This makes the point difficult to pass. This is not as significant in rappelling in "bell pits" with no rebelays.

2. The descender must not bend the rope more than 1 - 1.5 times the radius of the rope itself. In this case, the results are early rope wear and great overloading of the rope at the place of bending.

3. The descender must have narrow concentrated zones of local heat that result from the friction of the rope against the descender. Construction and materials of the descender must create conditions for quick conduction of heat from the friction zone for the purpose of holding the temperature within admissible limits. (This criterion is actually only for dry caves).

4. The descender must make it possible to lock the rope easily and securely freeing both hands of the rappelling caver from the descending manipulations.

5. The descender must make it possible for a smooth regulation of the speed of rappel with only a small load on the controlling hand. (It would still be better to have both hands free from contact with the rope.)

6. The descender must have sufficient strength.

7. The descender must have sufficient resistance. In fact, we could place criteria 6 and 7 at the very top of the list. We assume, however, that all the constructions should have sufficient strength and wear resistance to ensure rappelling safety. In other words, we are looking at the quantitative differences.

8. The descender must be simple in technology and manufacture.

9. The descender must have small weight and overall dimensions.

The examination of all the known (to us) constructions of descenders allowed us to select the 4 basic classes of descenders:

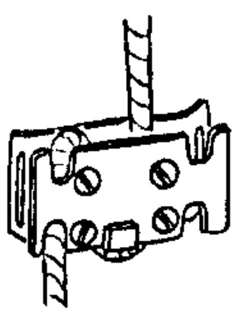
A. The class of construction of the "Ring"-type.

B. The class of construction of the "Whaletail"-type.

C. The class of construction of the "Bobbin"-type.

D. The class of construction of the "Rack"-type.

The above mentioned types of descenders are shown in Figures 1- 30. the results of the analysis, according to our criteria, age given in table 1, where "+" means a positive mark of the characteristic and a "-" means a negative without considering more exact gradations.



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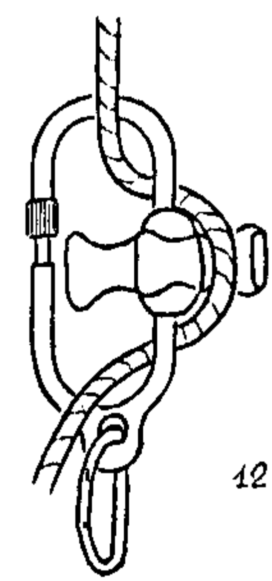

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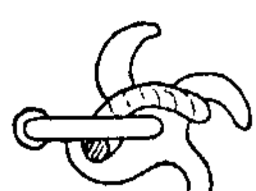
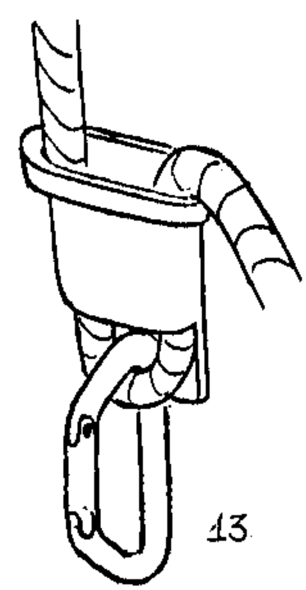
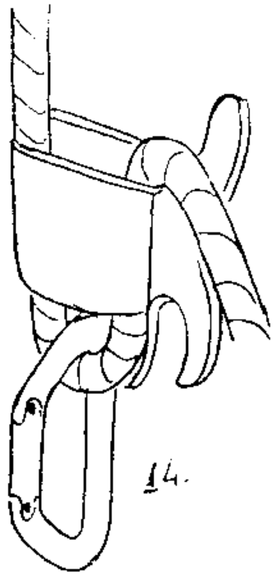




13

## Simple Descenders

11. Bukle by Kiev
12. Brake by Kovtun
13. Brake by Simonov
14. "Second"
15. Triangle by Kosorukov
16. Bobbin by Dressler-Petzl
17. Bobbin for Double Rope.
18. Whaletail Descender
19. Brake by Maznitsa



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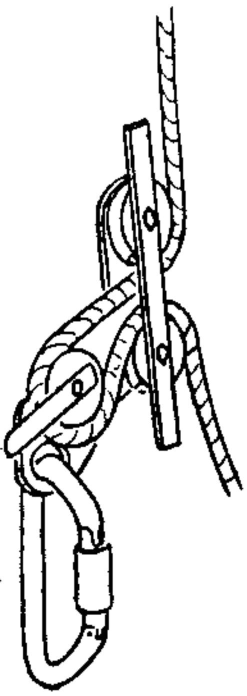

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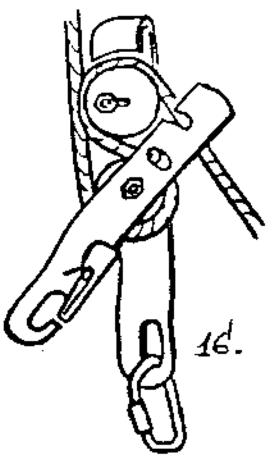

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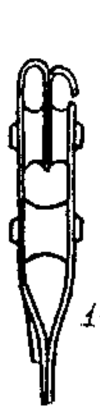

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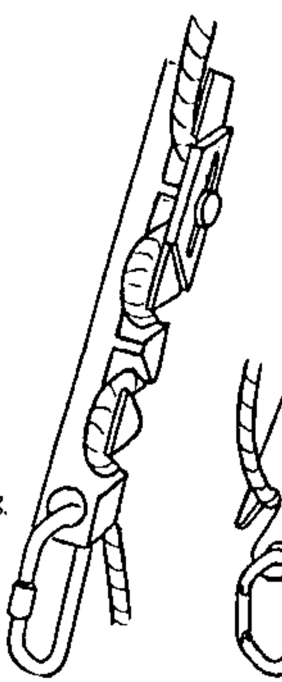

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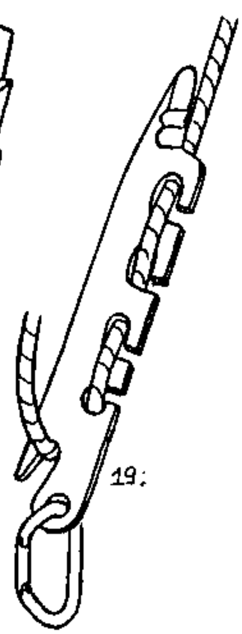


19.

The analysis shows that the best set of characteristics for use in SRT are the descenders of the "Rack"-type (in this class, the best are the "RS" and "Thumbscrew"). Further, the class of the "Whaletail" comes next and only then - the class of the "Bobbin". The constructions of the "Ring"-type are rarely used in SRT.

This is quite true when we are speaking about the so-called "simple" descenders. But, in practice, the introduction of one or more criterion is proved to be necessary: the ability of the descenders to auto lock. If the descender doesn't have this quality, then in case of an accident in the process of rappelling, when the caver loses the ability to control his descent (loss of consciousness, for example), falling in inevitable. Naturally, during falling, each of the descenders will slow down the fall proportionally to what is known to be the "effect of parachute" (effect "P"). That is to say, some of the free constructive friction of the rope against the descender remains even if the brake from the free end of the rope is removed. However, this effect "P" is too small to prevent the undesirable results.

So the need for auto locking descenders was realized and they were developed.

We know of several auto locking descenders made on the basis of all the main classes of construction, except the class of "Whaletail". They are represented in Figures 33-43.

Development of the auto locking descenders are connected first of all with the development of Single Rope Techniques. along with the criteria for "simple" descenders, the auto locking descenders - "stoppers", has their own criteria for the appreciation of their use in SRT.

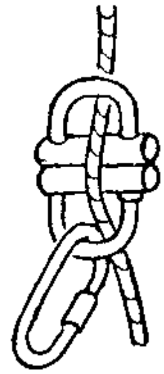
10. The stopper must make it possible to make a smooth brake to the point of stopping without a strong dynamic blow.

11. The stopper must secure reliable stopping. That is to say, auto lock descenders must be free from slippage along the rope after locking.

12. Not of little importance is the criterion of the descender to function after damage has occurred to the rope above the rappelling caver. The stopper must secure self braking after the free end of the rope has been loaded (to correspond to this criterion, the "rappel rack" has too little strength because of the open construction of the rack).

13. And the last - the criterion of the "psychological safety". The construction of the auto locking descenders must be calculated for the locking of the rope not only as a result of a loss of control by the caver, but also in the case of the cavers acting reflexively as a result of some unfavorable influence. For example, the reflex squeezing of the handle of the "Petzl- stop" in the moment of incident immediately annihilates all the of auto locking qualities after which leads to falling. The results of the analysis are given in table 2. And again, the best set of characteristics has the constructions of the "Rack"- type (stopper by Serafimov, 1982, t. Ust-Kamengorst, USSR), Figure 32.

So our analysis shows good prospects of descenders by "Rack"-type in Single Rope Techniques.



