

You Asked, We Tested...

Presented by:
John McKently, Bruce Parker, and Cedric Smith

You Asked, We Tested...

Ask rope rescue experts how large a pulley tread diameter should be and you will get several answers: 3 times the rope's diameter, 4 times, 8 times. We have heard all of these answers, but when does the bend in the rope really begin to affect the rope's strength? Each of these ratios can be found in the literature, which suggested a test project was needed.

Over the last three years, CMC test projects have exposed rescue rope to a number of abuses including heat, chemicals, and other suspicious substances. After each presentation, we would get a number of "what about _____?" questions, and during the year we have also investigated those substances as well.

About the Presenters

John McKently has been the School Administrator and Lead Instructor at CMC Rescue since 1995. Currently serving as CMC's School Director, he also teaches rope, confined space, tactical rappelling, and other specialized courses such as rescue for stage and arena riggers. Prior to his employment with CMC, McKently was Sr. VP in charge of Facilities at a mid-size bank. He has served with Montrose SAR for over 30 years, where he was Team Captain for seven years before being promoted to Commander. He has over 1600 rescue operations to his credit. In addition to his work at CMC, he is rated as a Senior Fire Instructor by the California State Fire Training and as Mine Rescue Instructor by MSHA. He occasionally teaches Search Management for California OES and "has no life".

Bruce Parker is Senior Lead Instructor at CMC Rescue School, a position he has held for 11 years. For the four years prior to his work at CMC he taught rescue for another training company. He is responsible for course development and compliance towards applicable standards and teaches rope rescue, confined space, tower rescue, and other specialized courses. Bruce is extremely concerned with rescuer and victim safety and has worked to develop or improve many products manufactured by CMC. He is a MSHA Mine Rescue Instructor and a State of California Senior Fire Instructor. Through ASTM Bruce has written several standards relating to SAR. He has been a member of the Montrose SAR team for 26 years, serving in all ranks up to Captain and has finally made it back to the bottom where the work is done.

Cedric Smith has been the Engineering Technician at CMC Rescue since January 2003. He works closely with the Product Development Committee and is involved with product development, testing, and certification. Prior to his employment with CMC he resided in Nova Scotia where he served for 5 years as a volunteer firefighter with the Meteghan Fire Department as well as a member of Clare Municipal SAR. Cedric attended Seneca College in Toronto, Ontario, where he received a diploma in Fire Engineering Technology. While residing in Ontario he taught rescue courses for a recognized outdoor adventure company in the fields of Technical Rope, Swiftwater, and Ice Rescue. Cedric is a Certified Rope Access Technician (SPRAT) and is a member of Santa Barbara County SAR. Being an avid rock climber, there is nothing that Cedric would rather do than spend a day on the ropes.

You Asked, We Tested...

Presented by
John McKently, Bruce Parker & Cedric Smith
CMC Rescue, Inc
ITRS 2004



You asked:

“What happens to my escape line after it gets exposed to actual fire ground conditions?”

Test Parameters



- Rope samples were submitted to firefighters to be secured to their SCBA packs.

- Ropes were unprotected.

- Tested both nylon/polyester and aramid fiber Escape Lines.



- Carabiners used to secure the ropes to the SCBA packs were also tested.

- Ropes were subjected to the same conditions as the firefighter and his equipment: Water, Steam, Flames, Chemicals, Cleaning Agents, etc...

- Cordage Institute slow pull test method.

CMC Rescue Escape Line

- UL Classified NFPA 1983 (2001 ED.) Escape Line
- Manufactured by New England Ropes
- Polyester sheath / nylon core
- Diameter: 8 mm
- 3 σ UL MBS: 20 kN (4,662 lbf)
- Weight: 3.5 lbs / 100 ft
- Temperature rating (melting point): 480° F (249° C)



CMC ProSeries Escape Line

- UL Classified NFPA 1983 (2001 ED.) Escape Line
- Manufactured by Sterling Rope
- Twaron® sheath / polyester core
- Diameter: 7.5 mm
- 3 σ UL MBS: 16.4 kN (3,687 lbf)
- Weight: 2.9 lbs / 100 ft
- Temperature rating (melting point): 900° F (482° C)



SMC Large Locking Carabiner



- Manufactured by Seattle Manufacturing Corp. (SMC)
- Aluminum
- 3 σ MBS: 34 kN (7,643 lbf)
- Weight 3.8 oz.
- Gate opening 1.20 in.

