Hauling System Limitations

Part III

A hauling rig's limitation varies depending on the type of components used in the system. For this discussion we will use a 3/8-inch Spectra® rope and look at different aspects of the system to optimize what components carry the greatest loads. It's important to understand how and why different components act on the system the way they do. Understanding this allows you to maximize the force a system can handle when you combine equipment from the group.

Let's review what we already know. A 90-degree or greater "bending" around carabiners is a compromising factor. While I could find no published data on this, swiftwater expert Tim Delaney who has decades of knowledge and practical testing, estimates that "carabiner bends" reduce a rope's strength by 40-50% of its original rating. Using double carabiners of the same size at connection points and making sure the looped ends of your rope have the clear plastic sleeves over the rope greatly reduces the "bending effect." This bending effect as well as the loss to friction makes carabiners next to worthless as pulleys for heavy loads. Use rescue pulleys to reduce the bending effect to negligible and greatly improve the efficiency of the haul system. The diameter of the pulley wheel should be 4 times the rope diameter. So a 3/8-inch rope needs a pulley that has a 1.5-inch "tread" diameter. This means plastic pulley wheels, while better than carabiners, still have a bending effect on the rope.

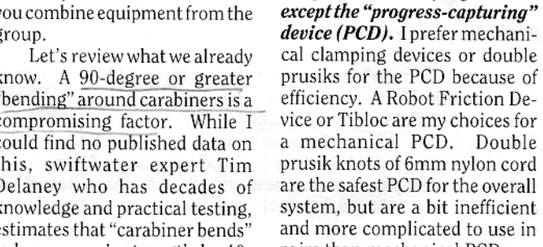
3/8 x 4 = 1.5
1/2 x 4 = 2.0

Clamping Devices...the limiting factor?

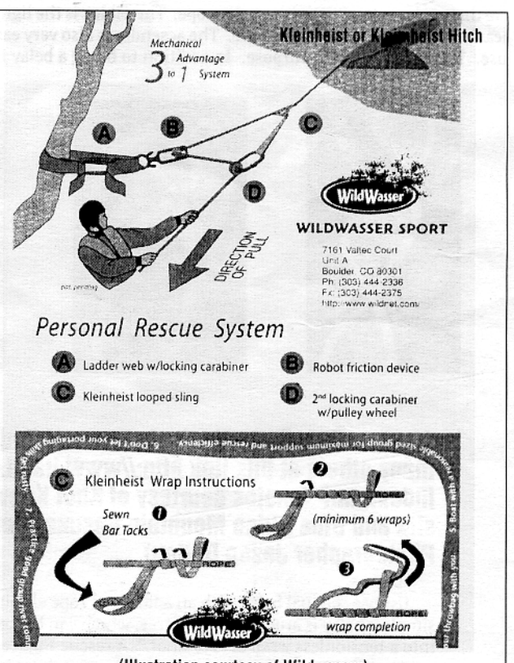
The next limiting factor in the sequence is the holding capacity of clamping devices. Clamping devices include cinching knots like the prusik or kleinheist/kleimheist and mechanical clamping devices like the Tibloc or ascender. ***I've chosen to use the kleinheist hitch tied with 1-inch nylon sewn slings for all clamping devices except the "progress-capturing" device (PCD).*** I prefer mechanical clamping devices or double prusiks for the PCD because of efficiency. A Robot Friction Device or Tibloc are my choices for a mechanical PCD. Double prusik knots of 6mm nylon cord are the safest PCD for the overall system, but are a bit inefficient and more complicated to use in pairs than mechanical PCDs.

The load that causes a clamping device to slip increases with the diameter of the rope. A prusik knot begins slipping between 900-1200 lbs on dry 1/2 in. (12.7mm) nylon rope. (Walbridge, "*Whitewater Rescue Manual*" p. 83) This means slipping loads will be even less for smaller diameter wet ropes. For knots, the slipping load is also very dependent on the exact rope and type cord or webbing used. Increasing the number of wraps or using the knots in pairs helps prevent slipping. A pair of 6mm prusiks evenly loaded should be able to hold 1800-2300 lbs. The trick is keeping them evenly loaded. The risk with cinching knots is that when the knot's slipping load is greater than the shear rating of the rope's sheath, the knot tears the sheath apart, causing the system to fail and possibly the rope to break. This is very likely with double prusiks that have an extra turn. The gray area is that manufactures don't publish shear ratings. Tim Delaney believes the shear for Spectra® is around 2200-2300 lbs. This is based on his personal tests and practical use.

The only cinching knot that has a slipping loader greater than its own failure point is a kleinheist hitch tied with 1-inch nylon tubular webbing sewn sling (Delaney). The strength of this hitch is about 50% of the webbing's tension rating. The 1-inch webbing in this hitch will fail between 3000 and 3700 lbs, which exceeds the effective rope strength of 3/8-inch Spectra®. The kleinheist hitch slips or causes shear failure when tied with 9/16-inch Super Tape or Spectra® webbing/cord. The reason 1-inch nylon works is that it has a greater surface area to distribute the load, yet still has enough friction to prevent slipping. The friction of cinching knots after they have been loaded is one of the disadvantages of using them as the PCD/brake knot.



