Series of tests on Cow's Tails used for progression on semi-static ropes

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These tests were carried out by Sylvain Borie, Gérard Cazes, Nicolas Clément and José Mulot, from 26th-29th June 2006, in the laboratory of the National Ski and Mountaineering School (*l'École Nationale de Ski et d'Alpinisme*) in Chamonix.

The summary has been put together by Sylvain Borie.

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To CAMP for providing several different types of Cow's Tails specially for this study.

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Index :

The page sequence of the original report has been adhered to in this translation. Footnotes and Annexes have been added to the text in translation to help clarify various points.

Introduction

Work carried out by the DPMC Technical Committee (a committee bringing together representatives from different companies who work with ropes, and training centres as well as the manufacturers) and by the French Caving School highlighted significant differences both in the material currently used to move along semi-static ropes, and in the difficulty they have in recommending one material in particular.

Many companies, clubs and individuals looking to purchase Cow's Tails[1] currently use those which conform to EN 354[2]. However it has been proved that some of these products that conform to EN 354, and more specifically those made from sewn tape, seem to generate considerable shock loading when subjected to a Fall Factor 1.

Another option involved using Cow's Tails made from rope with sewn ends, attaching them to the harness with a knot (in the middle).

Finally many people continue to make their own Cow's Tails by using a dynamic rope and three knots, a very common practice among cavers.

The objective of this series of tests is to measure the shock loads generated by the different Cow's Tails in several configurations, so as to be able to identify those which can cause risks and therefore make recommendations regarding good practice with existing material.

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[1] This translation uses the terms Cow's Tail(s) in place of the translation "speleological lanyard(s)" since this is the commonly known name in the UK for the item. It should be noted that some of the tests were undertaken on single lengths of rope with a loop at each end; which is known as a lanyard in the UK.

[2] Equivalent to BS EN 354 : 2002

The protocol

All the knots were tied by the same person, following the standard rules and without any crossing of strands.

The knots were then preloaded with a slow pull[3] of 3 kN[4]. This value represents a typical force exerted on a Cow's Tail by a 80 kg person moving somewhat "brutally" (cf. tests carried out by the French Cave Rescue Team in 1994 and 1996).

Furthermore after several attempts we were able to confirm that this figure of 3 kN gave knots which most closely represented those knots that we could find on Cow's Tails in use.

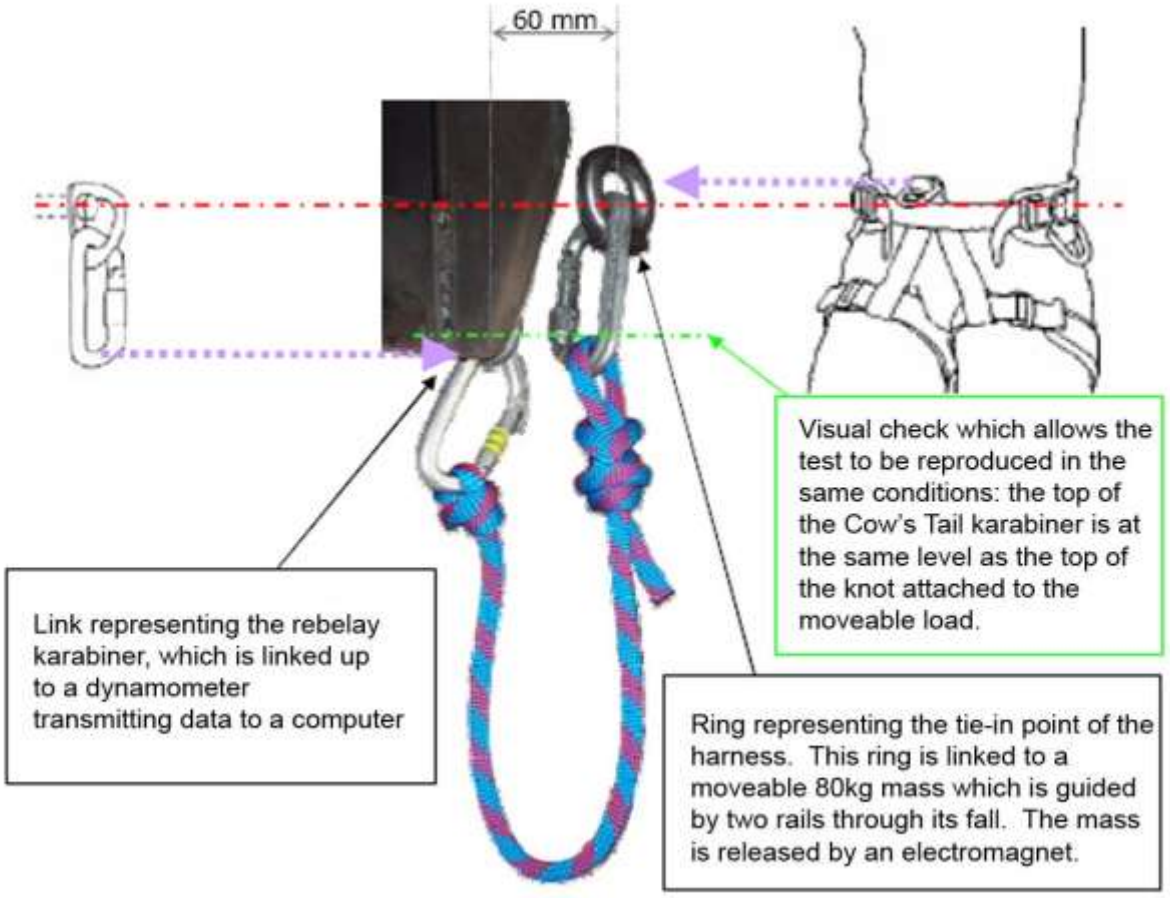
The Cow's Tails were then measured and marked.

[3] Where the knot is "dressed" and then subject to a preload of 3 kN by a slowly applied "static" load (as opposed to a dynamic load such as would arise from a sudden fall).

[4] The French document cites 300 daN. The deca newton (daN) is used as an approximation to the kilogram-force, being exactly rather than approximately 10 newtons. All forces quoted in this translation will be in kN using a conversion factor of 100 daN per kN.

The Fall-Factor 1 Test :

Here are the detail of the protocol for the Fall-Factor 1 tests which represented the vast majority of the tests that we carried out. The test rig, being used regularly for testing sporting equipment, was equipped with an 80kg load (and not 100kg as is the case for the standards for work equipment.)



Capturing the data and then classifying and storing the Cow's Tails.

Various Dynamic Tests :

The test described here is the one which will be referred to as a Fall Factor 1 in the whole of this document. It corresponds to the situation when the user is level with the anchor, that is to say when the tie-in point of the harness is level with the hanger. However, although you can effectively think of the Fall Factor in this exact case as close to 1 with a long length of rope, we are going to see that the Fall Factor in the case that we are interested in, that is in the case of Cow's Tails, is far from being a true Fall Factor 1[5].

In fact if we take the diagram from the previous page, we have in the case of one side of a Cow's Tail which is 36 cm long, a Fall Factor of:

The length of one side of the Cow's Tail = 36 cm

+

The length of the Cow's Tail karabiner = 9 cm

+

2 x the length of the harness karabiner[6] = 18 cm

=

63 cm

Which gives us a Fall Factor of : 63/36 = 1.75

For a Cow's Tail side which is 60cm long, this Fall Factor is : 87/60 = 1.45

The Fall Factor being equal to the height of the fall divided by the length of the rope able to absorb this fall[5].

This Factor would be slightly lower if the knot at the harness end were attached directly into the ring (representing the tie-in point of the harness). However, we should also take into account the turning of the tie-in point and the majority of Cow's Tail karabiners being more than 9cm long. Certain tests are titled "Real Fall Factor 1". In these cases we have measured the length of the Cow's Tails, have then suspended the load from it in the test rig and then raised the load to the length of the Cow's Tails. These tests then correspond correctly with a Fall Factor 1. For the tests titled "Real Fall Factor 2", we proceeded similarly but with the load raised to twice the length of the Cow's Tails.