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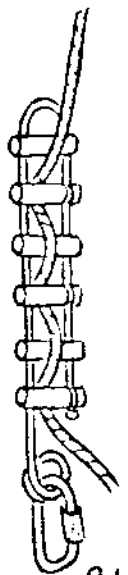

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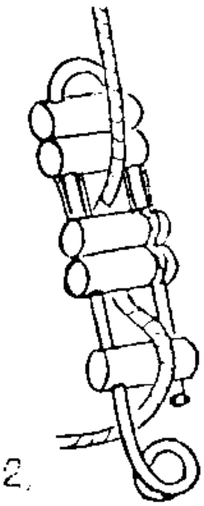

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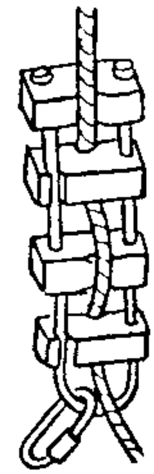

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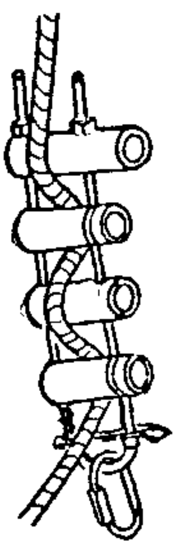

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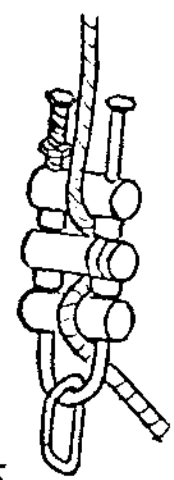

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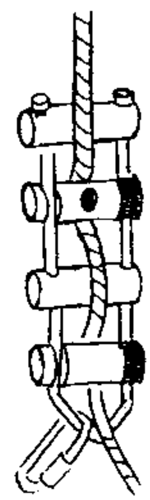

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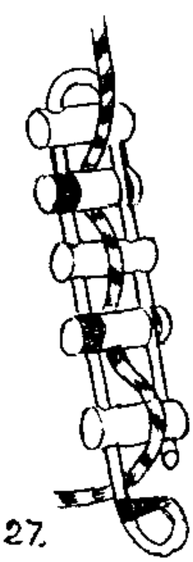

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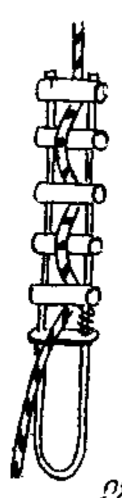

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20. Carabiner Brake Bar Ring
21. Rappel Rack
22. Rappel Rack for Long Drops
23. Super Rack
24. RS by Serafimov
25. Thumbscrew
26. Rakong - Bonaiti
27. Rack by Bulgaria

Table 1

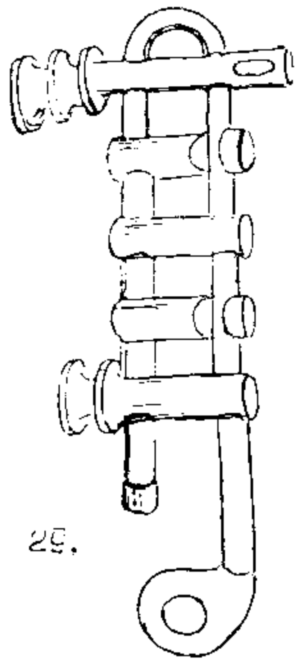
THE CHARACTERISTICS OF FRICTION DESCENDING DEVICES

| | | | Criteria | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Descender | Country | Twist | Minimum Radius | Easy Lock Off | Smooth Variable Friction | Strength | Wear Resist | Rope Damage | Weight grams | Overall Dimensions (mm) | Vertical Caving | SRT |
| 1 | Sticht Plate | Aus | + | – | – | – | + | + | – | 50 | 60/40 | + | – |
| 2 | MSR Longhorn Ring | Aust | – | – | + | + | + | + | – | 80 | 130/60 | + | – |
| 3 | Bugel by Nunter | Swiss | – | – | + | – | + | – | – | 200 | 180/125 | – | – |
| 4 | Figure 8 by Clog | British | – | + | – | – | + | + | – | 80 | 130/50 | + | – |
| 5 | Bukashka by Kashevnik | USSR | + | + | + | – | + | – | – | 100 | 190/60 | – | – |
| 6 | Bukashka-2 by Kashevnik | USSR | + | + | + | – | + | – | – | 100 | 95/60 | – | – |
| 7 | Bukashka-3 by Kashevnik | USSR | – | – | + | – | + | – | – | 100 | 112/60 | – | – |
| 8 | Horn Ring | Bulg | – | + | + | + | + | + | – | 80 | 100/70 | + | – |
| 9 | Petal | USSR | – | – | + | + | + | + | – | 40 | 150/55 | + | – |
| 10 | KR by Duisekin | USSR | + | – | + | + | + | + | – | 50 | 70/72 | + | – |
| 11 | Bukle by Kiev | USSR | + | – | + | – | + | + | – | 200 | 96/40 | + | – |
| 12 | Brake by Kovtun | USSR | – | + | – | – | + | – | – | ? | ? | – | – |
| 13 | Brake by Siminov | USSR | + | – | – | – | + | – | – | ? | ? | – | – |
| 14 | Second | USSR | + | – | + | – | + | – | – | 150 | 95/90 | + | – |
| 15 | Triangle by Kosorukov | USSR | + | + | + | – | + | – | – | 180 | 130/65 | + | + |
| 16 | Bobbin by Dressler-Petzl | France | + | + | + | – | + | – | – | 230 | 225/40 | + | + |
| 17 | Bobbin for double rope | France | + | + | + | – | + | – | – | 620 | 225/40 | + | – |
| 18 | Whaletail descender | USA | + | + | + | + | + | – | – | 350 | 280/30 | + | + |
| 19 | Brake by Maznitsa | USSR | + | – | + | + | + | + | – | ? | ? | – | + |
| 20 | Carabiner brake bar ring | USA | + | + | – | – | + | + | – | 30 | 60/20 | + | – |
| 21 | Rappel Rack (RR) | USA | + | + | – | + | – | + | y/n | 300 | 350/40 | + | + |
| 22 | RR for long drops | USA | + | + | – | + | – | + | y/n | 210 | 225/40 | + | + |
| 23 | Super Rack | USA | + | – | – | + | + | + | + | 200 | 300/50 | + | – |
| 24 | RS by Serafimov | USSR | + | + | + | + | + | + | + | 180 | 210/70 | + | + |
| 25 | Thumbscrew | Aust | + | + | + | + | + | + | + | 227 | 131/57 | + | + |
| 26 | Rakong by Bonaiti | Italy | + | + | – | + | + | + | + | 280 | ? | + | + |
| 27 | Petzl rack | France | + | + | – | + | – | + | y/n | 350 | ? | + | + |
| 28 | RR-BFPD | Bulg | + | – | + | + | + | + | + | 480 | 400/35 | + | + |
| 29 | Rack w/ self belay spool | USA | + | + | + | + | – | – | y/n | ? | ? | + | + |
| 30 | Mar-Mex Escapeline | USA | + | – | + | + | + | – | – | ? | ? | + | + |

Table 2

THE CHARACTERISTICS OF AUTOLOCKING (FRICTION) DESCENDING DEVICES (FDD)

| | Descender | Country | Criteria | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Twist | Minimum Radius | Easy Lock Off | Smooth Variable Friction | Strength | Resist Wear | Brake without Dynamic Blow | Doesn't Slip | Rope Damage | Psycho-logical Safety |
| 1 | Safetying descender (BSU) | USSR | – | + | + | – | + | + | – | + | – | + |
| 2 | ASSU by Dobrov | USSR | – | – | + | + | + | – | – | + | – | – |
| 3 | Autoblockant by Dressler | France | + | + | + | + | – | + | + | – | – | – |
| 4 | Diablo | Italy | + | + | + | + | + | + | + | – | – | – |
| 5 | Petzl stop bobbin | France | + | + | + | + | + | + | + | – | – | – |
| 6 | Kong-Bonait | Italy | + | + | + | + | + | + | + | – | – | – |
| 7 | Stopper by Golubev | USSR | + | + | + | + | + | + | + | – | – | + |
| 8 | Autoblockant by Stibrany | GSSR | + | + | + | + | + | + | + | – | – | – |
| 9 | Autoblockant Butkovic | Italy | + | + | ? | + | – | + | + | – | – | – |
| 10 | Brake Petal by Kushner | USSR | + | – | + | + | + | + | + | – | + | + |
| 11 | Stopper by Serafimov | USSR | + | + | + | + | + | + | – | + | + | + |



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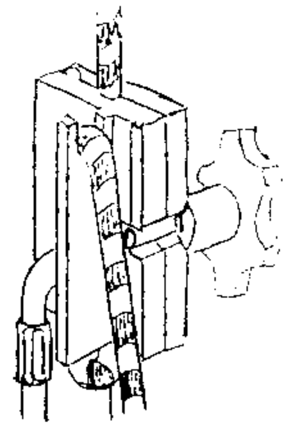

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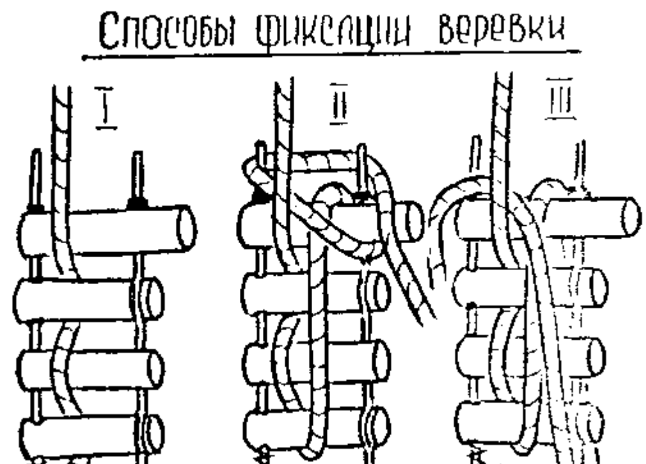
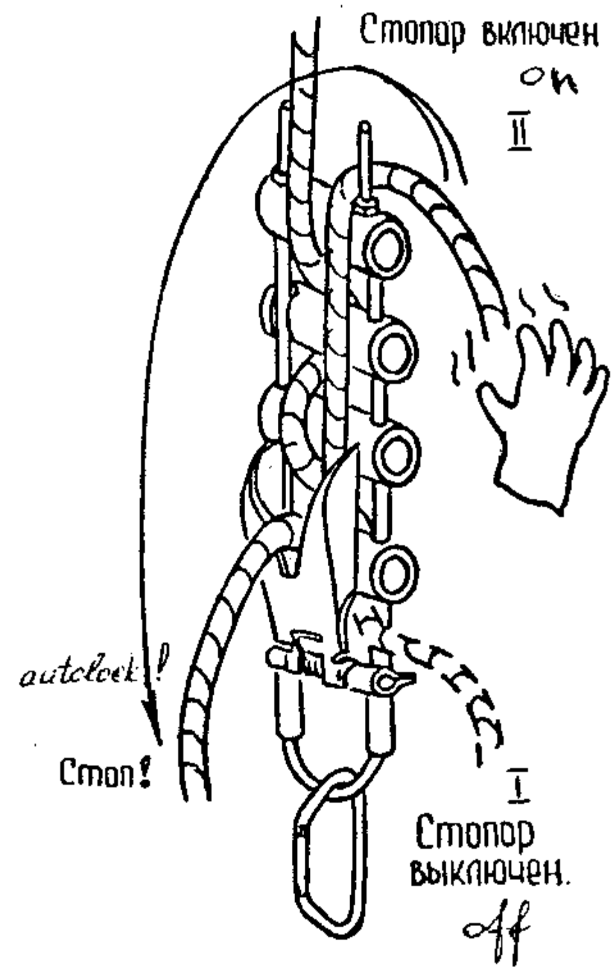
29. Rack and Brake Bars with Self-Belay Spool

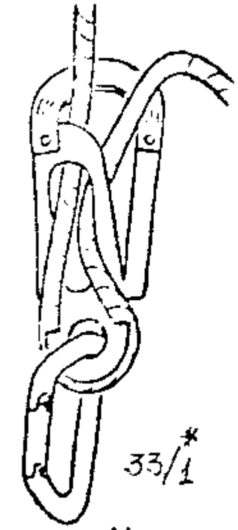
30. The Mar-Mex Escapeline

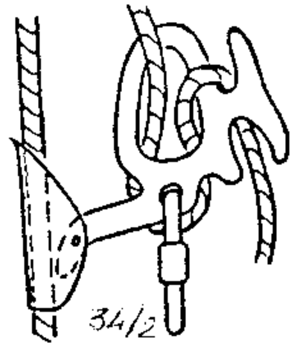
31. RS descender by Serafimov - Methods of Locking.

