An Analysis of the Modern-Day Belay:

Competent Belay or Competent Belayer?

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The acceptance and use of the Two Tensioned Rope System (TTRS) as safety and line management evolution of the traditional belay has gained increasing traction in North America. Much of the testing and credit to this gradual evolution can be attributed to the research and writings of Kirk Mauthner, Tom Pendley, and IKAR and ITRS proceedings. The advent of increasingly efficient and thoughtful descent control devices and belays has also played a significant role in this change. Devices such as the I'D, MPD, Maestro, D4, D5, and others of similar function have aided greatly in proliferating these techniques. The problem is, when these devices are operated in TTRS lowers, they pose an often-overlooked hazard to patients and rescuers that was mostly absent in other traditional belay methods. The purpose of this research is to identify these hazards and establish engineering measures or operating measures to mitigate these shortcomings.

Background

For expediency's sake, we shall we assume the following is true. During the growth of the professionalism of rescue in the 1980's, belays were greatly varied and mostly borrowed from alpinism and caving. These included the figure-of-eight, the Gibbs ascender, the Münter or Italian hitch, and various sticht plates. Starting in the mid-80's our friends from British Columbia and the Southwest helped spread the use of the Tandem Prusik Belay(TPB) for rescue sized loads. From the mid-80's through the mid-90's a battle-royale ensued between the TPB camps and the Münter camps. Victory would eventually fall to the TPB advocates and the Münter would become a much maligned and marginalized belay by the 2000's.

Much of this fight lost relevance due to the engineering and creation of specific devices for the purpose of rescue and belaying. First Kirk Mauthner would create the Traverse 540 Belay in the mid 90's. Petzl would bring the I'D to market in the late 90's. Mauthner would outdo himself and bring the rescue world the MPD in the late 2000's- around 2009. Today there are a myriad of descent-control and belay solutions from ISC, Climbing Technology, and more. Despite all of these advances, there are still many users of the TPB. In fact, there are even some users of the Münter hitch for rescue loads.

The most current research and literature adopts many of the tenets of the older BCCTR BCT, but employs two tensioned ropes that both serve as working lines. Kirk Mauthner and the Emergency Management of British Columbia have come to call this evolution or hybridization *Dual Capability Two Tensioned Rope Systems*. That is to say, both sides of the system are “competent belays” and are capable of operating in a full capacity as a main working line and belay line at the same time.

Belay Competency Test

Ripped right from the pages of the original article Are You REALLY on Belay?, by John Dill, the BCCTR belay competency test is as follows: a 200 kg mass falls one meter(1m) on three meters(3m) of rope, and the belay shall slip no more than one meter, and the maximum arrest force(MAF) shall be less than 15 kN. Most have been taught that the conditions are likened to a belay within 3m of the edge and a two-person load that slips during the edge transition and falls 1m(height of waist connection) to the edge.

The new EMBC version of the BCT has been adjusted to a 1 m drop on 3 m of rope, a 1 m stopping distance, and a 12kN MAF. The appliance must remain functional after drop. It also contains a “redline test” at 1.5M on 3M without failure (Mauthner, 2016).

This test criteria has persisted and pervaded many test standards, consensus standards, and manufacturer documents. Today’s NFPA 1983 and ASTM F2436 version requires a 300 lb and 617 lb test mass for Technical Use and General Use belay drops- respectively. The drop height is reduced from 1 m to 60 cm. Forces must stay under 15 kN and extension must be limited to 1 m.

Failings of the BCT

The most glaring problem with the BCCTR BCT is that it espouses a worst-case condition or circumstance, but tests an entirely different one. How can a test that is entirely predicated on a failure *during the edge transition*, eliminate the edge entirely in testing? Many are quick to offer this is to reduce variance, alpha, or to isolate the variables. The hypothesis and test method are so divergent, the author is surprised that this test method has persisted.