Smith - Rope Log

Date	Type of Exposure	Duration	Visible rope damage	Notes
3/14/2004	Fire & Heat	10 min	None	
3/20/2004	Light Smoke	20 min	None	Kitchen Fire
5/28/2004	Moderate Heat & Smoke	30 min	None	Attic Fire
5/30/2004	Smoke	4 hours	None	
6/1/2004	Smoke	45 min	None	Room & Contents Fire
6/5/2004	Chemical Spill	6 hours	None	Drug Lab (40+ Chemicals)
6/14/2004	Smoke	30 min	None	Roof
6/15/2004	Light Smoke	30 min	None	Investigation
6/18/2004	Smoke	2 hours	None	Electrical Fire
6/30/2004	Heavy Smoke	30 min	None	Roof / Overhaul
7/2/2004	Moderate Heat & Smoke	25 min	None	Roof / Overhaul
7/4/2004	Moderate Heat & Smoke	30 min	None	Overhaul
7/7/2004	Smoke	30 min	None	Roof
7/20/2004	Heat & Smoke	2.5 hours	None	Roof Fire

Smith - Rope Log 1

Date	Type of Exposure	Duration	Visible rope damage	Notes
4/10/2004	House Fire	2.0 hrs	None	High Heat
4/11/2004	Car Fire	.25 hr	None	Smoke
4/13/2004	Car Fire	.25 hr	None	Smoke
4/20/2004	House Fire	1.5 hrs	None	Medium Heat
4/30/2004	Car Fire	.25 hr	None	Smoke
5/2/2004	House Fire	2.0 hrs	None	Very High Heat
5/15/2004	House Fire	1.0 hr	None	Medium Heat
5/18/2004	Car Fire	.25 hr	None	Smoke
5/21/2004	House Fire	1.0 hr	None	High Heat
5/22/2004	Car Fire	.25 hr	None	Medium Heat
5/24/2004	House Fire	1.5 hrs	None	High Heat
5/28/2004	Truck Fire	.5 hr	None	Medium Heat
5/30/2004	Car Fire	.25 hr	None	Smoke
6/3/2004	House Fire	2.0 hrs	None	Very High Heat
6/5/2004	Car Fire	.25 hr	None	Smoke
6/12/2004	House Fire	.75 hr	None	Smoke
6/20/2004	Car Fire	.25 hr	None	Smoke
6/22/2004	Warehouse Fire	4.0 hrs	None	Medium Heat
6/25/2004	Car Fire	.25 hr	None	Smoke
6/27/2004	Car Fire	.25 hr	None	Smoke
6/29/2004	Natural Gas Leak	1.0 hr	None	Natural Gas
6/30/2004	Car Fire	.25 hr	None	Smoke
6/30/2004	Car Fire	.25 hr	None	Smoke
7/3/2004	House Fire	1.75 hrs	None	Medium Heat

Smith - Rope Log 2

7/4/2004	Car Fire	.25 hr	None	Smoke
7/4/2004	House Fire	1.5 hrs	None	High Heat
7/10/2004	Foundry Fire	1.0 hr	None	Smoke
7/12/2004	Car Fire	.25 hr	None	Smoke
7/18/2004	Car Fire	.25 hr	None	Smoke
7/20/2004	House Fire	2.0 hrs	None	High Heat
7/28/2004	Car Fire	.25 hr	None	Smoke

Exposure Log for Nylon / Polyester Escape Line

Date	Type of Exposure	Duration	Visible rope damage	Notes
3/14/2004	Fire & Heat	10 min	None	
3/20/2004	Light Smoke	20 min	None	Kitchen Fire
5/28/2004	Moderate Heat & Smoke	30 min	None	Attic Fire
5/30/2004	Smoke	4 hours	None	
6/1/2004	Smoke	45 min	None	Room & Contents Fire
6/5/2004	Chemical Spill	6 hours	None	Drug Lab (40+ Chemicals)
6/14/2004	Smoke	30 min	None	Roof
6/15/2004	Light Smoke	30 min	None	Investigation
6/18/2004	Smoke	2 hours	None	Electrical Fire
6/30/2004	Heavy Smoke	30 min	None	Roof / Overhaul
7/2/2004	Moderate Heat & Smoke	25 min	None	Roof / Overhaul
7/4/2004	Moderate Heat & Smoke	30 min	None	Overhaul
7/7/2004	Smoke	30 min	None	Roof
7/20/2004	Heat & Smoke	2.5 hours	None	Roof Fire

