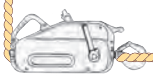
Forest Service
U.S. DEPARTMENT OF AGRICULTURE

National Technology & Development Program
2223–2806–NTDP
2300–Recreation, Wilderness, and Related Resource Management
August 2024

Rigging for Trail Work:

Principles, Techniques, and Lessons from the Backcountry

Cover photo—Moving a felled tree using a rigging skyline.



In accordance with Federal civil rights law and U.S. Department of Agriculture (USDA) civil rights regulations and policies, the USDA, its Agencies, offices, and employees, and institutions participating in or administering USDA programs are prohibited from discriminating based on race, color, national origin, religion, sex, gender identity (including gender expression), sexual orientation, disability, age, marital status, family/parental status, income derived from a public assistance program, political beliefs, or reprisal or retaliation for prior civil rights activity, in any program or activity conducted or funded by USDA (not all bases apply to all programs). Remedies and complaint filing deadlines vary by program or incident.

Persons with disabilities who require alternative means of communication for program information (e.g., Braille, large print, audiotape, American Sign Language, etc.) should contact the responsible Agency or USDA's TARGET Center at (202) 720-2600 (voice and TTY) or contact USDA through the Federal Relay Service at (800) 877-8339. Additionally, program information may be made available in languages other than English.

To file a program discrimination complaint, complete the USDA Program Discrimination Complaint Form, AD-3027, found online at https://www.ascr.usda.gov/filing-program-discrimination-complaint-usda-customer and at any USDA office or write a letter addressed to USDA and provide in the letter all of the information requested in the form. To request a copy of the complaint form, call (866) 632-9992. Submit your completed form or letter to USDA by: (1) mail: U.S. Department of Agriculture, Office of the Assistant Secretary for Civil Rights, 1400 Independence Avenue, SW, Washington, D.C. 20250-9410; (2) fax: (202) 690-7442; or (3) email: program.intake@usda.gov.

USDA is an equal opportunity provider, employer, and lender.

The Forest Service, an agency of the U.S. Department of Agriculture (USDA), has developed this information for the guidance of its employees, its contractors, and its cooperating Federal and State agencies.

The Forest Service assumes no responsibility for the interpretation or use of this information by anyone except its own employees.

The use of trade, firm, or corporation names is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval of any product or service to the exclusion of others that may be suitable.

All images are USDA Forest Service photos unless otherwise noted.

Rigging for Trail Work:

Principles, Techniques, and Lessons from the Backcountry

David E. Michael
Forest Trails Specialist (retired) U.S. Department of Agriculture, Forest Service, Tahoe National Forest

Jedediah J. Talbot
Forest Trails Specialist

John S. Glenn
Volunteer
U.S. Department of Agriculture, Forest Service

U.S. Department of Agriculture, Forest Service
National Technology and Development Program

1E12A72 Rigging for Backcountry Trails Manual

August 2024

Dedication

This manual is dedicated to John S. Glenn, volunteer extraordinaire, who devoted his retirement years to caring for the national forests. Through his example, his teaching, and his mentoring, he inspired others to love wilderness areas as he did.

Acknowledgments

With any project of this size and technical complexity, many people have made critical contributions along the way. First, the authors are grateful to Don Beers, California State Parks (retired) rigger extraordinaire, for his initial involvement with this publication. We also thank Lester Kenway, who has taught crews how to work safely with backcountry rigging for more than 30 years. In many ways, this manual is a testament to his dedication, vision, and pioneering innovations.

We thank our associates over many years, too numerous to mention, with whom we have been privileged to work in the backcountry. We have valued the friendships and problem-solving skills we encountered with these individuals as we made plans around a campfire for the next day's rigging challenges. We looked after and learned from one another. Many of the rigging insights in this publication come from this group of experienced workers.

David E. Michael gives special thanks to Mike Shields of the U.S. Department of the Interior, National Park Service (retired), for introducing him to basic trail-specific rigging back in the 1970s. Mike continues to inspire, influence, and teach a new generation of trail riggers.

Jedediah J. Talbot extends his gratitude to Peter S. Jensen for providing the guidance, vision, and unwavering confidence that a solution is always available when a person is open to seeing problems analytically and creatively.

John S. Glenn is indebted to all the trail workers, arborists, and loggers who willingly shared their expertise and experience to make working in the forest and using rigging rewarding and enjoyable.

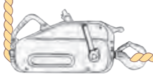
The authors extend their heartfelt thanks and gratitude to Alice Webber for her hard work and dedication as the talented illustrator of this manual. Her background working on trail crews and her involvement with rigging projects were invaluable to this project. From the very beginning, we recognized that a publication such as this could not convey the complex principles associated with trail rigging without clear, concise illustrations. Alice's beautiful illustrations have exceeded our expectations—we are forever grateful.

Special thanks to Susan Jenkins and Bob Beckley of the U.S. Department of Agriculture, Forest Service, National Technology and Development Program (NTDP) for shepherding this project through the publication process and to Dick Karsky, Ted Etter, Russel Wicka, and Christopher Murphy for providing guidance and support for the many technical aspects of this project. Their practical and skilled engineering, mathematical, and rigging experience was invaluable while finalizing this publication.

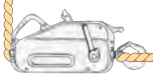
Thanks also to Caleb Jackson for all his talents and for his contributions to the illustrations. Caleb's focus and skill as an artist were integral to the success of this collaborative project.

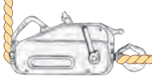
Finally, thanks also to the tech transfer division at NTDP for their contributions:

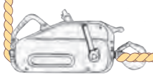
- Editors: Andrew D. McLean, Clara Wheeler, and Eva Masin
- Visual information specialists: George Toyama and Sunni Bradshaw
- Graphics assistance and support: Thorin Brown



Contents







Chapter 1: Introduction

Rigging is the use of specialized tools to safely move heavy objects from one location to another (figure 1–1) without causing undue strain on the body of a rigging crewmember (hereafter referred to as a "rigger" or "you"). When used properly, rigging greatly expands the options and efficiency of trail construction and maintenance activities—from simple, repetitive work projects involving minor forces (e.g., moving trail materials from one location to another) to complicated scenarios involving massive forces that require the use of mechanical advantage (e.g., moving bridge timbers, big rocks, or large trees). Rigging can also provide a safe alternative for bringing down lodged trees or for pulling stumps.

The authors of this manual have more than 70 years of combined experience using rigging, and can attest to the fact that knowledge and proper training increase efficiency and prevent accidents. However, rigging provides little room for error. If you willfully or inadvertently break one of the laws of physics, the results can be immediate and potentially disastrous. Because of the potential for serious injury or death during rigging operations, you must have an adequately trained and experienced lead rigger to lead you in rigging applications.

We recognize that an effective manual on safe rigging techniques must be based on a thorough understanding of the basic principles of force, movement, and environmental sensitivity, and on selecting good, quality rigging components.

In addition to many years working with trail rigging, we bring to this project our personal experiences in logging, marine stevedoring, military combat engineering, construction rigging, tree climbing and arborist activities, rock climbing, and high-angle rescue. We have gleaned information, regulations, and specifications from these experiences and related rigging situations.

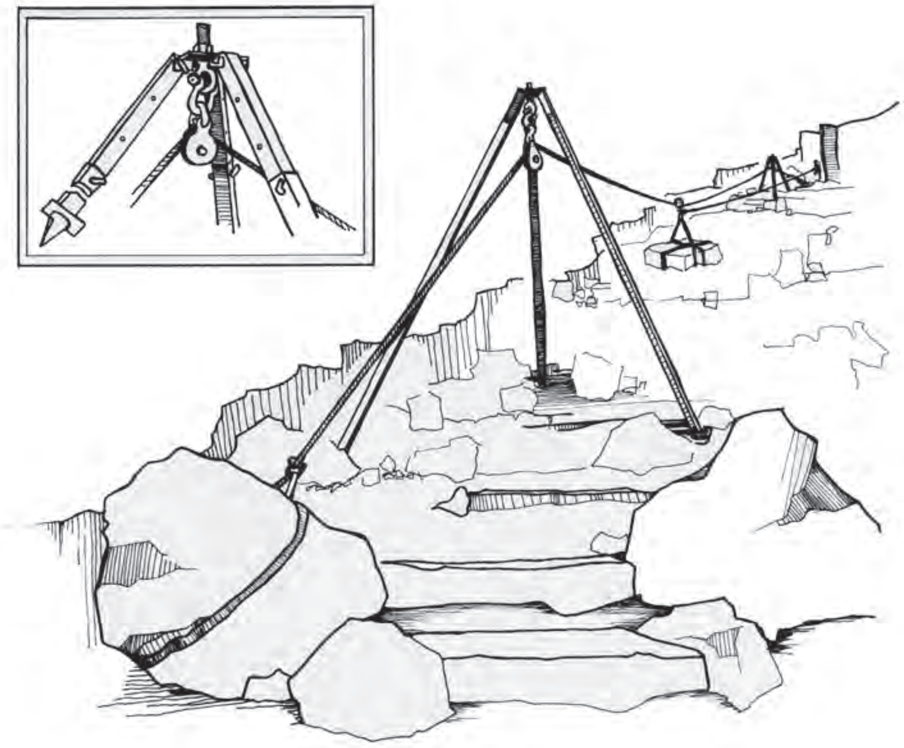


Figure 1–1—A portable, lightweight metal tripod with fiber rope.

In this manual, we refer to various historical structures and techniques that may be useful for trail rigging today. Though the laws of physics never change, today's riggers have lightweight materials and technology that make rigging jobs safer and more efficient.

We designed this manual primarily for U.S. Department of Agriculture, Forest Service trail maintenance and bridge construction work, but you can use the principles of rigging on many resource projects. Riggers can use this manual as a reference in the field, and rigging instructors and employees can use it to prepare a job hazard analysis (JHA). Though we focus mainly on the use of hand equipment, we also cover some power tools and basic information about using stock animals (such as horses, mules, or oxen) for rigging applications.

This manual teaches fundamental concepts of force and movement, rather than simply requiring you to memorize math formulas. Successful rigging depends on an understanding of the complexity of the forces at work and the effects of your actions on these forces. You must strive for a fail-safe rigging system and maintain the capacity to safely manage the failure of any component. This concept is very important because riggers often deal with unknown and highly variable physical environmental influences. Focus on when, rather than if, a component will fail. As the weight of the load on a system increases, the amount of force required to move the load also increases. This additional force makes damage or injury more likely when a component fails.

Identifying the weakest link in a rigging system and mitigating the effects if that link should fail are key components of a safe project. The best weak link is engineered into a power source, such as shear pins in a griphoist. Calculate and estimate the forces in all parts of a system; it is easy to generate forces far beyond the capacity of the weakest link in one part of a system. Angle is critical to the load limit. The greater the angle, the more stress on the component. The bottom line is that a failure can occur in any component. We describe how to select and safely use components in many rigging systems.

Knowledge of the equipment and materials used in backcountry trail rigging is one of the most important factors for preventing accidents and promoting efficiency. Manufacturers design each piece of equipment or material to provide a specific function. For this reason, we emphasize the selection, care, and inspection of all components within a rigging system. The maximum load on each individual component should fall within manufacturer-established limits. We have seen numerous rigging projects that used substandard, nonrated components bought at a general hardware store. We stress throughout that you must know the working load limit (WLL) of all components, and the WLL of each component's accompanying safety design factor. Know what safety design factor to use (generally, 5 to 1 and up to 10 to 1).

Rigging has far too many variables to comprehensively cover in a "how to" manual. This manual is not a substitute for training. We occasionally make recommendations of products or procedures based on our experiences. Our intent in writing this manual is not to prevent you from using other options for equipment or procedures. Consult with rigging professionals, equipment manufacturers, or rigging instructors about complex applications. Projects on National Forest System lands require a certification process for skills such as helicopter operations, tree climbing, saw use, and handling stock (pack animals). We do not describe these skills in detail. If you intend to use these skills but are not currently certified, check with your forest safety officer about obtaining certification, or find out when the next training and certification classes will be held. Rigging currently requires no certification, but proper training is essential.

Though written information cannot prevent accidents, understanding the information in this manual, along with applied field experience, can help you safely master the tasks of trail rigging.

Chapter 2: Wire Rope

Trail riggers use wire rope to accomplish much of their rigging work. Wire rope, often referred to as cable, consists of numerous wires laid out in a particular helix pattern. The wire rope runs through griphoists (figure 2–1) and onto drum-spool winches. As a rigger, you use wire rope for anchoring, slinging and guying, and for pulling, lowering, and suspending loads. Manufacturers make wire rope from different materials in conjunction with a wide range of designs for specific applications. You should consider some requirements when determining the best wire rope for a trail project:

- How strong must the rope be?
- How much will the rope need to bend?
- How will the rope connect to a winch or hoist?
- How well will the rope resist abrasion, corrosion, crushing, and rotation?
- What is the minimum diameter rope required for the application?

To meet the various needs for strength, wear resistance, and other factors, wire rope comes in four grades that identify different breaking strengths. The grades of wire rope, ranked from weakest to strongest, are:

- Plow steel (PS)
- Improved plow steel (IPS)
- Extra improved plow steel (EIPS)
- Extra extra improved plow steel (EEIPS)

Wire ropes used for rigging almost always fall into the last two grades, EIPS and EEIPS.

Wire rope suppliers can help determine the best rope for a specific application.

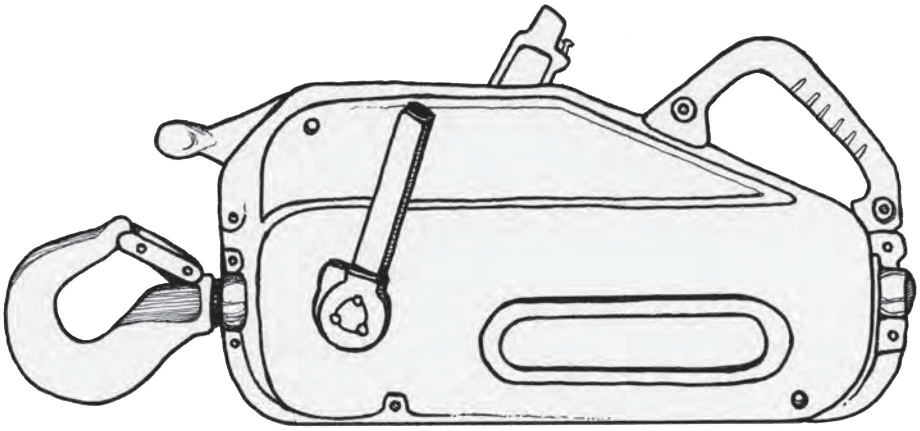


Figure 2–1 — A griphoist manual wire rope-pulling machine.

The three components of wire rope (figure 2–2) are:

- A core
- Individual wires that form the strands
- Strands composed of several individual wires laid in a helical pattern around the core

Core—The core is the foundation of wire rope (figure 2–3). Core material can be either steel or some form of fiber. The most common core designations are independent wire rope core (IWRC), which is a common rigging wire rope; fiber core (FC), either natural or synthetic; and wire strand core (WSC). The core can provide up to 50 percent of the overall strength in IWRC configurations.

Wires—One wire rope may contain hundreds of individual wires, which collectively determine the rope's strength and flexibility. When a wire rope bends, each wire slides and adjusts according to the difference in length between the inside and outside of the bend. The more sharply a wire rope bends, the more the wires on the outside circumference must move.

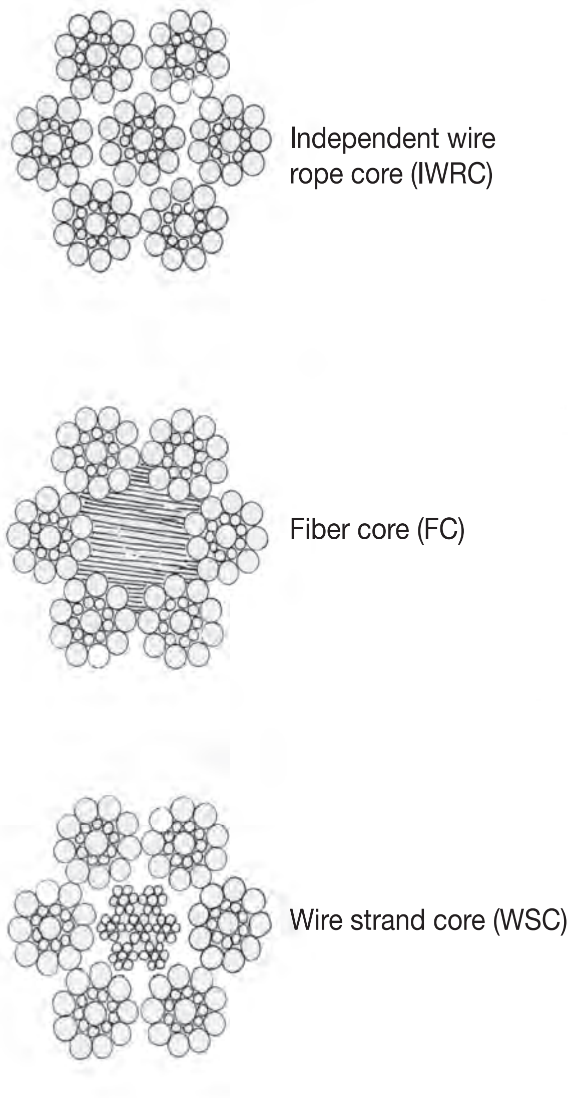


Figure 2–3—Typical 6 by 19 wire rope construction.

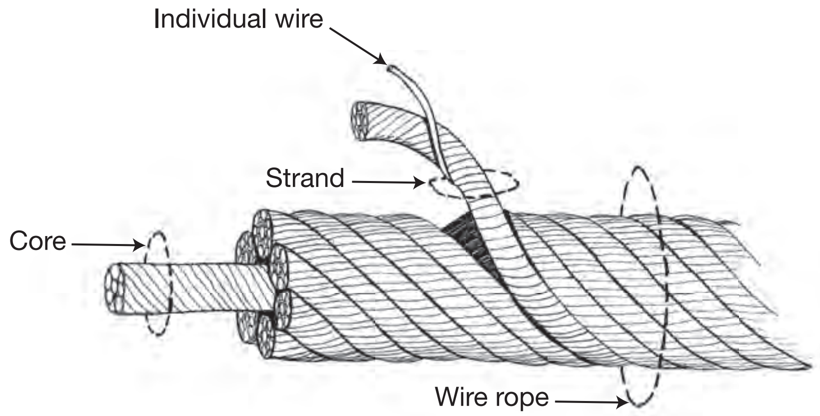


Figure 2–2—Typical wire rope anatomy.

Strands—Strands consist of a specific geometric arrangement of two or more wires. Most wire rope manufactured in the United States has six strands. Industry standards classify wire rope by the number of strands and the average number of individual wires in each strand. A 6 by 19 or 6 by 25 classification is common in most chokers used in the timber industry. A 6 by 19 wire rope can have between 9 and 26 wires of varying diameters in a strand (depending on the pattern), but the average number is 19 wires.

The higher the number of individual wires, the more flexible the wire rope; the fewer the number of individual wires, the stiffer the wire rope. Fewer wires also make the wire rope more wear resistant.

Wire rope that runs through a continuous-feed power source (such as a griphoist) is a special type of wire rope. Instead of typical 6 by 19 wire rope construction, griphoists use a 4 by 26 or 5 by 26, rotation-resistant, galvanized, maxiflex wire rope in a Warrington strand configuration. It is important to understand the difference in construction and application between the common 6 by 19 and the less common (and more expensive) 4 by 26 and 5 by 26 constructions. Refer to "Chapter 6: Winches and Hoists" for further information about using wire rope in a griphoist.

Wire rope diameter is measured at the widest cross-sectional dimension (figure 2–4). Manufacturers also identify wire rope by its lay: regular or lang.

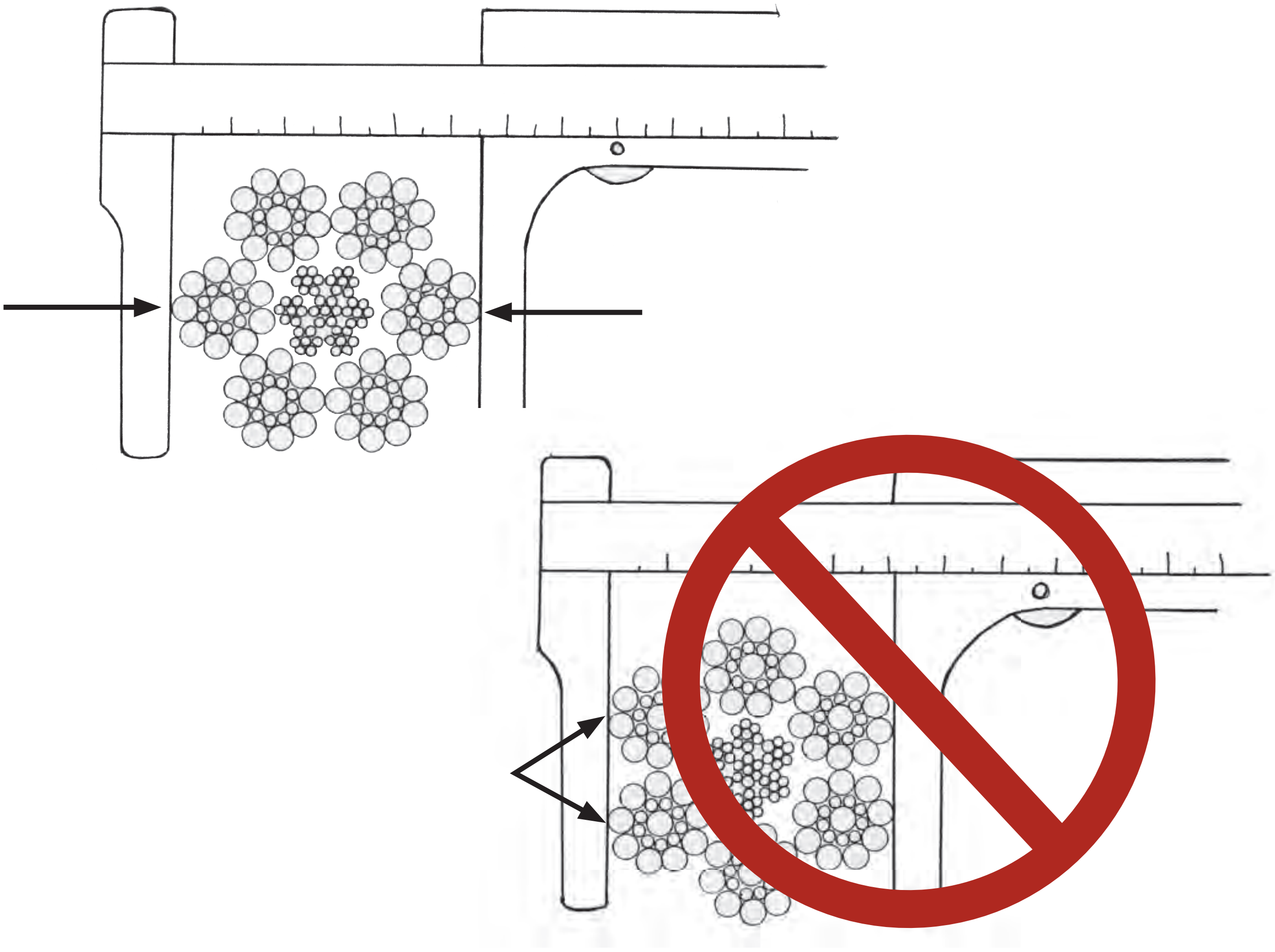


Figure 2–4—Correct and incorrect methods for measuring wire rope diameter.

Either type can lay to the left (figure 2–5) or right (figure 2–6). The difference is that, looking down the length of the rope in regular-lay construction, the individual wires appear to run parallel to the rope. In lang-lay construction, the individual wires appear to cross the rope at an angle. Right, regular-lay wire rope has the widest range of use and riggers generally use it for trail work. If chokers, slings, or lines appear to have a different construction than regular lay, they may be special, rotation-resistant ropes. These specialty wire ropes are more expensive and riggers primarily use them for helicopter operations.

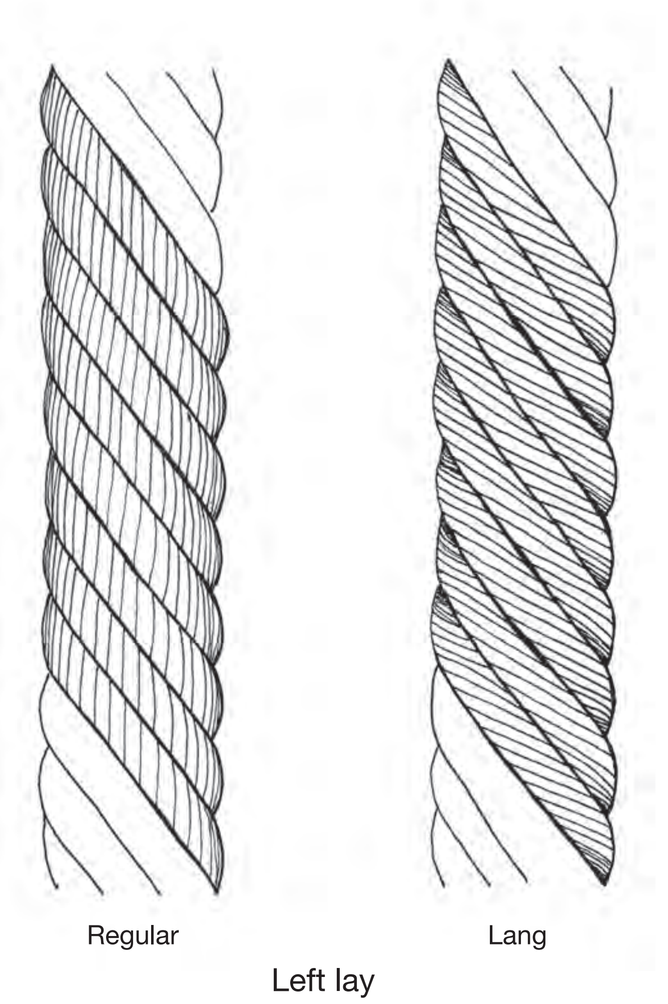


Figure 2–5—Regular and lang wire rope with a left lay.

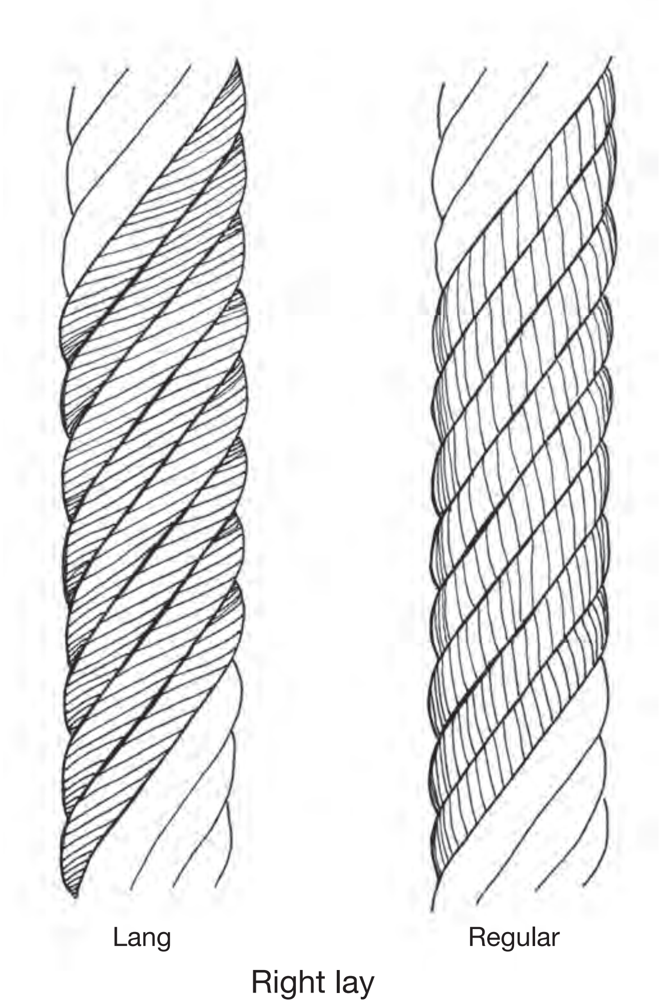


Figure 2–6—Lang and regular wire rope with a right lay.

Handling and Safety

You can maximize safety and the life of wire rope by:

- Always wearing protective gloves.
- Controlling wire rope from the spool or drum, or reeling it in a linear orientation, unless you use the over-under technique of coiling (figure 2–7).
- Never throwing loops of wire rope into stacks off to the side, as if it were fiber rope. Stacking will result in twisted wire rope that retains loops and potentially forms an open or closed kink (an open kink spreads the rope lay apart, while the closed kink twists the lay together). A kink may permanently damage wire rope.

Refer to "Appendix A: Terminating and Managing Wire Rope" for more information.

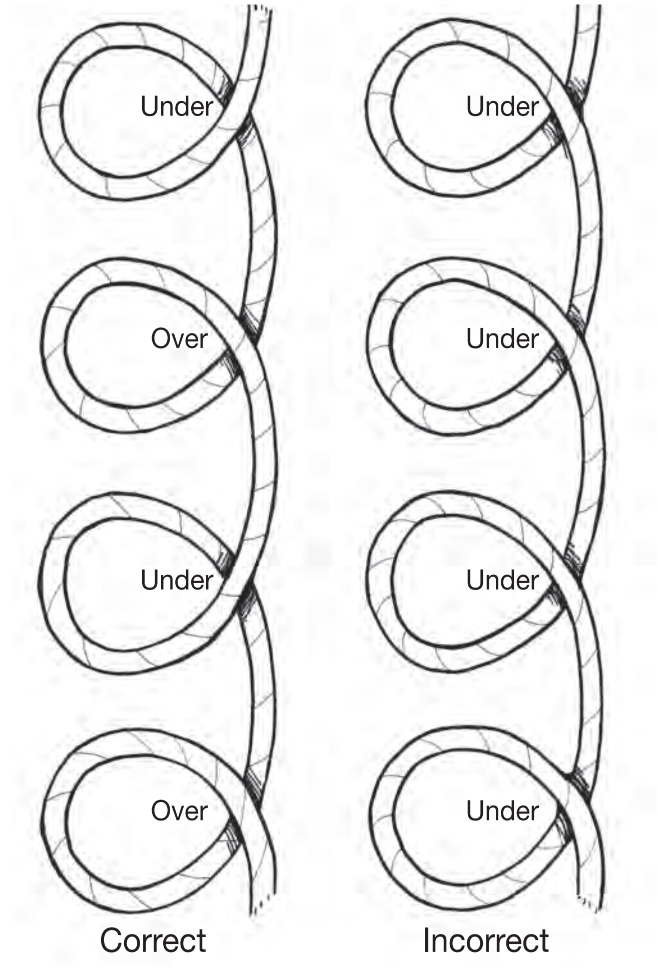


Figure 2–7—The correct (over-under) and incorrect techniques for coiling wire rope to avoid kinking.

Understanding Wire Rope Strength

Wire rope does not usually have a rating stamped on it, so a necessary skill for any rigger is the ability to calculate the working load limit (WLL) of a wire rope. As needed in the field, you can use two simple and safe methods to calculate the WLL of a wire rope.

Using a WLL of 250 pounds per 1/8-inch diameter for a particular type of wire rope, you would calculate the load limit for 1/2-inch wire rope as follows:

A wire rope with a diameter of 1/2 inch can also be described as wire rope with a diameter of 4/8 inch. The rope's cross-sectional area is proportional to the square of its diameter, so the area of the 1/2-inch wire rope is 4 squared, or 16 times greater than the 1/8-inch rope. Multiplying 16 by 250 pounds per 1/8 inch equals 4,000 pounds WLL.

Examples:
1/2-inch wire rope = 4/8 inch;
4^2 = 16 × 250 = 4,000 pounds WLL

5/8-inch wire rope = 5/8 inch;
5^2 = 25 × 250 = 6,250 pounds WLL

You can take the diameter of the wire rope in inches, square it, and multiply this result by 8 to calculate the WLL in tons.

Examples:
1/2-inch wire rope = 0.5^2 = 0.25;
0.25 × 8 = 2 tons or 4,000 pounds WLL

5/8-inch wire rope = 0.625^2 = 0.39;
0.39 × 8 = 3.12 tons or 6,250 pounds WLL

Another (less math-intensive) method for estimating wire rope strength is less numerically accurate but is still safe and adheres to basic common sense. If you use a griphoist rated to 4,000 pounds, the griphoist will accept a 7/16-inch-diameter wire rope with a 4 by 26 or 5 by 26 classification, so you can correctly surmise that the wire rope has a 4,000-pound WLL. Manufacturers design these types of wire ropes specifically for feeding into a griphoist machine, so these ropes are a bit stronger than the more common wire ropes with a 6 by 19 classification. Therefore, use only the wire rope designed for the griphoist and attach that wire rope to wire ropes that are 1/16-inch larger in diameter; or, any 6 by 19 classification wire rope that is 1/2-inch larger in diameter. Any 6 by 19 classification wire rope must be 1/2 inch in diameter to be rated to the same 4,000 pounds. Never use a wire rope that is smaller in diameter than the wire rope that runs through the griphoist.

You can oversize a wire rope. For example, you can attach a 1/2-, 3/4-, or 5/8-inch extension to a 4,000-pound hoist that uses a 7/16-inch, 4 by 26 classification IWRC, as long as you properly terminate the extension. This applies even though the larger lines are much heavier and the hoist can use up some of its power lifting the bulky line in aerial systems. You can have a difficult time ensuring that a system is never underrated (i.e., burdening the system with unnecessary dead weight that does not contribute to accomplishing the work).

You must always uphold safety margins; even though you calculate forces as static, the forces are rarely static in the field. Bends as the rope passes through blocks, methods of tensioning, and dynamic loading all influence wire rope. The calculated or stated WLL of a wire rope is in a vertical or linear orientation. A wire rope that bends at too sharp an angle—whether the rope serves as a sling, mainline, or high lead—reduces the WLL, compromises the strength of the rope, and shortens the life of the rope.

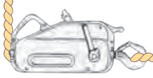
You can express the bend radius in a wire rope as a *D/d* ratio (figure 2–8), where "*D*" equals the diameter of curvature around which the body of the cable bends and "*d*" equals the diameter of the wire rope.

For a basket orientation (such as a wire rope running through a block to gain a 2-to-1 mechanical advantage), the recommended *D/d* ratio varies from about 16 to 1 to 20 to 1, depending on the composition and construction of the wire rope.

Examples:

4 by 26 griphoist wire rope D/d = 16;
5/16-inch wire rope × 16 = 5
5/16-inch wire rope requires a 5-inch block
6 by 19 IWRC D/d = 18 to 20 (use 20);
½-inch wire rope × 20 = 10
½-inch wire rope requires a 10-inch block

We discuss the *D/d* principle as it applies to fiber ropes and slings under the "Sheaves" section in "Chapter 7: Rigging Hardware."



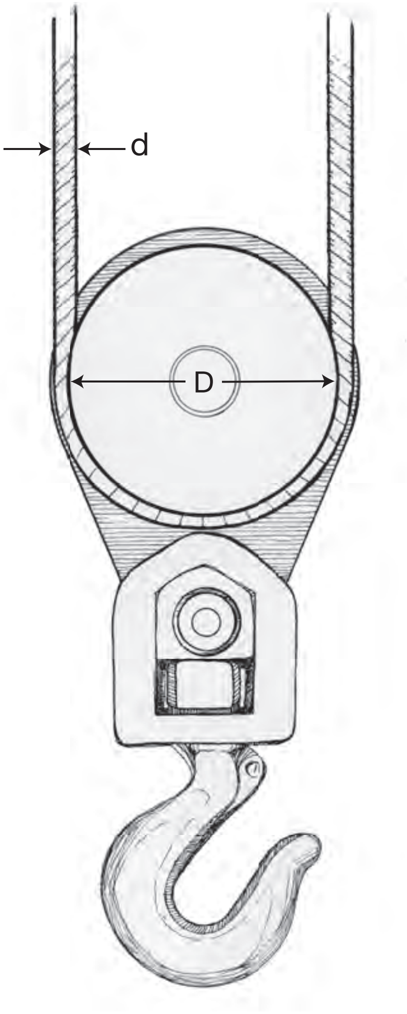


Figure 2–8—The "*D*" and "*d*" measurements used to calculate the *D*/*d* ratio for determining the allowable bend in wire rope.

Wire Rope Inspection and Storage

Regularly inspect a wire rope and store it properly to ensure that it remains safe and functions as designed. Some factors that can reduce the service life of wire rope include:

- **Shock loading—**Shock loading causes a drastic and incalculable increase of force to the rigging system. Signs of compromise from shock loading often are not visible in a wire rope. You should know the history of your rigging gear.
- **Kinking—**Avoid kinking (figure 2–9) by using proper wire rope management when spooling or unspooling, when feeding a winch in or out, and when the rope is under tension.
- **Excessive abrasion—**Excessive abrasion often occurs when wire rope bends across rocks, trees, or other surfaces. Bending across these surfaces can also push soil and grit into the rope, which introduces more friction into the rigging system and accelerates abrasion of the rope.
- **The wrong size sheave—**Using the wrong size sheave can cause wire rope to flatten or abrade. Sheave groove diameters that are too large for the wire rope cause flattening, and sheave groove diameters that are too small for the wire rope cause abrasion. These types of miscalculations are common in the field, where resources are limited. Using the wrong size sheave groove diameter is a main cause of wire rope or sheave failure.
- **Loss of lubricant—**Mitigate the loss of lubricant by keeping a manufacturer-specified lubricant and a few rags onsite and occasionally wiping down the wire rope.

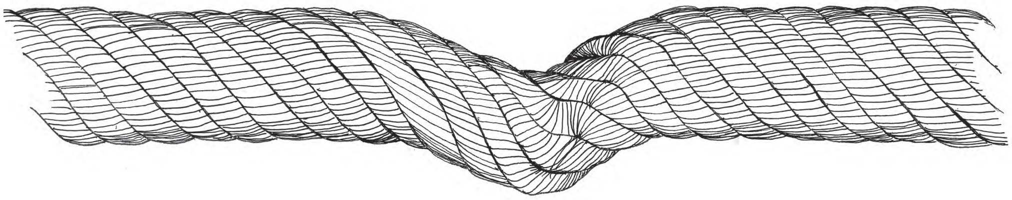


Figure 2–9—Kinking (caused by a loop in wire rope under tension).

You can reduce or eliminate all the factors above by using proper rigging practices. Poor maintenance of rigging equipment is inexcusable and dangerous; it could lead to catastrophic failure.

The exact inspection criteria for wire rope depends on its use and applicable regulatory codes, but some basic guidelines include:

- Inspecting the wire rope daily and looking for distortions, such as bird caging (figure 2–10), kinking, flattening, bulges, understranding, core protrusion (figure 2–11), strand displacement, and general corrosion.
- Removing the wire rope from service when any evidence of distortion or heat damage exists, or if the outside wires are worn or scraped down to two-thirds (or less) of their original diameter.
- Inspecting the wire rope for broken or cut wires and removing the rope from service if six randomly distributed wires are broken in one rope lay or three wires are broken in any one strand.
- Inspecting the wire rope for deformation or broken strands. A small deformation or a few broken strands of wire rope fed directly into a hoist may affect the ability of the machine to securely pull and hold the wire (refer to the “Manual Wire Rope Pulling Machines” section in “Chapter 6: Winches and Hoists” for details about using griphoist wire rope).
- Inspecting the end connections for deformities, corrosion, and cracks.
- Removing from service any hooks with throats that have opened up more than 15 percent or those that have twisted 10 degrees or more from their original orientation.

Store wire rope indoors in coils or on a reel in a clean, dry location. Storing wire rope for long periods on concrete or ash floors can cause the rope to corrode. Storing wire rope on a wood pallet allows you to move the rope easily using a forklift. If you store wire rope outdoors, use WD-40 or another water-displacement product to coat the rope's surface to prevent the strands from trapping moisture.

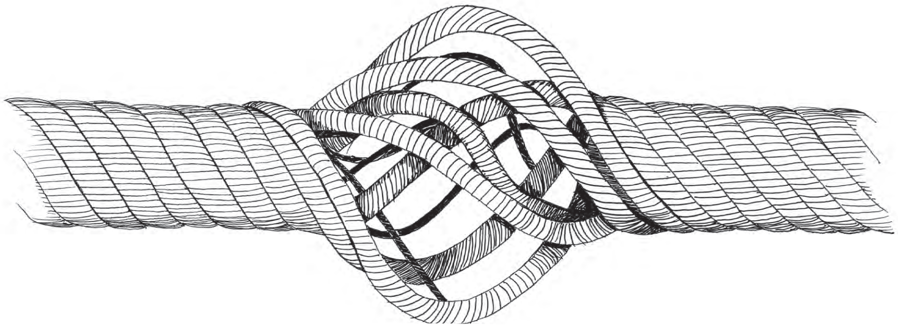


Figure 2–10—Bird caging (usually caused in wire rope by the sudden release of a load).

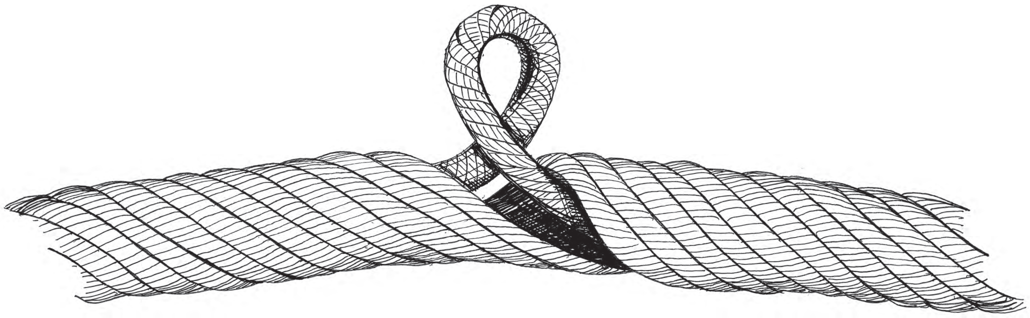


Figure 2–11—A popped core or core protrusion (usually caused in wire rope by rotation, the sudden release of a load, or core slippage).

Chapter 3: Fiber Rope

Fiber rope is more flexible and weighs far less than wire rope of the same diameter, while its abrasion resistance and working load limit (WLL) are equal to (or greater than) wire rope. As a result, riggers today often use fiber rope for trail rigging instead of wire rope.

Selecting and Using Fiber Rope

Fiber rope has many applications in trail rigging projects, but not all fiber rope is suitable. Before selecting fiber rope, clearly understand how you will use the rope to determine whether it is appropriate for the job. The intended use determines the size, strength, and type of construction of the fiber rope. A commonsense rule is to use the smallest size rope with the strength required for the job, especially for backcountry projects in which transportation logistics are a major factor. With that in mind, fiber rope is much lighter than wire rope, so opting for a slightly larger diameter rope is sometimes justified. For example, larger diameter fiber rope is beneficial when tasks involve gripping the rope with gloved hands; newer, stronger fiber ropes are more slippery, and larger diameters are easier to grip.

You must understand the following characteristics of different types of rope:

- Abrasion resistance
- Breaking strength
- Durability
- Elasticity
- Flexibility
- Resistance to environmental elements (sun, heat, and chemicals)
- Water absorption capacity

Types of Fiber Rope Construction

The four main types of fiber rope construction are:

- Braided
- Laid
- Plaited
- Sheath and core

These rope types describe the construction of the rope, regardless of the material.

Braided—Braided rope (figure 3–1) is commonplace, and many riggers prefer this type of construction for synthetic fibers. Braiding the fibers makes the rope more flexible. Rope can be either a single braid or a double braid. In single-braid construction, the manufacturer leaves a void in the center of the rope. This rope is rotation-resistant (i.e., it doesn't usually revolve as a load applies tension to it). Double-braid construction is actually two separate ropes in one. In specialty ropes, these two parts of a double-braided rope are often different materials. The manufacturer braids over the inner core with a second sheath. This method enables the manufacturer to completely cover and protect the inner core with a sheath of more abrasion-resistant material.

