Rope Access Equipment Testing: The back-up safety system
By Jan Holan and Steve Beason

In August 2002, The Bureau of Reclamation and Ropeworks, Inc. conducted testing of industrial rope access equipment used in the back-up safety system. One-person and two-person loads were considered. This research addresses some unanswered questions raised by an extensive 2001 study conducted by Lyon Equipment for the United Kingdom's Health and Safety Executive.

Introduction and Background

Much of the equipment used in commercial rope access was originally designed for other purposes and subsequently adopted for use in the industrial environment. While most rope access equipment is used in a similar manner to its original intended function, some equipment is routinely applied in ways never envisioned, much less tested, by its manufacturers. Additional variables, introduced by the unknown compatibility of various rope brands with the equipment chosen, are another potential cause for concern.

Properly trained and supervised rope access technicians uphold an impeccable safety record. Operatives generally employ a two-rope system, a *main working line* for support, and a *safety line* for back-up in the event of a failure in the primary means of support. The process of ascending and descending on the main working system is well tested in the field and the equipment used is generally consistent with manufacturer's intentions. Because the back-up safety system generally does not bear a load during use an extended incident-free history does not necessarily mean that the system is "bullet-proof".

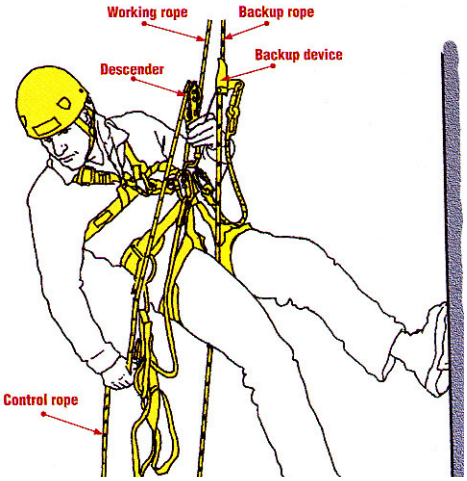

Figure 1. Common rope access system used for descent. Diagram courtesy NSL Ltd.

Purpose

The goal of the study was to test rope access equipment commonly used in the back-up safety system. We were especially interested in testing equipment that has been used, or considered for use, by the Bureau of Reclamation or Ropeworks, Inc. Additional types of equipment not commonly used in rope access were tested for comparison.

We were most interested in testing the "back-up device" used in a "self-belay" system. We also tested a few belay devices that might be used by a co-worker to provide an "attended belay" for regular work activities, or in a rescue situation. All of the belay devices were also (or mainly) designed to function as descenders. We tested a few other devices, techniques, and variables in a non-systematic manner to explore some curiosities. Although this additional data was not necessarily statistically valid, the results are informative nonetheless.

While we considered existing test standards, our test methods were designed to replicate conditions found in the field. We were less interested in seeing if a particular device met a specific standard, rather we wanted to make sure that it worked effectively in the manner that it was commonly used in the field.

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Our testing also explored how the devices would perform as a safety back-up when used in an emergency situation under a two-person load, in a pick-off descent for example.

Our aim was to test the compatibility of the equipment paired with North American rope brands in various diameters. The Lyon Equipment testing was conducted using rope brands and diameters that are not common in North America. Rope access technicians in Europe often use 10.5mm rope while 11 mm (7/16") or larger diameters are commonly used by operatives in North America. We were interested to see how the general construction characteristics of the ropes affected the performance.

Ropes

We included four rope manufacturers in our tests, noted in Table 1. Certainly, with more time and resources, we would have preferred to test more rope brands, models, and diameters. The ropes were chosen on the basis of availability as well as their prevalence in the North American market, and most specifically their use within the Bureau of Reclamation teams. We tested the Beal 10.5 mm rope to compare results with the aforementioned Lyon Equipment report. The Beal 10.5 mm rope is one of the most prevalent ropes in the European rope access market. Many European companies with operations in North America continue to use similar rope types.

Table 1: Ropes used in testing.

Brand	Model	Stated Diameter	Measured Diameter*	Sheath	Core	MBS
PMI	EZ-Bend	11 mm (7/16")	11.1 mm	Nylon	Nylon	
Sterling	HTP	11.1 mm (7/16")	11.6 mm	Polyester	Polyester	
Beal	Splenium	10.5 mm	10.1 mm	Nylon	Nylon	
Blue Water	ProLine	11mm (7/16")	10.6 mm	Polyester	Nylon	

*The "measured diameter" of the rope was determined using calipers while the rope was placed under a 100 kg load. You may notice that the range of the "measured diameters" was considerably larger than the range of the "stated diameters".

Back-up Devices

Back-up Devices used in rope access generally fall into two categories, *ascender-type rope grabs* and *self-trailing rope grabs* (mobile fall arrestors).

Ascender-type Back-up devices
1. Petzl Shunt
2. Petzl Rescucender
3. PMI Progressor

Mobile Fall Arrestors (ANSI Labeled)
4. MIO Rope Grab
5. PMI Arrestor
6. Troll/Yates Rocker

Ascender-type rope grabs generally employ a cam mechanism to clamp onto the rope. The device generally stays in place on the rope and is often moved up or down manually by the user. A short string attached to the device is usually employed to tow the device while descending. The advantage of this type of device for rope access is that the worker can usually keep the device high and out of the way of the work area thereby minimizing the distance of the potential fall if a failure were to occur. However, manual manipulation of the device, especially during descent, poses a potential risk of failure. Most of these devices can be defeated inadvertently by the user. Obviously thorough training is an integral component of the safe use of this type of back-up device.

Self-trailing rope grabs are designed to travel freely up and down the rope without manual manipulation by the worker. All the self-trailing rope grabs tested were marked as complying with the ANSI Z359.1 standard for conventional fall arrest applications. Although some of the devices were third-party tested to this standard, third-party verification is NOT required by the standard. To meet the standard the device must pass the dynamic and static tests, must be "self-trailing", and must not be defeated easily by the user. Field testing of many of the ANSI-labeled products, however, shows that this standard is often interpreted liberally by the manufacturer.

