Shock Absorbers In Rope Rescue
Questioning Their Use

Industrial shock absorbers are generally designed for use in Fall Protection. Yet, in a number of rope rescue techniques, the use of such shock absorbers is being advocated. This presentation will share the results of tests conducted to evaluate the performance of such devices in suggested rope rescue applications. The results may be 'shocking' to some.

About the Presenter:

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Introduction:
Much can be learned from observing what other disciplines do to overcome challenges similar to those that face rope rescuers practitioners. Over the years, we have borrowed many concepts, techniques and equipment from other disciplines, such as shipping and sailing, commercial rigging, and certainly mountaineering has had a tremendous influence on rope rescue's development. However, before borrowing techniques or equipment from other disciplines, rescuers must first give serious thought and consideration to the original application. What holds true in one discipline, may not at all apply to the conditions present in rope rescue.

Over the past few years, a number of rope rescue teams and organizations have incorporated shock absorbers, designed for personal fall arrest systems of single-person loads , into rope rescue systems. The presentation will take a critical look at how personal fall protection shock absorbers are currently being used in rope rescue.

Background Information:
When used in a personal Fall Arrest System (FAS), a shock absorber is placed between the dorsal "D" ring of the harness and a lanyard that is used to clip to suitable anchor points. Many variations of shock absorber and lanyard combinations exist, but the principles of how they work are generally the same.

If the person falls, then initially there will be a free-fall until the FAS comes tight; then, if enough kinetic energy is gained during the free-fall, the shock absorber begins to deploy once a certain force is reached (for North American shock absorbers, this is usually below 4 kN). The load then begins to decelerate, and the energy gained in the fall is dissipated in such a way that it should not injure that person.

The maximum arrest force (MAF) is controlled primarily by decelerating the load over a greater distance through the elongation of the shock absorber. As such, the user of such a fall arrest system must first anticipate and take into account this increase in total fall distance to ensure that the fall area is obstruction-free. Fall protection standards contain specific wording and requirements for users to consider both peak force and stopping distance.

The underlying premise of using shock absorbers in personal FAS's is to control and limit the maximum arrest force (MAF) a falling body experiences to within what are believed to be tolerable limits for sudden stops. However, there isn't common agreement between various standard setting bodies as to what this tolerable limit should be. For example, in North America, both CSA (Canadian Standards Organization) and OSHA (Occupational Safety and Health Administration) have set a limit of 8 kN, while most European countries following CE (Common

European) standards have limits set at 6 kN. In the climbing world, the UIAA (Union of International Alpine Associations) has set its upper limit at 12 kN.

Although MAF limit differences exist between standards, the body of research from which these limits are derived, is based on how much acceleration (or deceleration) a human can withstand without injury. Most medical research on this topic comes primarily from fields such as aerospace and aircraft safety, car safety, and military interests, and not necessarily from the direct testing of personal fall arrest systems using humans. As a result, the MAF limit differences between standards can largely be attributed to the difficulty of trying to extrapolate research data on tolerable limits to sudden deceleration from studies that do not necessarily represent the manner in which a fall might be arrested, whether in rope rescue or industrial fall protection.

Table 1 provides a partial summary of some studies used to establish fall protection limits. Most studies report their findings of human tolerance to sudden stops not in terms of MAF, but rather by the rate of deceleration, or m/s^2. For reference, a separate calculation has been added, to illustrate what the potential MAF would have been for an 80 kg person experiencing that rate of deceleration. Of the following, possibly the most representative study that incorporated actual human test subjects is the parachute harness study conducted by the US Military in 1968. Comparing this data to fall arrest standards, it appears that regulatory standard limits are generally fairly conservative.