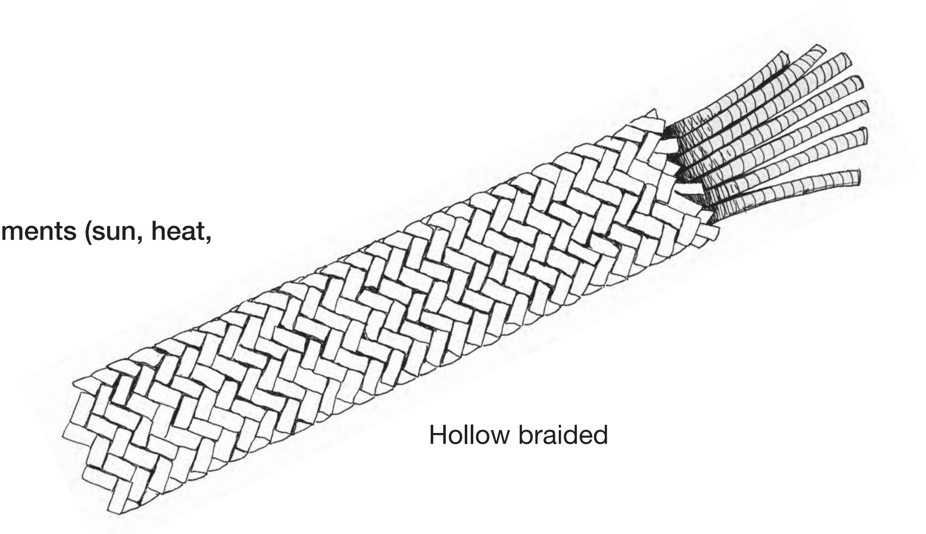


Figure 3–1—Hollow braided fiber rope construction.

Laid—Laid rope (figure 3–2) is the most common type of synthetic rope and is the easiest rope to splice. In general, three strands make a laid rope. The manufacturer twists the fiber into yarns and counter-twists it into strands. These counter-opposing forces hold the rope together. If the manufacturer exerts only a little tension while twisting the rope, the finished rope is flexible. If the manufacturer applies a lot of tension while twisting the rope, the finished rope is hard and stiff to handle. Hard-laid rope wears better than soft-laid rope, but tying knots in it is more difficult.

Plaited—Plaited rope (figure 3–3) is often made of eight strands woven into four pairs. Although it has about the same strength as three-strand laid rope, the major advantage is its ability to resist rotation. The plaited rope is also softer and more flexible than laid or sheath-and-core rope. The maritime industry uses many large-diameter ropes manufactured with plaited construction.

Sheath and core—Sheath-and-core rope (figure 3–4), often called “kernmantle,” is a special class of rope used primarily for climbing. The kern (core) supports most of the load. The tight, woven outer core provides protection for the core fibers. Manufacturers design these fibers to meet the high demand of shock loading, abrasion, and heat caused by rappelling and belaying.

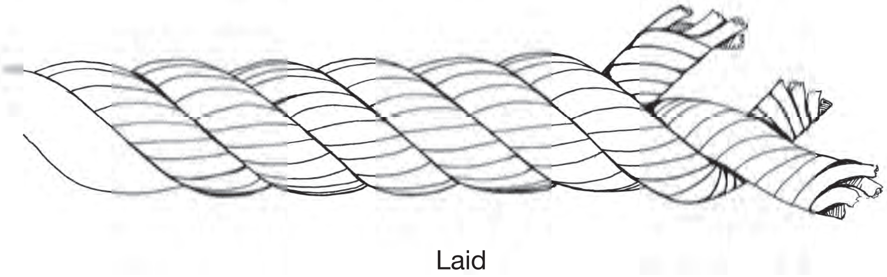


Figure 3–2—Laid fiber rope construction.

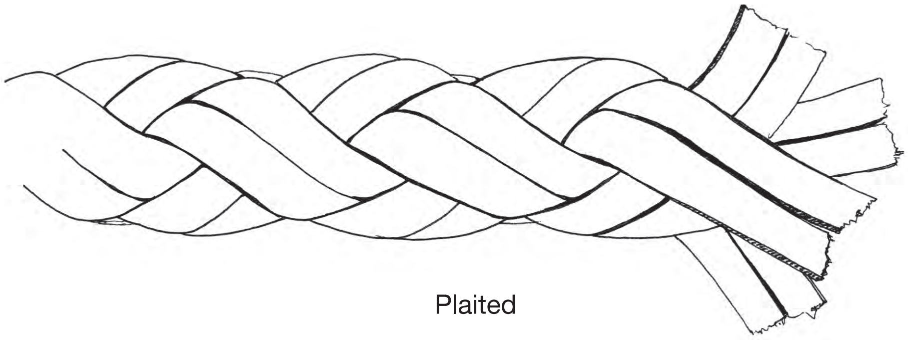


Figure 3–3—Plaited fiber rope construction.

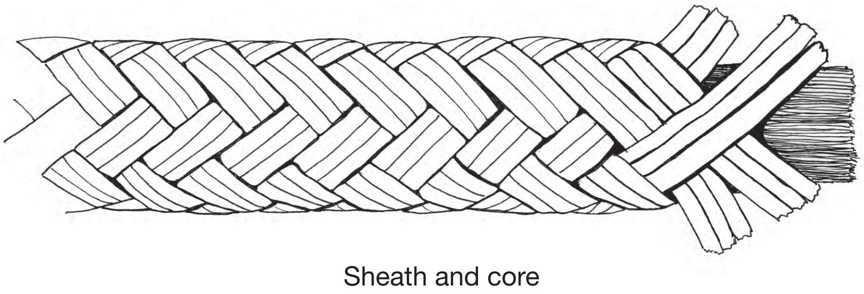


Figure 3–4—Sheath-and-core fiber rope construction.

Types of Fiber Rope Materials

Manufacturers can make fiber ropes from natural plant fibers or from synthetic fibers. Synthetic fibers produce much higher WLLs with an accompanying increase in cost. The wide variety of materials available for making fiber ropes result in products with different characteristics. You must understand how these different characteristics affect rope strength, wear, and other conditions.

Natural fibers—Until the 20th century, manufacturers made all rope from the fiber of plants, such as flax, jute, abaca, sisal, hemp, and cotton. Because natural-fiber ropes are comparatively weaker than synthetic ropes, you should not use them for rigging applications.

Simple synthetic fibers—During the 1930s, chemists developed fine synthetic filaments that had uniform diameters and circular cross sections. Manufacturers cut these monofilament fibers to specific lengths, combined them into multifilament bundles, and laid them up in numerous ways to create synthetic ropes. The manufacturers also split the synthetic filaments into flat, ribbon-like strings to make products such as hay-baling twine. These synthetic products are stronger and lighter than their natural-fiber counterparts. Synthetic fibers are almost as strong when wet or frozen as they are when dry, and they withstand shock loading better than natural fibers. Although not prone to rot and other limitations of natural fibers, synthetic fibers can be more susceptible to sunlight and to heat caused by friction.

The four main types of synthetic rope are:

- Nylon (polyamide)
- Polyester (also known by the trade name “Dacron”)
- Polyethylene (including thermoplastic polyethylene)
- Polypropylene (also known as poly rope)

While manufacturers make many ropes out of only one material, some specialty ropes may have a core of one material and an outer sheath of another.

Nylon rope—Nylon rope is the most common synthetic fiber rope. Elasticity is perhaps the most recognizable trait of nylon. Three-strand nylon rope can stretch from 30 to 40 percent and return to its normal length after you remove the load. It will part or break when it stretches 50 percent. This characteristic has desirable and undesirable applications in rigging work. A rope that stretches will also recoil quickly if it breaks. A nylon rope may recoil at almost 500 miles an hour if it snaps at its breaking strength and can cause serious injury for anyone in its path. Degrade the strength of nylon by 10 to 15 percent if it is wet.

Double-braided nylon rope stretches 15 to 20 percent under a normal load and parts or breaks at 35 percent. Nylon rope does not float on water and will break down after prolonged exposure to sunlight, although not as quickly as polypropylene rope.

Polyester rope—Rope made from polyester stretches only about one-half as much as nylon, but it wears better. Size for size, it is about 75 percent as strong as nylon. Polyester rope does not float on water, but has a high resistance to ultraviolet (UV) degradation and does not weaken when wet. Polyester rope is a good choice for work in wet environments and provides good strength without the elasticity of nylon.

Polyethylene rope—Simple polyethylene rope has limited applications in rigging work. This cheap, light rope barely floats on water and has limited strength and little stretch. As a synthetic, polyethylene rope is comparable to a natural-fiber rope in terms of shock loading. Anyone who has ever tried tying a knot in a polyethylene rope knows how difficult it is because the rope is so stiff. It is important not to confuse simple polyethylene (the plastic used to make water bottles) with thermoplastic polyethylene. Thermoplastic polyethylene is an advanced form of

polyethylene that provides great value for many trail rigging tasks. We discuss thermoplastic polyethylene later in this chapter.

Polypropylene rope—Polypropylene rope falls between nylon and natural-fiber ropes in terms of cost and performance. It has only one-third to one-half of the breaking strength of nylon (the lightest of all synthetic ropes). Manufacturers produce polypropylene rope in large quantities and price it reasonably. Riggers use it for rigging work that does not involve high risk. Polypropylene rope falls between nylon rope and polyester rope for elasticity. It is sometimes the rope of choice for riggers because it floats on water. However, this rope is susceptible to UV degradation. Do not use it for long-term outdoor applications, and store it away from sunlight. Because polypropylene rope also has a low melting point, do not use it in situations where it may be subjected to heat from friction, such as in belaying.

Perhaps the greatest recent improvement in rigging equipment has been the development of high-tech synthetic fiber ropes. Kevlar, Spectra, and Dyneema are some of the most common “miracle” fibers, along with Technora, Plasma, and Vectran. The manufacturers make these synthetic ropes from a type of thermoplastic polyethylene that far surpasses the previous high-strength and low-stretch limitations of fiber ropes. People often call these synthetic ropes “miracle” fibers, but they are more accurately known as ultra-high molecular weight polyethylene (UHMW or UHMWPE), high-modulus polyethylene (HMPE), or high-performance polyethylene (HPPE). We use the term HMPE.

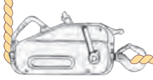
People have used HMPE ropes for years to replace wire rope or steel rod applications. Riggers soon recognized the value of HMPE ropes in backcountry rigging systems and now replace wire ropes with HMPE in a variety of applications across the United States. The advantages of this material are its weight-to-strength ratio (it is stronger than wire rope of the same diameter and one-seventh the weight) and virtual absence of recoil (which can make it safer to work around than wire rope). It splices easily, floats on water, and knots well. The preferred knot is the double bowline (or “figure 8”) on a bight. Most other knots can be difficult to untie if the system is heavily loaded. We recommend avoiding knots when possible and adding a spliced eye and closed thimble on each end. The disadvantages of HMPE rope are its cost and its lack of resistance to abrasion and heat.

The various types of synthetic rope have many subtle differences. For instance, Vectran and Technora are heat-resistant, but are less suited to feed through snatch blocks at right angles because bending fatigues the fibers. Riggers currently consider Dyneema the best synthetic for winch replacement lines, but there are many variations of this specific synthetic. Multiple types of Dyneema have different strength ratings; the most popular types are Sk60 and Sk75. Manufacturers are now producing ropes that they heat and prestretch to a smaller diameter with the same strength.

Manufacturers configure a 12-strand, open-weave pattern to construct most synthetic ropes used for winch and hoist purposes, although some ropes have an abrasion-resistant over-braided cover. Riggers increasingly prefer synthetic ropes to wire ropes for certain applications because of these types of technological advancements. Because of the vast, subtle differences among these synthetics, we recommend consulting with the manufacturers for specifications, such as the rope’s exact breaking strength, recommended uses, minimum bend radius, coefficient of friction, melting point, and cycles to failure.

Selecting Fiber Ropes

New, high-tech fiber ropes vary drastically in composition and characteristics, such as melting point, elasticity, bend radius, abrasion resistance, and the



ability to splice. Choosing the right fiber rope for the job takes research into individual rope specifications. Most high-end rope manufacturers, such as Samson <http://www.samsonrope.com/>, New England Ropes <https://www.neropes.com/en/>, and Yale Cordage <http://www.yalecordage.com/> offer catalogs and online resources that provide details about rope factors, such as elastic elongation, permanent extension, hysteresis, and cold flow. The most important factor in selecting rope, however, is its exact use. Choose fiber ropes for a single task and exclusively use the ropes for that task. It does little good to buy the best climbing line on the market only to use it as a belay line.

The three main uses for fiber ropes are climbing, rigging (lowering, pulling, etc.), and replacing wire ropes. Some general guidelines for each use include:

- Climbing lines should combine high strength with low stretch. They must work well with ascenders and friction hitches, such as the Prusik knot. These ropes are usually stranded polyester ropes that sometimes have a nylon core.
- Rigging lines must have high strength and low stretch, but they must also be abrasion-resistant. Common rigging lines include a double-braided polyester sheath over a polyester/polyolefin core, 3-strand polyester over a polyester core, or solid 12- and 16-strand braided polyester.
- Wire rope replacement lines generally consist of high-tech HMPE Spectra or Dyneema fibers, which are stronger than wire rope with the same elongation. The construction is generally a solid HMPE 12-strand braided or a polyester double-braided cover over an HMPE core.

Determining Fiber Rope Strength

The variety of fibers and weave patterns that yield ropes of many different capabilities can make it difficult to determine which type of rope is suitable for a rigging project. The strength of a ½-inch fiber rope is impossible to discern unless you know the type of fiber, weave pattern, and history of use for that particular rope. It is important to catalog the rope strength, characteristics, size (width and length), and history of use (refer to "Appendix B: Rope Log").

Originally, manila rope set the standard against which people measured other ropes. For example, a manufacturer might list nylon rope as 275 percent of the strength of manila rope. Nylon is now the standard rope material, so a manufacturer might rate manila rope at 0.33 percent of the strength of nylon rope. Whatever the rating method, you must understand a rope manufacturer's specifications for the minimum average breaking strength. Unfortunately, not all manufacturers base their data on the same standard, which makes comparison difficult.

Published data about rope sometimes does not take into account normal wear and tear, shock loading, or friction damage. Additionally, ropes rarely have a manufacturer's WLL tag, so it is up to you to determine the WLL. You can buy a special tape or kit to put on the ends of rope and use it to record the minimum breaking strength (MBS) or WLL. Ropes may have a rating that indicates tensile strength, nominal strength, or MBS. Although these three types of rope strength are technically different, they are all based on the forces that a rigging rope might encounter. The Cordage Institute <http://www.ropecord.com/terminology/> defines the MBS as "the force that a given rope is required to meet or exceed in a laboratory test when it is new and unused" (Cordage Institute 2006). Calculate the WLL using the rope manufacturer's rating. If the manufacturer offers multiple numbers, consider the lowest figure the safety rating. If the manufacturer rates the rope in kilonewtons (kN) or kilograms (kg), you must convert the rating to pounds.

A kilogram (kg) is equal to about 2.2 pounds, so multiply the rating in kg by 2.2 to convert it to pounds. A kilonewton (kN) is a measure of force that is equal to approximately 224.8 pounds. To convert a rope rating of 45 kN into pounds, multiply 45 by 224.8 for a rating of 10,116 pounds of tensile strength.

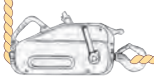
Calculating a Safety Design Factor for Fiber Ropes

The safety design factor is a term that describes the capacity range of a component or system above the WLL and below the MBS. Determine the WLL by dividing the MBS by the safety design factor, as explained below.

Determine the safety design factor by the type of component, the factors of stress, and the application of use. The safety design factor for fiber ropes generally varies from 5 to 12. This means that the WLL is between one-fifth and one-twelfth of the MBS. We recommend, if you borrow ropes and other components from arborists, rock climbers, and other application users, that you confirm the ropes have a 10-to-1 built-in safety design factor when new.

You must also know when to adjust the safety design factor to suit the project and system components. For example, you may need a higher safety design factor if the rope is older or subject to chafing, if the consequences of failure are particularly severe, if mild shock loading is a possibility, or if you use the rope under tension for extended periods.

For more information about safety factors, WLL, and MBS, refer to “Chapter 7: Rigging Hardware.”



Knots

Knots are an integral aspect of fiber rope work. Numerous references describe how to tie specific knots, and the internet has excellent video and audio instructions available. Consequently, in this manual we do not explain how to tie knots.

Riggers use knots and hitches to attach belay lines to loads, tie webbing and cordage into slings, connect people to safety lines, secure suspended loads, and for a variety of other functions. Every time you form a knot or hitch, the knot or hitch reduces the strength of the rope (table 3–1). Knots that reduce rope strength the most are those that bend the rope or webbing most tightly. The relationship between the bend radius of a strand and its relative strength after bending is a fundamental concept in rigging. It extends beyond knots to concepts such as *D/d* ratios and sling-to-angle vectors.

Table 3–1—Summary of knot strength and use

Knot	Relative strength (percent)	Typical use in rigging
No knot	100	Connecting through a spliced eye
Figure 8	70 to 75 (all variations)	Terminating a rigging line or high-modulus polyethylene rope
Single bowline	65 to 70	Terminating a rigging line
Double bowline	70 to 75	Terminating a high-modulus polyethylene rope
Double fisherman’s	65 to 70	Connecting two rigging lines
Water knot	60 to 65	Connecting webbing into a loop
Overhead knot	60 to 65	Safety tie to back up a knot
Timber hitch	70 to 75	Connecting a rope to a tree or log
Clove hitch	60 to 75	Any temporary connection
Square knot	45	Connecting light loads

Knots, hitches, and bends reduce
the strength of a rope.

Various knots also have properties such as slippage factors, profiles, and ease (or difficulty) to untie. Understanding which knot to use in a particular application is essential. Even a perfect knot may slip over time, particularly if the tension on it cycles on and off, rather than being constant. Frequently check all knots during use. It is a good idea to untie and retie knots often. Although it is important to realize that knots reduce the strength of ropes, most rope failures occur because of some physical defect in the rope rather than because of a knot. Inspect ropes regularly and keep a log of the rope's use (refer to "Appendix B: Rope Log").

As a rule, you should not leave knots in ropes that you store; untie the knots and store the ropes properly. Also, keep in mind that most types of rope deteriorate over time, even when they are not in use.

When tying any knot, remember "TDS:"
tie, dress, and set (figure 3–5).

T—Tie the knot loosely and double check to ensure you tied it properly.

D—Dress the knot by aligning the parts carefully and ensure that each strand runs exactly where it should. If you use a double strand of rope, ensure the strands remain parallel throughout the knot instead of crossing over each other.

S—Set the knot by pulling on each loose piece and tightening the knot from all sides.

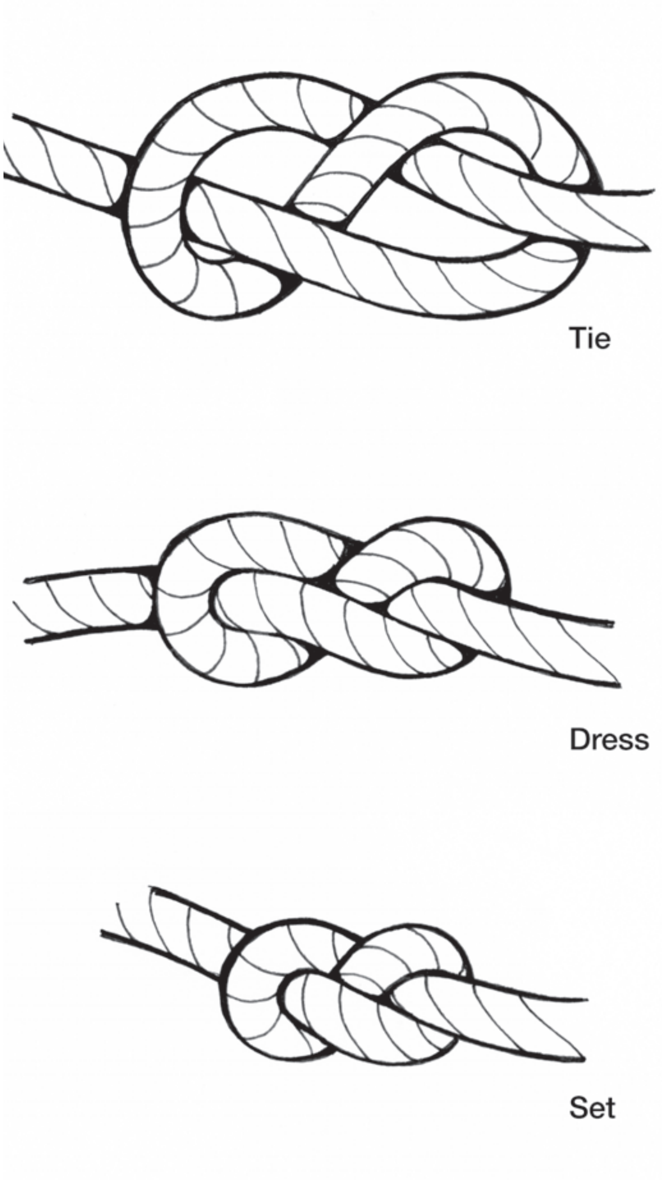


Figure 3–5—Steps in tying a "figure 8" knot.

Triple check any knot you tie, ensuring that it is neat, properly tied, and ready to go. Taking the time to tie, dress, and set a knot ensures that it functions properly and often makes it possible to untie the knot by hand after heavily loading the line. We use a specific technique when tying a knot in a rope that we intend to place under tension: we place spacers in the middle of the knot where the rope bends most tightly.

One or two short sticks about 1 inch thick and 2 inches long work well. An even better option is a couple of sections of 2-inch-long, 1-inch-diameter polyvinyl chloride (PVC) pipe with 2-inch-diameter washers held together on each end by a bolt and nut (figure 3–6). The washers prevent the PVC pipe from sliding out of the knot. This technique does not affect the integrity of the knot. In fact, the PVC pipe increases the bend radius of the rope and maintains a higher percentage of the rope's original strength. Just as importantly, this technique also makes the knot much easier to untie.

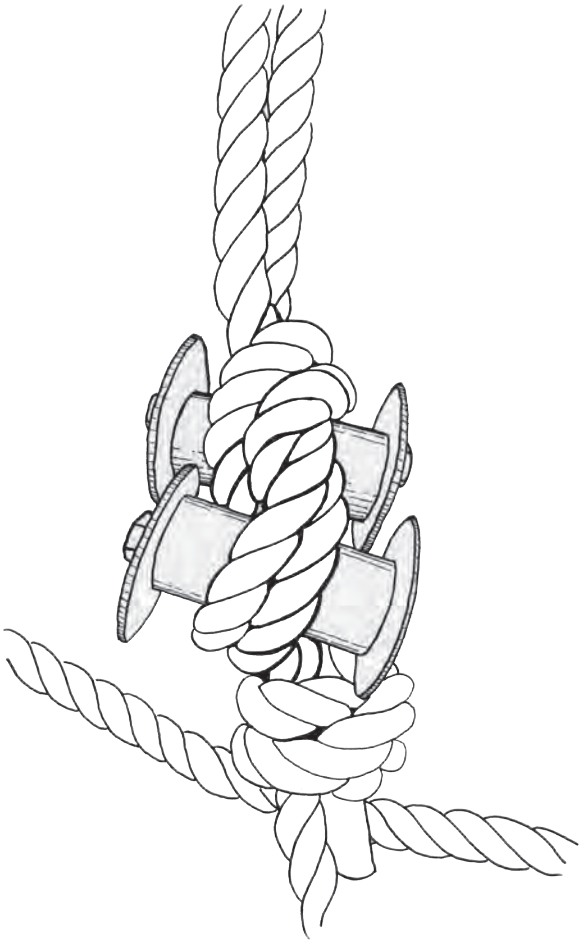


Figure 3–6—Using polyvinyl chloride pipe and washers to facilitate untying a "figure 8" knot.

Handling New Fiber Rope

Manufacturers often ship synthetic ropes, such as nylon, on reels. Remove the rope from the reel by pulling the rope off the top while the reel is free to rotate. Manufacturers sometimes ship fiber rope in a coil. If the rope is coiled, uncoil it from the inside so that the first turn comes off the bottom in a counterclockwise direction. Carefully remove any loops that form so that kinks do not form in the rope once the rope is under tension. In addition, some kernmantle rope requires a process called "milking the rope" before its first use. To do this, lay the rope out straight and work the sheath of the rope over the rope core by running your hands from one end of the rope to the other, squeezing gently. This technique stretches the sheath to better match the core.

Making Up a Rope

After removing the rope from the manufacturer's reel, use one of three methods to ready it (make it up) for transport, storage, or use: wind it onto a spool, coil it down, or flake it down.

When winding onto a spool, wind the rope back onto the spool in the opposite direction from which you removed it.

"Coiling down" or "stacking" means laying the rope up in circles, roughly one over the top of the other. Always coil down right-laid rope in a right-hand (clockwise) direction. When you coil down a rope, the top end is ready to run off. If you try to uncoil the rope from the bottom end, the line will kink. If for some reason you must use the bottom end first (e.g., if you are using a desired end attachment), turn the coil over to free it for running. Putting a rope directly into a rope bag keeps the rope clean, dry, off the ground, and well managed. Tree care suppliers offer many styles of rope bags you can use to store or transport rope.

"Flaking" a rope is similar to coiling a rope, but you lay the rope out in long, flat bights (one alongside the other) rather than in circles. The main advantage of using a flaked rope is that it runs off easily. It is important to remove loose sticks or other obstructions near the rope as you run it out. You can place the rope on a tarp to avoid picking up sticks.

Rope management is an art form in itself. Fiber rope tends to twist, hockle (when strands unwind and begin to spread apart), and tangle. It can catch on underbrush and under boots, and it often finds any pinch point into which it can wedge. Being an adept rope manager requires an awareness of how to feed out and bring in rope and an understanding of where it travels.

Rope Whipping

Because rope can ravel after you cut it, you must "whip" the rope (bind the ends to prevent fraying and raveling) using any small twine. Hard-laid, three-strand rope is particularly prone to raveling. Always use whipping on each side of an intended cut (figure 3–7). The length of whipping should be equal to the diameter of the rope. Always use two sets of whipping in case the first one pulls off. Exert firm pressure when whipping so the cut rope holds securely. After cutting the rope, apply heat to the ends of nylon and other synthetic ropes to seal the ends and make them more stable.

Back-splicing (splicing rope back onto itself by unbraiding the end and weaving it back into the rope below) is a good option for finishing the end of a rope when the construction type and application allow it. Back-splicing leaves a larger diameter at the "bitter" end to grip.

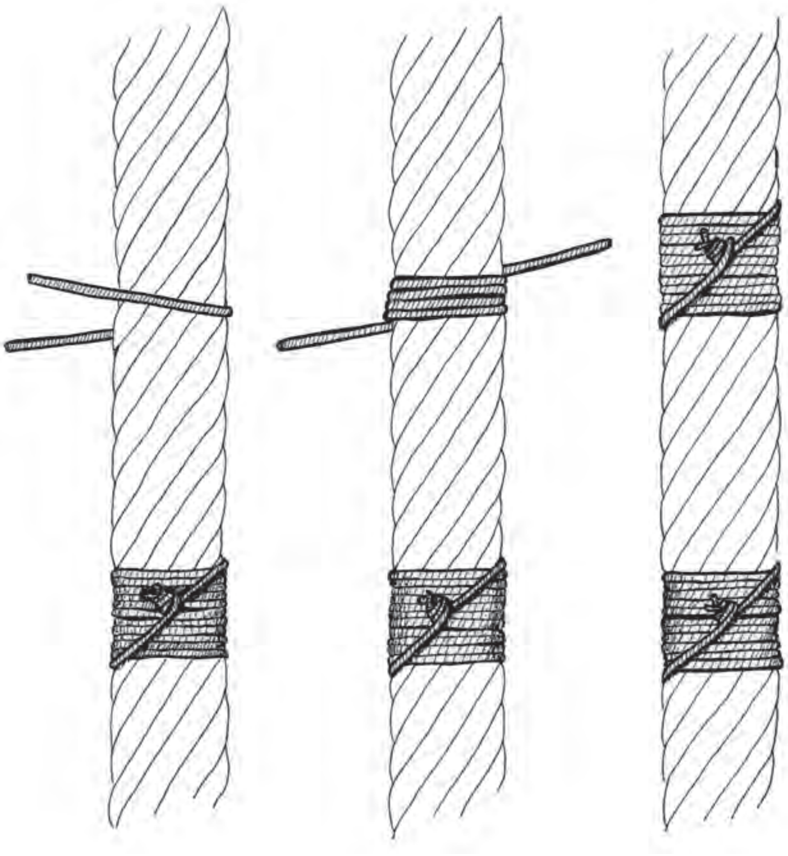


Figure 3–7—Steps for whipping a wire rope before cutting it.

Inspecting Fiber Rope

Inspect the outside layer of a rope to ensure that:

- No more than 5 percent of the fibers are broken or show signs of abuse, indicating overloading or excessive wear.
- There is no excessive dirt or grit between the rope fibers, which can cause excessive internal wear on the rope and reduce its strength.
- The surface of the fibers does not look wet or oily, which is often a sign of excessive loading.
- Strands of the rope are not raveling. When the strands ravel, the load is not evenly distributed and the rope can fail. Remove from service any rope that shows signs of raveling.
- There is no discoloration that indicates exposure to chemicals, heat, or products that are harmful to the rope fiber. Some ropes are more resistant to these factors (depending on the rope composition). Remove from service any nonresistant rope that shows discoloration due to exposure.

Inspect the inside layer(s) of a rope to ensure that:

- There are not excessive broken fibers, indicating overloading.
- The rope has a clean and bright interior. Do not use a rope that chemicals or other factors have discolored.
- The rope is sturdy and intact, not powdery like sawdust (an indication of severe internal wear).

Remove from service and destroy (by cutting into small pieces) any rope with these conditions. Do not be reluctant to destroy a rope; others could retrieve the rope, attempt to use it, and place themselves in danger.

Comparing Wire Rope and Fiber Rope for Rigging

Benefits of wire rope include:

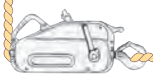
- UV light does not cause degradation
- WLLs are more uniform within given diameters and are less subject to damage caused by variations in conditions over time
- Constructed of time-tested materials
- A long life span
- Resistant to abrasion
- Easy to source block sheaves designed specifically for wire rope

Remember that loaded wire rope or stretchable fiber rope that comes loose or breaks can recoil and be deadly.

Benefits of fiber rope include:

- More lightweight and portable than wire rope
- Adjustable length without using connective devices
- Works with smaller, lighter blocks because of its lower *D*/*d* ratio (refer to the "Components Common to Most Blocks" section in "Chapter 7: Rigging Hardware" for more information about sizing fiber ropes with blocks)
- Enables quick belaying of light loads
- Easier to work with because you can spool, stack, flake, and untwist it by hand
- UV light does not degrade HMPE fibers

Remember that blocks specifically designed for synthetic ropes are more difficult to source and are available in limited styles.



Chapter 4: Chain

An old saying in construction rigging circles is "never use a chain when it's possible to use a wire rope." The main reason is that the overall chain is only as strong as its weakest link. Wire rope, on the other hand, is comprised of numerous individual wires—all wires must fail for the rope to break. Wire rope fails progressively over time, whereas a chain will break suddenly without warning. Although chain is about three times as heavy as wire rope for the same load rating, it has a place in trail rigging. Chain follows contours well, grips the load, does not retain metal memory like wire rope, and is resistant to abrasion. Welded, graded chain is the industry standard for rigging applications.

> "Never use a chain when it's possible to use a wire rope."

Chain Grade

A grade (g) number indicates certified chain strength. The higher the number, the stronger the chain (table 4–1). Standard grades of carbon steel chain are g30 ("proof coil"), g43 ("high test"), g70 ("binder" or "transport"), g80 ("alloy"), and g100 ("alloy"). A number of alloy chain grades have the advantage of being lighter in weight for the same strength. The minimum standard that crews should use for trail rigging is g70 chain. This grade of chain is the minimum grade that the U.S. Department of Transportation (DOT) allows for securing loads on trucks, so it is easy to obtain. Do not use g30 chain (commonly found in hardware stores) in any rigging application.

Only use alloy chain (g80 or g100) for overhead lifting. We recommend using only g70 or alloy chain at the worksite to eliminate the possibility of accidentally introducing low-strength chain into the rigging system. Chain with a higher grade is stronger for the weight, though it is more expensive.

Table 4–1—Certified chain strength (g = grade, WLL = working load limit, N/A = not applicable)

Chain size (inches)	g30 (WLL in pounds)	g43 (WLL in pounds)	g70 (WLL in pounds)	g80 (WLL in pounds)	g100 (WLL in pounds)
1/8	400	N/A	N/A	N/A	N/A
3/16	800	N/A	N/A	N/A	N/A
7/32	N/A	N/A	N/A	2,100	2,700
1/4	1,300	2,600	3,150	N/A	N/A
9/32	N/A	N/A	N/A	3,500	4,300
5/16	1,900	3,900	4,700	4,500	N/A
3/8	2,650	5,400	6,600	7,100	8,800
7/16	3,700	7,200	8,750	N/A	N/A
1/2	4,500	9,200	11,300	12,000	15,000
5/8	6,900	13,000	15,800	18,100	22,600
3/4	10,600	20,200	24,700	28,300	35,300
7/8	N/A	24,500	N/A	34,200	N/A
1	17,900	30,000	N/A	47,700	N/A
1 1/4	N/A	N/A	N/A	72,300	N/A

Inspecting Chain

Inspect chains link by link before putting them into service (the chain should be clean for this visual inspection). Look for excessive wear on bearing surfaces and twisted, bent, gouged, nicked, or elongated links (never use a chain with any of these issues). Also, check all master links and hooks for breakage, open links, deformed shape, and excessive or uneven wear. Remove any hook from service that is twisted sideways or has an increased opening (loading the end of the hook instead of the bottom of the hook is a common cause of this issue).

Care and Use

Jerking or suddenly loading a chain rapidly multiplies the stress on the chain. Never use a twisted or knotted chain, which can cause stress on the chain links, and never exceed the working load limit (WLL) of the chain.

Chain Attachments and Accessories

All components of chain assemblies must have the same grade, type, size, and WLL as the chain. Be especially careful to use only certified, graded rings in sling assemblies. Hooks or rings are the most common end devices for chains used in backcountry trail rigging. Manufacturers produce each of these devices in several different styles and design chain hooks to enable the chain to either slip through the hook or securely grab a link of chain. Many chains have a grab hook on one end and a slip hook on the other. Another common option is to have a round, oblong, or pear-shaped master link attached to one end of a chain.

Never use cold shuts, quick link, and lap link connectors for trail rigging projects. Use these joining links for g30, low-carbon chain only, and do not use them on trail rigging sites. We recommend joining chain ends with heat-treated, dropped, forged mid links (figure 4–1)—also known as double clevis links—of comparable size and grade (g70 or higher).

If you use either ratchet or snap load binders on a rigging site, the binders must meet DOT specifications.

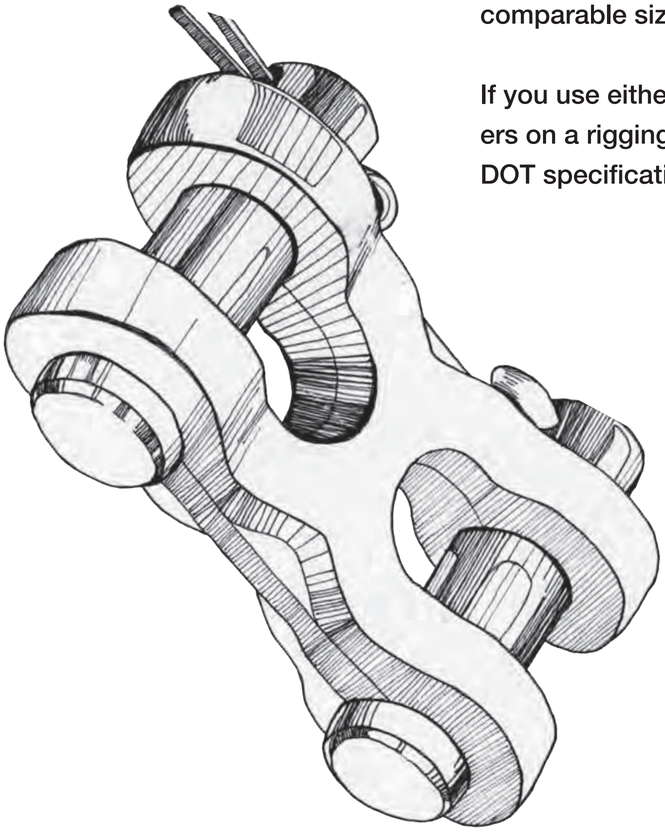


Figure 4–1—A forged mid-link connector.

Chapter 5: Slings

Slings are one of the most versatile components in a rigging system. Riggers use slings for different purposes, including attaching loads to cables or blocks to trees and as anchors for power sources. Riggers may also combine slings to position lines between anchor points. Manufacturers may construct slings from flat, round, or braided materials, build in a number of design features, and attach a variety of end devices to the slings to meet differing requirements.

Types of Materials for Slings

Manufacturers can make slings from synthetic rope, webbing, wire rope, or chain. Each of these materials has a wide range of sizes, strengths, and design characteristics. You will probably be most concerned with abrasion and flexibility when determining which type of sling material to use. For example, a sling made of chain or wire rope is better suited for dragging rocks over rocks than a sling made of synthetic material. Likewise, a sling made of flexible webbing is an excellent choice for hanging high blocks in trees, where the sling weight and potential tree damage are important considerations. We recommend checking with professionals at a rigging shop who can provide suggestions for individual applications. In general rigging practice, most slings are nylon flat slings, round synthetic slings, wire rope slings, or chain slings.

Synthetic slings—There are four main types of nylon flat slings, depending on the application:

- Manufacturers fold over and stitch the sling material to create an eye-to-eye sling (figure 5–1). This is the most common type of sling. If the material remains flat after the manufacturer folds it over, it is referred to as a "flat sling" and can be used most effectively for vertical, basket, or choker applications. Because the eyes are flat, you can easily remove these slings from under a load. The manufacturer may fold over the sling material with a half twist before stitching the eye. The twist provides a better choker hitch and nests together better in a basket configuration. These twisted-eye slings are the most versatile in trail rigging applications. You construct tapered-eye slings by folding the sling's width in half on the end so that the eye is one half the width of the rest of the sling. This method makes it much easier to connect shackles and other end fittings to the eye of wide slings. Most tapered-eye slings are at least 3 inches wide.
- Manufacturers sew hardware eyes onto the ends of a basket-hitch sling (figure 5–2). These metal eyes extend the sling life when compared with standard eye-to-eye slings. Both metal eyes are identical to facilitate their use in a vertical or basket-hitch configuration. The metal eyes are a bit heavier, and you cannot use them in a choker configuration, making these the least versatile sling type for backcountry trail projects.

Figure 5–1—An eye-to-eye nylon flat sling.

Figure 5–2—A basket-hitch nylon flat sling.

- Manufacturers design a choker-hitch sling (figure 5–3) with aluminum or steel triangular end devices sewn onto the ends of the sling. Like the basket-hitch sling, one end has a metal triangle. The other end has a forged choker that allows the end with the metal triangle to slip through. You can use this type of sling in a vertical, basket, or choker configuration.
- Manufacturers sew together the ends of an endless-loop sling (figure 5–4), forming a continuous loop. You can use this versatile sling in a vertical, basket, or choker configuration and can reduce wear on the sling by frequently changing the hook contact.

Synthetic round slings are shaped like their flat, nylon, endless-loop counterparts, but the construction materials are different. A round sling's strength comes from bundles of stranded polyester in the core of the sling. It has a soft, nylon, single- or double-layer sheath. You must discard the sling after the sheath wears through and exposes the polyester core to prevent its use in future rigging operations. We recommend the double-layer sheath sling because it usually has a significantly longer lifespan than a single-layer sheath sling. Synthetic round slings have different strength ratings, depending on the amount of polyester they contain. Manufacturers color code the different strengths, but the colors do not necessarily match among manufacturers. Refer to the tag on the sling for strength ratings. Nylon and polyester round slings are versatile and lightweight and are more flexible and packable than flat nylon slings.

Webbing slings—Lightweight nylon webbing, often referred to as climbing webbing, also has a place in backcountry rigging, but its applications are limited. It comes in flat (like a seatbelt) and tubular styles. Many sizes are available, but the 1-inch-wide tubular style is most common. You can order webbing in long spools and cut it to length as needed, making it very versatile. You can tie it into an endless loop, preferably using a water knot. The 1-inch-wide tubular style has a tensile strength of about 4,000 pounds. After determining a 10-to-1 safety design factor and accounting for about a 36-percent loss of

Figure 5–3—A choker nylon flat sling.

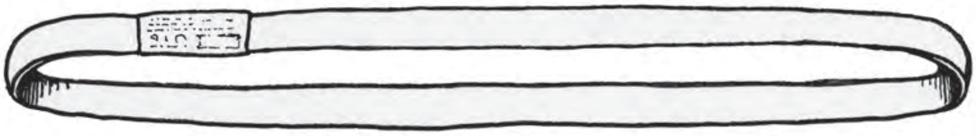


Figure 5–4—An endless-loop nylon flat sling.

strength when using a water knot, the working load limit (WLL) of this material is about 250 pounds. It is imperative that you never use climbing webbing in the same applications as a rated synthetic sling. Common uses of this webbing include tying back vegetation, chokering onto trees to store gear off the ground, forming lightweight tag lines as carry straps, etc. You can also use it to protect against wear by wrapping trees or by opening the tube and sliding the webbing over synthetic and wire ropes.

Each type of synthetic sling has its advantages and disadvantages. We recommend that you keep an assortment of each type and length of sling in your rigging cache.

Wire rope slings—Wire rope slings must be at least the same diameter as other lines you use within a cable system. The diameter of a wire rope sling must often be larger than other lines because of its loss of strength in certain configurations. We have seen new chokers fail when riggers used them in a rolling-hitch configuration because the wire rope lost strength when it bent 180 degrees back on itself. Refer to the "Sling-to-Load Angle" section later in this chapter for information about the rolling-hitch configuration.

The ends of wire rope usually have an eye, with or without a thimble. Thimble eyes work best for attaching an end device, such as a clevis or hook. Many premade wire rope slings have pressed ferrule eye ends, which you can use in vertical, basket, or choker configurations. The term "choker configuration" comes from a specially constructed wire rope sling of the same name. The most common type of choker is a "cat choker," a logging term that refers to a style of choker associated with skidding logs (dragging them along the ground) behind a bulldozer. These chokers feature a nubbin on one end and a pressed ferrule eye on the other. Sliding freely in between is a specially designed slot to receive the nubbin. Riggers use chokers to ground-skid logs where significant abrasion can occur. You can hook two cat chokers together (figure 5-5) for large-diameter logs to provide an equal pull from both sides of the log, reducing the log's ability to pivot when you move it. You may use the same two-choker configuration if one choker is too short to make it around the log. Take care to keep the bending back angle of the choker as narrow as possible. The earlier discussion about *D/d* ratio applies to setting chokers. The farther back the wire rope bends on itself, the greater the strain on the rope (refer to the "Sling-to-Load Angle" section later in this chapter).

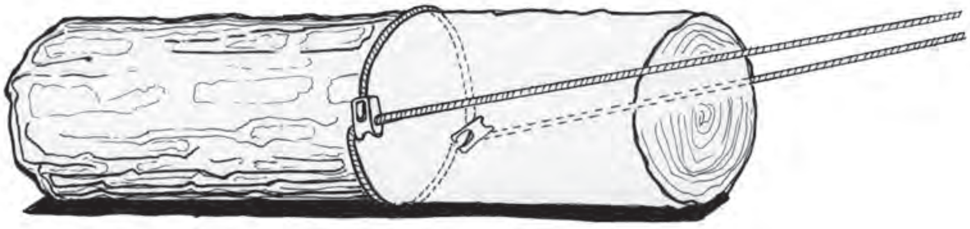


Figure 5–5—A log rigged with two equal-sized "cat chokers."