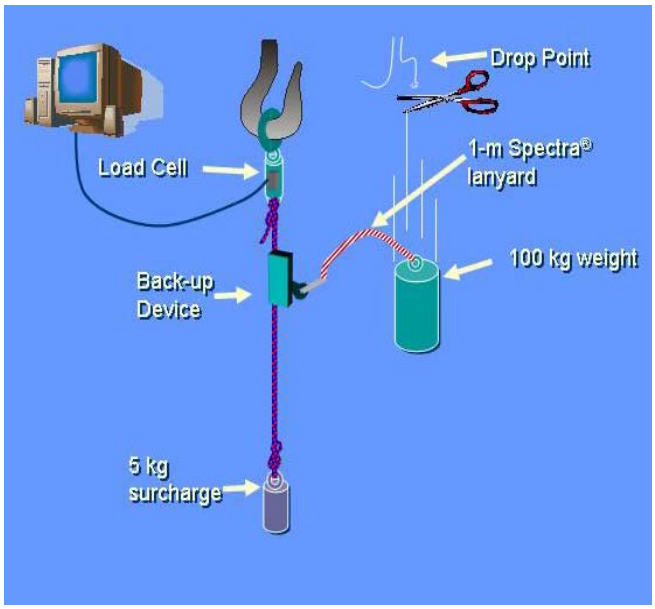
The Petzl Shunt is the most common rope access back-up device in use world-wide. The 2001 Lyon Equipment report raised some serious concerns about the Shunt's dynamic performance while identifying a promising alternative, the Rocker. Comparing the performance of the Rocker and the Shunt in simulated field conditions with North American ropes was high on the list of priorities. The Rocker and Shunt were tested more thoroughly in a variety of configurations.

Methods (Back-up Devices)

We referred to existing standards for a starting point for our test methodology. A provisional standard in Europe exists for back-up devices (prEN 12841), however the most relevant standard for rope grabs in North America is ANSI Z359.1. The Ascender-type Back-up device would not meet this ANSI standard because it does not self-trail, among other reasons. In both standards, the dynamic test requirement is similar.

See Figure 3 for a schematic of the test configuration. We used a 100 kg and 200 kg cylinder of concrete for our test masses to simulate one-person and two-person loads respectively. The lanyard was attached to an eyebolt at the top of the cylinder. Lanyard length for our baseline test was a 2-foot spectra sling for a total lanyard length with steel carabiners of just under 3 feet. Our first tests were conducted with a wire rope lanyard, but it was apparent that the stiffness of the lanyard was affecting the consistency of the results. We believed the flexible, yet static, Spectra® sling would produce consistent and conservative results. Other lanyard lengths and materials were also tested in specific situations.

Figure 2: Dynamic Test configuration for back-up devices



The load cell, connected to a data logger, was placed at the anchor (crane lifting hook). Each rope was attached to the load cell with a pre-tensioned figure 8 knot. All the knots were adjusted by the same person applying approximately 30 kg of force to set each knot. Each device was placed on a marked spot 60 cm below the anchor point.

The baseline test consisted of the worse case scenario, a factor 2 fall (twice the lanyard length). We also did some factor 1 drops (a more realistic scenario for most devices).

Note: "Self-trailing" rope grabs are most likely to be subjected to a factor 2 fall since they will generally not stay in place by themselves above the operative. The manufacturer-recommended lanyard length for some of these devices may be shorter than the lanyard length used in this test. For this reason, we also tested the Rocker using the manufacturer recommended length of approximately 30 cm including connections. The Shunt was also tested with a tied dynamic rope lanyard (cow's tail) of 1 meter (a common field use in rope access).

Perhaps the most unique part of our test method involved the placement of a 5 kg surcharge at the end of the rope to approximate the weight of 42 additional meters of rope. We reasoned that many rope access technicians would use these devices with more than a few meters of rope. We noted that none of the standards referenced required this surcharge.

The following data was recorded: distance of device slippage, total fall distance, peak impact force, and the post-testing rope and device condition. Video was taken of each drop.

Back-up Devices Dynamic Testing Results

Rope grabs designed for fall arrest should not slip more than 54 inches (138 cm) and must yield a maximum impact force of no greater than 8 kN (1760 lbsF) according to ANSI Z359.1. CSA standards also call for a maximum allowable impact force of 8kN while CE requirements limit impact force to 6kN.

We calibrated our testing rig with a few 100 kg, factor 1 drops (Figure. We tested the devices in this configuration on the PMI rope. All the devices faired well when the 100 kg load was dropped from the same height as the device (factor 1) with the PMI rope. All the devices were set onto the rope to prevent them from dropping before the test weight was released. Even the Petzl Ascension handled ascender managed to catch a drop of this severity without damaging the rope, or yielding excessive impact force. In the factor 2 tests the devices were not pre-set.

Figure 3: Factor 1, 100 kg test rig

Petzl Shunt

The Petzl Shunt is the most common rope access back-up device in use world-wide. The device is a "mechanical-prussik" originally designed to back up rappel devices for recreational users. It can also be classified as an ascender. While the use of the Shunt in the industrial environment has been controversial from the beginning, and is clearly outside of its original design parameters, the 2001 Lyon Equipment report raised serious concerns about the Shunt's ability to adequately withstand the forces subjected to it during a fall. The Lyon testing showed that slippage distances were excessive and the Shunt was prone to detaching from the rope if a knot was encountered before the device came to a stop.

