Parallel Plaquettes: A Lightweight Rope Rescue System Using Common Climbing Equipment

Presented by:

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Introduction:

A current review of rope rescue systems reveals a wide variety of techniques, equipment and risk management philosophies relative to moving live loads over complex terrain. Some teams use a single main line and a separate belay line; others employ the use of two mainlines to support the load without a separate belay. Descent control device choices run the gamut and include brakeracks, cammed devices, 8 plates and belay tubes just to name a few; rescue belay devices/systems are also numerous and include Tandem Prusiks, the Traverse 540° Rescue Belay, the Petzl I'D as well as several other devices. While some teams may elect to employ the use of single rope technique in certain circumstances, others would rarely move a live load without the use of a backup belay system.

The reasons for the diversity in all of these subject matters include terrain, regional influences, culture, typical number of respondents, skill and training levels, cost, weight, commonality of equipment, perceived levels of risk, type and size of agency and many other considerations. The nature of the task is improvisational. Because of that quality, the solutions will always require judgment and that alone will ensure a certain level of diversity amongst 'common industry practices'.

One 'big picture' theme that seems to be pretty well agreed upon amongst practitioners is:

1. having system-wide *auto-stop* in place

(i.e. the system does not require a human operator to hold or grip something in order to maintain security)

The *Parallel Plaquettes* system is currently being examined as a potential option to meet that key rope rescue principle. The system was not designed for all rope rescue groups for reasons discussed above. For example, it is not compatible with 12.5mm rope. However, for those operating in a mountain rescue environment using smaller diameter rope (≤ 11mm) it has the benefit of being constructed with ubiquitous gear that is likely already hanging from your harness.

Background:

The term *plaquette* is a colloquialism used generically for any auto-locking climbing belay plate. Plaquette is French for 'small plate'. The original auto-locking belay plate was the New Alp Plaquette Magique (aka Plaquette or Magic Plate). The device was popularized by climbing guides on the European continent as a means of belaying two clients simultaneously on one device. Other similar devices have since come on the market and include the Kong GiGi, the Petzl Reverso, the Simond Toucan, the Black Diamond ATC Guide and others. They are all referred to generically by the brandnomer *plaquette.*

The original device by New Alp was an excellent auto-locking device for belaying the second climber(s) on a hands-free top-rope belay, but was lacking as a lead climbing belay device. The modern devices incorporated some design changes to improve the performance as all-around lead climbing belay devices, while maintaining the auto-locking features.

Our research project focused exclusively on this newest generation of plaquette devices.

When rigged on an anchor in auto-locking mode, a plaquette device - in conjunction with a carabiner - acts as a one-way rope trap. The standing part of the rope pays through freely one direction (climber climbing up), but then auto-locks when tensioned in the opposite direction (climber falls). In principle it works similarly to a Garda hitch.

In order to release the plaquette while under tension, a sling is rigged on to the carabiner that creates the rope trap; that sling is then re-directed to an anchor point behind so that a pull on the sling re-orients the device and rope then runs freely. The release can be quite 'hair trigger' for the untrained climber, which is a valid safety concern and training issue. The extra step to 'defeat' the lock-up has likely contributed to the relatively slow adoption of the plaquette amongst the general recreational climbing population – it has been a requisite piece of kit for climbing guides for many years now.

Genesis of the System:

At *Rigging for Rescue* we work with a wide variety of rope rescue practitioners and agencies. Some of these practitioners respond or work in remote, mountainous areas where weight as well as commonality and versatility of equipment are premium considerations (e.g. military special ops, NPS climbing rangers). Some of these groups are exploring the use of specialty ropes such as Dyneema core/Polyester sheath construction, as well as smaller diameters down to 8mm.

Critically evaluating some of the current systems using smaller diameter rope revealed potential issues in the use of smaller diameter cordage to produce Prusik hitches (e.g. 6mm) and raised some concerns as to the integrity of the systems in specific circumstances.

Having used plaquette devices for years as a climbing guide, I was very familiar with how well they worked as a rope trap for smaller diameter ropes. Knowing that the forces applied to the rigging in a rescue scenario (2-persons) were essentially double to that of a similar climbing scenario (1-person), the key was to place the device in a position of use whereby it would not be subjected to the higher forces that can be generated by a multi-person load. That parameter led to the idea of insulating the plaquette behind another DCD, thereby subjecting it only to the running end tension of that forward DCD.

Parallel Plaquettes:

The idea behind the *Parallel Plaquettes* system is to incorporate the same rope management and safety considerations currently used in common rope rescue practices, but accomplish them using something other than Prusik hitches. To control the descent of the load, a suitable DCD (e.g. brakerack, Scarab, etc.) is placed on the primary (main) line; to ensure that the system has hands-free auto-stop, a plaquette device is placed on the running end of the DCD in auto-locking mode. It is through the combination of two devices in-series that adequate descent control and a hands-free stop is attained. The belay system is rigged identically, in parallel.

To initiate a descent of the load, the operator simply pulls on the re-directed sling thereby 'defeating' the plaquette and feeds in rope as required on the running end. It is a two-handed operation: one hand pulling the re-direct sling to open the plaquette and the other hand managing the rope on the running end. To stop you simply release the re-direct sling, which allows the plaquette to trap the rope. The system is hands-free and does not require a tie-off of the running end of the rope.

For *Two-Tensioned Rope Lower (TTRL)* teams using two DCDs, the only change would be to add plaquettes on to the respective running ends of each DCD. One of the Achilles Heels of a TTRL system using two DCDs is that it often does not include a system auto-stop. Some TTRL teams have addressed this with the use of Prusiks either on the running end or the standing part of the DCDs. The reliability (or lack thereof) of Prusik hitches has been a frequently discussed subject matter at ITRS for many years. The plaquette device in a similar position of function is simply an alternative to consider.

For the *Single Mainline Separate Belay (SMSB)* teams, the paradigm shift is also relatively small. The majority of SMSB teams use a suitable DCD on the main and a different device on the belay (e.g. Tandem Prusiks, 540°). However, once the operation gets to a point where there is significant rope-in-service, many SMSB teams add a DCD to their belay line in order to pre-tension that system and mitigate rope elongation. Additionally, adding auto-stop to the mainline is regularly done when transitioning into single rope technique applications (e.g. lower risk; lower consequence scenarios).