A 3:1 "Z-drag" with prusiks (Photo courtesy of Ken Laidlaw)



(Illustration courtesy of Wildwasser)

Mechanical devices should not be used as the traveling clamping device because they will slip at loads well below the rope's max load. The load on the PCD however, is always less than the pulling load due to the friction in the haul system as well as the friction caused by dragging the boat over rocks while the water applies pressure increasing the friction of the drag. This means the PCD can have a much lower slipping load than the clamping device(s) that pull the rope. This makes mechanical devices a real option, especially if backed up by a prusik.

Part IV

1 kN = 225 lbf 1 kg = 2.205 lbm

The Tibloc

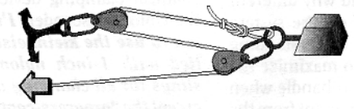
made by Petzl begins slipping between 900-1700 lbs and is designed for 8-11mm ropes. The Petzl Basic Ascender slips between 950-1450 lbs and is designed for 8-13mm ropes. Like cinching knots, the larger the rope diameter, the greater the slipping load is for mechanical devices. When most mechanical devices slip, their teeth damage the rope sheath, reducing rope strength and possibly causing rope failure. The exception to this is the Robot Friction Device by Kong. The Robot will hold loads greater than the rope's shear strength before slipping.

Left to right: Petzl Tibloc (12Kn=2727 lbs) 8-11mm rope slips 4kN-7.5kN, **Petzl Basic Ascender** (12kN) 8-13mm rope slips 4.2kN-6.5k, **Robot Friction Device** (21kN) 6-13mm (rope fails before Robot slips)

The Tibloc and ascender work well as the PCD, but should be backed up with a prusik for loads that may reach the devices slipping load. The Robot is an excellent PCD for a belay device in a 4:1 or other rig that replaces the PCD with a belay rope. The Tibloc is the lightest, least expensive and very easy to use. The acsender is also very easy to use. The Robot is multi-purpose. In addition to being a belay PCD, it can be used as a pulley and is very easy to release under tension by one person. As a pulley, the Robot has too much friction to be very efficient, but is better than a simple carabiner pulley. The Robot's other end serves as a belay or rappel device. The real advantage to the Robot is that it takes no time to set up. I own all three and decide which to carry based on the group size and specific run.

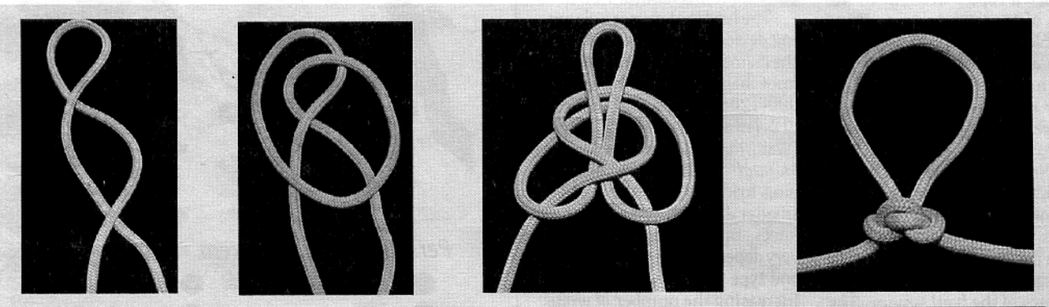
Haul Rigs without clamping devices

You can eliminate clamping devices that pull the rope by using "mid-rope" knots like the Butterfly loop or attaching the traveling pulley directly to the load. Attaching the traveling pulley to the load requires a lot more rope and is usually not practical in small groups.

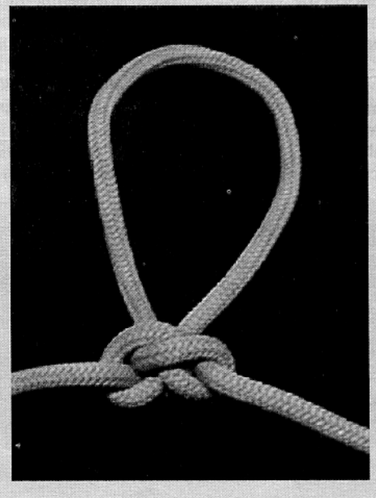


(Illustration courtesy of Ken Laidlaw)

Using "mid-rope" knots does however cause additional loss in rope strength. The Butterfly Knot reduces rope strength by 31% and a "mid-rope" Figure-8 loop by 35%. The real advantage of the Butterfly is that it is much easier to untie than the Figure-8 after they've been "loaded." A 3/8-inch Spectra® with figure-8 loops in the ends and Butterfly knots mid-rope would have a breaking strength of about 2650 lbs =[4500*0.59] (0.31 for Butterfly and 0.1 for effect of water).



Steps to tie a Butterfly Knot. You can find this knot and many others at this link http://www.iland.net/~jbritton/index.html (photos courtesy of Knot Knowledge web site and Blue Ridge Mountain Rescue Group Photographer Jason Dalton)



Using a manual belay with an additional rope eliminates the PCD. The simplest belay is around a sturdy tree, which can be easily tied off or made into a tensionless wrap or "No-knot." A rescue Figure-8 belay device also works well. The Munter hitch is another option, but I have no data on what load a Munter Hitch will hold or its breaking strength. I think its breaking strength will be around that of a Clove Hitch, 35-40%. I would not recommend using the Munter Hitch unless you have no other options under heavy loads

This kind of system is a bit complicated, but this method reduces the equipment required. No matter which method or what equipment you decide to use, it's important to practice the techniques before having to use them. Also take necessary safety measures. If the system fails under these kinds of loads, rescuers can be seriously injured.