Exposure Log For Twaron® / Polyester Escape Line

Date	Type of Exposure	Duration	Visible rope damage	Notes
4/10/2004	House Fire	2.0 hrs	None	High Heat
6/1/2004	Car Fire	25 hr	None	Smoke
4/13/2004	Car Fire	25 hr	None	Smoke
4/20/2004	House Fire	1.5 hrs	None	Medium Heat
4/30/2004	Car Fire	25 hr	None	Smoke
5/2/2004	House Fire	2.0 hrs	None	Very High Heat
6/16/2004	House Fire	1.0 hr	None	Medium Heat
6/18/2004	Car Fire	25 hr	None	Smoke
6/21/2004	House Fire	1.0 hr	None	High Heat
6/22/2004	Car Fire	25 hr	None	Medium Heat
6/24/2004	House Fire	1.5 hrs	None	High Heat
6/26/2004	Truck Fire	5 hr	None	Medium Heat
6/30/2004	Car Fire	25 hr	None	Smoke
6/30/2004	House Fire	2.0 hrs	None	Very High Heat
6/30/2004	Car Fire	25 hr	None	Smoke

Exposure Log For Twaron® / Polyester Escape Line

Date	Type of Exposure	Duration	Visible rope damage	Notes
6/12/2004	House Fire	75 hr	None	Smoke
6/20/2004	Car Fire	25 hr	None	Smoke
6/22/2004	Warehouse Fire	4.0 hrs	None	Medium Heat
6/25/2004	Car Fire	25 hr	None	Smoke
6/27/2004	Car Fire	25 hr	None	Smoke
6/29/2004	Natural Gas Leak	1.0 hr	None	Natural Gas
6/30/2004	Car Fire	25 hr	None	Smoke
6/30/2004	Car Fire	25 hr	None	Smoke
7/3/2004	House Fire	1.75 hrs	None	Medium Heat
7/4/2004	Car Fire	25 hr	None	Smoke
7/4/2004	House Fire	1.5 hrs	None	High Heat
7/10/2004	Foundry Fire	1.0 hr	None	Smoke
7/12/2004	Car Fire	25 hr	None	Smoke
7/19/2004	Car Fire	25 hr	None	Smoke
7/20/2004	House Fire	2.0 hrs	None	High Heat
7/29/2004	Car Fire	25 hr	None	Smoke



Nylon / Polyester Escape Line Results

Control Samples

- 1- 20.38 kN (4,581 lbf)
- 2- 20.55 kN (4,619 lbf)
- 3- 21.13 kN (4,749 lbf)
- 4- 20.50 kN (4,609 lbf)

3 σ = 19.64 kN (4,415 lbf)

Test Samples

- 1- 20.02 kN (4,500 lbf)
- 2- 20.38 kN (4,581 lbf)
- 3- 19.66 kN (4,419 lbf)
- 4- 19.62 kN (4,410 lbf)

3 σ = 18.85 kN (4,237 lbf)

Percent loss = 4%

NFPA Performance minimum: 13.5 kN (3,034 lbf)

Twaron® / Polyester Escape Line Results

Control Samples

- 1- 16.00 kN (3,596 lbf)
- 2- 14.63 kN (3,290 lbf)
- 3- 16.10 kN (3,620 lbf)
- 4- 15.45 kN (3,474 lbf)

3 σ = 13.52 kN (3,042 lbf)

Test Samples

- 1- 14.90 kN (3,350 lbf)
- 2- 13.50 kN (3,034 lbf)
- 3- 15.32 kN (3,445 lbf)
- 4- 15.93 kN (3,582 lbf)

3 σ = 11.82 kN (2,654 lbf)

Percent loss = 12.5%

NFPA Performance minimum: 13.5 kN (3,034 lbf)