In the end, combining devices on a single given system is relatively standard fare in rope rescue circles. The *Parallel Plaquettes* system is simply a different twist on the same theme.

Naturally, it would be great if there were a single device that accomplished both functions - adequate descent control and auto-stop - over a wide bandwidth of rope diameters (i.e. 8-11mm) while still being lightweight. However, to our knowledge that device does not yet exist. Other approaches that were considered included insulating a Petzl Gri Gri (i.e. Gri Gri on the running end of a DCD), but the device is only suitable for a relatively narrow bandwidth of rope diameter (10-11mm) and does not fit in the category of 'lightweight non-specialized equipment'.

System Analysis:

At *Rigging for Rescue*, we have been experimenting with a plaquette on the running end of the mainline during training seminars for around one year now. During that time we have had the opportunity to observe operations, solicit feedback and simply get a general sense for the pros and cons of the system in a wide variety of rope rescue scenarios.

Pros:

- the system auto-locks in a hands-free manner
- no tie-off is required on the running end of the rope
- eliminates a type of 'mainline failure' – namely, the loss of control of the running end of the rope by the operator
- eliminates the use of a Prusik hitch to safeguard the mainline in single rope technique
- works with a wide bandwidth of rope diameter ranging from 8-11mm

Cons:

- increased system profile versus simply a stand-alone DCD
- only allows for one hand on the running end of the rope
- increased rope management when adding or removing friction on a variable friction DCD (e.g. brakerack or Scarab) due to the second device in the system
- longer release distance required of the release hitch during a knot-pass due to the increased profile of the system (still less than 3m)
- two devices in-series is simply 'busier' than one device and results in additional rigging and inspection criteria

Anecdotally, the system works quite well on the mainline. Also, the addition of the plaquette safeguards that system against a failure due to loss of control of the running end of the rope (e.g. untying a loaded DCD and losing situational awareness as to which rope to grip).

In parallel on the backup (belay) line in a lowering scenario, the system offers the benefit of creating a 'mirror image' of the primary (main) line system. This quality would simplify both training and operational considerations.

The question then becomes: "Can the system be reliably used in parallel on the belay?"

This past summer, we attempted to answer this question by conducting two separate drop test series over a course of six days in total. A total of 94 drop tests were completed.

Test Method:

The tests were conducted in a 'quick look' exploratory style. The intentions were to confirm/refute certain suspicions as well as possibly identify further areas of study on the subject matter. Many variables were considered and as a result some combinations were only examined once. Further research on the subject matter is certainly warranted.

One example of the relatively non-scientific nature of the test series was that we elected to conduct the fall-factor-zero tests with the mainline failing while the test mass was in motion – simulating a controlled lowering of the rescue package at which point the mainline failed due to rock fall, for example. This test method made the examination more relative to actual field conditions, but much less repeatable from a scientific standpoint (i.e. slightly different lowering speeds from one test to the next; the resulting different momentum values of the test mass itself; etc.).

Four categories of mainline failure were addressed in the test series:

1. while lowering during the initial edge transition
2. while lowering following the initial edge transition
3. while raising with a snug top-belay
4. while raising with some inadvertent slack in the belay

In each of these scenarios, the mainline was intentionally failed via a quick release mechanism and the belay line rigged in *Parallel Plaquettes* mode was the fall arrest system.

In July, 2009, we conducted three days of drop testing in Ouray, Colorado focusing exclusively on the scenario of failing the mainline during the initial edge transition in a high angle setting. The drop tests were set up using the British Columbia Council of Technical Rescue (BCCTR) Belay Competence Drop Test Method (BCDTM) of a 1m drop on 3m of rope with a 200kg test mass.

As opposed to conducting the tests on a drop tower, we instead rigged the test series at a local crag with a 90° edge transition. This was not done in order to introduce an edge in the system, but rather due to the availability of a suitable testing site location. The edge was protected by a Russ Anderson edge roller. There was no human operator managing the belay device - the system was rigged, tensioned hand tight and then the drop test was conducted.

Force over time measurements were taken separately on both the DCD and the Plaquette using electronic load cells set to 2400 Hz.

The variables examined were as follows:

DCD:
- Conterra SS Scarab
- Black Diamond ATC Guide
- Petzl Reverso 3
- Simond Toucan

Plaquette:
- Black Diamond ATC Guide
- Petzl Reverso 3
- Simond Toucan

Rope (make, model, diameter):
- New England, KM III, 11 mm
- New England, KM III, 9.8 mm
- PMI, EZ Bend, 11 mm
- PMI, EZ Bend, 10 mm
- Sterling, HTP, 11 mm
- Sterling, HTP, 10 mm

The DCDs chosen for the test series were selected as a result of their lighter weight and compact profile. The plaquettes selected included likely the two most popular devices (Reverso 3 and ATC Guide) along with the third one due to it's unique releasing mechanism (Toucan). Finally, the ropes covered a Nylon/Polyester blend (KM III), an all Nylon model (EZ Bend) and an all Polyester model (HTP) in addition to the two different rope diameters.

In September, 2009, we conducted an additional three days of drop testing this time focusing on the mainline failure scenarios involving a snug top-belay both in a lowering and in a raising mode. The drop tests in the September test series included 15m of rope-in-service and a human operator on the belay system. No force measurements were recorded.

Results and Discussion:

July, 2009 Test Series:

The initial test series in July, 2009, was meant to address the scenario of failing the primary (main) line while transitioning the initial edge in a high angle setting. This system failure could be the result of a rigging error, an inspection error, poor command & communication, a toppled artificial high directional or simply a slip of the attendant managing the loaded stretcher, just to name a few scenarios.

The drop tests were conducted using the BCCTR BCDTM of a 1 meter drop on 3 meters of rope. The 1 meter drop height is meant to simulate the belay rope being elevated off of the ground (at around equal to the bridle/stretcher profile height) in order to clear edge obstacles.

Indicators were being sought on three matters:

1. Were the forces too high (i.e. > 15 kN)?
2. Was the stopping distance excessive (i.e. > 1 meter)?
3. Did the plaquette in use as the auto-stop fail to arrest the fall?