Test 238

[5] An inherent presumption in defining a Fall Factor is that the whole length from anchor to suspension point of the person is energy absorbing rope. In practice there will be two karabiners and possibly other items not made of rope in this length. Thus the length of energy absorbing material is not quite the overall length. This presumption can be neglected when the overall length is large, but it is not valid for distances of less than 2 metres. In addition, the presence of a knot plus a loop, which could be considered as two lengths of rope, also undermines this presumption.

[6] It should be noted that according to the diagram on page 5, the harness attachment point is one karabiner's length above the actual attachment point of the test rig, hence this distance is doubled.

The tests entitled "Fall Factor 2" correspond to the situation that is commonly described as when the user finds himself above his anchor point with the Cow's Tails pulled between the anchor and his central tie-in point. As a point of reference for these tests, we used the position of the Cow's Tails karabiner. That is to say that we raised the load until this karabiner was vertical but without it lifting the karabiner at the anchor.

The length of fall for ones die of a Cow's Tail with a length of 36cm:

2 x the length of one side of the Cow's Tail = 72 cm

+

2 x the length of the Cow's Tail karabiner = 18 cm

+

2 x the length of the harness karabiner = 18 cm

=

108 cm

Which gives us a Fall Factor of : 108/36 = 3

For a Cow's Tail side which is 60cm long, this Fall Factor is : 156/60 = 2.6

<u>The Static Tests:</u>

These tests were carried out with a hydraulic ram extending at a speed of 720mm/min. The force is given by the deforming of a metal sensor. The test rig records the peak load, that is, the highest force held by the material being tested.

<u>Averages and Standard Deviations :</u>

The results table shows the mean value of these tests in kN for all the tests repeated a minimum of 6 times using the same protocol, together with the standard deviation, both in kN and as a % of the mean. The percentage corresponds to the coefficient of variation reflecting the relative variability of the results (it corresponds to the relationship between the standard deviation and the mean).

From a purely statistical point of view, this data in not relevant given such a low number of values. It does, however, give the reader some additional information.

The Knots

We do not think it is necessary to describe either the Figure of Eight Knot[7] or the Overhand Knot[8], but we will spend some time on a knot which is becoming increasingly used in caving. To our knowledge it does not yet have a name. The name which best fits this dynamic knot is "half a double fisherman's" (or Barrel Knot)[9]. It has the double advantage of being compact and of holding the karabiner in the correct position without needing to add an accessory. To our knowledge this knot does not feature in any publication. It therefore became important to study its behaviour, both from the point of view of a static and a dynamic force.

Stage 1

Stage 2

Stage 3

A situation can occur where the knot sticks under the gate of the karabiner (photo opposite) and this is particularly prevalent with people who permanently have either a handled or a basic ascender in their Cow's Tails karabiner.

One of the objectives of these tests will also be to determine whether or not this can create a problem during a fall.

[7] It is considered that they mean the double figure of eight as can be deduced from some of the photographs used in the document, see Annex A.

[8] It is considered that they mean the overhand knot on a bight, see Annex B.

[9] This has been described in previous English publications as a Barrel Knot, see Annex C. The term Barrel Knot will be used in this translation.

Results

Tape Cow's Tail :

The model tested is the Spelegyca Cow's Tail from PETZL[10] which has a long side of 60cm and a short one of 32cm.

No	Name	length	Fall Factor	Force
		cm		kN
1	Spelegyca short side	32	1	11.45
2	Spelegyca short side	32	1	11.63
3	Spelegyca long side	60	1	10.41
4	Spelegyca long side	60	1	10.47
5	Spelegyca with both sides connected		1	14.76
6	Spelegyca with both sides connected		1	15.79
7	Spelegyca	32	Real Fall Factor 1	10.03
8	Spelegyca	60	do	9.18
9	Spelegyca	32	0.5	5.57
10	Spelegyca	60	0.5	5.95

Manufacturer's Data: The SPELEGYCA is made of static webbing with stitching that is designed to rip to dissipate the energy of a fall. This dissipation system allows the SPELEGYCA to meet the same impact force requirements as a EN 892 dynamic rope. In our laboratory, a factor 2 fall on a SPELEGYCA with a mass of 80 kg yields a maximum impact force of 12 kN (EN892 dynamic rope requirement for a factor 2 fall with an 80 kg mass = Impact force less than 12 kN).


Schéma PETZL

For tests 1, 2, 3, 4, 7 and 8, the stitching in the unused side of the Cow's Tail ripped completely which must absorb part of the energy.

For tests 9 and 10 this stitching started to rip but only by a couple of centimetres.

For tests 5 & 6 the very high shock load measured is explained by the fact that, as the two sides are connected to the rebelay point, the dissipation of energy by the ripping can only take place for about 15 cms.

[10] See Annex D

Sewn Cow's Tails :

We were able to test three models of entirely manufactured Cow's Tails :

- The Jane lanyard from PETZL[11], consisting of 11mm dynamic rope with sewn ends of about 4cm each.

Length 60 cm:

No	Name	length	Fall Factor	Force
		cm		kN
11	PETZL Jane 11 mm	63	1	8.30
12	PETZL Jane 11 mm	63	1	8.49
13	PETZL Jane 11 mm	63	Real Fall Factor 1	6.16
14	PETZL Jane 11 mm	63	2	11.09
15	PETZL Jane 11 mm	62	2	12.03
16	PETZL Jane 11 mm	62	2	11.40
17	PETZL Jane 11 mm	62	Real Fall Factor 2	9.73

- A CAMP prototype Cow's Tails made up of 11mm dynamic rope with sewn ends of about 8cm each.

Length 60 cm and 32 cm:

No	Name	length	Fall Factor	Force
18	CAMP 11 mm	59	1	8.67
19	CAMP 11 mm	59	1	8.95
20	CAMP 11 mm	33	1	9.54
21	CAMP 11 mm	33	1	10.03
22	CAMP 11 mm	60	2	12.73
23	CAMP 11 mm	60	2	12.67
24	CAMP 11 mm	35	2	13.37
25	CAMP 11 mm	35	2	12.98

The 5% difference that exists between tests 11-12 and 18-19 is to be explained by the difference in sewing between the two products. With the Jane there was about 80% of the rope free between the two sets of stitching, as against only 65% with the prototype made by CAMP for the occasion.

[11] See Annex E

- A CAMP prototype Cow's Tails consisting of 9mm dynamic rope with about 10cm of stitching at each end.

Length 60 cm and 32 cm:

No	Name	length	Fall Factor	Force
		cm		kN
26	CAMP 9 mm	58	1	8.40
27	CAMP 9 mm	58	1	8.71
28	CAMP 9 mm	33	1	9.42
29	CAMP 9 mm	33	1	9.59
30	CAMP 9 mm	60	2	12.28
31	CAMP 9 mm	60	2	12.26
32	CAMP 9 mm	35	2	13.04
33	CAMP 9 mm	35	2	12.94

The difference between the 11 mm and the 9 mm (that is between tests 18 to 25 and 26 to 33) is, for these entirely sewn Cow's Tails, insignificant as it is only 2.6%

Mixed Cow's Tails (Sewn & Knotted) :

For these tests we used Cow's Tails made with one sewn end (identical to those described above) and the other with different knots:

- **Sewn – Figure of Eight Knot**

(Average of these 14 tests: 7.07 kN - Standard deviation: 0.26 kN or 4 %):