1. In the fire / industrial rescue environment, when working with rescue sized loads, most problems have an edge with a 90-degree deviation and a .50 or greater coefficient of friction (carabiner, concrete, parapet, rail, etc).
2. Two person loads and litter attendants, during the edge transition, should be an option of last resort. Alternatives include the use of tag lines, SRT litter attendants, edge attendants during the edge transition (over the edge), skate blocks, guiding lines, positioning the litter first and having the attendant subsequently climb out.
3. Similar to the 1% solution of the BCT, the idea of 600 lb mass representing a constant 2-person load was predicated on an accident with two fully ensembled firefighters in 1980. This is hardly the norm for this type of rescue package. The author is unaware of any similar-such event taking place since the FDNY event in 1980.
4. This test method tests a device or method, but fails to capture the "human element." Instead of a using a hapless student or belay operator, it became preferable to use a "flaking shelf" or let the "self-braking" device act alone. In truth, in the field there will be a distinct opportunity for a human to fail an otherwise "competent" belay method. Thus, this should be reflected in our testing and training.

In short, the BCT is a 1% solution for a 95% world of rescue possibilities in the urban-industrial and fire-rescue realm. It is not without value or merit, it simply does not make sense to be quickly and arbitrarily dismissive of belay methods and paradigms that fall outside of the strictest BCT criteria. Furthermore, just because something works unattended in a sterile environment, does not mean a human will not defeat it in practical application. Pendley (2010) demonstrated this fact, as can many trainers who put students through the paces of catching a falling load while operating as a belay.

Münter Myths

It has been widely accepted that the Münter hitch is incapable of safely and reliably belaying a two-person load. This belief has descended from the arguments in favor of the BCCTR BCT and the passionate advocates of the TPB. The author's agency adopted their curriculum from ROCO Rescue in the mid 1990's.

Richie Wright's program advocated the use of the Münter hitch for belaying both one and two-person loads. For beginning students, the Münter is an ideal beginner belay. The hitch can be quickly taught and operated. It is a low-cost / no-cost tool that any team can employ and afford. It is also capable of arresting very heavy loads if edge friction is incorporated (carabiner, window, rough edge) and tension is maintained or slack is eliminated.

Since arriving at the MS State Fire Academy, the author has ensured that every Level 1 Rope Rescue student belays and catches a falling load, in accordance with NFPA 1006. Before each student is allowed to either belay or rappel, they must catch, tie-off, and lower, a 600 lb load using a Munter hitch. This is performed as a check-off on the first day of a student's first rescue class. The conditions presented are similar to those the students will encounter in their week of training and in their career. The main difference is that in practice, we strive to avoid two-person loads- especially the magnitude of 600 lb . We have video-documented this training process for the past two seasons. Below are Münter statistics from some southern states and NCRC.

MSFA Münter Belay Stats

Test Mass- Averages 620 lbs

Average pupil: 21-35 year old male weighing @ 200 lbs.

Hoisted with a CMC MPD in-line 5:1(Level 1), or Amkus ARRS1 Capstan Hoist (Level 2)

Released with a Wichard Snap Shackle with 550 cord remote release.

Belayed with a Münter hitch in 12.5 mm PMI EZ Bend Rope & SMC Extra Large Steel Locking Carabiner

Anchor distance to 10 mm Maillon Rapide half-round change of direction, with 70-degree inside angle: 35'

Distance from Münter to load upon release: Average- 37'-43'

Sample Size- 2010-Present: over 600 students

Informal / Anecdotal successful catches upon first attempt: 95%

Central Texas Program: Regional Standardization of Equipment and Training(ReSET) (Walker, 2017)

Test Mass- 300-600 lbs, most commonly a 400 lb mass is used

Average pupil: In the RESET program these are typical FFs, both female and male, of varying age.

Hoisted with an in-line 5:1

Released with a homemade lever release.

Belayed with a Münter hitch using either 11 or 12.5 mm PMI EZ Bend rope & SMC Extra Large Steel Locking Carabiner

Anchor distance to steel carabiner change of direction, with 70-degree inside angle: 20-30 feet, just depends on the availability of set-up

Sample Size- 2004-Present: ReSET- over- 600 students; various conferences and workshops- 100 participants.

Informal / Anecdotal successful catches upon first attempt: over 95%

National Cave Rescue Commission (Walker, 2017)

Test Mass- most commonly a 400 lb mass is used

Average pupil: Male and female of greatly varied size and age

Hoisted with multiple haul system configurations

Released with a homemade lever release.