Forces:

Total System MAF (kN) by rope diameter:

Data Summary	9.8 & 10mm	11mm
minimum	7.29	8.68
maximum	13.65	14.41
average	9.36	10.90

The maximum forces recorded were below the BCCTR BCDTM benchmark of 15kN regardless of rope type.

Stop Distance:

Stop Distance (cm) by rope diameter:

Data Summary	9.8 & 10mm	11mm
minimum	37	43
maximum	50	77
average	44	51

The maximum stop distances recorded were below the BCCTR BCDTM benchmark of 100cm regardless of rope type. The higher recorded stop distances on the larger diameter rope type were likely due to the differences in DCDs used for the drop tests on each given rope diameter. For example, all of the drops conducted with the 11mm ropes used a SS Scarab with 1 bar and 1 horn. Whereas, all of the drops conducted with 9.8 & 10mm rope used a climber-style DCD like a Black Diamond ATC Guide in lowering mode (i.e. *not* plaquette mode).

System Failures:

None of the drop tests conducted produced a failure to arrest the test mass by the plaquette device. However, Drop Test #21 (Appendix A) did produce a failure of the DCD; the device, a Simond Toucan, broke into two parts. However, the fall was still arrested by the plaquette which was also a Simond Toucan.

Additional observations:

- A human operator would cause maximum arrest forces to decline at the expense of an increase in stop distances due to reaction time in releasing the re-directed sling to the plaquette.

- The Petzl Reverso 3 was visually not as strong a performer as the Black Diamond ATC Guide as a plaquette device. Specifically, on some drops the ropes appeared to be close to passing each other within the plaquette slot, thereby defeating the fall arrest.

- The Simond Toucan appears to be unsuitable for this application due to the nature of its construction.

- Other DCDs not examined also may not be appropriate for this system set up.

- The Conterra Scarab as a DCD in this system requires 1 horn or 3 horns in order to bend the running end of the rope back towards the anchor side (i.e. it cannot be rigged with 2 or 4 horns).

September, 2009 Test Series:

The second round of drop tests focused on the less severe event of failing the primary system (1) while lowering following the initial edge transition, (2) while raising with a snug top-rope and (3) while raising with some slack in the belay line. These scenarios eliminate the 1 meter freefall event associated with a primary system failure during the initial edge transition in a high angle setting.

Excluding the drops incorporating intentional slack in the belay line, these are 'fall factor zero' events and the peak force can be expected to be around 2x the static load of 2kN (approximately 4-5 kN). This can be demonstrated with physics formulas as well as testing and has been addressed at ITRS in the past on several occasions. As a result we elected to not bother with measuring peak forces for the September drop tests.

The primary focus of the September drop tests was the *human factor*. Namely:

1. Can the operator by virtue of a panic reaction or loss of situational awareness affect the integrity of the belay?
2. Does the belay self-actuate or does it require the operator to react in some manner?
3. How far does the load travel before fall arrest is achieved?
4. Would slack in the system during a raising event compromise the integrity of the belay system using a stand-alone plaquette (e.g. an inattentive belayer not maintaining a snug top-rope)?

Observations- while lowering:

In the drop tests, it was evident that the plaquette device would not necessarily self-actuate when the belay line accelerated. The operator had to recognize the rope accelerating through their hand and consciously release the re-directed sling to allow the plaquette to arrest the fall. This would be referred to as a 'conditional belay' in that it was conditional on the belayer acting in a specific manner – namely, releasing the sling and gripping only the running end of the rope.

It is certainly possible for the belayer to defeat the belay by not releasing the re-directed sling. In a panic reaction you would likely increase the gripping force on whatever you had in your hands. An increase in grip on the running end of the belay line would aid in fall arrest; an increase in pulling on the re-directed sling to the plaquette would compromise fall arrest. Drop Test # 13 (Appendix B) was an example of the belayer not releasing the re-directed sling and causing excessive stopping distance as a result.

Observations- while raising:

During a raising scenario, the main line is configured as a pulley system and the belay line would be managed with a stand-alone plaquette device. Because the plaquette is not insulated by a DCD like in a lowering scenario, there was some concern that the device could be defeated by the 2-person load in a main line failure despite a snug top-rope.

A total of 14 drop tests were conducted with a snug top-rope. There were no observable issues with the plaquette devices arresting the fall on any of the combinations examined.

A total of 8 drop tests intentionally included an arbitrary 50cm of slack in the system. This was done in order to examine what affect inadvertent slack might have on the reliability of the fall arrest system. An example would be an inattentive belayer falling behind on taking up slack rope in a raising scenario.

Drop Test # 53 (Appendix B) combined a 10mm Sterling HTP rope with the Petzl Reverso 3 plaquette device and 50cm of slack in the system. The ropes passed each other within the slot of the Reverso 3 and the load went to the ground. Clearly, maintaining a snug top-rope is an important safety consideration. On a longer raising operation with significant rope weight in service, an appropriate technique would be to configure the belay line as a simple 3:1 pulley system to aid in keeping the belay rope snug at all times.

Future Research:

- A slow pull test series would provide some additional information on available margins for defeating a plaquette in a given scenario. Specifically, identifying at what force values the ropes pass each other on a given rope/plaquette combination.

- Possibly experimenting with different methods for re-directing the plaquette in a lowering scenario that increase the likelihood of the system self-actuating.

Recommendations:

- To date, we have observed no compelling reasons to not include a plaquette on the running end of the main line system in a lowering scenario. The device provides a hands-free stop on the main line, which has numerous benefits in a variety of rope rescue scenarios.

- The current concern in using the plaquette in parallel on the belay line as a replacement for a traditional rescue belay device (e.g. Tandem Prusiks or 540°) is that the system does not necessarily self-actuate. However, for the practitioner or team that is well-trained in the basic mechanics of a plaquette-releasing mechanism, the system offers a promising lightweight alternative that encompasses a wide bandwidth of rope diameters.

- All plaquettes are not created equally. Notable differences were observed in this 'quick look' test series.