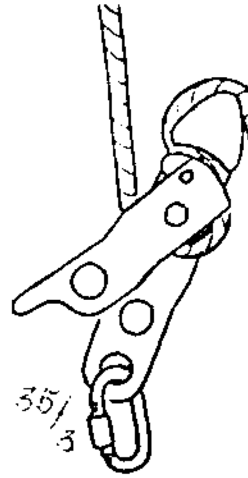
32. Stopper by Serafimov

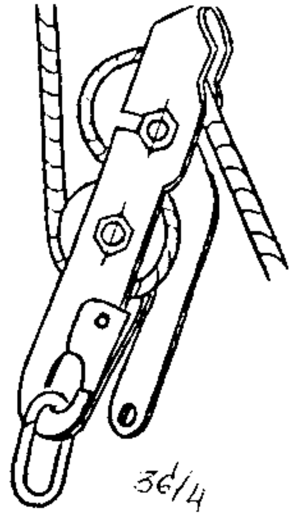


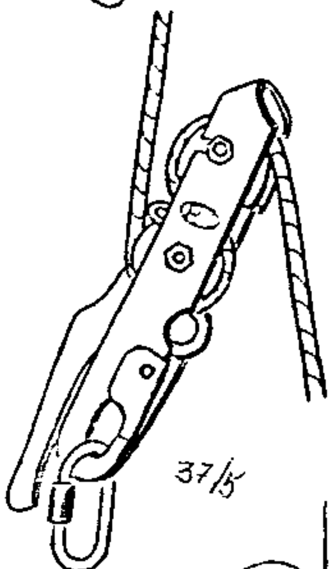





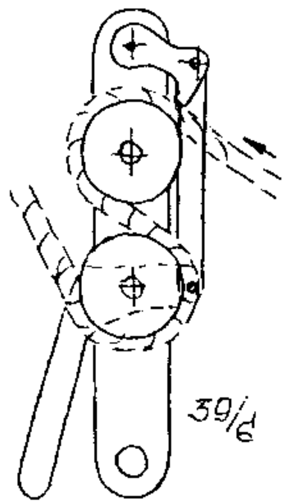



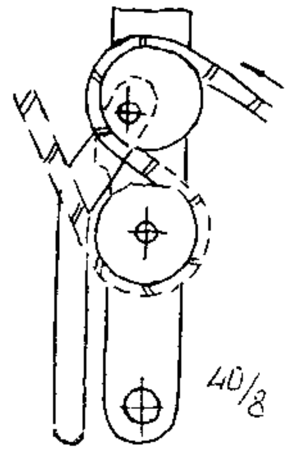



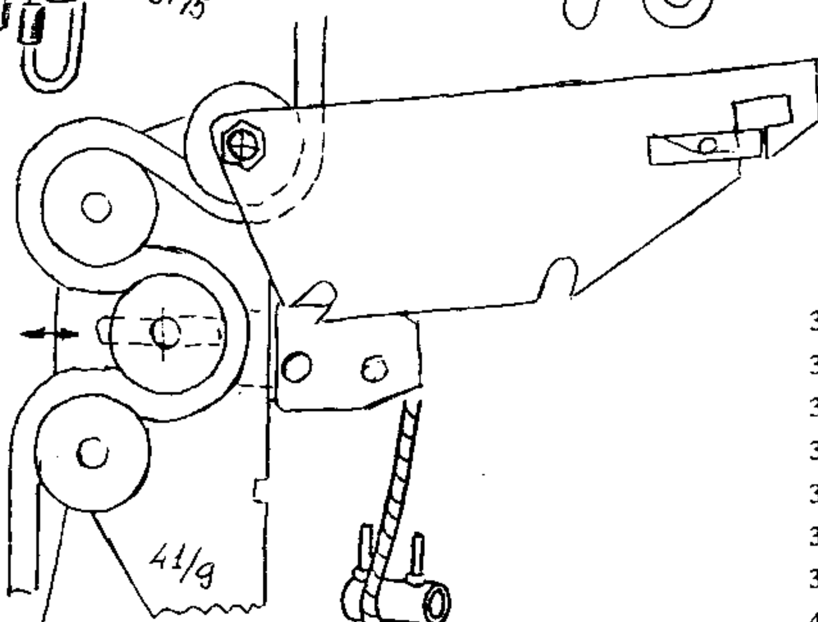



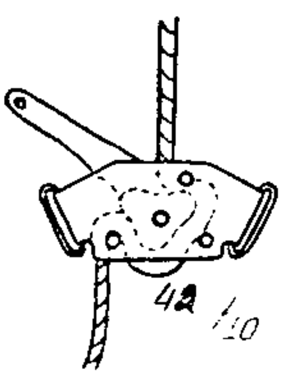



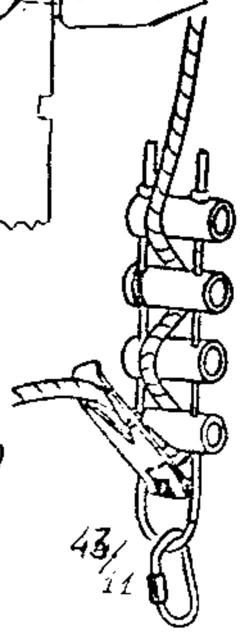





33/1. Safetying Descender (BSU)
34/2. ASSU by Dobrov
35/3. Autoblockant by Dressler
36/4. Diablo
37/5. Petzl Stop Bobbin
38/6. Stopper by Golubev
39/7. Kong Bonaiti
40/8. Autoblockant by Shtibrany
41/9. Autoblockant Butkovic
42/10. Brake Petal by Kushner
43/11. Stopper by Serafimov

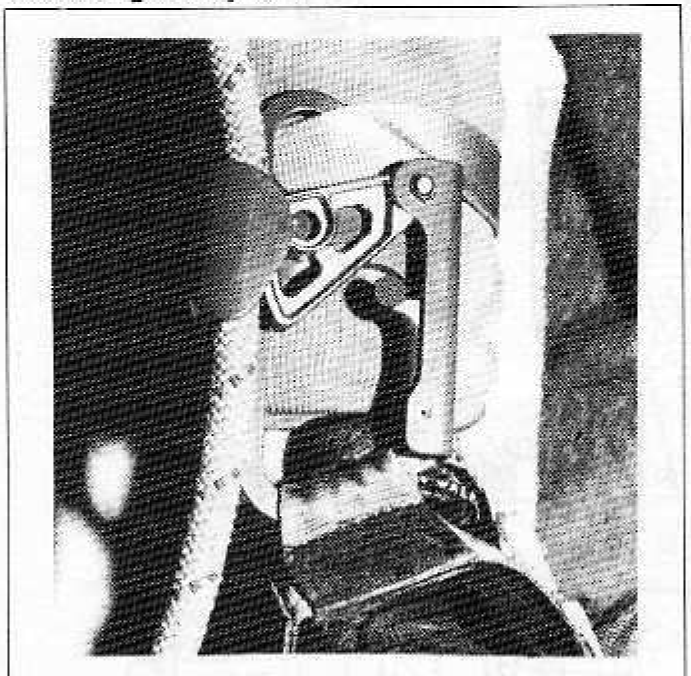
Note: 1st number is the figure number, 2nd number is from Table 2.

# THE FOOT CMI

## BY GARY BEASLEY

With the advent of the popularity of rebelay techniques in the U.S., the problems caused by closed ascenders became a sore point to be reckoned with.

Both the upper ascenders of a rope walker could be easily replaced by a variety of open face jammers. But the foot cam was not easily swapped for a simple arrangement. Any rig designed so far either caused a twisting side load on the ankle or had to be tethered in a double bungie like system.

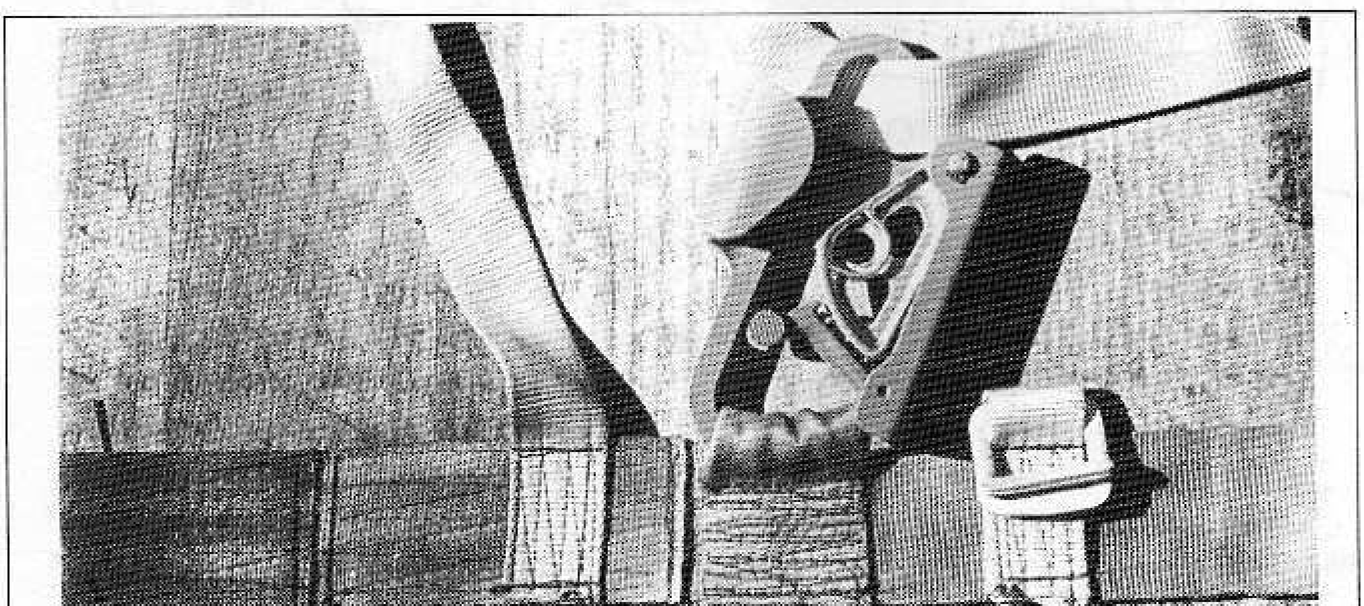


While browsing through the vendors at the '90 TAG Fall Cave-In, I noticed the design of the short CMI ultra ascender would fit a design I had been considering to a 'T'. The body of the ascender was a wide open frame that would have enough offset to allow the rope to run freely beside the foot while handing directly over the arch of the foot. This load distribution makes for a very comfortable fit of the foot loop.