Table 1: Partial Summary of Studies on Human Tolerance to Sudden Deceleration[2]

Deceleration Method	m/s^2	MAF (kN)[1]	Literature Source
Parachute Harness	147-167	12-13	Lochridge & Brinkley, 1968
Race car double shoulder and [lap] belt	196-245	16-20	Snyder, 1970
Car [lap] belt	133	11	Bruggink & Schneider, 1963
Aircraft [lap] belt	98-127	8-10	Lewis & Stapp, 1958
Car [lap] belt	98-147	8-12	Damon, Stoudt & Mcfarland, 1966
Aviation crash [lap belt]	69-147	6-12	Aviation Crash Injury Research, 1962
Aviation crash [lap & shoulder belt	245-353	20-28	Aviation Crash Injury Research, 1962

1. MAF values are based on using 80 kg to represent the mass of a person
2. Main Source: Chen H. Wang – see references

It is important to note that although the medical research demonstrates that it is the rate and duration of deceleration that determines human tolerance limits, since standard setting bodies have limited and specified the amount of mass to one person; they set their limits based on MAF. Therefore, when evaluating the use of shock absorbers for rescue work, because the loads are larger, further consideration should be given to the rate and duration of deceleration during fall arrest than just peak force, as this is what determines what humans can tolerate.

Question the Premise:

To critically examine the current use of shock absorbers in rescue work requires questioning the original premise of why they are being advocated. Some feel that the use of conventional kernmantle rescue ropes in their belay system will not provide sufficient absorptive capability to prevent injury in a fall. One source writes that, "static (low stretch) ropes do not absorb highimpact forces well enough to prevent injury to the person being belayed" (Confined Space and Structural Rope Rescue, 1998). While no documentation was provided to substantiate this claim, they go on to say that, "Many industrial teams use shock absorbers…to provide a dynamic effect in their static rope." While it has been proven that shock absorbers can effectively dissipate energy for personal fall arrest conditions, the original premise of whether or not rescue belays using conventional kernmantle rescue ropes provide enough energy dissipation to prevent patient and/or attendant injuries must still be questioned.

To assess the validity of this premise, some indicator drop tests were conducted to determine the rate and duration of deceleration of rescue belay systems using conventional kernmantle rescue rope, with and without the use of shock absorbers; this data was then compared to literature on tolerable deceleration limits. All drops were 1 m onto 3 m of Cancord 13 mm kernmantle rescue rope with a 280 kg rigid mass. The Cancord rope tends to have lower elongation properties than other similar diameter ropes, and therefore does not bias the test in favour of 'gentler' catches. Both peak force and fall distance over time were recorded. Since distance over time was measured, calculations could be made of the change in distance over time to obtain velocity; acceleration/deceleration could then be calculated by measuring changes in velocity over time.

Table 2 provides the data obtained on peak force and maximum rate/duration of deceleration for the Tandem Prusik Belay with the Radium Release Hitch (RRH), and the 540° Rescue Belay with and without a shock absorber.

Table 2: Demonstration Drop Test Data

Rescue Belay:	**MAF (kN)**	**Deceleration m/s^2**	**Duration (ms)**
Tandem Prusik Belay with RRH	16.7	43	120
540° Rescue Belay	10.8	11-19	310
540° Rescue Belay with shock absorber	8.1	12-20*	179*

* deceleration before load hit the ground; of course, deceleration rate increased substantially upon impact.

Referring back to some of the studies that OSHA used to establish their maximum fall arrest force limits, the tolerable deceleration limits seem to frequent a range of 100-150 m/s^2, which is considerably higher than the deceleration rates observed in the demonstration drops. However, since each of these reference studies are based on specific conditions, body orientations and environments, any comparisons should be done cautiously. Also, when looking at the reference studies, we need to know more about how long these deceleration rates are tolerable for.
In an article by Maurice Amphoux, entitled, "Physiological Aspects of Personal Equipment for Protection Against Falls" he writes that, "…accelerations of several thousands of m/s^2 have been tolerable for a thousandth of a second, while if the duration approaches a second, the maximum tolerance is of the order of 50 m/s^2." In other words, as the time exposure to deceleration increases, our ability to withstand higher decelerations decreases.