Belayed with a Münter hitch using 11 mm PMI EZ Bend rope & SMC Extra Large Steel Locking Carabiner

Anchor distance to steel carabiner change of direction, with 70-degree inside angle: 20-30 feet, just depends on the availability of set-up

Sample Size- 2004-Present: over- 300 students

Informal / Anecdotal successful catches upon first attempt: over 95%

The Münter hitch is not without failings and limitations. There are times where grip or hand strength can become an issue. Depending on rope age and construction, 11 mm ropes can be difficult to hold or belay the heavier test masses (600 lbs). The Münter obviously does not adhere to any whistle tests, but as has become the fashion, can be tailed by another team member. Some teams will even tie a Prusik around the braking side of the rope to honor the *whistle test*.

The Münter is the first belay a student learns at the MSFA. Students are told to a). Incorporate edge friction, b). Minimize all slack (run in tension), and c). Never take one's hands off of the brake hand side of the Münter. When these rules are maintained and there is a normal amount rope in service, the hitch is competent and capable of arresting heavy loads within acceptable force and slip ranges. As the students progress through their training, they are later introduced to the 540, I'D, MPD, and ASAP as additional tools. If the Münter is successful being operated as an untensioned belay with 400-600 lb loads 95%+ of the time, how does it fair as a TTRS hitch / appliance. The answer from experience and this research is: <u>very well.</u>

TTRS Procedures

Some quick-look testing in 2015 yielded some surprising results when lines were cut while employing a TTRS. Nuances of the I'D and MPD seemed to allow the load to slip an unacceptable distance. Tests 8-24 sought to test these events under more scrutiny. 11 mm Sterling HTP was utilized in a TTRS lower using CMC MPDs, Petzl I'Ds, and Münter hitches. A random line was released and the load would be transferred to the remaining line. Enforcer load cells were utilized at the load and the anchor. The ropes travelled 15' to an 80-degree change of direction in an AZ Vortex Tripod. Some tests utilized a Large SMC Steel Locking carabiner at this deviation, while others employed a Petzl Rescue Pulley. When the ropes were "cut" there was between 20-30' of rope in service.

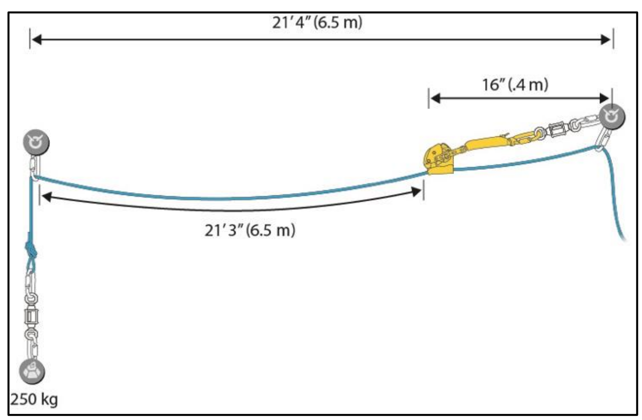
ASAP Procedures

Jeremiah Wangsgard with Petzl America presented findings on the ASAP as an anchored belay at the 2017 SPRAT Conference in Phoenix. He used the ASAP as an untensioned belay using a 250 kg load. Shortly thereafter Petzl France released a Tech Tip allowing for the same. Both of these tests involved slack in the rope (15") and 250 kg masses.

redirect to ASAP anchor = 21' 4" (6.5 m)
rope length = 22' 7" (6.9 m)
15" (38 cm) of slack

Petzl Vector 11mm rope
250 kg mass

	Redirect	Load MAF	Anchor MAF	Energy Absorber extension	Rope movement through ASAP
Test #1	OXAN steel carabiner	6.94 kN	5.06 kN	17 in. (43 cm)	16 in. (41 cm)
Test #2	OXAN steel carabiner	7.22 kN	5.6 kN	18 in. (46 cm)	15 in. (38 cm)
Test #3	RESCUE pulley	6.18 kN	5.5 kN	18 in. (46 cm)	28 in. (71 cm)



(Wangsgard, 2017)

The research set out to expand on this data and use the ASAP as a pseudo-tensioned belay with a 600 lb test mass. A directional pulley was placed behind the ASAP and 30 lbs of back-tension were applied to the rope using a spring scale.