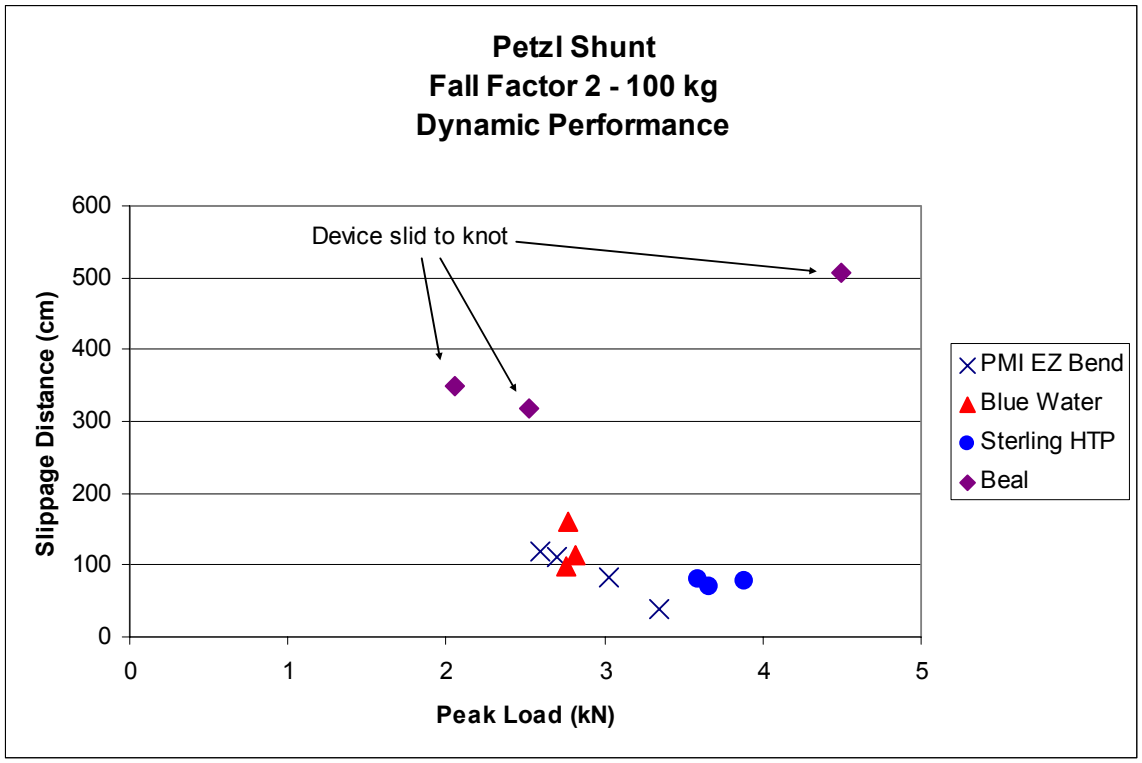
The data from the Lyon Report led us to expect poor results from the Shunt, however our testing showed otherwise. In our tests, the Shunt proved to be one of our most consistent performers on the 11mm ropes (measured diameter) yielding low impact forces and reasonable slippage distances.

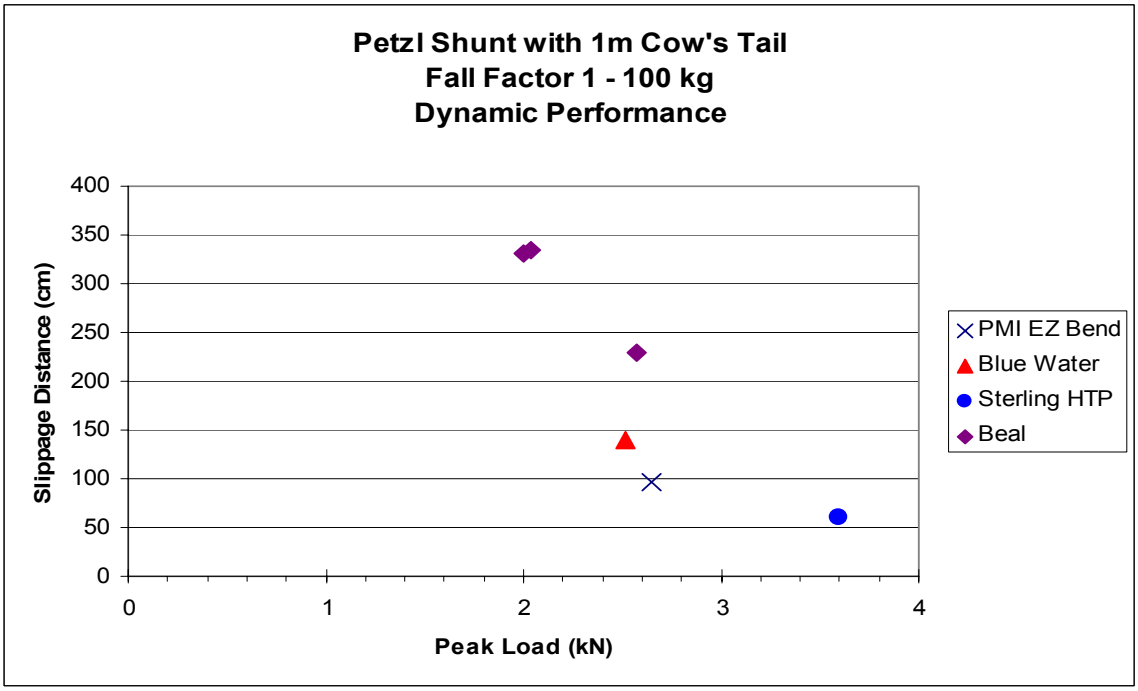
The Shunt performed poorly on the Beal 10.5mm (10.1 measured diameter), confirming the results of the Lyon Testing. In all three cases the device slipped in excess of 3 meters before hitting the knot. In order to give the Shunt every opportunity to perform on the Beal rope, we tested it in a factor 1 fall using a 1 meter dynamic rope lanyard (cow's tail), replicating the most realistic one-person

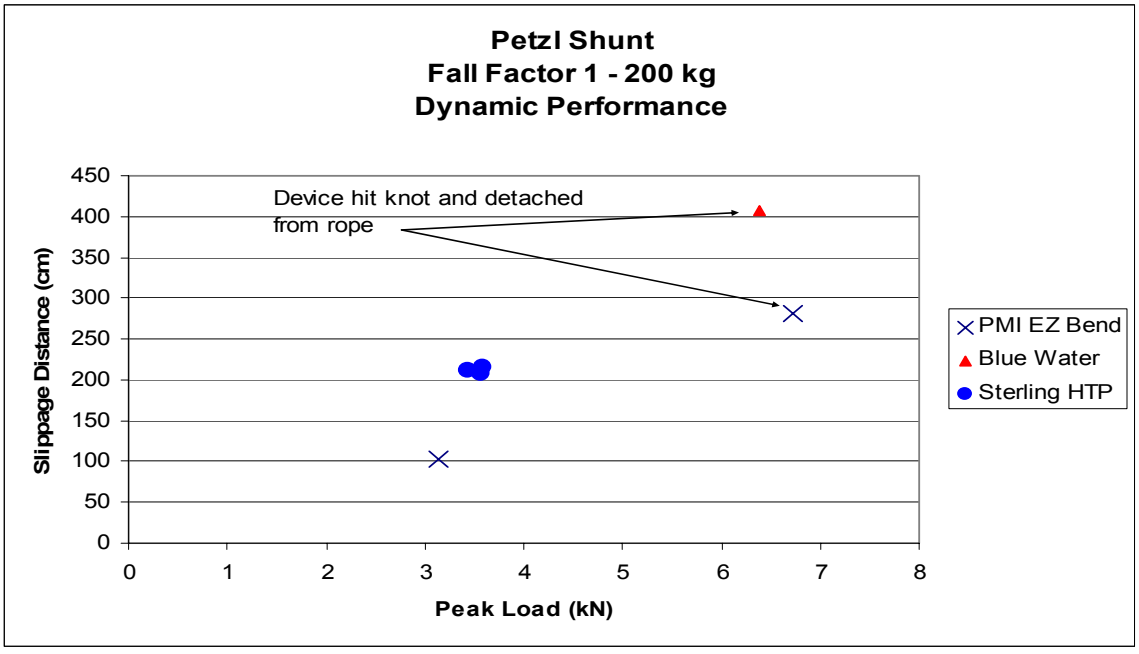
field configuration. Again, the Shunt performed poorly, allowing the test weight to drop nearly 3.5 meters. It hit the knot on the first drop at 2.3 meters. This led us to conclude that the Shunt should NOT be used as a back-up when paired with ropes of similar diameter to the Beal 10.5 mm.