No	Name	length	Fall Factor	Force
		cm		kN
34	CAMP 11 mm	60	1	6.98
35	CAMP 11 mm	60	1	7.20
36	CAMP 11 mm	33	1	6.74
37	CAMP 11 mm	33	1	6.96
38	CAMP 9 mm	58	1	7.08
39	CAMP 9 mm	58	1	7.25
40	CAMP 9 mm	32	1	6.82
41	CAMP 9 mm	32	1	7.22
42	PETZL Jane 11 mm	61	1	7.11
43	PETZL Jane 11 mm	62	1	6.98
44	PETZL Jane 11 mm	36	1	6.62
45	PETZL Jane 11 mm	37	1	6.96
46	MILLET 11 mm	36	1	7.46
47	MILLET 11 mm	37	1	7.59
48	PETZL Jane 11 mm	60	2	9.29

- Sewn – Overhand Knot

(Average of these 14 tests: 7.50 kN - Standard deviation: 0.33 kN or 4%):

No	Name	length	Fall Factor	Force
49	CAMP 11 mm	60	1	7.37
50	CAMP 11 mm	60	1	7.02
51	CAMP 11 mm	33	1	7.43
52	CAMP 11 mm	33	1	7.41
53	CAMP 9 mm	57	1	7.63
54	CAMP 9 mm	57	1	7.77
55	CAMP 9 mm	32	1	8.03
56	CAMP 9 mm	32	1	7.59
57	PETZL Jane 11 mm	58	1	7.52
58	PETZL Jane 11 mm	62	1	7.43
59	PETZL Jane 11 mm	38	1	7.46
60	PETZL Jane 11 mm	37	1	6.73
61	MILLET 11 mm	33	1	7.83
62	MILLET 11 mm	33	1	7.82

(Average of these 7 tests: 10.27 kN - Standard deviation: 0.10 kN or 1%):

No	Name	length	Fall Factor	Force
		cm		kN
63	CAMP 11 mm	60	2	10.33
64	CAMP 11 mm	60	2	10.40
65	CAMP 9 mm	60	2	10.29
66	CAMP 9 mm	60	2	10.16
67	PETZL Jane 11 mm	60	2	10.12
68	PETZL Jane 11 mm	60	2	10.33
69	PETZL Jane 11 mm	57	2	10.28

- **Sewn – Clove Hitch**

(Average of these 12 tests: 6.87 kN - Standard deviation: 0.25 kN or 4 %):

No	Name	length	Fall Factor	Force
70	CAMP 11 mm	60	1	7.12
71	CAMP 11 mm	60	1	7.06
72	CAMP 11 mm	30	1	6.92
73	CAMP 11 mm	30	1	6.46
74	CAMP 9 mm	60	1	7.06
75	CAMP 9 mm	60	1	7.26
76	CAMP 9 mm	30	1	6.85
77	CAMP 9 mm	30	1	6.84
78	PETZL Jane 11 mm	52	1	6.82
79	PETZL Jane 11 mm	54	1	6.92
80	PETZL Jane 11 mm	29	1	6.40
81	PETZL Jane 11 mm	32	1	6.74

- **Sewn – Barrel Knot**

(Average of these 12 tests: 6.61 kN - Standard deviation: 0.24 kN or 4 %):

No	Name	length	Fall Factor	Force
82	CAMP 11 mm	60	1	6.65
83	CAMP 11 mm	60	1	6.44
84	CAMP 11 mm	33	1	6.50
85	CAMP 11 mm	33	1	6.29
86	CAMP 9 mm	57	1	6.90
87	CAMP 9 mm	57	1	6.80
88	CAMP 9 mm	32	1	6.62
89	CAMP 9 mm	32	1	6.87
90	PETZL Jane 11 mm	59	1	6.98
91	PETZL Jane 11 mm	56	1	6.58
92	PETZL Jane 11 mm	36	1	6.21
93	PETZL Jane 11 mm	36	1	6.51
94	PETZL Jane 11 mm	54	2	8.80

Knotted Cow's Tails:

For these tests we have used Cow's Tails knoted at both ends :

- **Figure of Eight – Figure of Eight**

(Average of these 18 tests: 5.83 kN - Standard deviation: 0.25 kN or 4 %):

No	Name	length	Fall Factor	Force
		cm		kN
95	CAMP 11 mm	53	1	5.90
96	CAMP 11 mm	53	1	5.93
97	CAMP 11 mm	43	1	5.61
98	CAMP 11 mm	43	1	5.54
99	CAMP 9 mm	62	1	6.27
100	CAMP 9 mm	62	1	6.29
101	CAMP 9 mm	38	1	5.87
102	CAMP 9 mm	38	1	5.97
103	PETZL Jane 11 mm	60	1	5.31
104	PETZL Jane 11 mm	59	1	5.96
105	BEAL Apollo II 11 mm	58	1	5.88
106	BEAL Apollo II 11 mm	58	1	5.89
107	BEAL Flyer II 10.2 mm	60	1	5.95
108	BEAL Flyer II 10.2 mm	60	1	5.79
109	BEAL Verdon II 9 mm	60	1	5.95
110	BEAL Verdon II 9 mm	60	1	5.56
111	BEAL Ice Line 8.1 mm	59	1	5.67
112	BEAL Ice Line 8.1 mm	59	1	5.51

The results of these tests are all very close to each other, the standard deviation is only 0.25 kN, while the ropes used are very different. It seems, therefore, that the tightening of the knots has a lot more influence on the shock load than the type of rope.

In order to confirm this hypothesis, we therefore, subsequently carried out the same test but with semi-static rope:

No	Name	length	Fall Factor	Force
113	BEAL Antipodes 9 mm new	50	1	8.46
114	BEAL Antipodes 9 mm new	50	1	7.56
115	BEAL Antipodes 9 mm used (first used: 2002)	61	1	7.06
116	BEAL Antipodes 9 mm used (first used: 2002)	65	1	6.23

The average of these 4 tests (7.33 kN) is logically higher than with the dynamic rope, but still reasonable (and well within the forces reached with the entirely manufactured Cow's Tails).

- **Overhand Knot – Overhand Knot**

(Average of these 18 tests: 6.35 kN - Standard deviation: 0.27 kN or 4 %):

No	Name	length	Fall Factor	Force
		cm		kN
117	CAMP 11 mm	58	1	6.43
118	CAMP 11 mm	58	1	6.77
119	CAMP 11 mm	35	1	6.33
120	CAMP 11 mm	35	1	6.42
121	CAMP 9 mm	62	1	6.51
122	CAMP 9 mm	62	1	6.67
123	CAMP 9 mm	38	1	6.52
124	CAMP 9 mm	38	1	6.64
125	PETZL Jane 11 mm	52	1	6.27
126	PETZL Jane 11 mm	54	1	6.78
127	BEAL Apollo II 11 mm	58	1	6.32
128	BEAL Apollo II 11 mm	58	1	6.19
129	BEAL Flyer II 10.2 mm	55	1	6.34
130	BEAL Flyer II 10.2 mm	55	1	6.16
131	BEAL Verdon II 9 mm	60	1	5.97
132	BEAL Verdon II 9 mm	60	1	5.95
133	BEAL Ice Line 8.1 mm	53	1	6.04
134	BEAL Ice Line 8.1 mm	53	1	5.99

The results of these tests are also very close to each other, the standard deviation is 0.27 kN.

The same test but with semi-static rope:

No	Name	length	Fall Factor	Force
135	BEAL Antipodes 9 mm new	49	1	9.40
136	BEAL Antipodes 9 mm new	51	1	9.24
137	BEAL Antipodes 9 mm used (first used : 2002)	57	1	7.05
138	BEAL Antipodes 9 mm used (first used : 2002)	63	1	7.12

The average of these 4 tests is 8.20 kN.

As with tests 113 to 116 there is a reduction of about 20% in the shock load with used rope. This is explained by the fact that, with time, there is damage to part of the rope's fibres, making it more dynamic (but weaker).

