

# Climbing Ropes

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## 1. Introduction:

The following article is not quite the final report of the Rope Deterioration Study undertaken in 1974 by the American Alpine Club. Part of the statistical data is still missing. This was done in cooperation with the Union Internationale des Associations d'Alpinisme at the instigation of our honorary member, Fritz H. E. Wiessner. Many of the regional mountaineering clubs of North America participated in the financial support necessary to carry this project through. The AAC hereby gratefully acknowledges the ongoing assistance given by the Alpine Club of Canada, the Appalachian Mountain Club, the Arizona Mountain Club, the Mazamas, the Mountaineers, the Potomac Appalachian Trail Club and the Sierra Club.

C LIMBING ropes are chosen for a variety of reasons, such as the reputation of a manufacturer or retailer, the advice of an expert climber, the type of construction, and, last but not least, the price. Because accidents caused by rope failure are rare, most climbers have no occasion to be seriously dissatisfied with their choice. Yet there are differences which affect the operation, the forces developed in a fall situation, and the lifespan of a rope to a significant degree.

The most important link in the belay chain is the climbing rope. The theoretical aspects of this chain are complex. The following is an attempt to describe the energy and force effects of a fall. From these considerations follow important consequences for choosing and using climbing ropes. The requirements of the UIAA (Union Internationale des Associations d'Alpinisme) will be given together with other rope data. Comments on the life expectancy of ropes and a summary of the properties of some of the presently available ropes conclude this report.

## 2. The Energy and Force Balance

*2.1 The Energy Equations:* During his ascent, a climber acquires potential energy (energy of position)—the ability to do work. Such forms of potential energy are known from everyday life: a lifted mass can, while it descends, lift another. The value of the potential energy is given by

$$\text{P.E.} = mgh$$

where  $m$  = mass of the climber in pounds, lb (kilograms, kg)

$g$  = acceleration due to gravity; about 32 feet per second squared,  $\text{ft}/\text{sec}^2$  (9.8 meters per second squared,  $\text{m}/\text{sec}^2$ )

$h$  = distance the mass is raised i.e. the climber ascends in feet, ft (meters, m).\*

Thus when a 180 lb (81.6 kg) climber ascends for 50 ft (15.2 m) the total acquired energy is  $288000 \text{ ft}^2\cdot\text{lb}/\text{sec}^2$  or  $\text{ft}\cdot\text{poundals}$  ( $9000 \text{ ft}\cdot\text{lbf}$ ,  $12155 \text{ kg}\cdot\text{m}^2/\text{sec}^2$  or newton meters,  $\text{N}\cdot\text{m}$ ).

Another form of energy is the kinetic energy (energy of motion). Every moving body possesses kinetic energy. The kinetic energy is expressed by the equation

$$\text{K.E.} = (\frac{1}{2})mv^2$$

where  $m$  is again the mass of the climber and  $v$  its velocity in feet per second (meters per second).

A relationship is now required which ties the above expressions together. This is found in the principle of the conservation of energy:

In a closed system the total energy, i.e. the sum of potential and kinetic energy, remains constant.

One can now consider a falling climber under these aspects. Before the fall he possesses the potential energy  $mgh$  and his kinetic energy is obviously zero. During the fall, after he has fallen a distance  $h$ , his potential energy has been reduced by the amount  $mgh$ . The principle of the conservation of energy states, however, that the sum of kinetic and potential energy is a constant. Thus it follows that the kinetic energy must have grown by the same amount. At the point when the rope starts to arrest the fall, the total original potential energy has been converted into kinetic energy. From these considerations one can write the equation

$$(\frac{1}{2})mv^2 = mgh$$

where  $v$  is the velocity at the point where the rope starts to act and  $h$  is the height of the fall. From this relationship one can derive an equation for the maximum velocity in terms of the height of fall:

$$v = \sqrt{2gh}$$

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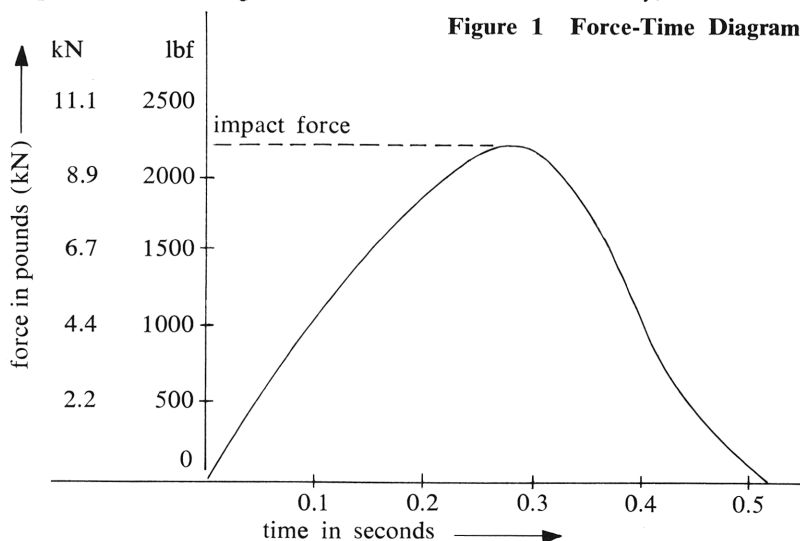
\* The British system and (in brackets) the SI system of units will be used. Mass and acceleration are defined as shown and the force is in poundals i.e.  $\text{ft}\cdot\text{lb}/\text{sec}^2$  (newtons, N, i.e.  $\text{m}\cdot\text{kg}/\text{sec}^2$ ). Because many readers may have a better feeling for force if it is expressed in pounds (pound-force, lbf) this conversion is also given where considered useful. It will precede the SI units in brackets. To convert from poundals to pound-force divide by  $g$ , the acceleration due to gravity.