The 200kg, factor 1 tests showed some of the Shunt's limitations. We didn't bother testing the Shunt on the Beal rope with the 2-person load. The Shunt hit the knot and detached from the rope on one of one drops on the thinner Blue Water rope and one of two drops on the PMI 11 mm. The Shunt performed remarkably well on the thicker Sterling HTP (11.6 measured diameter). The reasonable conclusion is that the Shunt performs better on ropes of larger diameter.

The Shunt will not conform to the requirements of the U.S. fall protection standards because of it has a relatively weak body, it can be defeated by the user, and it does not self-trail. However, at this point the Shunt should still provide a safe option for a rope access technician provided it is paired with the correct rope diameter and proper operator training.





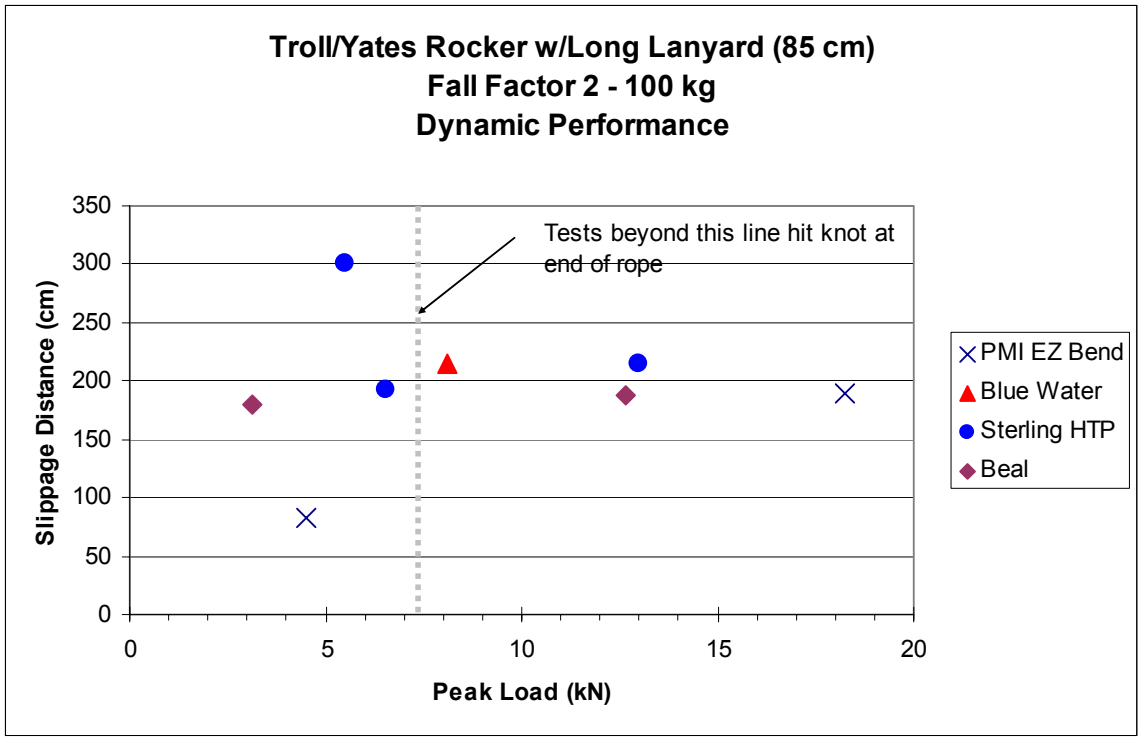


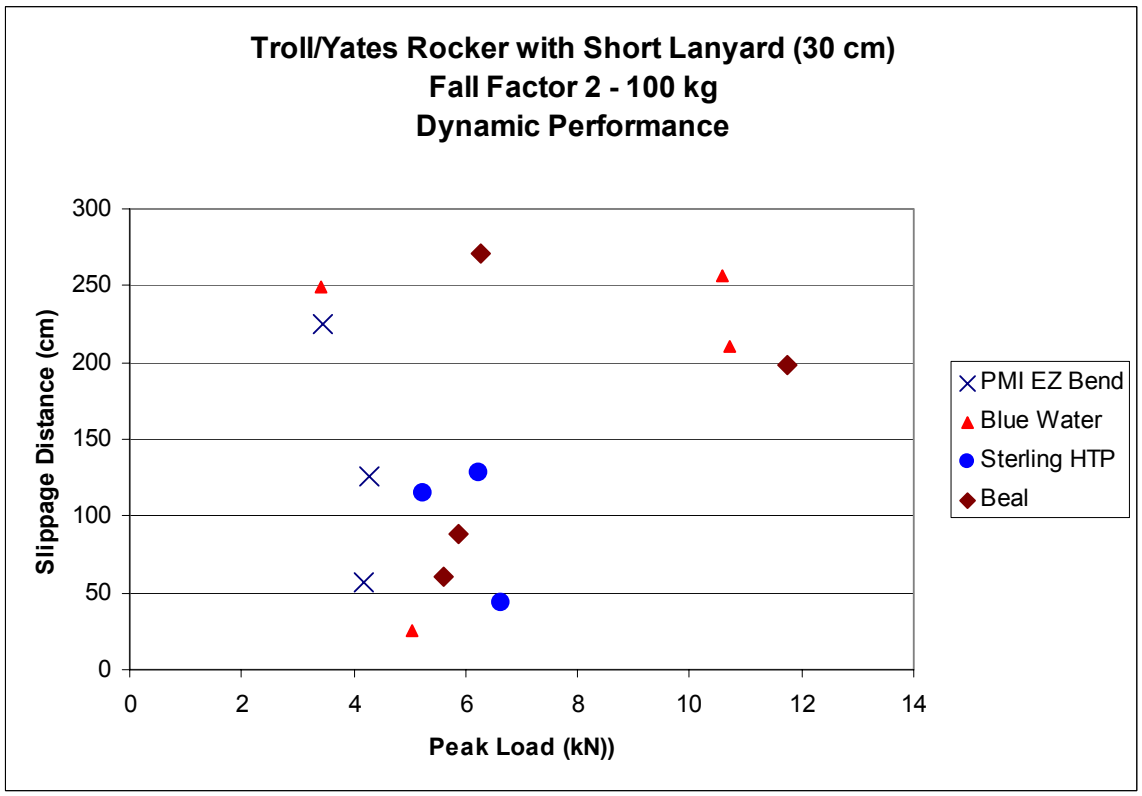
Rocker

The rocker is manufactured by ISC and distributed by Troll in the UK and Yates in North America. While the Lyon tests illuminated some glaring weaknesses in the Shunt, the tests identified the Rocker as a promising alternative. The Rocker yielded consistent impact forces and moderate slippage distances in the Lyon tests. The Rocker travels freely up and down the rope and recent improvements allow the user to lock it into place on the rope.

Using our test configuration, however, we were less than impressed with the Rocker's performance. It should be noted that the manufacturer recommends connecting the device directly to the sternal (chest) D-ring and does not recommend using a lanyard longer than 30 cm. For this reason, we also tested the Rocker in a short lanyard configuration. In both configurations, the results were inconsistent and sometimes downright frightening. Long drops to the knot were not infrequent and several such encounters with the knot produced high enough impact forces to sever the rope completely, sending the mass crashing to the floor.

At a later date, Ropeworks, Inc. conducted further testing with Yates to try to isolate the variables that contributed to the discrepancy between our data and that gathered in the UK by the manufacturer, several independent companies, as well as the UK and US distributors. Because the device relies on some rope deflection to engage the cams, the most important new variable was certainly the 5 kg surcharge placed at the end of the rope. Although still inconclusive, there also seemed to be a difference depending on the mass of the carabiners used to attach the lanyards. Aluminum carabiners paired with a direct connection to the sternal D-ring produced consistent and favorable results, while the use of heavy steel carabiners introduced some inconsistencies. Because the Rocker has many potential uses in industrial fall protection, further testing is warranted to clearly identify the variables which insure the device's consistent operation. Based on our experience with the one-person load we decided not to test the Rocker with a two-person load.