I enlisted the aid of Mike Artz and his sewing machine and proceeded to lay out the design. The foot loop is two inch webbing and a buckle, like the Gibbs loop, with chicken loops stitched on. The ascender is mounted with two inch webbing and is heavily stitched at the edge next to the foot. With the angled bottom of the ascender contouring to the top of the foot. This angle makes for a left- and right-handed mount. Mine is a lefty. When figuring the mount, be sure the ascender sits on the inside of the foot profile and faces forward (see photo). The top hole has another loop laced through it to keep the ascender upright while climbing. I recommend it be run under the ascender at the rope, through the hole and over to the buckle to avoid running the rope against it.

In use, I find it works best with all loops pulled tight, the more the better. As the ascender has a sharp edge to it, a knee pad should be worn under it to prevent wearing a hole in your leg.

I'm not much of a climber and I only enter the vertical contests to gauge my personal efficiency. With a time last S.E.R.A. of about 1:37, I tried the rig out for the first time at T.A.G. and got a time of 1:28 and that was with my knee in a brace! The system I use is Wm Shrewsbury's Murphy System, which is a very smooth and strain free climbing rig. Now I have all open faced ascenders in it. I was able to get on rope in about 30 seconds. I used to spend that much time just finding the hole in my Gibbs.



# WASHING ROPES

## BY RICHARD CHANG

Washing ropes is no fun. It's a job that just can't be ignored. With ropes costing what they do, we need to maximize their longevity, and to do that requires they be kept as clean as possible. If you've ever done this dirty deed, you might not looking forward to the cleanup that begins when the caving trip ends, especially if you had problems untangling the rope last time you pulled it out of the washing machine. An if you wash dynamic ropes you know their soft handling characteristics exacerbate the tangling problem. The bible for our sport, "On Rope", recommends washing ropes in a front loading washing machine, one of which I don't own. What's a caver to do?

After messing around for three years, I've evolved a system that works well in a tip loading machine. I start the process by braiding the rope into a single braid. Start by beginning the braid from the "bight" end with a figure 8 knot. This will prevent this end of the braid from shifting during the agitation cycle. Finish up the braid until the very end. When there isn't enough rope to but a bight through the last loop, insert the tag ends (you'll have two) and lay it next to itself near where it enters the last loop. This is where I used to try to tie enough knots that would last through the agitation cycle, but never could. Now I put a safety pin through all four pieces of rope. It holds beautifully, and, if you get diaper pins (rust free models are available) they're the perfect size. They're also great for keeping that rope in one lump when you're carting it up a 60% incline covered with lechuguillas. They store easily, just shove them through a non-loaded section of the working end of the rope near the rig point, they are easy to find, 'cause they come in great colors like pink, yellow and baby blue. You'll also like the great animal shapes: duckies, turtles and butterflies, but unfortunately, no bats.

When you're finished with the braiding, pack the rope in the machine as close to the outer circumference as you can. Next, put towels in between the agitator and the rope: they should be at least medium in size, arranged in a circular fashion.

I like to add a laundry soap. I use a liquid containing no phosphorous. You don't need much, only enough to break the surface tension of your local water supply. "On Rope" recommends using a non-detergent soap (like Ivory flakes) for new ropes and a good quality laundry detergent on older ropes. They also recommend not washing a new rope before using. Their research indicates washing "removes the natural slipperiness, causing it to become dry and brittle. This, in turn, shortens the life of a rope. So as not to prematurely dry out a new rope, it should not be washed, rinsed or soaked before initial use." Also, the addition of a fabric softener is not recommended, because "recent tests indicate fabric softeners substantially weaken rope". Never add chlorine bleach to a rope. I always fill the machine with as much water as possible, thinking that a larger volume to hold the dirt in suspension isn't a bad way to go.

When the spin cycle is over, remove the towels to the dryer and hang the rope in the garage (or equivalent) to dry. It might take several days depending on weather conditions.

If you can keep your ropes on a consistent cleaning cycle, they won't build up the dirt or black aluminum deposits left by rappel devices. Over time, these particles will be worked through the mantle into the kern by continuing to rappel on a dirty rope, resulting in weakened rope from these abrasive particles, compromising the integrity of the kern fibers. On another important note, "On Rope" recommends marking each end of your rope to facilitate rigging alternate ends on alternate trips which results in a more even rope wear pattern. This is especially important if you visit one specific cave many times. Wear and abrasion on the same section accelerate the retirement date of your rope.

While this is not a comprehensive study of rope washing, it should give you general idea of how to make your rope last longer. That's it, now there's no excuse for having a dirty rope!

# Are You Really on Belay?

## By John Dill

## Part II

This is the second part in a two-part report that summarizes tests of the ability of belay devices to catch a falling rescue load. Our emphasis has been on drop tests of the unloaded belay line, and we tried to rig the system as closely as possible to how it might be in the field. The report covers tests conducted in 1987 in Denver, Colorado and 1989 in Sedona, Arizona, and is based on 230 individual tests. And, as I noted in Part I, there are so many significant variables, that we consider our tests far from complete.

This article is note a scientific report. With this information alone, another investigation will not be able to duplicate our tests or otherwise check our claims. But despite these limitations, we believe we should share a summary of what we have discovered so far. We hope this article will cause rescuers to question the possible limitation in their systems, suggest direction for their own test programs, and stimulate a more informed and energetic public debate regarding methods and standards for rescue belays.

Part I of this report, published in the Summer 1990 Response, described the rationale behind these tests and the procedures used. It also reported the results for several devices that are commercially available and commonly used for rescue belays. According to our findings, some of these belay devices could fail to stop even the shortest fall.

Part II discusses the Prusik Hitch and some possibilities for additional energy absorption. **Read in isolation, Part II could be misleading and therefore, potentially dangerous. It is VERY important that you read both parts of the report, and wait until you have thoroughly digested the contents before drawing your own conclusions.**

### THE PRUSIK HITCH

The size, material and construction of both rope and cord affect the performance of Prusiks, as to the numerous ways to rig them. In our tests, we used 3 wrap Prusiks exclusively unless stated otherwise, they were made from Mammut, 8mm, low stretch nylon, kernmantle accessory cord, rigged on 7/16" PMI E-Z Bend[tm] rope. New, unused rope and cord specimens were used for each dorp.

After being tied onto the rope, each Prusik was clipped into the anchor carabiner and shaped into orderly coils. It was then made sufficiently snug to hold the weight of the rope that hung down to test the block. However, it remained loose enough to allow the belayer to slide rope through, as one must do in the process of belaying. Although a belayer normally tends the Prusiks in the field, for reasons of safety, we did not in our tests.

In a fall, friction between the suddenly moving rope and the Prusik draws the hitch tight. If the tension becomes high enough, the Prusik slips and begins to melt from the heat of the friction, leaving a glaze of melted plastic - primarily from the Prusik - on the rope. In all of our drop tests if something failed, it was the Prusiks, while the rope, including the sheath, appeared to remain intact.

### SINGLE PRUSIKS

Both 7mm (New England Ropes) and 8 mm (Mammut) single Prusiks held 100 cm falls with stopping distances of less than 100 cm. The Maximum Arrest Force (MAF) was roughly 10-11 kiloNewton (kN0. Stretch in the rope and other components accounted for most of the stopping distance, with Prusik slippage contributing to the rest. Eight mm cord failed to catch a 150 cm fall, and we did not pursue single Prusiks further.

### TANDEM PRUSIKS

In these tests, the short Prusik was made from 135 cm of cord and the long one from 165 cm. When clipped to the same anchor carabiner, with the slack pulled out of the system, the two hitches were roughly 10 cm (4") apart on the rope (Fig. 4). This arrangement, termed the Tandem Prusik Belay, consistently held 100 cm falls with a stopping distance of less than 100 cm (seven test drops at 100 cm). MAF was about 12.5 kN. The longest free falls arrested by this system ranged from 175 to 300 cm, depending on variations in the rigging, some of which are discussed below. (Unless stated otherwise, the rope was rigged in the "straight" fashion shown in Fig. 4.)

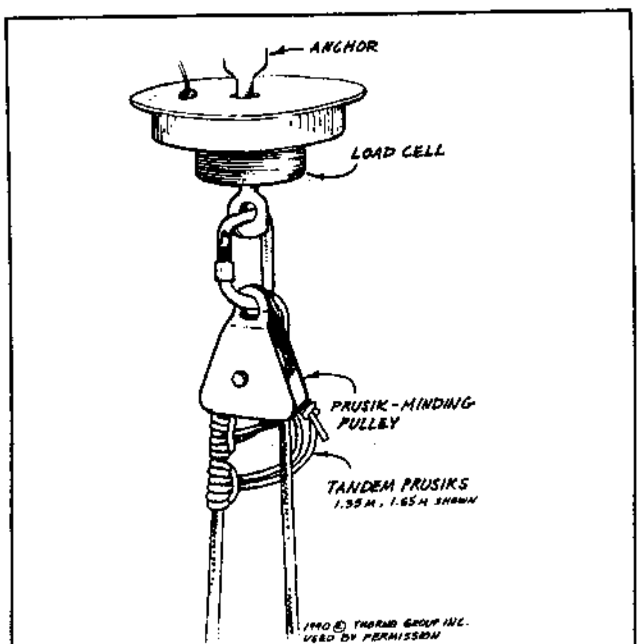



Figure 3: Prusik-Minding Pulley with Tandem Prusiks.