Key to Acronyms on Log Sheets

Item	Description
FAS	Fall Arrest System
MAF	Maximum Arrest Force
DCD	Descent Control Device
LSK	Low Stretch Kernmantle
HTP	High Tenacity Polyester
PMI	Pigeon Mountain Industries
SMC	Seattle Manufacturing Corporation
NE	New England
SS	Stainless Steel
DAQ	Data Acquisition
SMSB	Single Main Separate Belay
TTRL	Two Tensioned Rope Lower

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And the City of Ouray for the use of their bell tower as a drop testing structure.

Parallel Plaquettes
Drop Test Log Sheet
Date: 7-9-09

Test #	Rope Type: make, model, color	Rope Type: size, construction, material	Initial Rope Length (cm)	Mass (kg)	Drop Height (cm)	Fall Factor	DCD: make, model, configuration	DCD: slide/stretch distance (cm)	DCD: MAF (kN)	Plaquette: make, model	Plaquette: slide/stretch distance (cm)	Plaquette: MAF (kN)	Final Rope Length (cm)	Total System MAF (kN)*
1	NE, KMIII, red w/ white tracer	11mm, LSK, Poly/Nylon	300	200	100	0.33	Conterra, SS Scarab, 1 bar, 1 horn	47.0	5.81	Petzl, Reverso 3	26.0	3.00	377.0	8.68
Missed Russ Anderson Rollers, landed on canvas - only rope damage where contact canvas														
2	NE, KMIII, red w/ white tracer	11mm, LSK, Poly/Nylon	300	200	100	0.33	Conterra, SS Scarab, 1 bar, 1 horn	22.0	6.51	Petzl, Reverso 3	11.5	2.93	352.0	9.37
No visible rope damage														
3	NE, KMIII, red w/ white tracer	11mm, LSK, Poly/Nylon	300	200	100	0.33	Conterra, SS Scarab, 1 bar, 1 horn	26.5	5.65	Petzl, Reverso 3	11.0	3.84	357.0	9.51
Caught Scarab proximal horn on attaching carabiner														
No visible rope damage														
4	NE, KMIII, red w/ white tracer	11mm, LSK, Poly/Nylon	300	200	100	0.33	Conterra, SS Scarab, 1 bar, 1 horn	21.0	6.50	Petzl, Reverso 3	8.5	2.96	350.5	9.27
No visible rope damage														
After 4 drops Reverso 3 shows mild scoring from contact with rope capture carabiner														
5	NE, KMIII, red w/ white tracer	11mm, LSK, Poly/Nylon	300	200	100	0.33	Conterra, SS Scarab, 1 bar, 1 horn	17.0	6.75	Black Diamond, ATC Guide	5.5	3.19	350.5	9.79
No visible rope damage														
6	NE, KMIII, red w/ white tracer	11mm, LSK, Poly/Nylon	300	200	100	0.33	Conterra, SS Scarab, 1 bar, 1 horn	17.0	6.51	Black Diamond, ATC Guide	6.0	3.14	349.0	9.55
No visible rope damage														
7	NE, KMIII, red w/ white tracer	11mm, LSK, Poly/Nylon	300	200	100	0.33	Conterra, SS Scarab, 1 bar, 1 horn	17.0	6.59	Black Diamond, ATC Guide	5.5	3.10	350.0	9.64
No visible rope damage														
Black Diamond ATC Guide no visible damage after 3 drops														

DAQ Rate: 2400 Hz

***Total System MAF is the peak force incurred at any point in time; DCD and Plaquette MAF did not occur simultaneously**

Test #	Rope Type: make, model, color	Rope Type: size, construction, material	Initial Rope Length (cm)	Mass (kg)	Drop Height (cm)	Fall Factor	DCD: make, model, configuration	DCD: slide/stretch distance (cm)	DCD: MAF (kN)	Plaquette: make, model	Plaquette: slide/stretch distance (cm)	Plaquette: MAF (kN)	Final Rope Length (cm)	Total System MAF (kN)*
8	Sterling, HTP, yellow w/ red tracer	11mm, LSK, Polyester	300	200	100	0.33	Conterra, SS Scarab, 1 bar, 1 horn	18.5	8.64	Black Diamond, ATC Guide	7.0	5.87	348.0	14.33
Black Diamond ATC Guide scored at rope capture carabiner interface														
No visible rope damage														
9	Sterling, HTP, yellow w/ red tracer	11mm, LSK, Polyester	300	200	100	0.33	Conterra, SS Scarab, 1 bar, 1 horn	19.5	8.25	Black Diamond, ATC Guide	6.5	5.92	345.5	14.02
10	Sterling, HTP, yellow w/ red tracer	11mm, LSK, Polyester	300	200	100	0.33	Conterra, SS Scarab, 1 bar, 1 horn	17.5	8.42	Black Diamond, ATC Guide	5.5	6.07	346.5	14.41
11	Sterling, HTP, yellow w/ red tracer	11mm, LSK, Polyester	300	200	100	0.33	Conterra, SS Scarab, 1 bar, 1 horn	25.5	7.61	Petzl, Reverso 3	12.0	5.41	353.0	12.63
Rope damage visible: bight within Reverso 3 fused together distal to carabiner														
12	Sterling, HTP, yellow w/ red tracer	11mm, LSK, Polyester	300	200	100	0.33	Conterra, SS Scarab, 1 bar, 1 horn	23.5	7.24	Petzl, Reverso 3	12.0	4.90	355.0	11.99
No visible rope damage														
13	Sterling, HTP, yellow w/ red tracer	11mm, LSK, Polyester	300	200	100	0.33	Conterra, SS Scarab, 1 bar, 1 horn	22.5	7.69	Petzl, Reverso 3	11.5	5.56	353.0	12.93
No visible rope damage														
14	NE, KMIII, white w/blue tracer	9.8mm, LSK, Poly/Nylon	300	200	100	0.33	Black Diamond, ATC Guide	9.5	6.22	Black Diamond, ATC Guide	5.0	2.85	337.0	8.71
Rope damage visible: mild chafing at bight through DCD														

DAQ Rate: 2400 Hz

***Total System MAF is the peak force incurred at any point in time; DCD and Plaquette MAF did not occur simultaneously**