*2.2 The Action of the Rope:* It has been shown that during a fall the potential energy is converted into energy of motion. It is this energy which is first absorbed by the elongation of the rope and subsequently dissipated. In order to demonstrate the action of a modern climbing rope, one often makes a comparison between ropes made of wire and rubber. Because of its limited ability to stretch, a wire rope has very little capacity to store energy. The instant the rope is loaded, nearly the total energy would be passed on to the belayer and the leader and other members of the belay chain (pitons, slings, carabiners). The results would be devastating.

A properly dimensioned rubber rope, on the other hand, would store nearly all of the fall energy and then force upon the climber a harmonic up and down motion. Despite air and internal friction (in the material) this process would last a long time. Furthermore, because of the extremely high stretch of the rubber rope, the danger of hitting a ledge or the ground would be increased.

Nylon (Perlon) ropes offer a compromise. Part of the kinetic energy is already converted into heat while the rope elongates. This is a result of friction between the individual nylon fibres in the core of the rope. Additional energy is lost through friction heat when the rope runs through carabiners. The remaining energy results in up and down motion of the fallen climber and is again changed into heat.

*2.3 Impact Force and Impulse:* So far only energy balances have been considered. Now follows a look at the forces which act on the belay chain. Another quantity needs introduction—the impulse of the falling climber. This quantity is the product of mass and velocity ( $mv$ ). One can then interpret the arresting of a fall the following way: the impulse of the falling climber, or in this case his velocity, must be re-



duced to zero. For changes in impulse, however, forces are responsible. Now changes in impulse or in velocity do not occur instantaneously, rather they take place over a certain time interval (T). During the total time interval, T, the belayer must exert a force which reaches its maximum at the point of the maximum extension of the rope. A graphical representation of this is shown in Figure 1.

The maximum force reached is called the impact force. The area under the curve is equal to the total impulse of the falling climber. One can derive an equation for this maximum force, the impact force. For a *static belay* it depends only upon the mass of the climber, a material constant (the modulus of the rope which depends upon the cross-sectional area of the rope, the fibre content, and so on) and the fall factor which is defined as the distance fallen divided by the amount of rope paid out. This maximum force is given by [1]\*:

$$I = mg + mg \sqrt{1 + \frac{2fM}{mg}}$$

where  $I$  = impact force in poundals (newtons, N)

$M$  = rope modulus in poundals (newtons, N)

$f$  = fall factor = (distance fallen)/(amount of rope paid out)

and the other terms are as defined earlier.

The amazing fact emerges that the maximum impact force is independent of the absolute height of fall. Thus a fall of 5 ft (1.5 m) will induce the same force as a fall of 50 ft (15.2 m).

Another interesting aspect is discovered when one puts  $f = 0$  in the expression, the case where a climber is vertically below his belay without slack in the rope and falls off. The equation reduces to  $I = 2mg$ . Thus a free fall into the rope without slack for a 180 lb (81.6 kg) climber produces a maximum force equal to 11520 poundals (360 lbf, 1.6 kN\*\*).

For further clarification, two examples will be considered:

- 1) Last protection placed is 5 ft (1.5 m) above belayer. Leader falls from a point 5 ft (1.5 m) above this last protection: height of fall 10 ft (3.0 m), total rope paid out 10 ft (3.0 m), fall factor is 1.
- 2) Last protection placed is 20 ft (6.1 m) above belayer. Leader falls from a point 20 ft (6.1 m) above this protection: height of fall 40 ft (12.2 m), total rope paid out 40 ft (12.2 m), fall factor is 1.

In both cases the impact force is the same although the height of fall in the second example is four times larger than in the first example. This

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\* See list of references at end.

\*\* kN = kilonewton = 1000 newton.

fact may be explained intuitively, namely the energy of the falling climber and the energy absorption capacity of the rope are directly proportional to the amount of rope paid out.