In the same article, Maurice Amphoux provides a graph showing how tolerance to sudden stops decreases as duration increases. When the data from Table 2 was overlaid onto his graph, the resultant deceleration and duration of rescue belays during fall arrest, appear to be well within tolerable limits, *without* the use of shock absorbers. This would invalidate the original premise of the need for shock absorbers in rescue belays.

There are also many misconceptions about rescue belay peak forces, and how the peak force is distributed among the components that comprise the load. It is incorrect to assume that each person that comprises the load, would also experience the peak force that the belay device and rope experience; more accurately, it is proportionately divided among the components that comprise the load. As a highly simplified example, if the patient and attendant were the same mass, then for the peak force of the Tandem Prusik Belay of almost 17 kN, then each would have experienced less than half of that amount, or about 7 kN each, with the equipment being subjected to the remainder. Therefore, when comparing MAF limits of regulatory setting bodies, these need to be compared to what each person sees, and not to what the anchor, belay device and rope experience.

Other Considerations:

During fall arrest, not only does peak force need to be below injurious levels (which they appear to be without the use of shock absorbers), but stopping distance must also be sufficiently short to prevent/reduce the risk of serious injury or death due to striking obstacles such as ledges, beams or the ground. Fall arrest standards contain specific wording about the requirements of ensuring that the fall area is free of obstacles. As such, any additional fall distance due to the extension of a shock absorber must be taken into account before committing to such a Fall Arrest System.

The same thinking should be applied to rope rescue. No references were made to stopping distance considerations in the literature referenced. The sample drops clearly show that there is a significant difference in stopping distance (see Table 3) when a shock absorber is used, and when it isn't.

Table 3: Stopping Distance and Maximum Arrest Force (MAF) Comparison

Rescue Belay:	Stopping Distance (cm)	System MAF (kN)
Tandem Prusik Belay with RRH	78.6	16.7
540° Rescue Belay	86.7	10.8
540° Rescue Belay with shock absorber	> 219 (hit ground)	8.1

As you can see from table 3, a shock absorber in the belay system, resulted in an increase in stopping distance from 87 cm to over 219 cm, which is more than a 2 ½ fold increase in stopping distance. This results in a much higher chance of striking an obstacle during fall arrest.

In industrial applications for fall arrest, a requirement exists to ensure that there is an obstacle-free fall-area for whichever fall arrest system is selected. In rope rescue, fall area is *much* more difficult to assess because it continually changes during the course of moving the load. That said, from a rope rescue risk management perspective, because fall area cannot easily be determined, it can be better managed by seeking systems with the lowest stopping distances, provided that MAF values are still below tolerable limits.

Summary:

From the perspective of MAF and Stopping Distance, are shock absorbers beneficial to rescue belays? For MAF, there is only a minimal, *but unnecessary* benefit because values were already within tolerable levels. However, because of the significant increase in stopping distance with shock absorbers, there is a significant increase in the risk of injury due to an increased probability of striking objects during fall arrest.

The question remains: "Why add shock absorbers if the rescue belay system using conventional kernmantle ropes already provides sufficient shock absorption and a shorter stopping distance?" Shock absorbers only add to the stopping distance and therefore increase the risk of striking obstacles during fall arrest.

Is there any place for shock absorbers in rope rescue? Under very limited conditions, yes. They are sometimes used at the mainline load attachment in wire rope systems. Wire rope, by itself, does not have enough shock absorptive capacity to keep peak forces within tolerable levels, and therefore some form of additional shock absorption is warranted. However, shock absorbers come in many forms and we shouldn't restrict our thinking to just those typically used with lanyards in personal fall protection.

Even though personal fall protection and rope rescue belays have a common objective of safely dealing with fall arrest, the conditions between the two can be very different. Load sizes are different, as are the potential severity of falls, including any considerations of the fall area in terms of potential obstacles. All of these factors directly affect how we should think about back-up rope attachments. To conclude, when we look to other disciplines to see how we can further improve our rope rescue systems, we should encourage each other to first understand why they do things the way they do, and then challenge each other to see whether or not the premise for its use is valid for rope rescue.

Key References:

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