## COATED ROPES

Wellington Puritan Rhino-Kote$^{tm}$ Rescue Rope has a surface coating. Rhino-Kote$^{tm}$, intended to reduce abrasion. In our tests with new 7/16" Rhino-Kote$^{tm}$ Rope, tandem Prusiks held a 0 cm fall with normal slippage, but they could not consistently hold 100 cm drops. The rope slid through the hitches at low force (about 3.5 kN0 until the test block gradually came to a halt (with stopping distances of 140 cm or more), or the Prusiks failed from melting.

Do not confuse this rope with the uncoated version, Rhino Rescue Rope $^{tm}$. The latter is probably as suitable for use with Prusiks as is any other uncoated nylon rescue rope. However, we recommend you do not use the Tandem Prusik Belay on Rhino-Kote$^{tm}$, or on any other coated ropes prior to appropriate tests.

Note: We have drawn no conclusions from these results regarding the performance of any type of Prusiks on Rhino-Kote$^{tm}$ for applications such as hauling or personal ascending. In these cases, the hitches are deliberately set - cinched onto the rope - before they are loaded, and the load is applied relatively slowly.

## POLYESTER VS. NYLON

KM III$^{tm}$ (New England Ropes) is similar to other low stretch nylon rescue ropes, but with a polyester sheath. New England Ropes also makes Stayset$^{tm}$, an all-polyester, double braided yachting cord with about the same breaking strength as Mammut 8 mm nylon cord. Using 5/16" (7.9 mm) Stayset$^{tm}$ and 7/16" KM III$^{tm}$, along with our all nylon cord and rope, we compared tandem Prusiks in four combinations - nylon Prusiks on both nylon and polyester rope sheaths, and polyester Prusiks on both.

Nylon Prusiks on E-Z Bend $^{tm}$ held the longest drops, 250 cm, as reported above. Polyester Prusiks on KM III$^{tm}$ failed above 225 cm, but in successful arrests, it appeared to grip as well as nylon on nylon. Both nylon cord on km III$^{tm}$ and polyester on E-Z Bend $^{tm}$ showed significant wear at 200 cm and failed above that. Polyester on nylon seemed to get the poorest grip, slipping much farther at any given drop height than the other combinations.

Since we made only a few drops with most of these combinations, and because of the differences in flexibility and elasticity of the ropes and cords used, our results are suggestive at best. Once again, these results may not relate to the performance of these specific systems in applications such as hauling and personal ascending.

## PRUSIK- VS. ROPE-DIAMETER

Most riggers agree that the smaller the diameter of the Prusik cord, in relation tot he diameter of rope, the better the grip. This proved true in our tests. At all drop heights we tried, 8 mm tandem Prusiks on 1/2" E-Z Bend$^{tm}$ slipped much less than on 7/16" E-Z Bend$^{tm}$, and they showed less wear. The MAF was higher and stopping distances were shorter. This combination arrested a 275 cm fall with little slip or apparent wear. MAF was 23 Kn (5200lbf, or 23 big firefighters hanging on the line). Nine mm Prusiks on 1/2" E-Z Bend $^{tm}$ worked well, performing about the same as 8 mm on 7/16". Nine mm cord did not grip as well a 8 mm on 7/16", however. It held a 150 cm fall, but with significant damage and other signs of imminent failure.

## PRUSIK SPACING

We increased the gap between the Prusiks from 10 to9 25 cm, by making the longer hitch from a longer piece of cord. There were no obvious differences in performance at 100 cm, but the system held falls of at least 300 cm, compared to 250 cm for the 10 cm gap. The Prusiks slipped less and held higher forces, though we do not know why. A gap wider than 10 cm may be the best choice in the field. But a considerably wider gap may be difficult for the belayer to manage and may load the shorter Prusik more than the longer one.

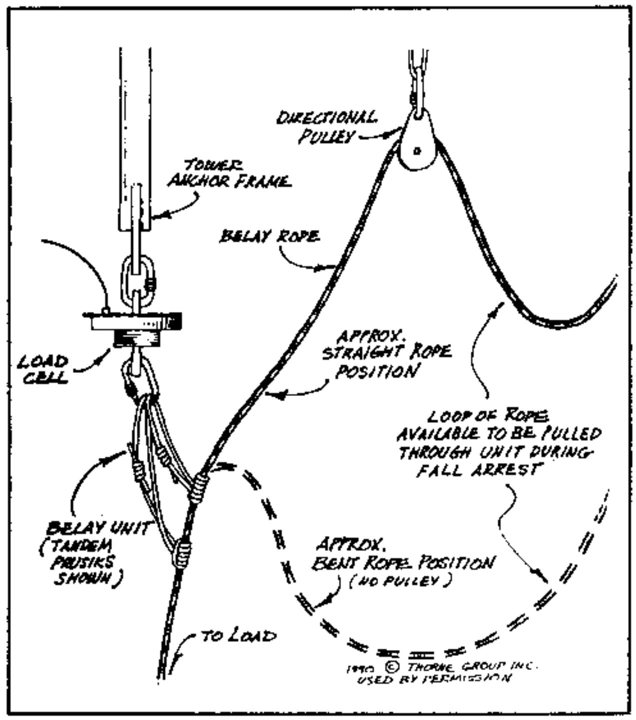



Figure 4.: Method for controlling Belay Rope Entry Angle.

## ROPE ENTRY ANGLE

In the field, the angle at which the unloaded rope enters the short Prusik varies with the rigging. During a raising, for example, the belayer may bend the rope around a Prusik-minding pulley clipped to the same carabiner as the Prusiks. The hitched are held in place by bumping against the pulley as the rope is taken in (Fig. 3). In a fall, the pulley holds the rope straight, on in-line with the load, as it enters the Prusik from above. If, during a lowering, the rope feed from a pile behind the belay, it is also more or less straight at the entry. If, instead, the rope feed from a pile to one side of the Prusiks, it may make a bend as it enters the short Prusik. We approximated these arrangements on the drop tower (Fig. 4). By supporting the rope (new 7/16" E-Z Bend$^{tm}$

on a pulley above the Prusiks, it entered almost straight. When the pulley was removed, it drooped below the Prusiks making a bend at the entry.

Tandem Mammut Prusiks appeared to hold much larger falls on a straight rope (250 cm) than on a bent one (175 cm). (I say "appeared" because we have not yet satisfactorily ruled out some other variables. In particular, the spacing of the hitches may play a role.)

In contrast, and more importantly, tandem Prusiks completely failed to cinch onto the straight rope, in the following circumstances:

1) When the Prusiks were left so loose that a finger could fit between the rope and the coils of the hitches, they failed to grab on a straight rope. the test block fell to the ground with essentially no resistance, and the Prusiks were not visibly damaged. They cinched onto the rope and held the fall normally, however, when the rope was bent at the entry.

2) One sample of 8 mm nylon cord (New England Ropes) was noticeable stiffer than previous samples of the same brand. (Variations in the properties of rope and cord seem to be common and not limited to this brand.) Prusiks from this sample would not stay snug on the rope when they were rigged for a drop. They failed to grab a straight rope, but grabbed a bent one and arrested the fall normally.

3) In another test, the rope was held straight by feeding it through a Prusik-minding pulley (Fig. 3). The Prusiks (Mammut again) were snugged normally - that is, the intention was not to have them loose. This system caught 100 and 250 cm falls, but in a 0 cm fall, the Prusiks failed to grab the rope and the block fell to the ground. There was no apparent damage to rope or cord. The block was repositioned, the same Prusiks were made a bit more snug, and the drop was repeated. The belay held. We do not know if the low impact of the 0 cm fall played a role, or if the Prusiks were originally set too loose.

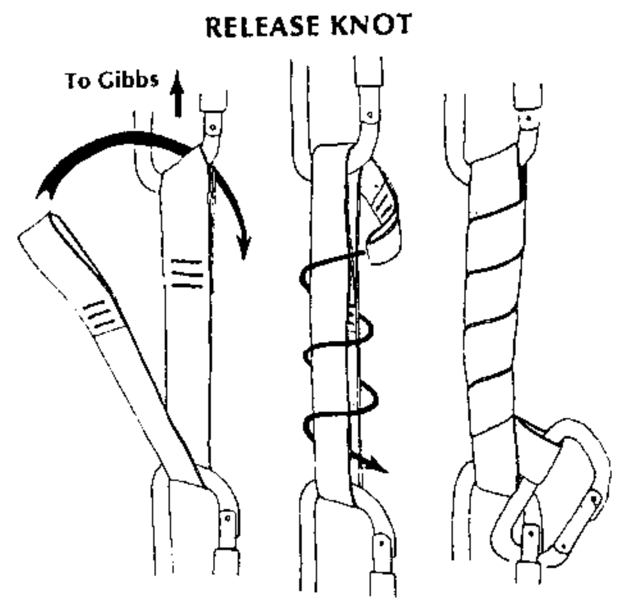



Figure 5: CMC Mariners Knot. Drawing courtesy of California Mountain Company.

4) When reacting to a fall, tandem Prusiks typically grab the rope within 5 cm (2") of their original positions, laying a glaze on its sheath from there on if they slip. In several instances, however, we found longer sections of clean rope preceding the glaze. This suggests a delay in the cinching action, allowing the falling block to pull additional rope through the hitches. So far we have found delays only when the rope was straight, not bent. Furthermore, they occurred in normally rigged drops - that is, the Prusiks were not deliberately loose or of stiff material, as discussed above.

The longest delay we observed, 40 cm, occurred with a 100 cm drop. The force as almost zero during this phase (delays are easily seen on our curves of force vs. time), so the drop height, or effective slack rope prior to the fall, was actually 140 cm, and the MAF was proportionally higher. A longer delay could turn a "safe" 100 cm fall into a failure, even if the Prusiks eventually grabbed.

In summary, tandem Prusiks appear to be less reliable at initially grabbing a straight rope than a bent one. They may delay before grabbing, or a complete failure to grab may occur. In some cases, at least, these effects do not require a hard fall. It remains to be seen whether subtle differences in setting the hitches are critical, and under what conditions. But, it is clear that Prusiks should not be used with blind confidence until these effects are understood and eliminated, or until it can be shown they do not occur under field conditions.