However, there is a significant difference in the two examples. In the second case, the impulse is twice the value of the first and the time over which the falling climber must be held has increased considerably. Thus the impact force alone is not a true measure of the severity of a fall. The time period over which the forces act is an intrinsic part of it. As it is well known that rather large forces but of short duration can be withstood by equipment and the human body alike, it is of paramount importance to avoid such severe falls as given in the second example.

**Table 1 Relationship of Fall Factor (f) and Impact Force for 180 lb (81.6kg) Climber.**

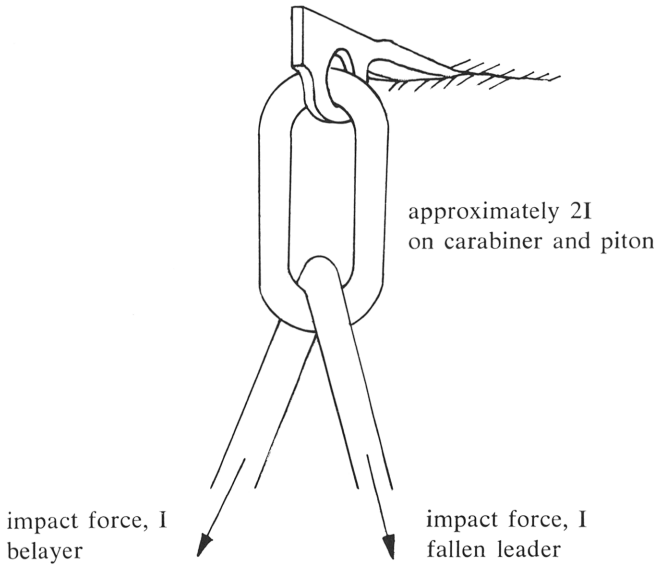
f	lbf	kN	f	lbf	kN
0.0	360	1.60	1.0	1676	7.46
0.1	683	3.04	1.2	1817	8.08
0.2	868	3.86	1.4	1947	8.66
0.4	1137	5.06	1.6	2067	9.20
0.6	1345	5.98	1.8	2181	9.70
0.8	1521	6.76	2.0	2288	10.18

Table 1 shows the relationship between fall factor and impact force for a modern kernmantel (core-and-sheath construction) rope and a climber whose mass is 180 lb (81.6 kg). As can be seen, the forces involved are considerable. Impact forces above 56300 poundals (1750 lbf, 7.8 kN) may lead to serious injuries. Only via chest and seat harnesses can these forces be distributed in a favourable way on the climber.

**Table 2 Relationship of Climber's Mass and Impact Force for Fall Factor 2.**

Mass of Climber		Impact Force		Mass of Climber		Impact Force	
lb	kg	lbf	kN	lb	kg	lbf	kN
130	59	1920	8.54	180	82	2288	10.18
140	64	1998	8.89	190	86	2357	10.48
150	68	2073	9.22	200	91	2423	10.78
160	73	2147	9.55	210	95	2489	11.07
170	77	2219	9.87	220	100	2553	11.35

Table 2 shows the impact force for various masses when the fall factor is two. The impact force with a fall factor of two is a guide post for strength considerations of other elements in the belay chain. It should be noted, however, that protection elements above the belayer such as carabiner, piton, nuts, and slings must at all times be capable of supporting twice the impact force which occurs under the given circumstances (Fig. 2).



**Figure 2 Forces in Belay Chain.**

*2.4 Conclusions:* The impact force is the force acting on the belay chain, the belayer, and the falling climber at the instant of the maximum elongation. This force is independent of the absolute height of fall but depends upon the fall factor.

The impact force alone is not a measure of the severity of a fall. Of importance is also the time period over which this force acts. The larger the impulse, the longer the time required to arrest the fall.

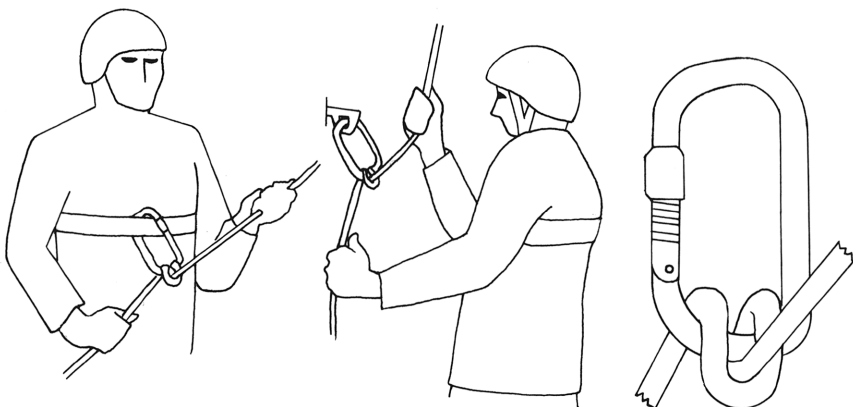
The following deduction can be made:

- i) A fall, even with an unquestionable belay stance, is at all times dangerous and should not be risked consciously, especially in the mountains or where assistance is not readily available.
- ii) The belayer must at all times be in a position to hold a force of about 74000 poundals (2300 lbf, 10.2 kN) and that independent of the expected height of fall. That is about the weight of a loaded Volkswagen.
- iii) Protection should be placed as soon as possible after leaving the belay stance in order to keep fall factors low.
- iv) Intermediate protection should be placed to keep fall factors and impulse low. It is more important, and should be placed more frequently, in the first half of the pitch than in the second.