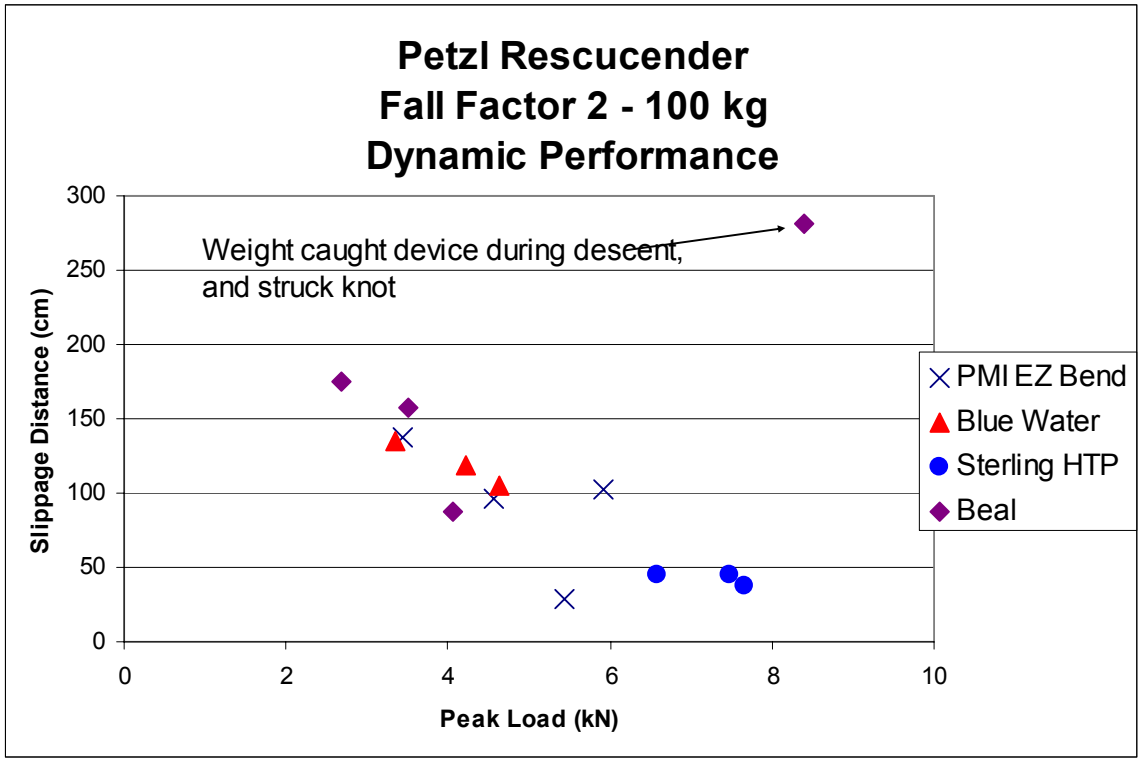


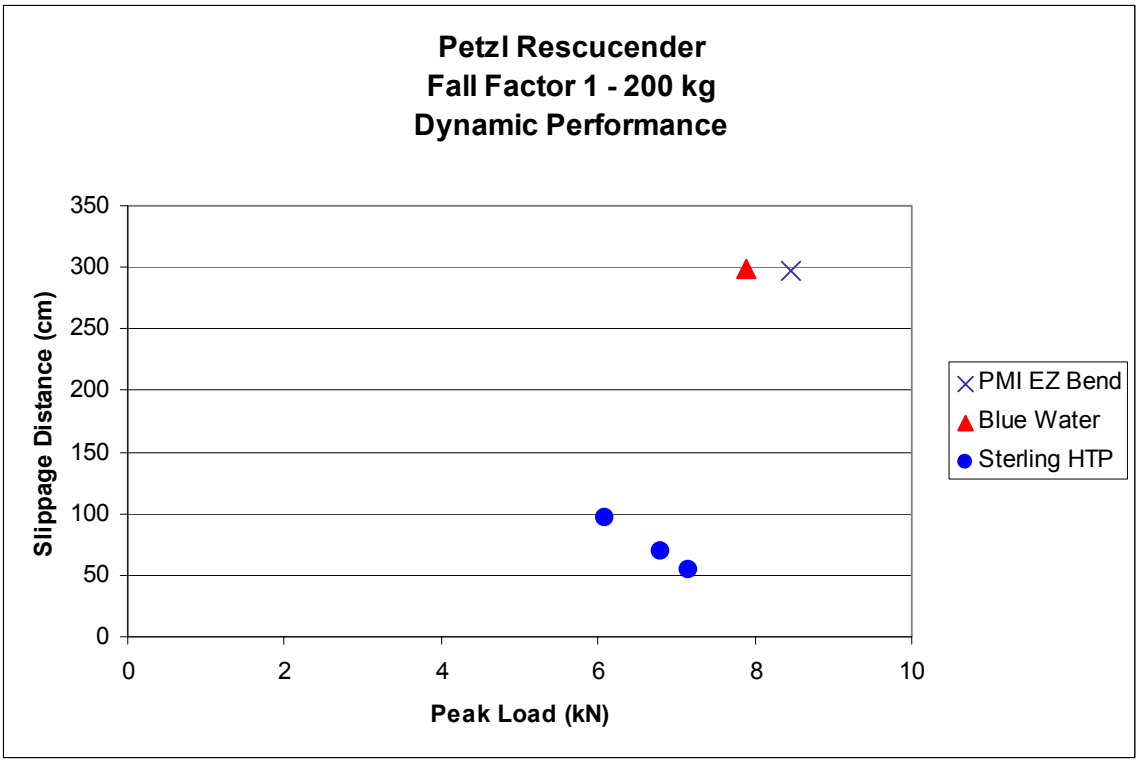


Petzl Rescucender
This device is originally designed for use in hauling and ascending systems. A removable pin is the cam's pivot point. The Rescucender is not as quick to place on and off the rope as the Shunt, but it is otherwise user-friendly for the rope access technician. It is relatively lightweight but stout enough to take a beating in the industrial environment.

One significant concern with the Rescucender involves the relatively thin wire cable that serves as the keeper sling for the cam and creates spring tension to help keep the cam engaged on the rope. This cable is likely to kink or become damaged during use. A compromised cable is inconsequential if used in hauling systems and similar applications, but the defect can cause the device to slide down the rope inadvertently when used as a back-up device. We have experimented with other after-market replacements for the wire, such as heavy fishing line, with limited success.

The Rescucender was a consistent performer on all rope diameters. The impact forces were a bit high, but within OSHA 8 kN limits, when tested on the Sterling rope, presumably because of the rope's larger diameter. Conversely, the slippage distance was higher on the thinner Beal rope. One test on the Beal rope resulted in an outright failure. This may have occurred because of a compromised cable that affected the cam's ability to set on the rope, illustrating one of our main concerns with this device.



