

A Preliminary Critical Look at Brake Rack Operation and Tying Off

Over the years a wide variety of techniques used to operate and tie-off brake racks have been observed. Some have been very good, others perhaps dangerous. Suffice it to say there are many different ways being used to operate and tie-off brake racks and there is a need to identify what is appropriate and what is not in an effort to seek standardization.

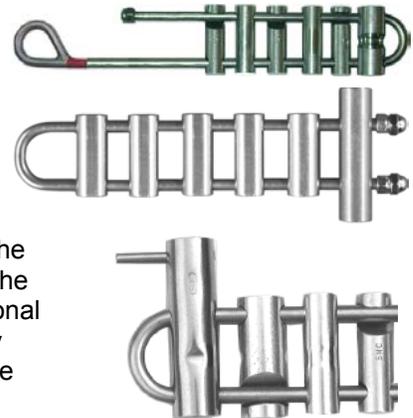
Since it is felt that this is such a broad topic it is being presented to the instructor community as a whole at this initial level so that all instructors will be able to provide feedback to the Technical Committee. With that feedback we can, hopefully, work toward a standardization of techniques for both operation and tying off of the brake rack.

Please peruse this document and offer any comments on its content. This is designed to see what things instructors feel are worth addressing and to start discussion. A number of the techniques being used or being described in text books are examined here but there are certainly many more. Lets see if we can work towards some sort of standardisation on what we feel are the safest and most appropriate techniques.

Bob Manson
Chair, Rope Rescue Technical Committee

Definitions:

- 'J' Rack** The traditional style of rack where the attachment is on the end of one leg.
- 'U' Rack** Another style of rack where the attachment is at the mid point of the frame. (Please excuse the use of 4-bar 'U' racks in this document as that was all that was available. Rescuers should always use 6-bar racks.)
- Hyper Bar** aka tie-off bar. An extra long bar, usually at the top of the rack used to aid in tying-off. Some have a peg to keep the rope from sliding off allowing it to be used to add additional friction. Can be found on both 'J' & 'U' racks; some may even have 2 hyper bars. Some only extend out one side of the rack (shown).
- Hold** The brake rack operator applies the maximum amount of friction available and holds the load for a temporary stop.
- Tie-off** The brake rack operator applies the maximum amount of friction available and ties the rack off so that it can be left unattended and will not allow any rope to pass through. This may be done with or without tension on the rope. Some also call this "Lock-off" though I have seen "Lock-off" used interchangeably with "hold".
- Settling** After tying-off, rope creeping through the rack until the tie-off has come under sufficient tension to equalize and stop creeping.



Most common rack types

- Standard 'J' rack
- Standard 'J' rack with hyper bar
- 'U' rack
- 'U' rack with hyper bar

It should also be noted that even among the common racks there is variety. SMC for example has, in the past, been providing aluminum bars for their racks made from 3/4" bar stock. They have recently switched to 7/8" bar stock. This will have some effect on performance and users of different racks may not notice the differences prior to operation.

Less Common Rack Types – not examined here

- Standard 'J' rack with 2 hyper bars, top & bottom
- 'U' rack with 2 hyper bars, top & bottom

There is some variety in the types of racks used and the number and type of accessories. See <http://storrick.cnchost.com/VerticalDevicesPage/Glance.html> for an example of the large variety of types available.

A Note on Gripping Ability

In the report, Gripping Ability on Rope In Motion, (Rigging for Rescue, 1994), a number of qualified rope rescuers were examined to determine their ability to grip a rope in a realistic scenario. (Gripping a moving 11mm rope with one gloved hand.) The results were surprising with a gripping ability ranging from 46N to 425N with an average of 209N. This is a significant factor when determining techniques where gripping ability is an important consideration on a load considered to be 2000N. Rigging where tension of 10% of the load is required to safely operate the rack would mean that 50% of rescuers simply could not operate it. Another concern of mine and one that was not examined by the RFR report is the degree and magnitude fatigue plays.

Brake Rack Operation

Brake rack operation varies widely. Some techniques being practiced do not make full use of the equipment's capabilities while some other techniques present safety issues. With an eye to examining the predominant techniques used and a hope of bringing about some standardization to something that should be easily standardized, this report has been prepared.

There seem to be two basic techniques practiced for operating a brake rack:

In-Line The rope is kept in a straight line, leaving the rack largely in the same direction as it entered it, as when rappelling.