- v) If possible, belay stances should be established after crux moves rather than before to keep the fall factor low in a potentially dangerous situation (this assumes the crux can be protected).
- vi) Tying in around the waist is strongly discouraged. Only with a chest-seat harness can the maximum impact force be tolerated safely.
- vii) Shoulder and hip belays are totally inadequate in a maximum fall situation. Severe falls with high fall factors can only be held with a modern dynamic belay.
- viii) Intermediate protection must be capable of withstanding approximately twice the impact force. For a high fall factor this may be about 128700 poundals (4000 lbf, 17.8 kN). Tie-in points at a belay stance are loaded by the impact force only but this force may act in various direction. This means, for instance, that the strongest carabiners are not necessarily required at the belay stance.

It should be pointed out again that a static belay was assumed in the derivation of the impact force. It has been known for a long time [1, 15] that these forces can and should be reduced in order to avoid belay and equipment failure and possible injury to leader and belayer alike.

Various devices are on the market, such as the Munter plate, which have been designed for dynamic belays. Not all of them do what they are supposed to. The UIAA has tested, approved and recommended the Munter hitch shown in Figure 3. In all instances each method acts



**Figure 3 The Munter Hitch.**

This is copied out of *Mountain* No. 32 February 1974 where it is called the Italian hitch because Munter demonstrated the method in Italy (at UIAA meeting) for the first time.

statically up to a certain force (the maximum force developed) after which the rope will start to slide, i.e., the rope will run through the device. Generally this run-through cannot be stopped simply by holding the rope harder but will stop once the energy of the fall has been dissipated. Thus in a severe fall, skin burn may result on the belayer's hands if no protective gloves are worn. It is obvious that a certain amount of rope must be reserved at the end of each lead for this run-through. The forces generated during dynamic belays vary from device to device but are much less than the ones occurring during static belays. Fortunately, extremely severe falls and perfectly static belays are a rarity in practice. Very few people are willing to make long leads without protection and many a burned hand and body have supplied an unwilling, although effective, dynamic belay. Otherwise many climbing accidents would have more serious consequences.

### 3. UIAA Guidelines

The UIAA (Union Internationale des Associations d'Alpinisme) has established certain guidelines for the testing of climbing ropes [2]. Ropes falling within these guidelines are given the UIAA label which is attached to each new climbing rope.

Fig. 4 shows schematically the drop-test set-up prescribed by the UIAA. This drop-test (or Doderer Test after its inventor) uses a mass of 176.4 lb (80 kg) for full weight ropes or ropes which may be used singly and 88.2 lb (40 kg) for half weight ropes or double ropes because they are designed to be used doubly. For double ropes it is also permitted to use two strands and test them with 176.4 lb (80 kg). The fall factor is 1.79 and the UIAA standard prescribes a maximum allowable impact force of 85112 poundals (2646 lbf, 11.77 kN) for single ropes or two double ropes and 42556 poundals (1323 lbf, 5.88 kN) for one strand of a double rope. The standard requires the rope to hold at least three drops without breaking. It should be noted that the impact force given on a UIAA rope label refers to the impact force at the fall factor of 1.79 and not to the higher value at fall factor two. Furthermore, the impact force limitation is applied to the first drop only. The magnitude of the impact force increases with each subsequent drop. This is a result of the permanent deformations which take place during each loading which the rope experiences.

A further test measures the elongation in use. This is a static tension test in which a force of 5674 poundals (176.4 lbf, 784 N) is applied. The elongation of the rope under this force may not exceed 7% and 10% for single and double ropes, respectively. In practice, this corresponds to a climber on tension, a situation where little elongation is desired.