Larson and Thorne feel the latter is the case, if the Prusiks are correctly rigged and tended. In the field, the entering rope is under little tension as it feeds loosely around the pulley or directly out of the pile. When it is jerked through the Prusiks by a fall, it may develop waves and kinks that trigger the Prusiks like a bent rope does. On all four cases presented above, enough rope hung down from the spool side of the pulley that its weight may have prevented those kinks. This explanation is not yet confirmed, but it implies that even the friction of rope lying in the brush or rocks, or the tension applied by a belayer hauling rope through the pulley must be carefully controlled or eliminated, if the rope enters the Prusiks straight.

Perhaps, more importantly, in our tests, no belayer tended the Prusiks. When lowering a load in the field, the belayer holds the Prusiks, allowing the rope to slip through while keeping them snug enough to react properly to a fall. The details of Prusik tending are beyond the scope of this report and are more appropriately covered by a competent instructor.

## LOAD RELEASING HITCHES

When tied between the anchor and belay device, a load releasing hitch can be loosened and lengthened while under tension, allowing the load to be lowered until the tension is transferred to another system. (Several wraps of the anchor rope around a tree makes a simple load releaser.) Load releasers are handy when passing knots and when the belay grabs accidentally. We were interested in the ability of these devices to withstand the shock of a fall, and also in their energy absorbing capacity.

## CMC MARINERS KNOT

The CMC Mariners Knot, described in the California Mountain Company Rope Rescue Manual, is a release hitch usually made from 1" flat or tubular webbing. It is wrapped between the anchor and belay carabiners and then around itself (Fig. 5). We tied it with 7-8 wraps. In series with tied off 7/16" E-Z Bend[tm], the MAF for a 100 cm drop was about 7% less than with the tied-off rope alone (see Tied-off Rope, in Part I). We also rigged it in series with a Gibbs Ascender (see The Gibbs Ascender, in Part I). In three 100 cm drops with the Gibbs, there were two successful arrests and one failure (the rope was cut by the Gibbs). In all three drops, the type of damage and the MAF were similar to when the Gibbs was used alone. Under our test conditions, therefore, the Mariners Knot did not appear to absorb much energy. This hitch released easily and provided control for lowering the load. More tests are certainly warranted, particularly with fewer wraps.

## LR HITCH

The LR Hitch, used by the British Columbia Council of Technical Rescue, connects the anchor and belay carabiners via a Munter Hitch of doubled 8 mm accessory cord and finished with wraps on itself (Fig 6.)

When we rigged the LR Hitch in series with tied-off 7/16" E-Z Bend[tm], MAF for two 100 cm drops was about 14% less than without the hitch. When it was rigged in series with tandem 8mm Prusiks (Fig. 3), the MAF for 100 cm falls was 9.5 kN - a 25% decrease from the tandem Prusiks alone. Stopping distance was less than 100 cm. It was easy to untie the LR Hitch and lower the load.

The tandem Prusik/LR Hitch combinations held falls of up to 300 cm. When this system arrested a 200-300 cm fall, the Prusiks usually performed noticeably better than when the LR Hitch was absent. They slipped much less than at a given drop height, held longer falls and survived twice the MAF. In these arrests, the LR Hitch extended as much as 250%, and its strands fused together from sliding against each other (although they could be broken apart and the block lowered). Similar to the effect of high- stretch rope, therefore, the LR Hitch appeared to allow the Prusiks to get a better grip by absorbing much of the impact itself.

Separating the rope-grabbing from the shock-absorbing functions in this way offers flexibility to the designer. For example, several teams in Arizona that use 1/2" rope rig 8 mm Prusiks for grip, in series with a 9 mm LR Hitch for a strong but shock- absorbing connection.

In our tests with 8 mm cord, however, performance in drops above 150 cm was inconsistent for two reasons:

1) Although the Prusiks usually gripped while the LR Hitch slipped, occasionally the reverse occurred. In one case, the Prusiks failed by slipping in a 225 cm fall - a drop height they held consistently when no LR Hitch was present.

2) Despite generally holding falls to 300 cm, in one group of tests, this combination held 175 cm falls, but consistent broke the LR Hitch at 200 cm and above, at forces it had previously survived. (When the LR Hitch fails, one strand breaks where it is compressed in the Munter Hitch.) At this time we do not know if the difference is due to the cord (a manufacturing lot different from that used for the other tests), to some subtlety of the rigging, or to our small data base.

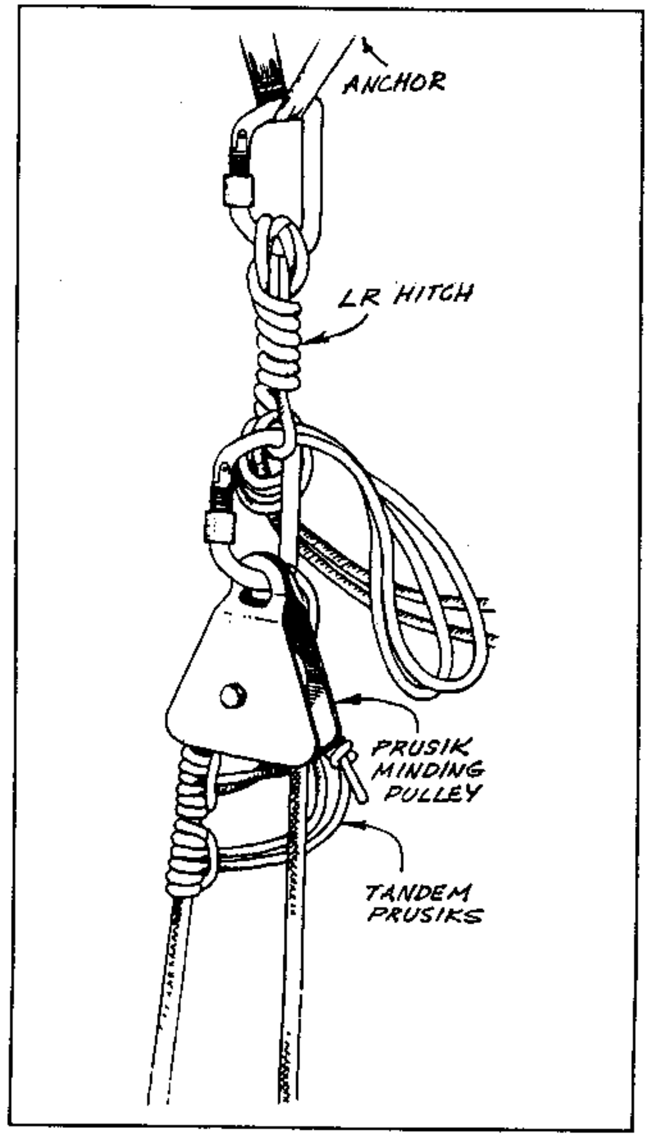



Figure 6: LR Hitch

Unless both of these effects can be eliminated, the maximum drop height for tandem Prusiks with an 8 mm LR Hitch must be considered to be less then 200 cm.

An additional note: Even in successful drops with this system we still saw instances of Prusik delay. They were not large, but the potential for catastrophe may exist, at least under our test conditions.

## THE TANDEM PRUSIK BELAY IN SUMMARY

Here's what our data currently suggest for rigging the Tandem Prusik Belay:

1) Use 8 mm low-stretch kernmantle cord on 7/16" kernmantle rope, and 8 or 9 mm on 1/2". Avoid using 9 mm on 7/16".

2) Use nylon Prusiks on nylon rope and either polyester or nylon Prusiks on a polyester rope.

3) Use a cord flexible enough to stay snug and retire it if it becomes stiff.

4) Rig the Prusiks such that, when they are stretched out away from the anchor, there is a gap of at least 10 cm between them.

5) Use an 8 or 9 mm LR HItch in series with tandem Prusiks.

In our tests, Prusiks were the only system that consistently held falls greater than 25 cm. However, rescuers must remember there are effects we do not understand; there are reasons for special procedures in the field, and, even in 0 cm drops, we cannot yet claim they are an idiot proof belay. Whether or not our test failures are limited to the lab, they demonstrate that the consequences of a mistake may not be trivial. If you decide to belay with Prusiks, do not just tear out the recipe above, thinking you have the problem licked. Learn Prusik belaying from someone with lots of field experience and a will to live. And do not let yourself get out of practice. One final note: I am not aware of any manufacturer that advertises its accessory cord be used for this purpose.

## WHERE DO YOU GO FROM HERE?

What belay should you use? Consider: Do you feel the need to protect against 100 cm falls? Or are you more concerned about the reliability of the belayer? Some teams feel it is easier to teach a belayer to use a Gibbs and keep slack out of the line, than to teach the subtleties of Prusiks. Others disagree. No one can make the decision for you, and your team's own training and experience may be the most important variable. I recommend that your team rigger attend not just one, but at least two courses representing opposing viewpoints. Remember: While the answer may seem simple to you, other teams have made different choices and instructors have their biases.

Regardless of your choice of a belay, the main lesson from our tests should be clear: **Do not trust your system unless you have tested it in conditions appropriate to your rescue environment.**

Our results are simply clues in a search, presented here to alert you both to danger and to opportunity. Think about them as you use your belay system in the field. If you have pertinent experiences to relate, feel that important concerns were not addressed in this report, or believe our test conditions were unsatisfactory, contact us directly. By sharing ideas we may gain the confidence to say, as we look up from the litter, "Now I really am on belay."

## CREDITS

John Dill is a SAR Technician at Yosemite National Park, California. Arnor Larson is a guide and rescue instructor in British Columbia, Canada. Hal Murray is a computer engineer for Digital Equipment Corp., Palo Alto, California. Reed Thorne is a captain in the Sedona Arizona Fire Department and a rope rescue instructor for the Arizona State Fire Marshal's Office.

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A more detailed version of this report can be obtained by writing: On Belay?, NASAR, P.O. Box 3709, Fairfax, VA 22038

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# Self-Equalizing Anchor Testing Program

**by T. Keith Schafer**

Tests were conducted on a variety of anchor systems incorporating a 'SEA' construction to determine the basic distribution and dynamic characteristics of these widely used methods of load distribution on the anchor points. The tests are not considered all inclusive, but do point out significant points that should be weighed during construction of 'SEA' systems in rescue situations.

The tests were conducted at the Seven Peaks Water Park located in Provo, UT, on October 23 and 24, 1990. Computerized force measurement was provided by the Alpine Center for Rescue Studies, St. Mary's Glacier, CO. Material was provided by Pigeon Mountain Industries, Lafayette, GA.