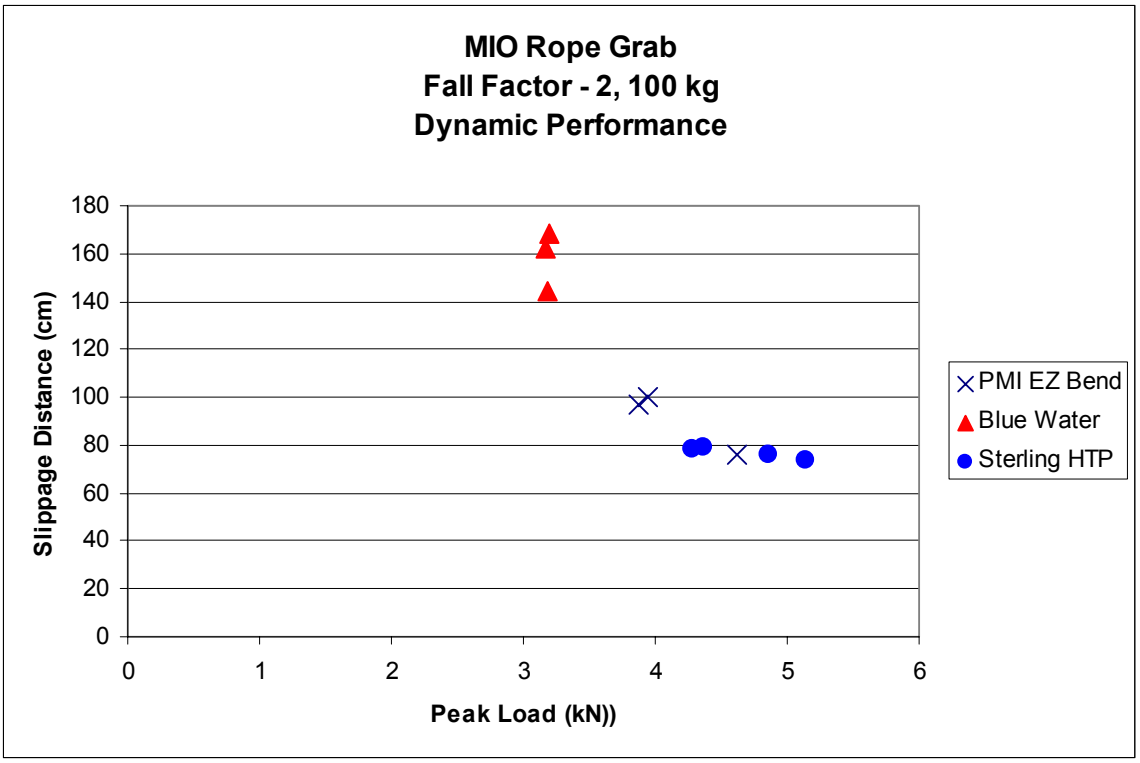


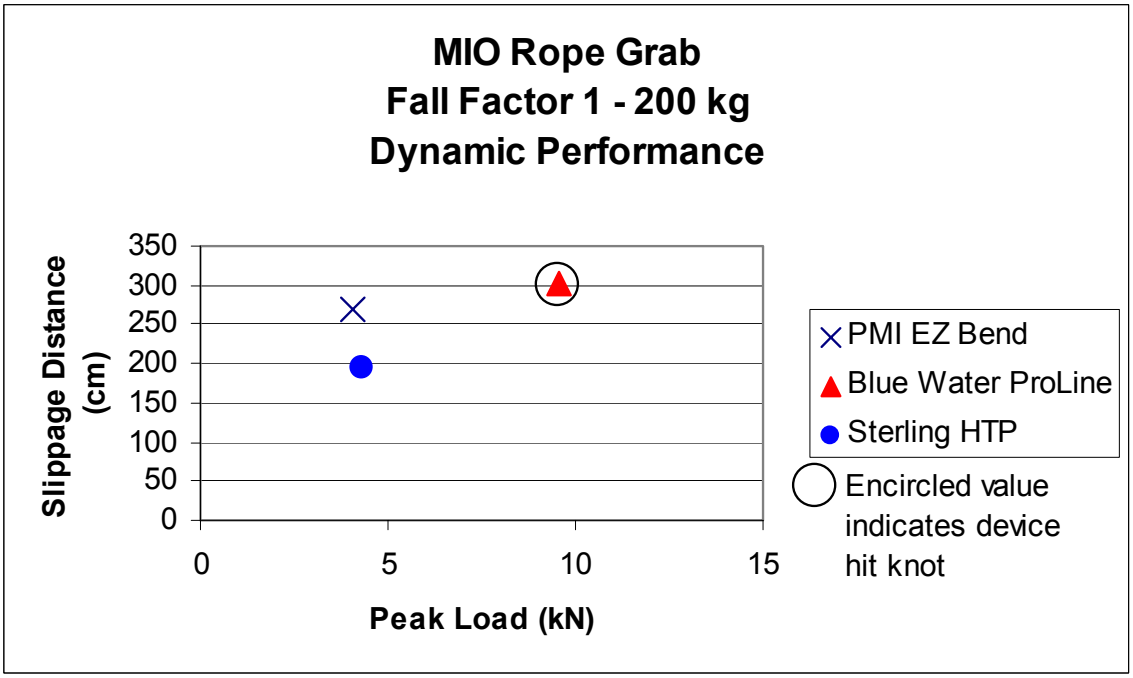
MIO Rope Grab

We obtained one of the first production samples of the 7/16" version of the MIO Rope Grab designed by Mark Ostrobrod of MIO Mechanical Corporation. The ½" version of this device continues to be popular for fall arrest applications. Testing done by the manufacturer documents compliance with ANSI Z359.1 standard. Like many of the devices that are marked to this standard the MIO does not "self-trail" easily. This fact coupled with the substantial size and weight of the device will not make it a popular choice for rope access technicians, however it is certainly useful for standard fall arrest applications where a 7/16" (11 mm) rope is used. The large size of the MIO does make it difficult to "defeat" inadvertently by the user.

The MIO was incredibly consistent on the 7/16" (11mm) ropes yielding low impact forces and slippage distances. Although still consistent, slippage distances on the Blue Water 7/16" ProLine rope (measured diameter of 10.6 mm) were a bit longer (beyond those required by Z359.1). We did one test on the Beal rope, but the test weight hit the knot and we decided that this diameter rope was outside of the design parameters for the device.

Clearly the MIO is a consistent performer for fall arrest applications when paired with the appropriate diameter rope for which it is designed.





PMI Arrestor and Progressor

The PMI Arrestor and Progressor are lightweight rope grabs that utilize a cam to clamp down on the rope. The Arrestor is third-party certified to the ANSI Z359.1 fall arrest standard while the Progressor is not designed for fall arrest applications. The Arrestor is outfitted with a smoother cam than the Progressor to allow the rope grab to slide before arresting the fall to lower impact forces. The keeper leash on the Arrestor is a string instead of a wire, which serves as a spring to keep the Progressor's cam engaged on the rope. Both designs are clean with an advanced spring-loaded pin system to lock the pivot point of the cam.