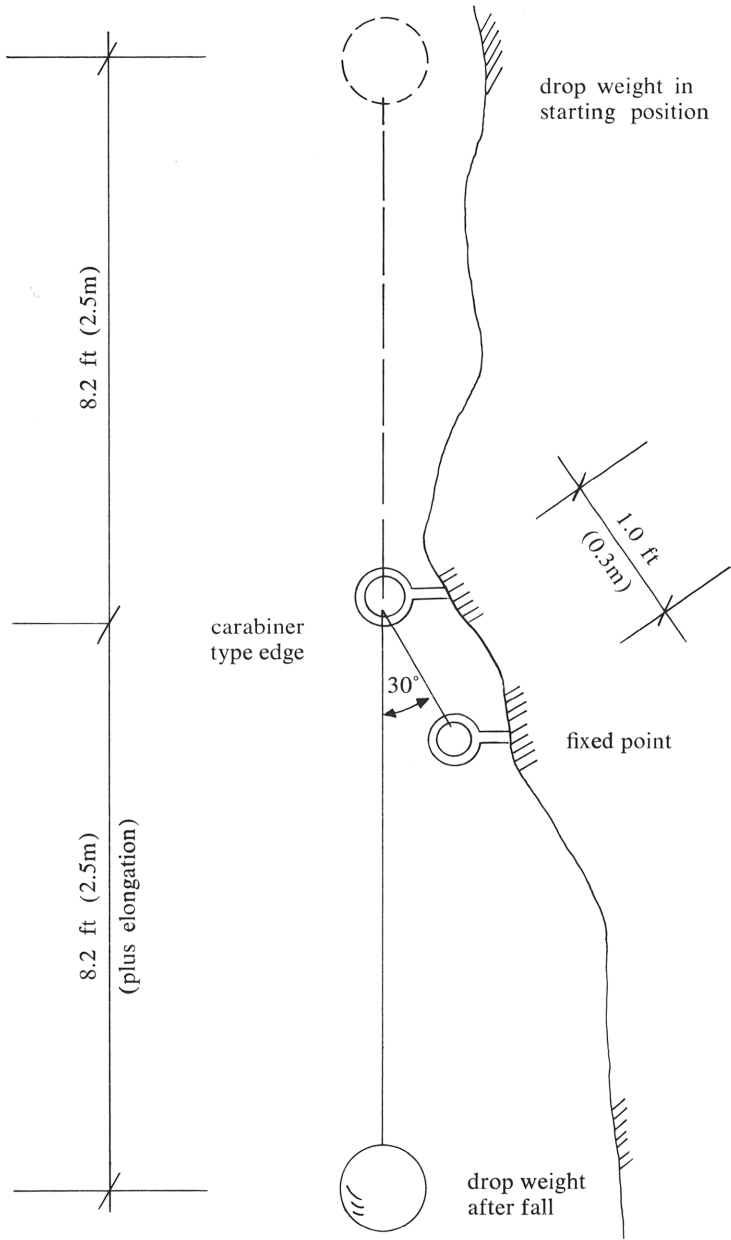


Figure 4 Schematic Drawing of UIAA Drop Test.

The elongation at impact force is the elongation which occurs under the UIAA impact force in the drop test. This value can be calculated from the data obtained in the drop test but is not subject to any UIAA standard. As the total height of fall includes the rope elongation, it is of benefit if this value is as low as possible. The danger of hitting a ledge or the ground because of rope extension is minimized.

A relatively recent (1973) addition to the rope standard measures the knotability of the rope i.e. how well a rope maintains a knot. This does not measure the strength of the knot but its durability. This is an important aspect as it has happened on several occasions that a tie-in knot has come undone only by the movements of the climber.

In order for a manufacturer to retain the UIAA label, he must have samples of his ropes tested by an independent testing laboratory every two years.

#### 4. Strength of Knots

The rope strength is not only reduced by an edge such as a carabiner, but also by knots. The literature [3, 4, 5, 6, 14] gives a considerable range of values, depending when the tests were made, the rope type used, the rope diameter, the speed of load application and the type of test set-up. It appears that all knots slip considerably during testing and in many cases to failure i.e. the knot slips open without the rope actually breaking. Note should be taken on how to tie the figure of eight loop knot. The difference of strength achieved in doing it the right or wrong way is about 8% for a kernmantel rope [4, 14] as shown in Figure 5.

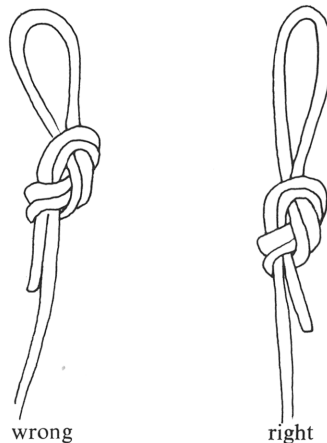


Figure 5 Figure of Eight Loop Knot.

**Table 3 Relative Strength of Knots for Single Kernmantel Rope.**

	%		%
Without knot	100	Double fisherman's	65-70
Bowline	70-75	Water knot (ring bend)	60-70
Figure of eight	75-80	Clove hitch	60-65
Fisherman's	60-65	Overhand	60-65

Table 3 shows the approximate relative strengths of some of the more commonly used knots.