Test #	Rope Type: make, model, color	Rope Type: size, construction, material	Initial Rope Length (cm)	Mass (kg)	Drop Height (cm)	Fall Factor	DCD: make, model, configuration	DCD: slide/stretch distance (cm)	DCD: MAF (kN)	Plaquette: make, model	Plaquette: slide/stretch distance (cm)	Plaquette: MAF (kN)	Final Rope Length (cm)	Total System MAF (kN)*
15	NE, KMIII, white w/ blue tracer	9.8mm, LSK, Poly/Nylon	300	200	100	0.33	Black Diamond, ATC Guide	10.5	6.19	Black Diamond, ATC Guide	5.0	2.69	339.5	8.67
No visible rope damage														
16	NE, KMIII, white w/ blue tracer	9.8mm, LSK, Poly/Nylon	300	200	100	0.33	Black Diamond, ATC Guide	13.0	6.03	Black Diamond, ATC Guide	5.5	2.54	341.0	8.72
Missed RA rollers, landed on side plates														
No visible rope damage														
17	NE, KMIII, white w/ blue tracer	9.8mm, LSK, Poly/Nylon	300	200	100	0.33	Black Diamond, ATC Guide	10.5	6.16	Black Diamond, ATC Guide	4.5	2.79	342.5	8.81
No visible rope damage														
18	NE, KMIII, white w/ blue tracer	9.8mm, LSK, Poly/Nylon	300	200	100	0.33	Petzl Reverso 3	23.5	5.43	Petzl, Reverso 3	16.5	1.96	350.0	7.29
No visible rope damage														
Appeared that two ropes approaching passing within plaquette														
19	NE, KMIII, white w/ blue tracer	9.8mm, LSK, Poly/Nylon	300	200	100	0.33	Petzl Reverso 3	18.0	5.78	Petzl, Reverso 3	10.5	2.15	343.5	7.79
20	NE, KMIII, white w/ blue tracer	9.8mm, LSK, Poly/Nylon	300	200	100	0.33	Petzl Reverso 3	15.0	6.47	Petzl, Reverso 3	6.5	2.18	343.5	8.53
21	NE, KMIII, white w/ blue tracer	9.8mm, LSK, Poly/Nylon	300	200	100	0.33	Simond, Toucan	Broke	6.03	Simond, Toucan	20.0	3.20	401.0	8.11
Rope damage visible: mild chafing at bight through DCD														
First test of 7-10-09														

DAQ Rate: 2400 Hz

***Total System MAF is the peak force incurred at any point in time; DCD and Plaquette MAF did not occur simultaneously**

Test #	Rope Type: make, model, color	Rope Type: size, construction, material	Initial Rope Length (cm)	Mass (kg)	Drop Height (cm)	Fall Factor	DCD: make, model, configuration	DCD: slide/stretch distance (cm)	DCD: MAF (kN)	Plaquette: make, model	Plaquette: slide/stretch distance (cm)	Plaquette: MAF (kN)	Final Rope Length (cm)	Total System MAF (kN)*
22	NE, KMIII, white w/blue tracer	9.8mm, LSK, Poly/Nylon	300	200	100	0.33	Black Diamond, ATC Guide	15.0	6.81	Black Diamond, ATC Guide	6.0	3.32	347.0	10.07
Visible rope damage: mild chafing														
23	PMI, EZ Bend, white w/ orange tracer	10mm, LSK, Nylon	300	200	100	0.33	Black Diamond, ATC Guide	16.5	6.80	Black Diamond, ATC Guide	6.0	3.63	344.5	10.37
No visible rope damage														
24	PMI, EZ Bend, white w/ orange tracer	10mm, LSK, Nylon	300	200	100	0.33	Black Diamond, ATC Guide	14.5	6.83	Black Diamond, ATC Guide	5.5	3.36	343.5	10.08
Missed Russ Anderson Rollers, on metal side plates and quick links, mild chafe to rope at roller														
25	PMI, EZ Bend, white w/ orange tracer	10mm, LSK, Nylon	300	200	100	0.33	Black Diamond, ATC Guide	15.0	7.09	Black Diamond, ATC Guide	4.5	3.56	343.5	10.53
26	PMI, EZ Bend, white w/ orange tracer	10mm, LSK, Nylon	300	200	100	0.33	Petzl Reverso 3	24.0	6.05	Petzl, Reverso 3	14.0	2.14	349.8	8.10
Missed Russ Anderson Rollers, on metal side plates														
27	PMI, EZ Bend, white w/ orange tracer	10mm, LSK, Nylon	300	200	100	0.33	Petzl Reverso 3	19.0	5.77	Petzl, Reverso 3	10.5	1.97	346.0	7.74
Missed Russ Anderson Rollers, hit canvas														
28	PMI, EZ Bend, white w/ orange tracer	10mm, LSK, Nylon	300	200	100	0.33	Petzl Reverso 3	22.5	6.30	Petzl, Reverso 3	14.5	2.19	348.5	8.37
Visible rope damage: mild chafe														
Focal point carabiner on 5k load cell change vertical to horizontal (this drop only)														

DAQ Rate: 2400 Hz

***Total System MAF is the peak force incurred at any point in time; DCD and Plaquette MAF did not occur simultaneously**