- **Figure of Eight Knot – Barrel Knot**

(Average of these 18 tests: 5.76 kN - Standard deviation: 0.28 kN or 5 %)

No	Name	length	Fall Factor	Force
		cm		kN
139	CAMP 11 mm	59	1	5.42
140	CAMP 11 mm	59	1	5.57
141	CAMP 11 mm	39	1	5.28
142	CAMP 11 mm	39	1	5.38
143	CAMP 9 mm	55	1	5.90
144	CAMP 9 mm	55	1	5.95
145	CAMP 9 mm	42	1	5.62
146	CAMP 9 mm	42	1	5.74
147	PETZL Jane 11 mm	66	1	6.02
148	PETZL Jane 11 mm	55	1	5.70
149	BEAL Apollo II 11 mm	58	1	5.85
150	BEAL Apollo II 11 mm	58	1	5.88
151	BEAL Flyer II 10.2 mm	60	1	5.84
152	BEAL Flyer II 10.2 mm	60	1	6.53
153	BEAL Verdon II 9 mm	60	1	5.66
154	BEAL Verdon II 9 mm	60	1	5.71
155	BEAL Ice Line 8.1 mm	55	1	5.88
156	BEAL Ice Line 8.1 mm	55	1	5.81
157	BEAL Verdon II 9 mm	60	2	7.25
158	BEAL Verdon II 9 mm	60	2	7.39

- **Overhand Knot – Barrel Knot**

(Average of these 18 tests: 5.97 kN - Standard deviation: 0.23 kN or 4 %):

No	Name	length	Fall Factor	Force
159	CAMP 11 mm	64	1	5.96
160	CAMP 11 mm	64	1	6.10
161	CAMP 11 mm	41	1	5.55
162	CAMP 11 mm	41	1	5.63
163	CAMP 9 mm	61	1	6.10
164	CAMP 9 mm	61	1	6.45
165	CAMP 9 mm	38	1	5.93
166	CAMP 9 mm	38	1	5.78
167	PETZL Jane 11 mm	48	1	6.05
168	PETZL Jane 11 mm	53	1	6.09
169	BEAL Apollo II 11 mm	58	1	6.07
170	BEAL Apollo II 11 mm	58	1	5.71
171	BEAL Flyer II 10.2 mm	60	1	6.05
172	BEAL Flyer II 10.2 mm	60	1	6.26
173	BEAL Verdon II 9 mm	60	1	5.90
174	BEAL Verdon II 9 mm	60	1	5.67
175	BEAL Ice Line 8.1 mm	54	1	6.16
176	BEAL Ice Line 8.1 mm	54	1	6.00

- **Figure of Eight Knot – Badly-positioned Barrel Knot**

One of the concerns with a Barrel Knot is that this self-tightening knot can often position itself, and even stick, under the gate of the karabiner (see photo p.8); a particularly likely occurrence among people who keep a handled or a basic jammer permanently in their Cow's Tail karabiner. A large force around this area of the karabiner could be critical, particularly when caving, where the snap-gate karabiners are used and where you can't prevent the gate opening at the point of shock loading.

Accordingly we carried out a series of tests for which, after preloading to 3 kN, we deliberately placed the knot just under the lower axis of the gate of the Cow's Tail karabiner (photo p.8)

(Average of these 8 tests: 5.70 kN - Standard deviation: 0.12 kN are 2 %):

No	Name	length	Fall Factor	Force
		cm		kN
177	BEAL Apollo II 11 mm	58	1	5.88
178	BEAL Apollo II 11 mm	58	1	5.68
179	BEAL Flyer II 10.2 mm	60	1	5.63
180	BEAL Flyer II 10.2 mm	60	1	5.81
181	BEAL Verdon II 9 mm	60	1	5.60
182	BEAL Verdon II 9 mm	60	1	5.50
183	BEAL Ice Line 8.1 mm	53	1	5.76
184	BEAL Ice Line 8.1 mm	53	1	5.75

The results are almost identical to those obtained for tests 139 to 156 (5.70 kN as against 5.76 kN). But it is important to note here that, during the shock, the knot moved to take up its normal position at the base of the karabiner.

- **Figure of Eight Knot – Badly-positioned Barrel Knot : Fall Factor 2**

(Average of these 11 tests: 7.65 kN - Standard deviation: 0.36 kN or 5 %):

No	Name	length	Fall Factor	Force
		cm		kN
185	CAMP 11 mm	55	2	7.80
186	CAMP 9 mm	55	2	8.14
187	CAMP 9 mm	55	2	7.87
188	BEAL Apollo II 11 mm	55	2	8.04
189	BEAL Apollo II 11 mm	55	2	7.75
190	BEAL Flyer II 10.2 mm	55	2	7.61
191	BEAL Flyer II 10.2 mm	55	2	7.90
192	BEAL Verdon II 9 mm	55	2	7.24
193	BEAL Verdon II 9 mm	55	2	6.95
194	BEAL Ice Line 8.1 mm	55	2	7.44
195	BEAL Ice Line 8.1 mm	55	2	7.43

As for tests 177 to 184, each time the knot moved to take up its normal position at the base of the karabiner during the shock.

Special Cases :

After covering the normal usage of Cow's Tails (Fall Factor 1) we tried to imagine the extreme or obscure situations that might be encountered.

Badly tied knots :

For these two series of tests the knots were intentionally badly made. That is to say the ropes crossed over each other in several sections of the knot. They were then preloaded in the same way as for other tests.

- **Figure of Eight Knot – Figure of Eight Knot**

(Average of these 6 tests: 5.69 kN - Standard deviation: 0.13 kN or 2 %):

No	Name	length	Fall Factor	Force
		cm		kN
196	BEAL Flyer II 10.2 mm	60	1	5.78
197	BEAL Flyer II 10.2 mm	60	1	5.91
198	BEAL Verdon II 9 mm	60	1	5.71
199	BEAL Verdon II 9 mm	60	1	5.59
200	BEAL Ice Line 8.1 mm	60	1	5.58
201	BEAL Ice Line 8.1 mm	60	1	5.58

- **Overhand Knot – Overhand Knot**

(Average of these 6 tests: 6.19 kN - Standard deviation: 0.20 kN or 3 %):

No	Name	length	Fall Factor	Force
202	BEAL Flyer II 10.2 mm	60	1	6.49
203	BEAL Flyer II 10.2 mm	60	1	6.33
204	BEAL Verdon II 9 mm	60	1	6.22
205	BEAL Verdon II 9 mm	60	1	6.13
206	BEAL Ice Line 8.1 mm	60	1	6.02
207	BEAL Ice Line 8.1 mm	60	1	5.97

If we compare the table of "Badly tied knots" with the table of the same tests for the "Well tied knots", that is to say 107 to 112 for the Figure of Eight and 129 to 134 for the Overhand, we can see that the differences are insignificant. So for the Figure of Eight the average is 5.74 kN for the well-tied knots as against 5.69 kN here, giving a difference of less than 1%. For the Overhand Knot we go from 6.08 kN to 6.19 kN, a difference of less than 2%. We can, therefore, say that the knots perform their shock absorbing role just as well when well-tied as when badly tied, that is with ropes crossing each other.

Knots which were not pre-tightened :

- **Sewn – Barrel Knot**

For the following two tests, the Barrel Knots were not pre-tightened, either by machine or by hand.

No	Name	length	Fall Factor	Force
		cm		kN
208	CAMP 11 mm	60	1	5.80
209	CAMP 9 mm	60	1	5.93

As could be anticipated, the shock loads registered are lower than those registered for the same tests with pre-tightening. 5.80 kN here, against 6.55 kN (average of tests 82-83) representing 11.5 % for 11mm and 5.93 kN versus 6.85 kN (average of tests 86 and 87) representing 13.5% for the 9mm. But what is particularly interesting to note is that the slippage of the tail end in the knot was not significant (between 1 and 1.5cm measured).

Two Cow's Tails connected :

It could well happen that, at the moment of the fall, the two ends of the Cow's Tail are connected and that they both help in stopping the fall, something which is more likely to occur with identical, or very similar Cow's Tail lengths.