Pulled-Back After threading through the bars the rope is immediately pulled back toward the load as much as 180°



Brake racks reduced to 4 or even 3 bars and pulled-back during the lowering of two-person loads seems to be a fairly common practice, especially among newer practitioners who seem to be unaware of the technique of adjusting the bar spacing.

There are some advantages and disadvantages to each technique. This is an effort to identify those in an effort to foster better understanding amongst the rope rescue community.

In-line vs. pulled-back, a comparison

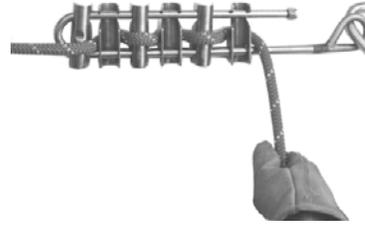
In-line

- operator faces the load and can keep a clear view of the action area
- operator does not need to be beside the rack and not behind it
- It is not necessary to twist (roll) the rack when adding or removing bars
- There is no rope twist
- No wear to the rack frame
- Bars are easily available to vary friction by varying spacing
- By pulling back when needed the operator can add lots of friction quickly and easily to hold a load
- Adding and removing bars is easier
- Accommodates operators with weak gripping strength
- Any danger of fingers getting sucked into the rack is less than when using the pull-back – the rack frame provides a guard.
- The rack can be rigged the same way every time, whether for one or two-person loads.
- Pushing the bars together first makes adding and removing bars much easier.

Pulled-back

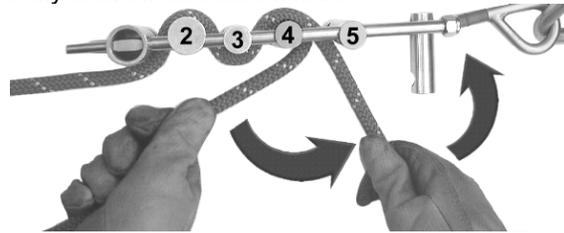
- operator may have their back to the action
- adding or removing one bar has the rope exiting the opposite side of the rack which can cause the operator to put a twisting action on the rack

- If the rope is pulled off to one side it can impart a small amount of twist and rope may be contacting the rack frame causing wear



- Rack is already providing all the friction it can without adding extra bars
- Reducing friction is difficult and often sees operators dropping bars
- Extra friction, when required suddenly, can only be provided by the operator's hands
- If minimal bars are used, relies heavily on operator's gripping ability: fatigue becomes a factor
- Tying-off may require that more bars be added first.
- Operator may already be in a position to effectively lock-off and hold a load

- Adding bars under tension can be difficult: Since the bars are already as close together as they can be, by bringing the rope around the rack friction is actually reduced before the new bar is engaged.



As shown, bar #4 is partially unwrapped as the rope is brought around before engaging bar #5. Bar #4 tends to slide away from bar #3 in the process. Both unwrapping and increasing the spacing between bars results in significant reduction in friction when the effort was to add friction.

- Reducing friction when using the 'pulled-back' technique is not easy. Returning the pulled-back angle from 180° to 90° has very little effect on reducing friction as the bars are still squeezed together. This may lead novices into removing more bars.

NOTE: Dropping bars on 'U' racks is equivalent to dropping 1 ½ - 2 bars of friction.

According to Smith and Padgett, **On Rope 2nd Ed.**, there are 4 ways to vary the friction in a rack:

- Changing the number of bars in contact with the rope
- Changing the distance between the bars
- Changing the tension on the rope to place greater pressure on the friction surface
- Change ropes to a larger or smaller diameter

Given that changing the rope diameter is not desirable, that leaves us with 3 ways. The third way, during a lower, can only be provided by the operator's hands.

Are we always using the most appropriate technique to vary the friction?

Suggested basic rules for brake rack operation:

- Wear gloves
- Start with more bars than you think you'll need – all 6 bars for a two-person load
- Always have extra friction immediately available
- Do not rely on the operator's hands to provide additional friction when required
- Try adjusting bar spacing before removing bars
- Never use less than 4 bars
- At least tie a knot in the end of the free rope, prefer to have it clipped-in to anchor
- Keep hair, clothing or debris from tangling in the rack

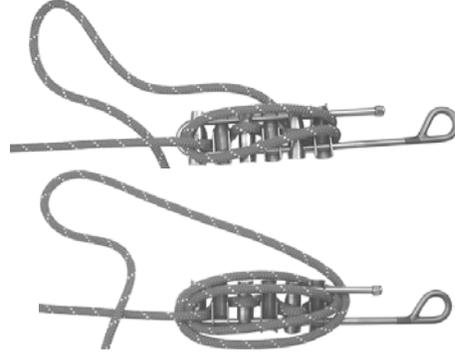
Brake Rack Tie-Off

There are a wide variety of techniques used to tie-off brake racks. In an effort to examine the most common in an effort to make an informed decision about their suitability I have compiled a list here as well as some criteria for examination.