A few tests confirmed that the Progressor is not suitable for fall arrest applications. The sheath was stripped off of the rope on several drops, yielding high impact forces.

Given our test method, our experience with the Arrestor was not positive. Six out of nine factor 2 drops with the 100 kg load produced long drops of 2 to 3 meters before the device hit the knot. It appeared that the device was pushed down on a couple of occasions by the falling mass. Given the long distances that the cam was grabbing the rope on several of the drops, however, our hypothesis is that the smooth cam reacts differently to ropes weighted with the 5 kg surcharge. Again, this surcharge is not required by existing standards, but seems to replicate field conditions more accurately.

Belay Devices
We conducted a limited study of belay devices commonly used in the rope access system. Specifically we wanted to know how the Petzl I'D and Gri Gri would function when used to belay a two-person load in an emergency attended rescue situation. It is important to note that we are not necessarily condoning the use of these devices as rescue belays for professional rescuers. We wanted to learn if some of the devices already in use by rope access technicians would perform adequately in the event of an emergency. Obviously this aspect of our research could have involved many more devices and different types of tests. In an effort to not replicate existing research and to focus on the gear that was most relevant to the Bureau of Reclamation teams we chose to test the Petzl I'D and Gri Gri. We also were curious to see how the Petzl Stop (threaded on one bobbin) would perform as a belay device with a one person load. This particular use is common among rope access professionals in the UK.

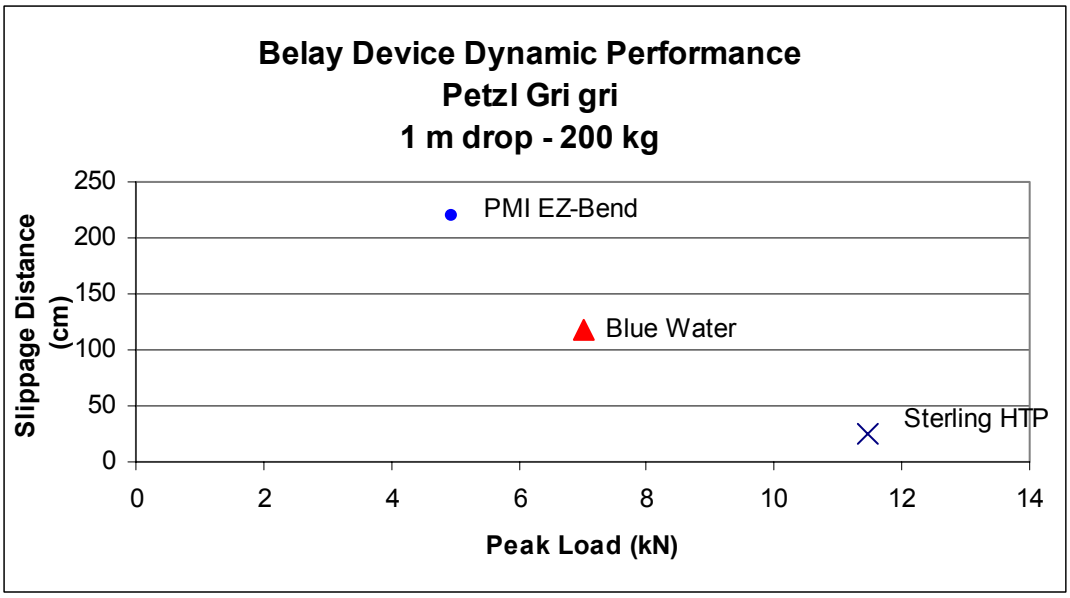
Methods
We used a 200kg cylinder of concrete for the two-person load. It was dropped onto the belay devices 1 meter on 3 meters of rope for a .33 factor fall. The devices were not locked off manually. The distance of slippage, total fall distance, peak load, rope condition, and device condition were all recorded. Video was taken.