Chain slings—Riggers most often use chain slings to transport large rocks and often arrange the slings in a bridle configuration constructed of a central master round ring with several lengths of chain attached. These chains usually have hooks or links on the ends (figure 5–6) so you can place the chains around the rock and adjust them to the proper length. You can also use a reverse configuration, attaching the grab hooks to the ring and fastening the hooks to several short lengths of chain secured around the rock.

Ordering Slings

Consider the following items when custom-ordering slings:

- The type of sling material
- The sling diameter or thickness
- The sling width (if it is a webbing sling)
- Overall length of the sling
- End devices, if factory installed (i.e., hook-in-thimble, eye-in-wire rope, etc.)
- Material of the end devices (steel or aluminum for webbing)
- Length of the sling eye, if necessary
- Type of wear pads, if desired

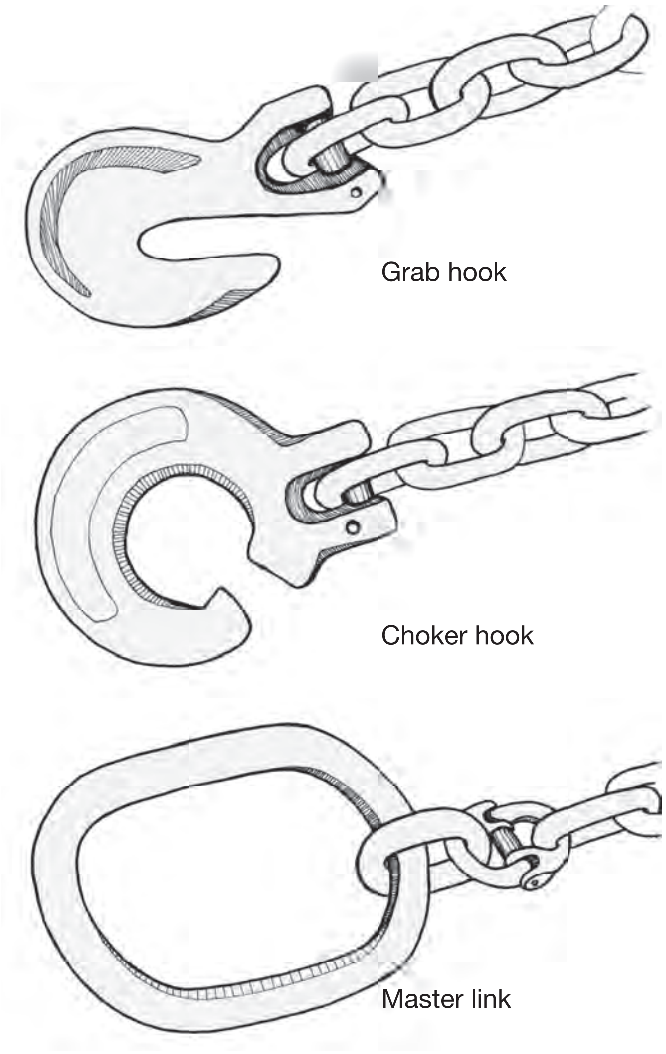


Figure 5–6—Chain sling ends.

Protecting Slings Against Wear

Whenever practical, use suitable material to protect slings against cuts and abrasions. The factory can install wear protection based on your specifications when you order slings, and you can acquire protective aftermarket products that fasten to an existing sling using hook-and-loop fasteners. Consider adding body sleeves and eye sleeves to protect any sling. Body sleeves cover both sides of the sling and can slide up and down the sling to add protection when needed.

This approach works well when you use slings to transport rocks. You can buy eye sleeves as an aftermarket product, but the manufacturer must know the sling's width and thickness. Attach eye sleeves using hook-and-loop fasteners and remove them to inspect the sling eye beneath the fasteners. Sling manufacturers also have other types of wear protection available.

Retired fire hose is a cheap and abundant alternative for protecting slings against wear. You can place the hose between a sling and a sharp edge. You may fit larger diameter fire hose over a sling and slide it along the sling to cover any area that may abrade.

All rated slings contain a heavy tag (often leather)—called a sling tag (figure 5–7)—with information about the sling branded into it. Sling tags must contain the name or trademark of the manufacturer, the manufacturer's stock number or code, the type of synthetic material used, and the rated loads by hitch configurations and angles. The manufacturer also may sew other safety information to the sling. Do not use a sling if the tag is not present or if the information is illegible.

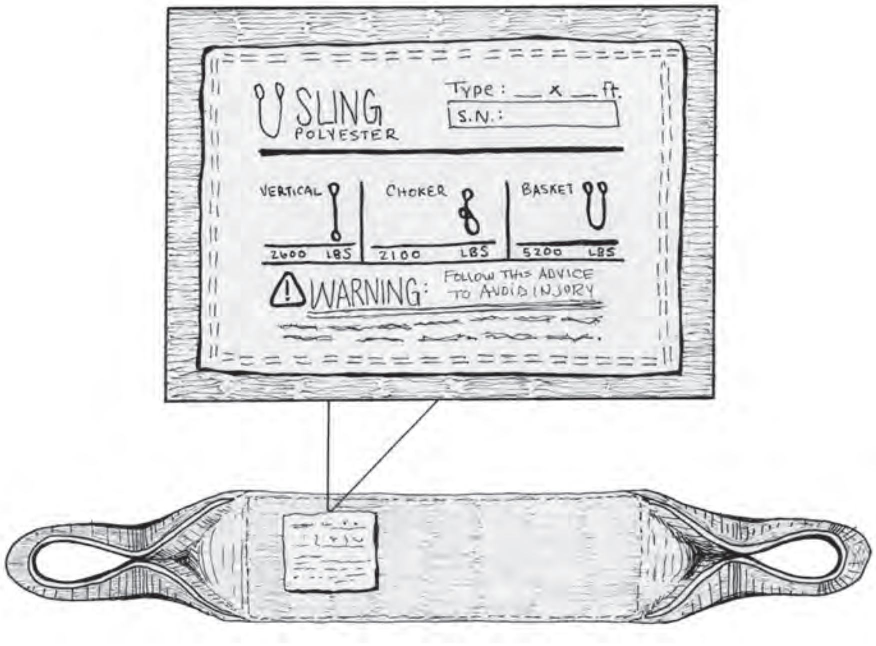


Figure 5–7—A sling with a manufacturer's tag.

Sling Configurations

You must rig slings to provide proper control. It is dangerous to use only one sling to lift a load overhead because the load may slip out. When lifting a load, ensure that the hook is directly above the center of gravity. Determine the WLLs by the hitch you use. Manufacturers design some slings for use in only one configuration, but you can use most slings in any of three hitch configurations: vertical, choker, or basket (figure 5–8).

Vertical hitch—Secure one sling eye to the lifting or skidding hook and connect the other eye directly to the load. This configuration has only 50 percent of the WLL of the basket-hitch configuration.

Choker hitch—Pass the sling around the load and pass one sling eye through the other, then attach the other sling eye to the hook. This configuration has a significantly lower WLL than either the vertical-hitch or basket-hitch configuration. Pull the choker tight before lifting or skidding the load. Always consider the choker angle because the choker configuration significantly reduces the WLL of the sling. It is better to use a basket configuration around a tree as an anchor for the power source than to use a choker configuration. To get a tighter grip around the load, wrap a sling more than once around the load before chokering.

Basket hitch—Attach both sling eyes to the lifting hook so the sling cradles the load. This configuration divides the weight of the load onto two legs of the sling. Slings used in a basket configuration provide the greatest WLL. Some power sources, like the TU-32 griphoist, can make it difficult to connect the eyes of large slings to the anchor pin of the power source. Some riggers solve this problem by using a short, wire rope, pigtail sling connected to the anchor pin of the power source to secure the two sling eyes.

We do not recommend using inverted basket hitches (sometimes called equalizing hitches) for trail rigging applications because the weight of the load is on the sling's eyes, which could cause the sling to slip through the hook and change the load's center of gravity. This can introduce shock loading to the configuration.

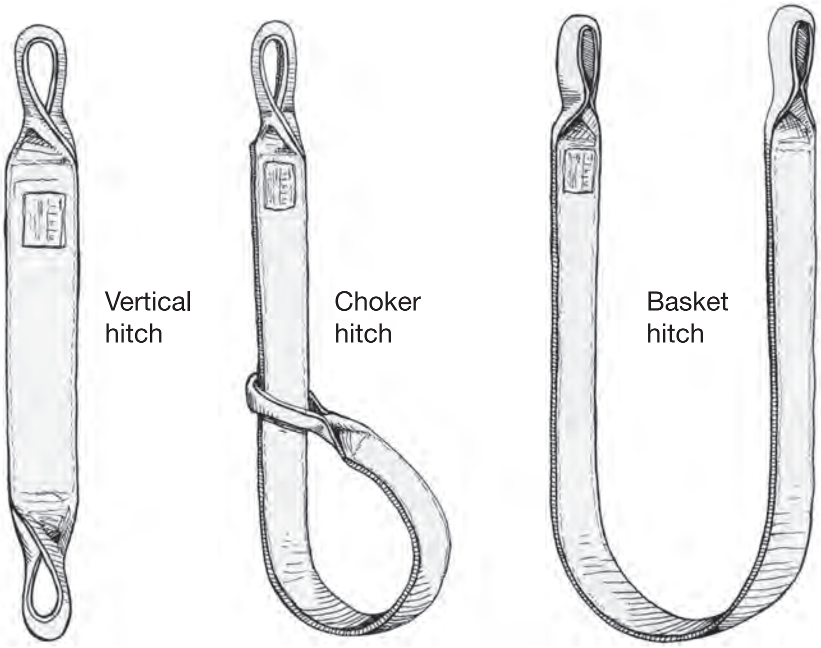


Figure 5–8—Standard sling configurations.

Two conditions must exist to achieve a true basket hitch with a load that falls within the WLL stamped on the label of the sling:

- The corner angles of the two lines must be no more than 5 degrees from vertical.
- The load's rounded surface must have a ratio between 35 to 1 and 30 to 1.

Sling-to-Load Angle

In practical application, you must downgrade the load-rating capacity of a sling anytime you use the sling in a straight-hitch configuration of more than 30 degrees. One of the most severe downgrades of a sling comes when you change the angle by 180 degrees or more by using a choker hitch to roll over a log, commonly called a "rolling hitch." Bending the sling material back on itself can reduce the strength of the sling by about 50 percent (figure 5–9).

Inspecting Slings

Many synthetic slings feature a "stuffer" construction technique. Manufacturers accomplish this weave when they surround the inner yarns (that carry 70 percent of the load) with an outer covering. The manufacturers weave colored core yarns into the inner yarns. These warning yarns are usually red, but may also be green, blue, or other bright colors. As the outer covering wears away, it exposes the colored yarns. The manufacturers may place other yarns within the sling that stretch at a different rate than those of the sling material. These colored fibers break or appear when you overload a sling. When you see colored yarns (whether exposed by wear or shock loading), take the sling out of service. Because exposed red yarns are difficult to see when slings are dirty, clean the slings before using them.

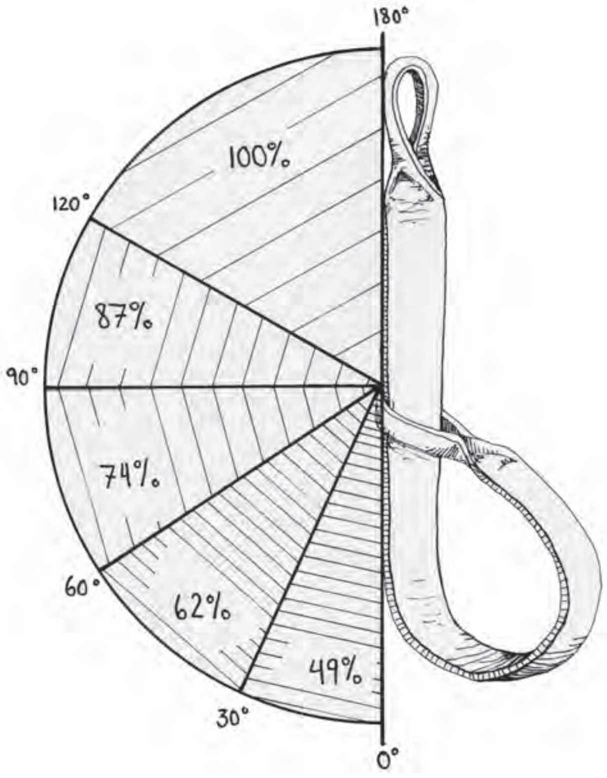


Figure 5–9—The sling strength in a choker orientation decreases as a rigger pulls the sling leg back on itself in the direction of the anchor.

Sling Care and Storage

When you are not using slings, store them in a location that is out of direct sunlight, cool, dry, and free of potential environmental or mechanical problems. Keep slings clean and free of dirt and other materials by cleaning them with mild soap and water. Air-dry the slings and inspect them before storing them.

Using Slings

Follow these guidelines for using slings:

- Ensure that the weight of the load is within the WLL of the sling.
- Ensure that the sling is long enough for you to choker the sling body when using a choker-hitch configuration.
- Ensure that all hooks, shackles, or other connective devices are free of sharp edges that could damage the sling.
- Only use the most suitable sling for the work you perform.
- Balance the load when you use a sling in a basket configuration.
- Always protect a rated sling from cuts and abrasions by padding it with suitable material.
- Provide a proper seat to ensure that fittings are the proper size and shape to prevent damage to the sling eye.
- Make sure to properly align the sling before tensioning (especially when encircling a tree) to prevent girdling (cutting through the bark of a tree down to the wood, damaging and potentially killing the tree).
- Don’t use a knot in a rated sling.
- Don’t use a knot to join slings together.
- Don’t use a hammer to tighten a sling used in a choker configuration.
- Don’t use a defective or damaged sling.
- Don’t use a sling with missing or illegible tag information.
- Don’t overload a sling’s capacity (taking into account the sling’s angle).
- Never choker against the sling tag, splice, fitting, eye, or the base of the sling eye.

Chapter 6: Winches and Hoists

The numerous winches and hoists available for rigging applications fall into two basic categories: nonmotorized and motorized. Backcountry riggers historically relied almost exclusively on a nonmotorized, wire-rope-pulling griphoist machine to accomplish most rigging projects.

Manufacturers design winches to pull loads horizontally. An example is a drum-spool winch mounted on the front of a vehicle. Conversely, manufacturers design hoists to operate in any orientation—horizontally, vertically, and diagonally. Many riggers call everything a winch or refer to a tool by its common name, such as a griphoist or come-along. With the use of synthetic fiber rope on the rise, machines such as power-driven capstans are becoming more viable for rigging applications. The following sections describe a few of the hoists and winches commonly used for trail projects.

Manual Wire-Rope-Pulling Machines

The Tractel Tirfor series griphoist (table 6–1) is the most commonly recognized name in this class of machines. One advantage of these machines is that the hoist doesn't require a drum to retrieve the cable. This hand-powered, continuous-feed hoist requires a special wire rope (sized specifically for the hoist) that you should maintain in good condition. Tractel manufactures these machines in several sizes, depending on the load requirements.

The griphoist, like similar machines, has two internal camming mechanisms controlled by two levers and a clutch. You open the rope release lever (clutch) and hand feed the wire rope into the front of the machine, through the internal cams, and out the back of the machine. After closing the rope release lever, you control the movement of the wire rope using the operating handles on the machine.

Table 6–1—Griphoist model and specification table (N/A = applicable)

Model	Rated capacity for people (pounds)	Rated capacity for materials (pounds)	Weight (pounds)	Wire rope diameter (inches)
T–532	N/A	8,000	51	5/8
T–516	N/A	4,000	30	7/16
T–508	N/A	2,000	14 1/4	5/16
TU–32	6,000	8,000	59 1/2	5/8
TU–28	3,000	4,000	41	7/16
TU–17	1,500	2,000	18 1/2	7/16

> “Manufacturers design winches to pull loads horizontally.”

Placing a removable, telescoping handle over one lever and moving it back and forth feeds the wire rope out toward the front of the machine. Riggers often call this configuration the "slack" lever because it generally puts slack into the system. Placing the handle on the other lever feeds the wire rope out the back of the machine. Riggers often call this configuration the "tension" lever because it puts tension into the system or pulls the load toward the machine. The tension lever is also the lever that contains the shear pins, which are designed to fail when a load applies excessive force.

The internal cam mechanisms inside these types of machines simulate pulling in a line hand over hand. Although the speed of the wire rope moving through the machine is relatively slow, the machine maintains a positive hold on a load as you raise or lower that load. This positive hold makes these machines safe to use and also makes them more versatile than other hoists. The rope release lever opens the internal cams and enables you to feed wire rope freely through the machine in either direction. As a safety precaution, the manufacturer designed the rope release lever not to engage when a load places tension on the machine.

The machine has shear pins engineered into the design that prevent overloading. Remember, however, that the pins may shear at 150 to 200 percent above the griphoist rating (figure 6–1). Always carry spare shear pins and the tools to install them. We recommend this class of machines for general backcountry rigging projects because of their safety, weight, reliability, and versatility.

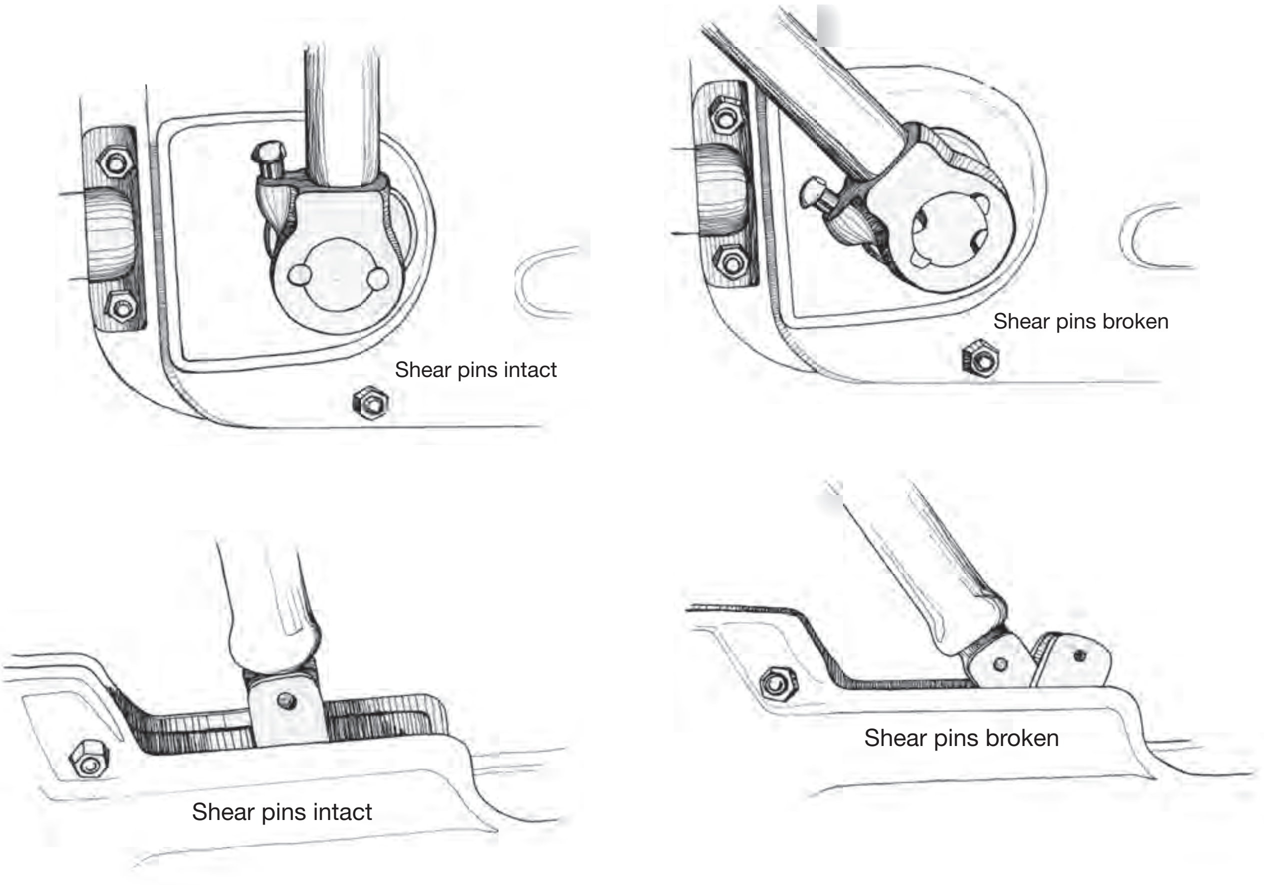


Figure 6–1—Typical shear pin placement (intact and broken) in handles of two different types of griphoist.

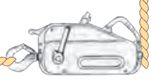
Ratchet Lever Hoists (Come-Alongs)

Manufacturers today offer many types of ratchet lever hoists commercially (commonly referred to as “come-alongs”). Ratchet lever hoists consist of a small-diameter wire or fiber rope spooled onto a ratchet drum powered by a short lever. Riggers often use these hoists in backcountry scenarios because the hoists are lightweight and inexpensive. For a number of reasons, we do not recommend ratchet lever hoists for heavy-duty work. The hoists are limited by the amount of wire rope they can spool. Therefore, many manufacturers undersize the diameter of the wire rope relative to the strength of the hoist so that the wire rope can be longer. The overload-protection device (if the hoist even has one) consists of the handle breaking, which can make releasing the tension on the hoist difficult. The release mechanism can be tricky to engage under tension, even when the handle is intact, making it necessary for operators to place their fingers close to the tensioned spool on the hoist.

Chain Hoists

A chain hoist, often referred to as a chain fall, has some uses in trail work. Its applications are generally limited to lifting and lowering loads vertically to a skyline. A chain hoist is based on a differential pulley system. Internal-compound pulleys have different radii and sheaves shaped specifically to handle chain. A chain runs through the pulleys and ends in a lifting hook that moves up and down from the bottom of the hoist. You pull on the chain hand over hand, and the ratio of the radii difference between the pulleys creates a significant mechanical advantage. Chain hoists commonly have a 50-to-1 mechanical advantage, which means you have to pull 50 feet of chain hand over hand to move the lifting hook 1 foot. This mechanical advantage enables you to lift a 1,000-pound load with only 20 pounds of pulling force. Some chain hoists have a lever to move the chain instead of pulling it by hand, but the concept remains the same. A disadvantage of these hoists is that they are heavy.

> **“Ratchet lever hoists (commonly referred to as “come-alongs”) consist of a small-diameter wire or fiber rope spooled onto a ratchet drum powered by a short lever.”**



Engine-Driven Drum Winches

Numerous engine-driven winches are available; some stand on their own and some require an external power source. One of the most common engine-driven winches, made by Lewis Winch, uses a chain saw engine for power (figure 6–2). The Lewis Winch converts the high revolutions per minute of the chain saw head into low-speed torque, giving the winch a straight pulling rating of 4,000 pounds. Chain saw winches usually hold about 250 feet of 1/8-inch or 150 feet of 3/8-inch galvanized aircraft cable. Because many winches are attachments to already-existing powerheads (usually chain saws), it is important to size the engine adequately. Most of the heavier duty chain saw winches operate on a powerhead of about 90 cubic centimeters (cm^3), with smaller winches down to about 50 cm^3. The 70 cm^3 models are the most popular.

Although engine-driven winches are generally dependable, they are often difficult to repair in the field. The chain saw must have a throttle and clutch in good condition. The more expensive winches have shear pins, a screw-down braking mechanism, and a fairlead. Gear ratios are also an important factor to consider when selecting engine-driven winches. The best winches have gear ratios of about 100-to-1 to 150-to-1, but ratios in the 50-to-1 to 75-to-1 range are common. Spool line takeup speed varies between 60 and 80 feet per minute.

The same rigging principles that apply to power-driven winches also apply to hand winches. If you operate a chain saw winch, you must be able to control the line speed with the engine throttle and hold the load under power when applying the brake. Manufacturers design most winches for an operator to stand on the left and use the right hand to run the throttle. For most winches, operators must use the tool from a stationary position, as opposed to a mid-air operation. You must take care to spool the cable evenly back and forth.

There are many types of engine-driven drum winches. People have used massive drum-spool machines in aerial cable-logging and ski lift operations for decades. Among the many types are 32-inch-wide tracked machines with gas engines that power the tracks and the winch. Hydraulics power some drum-spool winches, such as the winches on cable skidders. A battery powers other winches, such as vehicle recovery winches on jeeps, trucks, and all-terrain vehicles. Many of these units are homemade or customized for the application. These types of winches are uncommon in trail work applications.

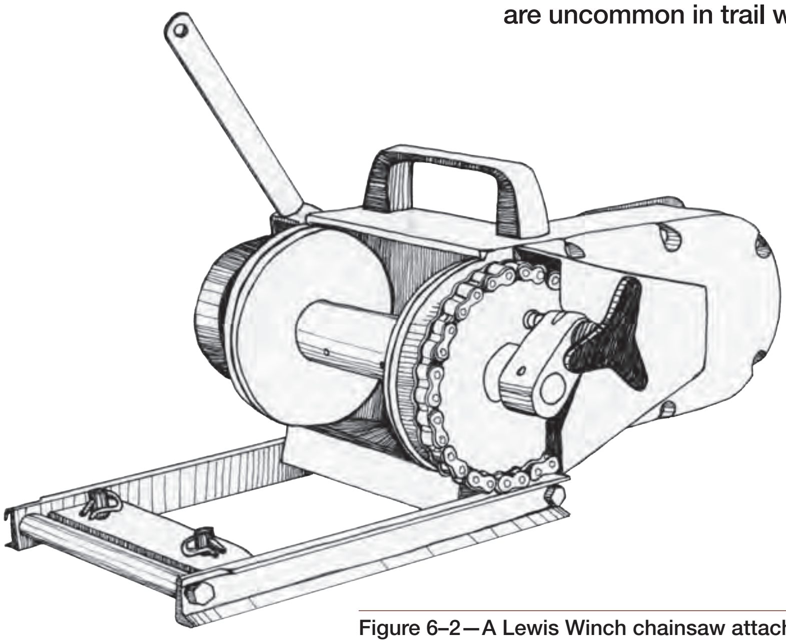


Figure 6–2—A Lewis Winch chainsaw attachment.

Engine-Driven Capstan Winches

A capstan (figure 6–3)—or windlass—is a pulling machine that works by wrapping rope around a cylinder that rotates. Using a capstan winch has definite advantages. Capstans use lightweight synthetic rope (nylon, polyester, or HMPE). You wrap the rope several times around the capstan and out the opposite side, then initiate the pull by applying slight pressure to the rope. When you ease off pressure, the rope slips around the capstan, maintaining a hold on the line until you secure it. The capstan has no takeup drum, so it is not limited by the length of rope the drum will hold. You can obtain most 5/16- or 3/8-inch rope (with which the capstans operate) in 600-foot, continuous spools, if needed. Although they can pull up to 2,500 pounds, the main advantage of capstans is the speed with which you can cycle repetitive loads. This method is especially helpful for long hauls of light material, such as gravel fill. Capstan winches are available with small, gas-powered engines or in chain saw-powered models.

Engine-Driven Wire Rope-Pulling Machines

The Habegger HIT-TRAC performs like a hand-operated, wire rope-pulling machine, but it is motorized. A large, Stihl chain saw engine fitted with a drive sheave powers the HIT-TRAC. The machine's side opens and you loop a wire rope over a couple of tensioning rollers and around a drum drive. The machine does not require you to feed the end of the wire rope into it, as does the griphoist.

The HIT-TRAC pulls an endless length of wire rope and can wind nontensioned wire rope on an accessory spool. It uses a braking device to reverse or lower a load, much like a standard-drum chain saw winch. Although this machine is expensive, some features are cost effective in certain situations.

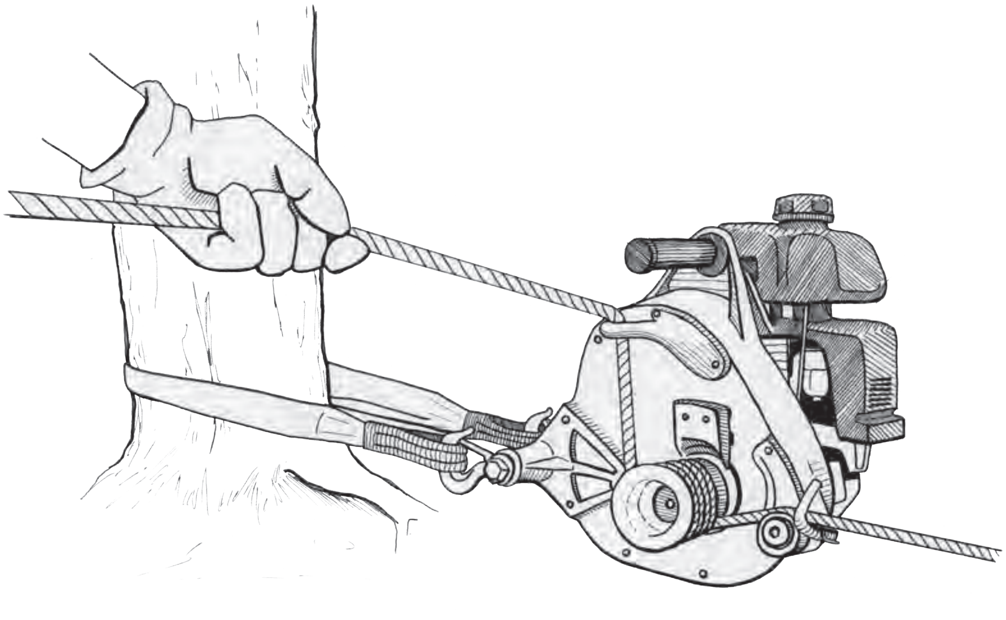


Figure 6–3—An engine-driven capstan winch.

Notes

Chapter 7: Rigging Hardware

Manufacturers frequently introduce newly designed rigging hardware innovations to the market. The following sections describe the general categories of hardware available.

Rigging Components

Manufacturing, transportation, construction, and maintenance activities all use rigging. The range of rigging use requires many specialty tools and products. This manual covers only the most common products needed for trail rigging. Because of the forces that rigging components must handle and the safety considerations required, the components are often large and heavy. Manufacturers can usually offer lighter weight components by making them out of a high-tensile strength alloy, but these components are more expensive. Lighter weight rigging components are often a safety consideration because they are easier to carry and hang, especially in trees.

Blocks

People tend to equate blocks with mechanical advantage, but they are also useful for performing a simple change of direction. This use can often change an unsafe situation into a safer one by placing the operator of the power source in a better working position. Never hesitate to incorporate blocks into a project.

Riggers size steel blocks based on the diameter of the sheave and sheave groove. Blocks contain one or more sheaves assembled in a metal, wood, or polymer frame. Riggers traditionally used wood blocks for trail work as part of a “block and tackle” with fiber rope pulled by hand, but they currently use wood blocks less frequently.

You should always use steel blocks with wire rope. Manufacturers recently developed blocks specifically for new synthetic ropes that can accommodate various attachments, such as rings, eyes, shackles, and hooks, depending on the application. Some of these blocks are made of polymer, stainless steel, and Kevlar.

> “Manufacturers frequently introduce newly designed rigging hardware innovations to the market.”

Types of Blocks

Block names indicate the type of construction and application for which riggers use them. Below are descriptions of various block types.

Snatch blocks—The most common and useful blocks for trail work. You can swing open one side of a snatch block to place a bight of line (rope) on the sheave. The advantage of these blocks is that you do not have to feed the end of the line through the block. You can assemble snatch blocks using pins, bolts, or rings. Because it is easy to lose or misplace pins and bolts, you should paint them a bright color so you can easily find them. Always bring appropriate spare replacement pins or bolts to the rigging site. A snatch block with a swivel incorporated into the design (figure 7–1) is the most useful block on a rigging site.

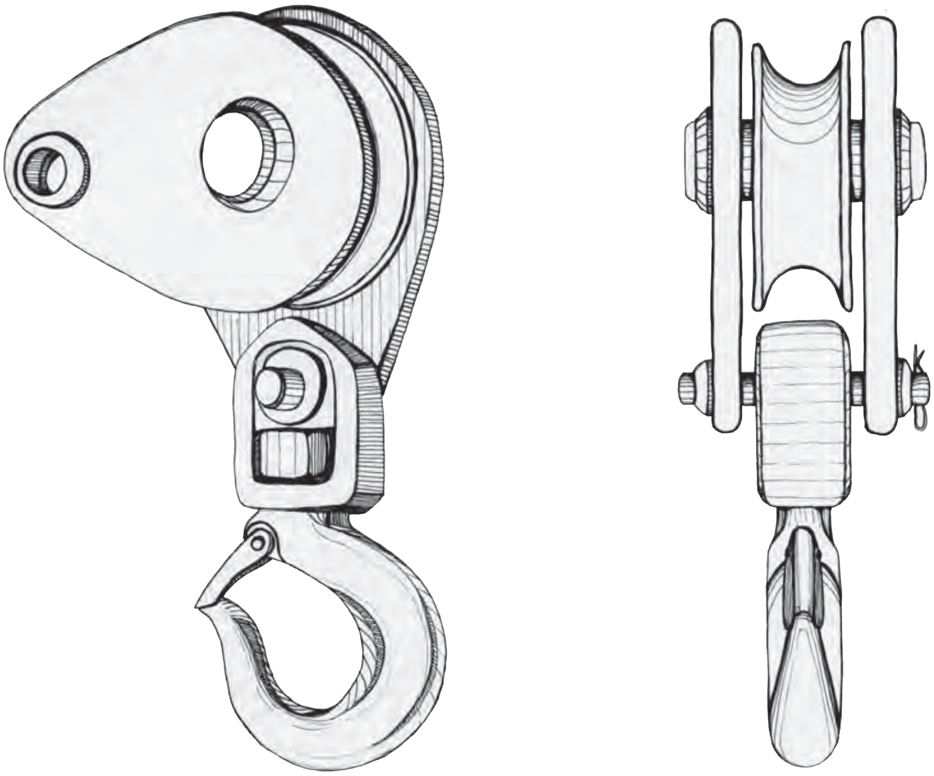


Figure 7–1—A swivel snatch block with a side opening.

Pass or rigger's blocks—A specialized snatch block that has a wide, long throat that allows splices, fittings, and other connections to pass through the sheave. Because of its unique application, this block is useful for any rigging project. High climbers typically set the pass block (figure 7–2) above the location where they position the blocks, slings, and guy lines on the tree.

Block and tackle—The term most often used for wooden blocks with a fiber rope, although lighter weight metal block and tackle systems designed for high-angle or swiftwater rescue are readily available. This type of system is versatile for any trail work where you pull the line by hand to provide the power source. With reasonable footing, you can pull with a force approximately equal to your body weight, so it is easy to approximate the load applied to a block and tackle (do not use a griphoist or other winch to pull on these systems). Riggers often use this system when they have to move a load a short distance along a line that inclines uphill.

You can use stock animals with this type of system to clear downfall from a trail. Fiber rope, more pliable and lighter than wire rope, is easy to transport. The tackle usually consists of two double or triple blocks. To rig blocks of more than two sheaves, lay them on the ground in line with each other and secure one end of the rope to the becket. Start by leading the other end of the line through the center sheave of the second block, and continue until a line passes over all sheaves, ensuring that no lines cross.

Friction occurs on all blocks, although blocks with bearings have less friction. You must account for each sheave in the rigging system to add a friction load of about 10 percent. The more blocks in the system, the more friction.

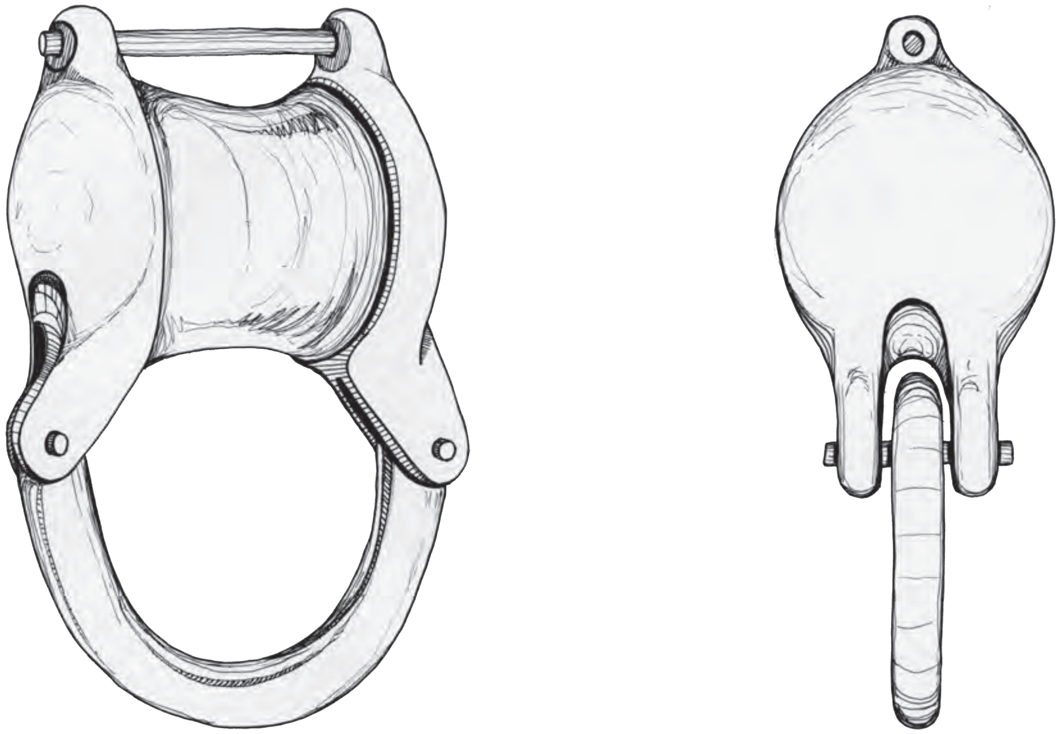


Figure 7–2—A pass (or rigger's) block.

Components Common to Most Blocks

Blocks consist of a variety of components. The specific components in a block determine their suitability for any given rigging application and diameter and type of rope. The following explanations provide information about various block components.

Sheave—A round, grooved wheel over which a line passes. A discussion about sheaves involves two diameters. One is the sheave pitch diameter (*D*), which is the overall diameter of the sheave expressed in inches (e.g., 8-inch block). The other is the inside diameter of the sheave groove (*d*), usually expressed in fractions of an inch (e.g., 1/2 inch), which indicates the diameter of rope for which the manufacturer designed the block. It is important to know both values, as they dictate the size and type of rope you can use with a given block. You can use fiber ropes for blocks with either metal or plastic sheaves. The sheave pitch diameter in fiber ropes may be less than wire ropes, but the sheave groove should be a bit larger.We recommend that you size the sheave groove diameter 1/8 inch larger than the diameter of the fiber rope. Therefore, you should match a 3/8-inch fiber rope to a 1/2-inch sheave groove diameter because fiber ropes naturally flatten more than wire ropes when loaded around a block. Blocks designed for wire rope have a sheave groove diameter that fits the diameter of the wire rope within 1/16 inch, so that the wire rope sits well in the groove and does not flatten or deform when loaded. Manufacturers make gauges to measure the groove diameter. Metal rigging blocks designed for wire rope have a larger overall sheave diameter because wire rope is not as flexible and has a higher *D*/*d* ratio.

A common mistake riggers make is using sheaves that are too small in diameter for the wire rope. Only use the sheave diameters recommended by the wire rope manufactures. If the sheave groove is too small, the sheave can pinch or wear the rope quickly, or the sides of the sheave can fracture off. If the wire rope is too small in diameter for the sheave, the groove does not support it evenly, and all the strain is on just a few strands. This is typical when using blocks on a small-diameter chain saw winch mainline. The strands flatten and become weak. When sizing the overall sheave pitch diameter, the bigger the better. Having a large overall sheave diameter will not negatively affect a rope, but a sheave diameter that is too small can permanently kink and deform a wire rope.

If you do not know the manufacturer's recommendation, follow these guidelines:

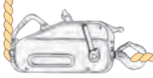
- For wire rope, the sheave pitch diameter should be 16 to 20 times the diameter of the rope.
- For fiber rope, the sheave pitch diameter should be 5 to 10 times the diameter of the rope, depending on the composition of the rope.

Shell—A frame that houses the sheave, the sides of which are called "side plates" or "cheeks."

Axle—A round rod on which the sheave rotates. It runs from one side of the shell to the other. The sheave fits over the axle using either a bushing or a bearing. Many blocks have a greased fitting to lubricate the axle.

Hook—A connective end that attaches to the shell by either a rod or strap. It can be either fixed or on a swivel.

Becket—A hole or opening for a connecting device, physically located opposite the hook. Riggers use a becket to secure the standing part of a rope or another clevis or block. Most blocks used with wire rope do not have beckets. There is a distinct advantage to using blocks with beckets. While you can most often accomplish the same result by anchoring to a fixed object, using a becket often requires fewer straps and other rigging components.



Anchoring Hardware

Anchors are the foundational, immovable elements in a rigging system to which everything else connects. They are most often live trees or large boulders, but they can be anything that will not move under the forces generated by the rigging system (refer to "Chapter 11: Setting Anchors and Spars" for more information about anchors). When you cannot locate adequate trees or boulders, you may require anchoring hardware.

Rock anchors—Rock anchors are either an expanding type or a grout type. You secure rock anchors in holes you drill in sound rock, based on the depth recommended by the manufacturer. The long axis of the bolt should point in the direction of the pull, not at right angles to the pull. The angle the load places on the bolt should be as narrow as possible. Many of these anchors use a ¾-inch-diameter rod. Expansion anchors usually require drilling a 1⅞-inch-diameter hole. Manufacturers design expansion anchors (figure 7–3) to pull directly up the length of the rod. The greater the pulling force, the tighter the anchor holds. We recommend that you do not rig rock anchors for a sideways pull (called shear), which significantly lowers the breaking strength of the bolt

Riggers usually "grout" in nonexpansion anchors using a special two-component epoxy instead of grout. The chemicals that form this type of epoxy even allow you to secure anchors underwater. Rock anchors usually have ridges or other protrusions along the shaft to increase holding power. Never use a standard eyebolt in place of a rock anchor.

Tent peg rock anchors require you to drill a series of holes in the rock at right angles to the pull. You place steel bars in the holes and equalize the anchor cable between the bars. Do not grout the bars into the rock (you can recycle the bars).

Retracted for insertion

Expanded after tightening

Figure 7–3—An expansion rock anchor.

Soil anchors—Soil anchors have been around for centuries. The utilities industry commonly uses them today. The three types of soil anchors are screw-in (soil auger), drive-in, and expanding.

As with all anchoring, field conditions dictate which anchors to use. Soil anchors are particularly beneficial in creek bottoms that do not have trees or rocks. The holding strength of an anchor depends on the soil type. Follow the manufacturer's recommendations to install the soil anchors. Because of the variability in the holding power of soil anchors, do not use a soil anchor as a hoist anchor unless you first test it with a dynamometer.

Screw-in soil anchors (figure 7–4) usually have a single or double helix screw plate (4- to 14-inch diameter) welded to a 3/4-inch- to 1 1/4-inch-diameter rod with an eye on the top. You can insert a large bar through the eye to screw the anchor into the soil at an angle. Install screw-in anchors at the same angle as the anchor line, with the eye toward the load (e.g., the guy lines on power poles). We find it is often easier to start the first revolution straight down, then push the rod to the correct angle, and finish screwing the anchor clockwise to the proper depth. As a rule, you should install a soil anchor to a minimum of at least three times the diameter of the screw anchor plate. If you bury the anchor at a shallower depth, it will likely pull out of most types of soil. Screw-in anchors work best in normal clay soils without rocks. If you cannot screw the anchor to the proper depth at the preferred site or at alternate locations, use a drive-in anchor instead.