Aluminum Carabiner Results

Control Samples

1- 35.41 kN (7,960 lbf)
 2- 33.79 kN (7,596 lbf)
 3- 34.61 kN (7,781 lbf)
 4- 34.81 kN (7,826 lbf)
 3 σ = 32.65 kN (7,339 lbf)

Test Samples

1- 33.47 kN (7,525 lbf)
 2- 33.81 kN (7,602 lbf)
 3- 33.66 kN (7,502 lbf)
 4- 34.55 kN (7,767 lbf).
 3 σ = 32.45 kN (7,239 lbf)

Percent loss = 0.61%

You asked:
 “Do moderate bends affect
 overall rope strength?”

Test Parameters

- Only new rope from the same lot (spool) was used.
- Rope diameter: 7/16” (11mm)
- A bight of rope was reeved around the test bollards. Both ends were secured to a standard 4-inch bollard.
- Control samples were pulled end-to-end.
- Cordage Institute slow pull test method



Results

	end-to-end (control)	0.5 inch Bight	FP	1 inch Bight	FP
1	28.73 kN (6,459 lbf)	44.08 kN (9,910 lbf)	A	53.13 kN (11,944 lbf)	A
2	29.35 kN (6,598 lbf)	46.65 kN (10,487 lbf)	A	53.64 kN (12,059 lbf)	A
3	29.66 kN (6,668 lbf)	47.05 kN (10,577 lbf)	A	55.06 kN (12,378 lbf)	A
4	29.87 kN (6,715 lbf)	47.17 kN (10,694 lbf)	A	57.76 kN (12,984 lbf)	A
5	30.10 kN (6,767 lbf)	48.08 kN (10,809 lbf)	A	58.32 kN (13,111 lbf)	A
3 sigma	27.95 kN (6,283 lbf)	42.09 kN (9,448 lbf)		46.50 kN (10,903 lbf)	
	FP = Failure Point	A = @ Bight		B = @ Bollard	

	1.5 inch Bight	FP	2 inch Bight	FP	4 inch Bight	FP
1	60.25 kN (13,545 lbf)	A	60.72 kN (13,650 lbf)	B	61.84 kN (13,902 lbf)	B
2	61.05 kN (13,725 lbf)	A	60.80 kN (13,668 lbf)	A	62.71 kN (14,098 lbf)	B
3	61.06 kN (13,727 lbf)	A	61.42 kN (13,808 lbf)	A	63.11 kN (14,188 lbf)	B
4	61.47 kN (13,819 lbf)	A	63.01 kN (14,165 lbf)	A	63.13 kN (14,192 lbf)	A
5	62.39 kN (14,028 lbf)	A	63.72 kN (14,325 lbf)	A	63.60 kN (14,298 lbf)	B
3 sigma	58.91 kN (13,243 lbf)		57.86 kN (13,007 lbf)		60.69 kN (13,690 lbf)	
	FP = Failure Point		A = @ Bight		B = @ Bollard	

Summary

Bollard Diameter	Average 3 σ Breaking Point	Average loss due to bending
4" (9.1x rope diameter)	60.69 kN (13,690 lbf)	
2" (4.5x rope diameter)	57.86 kN (13,008 lbf)	5%
1-1/2" (3.4x rope diameter)	58.91 kN (13,243 lbf)	3%
1" (2.3x rope diameter)	48.50 kN (10,903 lbf)	20%
1/2" (1.1x rope diameter)	42.09 kN (9,462 lbf)	31%

Results

	4 inch Bollard (control)		0.5 inch Bight	FP	1 inch Bight	FP
1	28.73 kN (6,458.76 lbf)		44.08 kN (9,909.58 lbf)	A	53.13 kN (11,944.10 lbf)	A
2	29.35 kN (6,598.14 lbf)		46.65 kN (10,487.34 lbf)	A	53.64 kN (12,058.75 lbf)	A
3	29.66 kN (6,667.83 lbf)		47.05 kN (10,577.26 lbf)	A	55.06 kN (12,377.98 lbf)	A
4	29.87 kN (6,715.04 lbf)		47.17 kN (10,694.24 lbf)	A	57.76 kN (12,984.96 lbf)	A
5	30.10 kN (6,766.75 lbf)		48.08 kN (10,808.81 lbf)	A	58.32 kN (13,110.86 lbf)	A
3 sigma	27.95 kN (6,282.99 lbf)		42.09 kN (9,461.85 lbf)		48.50 kN (10,903.04 lbf)	
	FP - Failure Point		A - @ Bight		B - @ Bollard	