No	Name	length	Fall Factor	Force
		cm		kN
210	CAMP 11 mm Sewn - Sewn	60	1	9.95
211	CAMP 11 mm Sewn - Sewn	60	1	9.92
212	PETZL Jane 11 mm Sewn - Overhand	60	1	8.05
213	PETZL Jane 11 mm Sewn - Overhand	60	1	8.30
214	BEAL Verdon II 9 mm Overhand - Overhand	54	1	6.80
215	BEAL Verdon II 9 mm Overhand	54	1	7.43
216	BEAL Verdon II 9 mm Overhand	49	1	6.66
217	BEAL Verdon II 9 mm Overhand	49	1	6.64
218	BEAL Verdon II 9 mm Overhand - Barrel	54	1	7.30
219	BEAL Verdon II 9 mm Overhand	54	1	7.40
220	BEAL Verdon II 9 mm Overhand	52	1	6.09

If we compare the tests with the 11 mm CAMP with tests 18 & 19, we can see an increase of 11 % in the shock loading, 9 % with the PETZL Jane, 13 % with the Verdon II overhand-overhand and 17 % for the Verdon II Overhand-Barrel Knot. The shock load therefore increases even if the fall is stopped simultaneously by the two Cow's Tails, although this increase is limited.

Fall Factor 2 Falls :

Although good practice excludes these situations, we wanted to know what would happen, knowing that it is very easy to encounter a Fall Factor 2, either voluntarily or involuntarily.

The following tables show tests appearing previously and thus keep the same numbers.

Sewn Cow's Tails

(Average of these 11 tests: 12.44 kN - Standard deviation: 0.71 kN or 5 %):

No	Name	length	Fall Factor	Force
		cm		kN
14	PETZL Jane 11 mm	63	2	11.09
15	PETZL Jane 11 mm	62	2	12.03
16	PETZL Jane 11 mm	62	2	11.40
22	CAMP 11 mm	60	2	12.73
23	CAMP 11 mm	60	2	12.67
24	CAMP 11 mm	35	2	13.37
25	CAMP 11 mm	35	2	12.98
30	CAMP 9 mm	60	2	12.28
31	CAMP 9 mm	60	2	12.26
32	CAMP 9 mm	35	2	13.04
33	CAMP 9 mm	35	2	12.94

Mixed Cow's Tails (sewn and knot)

No	Name	length	Fall Factor	Force
48	PETZL Jane 11 mm Sewn - Figure of Eight Knot	60	2	9.29

(Average of these 7 tests: 10.27 kN – standard deviation: 0.10 kN or 1%):

No	Name	length	Fall Factor	Force
63	CAMP 11 mm Sewn – Overhand Knot	60	2	10.33
64	CAMP 11 mm Sewn – Overhand Knot	60	2	10.40
65	CAMP 9 mm Sewn – Overhand Knot	60	2	10.29
66	CAMP 9 mm Sewn – Overhand Knot	60	2	10.16
67	PETZL Jane 11 mm Sewn – Overhand Knot	60	2	10.12
68	PETZL Jane 11 mm Sewn – Overhand Knot	60	2	10.33
69	PETZL Jane 11 mm Sewn – Overhand Knot	57	2	10.28
94	PETZL Jane 11 mm Sewn – Barrel Knot	54	2	8.80

Cow's Tails made entirely from knots :

- **Figure of Eight Knot – Barrel Knot**

No	Name	length	Fall Factor	Force
		cm		kN
157	BEAL Verdon II 9 mm	60	2	7.25
158	BEAL Verdon II 9 mm	60	2	7.39

Cow's Tails made entirely from knots - **Overhand Knot – Barrel Knot**

(Average of these 11 tests: 7.65 kN - Standard deviation: 0.36 kN or 5 %):

No	Name	length	Fall Factor	Force
185	CAMP 11 mm	55	2	7.80
186	CAMP 9 mm	55	2	8.14
187	CAMP 9 mm	55	2	7.87
188	BEAL Apollo II 11 mm	55	2	8.04
189	BEAL Apollo II 11 mm	55	2	7.75
190	BEAL Flyer II 10.2 mm	55	2	7.61
191	BEAL Flyer II 10.2 mm	55	2	7.90
192	BEAL Verdon II 9 mm	55	2	7.24
193	BEAL Verdon II 9 mm	55	2	6.95
194	BEAL Ice Line 8.1 mm	55	2	7.44
195	BEAL Ice Line 8.1 mm	55	2	7.43

Tests Repeated on the Same Cow's Tails :

In order to see what happened with a shock load when the Cow's Tail had already been used to hold a fall, we carried out certain tests on the same Cow's Tails. The second test was done after at least 24 hours during which the Cow's Tails were left alone. The third and fourth tests were carried out with only 10 minute intervals.

No	Name	length	Fall Factor	Force
		cm		kN
27	CAMP 9 mm Sewn - Sewn	58	1	8.71
221	Repeating the preceding test			10.40

Increase in shock loading: +19%

No	Name	length	Fall Factor	Force
96	CAMP 11 mm Figure of Eight – Figure of Eight	53	1	5.93
222	Repeating the preceding test			7.32

Increase in shock loading: +23%

No	Name	length	Fall Factor	Force
99	CAMP 9 mm Figure of Eight – Figure of Eight	62	1	6.27
223	Repeating the preceding test			7.58

Increase in shock loading: +21%

No	Name	length	Fall Factor	Force
140	CAMP 11 mm Figure of Eight – Barrel Knot	59	1	5.57
224	Repeating the preceding test			7.20

Increase in shock loading: +29%

No	Name	length	Fall Factor	Force
145	CAMP 9 mm Figure of Eight – Barrel Knot	42	1	5.62
225	Repeating the preceding test			7.19

Increase in shock loading: +28%

No	Name	length	Fall Factor	Force
163	CAMP 9 mm Overhand – Barrel Knot	61	1	6.10
226	Repeating the preceding test			8.31
227	Repeating the preceding test			9.11

Increase in shock loading between the 1st and 2nd test: +36%, between the 2nd and 3rd test: +10% (between the 1st and the 3rd: +49%)

No	Name	length	Fall Factor	Force
		cm		kN
182	BEAL Verdon II 9 mm Figure of Eight – Barrel	60	1	5.50
228	Repeating the preceding test			6.93
229	Repeating the preceding test			7.95
230	Repeating the preceding test			8.35

Increase in shock loading between the 1st and 2nd tests : +26%, between 2nd and 3rd test: + 15 % (between 1st and 3rd: 45 %), between 3rd and 4th test: + 5 % (between 1st and 4th: 52 %)

No	Name	length	Fall Factor	Force
169	BEAL Apollo II 11 mm Overhand – Barrel	58	1	6.07
231	Repeating the preceding test			7.08
232	Repeating the preceding test			7.88
233	Repeating the preceding test			8.17

Increase in shock loading between the 1st and 2nd tests: + 17 %, between 2nd and 3rd test: + 11 % (between 1st and 3rd: 30 %), between 3rd and 4th test: + 4 % (between 1st and 4th: 35 %)

No	Name	length	Fall Factor	Force
172	BEAL Flyer II 10.2 mm Overhand - Barrel	60	1	6.26
234	Repeating the preceding test			7.05
235	Repeating the preceding test			8.19
236	Repeating the preceding test			8.72

Increase in shock loading between the 1st and 2nd tests: + 13 %, between 2nd and 3rd test: + 16 % (between 1st and 3rd: 31 %), between 3rd and 4th test: + 6 % (between 1st and 4th: 39 %)

No	Name	length	Fall Factor	Force
176	BEAL Ice Line 8.1 mm Overhand - Barrel	54	1	6.00
237	Repeating the preceding test			7.43
238	Repeating the preceding test Sheath of the rope totally torn following this test[12]			7.25

Increase in shock loading between the 1st and 2nd test: + 24 %. The tearing of the sheath at the time of the 3rd test explains the fact that the recorded shock load is lower than during the previous test.