Test #	Rope Type: make, model, color	Rope Type: size, construction, material	Initial Rope Length (cm)	Mass (kg)	Drop Height (cm)	Fall Factor	DCD: make, model, configuration	DCD: slide/stretch distance (cm)	DCD: MAF (kN)	Plaquette: make, model	Plaquette: slide/stretch distance (cm)	Plaquette: MAF (kN)	Final Rope Length (cm)	Total System MAF (kN)*
29	PMI, EZ Bend, white w/ black tracer	11mm, LSK, Nylon	300	200	100	0.33	Conterra, SS Scarab, 1 bar, 1 horn	16.0	6.90	Black Diamond, ATC Guide	5.0	3.98	343.5	10.65
No visible rope damage														
30	PMI, EZ Bend, white w/ black tracer	11mm, LSK, Nylon	300	200	100	0.33	Conterra, SS Scarab, 1 bar, 1 horn	15.0	7.10	Black Diamond, ATC Guide	4.5	3.55	343.0	10.62
No visible rope damage														
31	PMI, EZ Bend, white w/ black tracer	11mm, LSK, Nylon	300	200	100	0.33	Conterra, SS Scarab, 1 bar, 1 horn	91.0	4.19	Petzl, Reverso 3	135.0	2.67	416.5	6.85
Measurement taken on relaxed rope (30 sec.) so rope could be removed from DCD, measure to x mark														
Possible error in test setup: rope capture carabiner on plaquette in contact (pinned) w/ 10k load cell														
32	PMI, EZ Bend, white w/ black tracer	11mm, LSK, Nylon	300	200	100	0.33	Conterra, SS Scarab, 1 bar, 1 horn	30.0	5.84	Petzl, Reverso 3	16.5	4.29	357.0	9.80
No visible rope damage														
33	PMI, EZ Bend, white w/ black tracer	11mm, LSK, Nylon	300	200	100	0.33	Conterra, SS Scarab, 1 bar, 1 horn	21.5	6.26	Petzl, Reverso 3	10.0	3.76	347.0	9.90
No visible rope damage														
34	PMI, EZ Bend, white w/ black tracer	11mm, LSK, Nylon	300	200	100	0.33	Conterra, SS Scarab, 1 bar, 1 horn	23.0	5.96	Petzl, Reverso 3	10.0	3.64	347.5	9.49
No visible rope damage														
35	PMI, EZ Bend, white w/ black tracer	11mm, LSK, Nylon	300	200	100	0.33	Conterra, SS Scarab, 1 bar, 1 horn	18.0	6.74	Black Diamond, ATC Guide	5.5	4.09	346.5	10.57
No visible rope damage														

DAQ Rate: 2400 Hz

***Total System MAF is the peak force incurred at any point in time; DCD and Plaquette MAF did not occur simultaneously**

Parallel Plaquettes
Drop Test Log Sheet
Date: 7-10-09

Test #	Rope Type: make, model, color	Rope Type: size, construction, material	Initial Rope Length (cm)	Mass (kg)	Drop Height (cm)	Fall Factor	DCD: make, model, configuration	DCD: slide/stretch distance (cm)	DCD: MAF (kN)	Plaquette: make, model	Plaquette: slide/stretch distance (cm)	Plaquette: MAF (kN)	Final Rope Length (cm)	Total System MAF (kN)*
36	Sterling, HTP, white w/ blue tracer	10mm, LSK, Polyester	300	200	100	0.33	Black Diamond, ATC Guide	12.5	9.85	Black Diamond, ATC Guide	4.5	3.81	343.5	13.65
No visible rope damage														
37	Sterling, HTP, white w/ blue tracer	10mm, LSK, Polyester	300	200	100	0.33	Black Diamond, ATC Guide	14.0	9.72	Black Diamond, ATC Guide	4.5	3.91	343.0	13.63
No visible rope damage														

DAQ Rate: 2400 Hz

***Total System MAF is the peak force incurred at any point in time; DCD and Plaquette MAF did not occur simultaneously**

Parallel Plaquettes
Drop Test Log Sheet
Date: 9-14-09 and 9-15-09

Test #	Rope Type: make, model,color	Rope Type: size, construction, material	Initial Rope Length (cm)	Mass (kg)	Drop Height (cm)	Fall Factor	DCD: make, model, configuration	Plaquette: make, model	Final Rope Length (cm)	Lowering Method
1	NE, KMIII, blue w/ white tracer	11mm, LSK, Poly/Nylon	1500	200	0	0	Conterra, SS Scarab, 1 bar, 1 horn	Black Diamond, ATC Guide	1550	TTRL
Baseline test w/ drop count "3-2-1-0"										
2	NE, KMIII, blue w/ white tracer	11mm, LSK, Poly/Nylon	1500	200	0	0	Conterra, SS Scarab, 1 bar, 1 horn	Black Diamond, ATC Guide	1590	TTRL
3	PMI, EZ Bend, white w/ black tracer	11mm, LSK, Nylon	1500	200	0	0	Conterra, SS Scarab, 1 bar, 1 horn	Black Diamond, ATC Guide	1545	TTRL
4	PMI, EZ Bend, white w/ black tracer	11mm, LSK, Nylon	1500	200	0	0	Conterra, SS Scarab, 1 bar, 1 horn	Black Diamond, ATC Guide	1525	TTRL
5	NE, KMIII, blue w/ white tracer	11mm, LSK, Poly/Nylon	1500	200	0	0	Conterra, SS Scarab, 1 bar, 1 horn	Black Diamond, ATC Guide	1585	TTRL
6	NE, KMIII, red w/ white tracer	11mm, LSK, Poly/Nylon	1500	200	0	0	Conterra, SS Scarab, 1 bar, 1 horn	Black Diamond, ATC Guide	1580	TTRL
7	NE, KMIII, red w/ white tracer	11mm, LSK, Poly/Nylon	1500	200	0	0	Conterra, SS Scarab, 1 bar, 1 horn	Black Diamond, ATC Guide	1590	TTRL
First test of 9-15-09										
8	NE, KMIII, red w/ white tracer	11mm, LSK, Poly/Nylon	1500	200	0	0	Conterra, SS Scarab, 1 bar, 1 horn	Black Diamond, ATC Guide	1875	SMSB-Pretensioned Belay
Mainline Configuration-SS Scarab; 1 bar, 3 horns										
Belay Configuration-SS Scarab; 1 bar, 1 horn										
Faulty drop: belayer was not gripping running end of rope (incorrect technique)										
9	PMI, EZ Bend, white w/ black tracer	11mm, LSK, Poly/Nylon	1500	200	0	0	Conterra, SS Scarab, 1 bar, 1 horn	Black Diamond, ATC Guide	1535	SMSB-Pretensioned Belay
Mainline Configuration-SS Scarab; 1 bar, 3 horns										
Belay Configuration-SS Scarab; 1 bar, 1 horn										