### 5. Life Expectancy

During its use, a climbing rope ages due to climatic and mechanical influences. In general, the service life of a rope depends on the frequency of its use, its handling, the kind of terrain, the weather conditions, damage beyond normal use (rock fall, crampons, etc.), and the actual age of the fibres and the rope itself. In addition to these major factors many other influences enter the picture. It is, therefore, not surprising that few hard facts are available to the rope user.

Although synthetic fibre ropes (nylon and Perlon) have been around for about 30 years, very few investigations have been carried out regarding the aging of these ropes. Initially this may have been based on the fact that nylon ropes do not rot like hemp ropes. Although various conjectures about the service life of ropes were made now and then, it is only in the last few years that serious inquiries have been carried out.

The first studies were carried out in the U.S., however, they dealt solely with hawser-laid ropes. Extensive studies on kernmantel ropes were only carried out by the Austrian Alpine Club (ÖAV, Dr. Kosmath) [7] and the British Mountaineering Council (BMC) [8]. Specific problems were investigated by the Fédération Française de la Montagne (FFM) as well as by the manufacturers of Mammut ropes, AROVA—Lenzburg AG [9]. A common finding in all these studies was the considerable spread of the results. This is partly due to the small sample size and the inadequate data (uncertainty of properties of new ropes and inexact records of use) but it also indicates the complexity of the problem. The recommendations for the life time of a rope ranged from 40 to 240 hours.

The work by the ÖAV and the BMC as well as the recent AROVA—Lenzburg publication [10] express the aging in terms of the working capacity over an edge (WCOE)\*. Once the WCOE reaches a value of

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\* Obtained by statically testing a rope to failure while it runs over an edge with a 5mm radius. The WCOE is the total area under the resulting load-elongation curve. It is generally expressed per unit length of the rope.

about 11260 ft·poundals/ft to 12870 ft·poundals/ft (350 ft lbf/ft to 400 ft lbf/ft, 1560 N·m/m to 1780 N·m/m), the energy of a severe fall, the rope should be retired. If the new rope has a WCOE of, say, 27350 ft·poundals/ft (850 ft·lbf/ft, 3780 N·m/m) it would only be a matter of finding the loss in the WCOE per hour of use in order to predict the service life of a rope.

In 1971 the BMC estimated an average loss of 14.2 ft·poundals/ft (0.44 ft·lbf/ft, 2 N·m/m) per day of use while the ÖAV came up with a value of 567 ft·poundals/ft (17.6 ft·lbf/ft, 78 N·m/m) per day. These differences were partly due to the use of different statistical approaches and evaluation procedures. Furthermore, the initial values of the new ropes were not known exactly. More recently (1973) the ÖAV (Dr. Kosmath) estimates the loss of the WCOE per hour as [5]:

70.9 ft·poundals/ft (2.2 ft·lbf/ft, 9.8 N·m/m) for easy climbs

141.9 ft·poundals/ft (4.4 ft·lbf/ft, 19.6 N·m/m) for difficult climbs

283.7 ft·poundals/ft (8.8 ft·lbf/ft, 39.2 N·m/m) for artificial routes

The recent Swiss study [10] found a loss of 156.0 ft·poundals/ft (4.9 ft·lbf/ft, 21.6 N·m/m) per day for their ropes; certainly a much closer result. It should be mentioned that in this study the initial properties of the ropes were known precisely. Furthermore, the rope history (hours of use, weather, rock type, etc.) was properly documented.

Questionable in the ÖAV results is the higher value for artificial routes. One of the reasons may be found in the climbing techniques used in Europe, namely, much tension climbing, a very sparing use of slings to reduce friction drag and the abundance of limestone climbs (Dolomites), where continuous crack systems are rare. It is certainly possible that proper technique on aid routes may put less wear on a rope than many a free climb of moderate difficulty.

The problem now is that (UIAA approved rope or not) there is not a single rope manufacturer who lists the WCOE with the data supplied on the various labels which come with a rope. Only AROVA—Lenzburg, the manufacturers of Mammut ropes, give this information in their catalog on mountaineering equipment. They even add a note saying that this value—the larger the better—is an indicator of the rope's life expectancy. The reason other manufacturers do not supply these values is not only because theirs may be lower than that of a competitor or because the UIAA does not require it. There is some disagreement as to its validity because it is measured statically while in reality the loading occurs dynamically. There is even some justification in this reluctance because ropes have held one fall in the drop test while WCOE data predicted failure. Furthermore, one would expect that the rope with the highest WCOE would hold the most falls, an expectation which has not been confirmed.

Nevertheless, at the present time the only way out of this dilemma is to assume that generally the WCOE increases with the number of falls held (and this may be true for a dynamically measured WCOE) and use this number to estimate the service life of a rope. Nearly every UIAA approved rope shows on an attached label the number of falls held in accordance with the UIAA standard. Dr. Kosmath [5] of the ÖAV found that this assumption is reasonable and recommends the following values for single ropes:

<i>No. of UIAA Falls held</i>	<i>Approx. Average Service Life (hours)</i>
2	50
4	200
6	400

## 6. How Strong Are Wet and Iced-over Ropes?

The testing for the UIAA label is done with dry ropes at room temperature. The minimum requirement asks that three falls be held without a rope break.