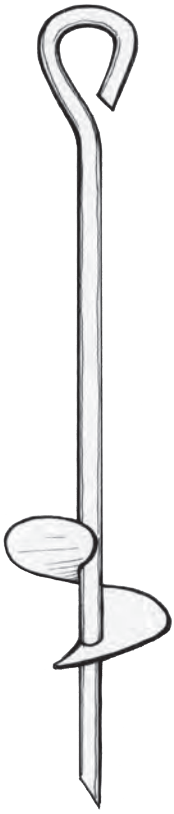


Figure 7–4—A screw-in soil anchor.

Driven, tipping-plate soil anchors (figure 7–5) have an arrowhead-shaped end plate attached to a wire rope. You use a special rod to drive the anchor plate into the ground with a sledgehammer, fence-post driver, or jackhammer driving attachment. Although manufacturers design drive-in anchors for use in all types of soil, these anchors do especially well in rocky soils. You must drive the plate into the ground at the same angle as the anchor line so that only a strain-out pull is exerted on the underground cable. Follow the manufacturer's recommendation for placement depth. This approach usually leaves only 2 to 4 inches of the thimble cable eye aboveground. At the proper depth, remove the drive rod and apply lifting power to the thimble wire rope end of the anchor. You typically use a special 10-ton hydraulic jack to tip the underground plate 90 degrees into a holding position. Do not place a load on the rigging system until you tip the toggle and determine that the anchor will not pull out.

Expanding soil anchors (figure 7–6) require you to first dig a hole (usually using an auger) at the appropriate angle. Screw the expanding anchor to the end of a rod and place it into the bottom of the hole. The anchor expands into the undisturbed soil as you twist the rod, similar to lowering a fully extended scissor jack. Fill and tamp the hole after expanding the anchor.

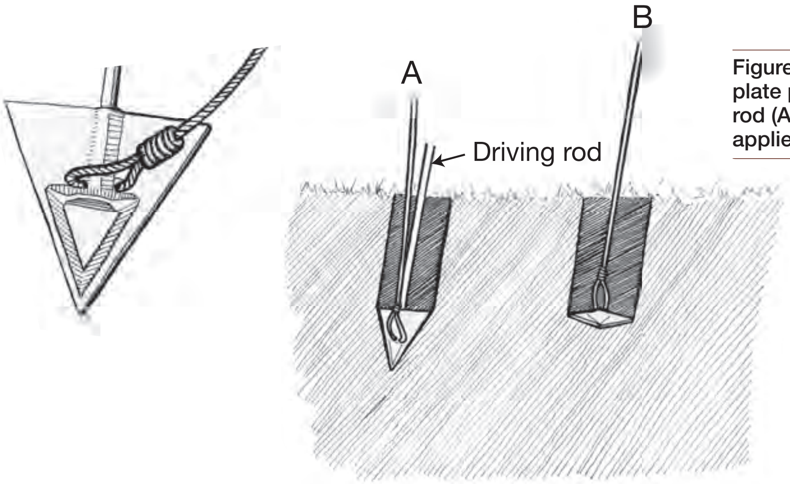


Figure 7–5—A driven, tipping-plate soil anchor. The plate point is driven into the ground using a driving rod (A), then the driving rod is removed and a load is applied to the wire rope, causing the plate to tip (B).

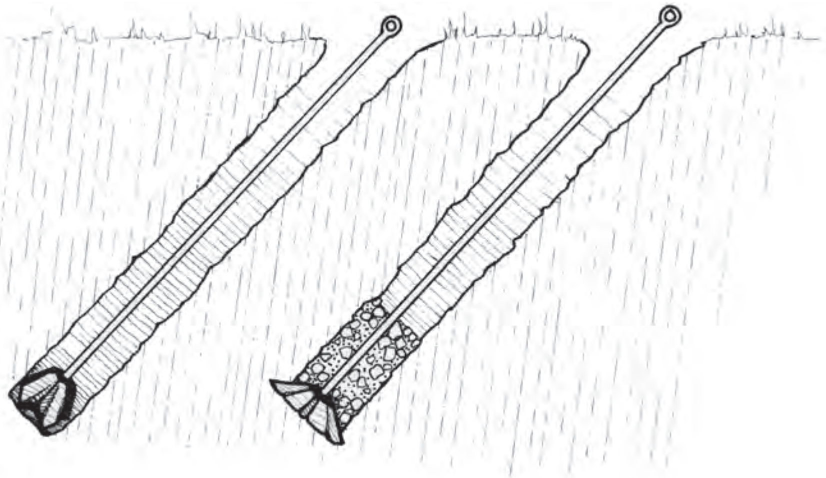


Figure 7–6—An expanding soil anchor in a drilled hole.

Deadmen—Deadmen are very important for the rare situations when no other anchors are available. A deadman is a buried object to which you attach an anchor cable or rope. It is usually a dug-in or buried log (figure 7–7) that incorporates the use of two trenches; one for the line to rest in and the other, perpendicular to the first, where the deadman lies. The log must be sound and sufficiently sized not to break under loading. Be sure to rest the log against an undisturbed soil wall in a trench. The holding power of a properly placed deadman relies on the forward pressure placed on the anchor cable to push against the undisturbed soil. Depending on the soil type, digging a deadman anchor is labor-intensive and time consuming, but is sometimes the only option. A common mistake when using a deadman is not placing it deep enough; the upward angle of force can pull it out of the ground.

You can also use steel rods to pin steel plates to the ground to provide an anchor. Use this technique to provide anchors in wilderness areas above timberline, and construct various configurations (depending on the soil characteristics) using the principle of distributing the load across a number of rods that provide resistance in the soil.

End Devices

Riggers usually construct end devices into lines or slings to allow the end devices to connect to other rigging components. Each type of material (wire rope, chains, etc.) has its own type of end device. Some end devices are permanent, such as stitched eyes or the ends of slings, but others may simply be a knot at the end of a piece of rope that you can untie and reuse. Installing many devices in the field may reduce the working load limit (WLL) of the line. You must consider this reduction in WLL. We recommend using professionally installed permanent end devices.

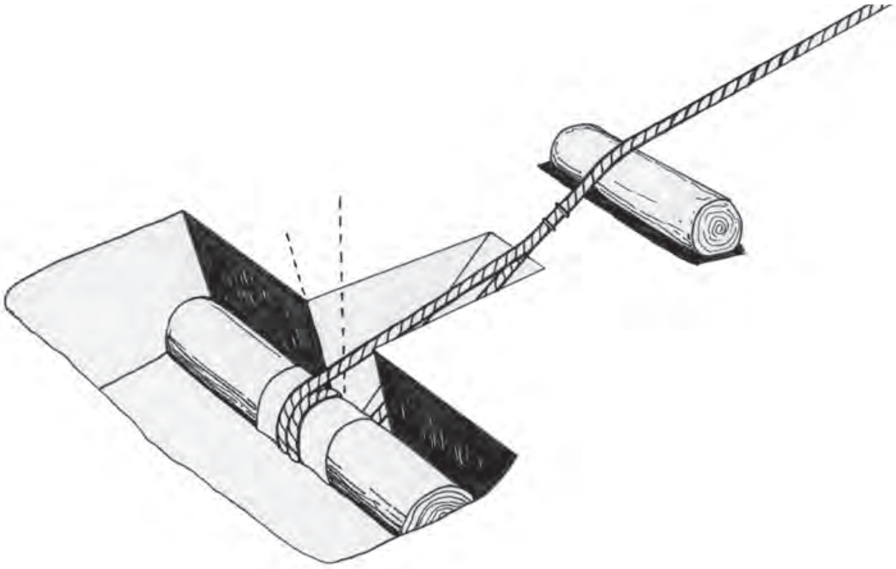
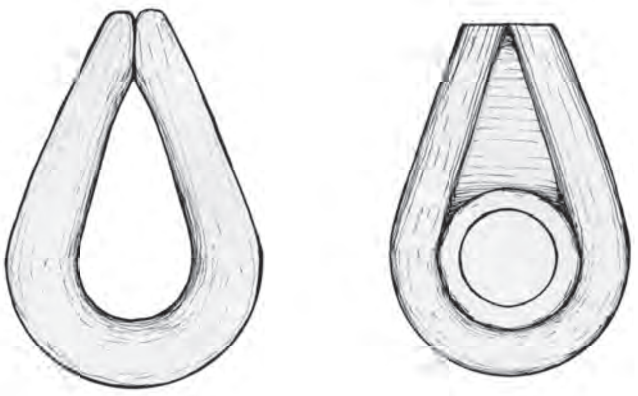


Figure 7–7—A deadman anchor (buried log).

Thimbles

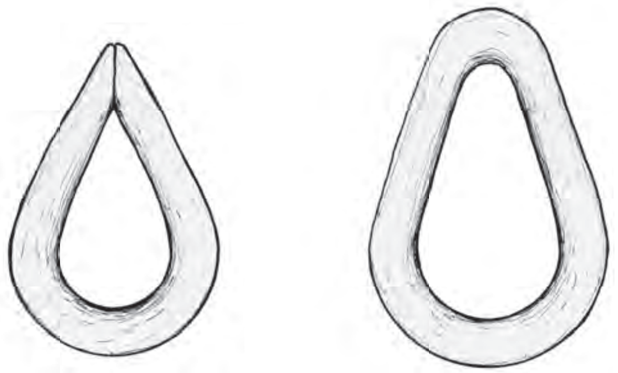
Thimbles (figure 7–8) are preformed rigid metal inserts that manufacturers place on the inside surface of the wire or flexible rope when they construct the eye of the rope. Thimbles protect the wire rope from wearing, flattening, or deforming. They also minimize loss of strength at the cable end where the rope joins to other devices, such as clevises. Without a thimble, the eye in the wire rope deforms, its breaking strength reduces, and the possibility of failure increases. Fiber rope and wire rope have several thimble styles. Use the proper size thimble for the diameter of rope you select.

Manufacturers produce numerous types of thimbles (light duty, standard duty, and heavy duty) in a wide variety of sizes and shapes for general rigging use. The most common are standard-duty open thimbles and heavy-duty open thimbles that are either stainless steel or galvanized. Use Hawser closed thimbles for heavier duty applications. Blueline closed thimbles have a tubular, gusseted design made specifically for synthetic fiber ropes. Riggers commonly use thimbles on more permanent installations (e.g., on an eye at the end of a hauling line).



Heavy-duty metal

Solid metal



Standard-duty metal

Synthetic rope nylon

Figure 7–8—Types of thimbles.

Connection Devices

Connection devices attach various components of the rigging system together. Riggers also use them to connect products made of different materials (e.g., using a clevis to attach a nylon sling to the thimble eye end of a piece of wire rope). Clevises, wire rope clips, and grippers are probably the most common connecting devices used on trail rigging projects.

Clevis

Riggers often use the terms “clevis” and “shackle” interchangeably, although a shackle is a more general term that can describe many different types of connection devices. Clevises connect or secure lines and other rigging components. A clevis has two main parts: a pin and a bail. The bow is the part of the bail opposite the pin.

Bails and pins come in a variety of shapes, depending on the intended use. Manufacturers often describe clevises by their shape. The bail can be straight (chain clevis), slightly belled, or heavily belled. Pins can be a screw type (figure 7–9), a round type, or a type that you fasten with a variety of safety pins to prevent the pins from unscrewing from the clevis.

The most common bolt type of clevis uses a hex or castle nut reinforced by a cotter pin. Use this configuration for permanent installations. In an emergency, you can also secure pins with a nut by making a wire loop (called a Molly Hogan) from a single wire raveled from a strand of cable. The wire will be wavy, and the newly formed loop will follow this pattern when you weave it back into a loop. From the piece of wire inserted through the pinhole, you develop a loop and

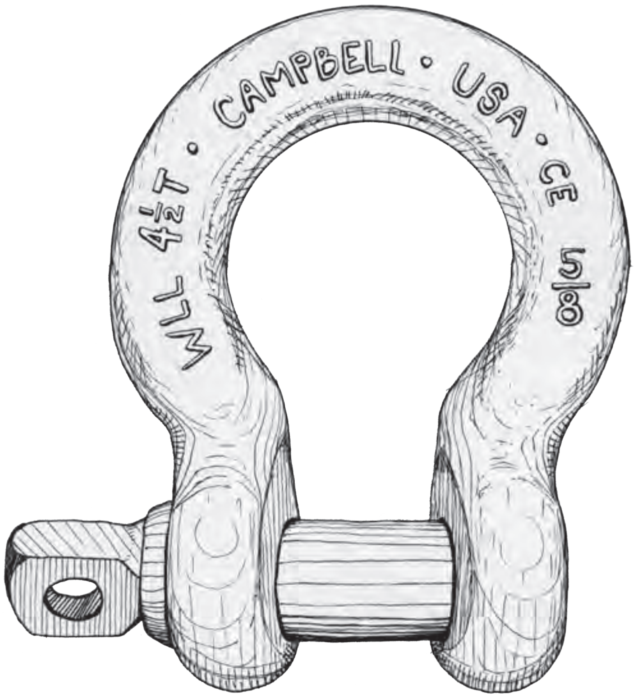


Figure 7–9—A screw-pin clevis.

wrap the bitter end back into the loop until it forms a wire circle. You may place two revolutions of the wire through the pinhole if the pinhole is large.

You should regularly check screw-pin clevises (see figure 7–9). It is important to tighten the pin and then back it off one-eighth of a turn in case it accidentally tightens further under the load. We recommend securing the pin to the clevis by using inexpensive nylon wire ties through the pin eye.

Manufacturers classify clevises according to the diameter of the bow on the bail, not the pin. Many clevises have 45-degree markings stamped into the bail. These markings indicate that slings applying a 45-degree side load will reduce the clevis WLL by 30 percent. Slings applying a 90-degree side load will reduce the clevis WLL by 50 percent. Some riggers, as a practice, use the next largest size clevis whenever they apply an appreciable side load.

Although clevises may seem indestructible, side loading can deform or break these components. It has been our experience that riggers commonly side load clevises. Avoid side loading clevises at 90-degree angles whenever possible. If you must side load the clevis at a 90-degree angle, reduce the stamped WLL limit by up to 50 percent.

When using a clevis in a choker-hitch configuration, or with any running line, place the pin in the eye of the sling. If you allow the running part of the sling to travel over the pin, the pin could loosen and fail. This is especially true when you use a screw-pin clevis you have not secured using a nylon tie or other safety device.

Some manufacturers produce a wide bail that reduces wear of synthetic slings because the wide body increases the bail radius to support the sling (figure 7–10).

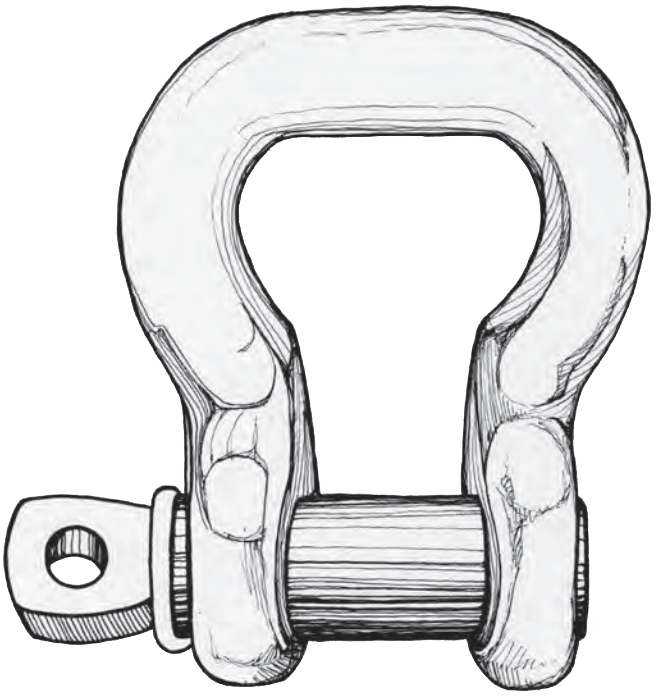


Figure 7–10—A wide-bail, screw-pin clevis used with flat, synthetic sling eyes.

Wire Rope Clips

Riggers commonly use wire rope clips (sometimes called “cable clamps”) for trail rigging applications (figure 7–11). You may only use clips that match the size of the wire rope. Manufacturers provide information about the number of clips required for each wire rope size, the amount of rope to turn back to make an eye, and the required torque on the bolts. You can accomplish a lot of trail work using ½-inch wire rope that requires three clamps and about a 1-foot turn back. Cable clips placed properly in a thimble eye retain 80 to 85 percent of the effective strength of the wire rope. Overtightening clamps reduces cable strength. Refer to “Appendix A: Terminating and Managing Wire Rope” for more information.

The expression “never saddle a dead horse” is a reminder that you must place the “saddle” over the long—or live—end of a wire rope (figure 7–12). If the wire rope is live on both ends, as in the case of a spliced line, use fist grips that have two saddles. Failure to place cable clamps correctly reduces the effectiveness of the wire rope by 50 percent.

Two cable-clamped eyes are the preferred method for splicing wire rope. An alternate method is to lay the two ropes parallel to each other and use twice as many cable clips and twice the turn back required for an eye splice. For example, a ½-inch rope would need a 2-foot overlap of cable and six clips. If fist grips are not available, the saddle for each group of three clips would be on the respective live end of the wire rope.

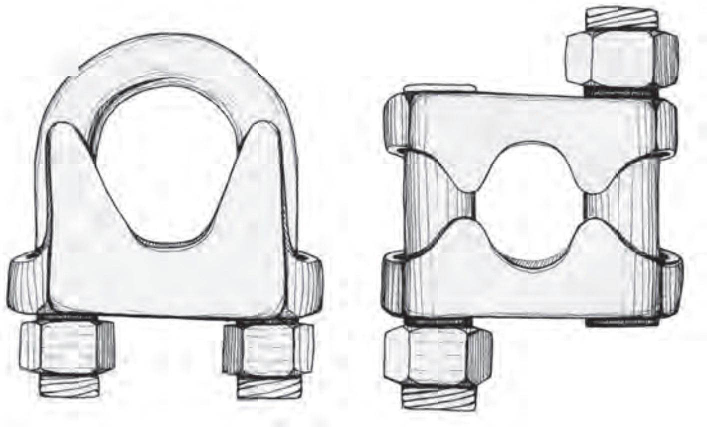


Figure 7–11—Common wire rope clips.

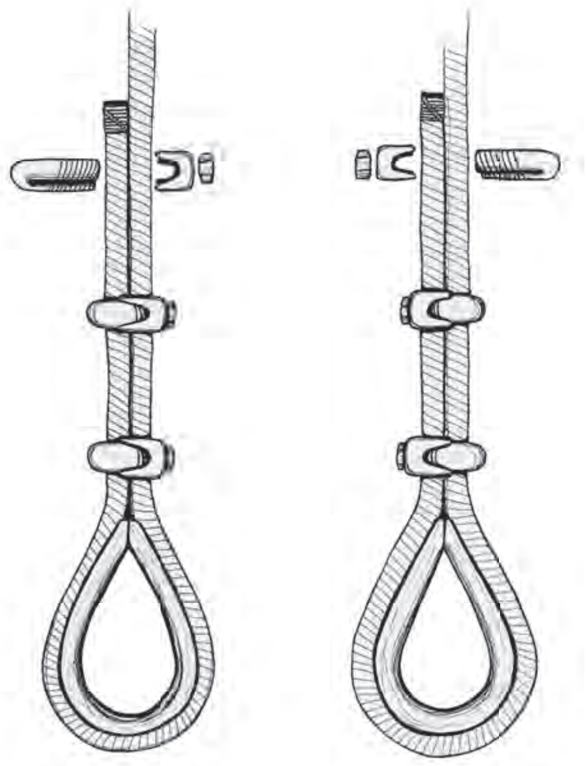


Figure 7–12—The correct and incorrect placement of wire rope clips.

Terminal Wedge Sockets

Terminal wedge sockets are among the quickest and simplest devices you can use to anchor a wire rope (figure 7–13). Wedge sockets are convenient to use because, similar to a grip, you don't have to attach them to the end of the wire rope. However, this type of device has only 70 percent of the strength of the wire rope. Another drawback of wedge sockets is that they can loosen, and the rope can slip if you don't maintain the wedges under a load. To prevent this, loop back 6 to 9 inches of wire rope and secure it with a cable clamp, but do not clamp the live end of the wire rope.

You can attach Sauerman continuous cable clamps (figure 7–14) anywhere along a cable and provide an eye for the attachment of another rigging component. Attach the clamps by placing a socket device over a cable, insert a tapered wedge into the socket body, and hammer the wedge lightly into the socket. Then, place a wire rope clip through an eye on the wedge and clamp it to the wire rope. This technique provides an added measure of security and safety to the wedge and socket. After you tension the wire rope, retighten (but do not over tighten) the wire rope clip. Different-sized wire ropes require different clamps, although the ⅜-inch and ½-inch wedges each fit in the same body. The drawbacks of clamps include their weight and the need to hammer the wedge loose after heavy loading. Their advantages include the ease with which you can place them anywhere along a wire rope, the security that they provide relative to grips, and the fact that they do not damage the wire rope.

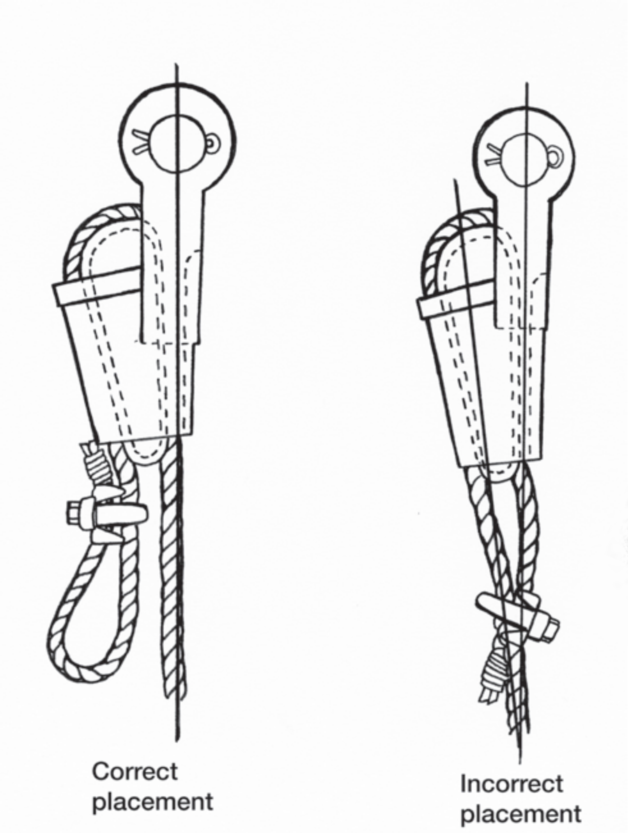


Figure 7–13—The incorrect and correct placement of a wedge socket clamp.

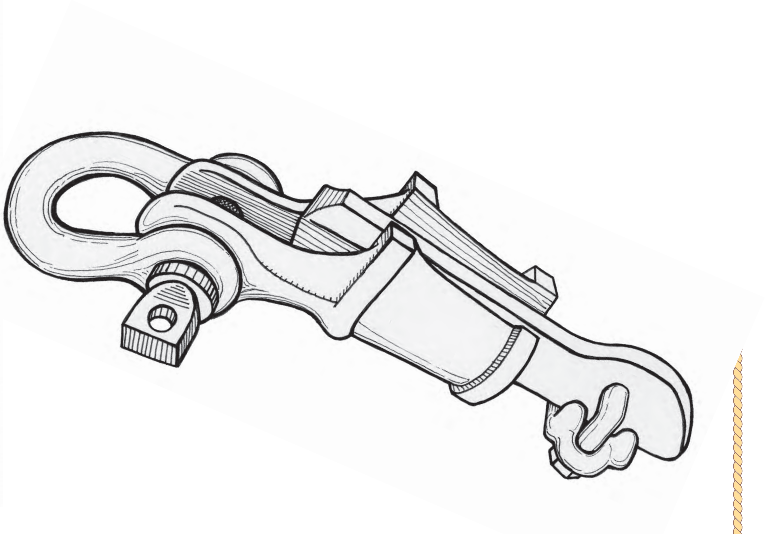


Figure 7–14—A Sauerman continuous cable clamp.

Pressed Eyes

Rigging shops with large hydraulic presses make eyes in wire ropes using pressed steel ferrules. Using these steel ferrules helps to retain about 90 percent of the wire rope's WLL. However, because ferrules are rigid, they can crack under a load if they pass over a sheave. Do not bend ferrules under a load around trees or stumps. In general, during a logging industry inspection, one wire broken above the ferrule is cause for removing the rope from service.

Wire Cable Grips

Power and communications companies commonly use grips for pulling cable. Manufacturers generally construct grips in either a parallel-jaw or a pinching-jaw configuration. Out of many dozens of varieties, manufacturers only design a few specifically for use with the type of wire rope used in trail rigging. The correct selection of grip jaws is important to ensure safety, to avoid damage to the wire rope, and to prevent slippage. Work with the grip supplier to obtain the correct grip and jaw design for each application.

Grips are an important investment in every rigger's toolbox because of the versatility they provide. Note that grips are not as secure as a Sauerman clamp and may slip over time or under high tension, even if you use the proper grip. Consider grips as temporary terminal devices and inspect them frequently. Grips require little care, but you should keep them clean to reduce the possibility of slippage. Periodically use emery cloths or a clean wire brush to keep the surfaces of the jaws clean. Also, clean greasy wire rope before inserting it into a grip. If you use a grip on galvanized cable, clean the jaws of the grip after each use; grips have a tendency to strip the zinc coating off the wires.

Haven's Grips

Haven's grips (figure 7–15) have a knurled (ridged) jaw that works on cam action and bites into the wire rope as pressure applies. Only use Haven's grips in situations where damage to the cable is acceptable (e.g., when securing logs together by wrapping and stapling, or when gripping working lines and wire rope that are expendable).

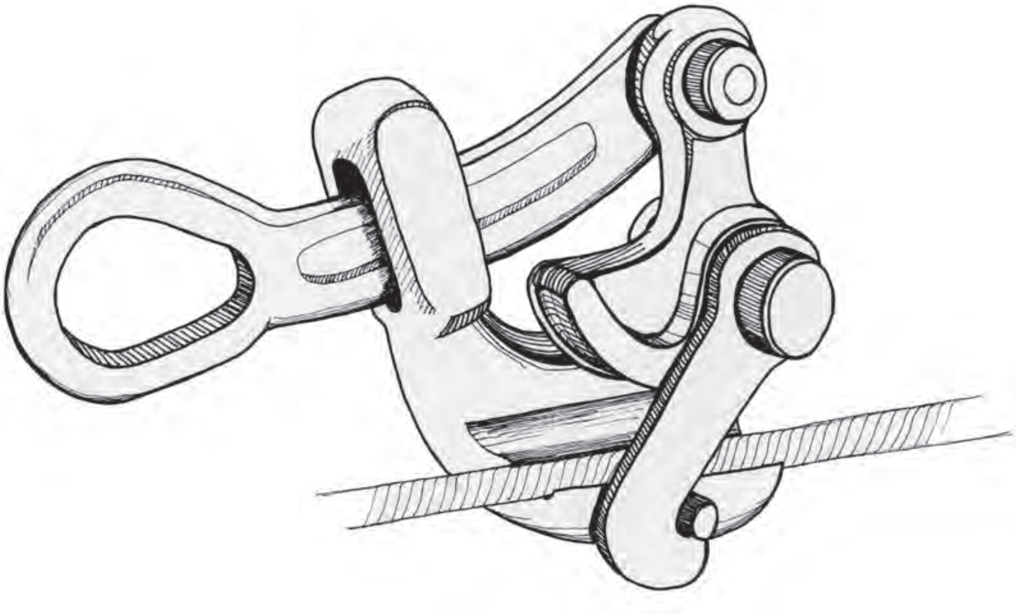


Figure 7–15—A Haven's grip.

Parallel-Jaw Grips

Parallel-jaw grips—commonly known as Chicago grips (figure 7–16)—sandwich the wire rope and apply equal pressure along the length of the jaw surface. Using the proper-sized parallel jaws of a Chicago grip will not distort or damage wire rope. We recommend a double "V" jaw to provide more gripping pressure and to enable proper alignment of the cable within the jaws. Some models have a "locking open" feature to facilitate placement. Always match the proper grip to the wire rope size and never exceed the safe WLL of the grip. Manufacturers usually stamp the body of a grip with the minimum and maximum size of wire rope the grip will fit. For ½-inch wire rope, we use grips stamped with a 15,000-pound maximum safe WLL.

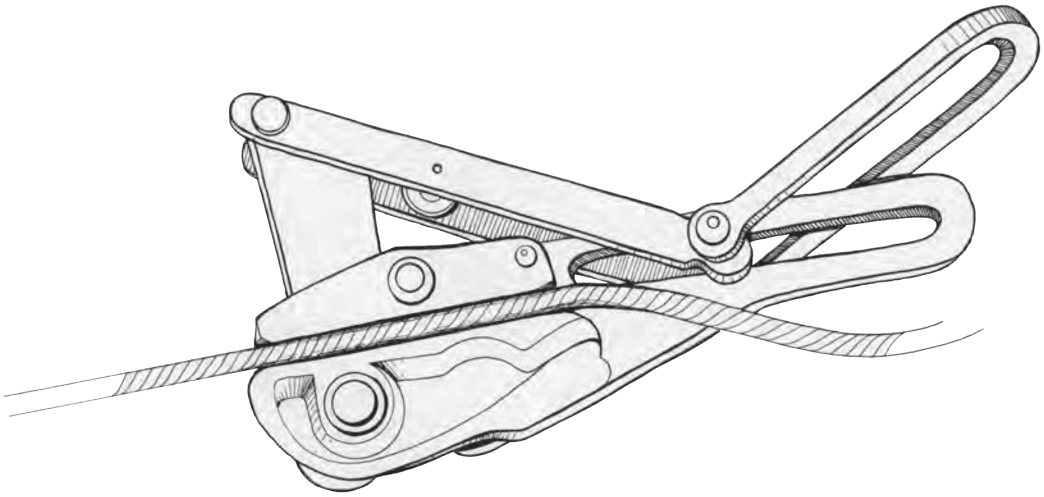


Figure 7–16—A parallel-jaw grip (commonly known as a Chicago grip).

Carriages and Rigging Plates

Carriages are metal plates that use two or more blocks to support the load on a skyline and provide for the terminal ends of two or more lines. Riggers do not usually purchase carriages commercially, but have them custom made to their specifications. For heavy lifting, we have made 9- by 24-inch carriages out of ½-inch plate steel with holes to attach clevises and blocks.

Commercial rigging plates are similar in function to carriages, but are usually smaller, round, and hang from a single block traveling along a skyline. Carriages and rigging plates (figure 7–17) eliminate the need for side-loading clevises and blocks when attaching lines to suspended loads. Although more expensive, you can reduce the system weight by substituting alloy aluminum for steel.

Although you will probably only use carriages to lift heavy loads, such as bridge stringers, the smaller rigging plates are practical for general aerial rigging because they keep lines and connecting devices organized and prevent the side-loading of clevises.

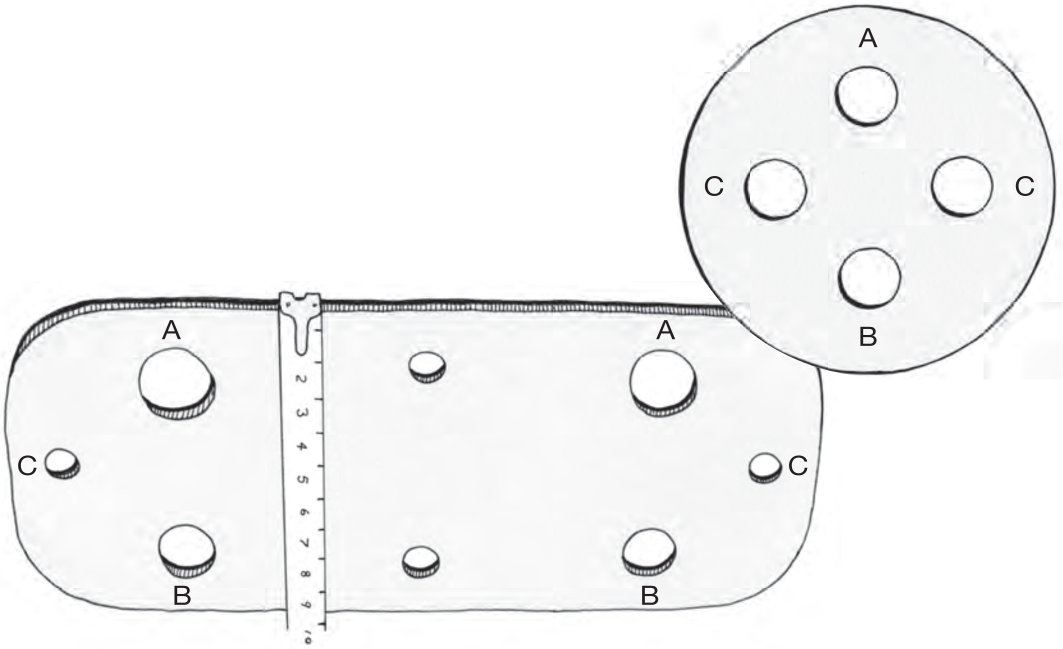


Figure 7–17—Various rigging plates can hold one (or more) block or clevis using skyline block attachment holes (A), load attachment holes (B), and mainline or belay line attachment holes (C).

Belaying, Braking, and Lowering Devices

Riggers accomplish belaying, braking, and lowering activities using a variety of devices. Arborist companies contribute new designs every season, but the following sections describe some of the most common trail work devices.

Friction-Braking Devices

The Buckingham Port-A-Wrap (figure 7–18) belay device is one of the simplest and most common friction-lowering devices well suited for trail work. It is a metal barrel, either aluminum or steel, attached to an anchor using a sling or rope. The belay line wraps over a cleat, around the barrel, and out through a fairlead. The more times you wrap the rope around the tube, the more friction it introduces. The Port-A-Wrap comes in several sizes, with WLLs up to 6,000 pounds.

Other companies provide friction-lowering devices that are similar to the Buckingham Port-A-Wrap. The United Kingdom-based International Safety Components, Ltd. (better known as ISC), also makes a friction-lowering device they call a port-a-wrap. This device comes in two sizes, the larger of which has a WLL of 2,200 pounds. Also based in the United Kingdom, Stein Company makes a number of lowering and belaying devices (figure 7–19). In addition to the simple port-a-wrap style, Stein manufactures single- and dual-bollard devices that can handle one or two belay ropes, respectively. The bollard (or drum) mounts to a tree, where you wrap it with the belay line. The bollard-style devices are heavier (25 pounds or more for the single and 60 pounds or more for the dual bollard), but when mounted correctly, they have a WLL of 6,614 pounds, making them suitable for larger loads.

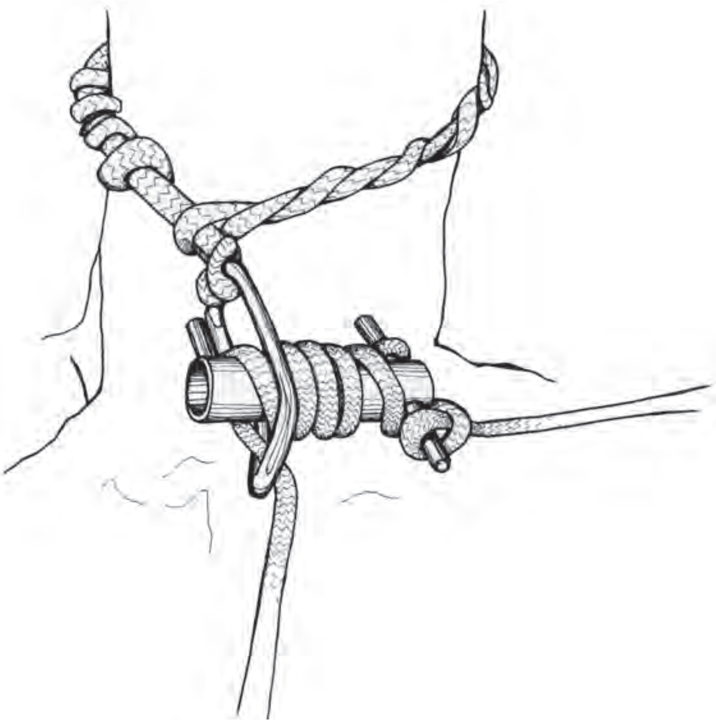


Figure 7–18—A Port-A-Wrap friction lowering device.

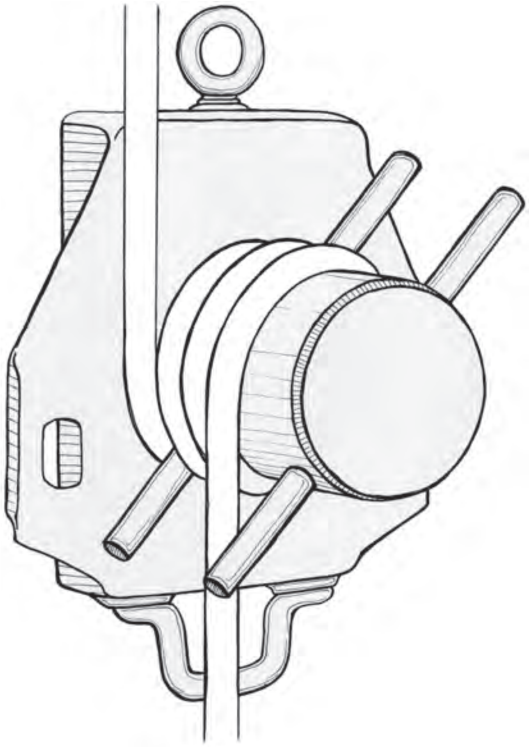


Figure 7–19—A Stein single-bollard lowering device.

Mechanical Braking Devices

Mechanical braking devices come in a variety of styles. They include cam-based winches, drum capstans, and spool winches, some of which have levers, gears, or motors. These devices give riggers a significant mechanical advantage and are designed to slowly lower large loads. They tend to be expensive and heavy, and some lack an overload-protection device to safeguard the mechanical components if you load the system beyond its safe capacity.

Manufacturers originally designed capstan-based belay devices, such as the Good Rigging Control System, for lowering tree limbs during top-down tree removal work. The devices work by anchoring a rope-brake winch to a tree and spooling a fiber rope around the drum on the winch and out fairleads on each side. A hand crank or portable drill spins the spool at either a 22-to-1 or a 44-to-1 mechanical advantage to lower or lift heavy loads.

Hand-powered, cable-pulling machines or other hoists used as a haulback are also considered braking devices. You can feed wire rope out of the hoist by placing the handle onto the lowering lever, allowing the load to move downhill along a skyline or the ground.

In short, most winches and hoists that can pull loads uphill can also lower them downhill. Whether you use a drum-spool machine (like the Lewis winch) powered by a chain saw or a battery-operated vehicle-recovery winch, the concepts remain the same.

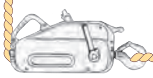
Evaluating Rigging Component Limits

Every rigging component is limited by the amount of force it can withstand before it fails. Understanding and adhering to these limitations is the cornerstone of a safe rigging system. Most rigging components have a rating that is either stamped or noted on a tag, along with an abbreviation for minimum breaking strength (MBS), WLL, or safe working load (SWL).

The MBS represents the lowest force that a new and unused component can withstand before failing in laboratory tests. Applying forces near or equal to a component's MBS is obviously risky. As a result, manufacturers created regulatory standards. The accepted terms are "working load limit" and "safe working load," along with the concept of a safety design factor.

The WLL reflects the manufacturer's recommendation for the maximum weight or force you should apply in any given situation. The safety design factor represents the ratio between the MBS and the WLL. This value is essentially the margin of safety. Manufacturers are free to use any safety design factor they please. As long as the WLL is less than the MBS, the manufacturer is protected, but you may not be.

You must always know the safety design factor before you can evaluate the WLL. According to Occupational Safety and Health Administration (OSHA) 29 CFR, Part 1926.753(e)(2) for multiple-lift rigging work, the industry standard safety design factor is 5 to 1. Most industries recognize a 5-to-1 safety factor as standard; it represents the minimum safety factors that we recommend for any rigging



component. Reliable rigging equipment manufacturers determine the WLL that they stamp on their equipment by using this standard and dividing the MBS by 5. This calculation indicates that the WLL is 20 percent, or one-fifth of the MBS. For example, a ¾-inch clevis may be stamped “WLL 4¾ T,” which means the WLL is 4¾ tons (9,500 pounds). With a safety design factor of 5 to 1, the MBS is 47,500 pounds. Components produced by recognized rigging fabricators include the fabricator’s name and logo, enabling you to research and ensure that the WLL includes a safety design factor of at least 5 to 1.

Be aware that some equipment designed for arborist work, vehicle recovery, and other applications may not have an adequate safety design factor for rigging. Equipment with a WLL but no manufacturer indicated is common. If you cannot verify the safety design factor through the manufacturer, the equipment’s compliance with industry standards is questionable at best.

Determining a safety design factor when using fiber rope is a bit more complicated. The range of common safety design factors is between 5 to 1 and 12 to 1. Considerations for determining a safety design factor include:

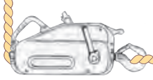
- The condition and history of use for the rope
- The composition of the rope
- The application of use for the rope
- The potential for dynamic loading or abrasion
- Personnel exposure
- The number of knots, splices, or hitches in the rope

Based on our experience, we generally recommend assigning a 10-to-1 safety design factor for fiber ropes. Sometimes, the MBS is the only value listed, so you must assign the desired safety design factor and calculate the WLL. Some fiber and wire ropes do not have a listed rating, so you must refer to the manufacturer for information.

People sometimes use an SWL in place of a WLL. This is most common with hardware store equipment that is not intended for serious rigging applications. Information about the relationship to MBS is usually not available. Additionally, distributors often import this equipment from countries with no testing certification. Most reputable rigging equipment companies avoid the term SWL because it implies that riggers are safe as long as they do not exceed the rating. Be cautious of imported equipment and equipment labeled with an SWL value.

You must know the working load limits and safety factors of the equipment. It is your responsibility to know the rated strengths of every piece of equipment you use, without exception.

Notes



Chapter 8: Rigging Tools

Riggers use a wide variety of tools for setting up and taking down rigging in the backcountry. They constantly introduce and adapt tools designed for various industries to trail rigging applications. This manual cannot cover all these tools, but the following sections describe some of the tools that riggers find most valuable and use most often.

Jacks

Jacks have many applications in rigging work. Riggers most often use them to raise a load and place chains, chokers, or slings. Riggers also use jacks for the final placement of a heavy load (such as a rock or bridge stringers) or on building renovation projects.

Jacks can exert a significant lifting force, but are limited by small contact points with the load (in proportion to the bases of the jacks). They can be wobbly if you do not place them securely. All jacking operations require cribbing and blocking. In our experience, screw-pin jack models are the most secure and reliable, and they are the easiest to operate. These jacks are particularly useful for raising rock slabs.

You can use two bumper jacks to raise large-diameter logs to insert rollers or rigging. With a jack on each side, the ends of the lifting plate bite into the log just below the widest diameter. Two jack operators work simultaneously to raise the log. If the operators must reset the jack, they should place wedges or blocking under the log to retain any height gained.

Some riggers have portable hydraulic wedges available for rock work. This versatile tool, which fire departments use to extricate people from wrecked vehicles, can also handle trail applications. You can extend the hydraulic cylinder using either a power or handpump unit.

You can use nonhydraulic jacks to move a load horizontally in small increments by canting the jack 5 to 10 degrees away from the direction in which you move the load. As the load rises, it also moves horizontally as the jack straightens up. You should know the limitations of a particular jack model and test all models before taking them to the field. Many automotive-type hydraulic jacks do not work in a horizontal position.

> “You should know the limitations of a particular jack model and test all models before taking them to the field.”

Ladders

Riggers use various types of ladders to set rigging blocks in trees. Although you may sometimes use lightweight hunting ladders, orchard ladders, and household extension ladders, we recommend using only industry-approved tree-climbing ladders that have a secure system for tightening around the tree. You must use a harness and adequate fall-arrest protection if you climb a ladder to set rigging blocks (figure 8-1).