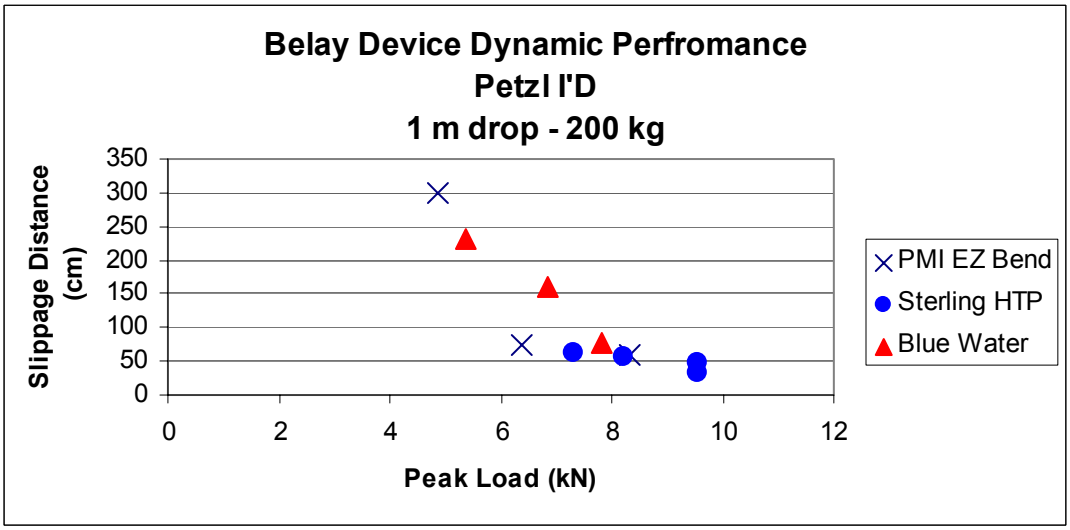
Data
Our first 100 kg drop onto the half-threaded Petzl Stop convinced us that it is not a good idea for any type of belay. The sheath of the rope stripped for several feet, rendering the rope and device useless. We did not test the device with a dynamic rope however.

Only three drops total were made onto the Gri Gri to focus our resources on getting reasonable sample points from the I'D. Those three drops returned acceptable results. Clearly these samples don't give statistically significant results, however it is interesting to note that the Sterling rope, with it's somewhat loose sheath and flattening core, slipped only 25 cm yielding relatively high impact forces of 11.47. It is important to note that this higher impact force is still within a reasonable range because it is distributed to a 2-person load. The PMI, a stiffer rope, slipped considerably more, but with very low impact force.

The I'D delivered predictable results on the Sterling HTP with low slippage and reasonable, but higher, impact force. The Blue Water ProLine may have been too thin for consistent results. The I'D dropped the two-person load twice when paired with the PMI EZ-bend. It is important to note, however, that in all of these tests there was no friction added by the operator. In a proper belay situation, the belayer would have been applying some additional friction. We were relying exclusively on the auto-lock characteristics.

We concluded that the I'D was a reasonable choice when belaying a two-person load in emergency situations when paired with the appropriate rope.





General Conclusions:
One of our most important conclusions is that the rope and device combination is important. Diameter of rope, and to a lesser extent the rope construction, seemed to play a significant roll in how the devices performed in the given tests.

As expected, our testing on back-up devices raised as many questions as it answered. In some respects our findings concerning the Petzl Shunt and Troll/Yates Rocker were surprising. In the Shunt's case, clearly the larger diameter ropes we tested produced favorable results when compared to those collected by Lyon Equipment in 2001. While the device is far from perfect, our conclusion leads us to believe the Shunt is a good option for a rope access technician provided it is paired with the correct rope diameter and proper operator training. The Rocker, on the other hand, produced uninspiring results and seemed to be very sensitive to the 5 kg surcharge at the end of the rope. More tests can be made to isolate the variables which made this device perform poorly.

Our testing on the "self-trailing" devices led us to some important questions. Do we really want to be trying to catch up to our self-trailing devices as we fall? Why are the most consistent devices, including the MIO rope grab, the least likely to self-trail? Should drop-test standards require the 5 kg surcharge at the end of the rope?

We have been reminded that just because a piece of equipment meets a standard it doesn't mean it will work in every field condition, or perhaps even in most field conditions. Keep an open mind to techniques and equipment that have been "proven" unsafe. The best way to make sure that your equipment will function the way you intend is to test it yourself.

Bio: Steve Beason is a supervisory geologist with the Bureau of Reclamation and has been involved in various types of rope access since 1983. He is presently a member of the Lower Colorado Regional Rope Access Team, and is serving on the Bureau's newly formed Rope Access Safety Board. Steve is a certified Rope Access Technician with the Society of Rope Access Technicians (SPRAT), and serves as a member-at-large on SPRAT's Board of Directors.

Bio: Jan (yôn) Holan is the founder and director of Ropeworks, Inc., an industrial rope access training and equipment provider established in 1994. Jan and other Ropeworks staff have helped build rope access programs within a variety of commercial and government organizations, including the Bureau of Reclamation, TVA, HDR Engineering, Army Corps of Engineers, and CalTrans, among others. Jan is actively involved in equipment testing and is helping to shape evolving regulatory standards for rope access through state, federal and international organizations. Jan is currently the President of the Society of Professional Rope Access Technicians (SPRAT) and is a certified SPRAT Technician and IRATA Level III.

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