[12] See page 6 for photograph of sample post test

For the Fall Factor 1 tests, the average increase in the shock load between the first and the second test is 23.5 %.

Repeating the Tests at Fall Factor 2

No	Name	length	Fall Factor	Force
		cm		kN
22	CAMP 11 mm Sewn - Sewn	60	2	12.73
239	Repeating the preceding test			15.31

Increase in shock loading: + 20 %

No	Name	length	Fall Factor	Force
23	CAMP 11 mm Sewn - Sewn	60	2	12.67
240	Repeating the preceding test			13.56

Increase in shock loading: +7%

No	Name	length	Fall Factor	Force
25	CAMP 11 mm Sewn - Sewn	35	2	12.98
241	Repeating the preceding test			16.03

Increase in shock loading: 23%

No	Name	length	Fall Factor	Force
30	CAMP 9 mm Sewn - Sewn	60	2	12.28
242	Repeating the preceding test : ripping of a sewn section			

No	Name	length	Fall Factor	Force
32	CAMP 9 mm Sewn - Sewn	35	2	13.04
243	Repeating the preceding test : ripping of a sewn section			

No	Name	length	Fall Factor	Force
		cm		kN
33	CAMP 9 mm Sewn - Sewn	35	2	12.94
244	Repeating the preceding test			15.00

Increase in shock loading: +16%

No	Name	length	Fall Factor	Force
		cm		kN
15	PETZL Jane 11 mm Sewn - Sewn	62	2	12.03
245	Repeating the preceding test			14.53

Increase in shock loading: 21%

No	Name	length	Fall Factor	Force
		cm		kN
16	PETZL Jane 11 mm Sewn - Sewn	62	2	11.40
246	Repeating the preceding test			13.25

Increase in shock loading: 16%

No	Name	length	Fall Factor	Force
63	CAMP 11 mm Sewn – Overhand Knot	60	2	10.33
247	Repeating the preceding test			13.47

Increase in shock loading: +30%

No	Name	length	Fall Factor	Force
64	CAMP 11 mm Sewn – Overhand Knot	60	2	10.40
248	Repeating the preceding test			13.55

Increase in shock loading: 30%

No	Name	length	Fall Factor	Force
65	CAMP 9 mm Sewn – Overhand Knot	60	2	10.29
249	Repeating the preceding test : rupture in the Overhand Knot			

No	Name	length	Fall Factor	Force
66	CAMP 9 mm Sewn – Overhand Knot	60	2	10.16
250	Repeating the preceding test : rupture in the Overhand Knot			

No	Name	length	Fall Factor	Force
67	PETZL Jane 11 mm Sewn – Overhand Knot	60	2	10.12
251	Repeating the preceding test			12.91

Increase in shock loading: 28%

No	Name	length	Fall Factor	Force
68	PETZL Jane 11 mm Sewn – Overhand Knot	60	2	10.33
252	Repeating the preceding test			12.80

Increase in shock loading: 24%

No	Name	length	Fall Factor	Force
186	CAMP 9 mm Overhand Knot – Barrel Knot	55	2	8.14
253	Repeating the preceding test : rupture in the Overhand Knot			

No	Name	length	Fall Factor	Force
		cm		kN
187	CAMP 9 mm Overhand Knot – Barrel Knot	55	2	7.87
254	Repeating the preceding test : rupture in the Overhand Knot			

No	Name	length	Fall Factor	Force
194	BEAL Ice Line 8.1 mm Overhand Knot – Barrel Knot	55	2	7.44
255	Repeating the preceding test : rupture in the Overhand Knot			

No	Name	length	Fall Factor	Force
195	BEAL Ice Line 8.1 mm Overhand Knot – Barrel Knot	55	2	7.43
256	Repeating the preceding test : rupture in the Overhand Knot			

No	Name	length	Fall Factor	Force
192	BEAL Verdon II 9 mm Overhand Knot – Barrel Knot	55	2	7.24
257	Repeating the preceding test			10.48

Increase in shock loading: 45%

No	Name	length	Fall Factor	Force
193	BEAL Verdon II 9 mm Overhand Knot – Barrel Knot	55	2	6.95
258	Repeating the preceding test : rupture in the Overhand Knot			

No	Name	length	Fall Factor	Force
191	BEAL Flyer II 10.2 mm Overhand - Barrel	55	2	7.90
259	Repeating the preceding test			9.74

Increase in shock loading: 23%

No	Name	length	Fall Factor	Force
189	BEAL Apollo II 11 mm Overhand - Barrel	55	2	7.75
260	Repeating the preceding test			10.31

Increase in shock loading: 45%

No	Name	length	Fall Factor	Force
157	BEAL Verdon II 9 mm Figure of Eight - Barrel	60	2	7.25
261	Repeating the preceding test			10.74

Increase in shock loading: 48%

All the ropes of diameters smaller than 10 mm suffered from ruptures during the second Fall Factor 2 tests, either in a knot or in a sewn section.

Static Tests :

- **Figure of Eight Knot– Barrel Knot**

In order to validate the use of a Barrel Knot we wanted to test its reaction to a static test involving a slow pull. For this we combined it with a Figure of Eight Knot. That is for the test we set up one Cow's Tail with a Figure of Eight at one end and a Barrel Knot at the other and pulled the combination until the rope broke.

No	Name	Fall Factor	Force
			kN
262	BEAL Apollo II 11 mm	Static Test	17.78
263	BEAL Apollo II 11 mm	Static Test	17.23
264	CAMP 9 mm	Static Test	12.96
265	CAMP 9 mm	Static Test	13.35
266	BEAL Ice Line 8.1 mm	Static Test	9.45
267	BEAL Ice Line 8.1 mm	Static Test	9.80

During these 6 tests the break occurred in the Figure of Eight Knot. The strength of the Cow's Tail (and more generally of a rope) is therefore better with a Barrel Knot than with a Figure of Eight Knot.

- **Cow's Tails subjected to shock loading 2 days earlier**

No	Name	Fall Factor	Force
268	CAMP 11 mm Overhand Knot- Overhand Knot	Static Test	16.38
269	CAMP 11 mm Overhand Knot- Overhand Knot	Static Test	16.31
270	CAMP 9 mm Overhand Knot- Overhand Knot	Static Test	11.50
271	CAMP 9 mm Overhand Knot- Overhand Knot	Static Test	11.70
272	BEAL Apollo II 11 mm Overhand Knot- Overhand Knot	Static Test	15.38
273	BEAL Apollo II 11 mm Overhand Knot- Overhand Knot	Static Test	15.69
274	BEAL Flyer II 10.2 mm Overhand Knot- Overhand Knot	Static Test	13.26
275	BEAL Flyer II 10.2 mm Overhand Knot- Overhand Knot	Static Test	13.15
276	BEAL Verdon II 9 mm Overhand Knot- Overhand Knot	Static Test	10.35
277	BEAL Verdon II 9 mm Overhand Knot- Overhand Knot	Static Test	10.52
278	BEAL Ice Line 8.1 mm Overhand Knot- Overhand Knot	Static Test	8.24
279	BEAL Ice Line 8.1 mm Overhand Knot- Overhand Knot	Static Test	8.01
280	PETZL Jane 11 mm Overhand Knot- Overhand Knot	Static Test	18.01
281	PETZL Jane 11 mm Overhand Knot- Overhand Knot	Static Test	17.81

Used Cow's Tails :

Numerous caving Cow's Tails had been collected for these tests and we thank all those who responded to our request. However, faced with an inability to interpret the results, we soon stopped these tests. These lasts tests seemed inconsistent since those Cow's Tails that had been used for several seasons and appeared quite badly worn gave much better dynamic results than those Cow's Tails that had only been used for a few trips. The opposite results occurred when the Cow's Tails were subject to the static tests. It appears that this can be explained quite simply by the fact that with time and repeated usage the fibres of the rope had broken making the rope more elastic but weaker. A more in-depth study with more precise histories (number of trips, type of trips, weight of the user…) could perhaps answer this question on the ageing of Cow's Tails.