Results

TTRS

The operators were proficient and yielded mostly positive outcomes in testing. Slip rates were mostly kept under 1m and forces were generally under 6 kN and averaging under 4 kN. With each device, there was an errant drop. The testers engineered a *delayed* reaction on an MPD drop to allaw a bypassed ASAP to engage. One test with an I'D and no extra friction yielded an over 2 m fall. Finally, a test using the Münter inflamed an old nerve injury and led to a slip of over 1 m.

Münter hitch catches yielded the shortest slip distances and lowest forces. The MPD was the next best performer with intermediate to low forces and low slip distances. The I'D had one long slip and generally higher forces. All forces and most slip rates were within acceptable limits for rescue best practices.

ASAP Lock

The ASAP Lock testing was consistent with test results performed, presented, and published by both Petzl France and Petzl America. Forces at the anchor averaged under 5 kN and forces on both the anchor and load averaged 5.6 kN. All the slips were under 1 m and most were under .5 m. The ASAP remained operational throughout the testing. It was notable that in two of the tests, the ASAP settle against the anchored pulley and allowed for several more inches of travel. These tests yielded less rope travel through the ASAP and less shock absorber deployment. The position of the ASAP relative to the pulley was not a significant factor. The need for manually advancing the ASAP with additions of bungee cords or similar techniques may be unwarranted.

Implications and Recommendations

Despite the diversity of options of devices that pass rigorous tests and brake automatically, there is not yet a perfect friction appliance for TTRS. This is because every device on the market must have the brake function "defeated" by the operator during the TTRS lower. Therefore, they are susceptible to human error, fatigue, and reaction time. The MPD and I'D require more training than users have come to expect- especially in this application. The user must let go of the handles for the device to arrest. Control is increased when extra friction is incorporated, but this is somewhat arduous with lighter loads and stiffer ropes. The Münter hitch belay is compromised when excessive slack is introduced to the system. It excels and performs even better when slack is entirely eliminated within the TTRS lower. In the Münter tests, forces were lower and slip distances were lessened. The Münter hitch operation with 11 mm rope and 600 lb loads requires strength, grip, and skill. It is not self-braking and as a result, an earlier injury presented itself and compromised one tester's ability to effectively arrest the load. Since it was not self-braking, but rather required the opposite response of the MPD and the I'D- that is to "grab and hold fast."

The ASAP Lock performed exceedingly well with a heavier load than had been previously tested and no slack in the rope. The ASAP Lock was also used to "back-up" the rescuer in cases with all three appliances. It also did this task within expectations. It therefore was used as an adjunct to provide an self-brake to the Münter, the MPD, and the I'D. Though the research indicated that the ASAP would be adequate as an anchored belay with 600 lb loads, the author recommends following the parameters outlined within Petzl's Tech Tip. As an addendum, keep the tailing end of the rope snug or hand-tight. If the load is in excess of 600 lbs, it should not be a problem. The ASAP can also be used to bypass a brake device that is being operated in a TTRS lower. This is an expensive option, but one that relies on an inertial brake and cannot be defeated by the operator.

The MPD and the I'D bode well as competent belay devices, but in TTRS lowering operations they have a distinct weakness. This problem can be mitigated with added friction, rope tailing, and training repetition. But to use the I'D, MPD, and the Münter hitch in a TTRS lower requires a highly *competent belayer*. With the proliferation of TTRS use, this problem is too often overlooked.

The ASAP does not have the ability to act as a progress capture or descent control device. When used judiciously, it can perform as a competent belay with heavy loads. As with the Münter tension should be maintained and edge friction should be incorporated into the rigging. The risk with an ASAP would be users placing the device on the rope in the wrong orientation for belay. For this reason, the device should undergo a function check prior to being placed in service. The genius of this device is that it resists defeat and operates utilizing an inertial brake. For these reasons, the device acts as a *competent belay*.