Figure 8–1—Riggers using a sectional tree climbing ladder.

Standard Rock or Tree-Climbing Gear

In trail rigging applications, be cautious, deliberate, and very selective when using lightweight equipment designed for backcountry applications, such as rock climbing, arborist work, high-rope courses, and zipline canopy tours. Equipment designed for body weights and light loads are usually underrated for large logs, rocks, and winch-based power sources. Manufacturers of this equipment often list the minimum breaking strength (MBS) instead of the working load limit (WLL) and do not design the parts for industrial use. You can use these lightweight components for tasks such as belaying or hauling loads along a line and raising or lowering rigging components when climbing, or you can use them for applications with body weight limits. We do not recommend subjecting lightweight equipment to the forces created by a hand-powered winch, such as a griphoist.

> “In trail rigging applications, be cautious, deliberate, and selective when using lightweight equipment designed for backcountry applications, such as rock climbing, arborist work, high-rope courses, and zipline canopy tours.”

Line Launchers

Arborist-industry workers primarily use line-launching tools, such as the SherrilTree Big Shot, but these tools can have useful applications in trail rigging projects. You can purchase or make these large, one- or two-person slingshots and can use the slingshots to shoot a small-diameter line either high into a tree or across a canyon. You can then use the small-diameter line to place a larger diameter rope for various rigging applications.

The design of the line-launching tool allows you to mount the slingshot head on (typically) a 6- to 8-foot pole. The slingshot is comprised of elastic made from industrial tubing and a central leather pouch. The pouch holds an 8- to 16-ounce weight attached to 20-pound monofilament fishing line or specially designed lightweight polyethylene line. You can attach a standard (spinning) fishing reel with either an open or closed spool design to the pole, allowing you to easily deliver and retrieve the line.

After you place the weighted line in the desired location, remove the weight from the monofilament or poly line and attach a larger diameter hauling line. Retrieve the original weighted line and consequently pull back the larger diameter hauling line. This hauling line has sufficient strength to pull the wire or synthetic rope high over the tree limb.

Dynamometer

A dynamometer (figure 8–2) measures force. The type of dynamometer used in trail rigging usually has a digital display with holes on either end for a shackled connection. Although this instrument is not necessary to set up rigging, it is an invaluable tool for enhancing safety and providing information. By moving the dynamometer around to different parts of the rigging set, you can clearly see in the display panel the invisible forces that are difficult to assess. You can check to ensure you are not putting unsafe stress on blocks, wire ropes, spars (elevated points of attachment in aerial rigging configurations), and anchors. Dynamometers are useful for measuring dynamic loading and vector forces. You can also use them to test the capacity of griphoists and the griphoist shear pins.

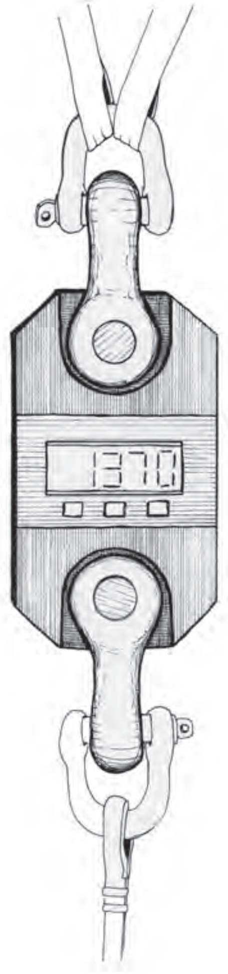


Figure 8–2—A digital dynamometer.

Torque Wrench

We recommend a torque wrench when using cable clamps because we have seen situations where riggers overtightened the nuts on the clamps, which deforms and weakens the wire rope. Inexperienced riggers can mistakenly believe that tighter is better. This is not the case. Consult a wire rope installation table to determine the three pieces of information you need:

- The number of clips to install
- The amount of turn back required
- The amount of torque (foot-pound) required (refer to "Appendix A: Terminating and Managing Wire Rope" for details)

Rock Bar

Most riggers in the field have at least one rock bar or pinch bar for placing slings or chokers on loads. You can use these versatile tools in many ways; they are especially valuable for directing the leading edge over or around obstructions when ground skidding loads. You can lay two or more bars side by side to form a ramp to skid loads up onto something, but make sure that the bars do not bend or slide out of place when you place the load on them.

Peavey and Cant Hooks

Peavey and cant hooks are valuable tools most often associated with ground-skidding logs over rough ground. Both tools contain a long handle with a pivoting hook near the end. The peavey hook has a spike on its end while the cant hook does not. Riggers often use these tools in conjunction with rock bars. The advantage these tools have over rock bars is that you can roll the log rather than prying it over to better align it for skidding. Experienced riggers often use a swivel between the sling and the hauling line to minimize the rotational effects of rolling the logs into a better lead. Another method we have used is to modify a rock bar with a removable peavey hook secured with a setscrew.

Safety Seizing Material

You should have a variety of seizing materials on all rigging sites. Such materials include small-diameter soft wire for seizing wire rope or for providing safety latches for hooks. We also recommend using various sizes of nylon ties to secure screw-pin shackles. These shackles are quicker to install than wire.

Stone Boat

Some riggers say that the stone boat (figure 8–3) is the pickup truck of yesteryear. A stone boat is any platform constructed to drag a heavy load across the ground. You can make the platform onsite using native materials or can construct it beforehand using timbers and planks. Many riggers have constructed platforms using the inverted hood of an old automobile or a heating oil tank cut in half because the metal glides easily over the ground. Constructed with low sides, a stone boat allows you to roll heavy rocks onto the low platform or to easily transport fill material or gravel.

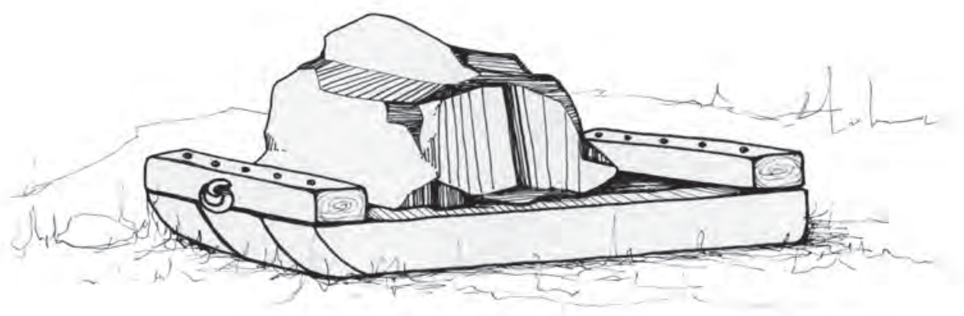


Figure 8–3—A stone boat.

Chapter 9: Basic Rigging Theory

Loads can be rocks, logs, or materials that you slide, roll, or lift. The weight and dimensions of loads are important. "Appendix C: Material Weights" provides values for estimating load weights based on material and approximate dimensions. Forces that you cannot see have a magnitude and a direction that you must carefully consider. Understanding the direction of the force is as important as understanding the amount of the force. "Appendix D: The Effects of Angle on Forces" summarizes the practical effects of the various forces encountered in common rigging systems, and "Appendix E: Calculating Force Vectors and Line Tension" provides information about the precise mathematical calculation of forces.

We can attribute a few basic concepts about forces to Isaac Newton's laws of motion. Newton's first law (often referred to as the "law of inertia") states, "an object at rest stays at rest and an object in motion stays in motion with the same speed and in the same direction unless acted upon by an unbalanced force." For example, when moving a log, you must overcome the static friction between the log and the ground before you can move the log. When you apply enough force to begin moving the log, the log tends to keep moving according to the law of inertia. Although the log "wants" to keep moving, friction between the log and the ground typically produces a greater force than the log's acceleration energy, causing the log to stop. Kinetic friction (friction produced when an object is moving) is always less than static friction when an object is at rest.

The application of Newton's first law demonstrates that, after a log begins to move, it requires less energy to keep moving. This principle is especially important when using stock animals to move logs. The animal requires a lot of energy to begin moving a log, but because kinetic friction is less than static friction, the animal does not need to continue exerting the same amount of energy to keep the log moving.

Newton's third law states, "for every action, there is an equal and opposite reaction." In terms of rigging, this means that when an equal but opposite force acts on two objects, the object with less mass is the one that moves. A force that acts on a mass produces acceleration. The greater the mass of the object you're accelerating, the greater the amount of force you need to accelerate the object. For example, if you anchor a lever-operated hoist to a pickup truck and try to skid a large log, the truck will move, not the log. However, if you make a direct, solid anchor to the earth or anchor the truck, the log will move. In other words, it is critical that any fixed anchor must be able to withstand more force than the object you move.

Static Loading, Dynamic Loading, and Shock Loading

The static load is the weight and force that a load at rest exerts on a system. Dynamic loading occurs when a load speeds up, slows down, or is in a steady state of movement. Dynamic loading puts more force on a system's components than static loading. Typical dynamic loading adds an additional 10 to 30 percent of the static load to the rigging components.

Shock loading occurs when a load's acceleration suddenly increases and tension in the rigging system brings the load to an abrupt halt (i.e., all the slack in the line is suddenly removed). This sudden jarring can cause equipment to fail and can be catastrophic. Shock loading can increase the tension on a system by 2 to 100 times the static load weight. Make every effort to prevent a shock load by ensuring a smooth application of power or braking.

Friction

Frictional force is inherent in every rigging system. Friction is opposition (resistance) to movement between two objects. When you ground-skid a log, the interaction between the irregular surface of the log and the ground inhibits movement. The amount of friction between the log and the ground depends on how smoothly the log slides over the ground. You can manage friction in a variety of ways. For example, you can reduce friction by either constructing or buying cones or angle plates to go over the leading end of a log. You can also shape the lead end of a log to a point (figure 9–1), cut the limbs flush, and peel the bark to enable the log to ride over minor obstructions more easily. A log skidding over wet grass will not encounter the same resistance as a log skidding over disturbed soil. Skidding over riverbed gravel reduces friction because the gravel acts like ball bearings.

Using a sled or stone boat can also help reduce ground resistance. Sleds with two runners work well on hard dirt, grass, or hard-packed snow. There is less ground resistance when the weight of a load rests on two runners, but sleds require firm surfaces. For uneven or soft surfaces, construct stone boats out of a solid piece of wood or metal with turned-up leading edges. Because sleds and stone boats are low to the ground, you can easily roll loads onto them.

Figure 9–1—A pointed log provides better efficiency in direct-pull ground-skidding.

Mechanical Advantage and Simple Devices

The simple devices riggers most often use to gain mechanical advantage are the inclined plane, the lever, and the pulley.

> “Riggers use mechanical advantage to minimize the force required to accomplish work.”

Work may be defined as force multiplied by distance traveled, or:

Work (*W*) = force (*F*) times distance (*D*).

You cannot often change the amount of work you must do, but at any given time, you can minimize the force you have to apply with your body. Riggers use mechanical advantage (figure 9–2) to minimize the force required to accomplish work. Mechanical advantage can be defined as the ratio of force produced by a simple machine versus the force applied to the machine. The tradeoff is that you must exert the reduced force over a greater distance.

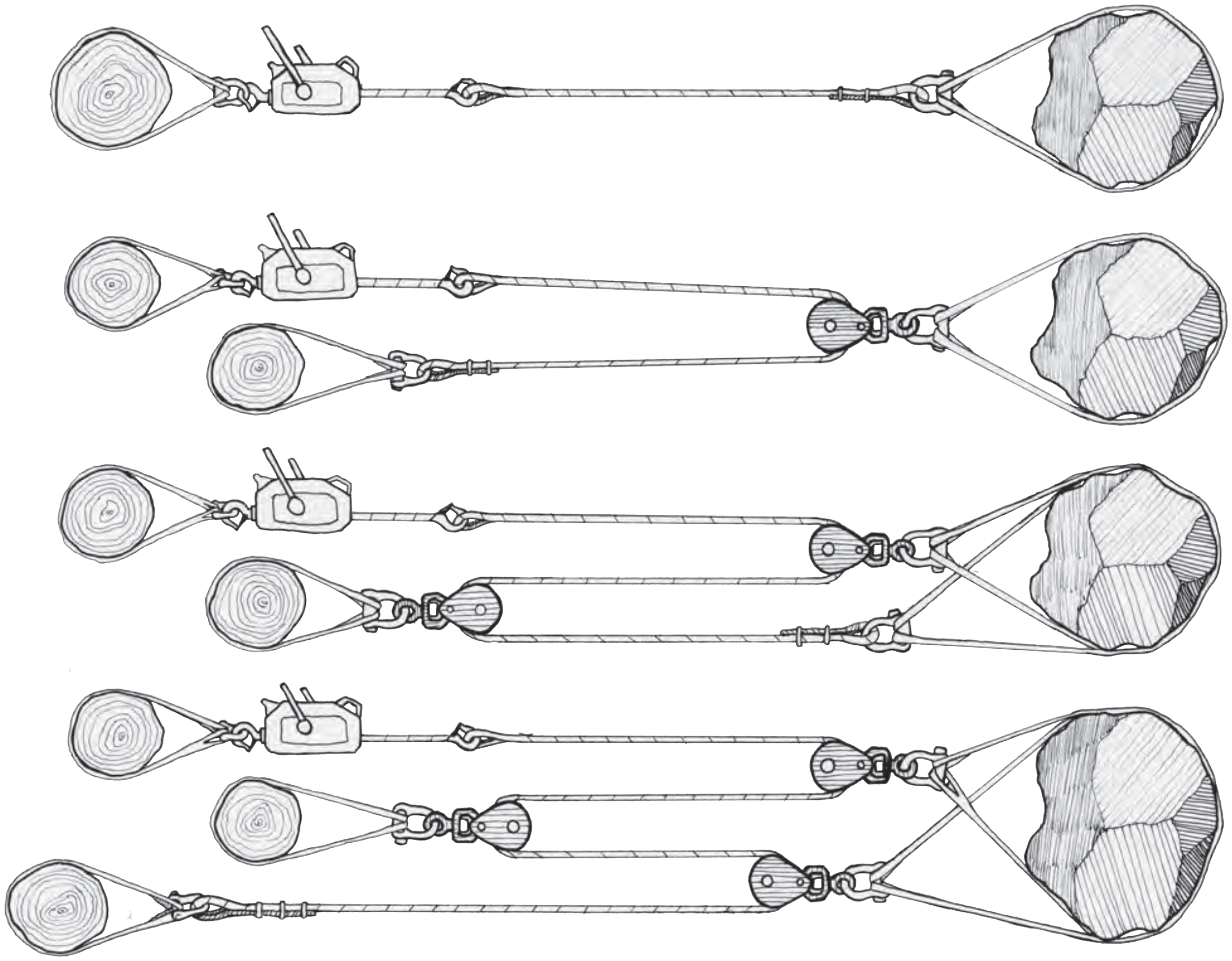


Figure 9–2—Mechanical advantage using blocks.

Inclined Plane

Riggers often use ramps of soil, rock, logs, and timbers to move heavy objects (figure 9–3). If you rig an object properly, skidding it up an inclined plane takes less force than lifting it vertically. The gentler the slope, the less force it takes to move the object. However, the object must travel a greater distance, and you will likely need to provide some type of cribbing under the ramp to support the weight of the load.

Screw jacks and wedges are other examples of inclined planes.

Lever

A lever is any rigid bar or pole that crosses over and is supported by a fulcrum point. Typically, for trail work, rock bars function as levers. Another example of a lever is the operating handle of a griphoist. Moving the handle, which operates as a lever, through a 30-inch arc (pull) moves the cable 1 inch through the griphoist, giving a mechanical advantage of 30 to 1. The general rule for levers is, the longer the better.

Pulley

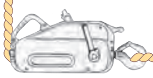
Riggers use pulleys in a rigging system to achieve mechanical advantage by connecting the pulleys to the moving load. The line from the power source goes through the pulley and back to an anchor. The resulting change of direction also changes the distance variable of $W = FD$, thus multiplying the force applied.

Moving Materials: Dragging, Rolling, Lifting, Pushing, and Pivoting

Riggers require a variety of techniques to move things from where they find them to where they need them. Pushing is often easier than pulling. The first step in moving an object is finding its center of gravity. After an object's center of gravity begins to move, it wants to continue moving (Newton's first law). Experience teaches you how best to locate the center of gravity, how to get it moving, and how to keep it moving in a controlled manner. This task often involves a combination of pushing, pulling, pivoting, lifting, and most importantly, communicating.

Skidding can be slow, generate significant friction, and create ground disturbance, but it is generally safer than other techniques. Rolling a heavy object is often faster than skidding, but it introduces greater potential for uncontrolled movement, which can result in equipment damage and compromised safety. Anyone who has seen a rock careening down a hillside can attest to this. Lifting by hand or with rigging can be the fastest technique with the least impact, but it often poses the greatest potential risk. The hazards in aerial rigging systems compound with the forces and angles created. When lifting and carrying by hand, the danger of slipping on the terrain or straining your body is always present. When it comes down to it, the best method for moving materials in a given situation is the one that requires the least effort and provides the best results with all safety factors considered.

> “Give me a lever long enough and a place to stand and I will move the world.”
>
> —Archimedes



After you determine an object's center of gravity (i.e., the balance point), if you can roll the object off the ground onto a fulcrum (e.g., a rock or small log) you can easily rotate the object in any direction. After moving the object onto a fulcrum, even if you have misjudged the balance point, downward pressure on the elevated end should still enable you to rotate the object.

You can easily rotate extremely heavy loads, such as long bridge stringers or boulders, around a balance point. Another method for moving a long log laterally is to alternately pivot one end and then the other. Riggers who learn how to use the principles of pivoting to their advantage are well on their way to working efficiently.

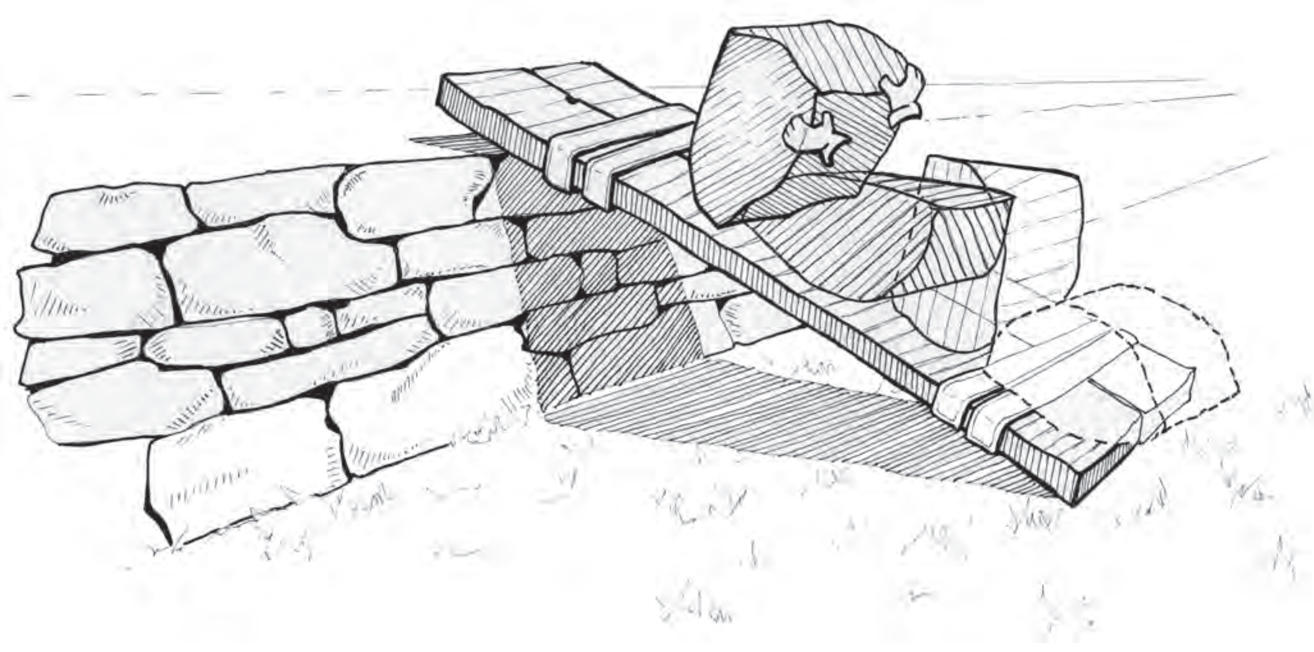


Figure 9–3—Rolling a rock up a ramp.

Notes

Chapter 10: Project Planning

This chapter focuses on basic backcountry rigging applications and on questions to address before using rigging at a worksite. Chapters 10 through 14 of this manual provide detailed descriptions of rigging systems and more complex applications.

Analysis is the first step in any rigging project. Trail settings can vary from an open, rocky alpine area with few anchors to a heavily forested location of deep soil in a fragile riparian area. Regardless of the setting or task, planning proper rigging techniques for the specific setting can increase efficiency, minimize resource damage, and maximize worker safety. For a rigging system to be practical, the advantages, such as reduced environmental impacts and the ability to move heavy objects, must outweigh the disadvantages, such as gear weight and time lost in setting up systems. During the site visit, you must answer some questions before deciding to use rigging systems. Although knowledgeable personnel can answer some questions offsite, there is no substitution for an actual site survey.

The Decision-Making Process: When to Use a Rigging System

You must consider many things during the planning process, but the first question you must answer is whether the time, effort, and materials required for a rigging system are justified. Other questions include:

- Can you do the work easily and safely without rigging?
- Will the use of rigging increase or decrease overall worker safety?
- Will the use of rigging increase or decrease overall project efficiency?
- How many systems will you require, and how complicated will they be?
- Is the project constrained to the use of only nonmotorized tools, as in a designated wilderness area?
- How far is the worksite from a trailhead?
- What is the approximate weight of the required rigging gear?
- How will you transport the rigging gear?
- How long will you use the rigging system?
- Who will be part of the crew, and how much rigging training will they require?
- Will using a rigging system provide a training opportunity?
- Is someone in the crew trained and qualified to lead the rigging operation?

After you decide to use rigging, you must answer additional questions to determine general system requirements. The answers to these additional questions establish the parameters for selecting the final rigging system. These questions may include:

- What types of materials are you moving?
- How heavy are the materials you are transporting?
- How far must you move the materials?
- Are you using the rigging system to move materials uphill or downhill?
- Will you use the rigging system repeatedly or only once?
- What is the terrain like?
- Is the terrain suitable for ground-skidding?
- Are suitable anchors available?
- Can you hang enough blocks to gain adequate slope for wire ropes?
- Can you set blocks from the ground or will you require ladders or climbing?
- Will you require a separate braking system to provide precise control of movement?
- What resource issues will you need to mitigate?
- What special skills will you require that are not part of your regular crew, such as climbing or sawing?

Most rigging systems can support a broad range of applications, but you should consider the factors in the following sections during the decision-making process.

Safety

Safety takes precedence over all other aspects of a rigging project. You must understand the effects of all forces generated by the load and ensure that each component in the system is designed to handle those forces. There may be more than one safe method to accomplish the project. Whenever possible, select the rigging system with the least risk. This manual stresses the importance of safety and appropriate safety measures throughout.

Rigging safety has four aspects:

- Ensuring that all components are in good working condition (not damaged)
- Ensuring that all components in the system are not loaded beyond their safe working capacity (WLL, covered in detail in "Chapter 6: Winches and Hoists")
- Assuming that any component can fail at any time
- Ensuring that everyone is located in a safe spot if anything goes wrong

Topography

The shape of the land may be an important factor in deciding which system to use. You may use a different setup for aerial systems, depending on whether you are moving the loads across a slope, uphill, or downhill. For ground-skidding, consistent slopes with few obstacles help prevent the load from hanging up and causing a potential shock load. For horse-skidding, gradual slopes are the most favorable because they provide the least jarring force on the animal.

Vegetation

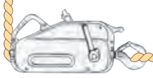
The availability of adequately sized trees from which you may hang blocks often dictates the type of system you can use. Although you can set up a tripod or A-frame, these structures take additional time and materials to assemble. You can often set up systems using only small trees and multiple anchors. Ground-skidding a load may be appropriate when numerous large trees or significant brush make directional changes a challenge. Using aerial systems can be difficult if it is hard to get a straight cableway with adequate sag, particularly in areas of dense growth.

Ground Surface and Soil Type

The friction resulting from the ground surface and soil type is an important consideration in ground-skidding. Soil type also greatly affects the holding capacity of anchors, guys, and spars. Riggers sometimes skid large logs over frozen ground or snow to reduce friction.

A Ground-Skidding System Versus an Aerial System

Aerial systems, although often more efficient than ground-skidding systems, take longer to set up and involve more equipment. They can also generate greater forces that are not immediately obvious. The main factor for you to consider is whether you have adequate anchors in place to handle the higher forces generated by an aerial system. This factor is particularly relevant when a lack of significant sag exists in the line that supports the load (refer to "Chapter 9: Basic Rigging Theory," "Appendix D: The Effects of Angles on Forces," and "Appendix E: Calculating Force Vectors and Line Tension"). Moving heavy loads by full aerial suspension requires large, tall trees that enable you to set blocks and other rigging off the ground. Areas without tall trees may require you to haul in a prefabricated tripod or construct an A-frame with onsite materials.



Laying Out a Proposed System

As you develop a plan of action, it is important to physically lay out the system in the field and draw a sketch of the system showing the distances and locations of the features in the list below. Creating a detailed drawing that indicates individual pieces of equipment required at each location is also helpful. You can use this information to develop a detailed list of equipment to take to the site. For example:

- Anchors
- Block locations
- Braking system locations
- Guy lines
- Loading and unloading zones
- Power source locations
- Spars

Mark the listed features in the field so you can find them when you begin the actual rigging setup. Mark trees or vegetation you may need to cut. We recommend that you not cut any trees until you lay out the ropes; you may not need to remove some trees. You can protect “rub trees” (where the rope touches a tree but the rope’s direction changes only a few degrees) against chafing instead of removing the trees. Laying out with small-diameter rope helps you determine the approximate rope lengths required for each component and identifies what trees or vegetation you must cut. A 300-foot measuring tape on a reel works well for this function.

To help other resource specialists do their assessment or mitigation work, flag areas that they must not disturb.

Before setting a standing skyline, we recommend laying out the system using a small-diameter rope weighted by a free sliding block to locate the low point. You can obtain the most favorable anchors and skyline length by walking each end of the rope to potential anchor points. Although it is more important to use this approach with a standing skyline, you can use the same procedure for any rigging layout. Tie a knot in the small-diameter line and measure it to determine how much skyline you require on the project.

Make an equipment list that includes the numbers, sizes, lengths, etc., of all components (figure 10–1). This master list will be the minimum picking and packing list when you assemble the equipment to transport to the site. Always include extra anchor straps, clevises, and blocks on the list.

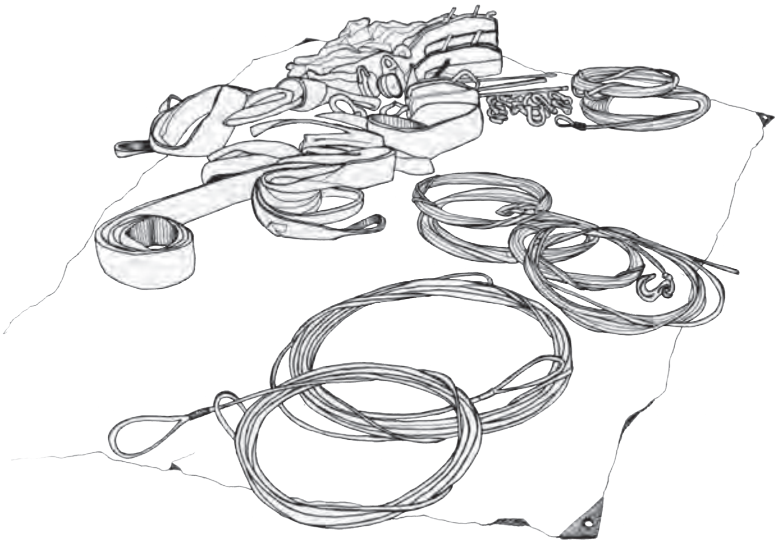
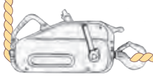


Figure 10–1 — Rigging project equipment laid out.

Notes



Chapter 11: Setting Anchors and Spars

Anchoring secures components in the rigging system to immovable objects. Anchors can be natural features (e.g., trees or rocks) or manmade (e.g., pickets, deadmen, or soil anchors). Because anchors can be subject to extreme loading, it is imperative that you carefully select and place anchor materials. From a safety perspective, the most important anchor is the one immediately behind the rigger operating the power source. If this anchor fails, the rigging components could project forward violently, potentially striking the rigger. For this anchor, always use the best and newest rigging components onsite.

Monitor all anchor systems, especially if the anchor appears to be small or conditions such as moisture-saturated soils are present. One easy way to monitor the movement of an anchor is to set up a stringline immediately in front of (but not touching) the anchor, perpendicular to the pulling force. When monitoring trees used as anchors, attach the ends of the string to stakes outside the root ball area. As you place the load on the anchor, any forward movement of the anchor will touch the string, indicating a weak anchor. In this case, you must reinforce the anchor.

Natural Anchors

The most common type of anchor used in trail rigging is a sound, live tree with sufficient diameter to handle a load. You may use sound stumps if you take precautions, such as chopping through any remaining bark to the wood. The groove through the chopped bark provides a place for the anchor cable to rest and prevents it from riding up and slipping off the stump. Chopping through the bark also enables you to examine the sapwood and determine how much the stump has deteriorated.

Whether using live trees or stumps, several factors affect an anchor's holding power. These factors include the soil type, soil moisture, soil density, and the steepness of the slope. Calculating an anchor's holding power can be difficult, but these guidelines can assist with the evaluation:

- The holding power is proportional to the square of the tree or stump diameter. In other words, a 32-inch-diameter tree is not twice as strong as a 16-inch tree, but is instead four times as strong.
- The holding power increases with soil depth and soil density.
- The soil's holding power decreases as its moisture content increases.
- The holding power of a stump or tree is stronger on an uphill pull. The roots on the uphill side are under tension (making them stronger), whereas the roots on the downhill side are under compression (making them weaker). Be aware that tree species have different root depths; some are shallow and some are deep.

Rocks

You may use rocks for anchors if the rocks are sufficiently heavy and dense. Keep in mind that even large boulders can move or pivot. To use a rock as an anchor, the rock must weigh more than the load it anchors after accounting for the significant additional force that the rigging configuration creates.

> “Because anchors can be subject to extreme loading, it is imperative that you carefully select and place anchor materials.”

Multiple Anchors

Multiple anchor configurations can consist of a combination of natural anchor points (trees, rocks), or wood or metal pickets driven into the ground. Use multiple anchors to anchor the end of a line or power source if one anchor is inadequate. Extending the line of force directly behind an anchor and securing it to a second anchor point is the simplest multiple-anchor configuration. Anchoring straight back is ideal, but anchoring up to a 15-degree angle from one side to another is acceptable (figure 11–1).

Keep the line between anchors tight. You can accomplish this by using grips and a power source and by securing the cable with cable clamps. Some riggers use chain and a ratchet chain binder to take up the slack. In the case of pickets, drive them into the ground at a 15-degree angle from the vertical and incline them away from the direction of pull. Riggers attach lines between pickets high on the front picket and near the ground on the succeeding picket, and often tighten the line using a stick for a windlass. If there is no backup anchor within 15 degrees horizontally of a fixed anchor or a soil anchor, you must set a deadman.

Figure 11–1—A line with multiple anchors terminating at a bridle block.

Distribute the load by tightening the line between the two anchors. You can also secure secondary anchors to a horizontal log placed behind two trees or rocks that are perpendicular to the line force.

You will often have to position or anchor a line in a location with no convenient attachment point. In this case, use two slings to bridge the space between anchor trees, and use a clevis to connect the two slings as a final anchor point. Changing the length of the slings changes the location of the anchor point. This system does not distribute the force equally on the anchors.

Rigging Spar Trees

Most aerial rigging systems require you to use spars, A-frames, or tripods to gain the vertical height necessary for lifting loads or transporting materials. You must understand how to rig spar trees so that bending stress failure does not pull the tree over. When you hang a block high in a tree, A-frame, or tripod, two distinct forces act on the block: lateral (horizontal) and longitudinal or compressive (vertical). Most spars can take a much higher compressive load than a bending load. In other words, it is a lot harder to break or uproot a tree by pulling it straight down than by pulling it sideways. Additionally, the higher up in a tree you hang a block, the more likely the resultant increased leverage will fracture or uproot the tree by pulling it laterally. Therefore, it is important to configure rigging systems in a more or less straight line so that the forces applied to a spar tree are primarily downward.

Spar Tree Selection

Requirements for a spar tree depend on several variables:

- The proximity of the spar tree to an intended skyline
- The height and width of available trees
- The tree species; some trees are more resilient to the stresses created by rigging systems
- The required deflection, which depends on the tree height and the availability of a suitable location for you to place the upper blocks and guys
- The overall tree condition; spar trees must be free of defects
- The maximum weight and size of the loads you expect to lift

Look for the best tree in the best position. This can mean extending the skyline back several hundred feet. After you determine the spar tree, you are ready to rig the tree.

Climbing

Setting spars (figure 11–2) generally requires climbing. Working up in trees is mentally and physically demanding. You must be flexible and have significant upper body and leg strength. This manual does not go into detail about the various techniques for climbing trees to set spar blocks. Refer to the "Forest Service Washington Office National Tree Climbing Program" <https://www.fs.usda.gov/treeclimbing/training.shtml> website for equipment specifications and training requirements.

Setting Spar Blocks

Regardless of the technique you use to climb to set a spar block, bring enough gear (a lightweight sling, a lightweight block, and a small-diameter rope that is at least twice as long as the height of the spar) up the tree to set up a tagline.

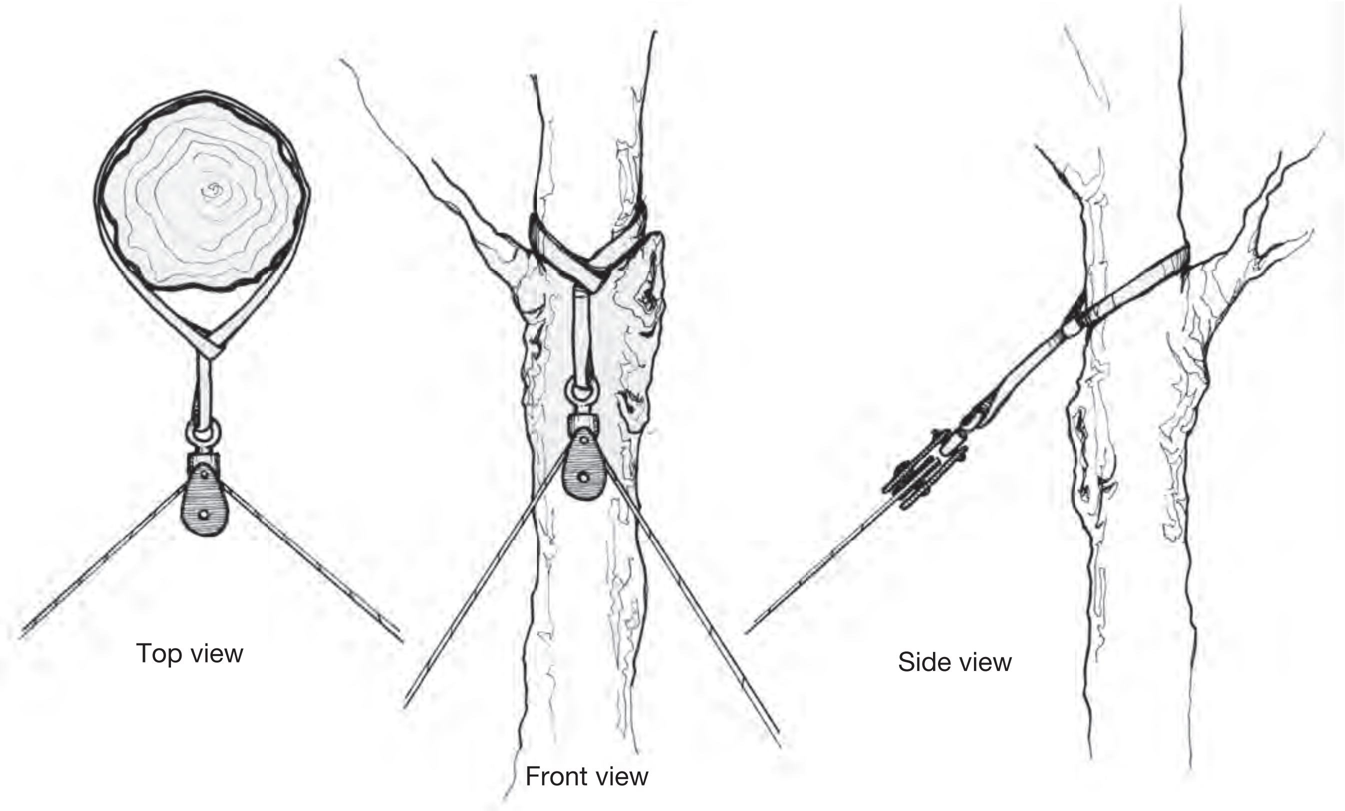


Figure 11–2—Three views of a spar block.

After you reach the location to set the spar block, wrap the sling around the tree, connect the lightweight block to the sling, and run the rope through the block to the ground. A person on the ground can use this tagline to send up any gear you need to set the spar.

When you set a spar block, you usually set the sling in a choker hitch configuration to prevent it from sliding down the bole of the tree. Set the sling in a "P" orientation so that the choked sling does not bend back on itself too tightly, yet still stays secure. Ensure that the block connects to the sling on the correct side of the tree so that the wire rope runs linearly and does not rub on the trunk. Cut flush (to the branch collar) any branches on the spar tree that might interfere with any part of the rigging.

There will be times when you cannot find a suitable spar tree in the proper location to create the desired downward force on the tree. In this case, add guy lines to a side-loaded spar, raise a spar tree by hand, set up a tripod or an A-frame, or use a block on a separate skyline as a spar.

The stem of the best spar tree in the area often is not ideally located with the rest of the configuration. For example, large, sprawling, deciduous trees may have a large limb that could be a spar, but you cannot use the stem. Sometimes, by necessity, riggers must hang rigging on large limbs. You may have the option of rigging a limb on the offside of a tree so the rigging system will apply an inward force toward the base of the tree instead of away from it. Deciduous trees often require tiebacks to mitigate the oblique shear that can potentially tear the limb laterally from the tree. Rig limbs as close to the trunk as possible. Only use this technique on large, healthy limbs when no other option exists, the tiebacks are thorough, and you have extensive experience in assessing tree bole and limb strength.

Tiebacks

Use tiebacks to strengthen a rigged tree at the points where blocks or other components exert force. The most effective tieback is directly opposite the force created by a block. Unlike with guy lines, you do not anchor a tieback to the ground, but rather to a sound location in another tree or on the opposite side of the same tree. Riggers typically use tiebacks when they place a block on the limb of a spreading deciduous tree that has some weak characteristics, but is in an otherwise ideal location for placing a block. Using a tieback to another sound limb or tree, you can reinforce conditions such as a weak, Y-shaped limb crotch. Because the tieback must be tight to be effective, some riggers find that using large turnbuckles, ratchet chain binders, or heavy-duty ratchet straps provides the most convenient placement method.

Setting Guy Lines

Set guy lines on a spar tree to reinforce the tree and reduce stress on it. Sometimes the spar tree does not align directly with the anchors on another spar tree, giving the spar tree a dangerous lateral pull that can cause the tree to snap or uproot.

Regardless of why you might need to use a guy line, the fundamentals remain the same: the guy line must oppose the lateral force applied to the spar tree. You must understand the direction in which forces will pull the spar. Set the guy lines 180 degrees (or straight back) from that direction. If estimating the direction of the lateral force is difficult, use two guy lines. If you use guy lines to keep a tree from buckling, set the guy lines at about the same height as the spar block.

You can set guy lines in a variety of ways using wire rope, slings, or chain, and can tension the lines with a hoist or chain binder.

If the forces are not too great, you can also use highly rated ratchet straps, such as the straps designed for securing cargo on trucks. Ensure that the guy line components and anchors are rated highly enough to handle the load placed on them. The more guy lines you use, the stronger the spar will be.

Raising a Spar Tree

If you can't find an appropriate spar tree in the location where you need it, you can cut a suitable tree from one location and place it at an ideal spar location. You cut a hole or depression to receive the lower end of the tree and attach the guy lines and the spar block (through which you will place the skyline) to the spar before you raise it. Place a short log under the lifting line at an angle leaning away from the power source, and raise the spar by tipping it vertically. Pivot the spar by anchoring the lower end so it cannot skid toward the power source. Locate the power source at a sufficient distance and angle to protect it in case you lose control of the spar as you raise it.

The log under the lifting line provides lift to the top of the spar rather than sliding the log toward the winch. The top of the spar lifts and the lifting log rotates and rises vertically as you shorten the lines. By the time the lifting log drops away, the spar is at a sufficient angle for you to slip the base of the spar into the hole.

Before raising the spar, estimate the length and temporarily anchor the two guy lines that oppose the direction from which you are raising the spar. Determine the length of the guy lines by finding the length of the hypotenuse of the right triangle created by the height of the guy lines on the spar and the length of the anchor tree away from the base of the spar. If necessary, readjust the forward guy lines when you set the final guy lines on the spar. Set the forward lines temporarily to avoid raising the spar too far vertically and having it fall over backward.

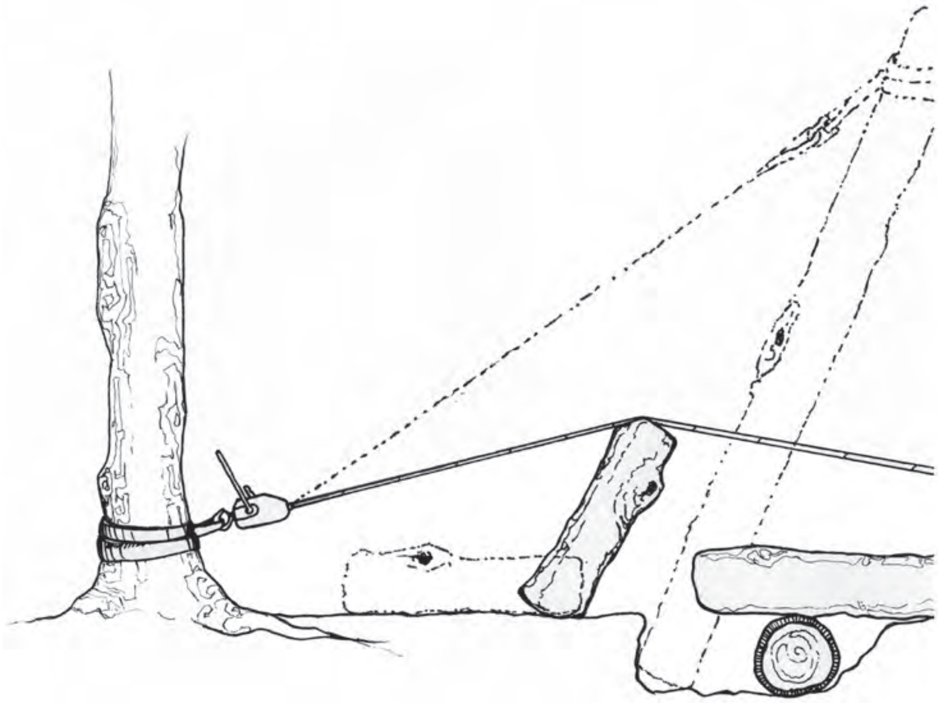


Figure 11–3—Raising a spar pole.

After the base of the spar is in the hole, set the back guy lines with the spar standing vertically. Never handle the guy lines or taglines while raising the spar. If you need a directional force to align the spar, place a grip on an appropriate guy line and hook it to another power source to provide the necessary directional correction.

Raising an A-frame

You usually construct an A-frame using three logs to form a triangle (figure 11–4). Fasten the base, horizontal log to the two angled upright poles, and use cable to wrap the log and poles tightly together. Lay the upright poles over the top of each end of the base log, and notch the poles for a better fit. Also, notch the logs to accept the cable, and use staples to secure the cable in place.