The results below will therefore not be commented on.

- Cow's Tails used for one season of caving (2004) used by CREPS of Chalain

No	Name	length	Fall Factor	Force
		cm		kN
282	BEAL Stinger 9.4 mm Overhand Knot – Barrel Knot	34	1	5.16
283	BEAL Stinger 9.4 mm Overhand Knot – Barrel Knot	37	1	5.15
284	BEAL Stinger 9.4 mm Overhand Knot – Barrel Knot	50	1	5.32
285	BEAL Stinger 9.4 mm Overhand Knot – Barrel Knot	48	1	5.07
286	BEAL Stinger 9.4 mm Overhand Knot – Barrel Knot	39	2	6.74
287	BEAL Stinger 9.4 mm Overhand Knot – Barrel Knot	38	2	6.85
288	BEAL Stinger 9.4 mm Overhand Knot – Barrel Knot	58	2	7.32
289	BEAL Stinger 9.4 mm Overhand Knot – Barrel Knot	58	2	7.32
290	BEAL Stinger 9.4 mm Overhand Knot – Barrel Knot	38	Static Test	10.22
291	BEAL Stinger 9.4 mm Overhand Knot – Barrel Knot	58	Static Test	9.90

- **Cow's Tails used for three seasons of canyoning by professionals (2004)**

No	Name	length	Fall Factor	Force
292	BEAL Stinger 9.4 mm Overhand Knot – Overhand Knot	46	1	5.80
293	BEAL Stinger 9.4 mm Overhand Knot – Overhand Knot	42	1	5.96
294	BEAL Stinger 9.4 mm Overhand Knot – Overhand Knot	60	1	5.50
295	BEAL Stinger 9.4 mm Overhand Knot – Overhand Knot	72	1	5.37
296	BEAL Stinger 9.4 mm Overhand Knot – Overhand Knot	45	2	7.50
297	BEAL Stinger 9.4 mm Overhand Knot – Overhand Knot	42	2	7.67
298	BEAL Stinger 9.4 mm Overhand Knot – Overhand Knot	68	2	7.47
299	BEAL Stinger 9.4 mm Overhand Knot – Overhand Knot	64	2	739
300	Repetition of the previous test: rope broke in the middle of the Cow's Tail			
301	BEAL Stinger 9.4 mm Overhand Knot – Overhand Knot	48	Static Test	7.50
302	BEAL Stinger 9.4 mm Overhand Knot – Overhand Knot	54	Static Test	7.70

- **Cow's Tails used for a year (2003) by Secondary School Pupils**

No	Name	length	Fall Factor	Force
		cm		kN
303	PMI 10.2 mm Figure of Eight Knot - Figure of Eight Knot	40	1	5.16
304	PMI 10.2 mm Figure of Eight Knot - Figure of Eight Knot	40	1	5.26
305	A Static test on the Cow's Tail used for test 303			11.78
306	A Static test on the Cow's Tail used for test 304			13.63
307	PMI 10.2 mm Figure of Eight Knot - Figure of Eight Knot	55	1	5.24
308	PMI 10.2 mm Figure of Eight Knot - Figure of Eight Knot	50	1	5.61
309	PMI 10.2 mm Figure of Eight Knot - Figure of Eight Knot	40	2	7.72
310	PMI 10.2 mm Figure of Eight Knot - Figure of Eight Knot	40	2	7.53
311	Repetition of the previous test			10.07
312	PMI 10.2 mm Figure of Eight Knot - Figure of Eight Knot	45	2	6.36
313	PMI 10.2 mm Figure of Eight Knot - Figure of Eight Knot	50	2	7.13
314	Repetition of the previous test			9.94

- **Cow's Tails used for caving and canyoning (professional environment)**

No	Name	length	Fall Factor	Force
315	Single canyon Cow's Tail rope Overhand Knot– Overhand Knot	50	Static Test	8.04
316	Single canyon Cow's Tail rope Overhand Knot– Overhand Knot	50	Static Test	8.06
317	Cow's Tail 9 mm Figure of Eight Knot - Figure of Eight Knot	35	Static Test	8.24
318	Cow's Tail 9 mm Figure of Eight Knot - Figure of Eight Knot	50	Static Test	9.53
319	Cow's Tail 9 mm Figure of Eight Knot - Figure of Eight Knot	70	2	8.47
320	Cow's Tail 9 mm Figure of Eight Knot - Figure of Eight Knot	70	2	8.47
321	Repetition of previous test : Cow's Tail broke			

- **Cow's Tails used for a year in rope work**

No	Name	length	Fall Factor	Force
322	PETZL Jane 11 mm Sewn - Overhand Knot	37	1	6.91

Summary

Comparison of different Cow's Tail ends:

In order to compare only the ends, we have created averages from the results of the tests on the Cow's Tails made from 11 mm rope (CAMP 11 mm, PETZL Jane and Beal Apollo II), excluding of course the Spelegyca Cow's Tail which is made from tape. The results are ranked from the best performer to the poorest performer and only for Fall Factor 1 falls.

		k N
1	Figure of Eight Knot Knot – Barrel Knot	5.64
2	Figure of Eight Knot – Figure of Eight Knot	5.75
3	Overhand Knot Knot – Barrel Knot	5.90
4	Overhand Knot – Overhand Knot	6.44
5	Sewn – Barrel Knot	6.52
6	Sewn – Clove Hitch	6.81
7	Sewn – Figure of Eight Knot	7.30
8	Sewn – Overhand Knot	7.34
9	Sewn – Sewn	9.00
10	Spelegyca tape Cow's Tail (long)	10.99

Ranking by the type of Cow's Tail is quite easy as the 4 best results correspond to the Cow's Tails made entirely out of knots, the next 4 corresponding to those made from one knot at one end and a sewn end at the other, the penultimate category corresponds to Cow's Tails made entirely from rope (with sewn ends at both ends) and the poorest are those Cow's Tails made from tape.

Only the Cow's Tails made from knots at both ends achieve values below the level of 6 kN.

We have not collected enough tests at Fall Factor 2 to rank all the ends, however the results we do have correspond to the previous ranking.

- 12.32 kN on average for the entirely sewn Cow's Tails

- 9.94 kN on average for the mixed Cow's Tails

- 7.86 kN on average for the Cow's Tails made entirely from knots

Comparison of different types of ropes:

In order to compare only the types and diameters of rope, we have produced averages of the results for each type of rope. These come from the tests on the 60 cm Cow's Tails knotted at both ends (taking exactly the same tests for all the Cow's Tails), except of course for the Spelegyca Cow's Tail, which is made from tape.

The results are ranked from the best performer to the poorest performer and only for Fall Factor 1 falls.

		kN
1	BEAL Verdon II 9 mm	5.80
2	BEAL Ice Line 8.1 mm	5.88
3	BEAL Apollo II 11 mm	5.97
4	CAMP 11 mm	6.01
5	PETZL Jane 11 mm	6.02
6	BEAL Flyer II 10.2 mm	6.12
7	CAMP 9 mm	6.27

The results are very close (average of 6.01 kN and standard deviation of only 0.15 kN or 2,5 %) although these ropes display very different characteristics and have varied diameters.

Comparison of different lengths of Cow's Tails :

These results all relate to Fall Factor 1 tests.

	kN
Spelegyca long (60 cm)	10.44
Spelegyca short (32 cm)	11.54
CAMP Cow's Tail sewn - sewn long (59 cm)	8.68
CAMP Cow's Tail sewn - sewn short (33 cm)	9.64
Mixed Cow's Tails long	6.82
Mixed Cow's Tails short	6.88
CAMP Cow's Tails with 2 knots long	6.61
CAMP Cow's Tails with 2 knots short	5.86

The differences between the short and the long Cow's Tails are not very significant. However, it is interesting to note that for the manufactured Cow's Tails (either in tape or with sewn ends) the shock load is lower with the long side of the Cow's Tail, whereas it's the opposite with those Cow's Tails made with 2 knots. For the mixed Cow's Tails, the average values are almost identical.