The market needs devices that are more resistive to human interference or defeat. The ideal adjunct would be a device with the functionality of the CMC MPD, the size and shape of the Petzl I'D, and containing an undefeatable inertial brake similar to that of the ASAP or the 540. As many innovations are currently in the pipeline, the author feels confident a solution is on the horizon. Regarding the title of this paper, one should not mince words, a *competent belay* may not act as such in the hands of users, during TTRS lowers. In fact, old staples like the Münter may thrive and excel in these environments. TTRS lowers require *competent belayers* with training and drop testing on the given device. The act of making the catch should be practiced and repeated. Additional rope tailing or a safety bypass such as a Prusik hitch or and ASAP may be needed to ensure 100% success.

The ASAP works very well as an untensioned or also a pseudo-tensioned belay. It performs well when anchored, and can arrest the heaviest rescue sized loads. Users should keep slack out of the system. There should be enough clearance for the shock pack to fully deploy. The rope should travel through a redirect anchor and preferably one with friction. Readers interested in this technique should refer to Petzl's Tech Tip on their website.

Whether employing TTRS or traditional untensioned belays, the belay methodology should be tested under actual conditions with real operators. A belay cannot be analyzed solely on its singular ability to meet certain criteria. This is the process of developing and employing competent *belayers*. The testing, history, and experience lead the author to believe that well-trained rescuers can be trained to use the Münter hitch as an efficient belay in untensioned conditions and perhaps one of the safest adjuncts for lowering in a TTRS, among current available options. An informed decision must include actual operations, rescuers, and the environment where trainings and rescues are likely to take place. This is why the TPB continues to lose favor. It performs adequately off the flaking shelf, but poorly in the hands of users. Pendley (2010) found a 10% instance of failure and over 40% chance of unacceptable arrest distances. The same problem is found with the devices that require an operator to defeat the belay during a TTRS lower. The load will fall or crash unacceptable distances in an indeterminate number of drops based on the users and conditions. The shift to TTRS demands even more training with the popular friction devices or adjuncts in favor today. Special attention should be given to practices such as “rope tailing”, “tea cupping”, and other techniques to mitigate the hazards associated with using these devices in a TTRS lower. But most importantly, practice cutting the line. Develop a level of *competency* in your team or students, because your chosen device may not otherwise be entirely *competent* in the hands of the wrong user.

Operated TTRS Test Results

Test Number	Test Mass	Conditions / Rope Type	Absorbica Extension	Total Travel	Anchor MAF lbf	Load MAF lbf	Comments
8	**600 lbs**	TTRS MPD 11mm HTP		24" (camera est.)	636	714	Minimum extension
9	**600 lbs**	TTRS MPD 11mm HTP		24" (camera est.)	692	724	More extesnion than #8
10	**600 lbs**	TTRS MPD 11mm HTP w/ ASAP bypass	No Activation	12" (camera est.)	722	804	Used Bungee to hold ASAP Lock forward
11	**600 lbs**	TTRS MPD 11mm HTP w/ ASAP bypass	Absorbica 13.75" – 11" = 2.75"	48" (camera est.)	1360	1472	Used Bungee to hold ASAP Lock forward / operator tried to delay reaction (make ASAP activate)
12	**600 lbs**	TTRS 'D 11mm HTP		90" (camera est.)	1094	1202	No friction redirect / long fall / "felt like arm locked, with no anti-panic activation"
13	**600 lbs**	TTRS 'D 11mm HTP		35" (camera est.)	1152	1286	No friction redirect / less fall than #12
14	**600 lbs**	TTRS 'D 11mm HTP		14" (camera est.)	1010	1086	Added friction redirect / good stop
15	**600 lbs**	TTRS 'D 11mm HTP		27" (camera est.)	1096	998	Added friction redirect / good stop
16	**600 lbs**	TTRS 'D 11mm HTP w/ ASAP Bypass	No Activation	18" (camera est.)	1050	1002*	Used no redirect / good catch / no ASAP Activation
17	**600 lbs**	TTRS Munter 11mm HTP		10" (camera est.)	832	656	Pulley CoD in AHD / Minimal travel distance
18	**600 lbs**	TTRS Munter 11mm HTP		53" (camera est.)	850	744	Pulley CoD in AHD / Big slide / Operator cited old injury & nerve damage in elbow / arrested fall
19	**600 lbs**	TTRS Munter 11mm HTP		6" (camera est.)	658	660	Pulley CoD in AHD / Minimal travel distance
20	**441 lbs**	TTRS Munter 11mm HTP		settling	628	556	Pulley CoD in AHD / Minimal travel distance
21	**441 lbs**	TTRS Munter 11mm HTP		settling	608	546	Pulley CoD in AHD / Minimal travel distance
22	**441 lbs**	TTRS Munter 11mm HTP		settling	424	612	Swapped for carabiner CoD / minimal travel distance / cited much easier by operators
23	**600 lbs**	TTRS Munter 11mm HTP		settling	622	890	Swapped for carabiner CoD / minimal travel distance / cited much easier by operators
24	**600 lbs**	TTRS Munter 11mm HTP		6" (settling)	590	790	Swapped for carabiner CoD / minimal travel distance / cited much easier by operators