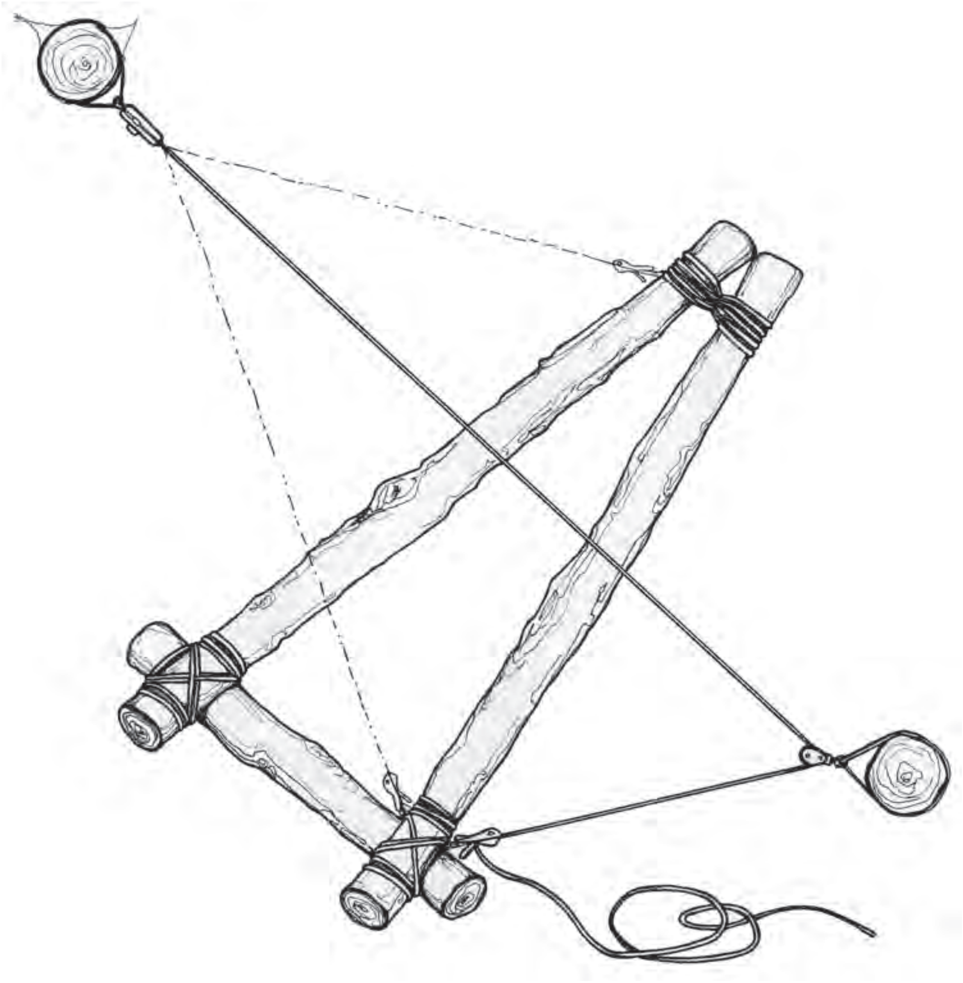


Figure 11–4—Wire ropes tightened with a gripper and secured with log staples to form an A-frame.

Because you set the upright poles of the A-frame at an angle, you only require two guy lines. Secure the guy lines to anchors after you raise the A-frame into the proper position. Similar to preparing a spar tree, use the technique described in the "Raising a Spar Tree" section in this chapter to rig the guy lines and blocks before raising them. Anchor each end of the base log of the A-frame in the opposite direction from the power source so you can pivot the A-frame as you raise it. Some riggers prefer an A-frame to a tripod if good, pole-sized logs are available onsite. A-frames can provide greater heights than a tripod and are a good alternative when stock animals are not available to transport tripod components.

Setting Tripods

Tripods work similarly to A-frames, but you construct them from steel tubing and welded steel plates. The parts are designed to break down for easier transport into the backcountry. You can assemble and adjust them using only hitch and cotter pins. The three steel legs fit into a top plate that has an eyebolt from which you hang a block. Although tripods are easy to set up, be careful when placing them because the tripods can tip over quickly if pulled to the side. Assemble the tripod (see figure 1–1) on the ground with the legs splayed out, near the location where you expect to place it. Remember to hang the block with the wire rope through it before lifting the tripod. With a rigger on each leg, carefully raise the tripod by pulling on one leg and pushing on the other two. Adjust the lengths of the legs according to the terrain so that the top plate is level and the legs all run at similar angles. Then, encircle the legs with a chain to keep them from spreading. If you set up the tripod on bedrock or ledge rock, you may drill pins to hold the legs in place.

When the setup is complete, tension the line slowly, keeping everyone at a safe distance. Adjust the location of the tripod, if necessary, so that it will not tip. If the block is not perfectly vertical, change the position of the tripod until it is. Ensure that the system is under full tension before attaching a load. For detailed drawings of the Forest Service specifications for a portable 6-foot tripod, please contact the National Technology and Development Program (NTDP). For more detailed information about tripod setup and use, refer to the NTDP publication "Portable Backcountry Rigging Tripod" (0523–2341–MTDC) <https://fsweb.wo.fs.fed.us/ntdp/products/0523-2341p>.

Some companies now manufacture lightweight, aluminum tripods that can telescope to a height of 16 feet. These tripods are gaining popularity with riggers working in remote alpine environments.

Setting a Spar Block with a Separate Skyline

You can use another method to place a spar block exactly where you need it when a tree, an A-frame, or a tripod is unavailable. If the number of trees is sufficient to construct skylines, construct two. Set up a second, separate skyline that runs more or less perpendicular to the main rigging configuration. You can hang the spar block for the main configuration from the travel block on the second skyline. The two configurations form a cross (or "T"). Tensioning the second skyline raises the spar for the main skyline. You can sometimes set the spar blocks at both ends of the main skyline, erecting three separate skylines that form an "H." The "H" configuration enables you to precisely set each spar, which can be useful for operations such as setting bridge stringers in place. These arrangements obviously require a lot of equipment and numerous spar and anchor trees. You would generally use these arrangements not because of a lack of trees, but because the trees are not in the right locations for the needs of the project.

Notes

Chapter 12: Rigging System Considerations and Inspection

A rigging system is composed of various individual components that work together to accomplish a specific purpose. You can use several systems within the entire rigging layout. The major activities commonly used in trail rigging applications are hauling, lifting, anchoring, guying, braking, and positioning. Within each of these activities, you can employ several different methods. This manual does not attempt to describe the seemingly endless variety of actual configurations you may construct because all worksites and equipment caches are different.

Because any component could fail if enough stress is placed on it, you must design a system that can accomplish the work within the WLL of all the components, including the identified “weak link.” The weak link is best located within the power source and is usually in the form of a shear pin. The term “shear pin” refers to any easily replaced part designed to break in order to protect the tool from damage. Many cable pullers and chain saw winches contain a shear pin. Engineers designing a tool for delivering power conduct tests to certify that the tool’s shear pin will fail when a certain amount of force is applied to it. Taking mechanical advantage and load angles into account, you must ensure that any potential forces exerted on every component of the rigging system are within the component’s WLL. When a shear pin fails, you know that you have reached the maximum amount of force you can apply to the system in that orientation. In order for work to continue, you must somehow change the system orientation.

In our experience, the shear pins on griphoists shear at significantly different forces, depending on the machine. Most griphoists shear the pin between 125 and 175 percent of the pin’s stated rating. In some instances, the pin does not shear until the hoist reaches 200 percent of the pin’s rating. For example, a T-516 griphoist rated at 4,000 pounds will most likely shear its pin between 5,000 and 7,000 pounds when new but can sometimes reach close to 8,000 pounds of tension before shearing. A T-508 griphoist rated at 2,000 pounds will usually shear its pin between 2,500 and 3,000 pounds but can sometimes reach close to 4,000 pounds of tension before shearing. So what steps should you follow to maintain confidence while operating within the working load limit (WLL)? First, we recommend using a dynamometer to test all power sources annually. Because each hoist is different, it is important to know (and label) the rating at which the pin shears for each machine. We also recommend that each potential hoist operator pull on the tensioning lever when the hoist is about at its maximum rating but before the pin shears. After each hoist operator gets a good feel for how difficult it is to move the handle when a 2,000-pound hoist is at 2,000 pounds of tension and a 4,000-pound hoist is at 4,000 pounds of tension, the operator can simply stop pulling at that point when operating the lever in the field. This practice keeps hoist operators from shearing pins repeatedly and tensioning rigging components beyond their WLL.

While you do not design a system thinking that the shear pin will fail, you also need not fear this outcome under the controlled condition of a shear pin failure. On the other hand, never get lulled into a sense of complacency by confusing the griphoist capacity rating with the actual force needed to shear the pin.

The tool delivering power should be able to hold the load under tension even when the shear pin fails. This redundancy prevents the load from dropping or from shock loading the system. To protect the integrity of the system, only use shear pins that the manufacturer has approved. Under no circumstances should you use any other materials—even materials with the same dimensions—than the replacement

pins. For trail rigging work, we recommend using only power sources with shear pins.

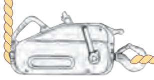
Inspecting a Rigging System

After you set up a rigging system, but before fully tensioning it, inspect each system component. You usually tension lines to the point where the lines run straight and are possibly pulled into the air, but where there is still significant deflection in the lines. This makes it easy to check the corridor for obstructions and to see the direction of the forces on each component without having enough tension in the system to create a fly zone or dangerous place to stand. A branch or other object may obstruct the line from lifting. If this happens, reduce the tension and free the line from its obstruction before continuing the operation.

Do not move or lift any loads until you perform a complete visual inspection and test-load the system. During the visual inspection, walk along the entire system from the power source to the anchor and back. During the inspection from the power source to the anchor, focus on the big picture—environmental and human hazards, system requirements, general working areas, the corridor of travel, loads to move, and the system of communication—and identify any necessary changes. During the inspection back from the anchor to the power source, focus on specific working zones, the individual components and the forces they will take during the rigging operation, and the delineation of fly zones.

As you walk the system for the first time, the big picture questions include:

- What potential environmental hazards (if any) exist near the system?
    - Hazards include snags with hanging limbs overhead, difficult terrain, fast-moving water, drop offs, high winds, rain, and poisonous plants.
    - After identifying the hazards, discuss how best to mitigate them.
- What potential human hazards (if any) exist near the system?
    - Having trail users walk up to or under the system when it is under tension.
    - Having inexperienced riggers assist with operating the system.
    - After identifying the hazards, discuss the best-techniques for mitigating them.
- How is the system set up to enable you to move the loads from their current location to the location where you want them?
    - If the loads are not within the loading zone of the rigging system, discuss how to move them to the loading zone.
    - If you must move the loads from the unloading zone, discuss the process for safely moving them.
- Have you sufficiently engineered the system to move the heaviest load safely?
- Do you need to adjust the system or the load?
    - In aerial sets, you can sometimes move the spar blocks higher to give more deflection and lift heavier loads. This technique involves evaluating the maximum value and direction of force for any guy lines.
- What obstructions exist in the travel corridor?
    - If the line is rubbing or is bent around vegetation, tie back the vegetation. When possible, cut the vegetation down or change the placement of the block.
    - If the line is rubbing on rocks or digging into the soil, change the placement of the block or add some type of chafing protection, such as fire hoses, logs, or rock bars.
    - You must consider the loads that will travel along the line and protect any sensitive features (like trees) that might get bumped.



- What type of braking system do you require?
    - Sometimes, when the path of travel is slightly downhill or one spar block is just a bit higher than the other, it is difficult to assess whether you require a braking or belay system. It is far better to set up a braking system and not need it than to not set one up and watch the load fly down a line at an uncontrolled speed.
- In what areas along the system will you need to work to accomplish a task?
    - Identify where crewmembers must stand to sling loads, run the braking and power systems, and observe trail users coming up and down the trail. Determine where the best lines of sight are for the whole system and analyze these general areas again after identifying the safest working zones.
- What specific duties must crewmembers perform to accomplish the rigging operation?
    - Establish each duty (communicator, hoist operator, load slinger, receiver, safety officer, traffic controller, etc.) and assign at least one crewmember to each duty.
- What is the system of communication?
    - Establish or review the commands used during the rigging process.

After walking the system in one direction, focus your attention on the individual components and crewmember positions. Ask and answer the following questions:

- Is the component properly rigged?
    - Ensure that slings are oriented properly, shackles are loaded over the pin and bow, lines are sitting in the sheave of the block, etc.
- What is the maximum amount of force that each component will experience?
    - The maximum amount of force is based on the rating of the power source and an understanding of sling-to-angle tension relationships as the line moves through blocks. It is also important to discuss any potential shock loading.
- What is the WLL of each component?
- Will the component stand up to the highest probable force?
    - This question can be difficult to answer for anchors with no stated WLL.
    - If any doubt exists, back up the anchor.
- What is the direction of force on each component?
    - The direction of force is relatively straightforward for straight pulls.
    - When a line runs through a block, creating an angle, the resulting direction of force is along the same plane that the block pulls away from the anchor. The block pulls in a trajectory that is close to the bisection of the angle. However, the wire rope attached to it pulls in a line toward each anchor or the closest block.
- Where are the fly zones if a component fails?
    - A component will fly in the direction of the force applied to it. Assume that the component will fly a long way, unless it is clear that it will hit an obstacle, such as a tree or boulder.
    - The fly zone (figure 12–1), also known as "the angle of death" (for good reason) is much wider than the direction of force and usually has a teardrop shape, emanating outward from the component. This teardrop-shaped fly zone is a result of the components connecting together. For example, if a sling holding a spar block breaks, the block will fly along the direction of force, but the line that runs through the block will also be carried with it. For this reason, the fly zone is the entire area that falls between any angle created by a line running through a block. Also, the wire rope usually pulls toward the power source, so in the event of a component line failure, the line will most likely fly quickly toward the hoist operator.

- Where are the safest working positions?
    - The safest working positions include the intersection where crewmembers need to move (addressed earlier) and the areas that are completely outside all fly zones.
    - It can be tricky finding the safest working positions, but remaining in these areas is essential whenever tension is on the line.
    - The farther crewmembers are from the rigging system components, the lower their risk of injury.
    - Constantly evaluate crewmember locations to determine if they could move to a safer position and still carry out their responsibilities.

After conducting the visual inspection and thoroughly answering or reviewing the questions above, it is time to test-load the system. With every crewmember in a safe working position, the lead rigger should tension the system without any loads attached. The purpose of this test is to ensure that everything within the system works properly. If you have a dynamometer available, place it behind the power source and tension the system to the winch's rated capacity.

During the test-loading, ensure that no lines are rubbing against trees or are under limbs. Lines running under limbs can be especially hazardous when the system is under tension and a limb breaks, causing an extreme shock load. During the test load, crewmembers are responsible for keeping watchful eyes on the parts of the system closest to them. After tension is relieved from the system, examine each component one more time to ensure that the component has not shifted, slipped, or loosened. If everything checks out, the system is ready to use.

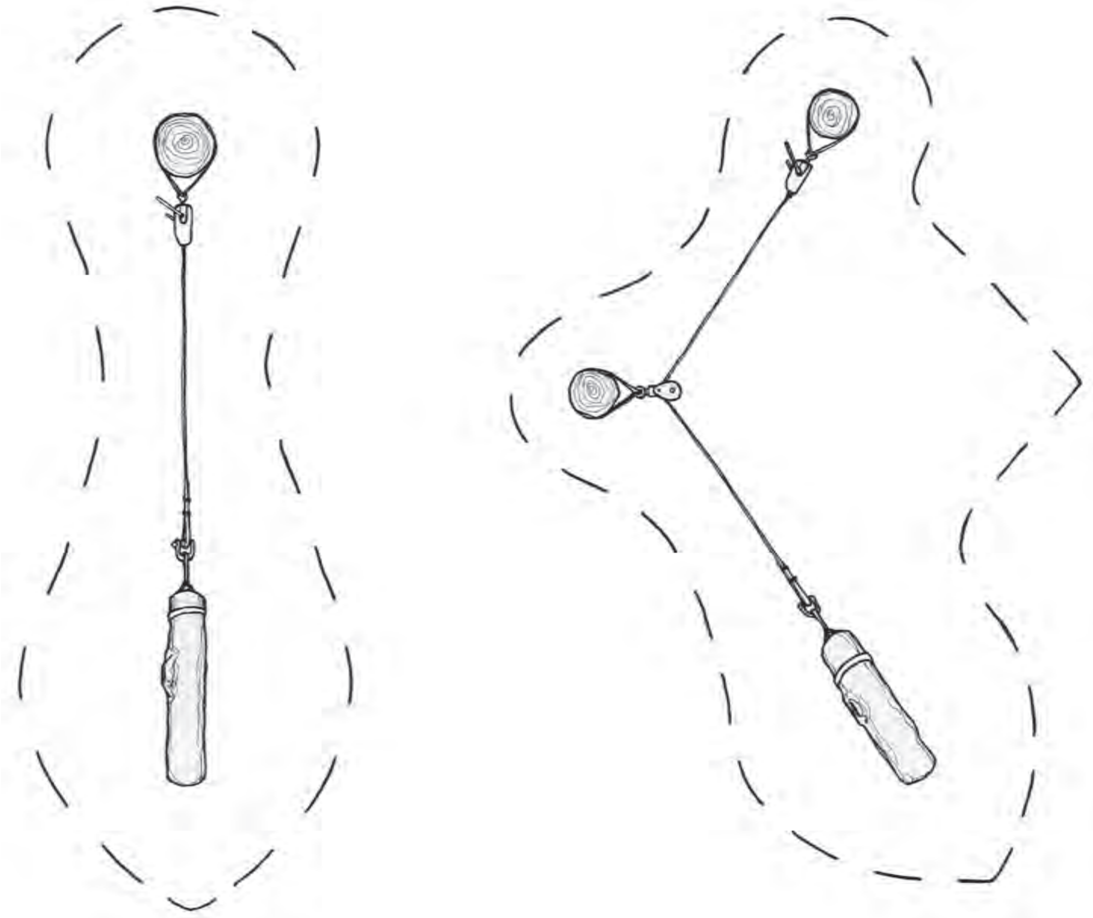


Figure 12–1—Fly zones associated with a 1-to-1 mechanical advantage configuration (left) and a 2-to-1 mechanical advantage configuration (right).

Chapter 13: Rigging System Configurations

Numerous terms describe trail-based rigging configurations. Much of the language comes from cable-logging systems, but terms have evolved to mean different things in various parts of the country. Most names describe the lines used or the configuration of components. Refer to the "Glossary of Rigging Terms" at the back of this manual for definitions.

Rigging Systems

Whether a rigging system is simple or complex, it generally falls into one of two categories:

- Moving objects across the ground
- Moving objects suspended above the ground

This section summarizes basic rigging system configurations. We discuss details and various modifications later in this chapter.

Rigging systems that move objects across the ground surface have two basic configurations:

- **The direct mainline**—The mainline does not elevate any of the loads when dragging them across the ground.
- **The high-lead**—The mainline runs through an elevated block to lift the front end of a load off the ground. This reduces friction and helps prevent the load from catching on obstacles.

Aerial rigging systems are systems that move objects suspended above the ground. There are two basic aerial configurations with numerous ways to customize them:

- **The double high-lead**—The load is positioned between a mainline and a secondary haulback line. Each line runs through elevated blocks. As you tension the lines, the load elevates above the ground. After suspending the load, you can tension it and move it using selective tensioning and slacking of the two lines.
- **The skyline configuration**—An elevated line anchored at both ends suspends the load from a carriage or block attached to the mainline. You can employ a secondary haulback line to move the load against gravity or a braking system to slow down the load when moving it with gravity. You can combine skylines, high-leads, mainlines, and haulback lines to move objects precisely in three planes.

You can use stock animals as the power source to skid a load in ground operations or to pull a line in aerial systems. "Appendix F: Stock Animals" provides information about caring for and handling stock animals during a rigging operation.

Descriptions of Rigging Configurations

One feature of trail-based rigging is that project needs and site conditions are never the same from project to project. The configurations described in the following sections represent the building blocks of limitless permutations and combinations of rigging sets. We do not describe configurations that are overly complicated or that involve numerous pieces of equipment. Configurations are ever changing and adept riggers will always see new ways to safely and effectively customize and improve the basic systems described in this chapter.

Ground Systems

Ground-based rigging systems describe rigging configurations where the load travels along the ground.

Mainline Configuration

The mainline configuration is the simplest rigging configuration for moving material. The mainline attaches to the load on one end and an anchored power source on the other. When you apply power, the load moves along the ground. Although this configuration may cause significant resource damage by skidding loads along the ground, it requires little equipment and is straightforward to plan and lay out. This configuration enables you to move heavy objects that would otherwise be difficult, impossible, or dangerous to move. The length of the mainline limits the distance a load travels, but it is usually easy for you to reset the power source on a different anchor. This basic configuration has many variations.

Typical Application: Ground Skidding Rocks or Logs

Mainline rigging can remove an unwanted, large rock (figure 13–1) or tree segment that has fallen onto the trail. As an alternative, you can move rocks or logs to the trail or beneath a skyline where you can lift them. Friction plays an important role in a ground-skidding configuration. You can modify the straight drag by running the winch line through a block positioned between the winch and the rock. Depending on how you set the block, this method can provide a change of pull direction, increase mechanical advantage, and place you safely uphill from potential rolling loads. You can use a stone boat (see figure 8–3) made of wood, plastic, or metal to skid rocks rather than skidding them directly on the ground.

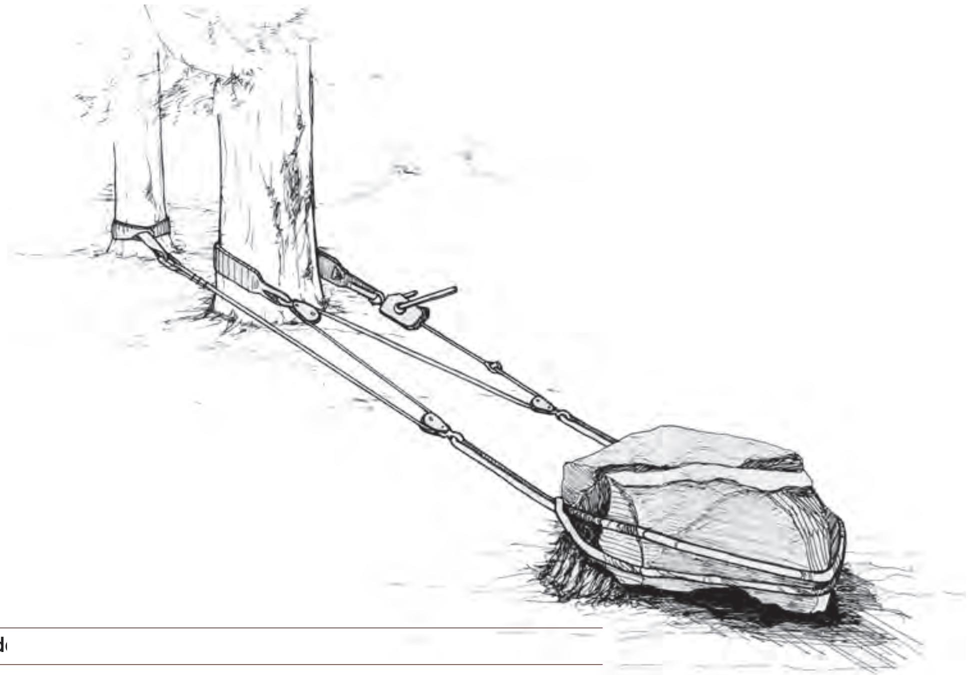


Figure 13–1 — Ground skid

In all ground-skidding operations, walk out the skid trail to become thoroughly familiar with obstacles and to determine the locations of each new "set." Pay particular attention to locations where the load must change direction or where a steep cross-slope exists. Moving long loads, such as bridge stringers, requires careful planning. Set stakes or ribbons so you don't take the load too far to meet the necessary turning requirements. When you use a stock animal, pay attention to the animal's footing, the grade, and the smoothness of the turns.

Safety Considerations

Avoid skidding across a steep side slope where the rock or log may roll down the fall line, resulting in a dangerous shock load to the configuration. Consider placing a directional block between the load and the hoist operator to keep the operator safe from a load-sling failure.

Typical Application: Pulling Stumps

Pulling stumps (figure 13–2) is a typical ground system mainline configuration. You can use rigging to pull stumps you would otherwise have to dig out of the treadway, particularly in new trail construction. The root placement on some trees may make tipping a tree over on its roots difficult. Blasting stumps may be quicker, but it is more expensive, requires a high level of training, and usually causes more collateral damage. You can best winch trees out of the trail tread when soil moisture is at its maximum. Some riggers have constructed an entire trail and left the centerline tree removal for the next wet season. This can be especially efficient when constructing a trail through a stand of dense poles. The more saturated the soil, the less you have to dig around the stump and cut roots. By previously preparing the trees, you can progress efficiently down the trail, pulling all the stumps from the tread.

An important step in removing stumps is leaving a stump as high as possible when felling the tree. This approach allows you to set the choker sling high, which provides the maximum amount of leverage when pulling. With experience, you will not place the choker so high up on the stump that the tree breaks at ground level when you apply force. It is important to understand the relative bending strength of trees.

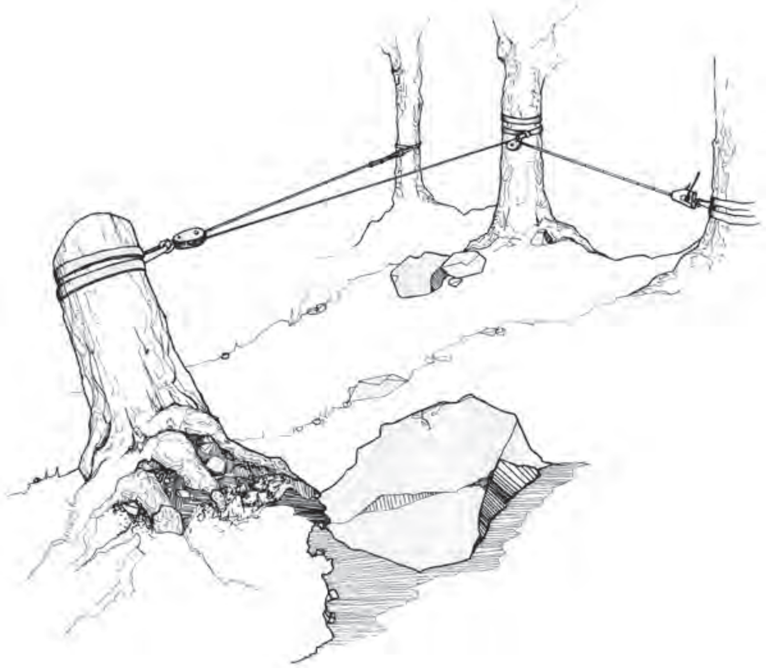


Figure 13–2—Using a directional block to pull a stump during new trail construction.

Some trees will bend a great deal, while others will simply snap off. Large stumps often require you to implement power blocks and mechanical advantage to double, triple, or quadruple the power of the hoist.

Many conifers have three major roots, whether the tree is on level ground or on a hillside. One good stump removal method is to tip over the tree by cutting one of the main roots and pivoting the tree over on the other two. Conifers generally have a smaller root system on the uphill side. By pulling the tree directly down the fall line, you accomplish the maximum amount of lift. Grubbing around the base of a tree before rigging enables you to examine the root placement. You may weaken the main roots by chopping or sawing. You should also determine whether to rig the choker to provide a rotational force on the stump, which would more effectively break the stump free. If you cannot remove the stump by pulling it out all at once, place a choker under one of the main roots to see if the rest of the roots will break under a load.

Safety Considerations

On steep ground, insert an additional snatch block to change direction to avoid winching directly below the stump.

Basic High-Lead Configuration

The high-lead configuration (figure 13–3) gets its name from the use of a block set high on a spar that provides lift for the load. The higher the block, the higher the lifting capacity, which helps the load overcome obstacles on the ground. It is essentially a mainline configuration with a high block. This configuration may reduce ground friction and cause less resource damage because of the simultaneous lifting and pulling forces, although it does require you to have enough experience to set blocks high in a tree.

Typical Application: Skidding on Uneven Ground

This configuration is best when you require a lifting force combined with a dragging force (e.g., when pulling objects uphill, over uneven ground, or over obstacles such as boulders). You can also use this configuration to pull rocks out of holes in the ground.

Safety Considerations

Avoid hanging blocks in unsound trees, and pay particular attention to side loading trees. We do not recommend this configuration for pulling loads downhill or on steep side hills.

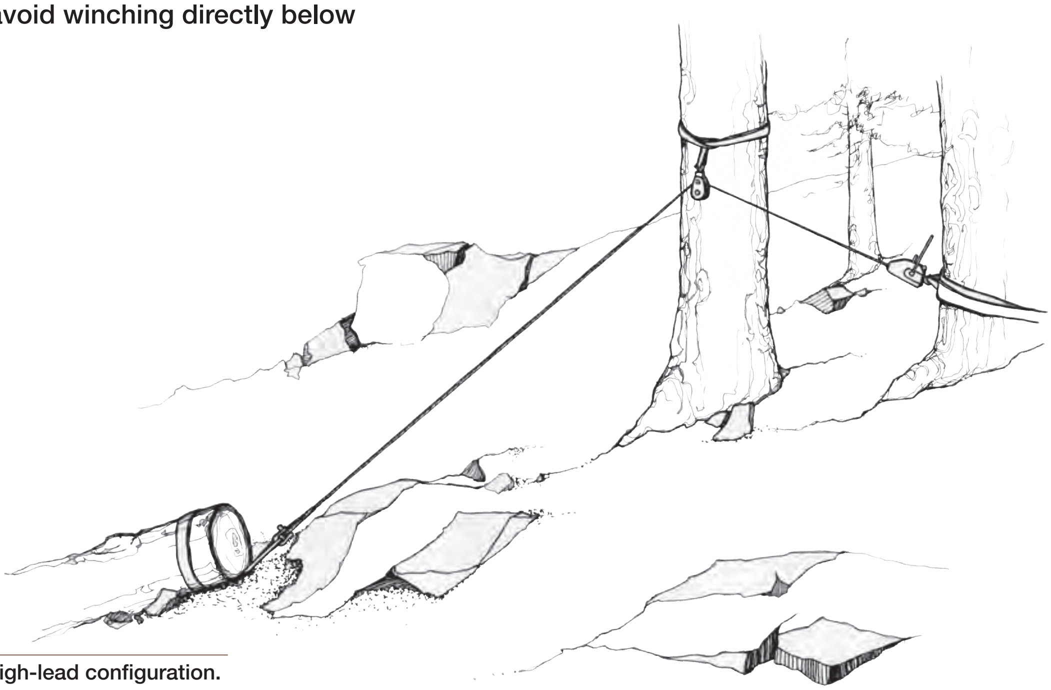


Figure 13–3—A typical high-lead configuration.

Aerial-Based Systems

Riggers use aerial-based rigging systems to raise loads off the ground and suspend the loads in the air for their entire length of travel.

Double High-Lead or High-Lead with Brake Configuration

The double high-lead configuration (figure 13–4) is one of the simplest powered aerial configurations. It uses two sources of power, one on each end of the configuration. The line coming out of each hoist runs through a spar block and down to the load. You do not attach the load directly to a block, but to lines coming from each hoist. You can suspend the load above the ground by applying tension to both power sources. When you tension one hoist and slack the other, the load moves toward the tensioning hoist. Because the movement of the load depends on the speed of the power source, the movement is fairly slow. This configuration, however, allows you to safely raise the load uphill or lower it downhill. By elevating the load using two power sources, the load causes minimal damage to the ground. The mainline is the line that pulls the load in the direction it moves, while the braking or haulback line is the line that opposes the direction in which the load moves.

Typical Application: Moving Loads Uphill, Downhill, or Across a Slope

The double high-lead configuration is similar to the high-lead configuration, but it produces much less ground disturbance because the load is suspended. You can move loads uphill, downhill, or across a slope because you control the loads from both sides. This configuration works well for setting bridge stringers.

Safety Considerations

You must analyze loading on spars and anchors, especially with limited deflection. The spars and anchors often require guying. This system also requires clear communication between winch operators simultaneously operating two winches.

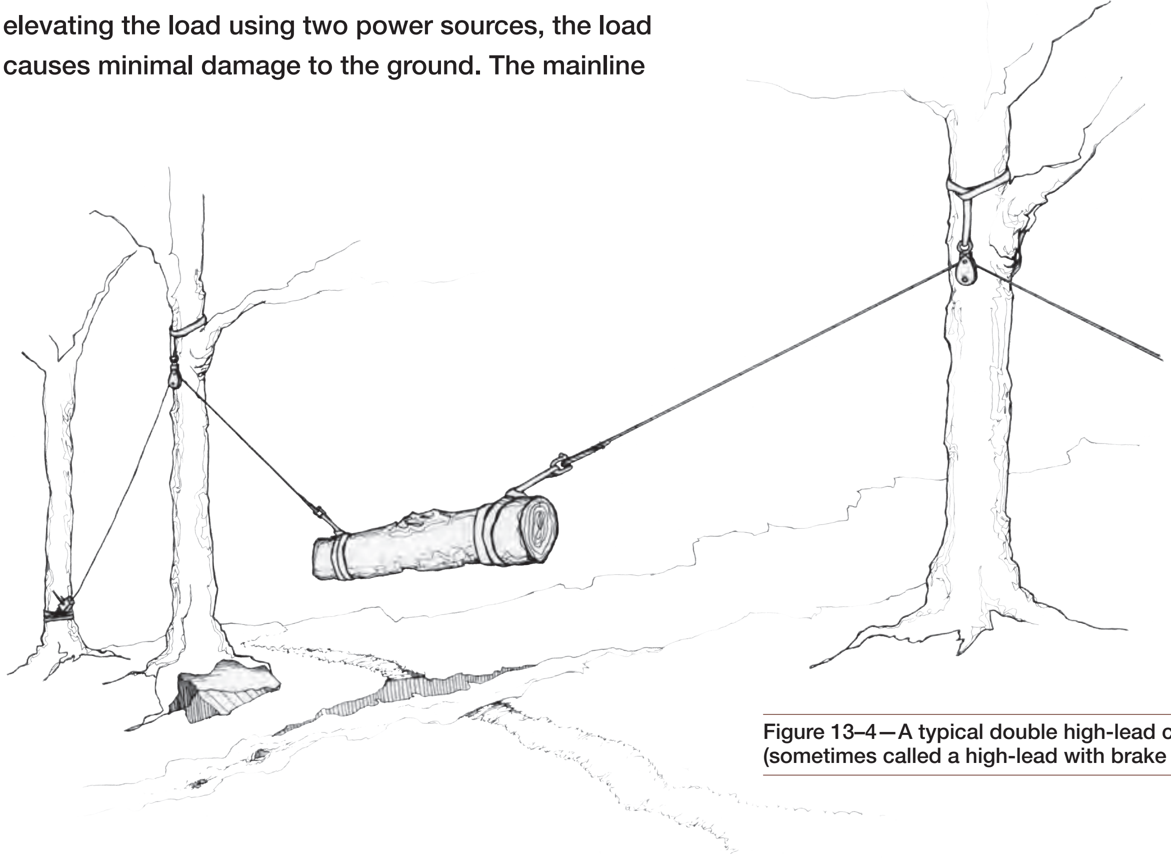


Figure 13–4—A typical double high-lead configuration (sometimes called a high-lead with brake configuration).

Skyline Configurations

Skylines have a wire rope that leads from an anchor through two high spar blocks and down to a second anchor. The load travels along a block suspended from the skyline between the two spar trees. The various skyline configurations provide flexibility for maintaining control over a load. Depending on the configuration, you can move loads safely in any direction, either fully suspended or partially suspended. Unlike the high-lead configuration, a separate skyline usually supports the load from the other lines (haulback or belay) that move the load along the skyline. Because a skyline carries most of the forces exerted on the configuration, its diameter is often one size larger than the other lines. Skylines require more rigging components than many other configurations. They are highly adaptable, and riggers probably use variations of this configuration most often, so it is impossible to describe every possible skyline configuration. The following sections provide examples of some typical skyline configurations.

Riggers configure skylines in three basic ways: fixed, live, or running. Each of these configurations has numerous variations. As the name implies, the fixed configuration has a line that you cannot raise or lower in elevation after you install it. The line is not involved directly in moving the load. The live configuration describes a variation in which you attach a power source to the skyline so you can raise or lower its elevation as needed. The running configuration describes a variation in which the skyline not only uses a carriage to support the load, but also uses the carriage to move the load along the skyline.

Fixed-Skyline Configuration

A fixed-skyline configuration consists of a fixed line anchored at both ends and does not include a power source. Riggers often use spar trees between the anchors to add height to the fixed skyline. A carriage or traveling block suspends the load, and other lines provide the force to transport the load. You cannot adjust the skyline length during operation, so you must carefully consider the selection of anchor points in the horizontal plane and the height of the blocks in the vertical plane. It is important to understand where the low point in the cable is in both the horizontal and vertical planes. You sometimes set fixed skylines by using a hoist (that you later remove from the configuration) in the same manner that you set guy lines (refer to the "Setting Guy Lines" section in "Chapter 11: Setting Anchors and Spars" for details). Although fixed skylines eliminate the need for a dedicated power source, the fixed-line configuration reduces its versatility.

With only one power source used for hauling, you use gravity or pull by hand to return the block back along the fixed skyline.

Typical Application

Riggers use the fixed-skyline configuration (figure 13–5) to move large quantities of lighter materials—such as buckets of gravel, crush fill, or organic matter for revegetation—and for raising a stringer onto a sill at a predetermined placement point.

Safety Considerations

You must analyze loading on the spars and anchors, especially with limited deflection. It is important to incorporate a mainline or braking configuration if there is any chance that the load could move out of control.

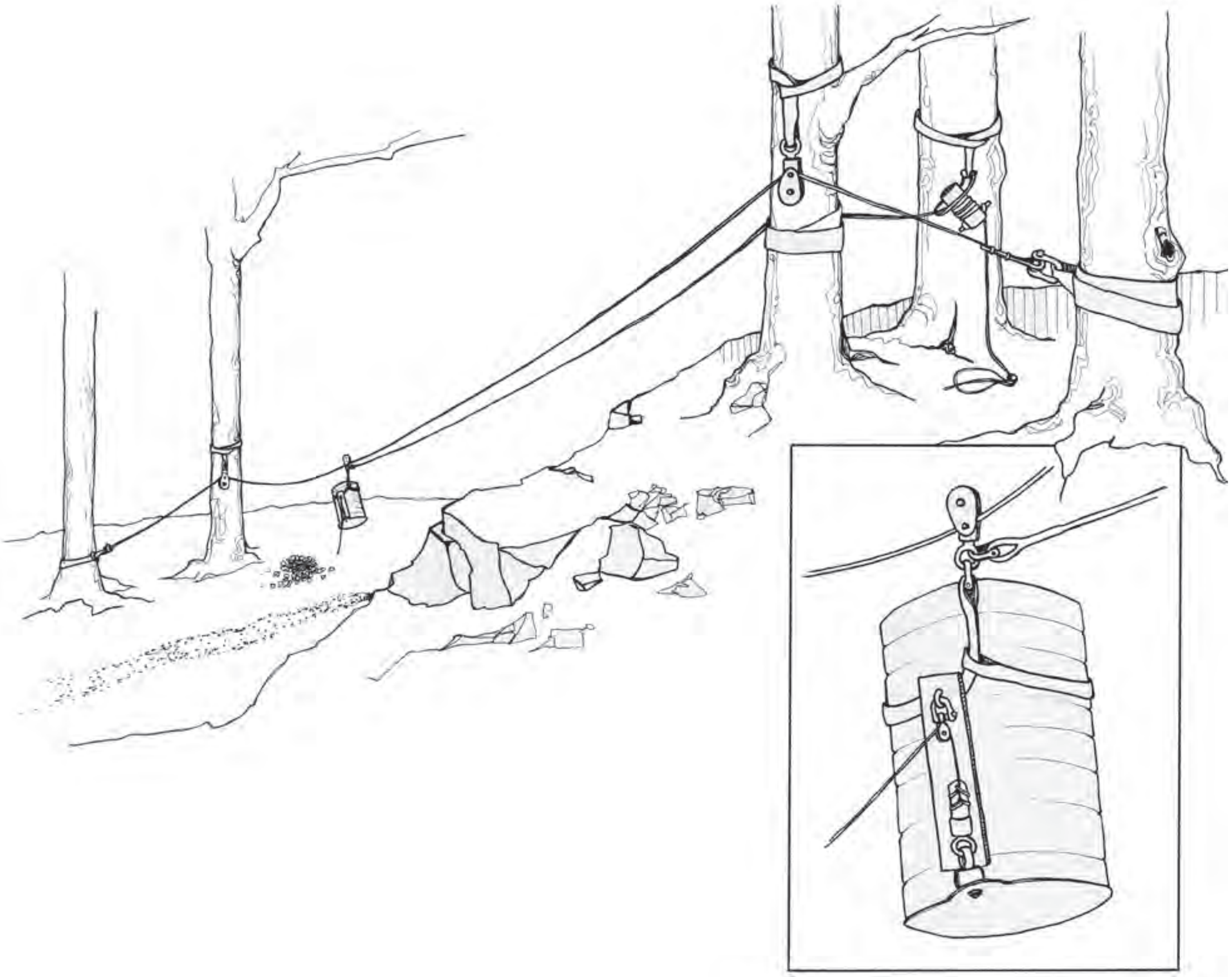


Figure 13–5—A fixed-skyline configuration with a belayed drop-bucket delivery system. The inset shows a closeup view of the drop bucket.

Basic Live Skyline Configuration

The basic live skyline configuration (figure 13–6) consists of a line you can raise or lower using a single power source. You use a skyline to raise and lower the load from the ground and transport the load along the line by hand. A crewmember on the ground holding onto a tag line attached to a travel block, trolley, or carriage manually pulls the load along the skyline. This configuration allows you to move loads quickly along the line. The basic live skyline is appropriate for nearly level ground or in locations where you place the two spar blocks about level with each other.

Typical Applications

Riggers often use the basic live skyline configuration with tripods as spars in subalpine and sensitive high-elevation work areas where there is little elevation change between the loading and unloading zones. This configuration works well for setting steppingstones across a level but muddy site.

Safety Considerations

You must analyze loading on spars and anchors, especially with limited deflection. Guying may be necessary. The lead rigger must ensure that the ground crew pulling the tag line remains clear of the load in case the load drops. It is important to incorporate a mainline or braking configuration if there is any chance that the load will move out of control when you lift it off the ground.