Thus, the concept of Fall Factor does not apply to the Cow's Tails made with one or several knots. In fact, we have seen (p. 5) that a Fall Factor 1 more accurately corresponds to a Fall Factor 1.75 for a short Cow's Tail and to a fall Factor 1.45 for a long Cow's Tail. We note that in all the tests on Cow's Tails with knots, the shock load is lower with the short side of the Cow's Tail than with the long side of the Cow's Tail. Therefore in this specific circumstance there is a lower shock load for a higher Fall Factor.

This is explained by the fact that, with such small distances, knots play a greater shock absorbing role than the stretch of the rope. This shock absorption by the knots is similar on either side of a Cow's Tail. Therefore it can be assumed that the shock load is lower with the short side of a Cow's Tail simply because the energy to be absorbed is less since the fall distance is less.

Conclusion

Cow's Tails currently on the market that are entirely manufactured, whether they be single or double, symmetrical or non-symmetrical, are not appropriate for either caving or work on ropes. In particular, Cow's Tails made from sewn tapes, in widespread use by cavers and rope workers, can pose a real risk. The tests have, in effect, shown that a Fall Factor 1 shock load could exceed 15 kN (test 6) when the recognised maximum for work equipment according to the European Standards is set at 6 kN.

However, it is possible to use manufactured goods by linking them to the harness with a knot to specifically perform a shock absorbing role and thereby serving to keep the shock load for a Fall Factor 1 fall within acceptable bounds. Different manufacturers offer lengths of dynamic rope with pre sewn ends. With a 150cm Cow's Tail, it is therefore quite easy to make a pair of non-symmetrical Cow's Tail, which is ideal for both caving and rope work. It can be joined directly to the harness tie-in point with a Figure of Eight Knot, an Overhand Knot or a Clove Hitch.

From the point of view of shock absorption, Cow's Tails made from dynamic rope and knots at both ends achieve the best results. The effect of the diameter and of the weave of the rope on this shock load is not significant. Furthermore, the results are similar for knots that are well tied and knots that are badly tied, that is when the ropes cross over each other, and also whether they have been pre-tightened or not. This method also allows the lengths of the Cow's Tails to be adapted to the size of the user. Figures of Eight Knots, Overhand Knots or Clove Hitches can be used at the harness end. At the other end, a Figure of Eight Knot or an Overhand Knot and also a Barrel Knot can be connected to the karabiner. The Barrel Knot is being increasingly used by cavers and has the advantage of holding the karabiner in place. It is, in effect, completely secure and furthermore is the knot that provides the best results in both the static and dynamic tests.

One of the lessons from this series of tests is that the theory behind Fall Factors inadequately explains how shock loads are absorbed by Cow' Tails. In particular it is the knots that absorb the greater part of the energy from a fall and in various identical set-ups, it has been demonstrated that the shock loads are inversely proportional to the fall factors (see p. 32[13]). Despite this we should continue to teach that cavers should not position themselves above their anchor point when using Cow's tails; fortunately this is a situation which is quite easy to identify. The tests carried out in less favourable conditions gave shock loads well in excess of those that can be sustained by the human body. Tests also showed that heavily used Cow's tails can break on the first fall.

Finally it is regrettable that the most recent laws and particularly article R 233-13-20 of the Fair Labour Standards Act (added by decree on 1st September 2004) are not based on shock loads and the limit of 6 kN. It requires that "[…] the protection of workers must be assured by means of an appropriate Fall Protection system which does not allow a free fall of more than one metre or limiting in the same way the effects of a fall from a greater height."; Yet these tests indicate that a fall of less than one metre can create a shock load above 15 kN.

[13] The original text said p33 but from the context it is clear it should be p 32.

Annex A Figure of Eight Knot

A (single) Figure of Eight Knot is shown in Figure A.1 and a Figure of Eight Knot tied on a Bight is shown in Figure A.2. This translation adopts the convention of using the term "Figure of Eight Knot" to mean a Figure of Eight Knot tied on a Bight.

Figure of Eight Knot

Figure A.1

Figure of Eight Knot
tied on a Bight
Figure A.2

Annex B Single and Double Overhand Knots

A (single) Overhand Knot is shown in Figure B.1 and a Double Overhand Knot is shown in Figure B.2. An Overhand Knot tied on a Bight is shown in Figure B.3. This translation adopts the convention of using the term "Overhand Knot" to mean an Overhand Knot tied on a Bight.

Overhand Knot

Figure B.1

Double Overhand Knot

Figure B.2

Overhand Knot tied on a Bight

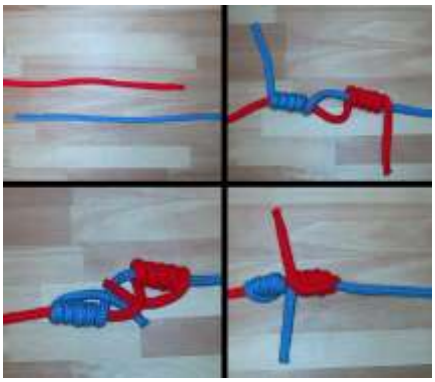
Figure B.3

Annex C Half a Double Fisherman's or Barrel Knot

The name Barrel Knot was given in an English publication[14] in 2001, see Figure C.1, to the knot shown on page 8, see Figure C.2. The description of a Barrel Knot[15] however, is one which applies to a number of turns, perhaps as many as 8 and is used to join two lengths of line, see Figure C.3. Variations in usage of the Barrel Knot within a Cow's Tail in the United Kingdom include using three turns. This translation adopts the convention of using the term "Barrel Knot" in place of the French name "Half a Double Fisherman's Knot" [Demi pêcheur double].

Barrel Knot
Figure C.1

Half a Double Fisherman's Knot
Figure C.2



Barrel or Blood Knot
Figure C.3[16]

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[14] Page 15, "Industrial rope access – Investigation into items of Personal Protective Equipment" by Lyon Equipment Limited, a Contract Reseach Report for the UK Health and Safety Executive, No 364/2001, see http://www.hse.gov.uk/research/crr_pdf/2001/crr01364.pdf as on 9 February 2008

[15] See http://en.wikipedia.org/wiki/Blood_knot as on 9 February 2008

[16] *This* Wikipedia *and* Wikimedia Commons *image is from the user* Chris 73 *and is freely available at* http://commons.wikimedia.org/wiki/Image:BloodKnot_HowTo.jpg *under the* creative commons cc-by-sa 2.5 *license.*

Annex D SPELEGYCA Asymmetrical Y-shaped Cow's Tail

The SPELEGYCA Asymmetrical Y-shaped Cow's Tail, see Figure D.1, is made by PETZL from flat sewn webbing and is stated as not being an energy absorber[17].

Figure D.1[18]

[17] See http://en.petzl.com/petzl/ProProduits?Produit=524 as on 9 February 2008

[18] Taken from 19 above

Annex E Jane Non-adjustable Dynamic rope lanyard

The Jane non-adjustable dynamic rope lanyard, see Figure E.1, is made by PETZL from 11 mm dynamic rope and comes with two sewn loop terminations[19].

Figure E.1

The literature which accompanies the lanyard specifies that the lanyard has a strength of 22 kN which is reduced to 18 kN if used with a knot termination. It also claims a shock load of 7 kN for a Fall Factor 1 drop of 0.6 m and 9 kN for a Fall Factor 2 drop of 1.2 m by a 80 kg mass.

[19] See http://en.petzl.com/petzl/ProProduits?Produit=310 as on 9 February 2008