Tests at  $-45^{\circ}\text{C}$  were carried out by Dr. Odriozola [11] who found a reduction in static breaking strength of 30% for iced ropes.

The suspicion that the working capacity is reduced not only for iced-over ropes but also for wet ropes was verified by tests done by the manufacturers of Edelweiss ropes [12]. According to the manufacturers, their new ropes which held 3 to 4 UIAA falls in the standard test, held only one or none after they were exposed to a sprinkler arrangement and absorbed about 37% of their own weight in water.

The German Alpine Club [5] carried out a series of tests on a variety of ropes. They tested wet ropes and wet-cold ropes (saturated ropes were stored for 10 to 14 hours in a refrigerator). They came to the following conclusions:

- 1) Ropes in wet and wet-cold conditions will generally hold fewer falls than dry ropes.
- 2) The effect on wet or wet-cold ropes was approximately the same.
- 3) The reduction of falls held on some products was as much as 3 falls for full weight ropes.
- 4) Some ropes held the same number of falls as indicated by the manufacturers for the dry condition. This was not taken to mean that some ropes are capable of holding the same number of UIAA falls whether dry or wet but rather that some ropes held more falls in the dry condition than indicated on the label (where obviously the lowest value has to be given).

- 5) A rope marketed as being resistant to water absorption held 2 falls less than in the manufacturers' own "wet test" condition (less saturation than in the German test).

## 7. Single or Double Rope

A single or full weight rope is by definition (UIAA) a rope which is adequately safe by itself. A half rope or double rope, on the other hand, is safe only if two ropes together are used. To clarify this further: the UIAA drop test uses a 176.4 lb (80 kg) mass for the test of single ropes, but only 88.2 lb (40 kg) for the test of one strand of a double rope. No diameter is specified but single ropes vary from 10.5mm to 12mm while double ropes vary from about 9mm to 10.5mm.

Various advantages arise from the use of two ropes on routes of a high technical standard, on rappels, for hauling, and on difficult maneuvers as a safety rope [13]. Additional benefits arise when one rope gets damaged by crampons or rock fall during a climb or when a 10.5mm diameter double rope is mistakenly used as a single (full weight) rope [5, p. 90].\*

In the use of double ropes care has to be exercised that both ropes are clipped into a particular runner (use two carabiners) when climbing free passages with little intermediate protection. There is still the question whether on some climbs it would not be prudent actually to climb with two single (full weight) ropes. This should be considered on big combined climbs where ropes may get wet and frozen or damaged by rockfall or crampons. The added safety and the advantage of clipping in alternately (reduced drag) may well be worth the extra weight. It is preferable in the latter case not to clip both ropes into the same runner even when protection is far apart as the sum of the impact forces of both ropes is larger than the impact force of a single rope in the same fall situation.

## 8. Properties of Available Ropes

Properties of some of the most commonly available ropes are listed in Table 4. Three ropes produced in the U.S. are included in this table. It may surprise that the static breaking strength has not been listed. It has been omitted intentionally as the strength per se gives no indication of the quality of a rope. Too many climbers do base their selection on this relatively unimportant quality.

Only one double rope listed was tested as a single strand with 88.2 lb. This results in a very high number of UIAA falls held and a low impact force. It is highly unlikely that the testing of two strands would produce

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\* A double rope, assumed to be a single rope, broke when the leader fell.