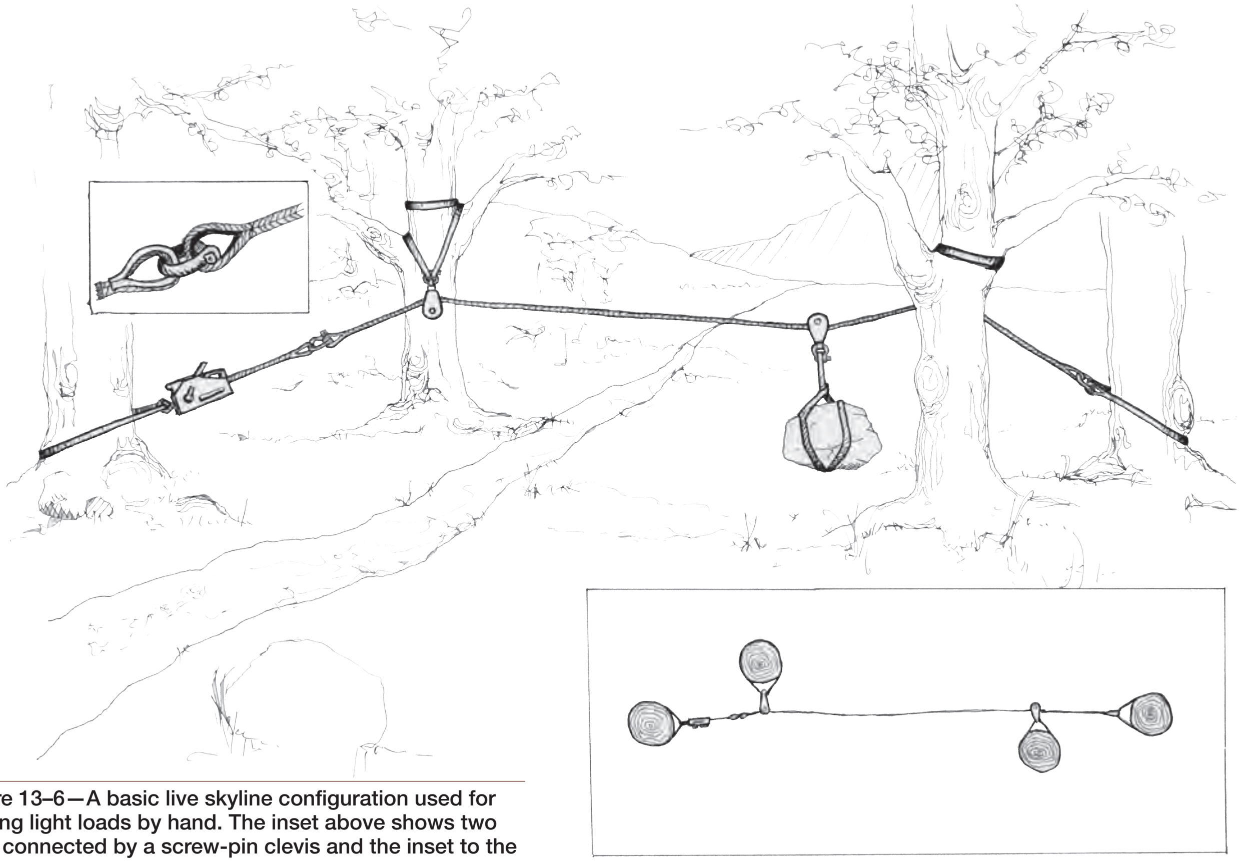


Figure 13–6—A basic live skyline configuration used for moving light loads by hand. The inset above shows two lines connected by a screw-pin clevis and the inset to the right shows the layout of the configuration from above.

Live Skyline with Belay Configuration

The live skyline with belay (figure 13–7) is the most efficient configuration for moving relatively light (2,500 pounds or less) materials downhill. It is similar to the basic live skyline, except that gravity pulls the load down the skyline with a fiber rope and belay device controlling the timing and speed of the descent. The belay offers great control for moving loads downhill but provides no way to pull loads uphill. You generally pull the belay line and travel block back uphill by hand. See “Chapter 14: Braking Systems” for details about belay system configurations.

Safety Considerations

Although the live skyline with belay configuration can theoretically move loads of more than 2,500 pounds, the working load limit (WLL) ratings of most commonly used belay devices and synthetic rigging rope have a threshold of 2,000 or 3,000 pounds. We recommend using a powered braking system for loads weighing more than 2,500 pounds.

Never use the body belay techniques used in rock climbing to try to control a load or material you move.

Typical Application

Riggers use this configuration for repeatedly moving maximum loads of 2,500 pounds downhill and often use this configuration to move rocks, gravel (in a gravel carrier), bridge stringers, or dimensional lumber they stage or quarry uphill of the work area.

You must analyze the loading on spars and anchors, especially with limited deflection. The spars and anchors may require guying. You must also know the WLL of all fiber ropes and must account for reductions in strength caused by knots.

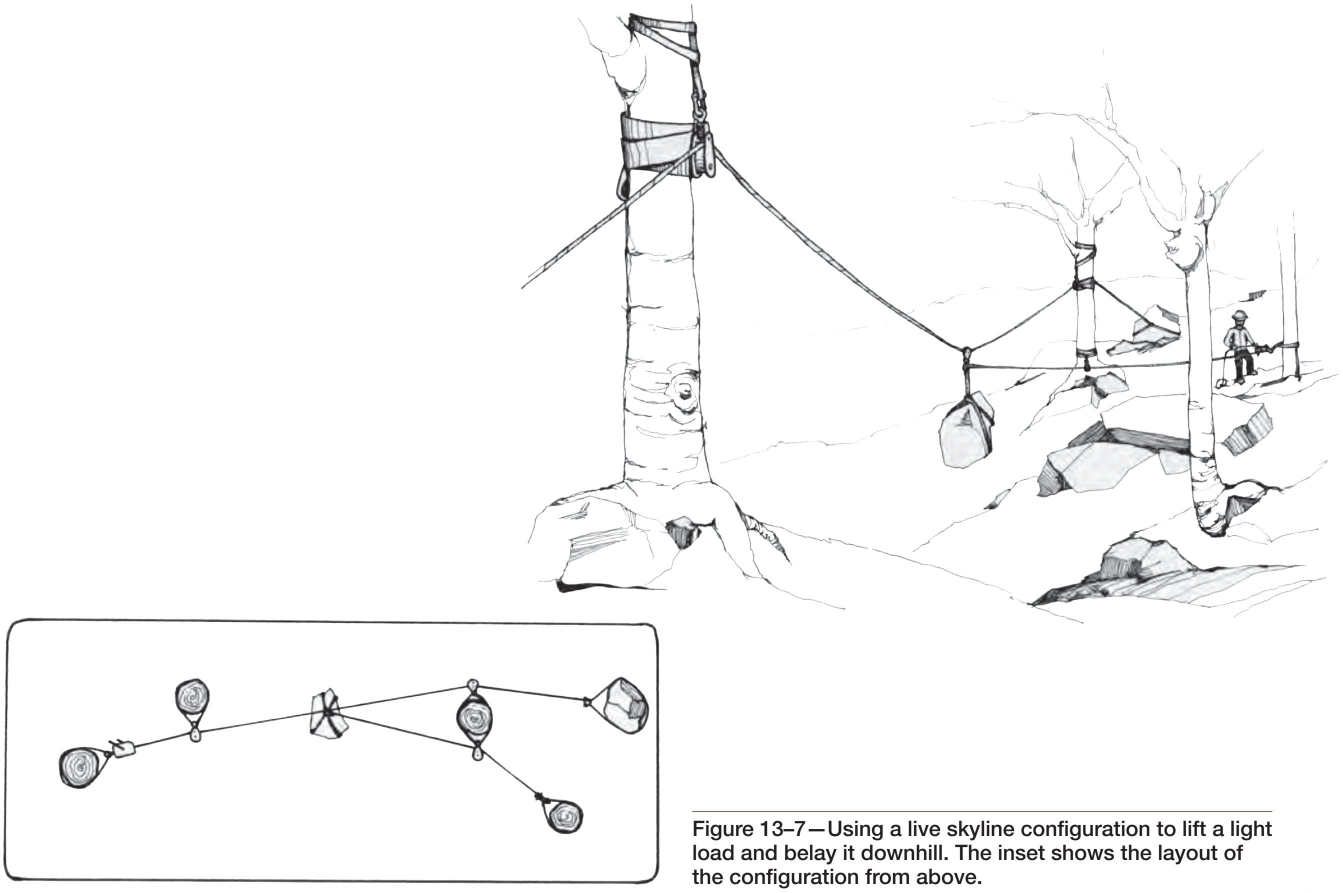


Figure 13–7—Using a live skyline configuration to lift a light load and belay it downhill. The inset shows the layout of the configuration from above.

Live Skyline with Mainline Configuration

A live skyline configuration consists of a skyline you can raise or lower using a power source on one end and another, separate power source for a mainline that pulls the load uphill or lowers the load downhill (figure 13–8). This configuration is similar to the live skyline with belay, except that a power source substitutes for the belay system. The ability to adjust the deflection in the cable enables you to better manage the load and the tension on the spars. With this configuration, a skyline raises the load and a travel block or carriage on the skyline moves the load. The load moves at the speed of the mainline power source as it powers the load up the skyline. Gravity returns the travel block to the loading zone. This configuration has no powered haulback. Unlike the double high-lead configuration, the two lines (skyline and mainline) are not opposed to each other. The skyline lifts the load off the ground and the mainline pulls the load along the skyline. The mainline must run parallel to but remain clear of the skyline at all times.

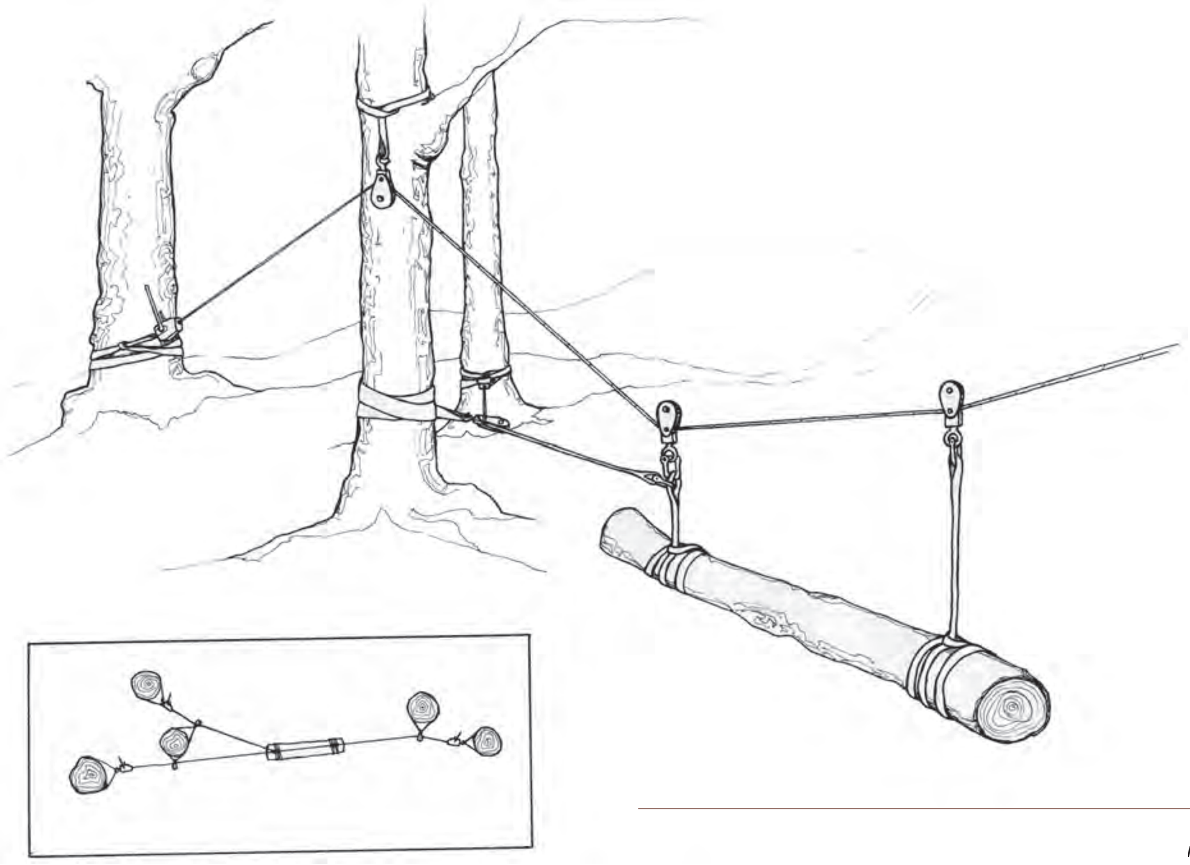
A griphoist, capstan, Lewis winch, or other drum-spool winch may power the mainline. In some cases, you run the mainline through one or more directional blocks to a horse or mule that moves the mainline by walking forward and back. In other cases, vehicles or equipment, such as skid steers, provide the power for the mainline.

Typical Applications

The live skyline is excellent for building rock retaining walls when the rock and gravel source are some distance below the trail. It is also useful for moving steel or timber bridge stringers up or down slopes.

Safety Considerations

You must analyze the loading on spars and anchors, especially with limited deflection, and should provide guy lines as necessary.



configuration
wer source
anchors). The inset shows the layout of the configuration from above.

Live Skyline with a Double High-Lead Configuration

The live skyline with a double high-lead configuration is similar to the live skyline with mainline configuration, but it uses three lines and three separate power sources (figure 13–9). A live skyline with a block or carriage attached to a powered mainline and haulback suspends the load. The mainline and haulback lines often use the same spar trees as the skyline. This configuration provides positive, powered control over the movement of the load in both directions.

Typical Applications

Riggers use the live skyline with a double high-lead configuration when they must move loads downhill on one side of a gully and then back up the other side. For example, you would use this configuration when a good selection of rocks for a trail project is located on the opposite side of a gully from the trail. You would set up a skyline that spans above the slope on the trailside and above the slope on the rock quarry side, then set up a double high-lead configuration on the same spars as the skyline, and lift the rock into the air using the skyline. You would then lower the rock using the high-lead on the uphill side until it reached the lowest point on the skyline, apply tension on the high-lead on the trailside (bringing the load uphill to the worksite), and lower the load to the ground using the skyline.

This configuration also works well for loads that are too heavy to finely adjust by hand. Because you have positive control forward, backward, and vertically, you use this configuration to accurately place bridge stringers over pins or to place large rocks for steps.

Safety Considerations

Because the live skyline with a double high-lead configuration uses three power sources, often some distance apart, you must have excellent communication to ensure the safe, coordinated operation of the power sources. You must analyze the loading on spars and anchors, especially with limited deflection and when you use the same spar for the skyline and high-lead blocks. Guying will probably be necessary.

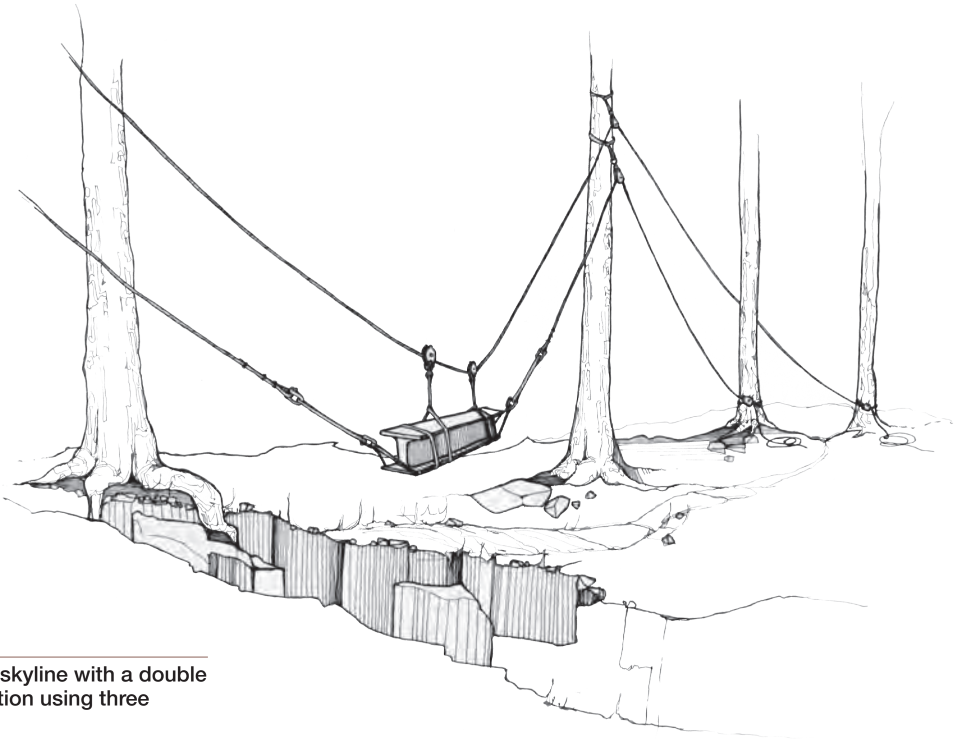


Figure 13–9—A live skyline with a double high-lead configuration using three power sources.

Running Skyline Configuration

A running skyline configuration (figure 13–10) consists of three suspended moving lines. It uses a tail block to change the skyline's direction 180 degrees at its farthest point. This configuration is versatile because it allows you to use a movable skyline and positive load control both forward and backward with only two power sources (which normally requires three power sources). You accomplish this configuration by using only one line to function as both the skyline and the haulback line. The haulback line acts as both the skyline and the haulback line because it runs around a block on the downhill or farthest end of the configuration (known as a tail block) and back toward the power source in a U-shaped configuration. The haulback line supports the load; it is the largest diameter cable of the rigging configuration. You fasten the load to a block or carriage that runs on the haulback line.

Typical Application

Riggers use the running skyline configuration for many aerial applications where they must place a load precisely while using a minimal number of power sources.

Safety Considerations

We recommend using a carriage in this application because the haulback line, which is also the lifting skyline, may exceed the load clevis side-pull rating. You must analyze the loading on spars and anchors, especially with a lack of deflection. Guying will probably be necessary.

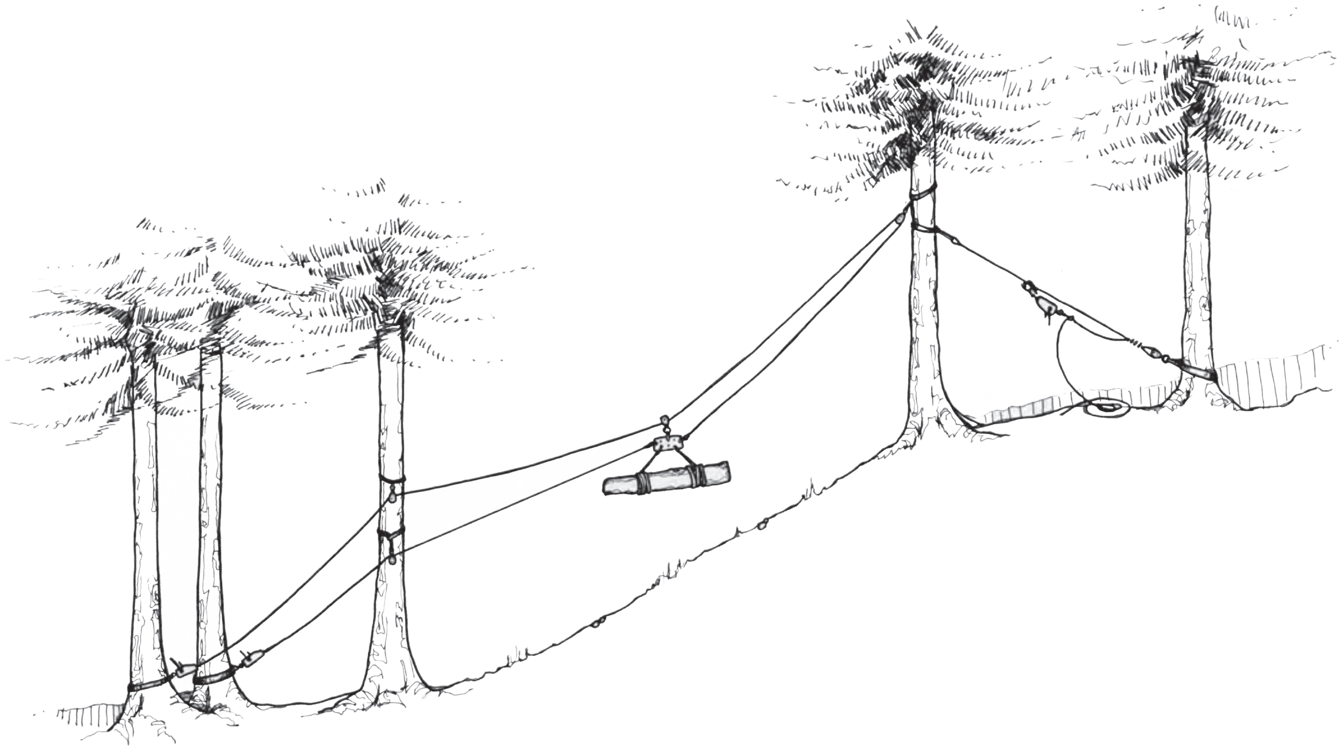


Figure 13–10—A typical running-skyline configuration using a trail block and carriage (note the use of a spar tree back guy).

Skyline with Hoist Configuration

Riggers sometimes use hoists to lift loads up to a skyline (figure 13–11). This method works well for fixed skylines, but you can also use it to reduce the amount of winching in a live skyline configuration. You most often use chain hoists, also known as chain falls, to lift the load because these hoists are portable enough to move along with the travel block and load. You can also use griphoists, but these hoists make moving the load along the line trickier after you lift the load.

Typical Application

Riggers can use the skyline with hoist configuration when certain physical parameters won't allow them to lower a live skyline to the ground. For example, if a project site is located between two narrowly spaced large boulders or at the base of a ledge, you may be unable to lower a skyline enough to pick up or drop a load without the line rubbing on the boulders or abrading on the ledge. The hoist allows you to move loads vertically up and down while the skyline stays high in the air. A chain hoist is also useful for vertically lifting and lowering when a connection point (such as a mainline to skyline or skyline to extension line) would run into a block when you use only a skyline system.

Safety Considerations

You should consider that the lifting hoist adds tension equivalent to the load weight and hoist weight. The chain hoist operator must always avoid getting beneath the load.

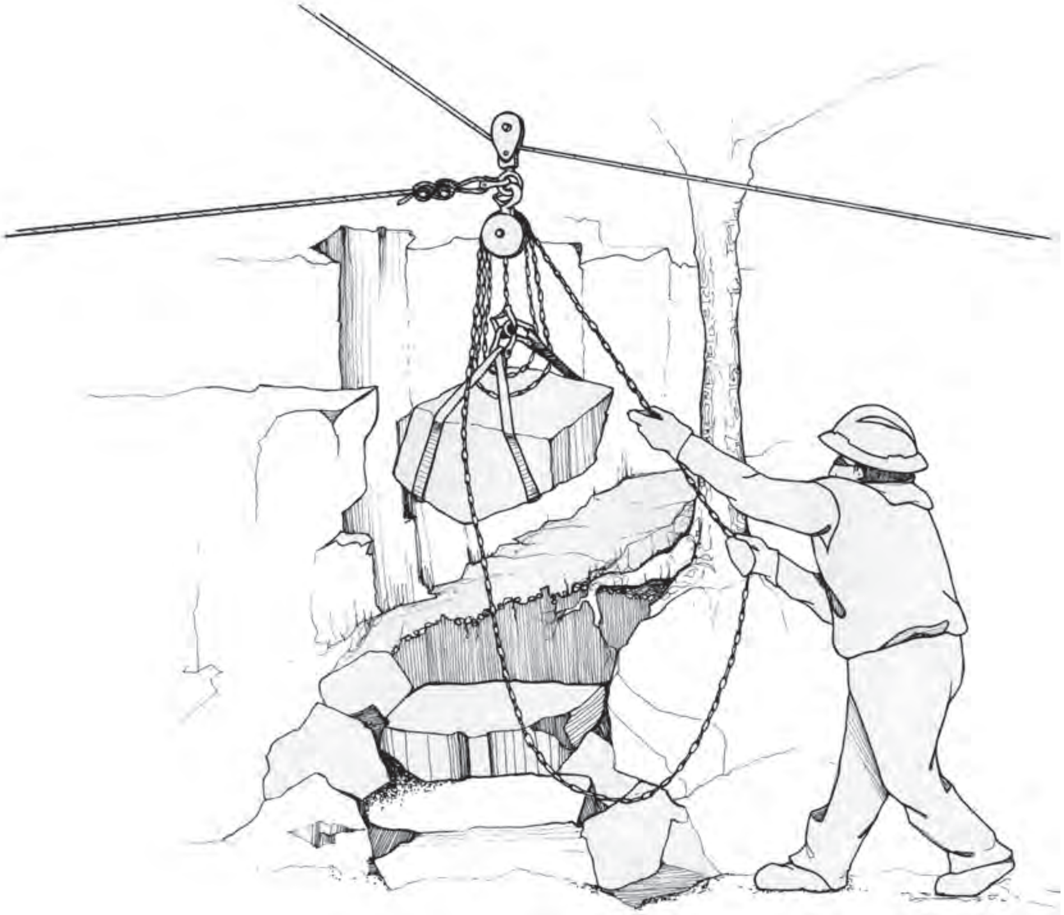


Figure 13–11—A skyline configuration with a hoist.

Skyline as High-Lead Spar Configuration

When material such as rocks for a retaining wall are scattered across a slope, you can set up a high-lead configuration to pull loads to the loading zone of a skyline. Although they are often two separate configurations, it is possible to accomplish this task by hanging the high-lead spar block directly off the carriage or travel block of the skyline so that one sheave rests on the skyline and the other holds up the high-lead. You set the high-lead anchor uphill of the skyline so that it is more or less perpendicular to the skyline. This configuration essentially creates a high-lead configuration in which you can move the spar along the skyline, eliminating the need to climb multiple trees for different high-lead setups. You can accomplish this using virtually any of the skyline configurations described in this manual. The double block setup on the skyline acts as a spar so you can apply both lifting and directional forces to the load. You lift the load higher by tensioning the skyline and drag the load toward the skyline by lifting the spar higher and tensioning the high-lead. You use this two-part process to pull the loads with the high-lead until the loads are within the skyline corridor, then drop the loads. The skyline can directly lift the loads. You can use a belay rope, haulback line, high-lead line, or temporary grippers and slings to hold the carriage or travel block in place on the skyline (figure 13–12).

Typical Application

The main reason riggers use the skyline as high-lead spar configuration is to access loads that are outside of the skyline's immediate loading zone. Riggers often use this configuration to quarry rocks scattered downhill from the skyline corridor. You can pull loads with the high-lead line below the skyline, where you drop the load. This method can be efficient when gathering materials because the skyline and anchor point for the high-lead line can remain fixed while crewmembers fan out across the hillside to farm rocks.

Safety Considerations

It is possible to overload skyline components if you tension the skyline to the hoist's capacity before tensioning the high-lead line. It is important to keep adequate deflection in the skyline and periodically test the skyline tension by pulling on the tension handle of the hoist or by using a dynamometer. Do not pull additional force on the lateral high-lead line if the skyline tension is close to its maximum.

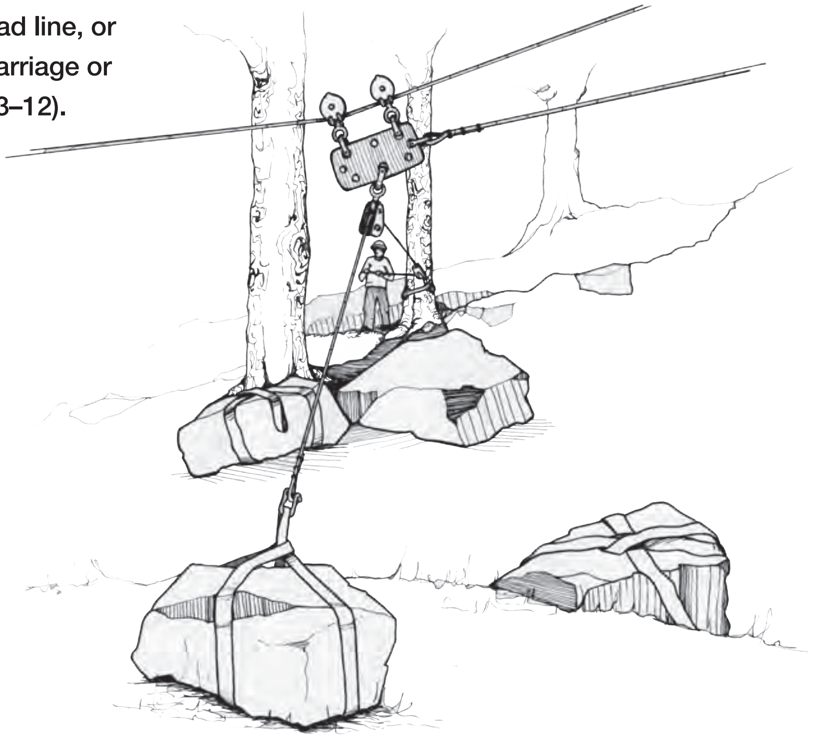


Figure 13–12—A carriage positioned on a skyline acting as a spar for a high-lead configuration.

Tramway Configuration

A tramway is a cyclic configuration that acts much like a ski lift—as one gondola moves up the mountain, another moves down on the other line. The setup of a trail-based tramway is a bit different from a ski lift. A tramway consists of two suspended, fixed skylines on which you carefully adjust deflection to facilitate loading and dumping material at specific locations. Each skyline supports a bucket or gravel carrier at opposite ends. As a carrier moves one way into position for you to dump, an empty carrier on the other line moves in the opposite direction for you to refill. A connecting loop configuration, like an old continuous clothesline, keeps the two carriers the same distance apart. This connecting loop runs through a block near the uphill spar trees of the two skylines. If you move material downhill, set up a braking configuration near the uphill directional block. If you move material uphill, you need a power capstan or chain saw winch on each carrier. The tramway configuration only works with specific site conditions and project needs, but it can be efficient when properly rigged.

Typical Application

The tramway configuration works well for moving large quantities of trail-surfacing material, especially when moving it downhill.

Safety Considerations

Communication is an important factor with a tramway configuration so that crewmembers at each end are aware when the carriers begin to move. You must have a positive holding device in place when loading a carrier. Rope management can also create a hazardous situation for the belayer. We recommend, whenever possible, that you only use one belay rope.

Special Example Applications

Several rigging applications are worth mentioning because riggers frequently use them for trail work.

Skyline with Midair Transfer

A skyline with midair transfer (figure 13–13) consists of two or more complete and separate skyline configurations that cross each other. The load switches from one wire rope to the other wire rope without touching the ground. This process requires you to add another clevis to the load before lowering it down the first line. When you stop the load at the intersection of the lines, you lower the second (and higher) wire rope to the load and attach the extra clevis to the travel block on the second line. A slight increase in tension on the second line takes the weight off the initial travel block so you can remove it and lower the load down the second line.

This transfer configuration is particularly useful in situations where you must move materials (such as boulders or gravel in a carrier) down a steep, densely vegetated slope that does not have an open, linear corridor to run a single line. Although it might be easier to bring each rock down the first line, set it on the ground, and then pick it up with the second line, there sometimes is no safe or flat place for this exchange to occur. While a skyline with midair transfer is equipment intensive, the midair transfer involves little winching when properly rigged. The crewmember attending the upper line can rig the next rock while the crewmember attending the second line lowers the first one, adding continuity to the process and reducing downtime.

Typical Application

Riggers use the skyline with midair transfer to move loads downhill when a straight line of travel is not possible and the terrain is steep, and often use this configuration when they want to set rocks in place directly off a skyline. The first skyline transports the rocks from the hillside to near the trail. The second skyline runs over the trail so you can lower the rocks and position them directly into a staircase or retaining wall.

Safety Considerations

You must analyze the loading on spars and anchors, especially with limited deflection. Guying may be necessary. Communication and experience is paramount because the two belayers and two hoist operators must coordinate precise movements. The crewmember responsible for transferring the load from one line to another must be right beside (but never directly under) the suspended load.

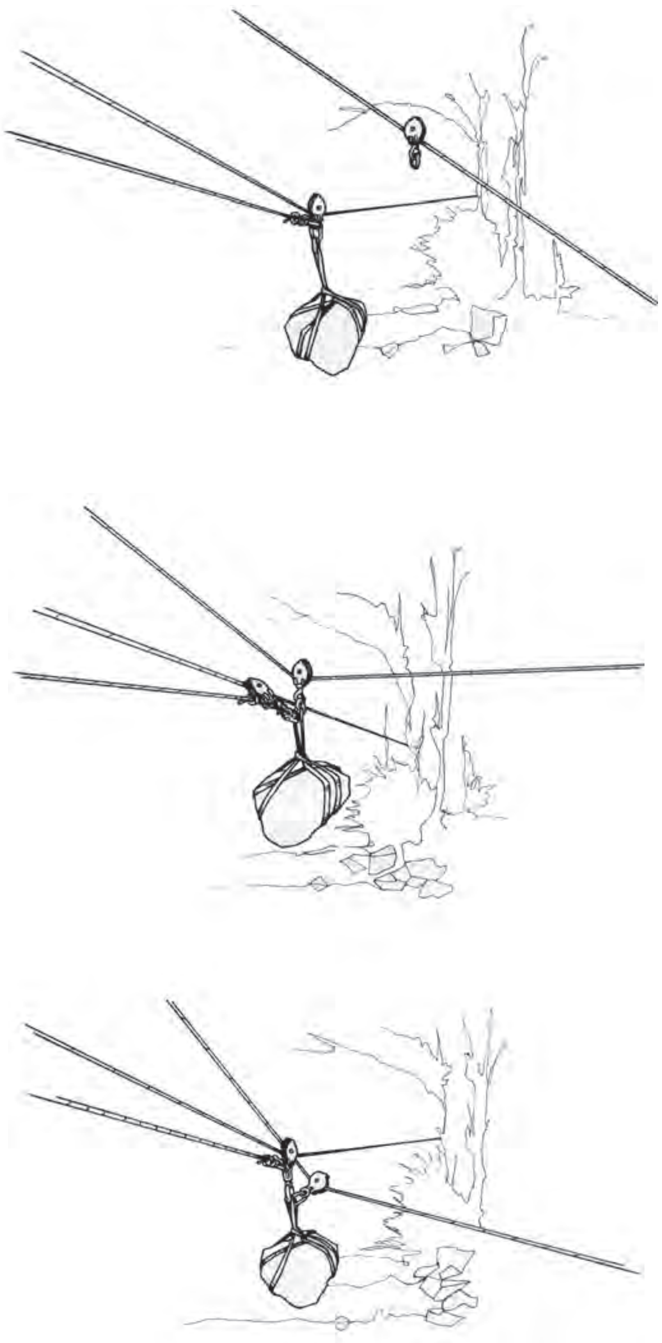


Figure 13–13—Using two skylines to transfer a load in midair.

Aerial Gravel Haul Application

The movement of gravel, soil, or wet concrete is often associated with trail construction or maintenance. You can carry small amounts by hand in buckets and dirt bags, or you can use a neck yoke or drop-bottom panniers with stock animals. You may also use small, mechanized carriers if the trail tread width and surfacing attributes are conducive. Each of these applications works well when the source of the material or stockpile is close to the trail. The source is often not near the trail but rather near a creek bottom below the trail or at a pit source hundreds of feet above the trail.

An aerial skyline can be the safest and most cost-effective method for delivering different sources of materials. Unlike rock or stone, delivering gravel requires moving more volume. You must estimate how to move the required amount of gravel in the least amount of time, including the rigging configuration setup and takedown time.

You can use several methods for transporting material uphill. Most of the methods use a skyline. One method is to use a bucket or similar low-volume container raised vertically by a live skyline. You then transport the load uphill using a haul rope attached to a power-driven capstan winch. A horse or mule walking along the trail could provide the hauling force in wilderness areas. The filling and cycle times for this method are short, but the volume transported is low. You could fill additional buckets at the source. Many 5-gallon buckets do not have a sufficient bail to support hauling gravel-like material aerially; therefore, replacing the metal bail with webbing is one way to move these buckets more safely.

One alternative to using buckets is to fabricate a gravel carrier out of plastic culvert that is ribbed on the outside and smooth on the inside. You can vary the length and diameter of the culvert according to the WLL of the configuration and the material you transport. You can rig a simple, hinged drop-flap made of wood, steel, or aluminum to cover one end of the culvert and can release the material using a hook-and-eye latch or a marine cleat connected to a rope pull. The carrier travels by means of a block, and you control it with a belay rope and coordinated belay configuration.

Notes

Chapter 14: Braking Systems

A rigging braking system counters gravity to control the speed of a load moving downhill. Because of the variety of techniques used for braking, we consider braking a system in and of itself. Braking devices commonly used in trail rigging fall into one of two categories: friction based or mechanical. We use the terms “braking” or “lowering” to refer to all types of devices that lower loads safely. Some braking devices are power sources that can also use a mainline to bring loads back uphill. The term “belay” describes a system that lowers loads using friction-based devices and fiber ropes. You cannot use belay devices to pull loads uphill. It is important to understand the difference between trail-based belaying and the recreational belaying that people commonly use on rope courses and in rock, tree, and ice climbing. Virtually no rescue and recreation belay equipment is strong enough for trail applications. Trail-based belaying involves equipment that manufacturers design for loads that far exceed body weights. The term “belayer” describes the individual who lowers a load, regardless of the method used. The terms “belay line” or “belay rope” refer to a fiber rope rated for the loads riggers lower after taking into account reductions for knot strength and possible shock loading.

Friction-Braking Devices

People have used friction-based braking techniques for centuries. Traditional techniques include wrapping a rope around a tree stump, person, or piece of metal. Although effective, this simple tactic has its limitations. Anyone who has had a rope run quickly through his or her hands knows that heat is a direct result of friction. If the system does not adequately dissipate the heat from friction, the heat may compromise the rope strength and shorten its lifespan. Techniques that bend the rope too tightly also tend to twist and hockle the lowering lines. Friction braking cannot pull loads uphill, as with its mechanical counterparts. Additionally, it can be difficult to determine the exact advantage gained by a friction system until you test it. Friction systems are advantageous because they require only a few pounds of gear, and you can set them up quickly in a variety of situations involving light loads.

Friction braking devices we recommend include varieties of the Port-A-Wrap and capstan winches. “Chapter 6: Winches and Hoists” provides information about these devices. Another friction-based technique, called the three-point friction belay, uses no special equipment.

> “A rigging braking system counters gravity to control the speed of a load moving downhill.”

Three-Point Friction Belay

The three-point friction belay system (figure 14–1) controls loads using only clevises, slings, and one snatch block. The idea is that a belay line moving through a clevis at an angle produces friction. Running the belay line through three clevises set at angles to each other produces enough friction to slow loads down on steep inclines. Although this method takes no special gear, a site must have specific conditions for this setup to work. The site must have three anchor points close together and should have a clear line of sight to the work project, while also providing the belayer a safe distance from any spar tree or perceived fly zones. Connect a sling with a clevis to three different anchors and connect a sling and a snatch block to the spar tree used in the aerial configuration. The belay line runs from the belayer's hands through the bow of each clevis, over to the directional block on the spar tree, and connects to the load. The placement of the anchors, length of the slings, and order in which the belay line threads through the shackles dictates the angles. Acute angles generate more friction and obtuse angles generate less friction. The belayer can change the angle closest to him or her by walking forward or backward.

It is best to start with three acute angles and then open up the angles, if needed. It is possible to lower loads with a two-point or four-point system, but it is our experience that a three-point system works best for loads that weigh between 200 and 2,500 pounds that are moving down slopes of 10- to 80-percent grade. It is important that the belay line runs across the bow of the clevis. A running line that moves over the pin of a shackle can cause the pin to unscrew and fall out, so you must secure the pin with a nylon tie or wire.

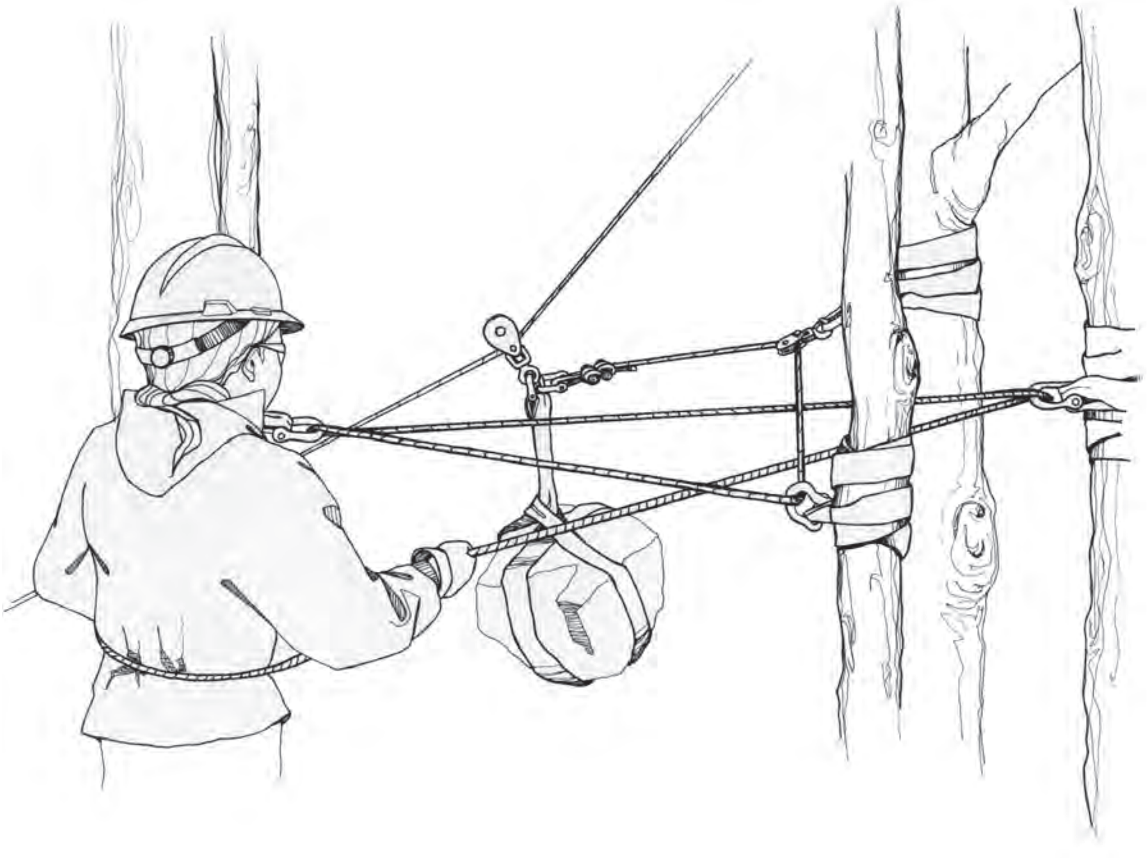


Figure 14–1—A three-point friction belay and directional block.

Countering gravity's pull and controlling a load's movement can be dangerous. You should always avoid:

- Wrapping the rope around a tree or stump.
    - Although loggers used this technique often during early logging times in the United States, it abrades and twists the rope. It can injure a living tree, snap a dead tree, or slip off the top of a stump.
- Using climbing equipment designed to lower body weights.
    - People use many types of lowering or belay devices for rock, ice, and tree climbing. These devices include the classic "figure 8" (not to be confused with the knot of the same name), tubular pieces such as the Black Diamond ATC, and self-braking devices such as the Petzl Gri-Gri. All these devices are underrated for trail work purposes. The "figure 8" device will also twist and tangle the belay line over time, making it difficult to manage.
- Using rope hitch techniques.
    - The münter hitch is a locking friction hitch that is used for lowering supplies in emergency situations, but it is not appropriate for trail work. It twists and heats the rope quickly because of the tight bends it makes over itself and the carabiner (a D-shaped ring with a spring catch on one side) or shackle it wraps around. The prüsik and kleimheist friction hitches are useful, but not for braking in trail work. They use small-diameter cord or webbing that wraps around a line. The hitch can move freely along the line when loose, but when weighted, the wraps tighten and hold securely.
- Using body wraps, belays, or boot belays.
    - Various techniques for belaying people involve wrapping the line around parts of a person's body. None of these techniques are safe for trail applications. Belaying usually involves running the rope through one or both hands. Gripping the rope is not dangerous, but wrapping the rope around a hand can be. Always wear leather gloves when belaying.

Figure 14–2 shows a friction braking belay system used for moving light loads in various aerial rigging configurations.