Note: A proper tie-off should help to pull the bars together.

There are some things that must be examined which apply to virtually all tie-off techniques:

- # of turns around the rack frame: 1 or 2

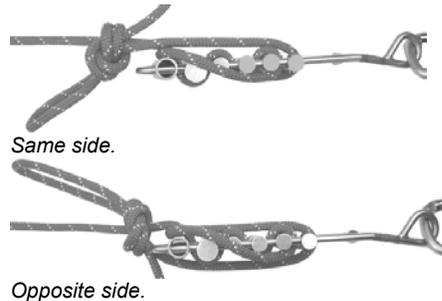


- Should more bars always be added before tying-off?

- Should a carabiner be part of a tie-off?

- Should all tie-offs be backed-up?

- Should a tie-off in front of the rack have the rope approach the loaded line from the same side or opposite side of the top bar?
Is this really a concern?



A selection was made of some of the more common tie-offs being used as well as a couple which are published in popular textbooks on the subject. To make a fair comparison between the different ties a list of criteria was established.

Evaluation Criteria

1. Able to provide secure tie-off	-Slippage -Can it come untied on its own -Can it sustain repeated loading and unloading? -Secure with stiff and supple ropes -Amount of settling should be minimal -withstands external influences such as vibration or someone tripping over loose rope.
2. Ability to untie under tension	Must be done safely and with control -Amount of drop if any as rack untied -chance of rope jamming? -Does operator have control of the rope and load at all times?
3. Ease of tying	-Speed -Teachability -Special knot required? -Easily tied incorrectly? -Can it be tied one-handed? – concern when rappelling
4. Compatibility	- Can be used on a variety of racks - Is a special tie required that is not used elsewhere? (Munter tie-off?) - Can it be used on rappel?
5. Ease of inspection	Self explanatory
6. Amount of rope consumed	-Factor when dealing with knot pass -measured from point where rope contacts last bar and with one turn around rack where appropriate.
7. Other considerations	

Standard 'J' Rack Tie-Offs

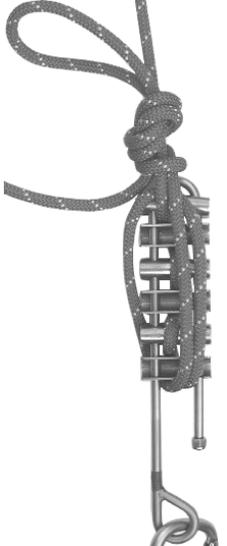
1. Clove hitch or Girth Hitch (2 half hitches) around short leg

	1. Able to provide secure tie-off	Yes. Questionable about use with stiff rope and ability to stay in place. Only reliable with very supple ropes.
	2. Ability to untie under tension	Easy
	3. Ease of tying	Quick and easy, little chance of mis-tying. Stiff ropes would be difficult -Can be tied one-handed
	4. Compatibility	-Only useable on 'J' racks. Will not work on CMC – NFPA racks w/swing plate. -If used on rappel the weight of the rope below may tend to pull the tie-off off the end of the rack.
	5. Ease of inspection	Very easy
	6. Amount of rope consumed	75cm Least amount of all those examined.
	7. Other considerations	Any creepage in the rope will tend to pull the tie up the short leg keeping it secure.

2. Single Half hitch on a bight around body of rack

	1. Able to provide secure tie-off	-Question about ability to stay tied securely, especially with stiff ropes. -Potential to slide down the rack. -Movement, vibration or someone tripping over the loose rope may cause this to come untied
	2. Ability to untie under tension	Easy
	3. Ease of tying	Easy
	4. Compatibility	Can be tied on 'J' and 'U' racks. -Do we use half hitches anywhere else? -NOT RECOMMENDED for rappel
	5. Ease of inspection	Easy
	6. Amount of rope consumed	138 cm
	7. Other considerations	This may be one that requires a carabiner to ensure security.