A questionnaire was distributed to numerous rescue teams throughout the United States. The following teams, agencies, and individuals provided information or reviews:

Utah County Sheriff's Search and Rescue, Orem, UT
Colorado Ground SAR, Boulder, CO
Bill and Louie Clem, Alpine Center for Rescue Studies
John Peleaux, Alpine Rescue Team, Evergreen, CO
Salt Lake County Search and Rescue, Salt Lake City, UT
Alan Erdahl, Salt Lake County Search and Rescue
China Lake Mountain Rescue Group, Ridgecrest, CA
Riverside Mountain Rescue Unit, Riverside, CA
Larimer County Search and Rescue, Fort Collins, CO
Arnör Larson, British Columbia Council of Technical Rescue, Invermere, B.C.
John Dill, Yosemite National Park, Yosemite, CA
Pigeon Mountain Industries, Lafayette, GA
Grand Teton National Park, Moose, WY
Grand Canyon National Park, Grand Canyon, AZ
Zion National Park, Springdale, UT
Rock Thompson, Rock Exotica, Centerville, UT

The tests were divided into two segments: Static and Dynamic. The static test dealt only with the forces as they are distributed in a stationary state with respect to angles and symmetry. The dynamic tests dealt with various types of symmetrical 'SEA' systems with similar drops and angles.

Although it was strongly suggested that SI units be used in measuring all weights, forces, and distances, the English system was used. The English system was used to make the data 'friendly' to the rescuer, rather than pleasing the researcher. The advantage of SI units to the international and research community is recognized and a copy of this report in SI units will be provided on request.

The goal of the program was to aid rescuers in establishing rules of thumb or standards for construction of 'SEA's that are based on tests and calculations. The following items could be considered:

1 - The tests did not show conclusive evidence that one type 'SEA' performed better than another. What small advantages were noticed could be perturbed by field conditions or errors in testing.

2 - Construction should be simple and use material carried by nearly all technical rescue persons. Systems using large amounts of rope and large bulky knots consumed more time in construction and adjustment than did their webbing counterparts. The construction and alignment of the 'SEA' should not take more than a minute. A Figure-8 'SEA' can be assembled and adjusted in less than 30 seconds.

3 - The angle between the two outside anchor legs at the load should be kept below $60^\circ$, if practical. During load direction shifts, angles larger than $60^\circ$ do not distribute the the load as efficiently. A $90^\circ$ angle should be considered maximum and is based on the load distribution created by the angle.

4 - The circumference of the large loop should be kept to less than eight feet. This ensures that the drop distance does not exceed one foot. Assembling an 'SEA' with a drop of less than one foot affects the distributing ability of the 'SEA'. That conclusion was reached based on field testing by Colorado teams. Assembling an 'SEA' with a drop of greater than one foot creates increasing amounts of force in the event of an anchor point failure.

5 - The anchor points should be extended to the 'SEA' rather than the 'SEA' being extended to the anchor points. Large 'SEA' systems create significantly larger dynamic forces by allowing farther drops.

6 - If the intention of construction is to equalize marginal anchors placements, the forces that may occur in rescue applications could cause a failure of he entire 'SEA'. The failure of one point could generate forces on the other two points in excess of 1500 pounds-force (lbf). It is not recommended that the primary purpose of the 'SEA' to be protection against a marginal anchor point.

A more appropriate purpose for the 'SEA' is to provide several 'bombproof' anchor points with a larger range of pull. In other words, the 'SEA' has the ability to shift its direction of pull and still distribute the load among the anchor points. Friction at the carabiners and the stiffness of the system will determine the efficiency of the load distribution.

## STATIC TESTS

The purpose of conducting the static tests was to demonstrate the equalizing nature of the 'SEA' construction. In these tests, the 'SEA' was constructed in a manner in which friction was minimized. In field conditions, it should be recognized that friction plays a large part in the distribution of forces. The expected errors when using various carabiners will be a topic of further research.

Suggested formulas explaining the distribution of forces in an ideal 'SEA' are listed on the data sheet. Friction is not considered in these formulas.

Tests 1 through 5 were conducted using new 1/2" PMI Rescue Rope, E-Z Bend, tied into a three point 'SEA' using a doubled figure-8 knot. A 440 pound-mass (lbm) load was suspended. Pulleys were used at points 2 - 6 (see Test Data Form) to reduce the effects of friction.

Before each run, the load was pulled approximately one foot to the side and allowed to swing back free and distribute the load on the anchors. The direction of pull was alternated with each run. The distance pulled, whether one or two feet, had insignificant effects on the loading of the anchors. Loads listed in the following tables are in pounds-force (lbf).

<u>Test 1</u> - Symmetrical 'SEA' with 54° angle between the outside anchors at the load.

| Run | Left Anchor | Center Anchor | Right Anchor |
|---|---|---|---|
| 1 | 181 | 170 | 157 |
| 2 | 172 | 170 | 164 |
| 3 | 168 | 172 | 167 |
| 4 | 167 | 172 | 168 |
| 5 | 180 | 171 | 156 |
| 6 | 172 | 171 | 165 |
| Mean | 173 | 171 | 163 |
| SDev | 6 | 1 | 5 |

Test 2 - Symmetrical 'SEA' with an 80° angle between the outside anchors at the load.

| Run | Left Anchor | Center Anchor | Right Anchor |
|---|---|---|---|
| 1 | 218 | 206 | 183 |
| 2 | 185 | 206 | 218 |
| 3 | 220 | 206 | 181 |
| 4 | 193 | 206 | 202 |
| 5 | 217 | 204 | 184 |
| 6 | 179 | 204 | 217 |
| Mean | 202 | 205 | 198 |
| SDev | 18 | 1 | 17 |

Test 3 - Symmetrical 'SEA' with an 89° angle between the outside anchors at the load. This 'SEA' was only a modification of the test 2 'SEA' by shortening the center loop. The center loop length was shortened, therefore creating a wider angle at the load.

| Run | Left Anchor | Center Anchor | Right Anchor |
|---|---|---|---|
| 1 | 221 | 203 | 179 |
| 2 | 188 | 203 | 209 |
| 3 | 224 | 202 | 176 |
| 4 | 180 | 202 | 220 |
| 5 | 223 | 202 | 178 |
| 6 | 179 | 202 | 221 |
| Mean | 203 | 202 | 197 |
| SDev | 22 | 0.5 | 22 |

Test 4 - Asymmetrical 'SEA' with 79° angle between the outside anchor at the load.

| Run | Left Anchor | Center Anchor | Right Anchor |
|---|---|---|---|
| 1 | 209 | 195 | 176 |
| 2 | 184 | 188 | 190 |
| 3 | 199 | 189 | 183 |
| 4 | 177 | 187 | 194 |
| 5 | 212 | 195 | 172 |
| 6 | 181 | 187 | 191 |
| Mean | 194 | 190 | 184 |
| SDev | 15 | 4 | 9 |

Test 5 - Asymmetrical 'SEA' with 110° angle between the outside anchor at the load.

| Run | Left Anchor | Center Anchor | Right Anchor |
|---|---|---|---|
| 1 | 220 | 212 | 193 |
| 2 | 191 | 224 | 215 |
| 3 | 227 | 216 | 193 |
| 4 | 201 | 214 | 217 |
| 5 | 214 | 213 | 207 |
| 6 | 190 | 216 | 226 |
| Mean | 207 | 216 | 209 |
| SDev | 15 | 4 | 13 |

## DYNAMIC TESTS

The purpose of the dynamic portion of the test program was to develop a feel for the forces involved in the failure of an anchor point and if there is a significant performance variation for different types of construction.

All dynamic tests were conducted using 3-point 'SEA's with a 440 lb load suspended. Load cells were placed at the center anchor, one outside anchor, and the load. The outside anchor point without the load cell was 'failed' using a quick release system.

Force graphs were created for the remaining anchors and load. All forces were measured in pound-force (lbf).

Test 7 - Doubled figure-8 'SEA' - One foot drop

New 1/2" PMI Rescue Rope, E-Z Bend - Starting angle between outside anchors at the load - 53°.

| Run | Before Drop | | Max During Drop | | After Drop | | Max Force @ Load |
|---|---|---|---|---|---|---|---|
| | Ctr Leg | Rgt Leg | Ctr Leg | Rgt Leg | Ctr Leg | Rgt Leg | |
| 1 | 188 | 143 | 673 | 1545 | 229 | 223 | 2450 |
| 2 | 198 | 157 | 949 | 1157 | 230 | 221 | 2690 |
| 3 | 182 | 192 | 1040 | 1760 | 210 | 241 | 2360 |
| 4 | 183 | 189 | 1080 | 1330 | 210 | 242 | 2920 |
| 5 | 163 | 157 | 847 | 1760 | 219 | 233 | 2290 |
| 6 | 127 | 163 | 789 | 1810 | 215 | 237 | 2650 |
| Mean | 174 | 167 | 896 | 1560 | 219 | 233 | 2560 |
| SDev | 26 | 20 | 156 | 268 | 9 | 9 | 236 |

Test 8 - Doubled figure-8 'SEA' - One foot drop

New 7/16" PMI Sport Extra, E-Z Bend. Starting angle between the outside anchors at the load - 53°.

| Run | Before Drop Ctr Leg | Before Drop Rgt Leg | Max During Drop Ctr Leg | Max During Drop Rgt Leg | After Drop Ctr Leg | After Drop Rgt Leg | Max Force @ Load |
|---|---|---|---|---|---|---|---|
| 1 | 138 | 170 | 874 | 1270 | 230 | 228 | 2020 |
| 2 | 188 | 162 | 1140 | 1570 | 227 | 230 | 1940 |
| 3 | 202 | 161 | 1070 | 1610 | 225 | 232 | 2450 |
| 4 | 195 | 211 | 1160 | 1360 | 222 | 235 | 2950 |
| 5 | 197 | 175 | 959 | 1690 | 224 | 233 | 2700 |
| 6 | 163 | 174 | 1120 | 1710 | 225 | 232 | 2300 |
| **Mean** | 181 | 176 | 1054 | 1535 | 226 | 232 | 2393 |
| **SDev** | 25 | 18 | 114 | 180 | 3 | 2 | 390 |

Test 9 - Gathered Loop 'SEA' - One foot drop

Used Four foot 1" sewn tubular runner (Wild Things). Starting angle between the outside anchors at the load - 65°.