**Table 4 Properties of Various Climbing Ropes.**

Rope Manufacturer or Distributor		Rope Type	Elongation			Impact Force		WCOE		No. of UIAA Falls Held	Mass in UIAA Drop Test lb	Weight per Meter	
			Diam-eter mm	In Use %	At Impact Force %	lbf	kN	ft•lbf/ft Approx.	kN•m/m Approx.			Grams	Ounces
CHOUINARD		DOUBLE	9.1	3.0	N.A.	2425	10.79	617	2.75	12+	176.4	52.0	1.83
		SINGLE	10.3	4.9	N.A.	2072	9.22	661	2.94	3	176.4	66.3	2.34
EDELRID		DOUBLE	9.0	N.A.	20	1155	5.15	N.A.	N.A.	17	88.2	51.0	1.80
CLASSIC-EVERDRY		SINGLE	11.0	N.A.	21	2205	9.81	N.A.	N.A.	4	176.4	70.0	2.47
BAVARIA		SINGLE	11.5	N.A.	20	2185	9.71	N.A.	N.A.	6	176.4	75.0	2.65
EDELWEISS	STANDARD	DOUBLE	9.0	4.9	26	2315	10.30	325	1.4	10+	176.4	51.0	1.80
	STANDARD	SINGLE	10.5	3.2	29	2095	9.81	470	2.1	4	176.4	65.0	2.29
	STANDARD	SINGLE	11.0	2.4	26	2535	11.28	595	2.6	8	176.4	70.0	2.47
	EVERDRY	DOUBLE	9.0	2.5	26	2315	10.30	325	1.4	10+	176.4	51.0	1.80
	EVERDRY	SINGLE	11.0	2.4	26	2535	11.28	595	2.6	8	176.4	70.0	2.47
GOLDLINE		SINGLE	11.8	7.2	38	2170	9.64	475	2.11	12	176.4	86.4	3.05
MAMMUT	DYNAMIC	DOUBLE	9.1	3.0	24	2425	10.79	615	2.75	12+	176.4	52.0	1.83
	DYNAMIC	SINGLE	10.3	4.9	24	2070	9.22	660	2.94	3	176.4	66.3	2.34
	DYNAFLEX	DOUBLE	9.0	4.0	24	2425	10.79	615	2.75	12+	176.4	49.0	1.73
	DYNAFLEX	SINGLE	11.1	3.1	24	2335	10.40	815	3.63	8	176.4	72.0	2.54
MSR		SINGLE	10.1	8.0	35	2365	10.53	295	1.32	2	176.4	62.6	2.21
NEBTEX		SINGLE	11.7	6.4	40	1890	8.40	N.A.	N.A.	4	176.4	74.0	2.61
ROCCA	TOP	DOUBLE	9.2	5.4	N.A.	2270	10.10	N.A.	N.A.	10	176.4	47.0	1.66
	TOP	DOUBLE	10.1	4.6	N.A.	2205	9.81	N.A.	N.A.	10+	176.4	60.0	2.12
	TOP	SINGLE	11.1	3.5	N.A.	2160	9.61	N.A.	N.A.	5	176.4	71.0	2.50
	ENERGETIC	SINGLE	11.1	3.5	N.A.	1810	8.04	N.A.	N.A.	5	176.4	74.5	2.63

N.A. = Not available.

**Notes on Table 4**

CHOUINARD	— Data from 1976 production.
EDELRID	— Data from 1975 production but 1976 production appears to have same properties. — Not willing to provide WCOE values. — Note that double rope is tested as single strand with 88.2 lb mass. Double the impact force to obtain representative value.
EDELWEISS	— Data from 1975 production. — WCOE of double ropes is for a single strand only. Double the figure to obtain representative value.
GOLDLINE	— Data from 1975 production. — Only the first sample was tested to failure while the second and third test specimen were removed undamaged after four drops. The number of UIAA falls held is, therefore, around 10 to 14. — This rope is not UIAA approved.
MAMMUT	— Data from 1976 production.
MSR	— Data from 1976 production. — This rope is not UIAA approved.
NEBTEX	— Data from 1976 production.
ROCCA	— Data from 1975 production. — Not willing to provide WCOE values.

exactly the same number of falls held or result in merely twice the impact force shown. It should also be remembered that one strand of a double rope will most likely not hold a single UIAA fall with 176.4 lb. Furthermore, that the test condition assures uniform loading of both strands, a condition which rarely exists in real life.

The number of falls listed is always the least number from three tests. The difference between the minimum number given and the maximum number of falls held can easily be two.

On rope labels the impact force is often given in kilopond (kp) and sometimes in kg. The values are identical as a kilogram—force is called a kilopond in some European countries.

Three U.S. made ropes are listed: GOLDLINE, produced by Columbian Rope Co. in Auburn, N.Y.; MSR, produced by Mountain Safety Research, Inc. in Seattle, Washington; and NEBTEX, produced by New Bedford Textile Co. in New Bedford, Mass. Only the NEBTEX rope has been submitted to the UIAA and satisfied all its requirements and has been granted the UIAA label.

**9. Conclusions**

Climbing ropes, like most products, differ from manufacturer to manufacturer. In order to make a good choice one has to become familiar with the many varieties available. The UIAA norm was partly created to help climbers and mountaineers select a safe rope. However,

it provides a minimum standard and thus the UIAA label on a rope does not necessarily guarantee highest quality.

For a certain price the choice of a rope should be based upon the highest number of UIAA falls held (think of the life expectancy here), the smallest impact force elongation and the lowest weight per unit length. The WCOE should be as high as possible while the impact force should be as low as possible. For these last two points one should keep in mind that presently the WCOE is obtained statically and thus not a true indicator of the working capacity in a real fall situation and that the magnitude of the impact force has to a large extent lost its importance because of the possibilities of providing reliable dynamic belays. This fact is reflected in the rather high impact force values of recently manufactured ropes which, of course, hold more UIAA falls than before while maintaining the same unit weight. This last development is a direct result of the work carried out by the UIAA and its recommendation of the Munter hitch for dynamic belays.

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