3. Stopper Knot with overhand-on-a-bight backup around standing rope

	1. Able to provide secure tie-off	Yes
	2. Ability to untie under tension	Easy. Stopper knot unties such that operator can have both hands at the ready as load comes on the rope.
	3. Ease of tying	Easy
	4. Compatibility	-Can be used with "J" and "U" racks -Stopper knot is the same as used for tying-off a Munter hitch, pretensioned back-tie, etc. -Suitable for rappelling
	5. Ease of inspection	Moderate. May be difficult to see if overhand is in place of stopper knot.
	6. Amount of rope consumed	171cm
	7. Other considerations	-Most common currently in use by lower mainland SAR teams. -Easiest to tie tightly and minimize creepage and settling. -Untying ensures good control at all times.

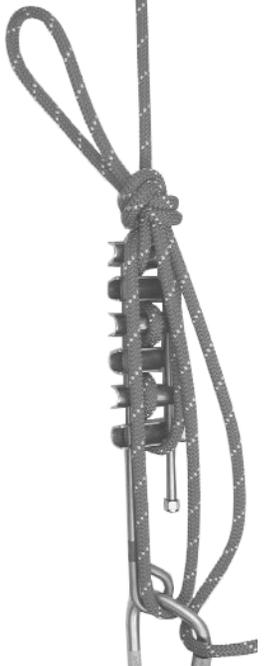
4. 1 turn, single overhand on loaded line (Technical Rescue Riggers Guide p.56 and others)

	1. Able to provide secure tie-off	Yes -May not be as secure with stiff rope
	2. Ability to untie under tension	Moderate, both hands required to untie.
	3. Ease of tying	Easy
	4. Compatibility	-“J” and “U” racks -Can be used on rappel -Can't be used on Munter
	5. Ease of inspection	Easy
	6. Amount of rope consumed	134 cm
	7. Other considerations	Most common depicted in text books.

5. Overhand knot with overhand backup around standing rope

	1. Able to provide secure tie-off	Yes
	2. Ability to untie under tension	Moderate. Requires both hands to untie overhand and when undone operator may not have complete control of the rope.
	3. Ease of tying	Easy
	4. Compatibility	-Use on both “J” and “U” racks -Simple, familiar tie. May be confused with blocker. -Hand position during untie may not be ideal.
	5. Ease of inspection	Easy
	6. Amount of rope consumed	186 cm
	7. Other considerations	Is second overhand really necessary?

6. Bight through carabiner and tied to standing rope (From On Rope 2nd ed., pp. 123)

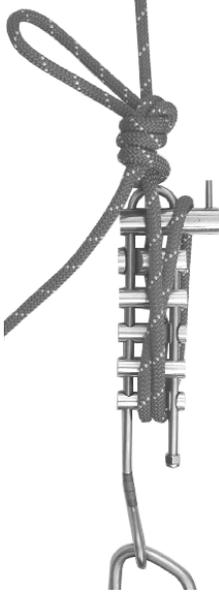
	1. Able to provide secure tie-off	Yes
	2. Ability to untie under tension	Easy
	3. Ease of tying	Slower, may be difficult to push a bight through small 'biners.
	4. Compatibility	- Use on both "J" and "U" racks -Use on rappel
	5. Ease of inspection	Moderate. Dependent on tie used.
	6. Amount of rope consumed	203 cm
	7. Other considerations	Unfamiliar to most rescuers. Pushing a bight through the carabiner may be difficult with a smaller carabiner. Much slower than simply wrapping between rack legs. This seems like an extra step that does not solve any problems yet makes a slower and more complicated tie.

7. Two half hitches on a bight around standing rope

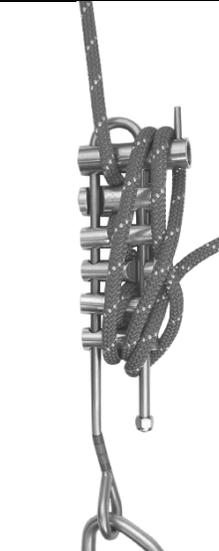
	1. Able to provide secure tie-off	-May not be secure, especially with stiff ropes. -Permits more settling than overhand
	2. Ability to untie under tension	Easy
	3. Ease of tying	Easy
	4. Compatibility	"J" and "U" racks -Do we use half hitches anywhere else? -Not recommended for rappelling
	5. Ease of inspection	Easy
	6. Amount of rope consumed	146 cm
	7. Other considerations	