Test Number	Test Mass	Conditions / Rope Type	Absorbica Extension	Total Travel	Anchor MAF kN	Load MAF kN	Comments
8	**280 kg**	TTRS MPD 11mm HTP		61 cm (camera est.)	2.83	3.18	Minimum extension
9	**280 kg**	TTRS MPD 11mm HTP		61 cm (camera est.)	3.08	3.22	More extesnion than #8
10	**280 kg**	TTRS MPD 11mm HTP w/ ASAP bypass	No Activation	30 cm (camera est.)	3.21	3.58	Used Bungee to hold ASAP Lock forward
11	**280 kg**	TTRS MPD 11mm HTP w/ ASAP bypass	Absorbica 35 cm – 28 cm = 7 cm	122 cm (camera est.)	6.05	6.55	Used Bungee to hold ASAP Lock forward / operator tried to delay reaction (make ASAP activate)
12	**280 kg**	TTRS 'D 11mm HTP		229 cm (camera est.)	4.87	5.35	No friction redirect / long fall / "felt like arm locked, with no anti-panic activation"
13	**280 kg**	TTRS 'D 11mm HTP		89 cm (camera est.)	5.12	5.72	No friction redirect / less fall than #12
14	**280 kg**	TTRS 'D 11mm HTP		36 cm (camera est.)	4.49	4.83	Added friction redirect / good stop
15	**280 kg**	TTRS 'D 11mm HTP		69 cm (camera est.)	4.88	4.44	Added friction redirect / good stop
16	**280 kg**	TTRS 'D 11mm HTP w/ ASAP Bypass	No Activation	46 cm (camera est.)	4.67	4.46	Used no redirect / good catch / no ASAP Activation
17	**280 kg**	TTRS Munter 11mm HTP		25 cm (camera est.)	3.70	2.92	Pulley CoD in AHD / Minimal travel distance
18	**280 kg**	TTRS Munter 11mm HTP		135 cm (camera est.)	3.78	3.31	Pulley CoD in AHD / Big slide / Operator cited old injury & nerve damage in elbow / arrested fall
19	**280 kg**	TTRS Munter 11mm HTP		15 cm (camera est.)	2.93	2.94	Pulley CoD in AHD / Minimal travel distance
20	**200 kg**	TTRS Munter 11mm HTP		settling	2.79	2.47	Pulley CoD in AHD / Minimal travel distance
21	**200 kg**	TTRS Munter 11mm HTP		settling	2.70	2.43	Pulley CoD in AHD / Minimal travel distance
22	**200 kg**	TTRS Munter 11mm HTP		settling	1.89	2.72	Swapped for carabiner CoD / minimal travel distance / cited much easier by operators
23	**280 kg**	TTRS Munter 11mm HTP		settling	2.77	3.96	Swapped for carabiner CoD / minimal travel distance / cited much easier by operators
24	**280 kg**	TTRS Munter 11mm HTP		15 cm (settling)	2.62	3.51	Swapped for carabiner CoD / minimal travel distance / cited much easier by operators