	1.5 inch Bight	FP	2 inch Bight	FP	4 inch Bight	FP
1	60.25 kN (13,544.74 lbf)	A	60.72 kN (13,650.40 lbf)	B	61.84 kN (13,902.18 lbf)	B
2	61.05 kN (13,724.58 lbf)	A	60.80 kN (13,668.38 lbf)	A	62.71 kN (14,097.77 lbf)	B
3	61.06 kN (13,726.83 lbf)	A	61.42 kN (13,807.76 lbf)	A	63.11 kN (14,187.69 lbf)	B
4	61.47 kN (13,819.00 lbf)	A	63.01 kN (14,165.21 lbf)	A	63.13 kN (14,192.19 lbf)	A
5	62.39 kN (14,025.83 lbf)	A	63.72 kN (14,324.82 lbf)	A	63.60 kN (14,297.85 lbf)	B
3 sigma	58.91 kN (13,243.20 lbf)		57.86 kN (13,007.76 lbf)		60.69 kN (13,690.17 lbf)	
	FP - Failure Point		A - @ Bight		B - @ Bollard	

Summary

Bollard Diameter	Average 3σ Breaking Point	Average loss due to bending
4" (8x rope diameter)	60.69 kN (13,690 lbf)	
2" (4x rope diameter)	57.86 kN (13,008 lbf)	5%
1-1/2" (3x rope diameter)	58.91 kN (13,243 lbf)	3%
1" (2x rope diameter)	48.50 kN (10,903 lbf)	20%
1/2" (rope diameter)	42.09 kN (9,462 lbf)	31%

You asked:
“What if I get DEET on my
rescue rope?”



You asked:
“What if I spit Tobacco Juice
on my rescue rope?”

(You asked!)



Test Parameters

- Only new rope from the same lot (spool) was used.
- Rope diameter: 1/2" (12.5mm)
- Both ends wrapped around standard 4 inch bollards.
- Cordage Institute slow pull test method.
- Standard “Chew & Spit” method used (Bruce).
- Tobacco juice contained saliva of unknown contents.

Results DEET (100%)

Control Samples	Test Samples
1- 43.64 kN (9,811 lbf)	1- 41.43 kN (9,324 lbf)
2- 40.84 kN (9,181 lbf)	2- 42.65 kN (9,588 lbf)
3- 42.84 kN (9,631 lbf)	3- 43.43 kN (9,763 lbf)
4- 43.54 kN (9,788 lbf)	4- 43.82 kN (9,85 lbf)
3 σ = 38.82 kN (8,746 lbf)	3 σ = 39.02 kN (8,993 lbf)

Percent gained = 0.5%

Results Tobacco Juice & Saliva

Control Samples

1- 43.64 kN (9,811 lbf)

2- 40.84 kN (9,181 lbf)

3- 42.84 kN (9,631 lbf)

4- 43.54 kN (9,788 lbf)

$3\sigma = 38.82\text{ kN (8,726 lbf)}$

Test Samples

1- 39.25 kN (8,824 lbf)

2- 42.49 kN (9,552 lbf)

3- 42.95 kN (9,655 lbf)

4- Slipped @ 38.42 kN (8,637 lbf)

Broke @ 34.11 kN (7,668 lbf)

$3\sigma = 27.48\text{ kN (6,177 lbf)}$

Percent loss = 29%

Disclaimer

- The reported results are based on a limited amount of testing which included irreproducible variables.
- Results may vary with different ropes having different constructions and/or materials.
- Extended exposure times to chemicals may change the outcome.

Recommendations

- Inspect your rope after each use and do a cursory inspection prior to each use.
- Inspect your escape line on a regular basis.
- Follow manufacturers instructions regarding inspection and removing from service criteria.
- Keep your ropes clean.
- If in doubt, retire your equipment!

Acknowledgement

- Milwaukee Fire Dept. (Heavy Urban Rescue Team)
- Waukesha Fire Dept.

Thank you!