'J' Rack with hyper (tie-off) bar

8. loop over tie-off bar then tied-off to standing rope

	1. Able to provide secure tie-off	Dependant on actual tie used. Improves functionality of tie.
	2. Ability to untie under tension	Easy. Hyper bar provides extra friction that makes untying and returning to a smooth lower very easy for the operator.
	3. Ease of tying	Easy
	4. Compatibility	"J" and "U" racks -Very suitable for rappelling
	5. Ease of inspection	Easy
	6. Amount of rope consumed	166 cm
	7. Other considerations	-Eliminates chance of a turn of rope jamming between the frame and loaded rope. -Hyper bars may be used with various other tie-off techniques and are available as a retrofit to some existing racks. -Cleaner and neater, improves confidence and comfort -Looping over the hyper bar adds friction quicker and easier than adding bars

9. Cleat around tie-off bar and short leg

	1. Able to provide secure tie-off	Yes, if set properly -hyper bar must have a peg
	2. Ability to untie under tension	Easy
	3. Ease of tying	Easy -Can be tied one-handed
	4. Compatibility	"J" rack only or "U" rack w/2 nd hyper bar -Good for rappel
	5. Ease of inspection	Easy
	6. Amount of rope consumed	76 cm
	7. Other considerations	

'U' Rack tie-offs (NOTE: Rescuers should use 6 bar racks. 4 bar rack was used for images, measurements are for a 6 bar rack.)

10. Bight through the frame and tied to standing rope

	1. Able to provide secure tie-off	Yes
	2. Ability to untie under tension	Moderate
	3. Ease of tying	Cumbersome, especially with gloves on, to push a bight through the rack frame
	4. Compatibility	Dependant on actual tie used.
	5. Ease of inspection	Dependant on actual tie used.
	6. Amount of rope consumed	190 cm
	7. Other considerations	If the rack does not have a hyper bar (most 6 bar "U" racks do) this is the only reliable tie-off for a "U" rack.

11. "Cleat" around hyper bar

	1. Able to provide secure tie-off	-May not be secure with stiff rope -short hyper bars would be a concern -can be done without pegs in the hyper bar by incorporating the rack legs.
	2. Ability to untie under tension	Easy
	3. Ease of tying	Very easy Little chance of mis-tying -Can be tied one-handed
	4. Compatibility	-Only use on "U" racks, "J" rack would require a hyper bar with pegs on both sides -Quick and easy to do on rappel
	5. Ease of inspection	Very easy
	6. Amount of rope consumed	No turn:(shown) 54 cm 1 turn: 113 cm
	7. Other considerations	Cannot be done with one-sided hyper bars.

Questions:

- Are any teams using "U" racks?
- Are any teams using stainless steel racks?
- Are any teams using hyper bar racks?
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Conclusions

This is only a preliminary look at brake bar racks in an effort to stimulate some feedback on what is currently being used and preferred. With information gathered we should be able to come to some sort of standardization on both operation and tying-off the brake bar rack.

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Brake Rack Tie-Off Comparison Chart

CRITERIA	1 Secure		2 Controlled untie	3 Easy to tie		4 Compatibility				5 Ease of Inspection	6 Rope Consumed	
	Supple Rope	Stiff Rope			One-handed		"J"	"U"	Existing Tie	Rap		cm
1) Hitch around short leg	Yes	No	Easy	Easy	Y		Y		Y	RA	Easy	75
2) Tie around body of rack	No	No	Easy	Moderate			Y	Y	No	RA	Moderate	138
3) Stopper w/ OH	Yes	Yes	Easy	Easy		Consistent w/other ties used; familiar	Y	Y	Y	Y	Moderate	171
4) Single OH	Yes	Moderate	Easy	Easy		Most common in text books	Y	Y	Y	Y	Easy	134
5) OH w/OH backup	Yes	Yes	Moderate	Easy			Y	Y	Y	Y	Easy	186
6) Bight through biner & OH	Yes	Moderate	Easy	Moderate			Y	Y	Y	Y	Moderate	203
7) Double Half Hitches	Iffy	No	Easy	Easy			Y	Y	No	RA	Easy	146
8) Loop over hyper bar		Yes	Easy	Easy		Hyper bar offers benefits to all ties	Y	Y	*	Y	Easy	166
9) Cleat on hyper bar & short leg	Yes	Yes	Easy	Easy	Y		Y		No	Y	Easy	76
10) "U" – bight through frame	Yes	*	Moderate	No				Y	*	Y	*	190
11) Cleat around hyper bar	Yes	Moderate	Easy	Easy	Y			Y	No	Y	Easy	54/113

RA = recommend against

* Dependent on the tie used