| Run | Before Drop Ctr Leg | Before Drop Rgt Leg | Max During Drop Ctr Leg | Max During Drop Rgt Leg | After Drop Ctr Leg | After Drop Rgt Leg | Max Force @ Load |
|---|---|---|---|---|---|---|---|
| 1 | 242 | 133 | 1480 | 1140 | 247 | 208 | 2820 |
| 2 | 189 | 156 | 1890 | 1270 | 239 | 209 | 2290 |
| 3 | 235 | 138 | 1840 | 1090 | 228 | 219 | 2430 |
| 4 | 220 | 168 | 1420 | 1390 | 227 | 227 | 2820 |
| 5 | 187 | 150 | 1800 | 1250 | 225 | 228 | 2770 |
| 6 | 233 | 157 | 1960 | 1390 | 227 | 224 | 2260 |
| 7 | 193 | 154 | 1470 | 1090 | 224 | 228 | 3110 |
| **Mean** | 214 | 151 | 1694 | 1231 | 231 | 220 | 2643 |
| **SDev** | 24 | 12 | 228 | 129 | 9 | 9 | 320 |

Test 10 - Figure-8 'SEA' - One foot drop

Used four foot 1" sewn tubular runner (Wild Things) and SMC Rescue-8 w/ears. Starting angle between the outside anchors at the load - 60°.

| Run | Before Drop Ctr Leg | Before Drop Rgt Leg | Max During Drop Ctr Leg | Max During Drop Rgt Leg | After Drop Ctr Leg | After Drop Rgt Leg | Max Force @ Load |
|---|---|---|---|---|---|---|---|
| 1 | 205 | 146 | 1220 | 1260 | 218 | 234 | 2990 |
| 2 | 198 | 148 | 1430 | 1600 | 230 | 225 | 2240 |
| 3 | 252 | 138 | 1350 | 1670 | 223 | 230 | 2590 |
| 4 | 233 | 145 | 1500 | 1670 | 212 | 237 | 2460 |
| 5 | 196 | 169 | 1260 | 1630 | 223 | 230 | 2760 |
| 6 | 229 | 163 | 1490 | 1620 | 227 | 228 | 2520 |
| **Mean** | 219 | 152 | 1375 | 1575 | 222 | 231 | 2593 |
| SDev | 23 | 12 | 118 | 157 | 6 | 4 | 258 |

Test 11 - Figure-8 'SEA' - One foot drop

Used four foot 9/16" sewn Spectra™ Runner (Blue Water) and SMC Rescue-8 with ears. Starting angle between the outside anchors at the load - 60°.

| Run | Before Drop Ctr Leg | Before Drop Rgt Leg | Max During Drop Ctr Leg | Max During Drop Rgt Leg | After Drop Ctr Leg | After Drop Rgt Leg | Max Force @ Load |
|---|---|---|---|---|---|---|---|
| 1 | 217 | 150 | 1890 | 1840 | 226 | 226 | 2180 |
| 2 | 183 | 152 | 1060 | 1280 | 218 | 230 | 3630 |
| 3 | 195 | 157 | 1720 | 1250 | 218 | 233 | 3480 |
| 4 | 232 | 136 | 845 | 1740 | 224 | 226 | 3600 |
| 5 | 208 | 160 | 1110 | 1920 | 226 | 225 | 3480 |
| 6 | 179 | 168 | 1120 | 1940 | 211 | 234 | 3420 |
| **Mean** | 202 | 154 | 1291 | 1662 | 221 | 229 | 3298 |
| SDev | 21 | 11 | 414 | 315 | 6 | 4 | 554 |

Test 12 - Figure-8 'SEA' - One foot drop

New 120 cm (47.2 inch) sewn nylon Petzl Express C40 runner and RA Rescue-8 without ears. Starting angle between the outside anchors at the load - 60°.

| Run | Before Drop Ctr Leg | Before Drop Rgt Leg | Max During Drop Ctr Leg | Max During Drop Rgt Leg | After Drop Ctr Leg | After Drop Rgt Leg | Max Force @ Load |
|---|---|---|---|---|---|---|---|
| 1 | 238 | 152 | 1240 | 1550 | 226 | 226 | 2560 |
| 2 | 211 | 152 | 1460 | 1400 | 223 | 222 | 2500 |
| 3 | 229 | 150 | 1390 | 1250 | 223 | 224 | 2940 |
| 4 | 226 | 149 | 1480 | 1520 | 224 | 225 | 2200 |
| 5 | 200 | 145 | 1350 | 1600 | 226 | 220 | 2490 |
| 6 | 235 | 145 | 1330 | 1240 | 225 | 225 | 2970 |
| **Mean** | 223 | 149 | 1375 | 1426 | 225 | 224 | 2610 |
| **SDev** | 15 | 3 | 89 | 155 | 1 | 2 | 295 |

Test 13 - One run tests

Three Point Twisted-Loop 'SEA' - One foot drop

Used four foot 9/16" sewn Spectra™ runner (Blue Water)

| Run | Before Drop Ctr Leg | Before Drop Rgt Leg | Max During Drop Ctr Leg | Max During Drop Rgt Leg | After Drop Ctr Leg | After Drop Rgt Leg | Max Force @ Load |
|---|---|---|---|---|---|---|---|
| 1 | 143 | 188 | 1210 | 1470 | 230 | 226 | 2240 |

Three Point Figure-8 'SEA' - Ten inch drop

Used three foot 1" nylon tied runner (Wild Things) and SMC Rescue-8 w/ears.

| Run | Before Drop Ctr Leg | Before Drop Rgt Leg | Max During Drop Ctr Leg | Max During Drop Rgt Leg | After Drop Ctr Leg | After Drop Rgt Leg | Max Force @ Load |
|---|---|---|---|---|---|---|---|
| 2 | 246 | 139 | 1500 | 561 | | | 2120 |

Self Equalizing Anchor - Test Data Form

Date: Time: Test No.:

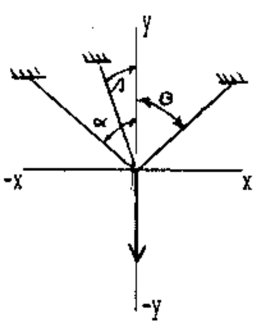
Type System: Material:

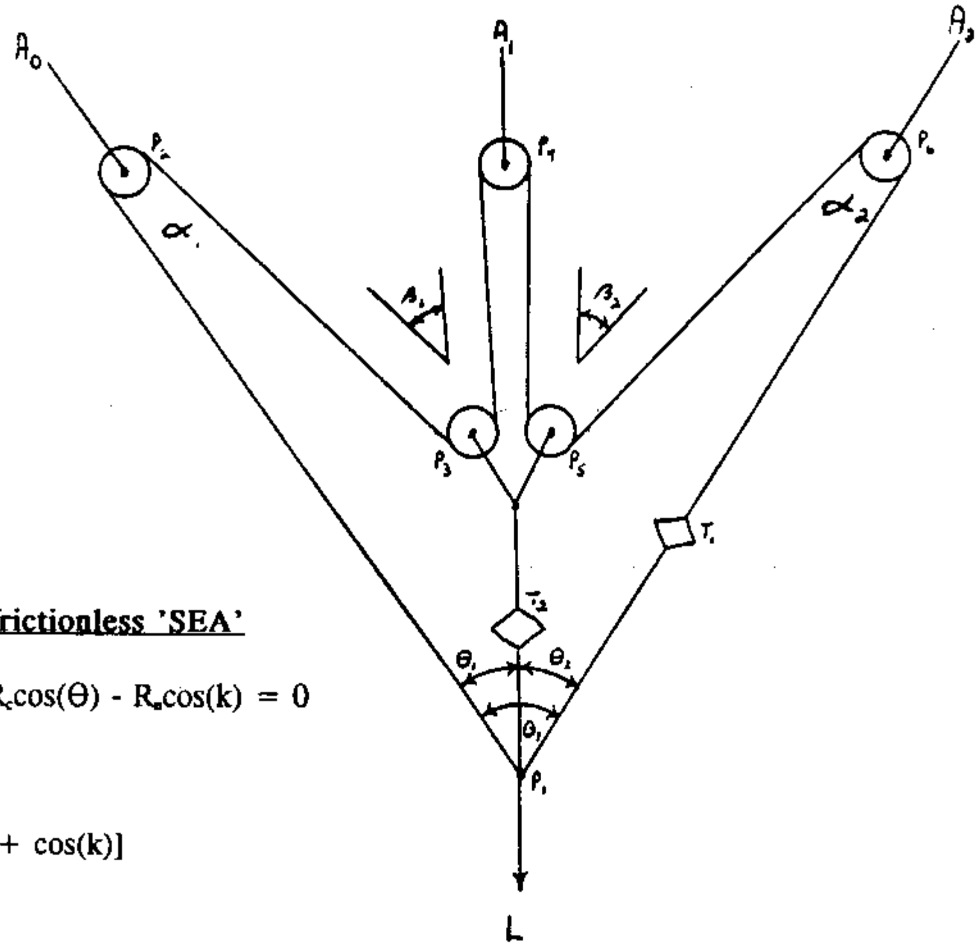
Description of Test: [Static] [Dynamic]

| # | L | θt | θ1 | θ2 | θ3 | β1 | β2 | α1 | α2 | D1 | D2 | D3 | D4 | D5 | D6 | D7 | A0 | A1 | A2 | # |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | | | | | | | | | 1 |
| 2 | | | | | | | | | | | | | | | | | | | | 2 |
| 3 | | | | | | | | | | | | | | | | | | | | 3 |
| 4 | | | | | | | | | | | | | | | | | | | | 4 |
| 5 | | | | | | | | | | | | | | | | | | | | 5 |
| 6 | | | | | | | | | | | | | | | | | | | | 6 |
| 7 | | | | | | | | | | | | | | | | | | | | 7 |

Distances

D1 = P1 to P2
D2 = P2 to P3
D3 = P3 to P4
D4 = P4 to P5
D5 = P5 to P6
D6 = P6 to P1
D7 = P4 to P1




**Formulas applicable to a static, frictionless 'SEA'**

$$\sum F_v = W - R_a\cos(\alpha) - R_b\cos(\beta) - R_c\cos(\Theta) - R_n\cos(k) = 0$$

$$R = R_a = R_b = R_c = R_n$$

$$W = R[\cos(\alpha) + \cos(\beta) + \cos(\Theta) + \cos(k)]$$