Test #	Rope Type: make, model,color	Rope Type: size, construction, material	Initial Rope Length (cm)	Mass (kg)	Drop Height (cm)	Fall Factor	DCD: make, model, configuration	Plaquette: make, model	Final Rope Length (cm)	Lowering Method
10	PMI, EZ Bend, white w/ black tracer	11mm, LSK, Nylon	1500	200	0	0	Conterra, SS Scarab, 1 bar, 1 horn	Black Diamond, ATC Guide	1645	SMSB-Prestensioned Belay
Mainline Configuration-SS Scarab; 1 bar, 3 horns										
Belay Configuration-SS Scarab; 1 bar, 1 horn										
Pelican ring slightly caught										
11	NE, KMIII, blue w/ white tracer	11mm, LSK, Poly/Nylon	1500	200	0	0	Conterra, SS Scarab, 1 bar, 1 horn	Black Diamond, ATC Guide	1750	SMSB-Untensioned Belay
Mainline Configuration-SS Scarab; 1 bar, 3 horns										
Belay Configuration-SS Scarab; 1 bar, 1 horn										
Belayer was instructed to actively feed slack through the system which resulted in the plaquette migrating toward the change of direction and ultimately causing a more violent event										
12	NE, KMIII, red w/ white tracer	11mm, LSK, Poly/Nylon	1500	200	0	0	Conterra, SS Scarab, 1 bar, 1 horn	Black Diamond, ATC Guide	1675	SMSB-Untensioned Belay
Mainline Configuration-SS Scarab; 1 bar, 3 horns										
Belay Configuration-SS Scarab; 1 bar, 1 horn										
13	Sterling, HTP, blue w/ yellow tracer	10mm, LSK, Polyester	1500	200	0	0	Conterra, SS Scarab, 1 bar, 1 horn	Black Diamond, ATC Guide	ground	TTRL
Thought from the guy who dropped the load: "I found myself focused on trying to grab the rope and failed to release the plaquette."										
14	Sterling, HTP, red w/ blue tracer	11mm, LSK, Polyester	1500	200	0	0	Conterra, SS Scarab, 1 bar, 1 horn	Black Diamond, ATC Guide	1550	TTRL
15	Sterling, HTP, black w/ gold tracer	11mm, LSK, Polyester	1500	200	0	0	Conterra, SS Scarab, 1 bar, 1 horn	Black Diamond, ATC Guide	1650	SMSB-Untensioned Belay
Mainline Configuration-SS Scarab; 1 bar, 3 horns										
Belay Configuration-SS Scarab; 1 bar, 1 horn										
16	Sterling, HTP, red w/ blue tracer	11mm, LSK, Polyester	1500	200	0	0	Conterra, SS Scarab, 1 bar, 1 horn	Black Diamond, ATC Guide	1570	SMSB-Untensioned Belay
Mainline Configuration-SS Scarab; 1 bar, 3 horns										
Belay Configuration-SS Scarab; 1 bar, 1 horn										
17	Sterling, HTP, blue w/ yellow tracer	10mm, LSK, Polyester	1500	200	0	0	Conterra, SS Scarab, 1 bar, 1 horn	Black Diamond, ATC Guide	1610	SMSB-Untensioned Belay
Mainline Configuration-SS Scarab; 1 bar, 3 horns;										
Belay Configuration-SS Scarab; 1 bar, 1 horn										
18	Sterling, HTP, red w/ blue tracer	11mm, LSK, Polyester	1500	200	0	0	Petzl, Reverso 3	Black Diamond, ATC Guide	1565	TTRL

Test #	Rope Type: make, model,color	Rope Type: size, construction, material	Initial Rope Length (cm)	Mass (kg)	Drop Height (cm)	Fall Factor	DCD: make, model, configuration	Plaquette: make, model	Final Rope Length (cm)	Lowering Method
19	Sterling, HTP, red w/ blue tracer	11mm, LSK, Polyester	1500	200	0	0	Petzl, Reverso 3	Black Diamond, ATC Guide	1650	TTRL
20	Sterling, HTP, white w/ black tracer	11mm, LSK, Polyester	1500	200	0	0	Petzl, Reverso 3 (low friction)	Black Diamond, ATC Guide	1550	TTRL
21	NE, KMIII, red w/ white tracer	11mm, LSK, Poly/Nylon	1500	200	0	0	Petzl, Reverso 3	Black Diamond, ATC Guide	1570	TTRL
22	NE, KMIII, blue w/ white tracer	11mm, LSK, Poly/Nylon	1500	200	0	0	Petzl, Reverso 3 (low friction)	Black Diamond, ATC Guide	1645	TTRL
23	PMI, EZ Bend, white w/ black tracer	11mm, LSK, Nylon	1500	200	0	0	Petzl, Reverso 3	Black Diamond, ATC Guide	1590	TTRL
24	PMI, EZ Bend, white w/ black tracer	11mm, LSK, Nylon	1500	200	0	0	Petzl, Reverso 3 (low friction)	Black Diamond, ATC Guide	1565	TTRL
25	Sterling, HTP, red w/ blue tracer	11mm, LSK, Polyester	1500	200	0	0	Petzl, Reverso 3	Black Diamond, ATC Guide	1555	SMSB-Untensioned Belay
26	Sterling, HTP, blue w/ yellow tracer	10mm, LSK, Polyester	1500	200	0	0	Petzl, Reverso 3 (low friction)	Black Diamond, ATC Guide	1750	SMSB-Untensioned Belay
27	NE, KMIII, red w/ white tracer	11mm, LSK, Poly/Nylon	1500	200	0	0	Petzl, Reverso 3	Black Diamond, ATC Guide	1625	SMSB-Untensioned Belay