ASAP Lock Test Results

Test Number	Test Mass	Conditions / Rope Type	Absorbica Extension	Total Travel	Anchor MAF lbf	Load MAF lbf	Comments
1	600 lbs	12.5mm HTP / carabiner redirect at AHD /	Absorbica 29.5" - 11" = 18.5"		1102	1532	Drops 1-3 Carabiner Redirect @ 15'9.5" Distance
2	600 lbs	12.5mm HTP / carabiner redirect at AHD /	Absorbica 27.5" - 11" = 16.5"	34" (roll + absorbica)	1046	1392	17.5" ASAP Travel
3	600 lbs	12.5mm HTP / carabiner redirect at AHD /	Absorbica 22" - 11" = 11"	24.5" (roll + absorbica) (camera est 36")	1176	1558	13.5" ASAP Travel
4	600 lbs	12.5mm HTP / carabiner redirect at AHD /	Absorbica 18" - 11" = 7"	15" (roll + absorbica) (camera est 24")	1140	1514	15'7.5" ASAP to AHD Redirect / Slack as ASAP tested by anchor CoD pulley / @ 8" Trvl per video
5	491 lbs	12.5mm HTP / carabiner redirect at AHD /	Absorbica 14.5" - 11" = 3.5"	11.5" (roll + absorbica) (camera est 18")	934	1256	Initial mass + 50 lb Sandbag / 8" ASAP Travel
6	600 lbs	12.5mm HTP / pulley redirect at AHD /	Absorbica 27" - 11" = 15"	17.5" (roll + absorbica) (camera est. 36")	1142	1272	Slack as ASAP tested by Anchor CoD Pulley / 2.5" Apparent Travel
7	600 lbs	12.5mm HTP / pulley redirect at AHD / Munter behind ASAP	Absorbica 23.25" - 11" = 12.25"	18.25" (roll + absorbica) (camera est 26")	1224	1408	6" Travel

Test Number	Test Mass	Conditions / Rope Type	Absorbica Extension	Total Travel	Anchor MAF kN	Load MAF kN	Comments
1	280 kg	12.5mm HTP / carabiner redirect at AHD /	Absorbica 75 cm - 28 cm = 47 cm		4.90	6.81	Drops 1-3 Carabiner Redirect @ 4.81 meters Distance
2	280 kg	12.5mm HTP / carabiner redirect at AHD /	Absorbica 70 cm - 28 cm = 42 cm	86 cm (roll + absorbica)	4.65	6.19	44.5 cm ASAP Travel
3	280 kg	12.5mm HTP / carabiner redirect at AHD /	Absorbica 56 cm - 28 cm = 28 cm	62 cm (roll + absorbica) (camera est 91 cm)	5.23	6.93	34 cm ASAP Travel
4	280 kg	12.5mm HTP / carabiner redirect at AHD /	Absorbica 45.5 cm - 28 cm = 17.5 cm	38 cm (roll + absorbica) (camera est 61 cm)	5.07	6.73	4.76 m ASAP to AHD Redirect / Slack as ASAP tested by anchor CoD pulley
5	222.7 kg	12.5mm HTP / carabiner redirect at AHD /	Absorbica 37 cm - 28 cm = 9 cm	29 cm (roll + absorbica) (camera est 46 cm)	4.15	5.59	Initial mass + 50 lb Sandbag / 20 cm ASAP Travel
6	280 kg	12.5mm HTP / pulley redirect at AHD /	Absorbica 68.5 cm - 28 cm = 40.5 cm	45 cm (roll + absorbica) (camera est. 91 cm)	5.08	5.66	Slack as ASAP tested by Anchor CoD Pulley / 6 cm Apparent Travel
7	280 kg	12.5mm HTP / pulley redirect at AHD / Munter behind ASAP	Absorbica 59 cm - 28 cm = 31 cm	46 cm (roll + absorbica) (camera est 66 cm)	5.44	6.26	15 cm Travel

Works Cited

Dill, J. (1990a). Are you really on belay part 1. *Response Magazine*, *9*(3), 14, 22-24.

Dill, J. (1990b). Are you really on belay part 2. *Response Magazine*, *9*(4), 16-21.

Mauthner, K. (2016). *EMBC Rope Rescue NIF Equipment Testing Summary Report.* Invermere, BC.

Pendley, T. (2010) Trying the "true" belay: informal belay test reveals rescuers' slow reaction time. *Fire-Rescue Magazine*. *28*(7). 46-54.

Walker, DJ. (2017). Personal email communication on the use of Münter belays in courses.

Wangsgard, J.(2017). *Anchored ASAP as a Belay for 250 kg Loads.* SPRAT Annual Conference. Phoenix, AZ.