Test #	Rope Type: make, model,color	Rope Type: size, construction, material	Initial Rope Length (cm)	Mass (kg)	Drop Height (cm)	Fall Factor	DCD: make, model, configuration	Plaquette: make, model	Final Rope Length (cm)	Lowering Method
28	NE, KMIII, red w/ white tracer	11mm, LSK, Poly/Nylon	1500	200	0	0	Petzl, Reverso 3 (low friction)	Black Diamond, ATC Guide	1575	SMSB-Untensioned Belay
29	PMI, EZ Bend, white w/ black tracer	11mm, LSK, Nylon	1500	200	0	0	Petzl, Reverso 3 (low friction)	Totem	1750	TTRL
Mainline-Black Diamond ATC Guide										
Belay-Totem										
30	PMI, EZ Bend, white w/ black tracer	11mm, LSK, Nylon	1500	200	0	0	Petzl, Reverso 3 (low friction)	Totem	1720	SMSB-Prestensioned Belay
Mainline-Black Diamond ATC Guide										
Belay-Just the Totem										
31	NE, KM III, white w/ blue tracer	9.8 mm, LSK, Poly/Nylon	1500	200	0	0	Petzl, Reverso 3	Black Diamond, ATC Guide	1555	TTRL
32	NE, KM III, white w/ blue tracer	9.8 mm, LSK, Poly/Nylon	1500	200	0	0	Petzl, Reverso 3	Black Diamond, ATC Guide	n/a	TTRL
Faulty drop due to rap ring catch										
33	PMI, EZ Bend, white w/ orange tracer	10mm, LSK, Nylon	1500	200	0	0	Petzl, Reverso 3	Black Diamond, ATC Guide	1570	TTRL
34	NE, KM III, white w/ blue tracer	9.8 mm, LSK, Poly/Nylon	1500	200	0	0	Petzl, Reverso 3	Black Diamond, ATC Guide	1550	TTRL
35	NE, KM III, white w/ blue tracer	9.8 mm, LSK, Poly/Nylon	1500	200	0	0	Petzl, Reverso 3	Black Diamond, ATC Guide	1625	TTRL
36	PMI, EZ Bend, white w/ black tracer	11mm, LSK, Nylon	1500	200	0	0	n/a: Raising Scenario	Black Diamond, ATC Guide	1570	n/a
First Test of 9-16-09										

Test #	Rope Type: make, model,color	Rope Type: size, construction, material	Initial Rope Length (cm)	Mass (kg)	Drop Height (cm)	Fall Factor	DCD: make, model, configuration	Plaquette: make, model	Final Rope Length (cm)	Lowering Method
37	PMI, EZ Bend, white w/ black tracer	11mm, LSK, Nylon	1500	200	0	0	n/a: Raising Scenario	Petzl, Reverso 3	1580	n/a
38	PMI, EZ Bend, white w/ black tracer	11mm, LSK, Nylon	1500	200	0	0	n/a: Raising Scenario	Black Diamond, ATC Guide	1575	n/a
39	PMI, EZ Bend, white w/ black tracer	11mm, LSK, Nylon	1500	200	0	0	n/a: Raising Scenario	Petzl, Reverso 3	1580	n/a
40	NE, KMIII, blue w/ white tracer	11mm, LSK, Poly/Nylon	1500	200	0	0	n/a: Raising Scenario	Black Diamond, ATC Guide	1585	n/a
41	NE, KMIII, blue w/ white tracer	11mm, LSK, Poly/Nylon	1500	200	0	0	n/a: Raising Scenario	Petzl, Reverso 3	1585	n/a
42	NE, KMIII, red w/ white tracer	11mm, LSK, Poly/Nylon	1500	200	0	0	n/a: Raising Scenario	Black Diamond, ATC Guide	1600	n/a
43	NE, KMIII, red w/ white tracer	11mm, LSK, Poly/Nylon	1500	200	0	0	n/a: Raising Scenario	Petzl, Reverso 3	1585	n/a
44	Sterling, HTP, red w/ blue tracer	11mm, LSK, Polyester	1500	200	0	0	n/a: Raising Scenario	Black Diamond, ATC Guide	1530	n/a
45	Sterling, HTP, blue w/ yellow tracer	10mm, LSK, Polyester	1500	200	0	0	n/a: Raising Scenario	Petzl, Reverso 3	1555	n/a
46	Sterling, HTP, black w/ green tracer	11mm, LSK, Polyester	1500	200	0	0	n/a: Raising Scenario	Black Diamond, ATC Guide	1555	n/a
47	Sterling, HTP, white w/ black tracer	11mm, LSK, Polyester	1500	200	0	0	n/a: Raising Scenario	Petzl, Reverso 3	1555	n/a

Test #	Rope Type: make, model,color	Rope Type: size, construction, material	Initial Rope Length (cm)	Mass (kg)	Drop Height (cm)	Fall Factor	DCD: make, model, configuration	Plaquette: make, model	Final Rope Length (cm)	Lowering Method
48	PMI, EZ Bend, white w/ black tracer	11mm, LSK, Nylon	1550	200	50	0.03	n/a: Raising Scenario	Black Diamond, ATC Guide	1630	n/a
49	PMI, EZ Bend, white w/ black tracer	11mm, LSK, Nylon	1550	200	50	0.03	n/a: Raising Scenario	Petzl, Reverso 3	1645	n/a
50	NE, KMIII, blue w/ white tracer	11mm, LSK, Poly/Nylon	1550	200	50	0.03	n/a: Raising Scenario	Black Diamond, ATC Guide	1635	n/a
51	NE, KMIII, blue w/ white tracer	11mm, LSK, Poly/Nylon	1550	200	50	0.03	n/a: Raising Scenario	Petzl, Reverso 3	1640	n/a
52	Sterling, HTP, red w/ blue tracer	11mm, LSK, Polyester	1550	200	50	0.03	n/a: Raising Scenario	Black Diamond, ATC Guide	1600	n/a
53	Sterling, HTP, blue w/ yellow tracer	10mm, LSK, Polyester	1550	200	50	0.03	n/a: Raising Scenario	Petzl, Reverso 3	ground	n/a
54	NE, KM III, white w/ blue tracer	9.8 mm, LSK, Poly/Nylon	1500	200	0	0	n/a: Raising Scenario	Black Diamond, ATC Guide	1580	n/a
55	NE, KM III, white w/ blue tracer	9.8 mm, LSK, Poly/Nylon	1500	200	0	0	n/a: Raising Scenario	Petzl, Reverso 3	1580	n/a
56	NE, KM III, white w/ blue tracer	9.8 mm, LSK, Poly/Nylon	1550	200	50	0.03	n/a: Raising Scenario	Black Diamond, ATC Guide	1640	n/a
57	NE, KM III, white w/ blue tracer	9.8 mm, LSK, Poly/Nylon	1550	200	50	0.03	n/a: Raising Scenario	Petzl, Reverso 3	1665	n/a

some visible damage to sheath on rope

NOTES