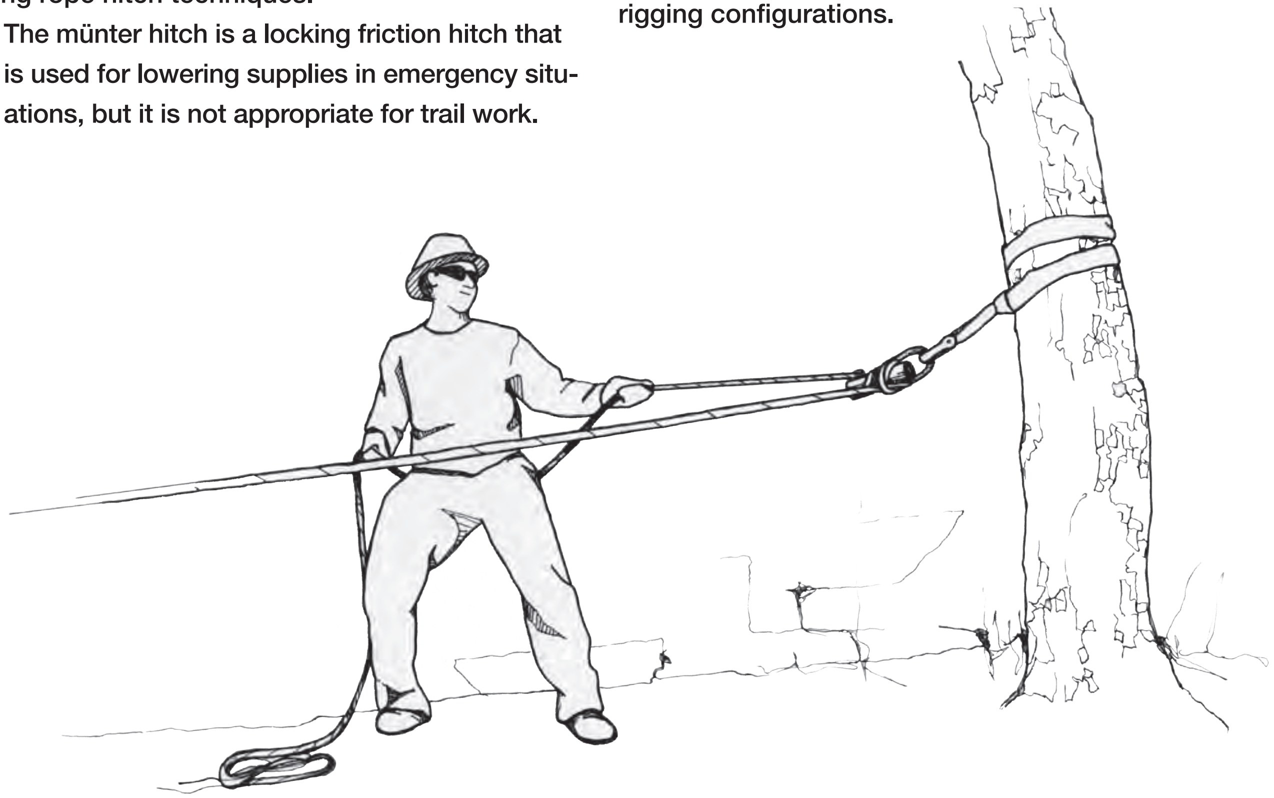


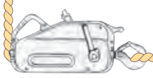
Figure 14–2—A friction breaking belay system used for light loads in various aerial rigging configurations.

Mechanical Braking Devices

The end of “Chapter 7: Rigging Hardware” describes the specialized mechanical braking devices we recommend. The arborist industry developed some of these components, but some are winches and hoists used to lower rather than pull. You operate the devices the same way, whether you are lowering or pulling a load.

Whether you use a Port-A-Wrap, a three-point friction belay, a bollard device, a capstan winch, or a hoist, the fundamental concepts of braking remain the same. A successful braking system has the following characteristics:

- The braking device must be rated high enough to handle the loads and rigging system with which you use it.
- Every component must have a working load limit (WLL) that exceeds the weight of the heaviest load you lower.
    - You must take into account reductions for knot strength with fiber ropes and must apply a 10-to-1 safety design factor for all fiber ropes.
- If you run the braking device, you must be able to slow down, speed up, or stop the movement of the load at any time.
    - Controlling the speed of the load is necessary for accurately moving material while maintaining the safety of your crew.
- If you hold the rope (whether on a Port-A-Wrap or a capstan), you must be able to control the heaviest load you move with an amount of pressure generated between the thumb and the forefinger of one hand.
    - While braking, you let the rope run through your loosely gripped hand. The braking device, not your strength, holds the load back. Controlling the speed with a minimal amount of pressure during normal travel helps to ensure you can handle unexpected dynamic loading.
- A braking system that depends on friction alone must dissipate the resultant heat so that the rope or braking device does not overheat.
    - Most commercial-work lowering devices take the need to dissipate heat into account. Design features—such as open-ended tubes, aluminum construction, and large-diameter wraps—all serve to dissipate heat and reduce line strain.
- If you operate the brake, you must maintain the safest working position possible.
    - The lead rigger must set up the belay so that the belayer can view the rigging set (ideally in the loading and unloading zones) and communicate effectively with crewmembers while staying in the safest position possible. This position is usually located laterally from the spar tree, opposite the side on which the spar block hangs. Using an extra-long belay rope enables the belayer to stand farther away from the rigging.
- The braking configuration must run in line with the rigging configuration. You should not pull a load to the side to control its movement.
    - You are usually located laterally and some distance away from the spar tree. If the braking line runs directly from the braking device to the load, the load will pull to the side and the braking line will probably bend around obstacles (such as trees and rocks) as the load moves down the skyline. Therefore, place a directional block on the spar tree used for the hoist rigging. The braking line runs from your hands (if you are operating the brake), through the braking device, over to the directional block on the spar tree, and down to the load. This method ensures that the braking line and the main rigging line run parallel. The load does not pull to the side, and the braking line remains clear of obstacles.
- If you operate the brake, you must maintain at least an arm’s length from the braking device. You must also stand so that the rope cannot pull your hand into the lowering device if you inadvertently grip the rope rather than letting it slide through your fingers.



Chapter 15: Rigging Safety

The physics of rigging involves work with powerful forces. Using mechanical advantage can significantly multiply any force applied by a power source. You must control the energy from a power source to maintain safety on the worksite and must understand every aspect of the system, including individual pieces of equipment, the physical environment, and human factors. This chapter describes some of the equipment, practices, and protocols that promote safety and mitigate risks at a rigging site.

Safe Work Practices

Safe work practices involve the preparations riggers should take before beginning work at a site. These are the first steps toward preventing accidents.

Training

Lead riggers must ensure that all people involved in rigging operations are trained for their duties. Climbing and saw operations require formal certifications; only certified riggers can perform these operations. The Forest Service does not currently require certification for rigging. It is the responsibility of the lead rigger to provide all on-the-job training and to follow up on all delegated tasks.

Personal Protective Equipment

All riggers should be aware of the personal protective equipment (PPE) required and documented on the job hazard analysis (JHA). Additionally, we recommend that all equipment operators wear high-visibility clothing to facilitate better communication between the lead rigger and members of the rigging crew.

Safe Project Management

Safe project management is an ongoing process that addresses behavior at the worksite. The lead rigger must constantly monitor the safety of the rigging crew, but all crewmembers play an integral part in the safety of the operation. Revise and adjust rigging operations as needed to ensure the safety and well-being of all rigging crewmembers.

Crew Communication (Chain of Command)

Only one person can be in charge on a rigging project. Although any crewmember can and should declare an emergency stop or lookout situation, the lead rigger directs the entire operation. Rigging operations often spread out over considerable distances. Normal voice communication can be difficult because of vegetation or background noise, such as flowing water. The lead rigger must decide whether to use voice, radio, or hand signals. The lead rigger must be in position to see both the load and the crewmembers whenever possible. On a complex rigging operation, four to six crewmembers may operate equipment concurrently. Whether the lead rigger uses voice, radio (when available), or hand signals, all crewmembers must know, understand, and practice the communication method used. Unless someone declares an emergency stop (hold), all crewmembers must follow the directions of the lead rigger alone. Trained crewmembers remain silent and do not interfere with the directions of the lead rigger.

Voice, Radio, or Hand Signals

One technique we have used successfully to communicate verbally is to assign a name and number (e.g., hoist operator 1) to each crewmember operating a winch or braking device. The lead rigger should draw on a notepad the system layout with corresponding numbers and keep it onhand for quick reference (in wet conditions, we have used ink to sketch on the back of our hands or gloves). If, for example, hoist operator 1 needs to take in line (called "tensioning"), the lead rigger would say, "hoist 1, tension." Hoist operator 1 would repeat the command in the present tense to the lead rigger, "tensioning," and immediately execute the command. The hoist operator must continue with the command until the lead rigger gives him or her another command. If, at the same time, hoist operator 2 needs to let out cable (called "slacking"), the lead rigger would say, "hoist 2, slack." Hoist operator 2 would repeat back, "slacking," and immediately execute the command. After identifying the specific operator, the lead rigger can use other commands, such as "slower," "hold," or "8 feet," to coordinate rigging movement. If a braking system is in place, the lead rigger names the rigging crewmember "belay," and the number assigned corresponds to the hoist number connected to that braking system. For example, belay 1 would lower the load for hoist 1 and belay 2 would lower the load for hoist 2.

When using radios, it is helpful to clip a microphone to the crewmember or place the radio around the crewmember's neck. Because communication is so critical for a safe and efficient rigging operation, crews should keep an ample supply of replacement batteries on hand.

Hand signals work well for finishing work when crewmembers are located near each other. Although the lead rigger is close enough to issue voice commands, the crewmember can respond more quickly to a hand signal. Some crewmembers like to use hand signals in combination with verbal signals because hand signals provide eye-to-eye contact between a lead rigger and a crewmember. Common hand signals used in winching operations include the arms crossed in front of the body for "hold," a rotating finger pointing down for "slack," and an arm pointing up in a cranking movement for "tension." Crewmembers may use any hand signal on which all crewmembers agree. It is important when using hand signals for crewmembers to keep an eye on the lead rigger instead of the load.

Equipment Inspection

Inspect all equipment and components daily for wear, damage, and maintenance requirements. Be familiar with a manufacturer's wear indicators and recommendations about when to remove components from service.

Marking Equipment

Developing a marking scheme for tools and equipment is a good idea. This scheme is especially important when you use equipment from a variety of sources. In addition to identifying ownership, spray painting small components (such as clevis or block pins) makes them easier to see when you drop one.

Immediately tag as unserviceable all equipment and components removed from service. We recommend spray painting a black "X" on any item you should throw away. If you must throw away an item, make it unserviceable first so that no one can remove it from the trash and use it again.

Equipment Failure

Whenever possible, take steps to reduce potential hazards caused by equipment failures. For example, place a jacket or a rubber mat (or some other material) midway between components to serve as a snubber (a device that reduces the recoil of a broken line under tension). The snubber reduces the violent release of energy, mitigating some of the danger should the line break.

Safe Working Positions

When you operate equipment, situate yourself to minimize the possibility of injury if any component of the system fails. You should not be in the bight of any line nor situated in front of or beneath any hazardous tree or rock. Failed rigging does not always travel in a predictable, straight line. Anyone not specifically required to move a load must be clear of the area before you raise the load. This safety precaution is especially important when you load material at the lower end of an uphill haul using a skyline configuration. Crewmembers unhooking a load must remain in the clear until the load is on the ground before they approach it. Crewmembers are not permitted directly below the fall line of the load. Crewmembers operating equipment must use a change-of-direction block to ensure compliance. All crewmembers must plan for and create an escape route.

Attaching a Load

Only the lead rigger or most experienced rigger should secure a load for lifting or skidding. The rigger must carefully analyze the placement of chokers or slings, especially when lifting rocks, to ensure that the center of gravity is situated correctly. The center of gravity is the spot where the weight of the load is concentrated. As long as a rigger rigs a load directly above its center of gravity (balance point), the load should be stable. Finding the center of gravity for loads, such as oddly shaped rocks and forked tree stems, and then setting slings so that they are directly above that balance point, takes experience and sometimes an adjustment or two. Take the necessary time to attach loads properly and securely, because an unbalanced load has a tendency to shimmy and bounce around during transport. Aside from increased susceptibility to falling out of the slings, a bouncing load creates dynamic tension (shock loading), which considerably increases the forces on the rigging system.

Leaving Equipment at the End of the Day

Lower all loads at the end of the workday. When suspended lines are within 12 feet of the ground, you must also lower the lines to the ground. This requirement is especially important along trails where mounted riders could run into a line they don't see. Secure all lowered lines on one end; deer or other large animals can drag a light line or rope for some distance with their feet.

Some crewmembers have adopted the practice of lightly tensioning a system overnight and taking away the winch handle so that no one can tamper with the system (aside from cutting a sling). When doing this, verify that no load is on the wire rope, that you have removed all travel blocks and wrapped the winch in a tarp, and that the wire rope is high enough not to create a hazard. Take care not to over-tension the system and strain the anchor and spar points needlessly.

Related Agency Policies

All tree-climbing activities, helicopter operations, and the use of chain saws and crosscut saws require special training and certification. Although many different regulations apply to rigging methods, the OSHA Logging Standard is the most relevant for trail rigging operations. Many States have additional OSHA-type logging regulations. You must use the more stringent of the Federal or State standards for your location.

Job Hazard Analysis

Most Federal and State land management agencies and many trail organizations have a formal JHA or risk analysis riggers must complete before they begin work. This process requires the person who prepares the JHA to identify the tasks, the hazards associated with all aspects of the tasks, and the actions necessary to reduce or mitigate the hazards.

The person preparing the JHA must also reference published agency direction and national health and safety standards, such as the Occupational Safety and Health Administration's. The JHA must include required PPE. A responsible official signs the JHA and carefully assesses the skill and qualifications of crewmembers on the ground. If a crew supervisor has limited rigging experience, the JHA must identify mitigation measures the crew must take to ensure safe working conditions. One measure may be to use an experienced rigger to perform the actual work. The crew supervisor should consider assigning skilled workers, such as engineers, heavy equipment operators, timber sale administrators, or others with related yet nonspecific rigging backgrounds. With their backgrounds, these skilled workers should be able to research and secure adequate equipment and apply rigging techniques in a safe manner. Most volunteers or Forest Service crews have limited experience and no formal training as trail crew supervisors; they are not qualified to handle any aerial rigging projects. The main thing to keep in mind is that the responsible official is certifying an awareness of the risks of the work and attesting that adequate equipment and skills are available to accomplish the task safely.

Tailgate Safety Session

At the start of each workday, each crew must discuss likely hazards and the techniques for mitigating these hazards. This discussion serves as a reminder to everyone to work safely. Because many accidents occur later in the day, the crew should conduct an informal discussion after lunch to review what happened during the morning and to reinforce the need to stay alert and be safe.

After-Action Review

At the end of each day, crews should review the day's events, cover any safety concerns, discuss what went well and what did not go as planned, and consider alternatives and better ways to accomplish certain tasks. The point is not to criticize but to improve job safety and efficiency for the next day.

First Aid Kit

At a minimum, crews should have an OSHA Type IV first aid kit available onsite. Along with the standard medical kit equipment, the first aid kit should contain the following information:

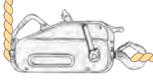
- The level of training for each crewmember (basic first aid, emergency medical responder, emergency medical technician, paramedic, etc.)
- A designation of the lead medical resource (the crewmember with the highest level of medical training who will take charge in the event of an accident or injury)
- The pertinent medical history of each crewmember (diabetes, allergy to stings, etc.)
- The emergency contact information for each crewmember

Rigging crews should keep this history in a sealed envelope and only open it in the event of an emergency.

Emergency Communication and Evacuation Plan

The Forest Service requires an emergency action plan, including a communication plan, for all rigging projects. The emergency action plan complements the JHA, and crews must update it as rigging locations change. It is critical in an emergency that all crewmembers thoroughly understand the emergency plan. The plan must describe the worksite's longitude, latitude, a legal description of the project, and the designated helicopter landing area. The plan must also contain a map and description of the route to the nearest hospital, phone numbers, radio contacts, and radio frequencies. Each crewmember must know the location of the plan and the first aid kit.

Each crewmember must understand and demonstrate the use of all communications equipment on the rigging site. This equipment includes radios, cell phones, and satellite phones.



Chapter 16: Conclusion

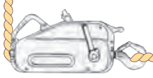
Our goal in this manual has been to present practical rigging knowledge and applications you can use to accomplish backcountry rigging projects safely. Based on our familiarity with numerous disciplines that use various rigging techniques, we have attempted to capture the most important aspects of rigging for backcountry applications. This manual covers traditional tools and methods, as well as modern equipment, materials, and approaches. Using a combination of these diverse techniques and components, you will best be able to undertake unique and often complex backcountry challenges.

Although it is impossible to discuss every potential rigging scenario, we have attempted to convey—through text and illustrations—that you should consider even simple rigging projects as a complex system made up of a number of subsystems and components. You must be able to understand the principles of force and how a change in angles can significantly affect the load on components.

In closing, we wish to reinforce the need for good planning and the use of only quality-rated components. You must know the rating for each clevis, block, sling, and line. Additionally, you must understand the variable strength of trees, soils, and rocks to withstand the forces exerted on them. Lastly, competent riggers understand the limits of their own knowledge and readily seek out and collaborate with other professionals to ensure safety. In order to rig safely, it is imperative to understand, even see in your mind's eye, the direction and maximum magnitude of each potential force.

> **Only those who can see the invisible can do the impossible.**
>
> —Albert Einstein

Notes



Glossary of Rigging Terms

A-frame—A triangle-shaped structure constructed of two independent poles fastened at the top, separated at the bottom to provide stability, and used to support a spar block in rigging.

anchor—Any natural or manmade object that has greater holding power than the load placed on it, providing a terminal attachment point for lines or block slings.

anchor log—A log buried in the earth to firmly hold a guy line. Also called a deadman.

back guy—A guy line attached to the back of a spar, opposite the lead of the mainline or skyline. It opposes most of the pull when moving logs.

back splice—An end treatment in lay rope where strands are tucked back, preventing raveling and creating a cylindrical, enlarged end for better grip.

basket hitch—A sling configuration where the sling passes beneath the load and both ends, end attachments, eyes, or handles of the sling attach to a hook or a single master link.

belay—To wind or make turns with a running line around a belaying pin or cleat to secure or stop a load.

belaying pin—A pin or rod (typically made of wood or metal) inserted into a hole to secure ropes that carry a load.

bell—The socket that slides back and forth on the choker cables between the eye and the knob. The knob (or nubbin) hooks into the bell to choke the load.

bight—Primarily, a bend or loop in a rope. Riggers also use the term to describe the hazardous zone created by angled lines under tension.

block—A metal case (shell) enclosing one or more pulley sheaves and containing a hook, swivel, or gooseneck that attaches to an object. Riggers describe blocks according to their use, such as guy line blocks, corner blocks, tail blocks, and moving blocks.

block and tackle—The prestrung assembly of one or more blocks that use rope to provide mechanical advantage for moving heavy loads by one or more riggers.

blowdown—A tree or stand of timber blown down by the wind.

braided wire rope—A wire rope formed by interlacing component wire ropes.

braided wire rope sling—A sling made from braided wire rope.

bridle—A length of line or chain fastened at the ends so that a rigger can attach another line or chain to its middle or bight.

cable clip (or clamp)—A fitting, usually used in a series, for clamping two parts of a wire rope.

cable cutter—A physical, mechanical, or hydraulic tool that cuts wire rope.

cableway—An aerial system for moving single loads along a suspended line.

capstan—A revolving, spool-shaped drum, generally used for controlling the movement of a fiber rope.

carriage—A device on an aerial configuration that forms a connection between the load and traveling blocks. Riggers can connect multiple lines to the device. Trail rigging carriages are often simple metal plates with holes that accept clevises.

choke—To pass a line, sling, or choker around an object and pull it tight.

choker—A wire rope used to choke logs. Also, the configuration of a sling when it is set to choke (see “choke”).

choker hitch—Loading with a sling passed through one end attachment (eye or handle) and suspended by the other.

choker hook—A hook-shaped sliding attachment on the bight of a choker.

choker rope—A short, wire rope sling riggers use to form a slip noose around an object they are moving or lifting.

clevis—A U-shaped fitting with a pin (a type of shackle).

climbing irons or climbing spurs—Irons with sharp spurs that riggers strap to their legs below the knees and at the ankles when climbing trees.

dampener—A fabric or rubber device placed over a line under tension to reduce the risk of possible injury by significantly reducing the recoil of a broken line and absorbing the energy (also called a “snubber”).

deadman—See “anchor log.”

deflection—The amount of sag at the midpoint of a suspended wire rope anchored at both ends (often called “the sag”).

directional block or lead block—A block riggers use to change the direction of a line pull.

dynamometer—A device used for measuring force, torque, or power.

extension—A line, usually with eyes on each end, that riggers add to another line to make it longer.

eye—A loop, with or without a thimble, formed at the end of a rope.

factor of safety—See “safety design factor.”

fair lead—Rollers, pulleys, or guides arranged to enable riggers to spool cable neatly onto a drum. Often found on chain saw winches.

farmer’s eye—An eye splice formed by separating cable strands and rerolling them to form an eye. A fast, temporary splice used in emergencies.

ferrule—A metal sleeve or collar (also called a “knob”) hydraulically pressed onto the ends of a section of wire rope to make a choker. Also used to make eyes in the wire rope by bending the wire rope back and securing the rope together using a sleeve.

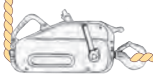
fly zone—The area within which a tensioned rope or components can move if there is a component or system failure.

guy line—A line or cable used to steady or swing a boom or spar and to counterbalance forces.

hang a block—To place a block in position.

hangup—Logs stuck behind a stump or other obstacle when riggers are pulling the logs.

haulback block—A block through which the haulback line runs.



haulback line—A wire or fiber rope used as a brake or pulling line that controls the mainline and rigging carriage.

high lead—An aerial rigging system that provides directional and lifting force using a line that runs from a power source through an elevated block and down to a load.

highline—A general term riggers use in various contexts to describe many different aerial rigging configurations. Riggers often use this term to describe a live skyline.

hockle—The spreading and kinking of yarns in a rope strand that result from twisting during use.

hoist—A general term that refers to a mechanical device used to increase or decrease the tension of a synthetic or wire rope in either a vertical or horizontal orientation.

jagger—A broken strand on wire ropes that sticks out and can cut hands or clothing.

kink—A sharp bend in a wire rope that permanently distorts the wires and strands.

knob—A choker ferrule hydraulically pressed onto the end of a wire rope.

lang-lay rope—Wire rope in which the wires in the strands and the strands in the rope are laid in the same direction as the lay of the strands.

lay—The manner in which wires are helically laid into strands or strands into rope.

line—Wire or fiber rope.

mainline—The line that moves the load when power is applied. The mainline can pull or lower the load and on occasion can double as a haulback line.

master link (gathering ring)—A forged or welded steel link used to support all members (legs) of an alloy steel chain or wire rope sling.

mechanical advantage (MA)—The ratio by which a machine multiplies the force applied to it in order to lift or move a load.

mechanical link coupling (alloy steel chain)—A nonwelded, mechanically closed link used primarily to attach master links, hooks, etc., to running length alloy steel chain.

Molly Hogan—A single strand of wire rope rolled into a circle with six wraps. Riggers can use it to temporarily connect the eye splices of two lines. Riggers also use a Molly Hogan in some pin shackles in place of a cotter key.

pass block—A specialized block with an oversized bail and a wide sheave that allows thimble eyes and shackles to pass through.

port-a-wrap—A device that operates on the capstan principle to control the lowering of objects.

purchase—Obtaining additional pull by using lines and blocks.

purchase block—A block configuration riggers use to obtain mechanical advantage on a line.

proof test—A nondestructive tension test the sling manufacturer (or equivalent entity) performs to verify the construction and workmanship of an individual sling.

raising line—The cable used to raise an A-frame or spar off the ground.

regular-lay rope—Wire rope in which the wires in the strands are laid in the opposite direction of the lay of the strands.

rigging—All lines, blocks, hooks, chokers, carriages, etc., used to transport material.

rigging block—A light block hung in a spar to help a climber pull up heavier rigging equipment.

roll—A choker hold on a log that causes the log to roll in the desired direction when the line tightens.

rotation-resistant wire rope—Wire rope constructed of left lang and right regular lays that reduce the spin of suspended loads.

running block—A single sheave block with a load hook at the bottom traveling along a line.

running line—A moving synthetic or wire rope.

safety design factor—The ratio between the ultimate strength of a rope and its actual recommended load (also referred to as the design factor).

safe working load (SWL)—The maximum load the manufacturer recommends. Often used for nonrigging-related equipment (see "working load limit").

safe working position—Any position where crewmembers are unlikely to be injured in the event of a system failure.

seize—Securely binding the ends of a wire rope to prevent unraveling.

seizing wire—A small-diameter, easily bent wire that riggers use to seize wire rope.

shackle—A U-shaped fitting with a removable pin used to connect two components (see "clevis").

sheave—A grooved pulley inside a block used with a rope.

shell—The outer framework of a block.

skid—To drag a load along the ground.

skyline—A suspended line that riggers use to support and, along with another line, help move a load in an aerial rigging configuration.

slack—To ease up on or pay out a line.

sling (braided)—A flexible sling composed of several individual wire ropes braided into a single sling.

slings—An arrangement of ropes, chains, or synthetic materials made into forms (with or without fittings) that handle loads and enable riggers to attach an operating line.

snatch block—A specialty block that opens, allowing riggers to place a bight of line over the sheave.

snubber—See "dampener."

socket—A type of wire rope end fitting.

spar—A tree (or mast) on which rigging hangs to provide a lifting force in aerial system configurations.

spar block—A block slung high in a tree or otherwise situated to provide a lifting force in a system.

splicing—Interweaving two ends of ropes to make a continuous or endless length without appreciably increasing the diameter. Also, making a loop or eye in the end of a rope by tucking in the ends of the strands.

strand—An arrangement of wires helically laid about an axis, or another wire or fiber centered to produce a symmetrical section.

strand-laid rope—A wire rope made with strands (usually six or eight) formed around a fiber core, wire strand core, or independent wire rope core (IWRC).

strap—A short length of cable with an eye in each end.

swaged fittings—Fittings into which wire rope is inserted and attached using high-pressure hydraulic methods.

swivel—A universal joint used to prevent lines from twisting.

tagline—A length of small line used as a guide or to steady or control the position of a load.

tailhold—An anchor point for the dead end of a purchase line or rigging assembly.

tension—Apply force to a line.

thimble—A metal fitting, semicircular in cross section, that fits within an eye splice and protects the rope from chafing.

thread—Pull a line through a block.

trolley—See “carriage.”

twister—A method of twisting a line with a pole to increase tension on the line. For example, if a tailhold does not appear to be strong enough, it should be tied back to another stump (or stumps) by use of a length of line and a twister pole.

vector—A mathematical term used to describe the physical quantity of force that has both magnitude and direction.

wedge socket—Any wire rope fitting that uses a wedge to secure the rope.

winch—A general term that refers to a mechanical device used to increase or decrease the tension of a synthetic or wire rope in a relatively horizontal direction.

wire rope—A plurality of metal strands laid helically around an axis or a core.

working load limit (WLL)—The maximum capacity of a component recommended by the manufacturer. For recognized rigging equipment, this usually includes a safety factor of 5 to 1.

wrap—A turn of line around an object, such as a stump or winch drum.

yarding—A logging term that means “to pull logs” using either aerial or ground configurations.

Acronyms

CFR—Code of Federal Regulations

EEIPS—extra extra improved plow steel

EIPS—extra improved plow steel

FC—fiber core

g—grade

HMPE—high-modulus polyethylene

HPPE—high-performance polyethylene

IPS—improved plow steel

IWRC—independent wire rope core

JHA—job hazard analysis

kg—kilograms

kN—kilonewtons

MBS—minimum breaking strength

OSHA—Occupational Safety and Health Administration

PPE—personal protective equipment

PS—plow steel

PVC—polyvinyl chloride

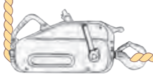
SWL—safe working load

UHMW (or UHMWPE)—ultra-high molecular weight polyethylene

UV—ultraviolet

WLL—working load limit

WSC—wire strand core



Selected References and Additional Resources

The following references and resources provide additional information about rigging.

References

Ashley, C.W. 1944. The Ashley book of knots. New York, NY: Doubleday and Company. 619 p.

Beckley, B. 2005. Portable backcountry rigging tripod. Tech. Tip. 0523–2341P–MTDC. Missoula, MT: U.S. Department of Agriculture, Forest Service, Missoula Technology and Development Center. 6 p.

Binkley, V.W.; Sessions, J. 1983. Chain and board handbook for skyline tension and deflection. Washington, DC: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region. 80 p.

Broderick and Bascom Rope Company. 1982. Rigger's handbook: yellow strand wire rope slings. 11th edition. St. Louis, MO: Broderick and Bascom Rope Company. 220 p.

Committee of Wire Rope Producers/American Iron and Steel Institute. 1979. Wire rope user's manual. Washington, DC: Committee of Wire Rope Producers/American Iron and Steel Institute and the Wire Rope Technical Board. 128 p.

Cordage Institute. 2004. Fiber rope inspection and retirement criteria. International Guideline CI 2001-04. Wayne, PA: Cordage Institute <https://ropecord.com/product/ci-2001/>. 67 p.

Cordage Institute. 2006. Safer use of fiber rope. International Guideline CI 1401-06. Wayne, PA: Cordage Institute. 1p.

Donzelli, P.S.; Lily, S.J. 2001. The art and science of practical rigging. Champaign, IL: International Society of Arboriculture. 172 p.

Food and Agriculture Organization of the United Nations. 1982. Basic technology in forest operations. Forestry paper 36. Rome, Italy: Food and Agriculture Organization of the United Nations <https://archive.org/details/basictechnologyi034660mbp>. 145 p.

Foster, G.P.; McKenna, H.A.; Monaco, A. 1997. Fiber rope technical information and application manual. 2nd edition. CIB, 1.4. Hingham, MA: Cordage Institute, Technical Information Service. 130 p.

Jepson, J. 2000. The tree climber's companion: a reference and training manual for professional tree climbers. 2nd edition. Longville, MN: Beaver Tree Publishing. 104 p.

Job Training Systems, Inc. 1997. Basic rigging administrative guide. Course no. 161. Unionville, PA: Job Training Systems, Inc.

Klinke, J. 2012. Rigging handbook: the complete illustrated field reference. 4th edition. Stevensville, MI: ACRA Enterprises. 256 p.

Lansky, M. (editor). 2003. Low-impact forestry: forestry as if the future mattered. Hallowell, ME: Maine Environmental Policy Institute. 178 p.

Leach, R. 1955. Riggers bible: a handbook of heavy rigging. Springfield, MO: Roark Printing. 144 p.

McDonald, J.A.; Rossnagel, W.E.; Higgins, L.R. 2009. Handbook of rigging: for construction and industrial operations. 5th edition. New York, NY: McGraw-Hill Book Company. 792 p.

McGonagill, K.L. 1978. Logging systems guide. Series No. R10-21. Juneau, AK: U.S. Department of Agriculture, Forest Service, Alaska Region, Division of Timber Management. 370 p.

Shapiro, L.K.; Shapiro, J.P. 2010. Cranes and derricks. 4th edition. New York, NY: McGraw-Hill Co.

Simmons, F.C. 1951. Northeastern loggers' handbook. Agriculture handbook no. 6. Washington, DC: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 160 p.

Studier, D.D.; Binkley, V.W. 1974. Cable logging systems. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region, Division of Timber Management. 221 p.

Telleen, M. 1977. The draft horse primer: a guide to the care and use of work horses and mules. Emmaus, PA: Rodale Press. 400 p.

Toss, B. 2016. The complete rigger's apprentice: tools and techniques for modern and traditional rigging. 2nd edition. Camden, ME: International Marine/Ragged Mountain Press. 432 p.

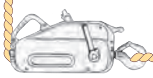
U.S. Department of the Army. 1968. Rigging. Technical manual 5-725. Washington, DC. Available at <http://www.jatonkam35s.com/DeuceTechnicalManuals/Tm5-725-Rigging.pdf>. 136 p.

U.S. Department of the Army. 2001. Rigging techniques, procedures, and applications. Field manual 5-125. Washington, DC. Available at <http://www.marines.mil/Portals/59/MCRP%203-17.7J%20With%20Ch.%201%20z.pdf>. 169 p.

U.S. Navy. 1999. Naval ships' technical manual, chapter 613, wire and fiber rope and rigging. Naval Sea Systems Command. 126 p.

U.S. Steel Corporation, Columbia–Geneva Steel Division. 1959. Wire rope handbook for western wire rope users. San Francisco, CA: U.S. Steel Corporation, Columbia–Geneva Steel Division. 194 p.

Workers' Compensation Board of British Columbia. 1981. Yarding and loading handbook. 2nd edition. Vancouver, BC: Workers' Compensation Board of British Columbia. 188 p.



Additional Resources

The following is a sample of vendors who supply equipment related to rigging operations. The list is not comprehensive and the authors provide it only for the convenience of the reader. This list does not constitute an official endorsement by the Federal Government or the approval of any product or service to the exclusion of others that may be suitable.

Selected Rigging Equipment Vendors

Acme Rigging and Supply Company

3350 North State Street
Ukiah, CA 95482
Phone: 707–462–0567
Phone: 800–862–4639
<http://www.acmerigging.com>

Acme Rigging and Supply Company manufactures and sells (retail) nylon slings, synthetic winch lines, wire rope, chain and other rigging equipment. They also custom-fabricate slings.

Klein Tools

450 Bond Street
Lincolnshire, IL 60069
Phone: 800–553–4676
<http://www.kleintools.com>

Klein Tools manufactures tools and occupational protective equipment for lineman, tree workers, and others. They are a good source for wire rope grippers.

Lift-All

1909 McFarland Drive
Landisville, PA 17538-1810
Phone: 717–898–6615
Phone: 800–909–1964
<http://www.lift-all.com>

Lift-All manufactures fabric, wire rope, chain, and metal mesh slings.

Master Pull, LLC

5215 Industrial Place
Ferndale, WA 98248
Phone: 360–714–1313
Phone: 877–797–0202
<https://www.masterpull.com/>

Master Pull, LLC, manufactures rigging supplies, such as lightweight snatch blocks and abrasion-resistant synthetic ropes.

Meader Supply Corporation

23 Meaderboro Road
Rochester, NH 03867-4265
<http://www.meadersupply.com>

Meader Supply Corporation sells (retail) a complete line of draft harness and other equipment.

SherrillTree

200 East Seneca Road
Greensboro, NC 27046
Phone: 336–378–0444
Phone: 800–525–8873
<http://www.sherrilltree.com>

SherrillTree sells (retail) and provides information about lightweight recreational and professional tree rigging and climbing gear.

The Cordage Institute

994 Old Eagle School Road, Suite 1019
Wayne, PA 19087
Phone: 610–971–4854
<http://www.ropecord.com>

The Cordage Institute is a nonprofit corporation comprised of fiber rope and cordage manufacturers, producers, and resellers. They publish documents (available on their website) about safe rope use and care. They also have a technical committee that is involved with the development of standards and guidelines.

The Crosby Group
2801 Dawson Road
Tulsa, OK 74110
Phone: 918–834–4611
Phone: 800–772–1500
<http://www.thecrosbygroup.com/>

The Crosby Group manufactures heavy-lifting rigging products, including wire rope blocks, slings, and chain. They are also a source for information about rigging.

Trail Services, LLC
15 Westwood Road
P.O. Box 8057
Bangor, ME 04402
Phone: 207–947–2723
<http://www.trailservices.com>

Trail Services, LLC, sells (retail) many hard-to-find tools, including Griphoists, rock drills, and handtools. They also provide tool training and consulting services.

WesSpur Tree Equipment, Inc.
2121 Iron Street
Bellingham, WA 98225
Phone: 360–734–5242
Phone: 800–268–2141
<http://www.wesspur.com>

WesSpur Tree Equipment, Inc., is a large arborist and tree care supplier and a good source for information about tree care.

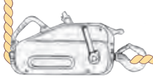
Wood’s Logging and Industrial Supply
702 Industrial Way
Longview, WA 98632
Phone: 360–577–8030
<http://www.woodsindustrialsupply.com>

Wood’s Logging and Industrial Supply is a full wire rope rigging fabricator and supplier of domestic and imported products. They are also a source of climbing gear and logging clothing and accessories.

Selected Trail-Related Equipment Vendors

Bailey’s, Inc.
1210 Commerce Avenue, Suite 8
Woodland, CA 95776
Phone: 800–322–4539
<https://www.baileysonline.com/>

Forestry Suppliers, Inc.
205 West Rankin Street
P.O. Box 8397
Jackson, MS 39284-8397
Phone: 800–647–5368
<http://www.forestry-suppliers.com/>



Appendix A: Terminating and Managing Wire Rope

Cutting Wire Rope

You usually cut wire rope with an abrasive wheel or a cutting torch. However, riggers in the field often cut wire rope with a guillotine or hydraulic cable cutter. Before cutting, you must properly seize the wire rope on each side of the cut using a soft wire (see figure 3–7). This seizing binds the strands together and protects the integrity of the wire rope construction when you cut it. Space the two seizings six rope diameters apart; each seize should be as long as the diameter of the rope. Use tape as a substitute if small-diameter wire is not available.

To cut wire rope safely:

- Always wear safety goggles (including all helpers).
- Place a guillotine cutter on a stump (rather than a hard surface, like a rock) to prevent the cutter from bouncing.
- Stand on the closed side of the guillotine when striking the rope.
- Keep the cutting blade in the same position to avoid making multiple cuts and to prevent pieces of wire from flying off.
- Never strike the guillotine hard when the wire rope is nearly severed (to avoid damaging the cutter blades).

Terminating Wire Rope With Clips

Only use thimbles and wire rope clips that are sized for the wire rope on which you work. Use the information in table A-1 to determine the correct number, spacing, and tightening torque of wire rope clips for the type of wire rope you use.

Never orient the nuts and saddle side of the wire rope clips on the dead (cut) end of the wire rope, as shown in figure 7–12. One way to remember this is to use the mnemonic, “Never saddle a dead horse.”

Tighten each wire rope clip to the torque listed in tables A–1 and A–2. Only tighten to the point where the wire rope begins to flatten, but before it deforms.

Notes:
Wire rope clips are about 80-percent efficient.

Torque the clips to the required tension, place the clips under an operational load, and retorque.

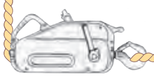
The Bethlehem wire rope general-purpose catalog has tables similar to tables A–1 and A–2, as do the Crosby Group publications “Crosby Clips” and “Pocket Reference,” compiled by Thomas Glover.

Table A–1—U-bolt cable clips for wire rope

Wire rope and clip size (inches)	U-bolt diameter (inches)	Number of clips	Clip spacing (inches)	Loop length (inches)	Bolt torque (foot-pounds)
1/4	5/16	2	2 3/8	4 3/4	15
5/16	3/8	2	2 5/8	5 1/4	30
3/8	7/16	2	3 1/4	6 1/2	45
7/16	1/2	2	1/2	7	65
1/2	1/2	3	3 3/4	11 1/2	65
9/16	9/16	3	4	12	95
5/8	9/16	3	4	12	95
3/4	5/8	4	1/2	18	130
7/8	3/4	4	5 1/4	19	225

Table A–2—Double-saddle fist-grip clips for wire rope

Wire rope and clip size (inches)	Nut size or stud diameter (inches)	Number of clips	Clip spacing (inches)	Loop length (inches)	Bolt torque (foot-pounds)
1/4	3/8	2	1 7/8	4	30
5/16	3/8	2	2 1/8	5	30
3/8	7/16	2	2 1/4	5 1/4	45
7/16	1/2	2	2 5/8	6 1/2	65
1/2	1/2	3	3	11	65
9/16	5/8	3	3 3/8	12 3/4	130
5/8	5/8	3	3 3/4	13 1/2	130
3/4	3/4	3	4 1/2	16	225
7/8	3/4	4	5 1/4	26	225



Appendix B: Rope Log

Inspect rope for damage or excessive wear each time you use it and immediately retire all suspect ropes.

Rope log (usage and history) Unit identification marking

Manufacturer Vendor

Model Date of manufacture

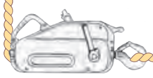
Date in service Diameter Fiber Rope color

Construction Length Bag color Minimum breaking strength

Log the relevant information for each rope below. Under “Rope condition and comments,” include information such as the function of the rope in the rigging system (belay, skyline, mainline), whether the rope had a knot, whether it passed through blocks or a capstan, etc.

Date used	Location	Type of use	Possible damage	Inspector’s initials/date	Rope condition and comments

Notes



Appendix C: Material Weights

Determine the weight of the load during the system planning stage. In practice, you usually have two sizes of components: one size for normal rigging applications and a second, larger size of components rated for heavy lifting. The amount of force that the load exerts on the rigging components is more important than the actual weight of the load. For this reason, be conservative when calculating and rounding the weight figures. Load weights become much more important when the system contains weaker components, such as a small-diameter chain saw winch cable or sized soil anchors.

Log Weights

Woodweb, <http://www.woodweb.com/cgi-bin/calculators/calc.pl?calculator=log_weight> a website that provides woodworking industry information, has a calculator for estimating wood weights. However, you can use some shortcuts in the field to estimate log weight.

The standard formula for calculating log weight is:

(radius^2 – inches) (π) (length – feet) (density ÷ cubic foot) ÷ 144 = log weight

There is also an alternate (and simpler) way to approximate the weight. The answer will always be slightly more than the true weight, but within 2 percent.

Approximating log weight using a density of 60 pounds per cubic foot:

Log diameter (inches) × log diameter (inches) × log length (feet) ÷ 3 = log weight

For a log density of 50 pounds per cubic foot, divide by 3.6 instead of 3.

For a log density of 40 pounds per cubic foot, divide by 4.5 instead of 3.

Because water has a density of 63 pounds per cubic foot, any log that floats has a density less than water. For quick calculations, it is handy to use 60 pounds per cubic foot for logs. Because many logs fall within the range of 40 to 50 pounds per cubic foot, this simply increases the safety factor and eliminates any need to guess how dry a log is or to consider its species. Pressure-treated poles require different calculation formulas, as do logs that have been immersed in water for long periods.

Table C-1 provides weights for some common materials (other than logs) found in trail rigging operations.

Table C-1—Weights of materials commonly found in trail rigging operations (N/A = not applicable)

Material	Type	Pounds per cubic foot
Basalt	Solid	173
Basalt	Crushed	122
Clay	Excavated, dry	68
Clay	Excavated, wet	114
Clay	Naturally compacted	109
Clay and gravel mix	Dry	100
Clay and gravel mix	Wet	114
Concrete	N/A	148
Soil (loam)	Excavated, dry	78
Soil (loam)	Excavated, wet	90
Granite	Solid	170
Granite	Crushed	100
Gravel (¼ inch to 2 inches)	Excavated, dry	105
Gravel (¼ inch to 2 inches)	Excavated, wet	125
Limestone	Solid	165
Limestone	Crushed	97
Sandstone	Solid	145
Sandstone	Crushed	94
Sand	Loose, dry	100
Sand	Loose, wet	130
Sand and gravel mix	Dry	108
Sand and gravel mix	Wet	125
Slate	Solid	168
Slate	Crushed	104

Calculations:

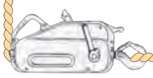
1 cubic yard = 27 cubic feet

Volume of a 5-gallon bucket = 0.67 cubic feet

1 cubic foot = 1,728 cubic inches

Weight per 5-gallon bucket = weight per cubic foot × 0.67

Volume of a sphere = 4/3 (π) radius^3



Appendix D: The Effects of Angles on Forces

A properly designed rigging operation can easily move large objects and significant weights. Understanding the relationship between angles and the forces encountered in a rigging operation is important for rigger safety. The analysis of supports and redirected force in rigging requires a basic understanding of trigonometry. Trigonometry is a branch of mathematics that deals primarily with the relationships between the sides and angles of right triangles (triangles that contain one 90-degree angle). Riggers use right triangles, through the lens of trigonometry, to describe as vectors the angles and forces typical in rigging work.

Introduction to Vectors and Trigonometric Functions

Vectors have **direction** and **magnitude**, represented by the lengths of the sides of a right triangle and the angles between the sides. The sides of the right triangle shown in figure D–1 have arrows at one end of each side to represent the direction of the vectors. The figure illustrates how you can add vectors in terms of lengths and angles (*a* + *b* = *c*). Note that diagrams often show vectors in bold print to indicate they have both a direction and a magnitude.

We labeled the sides and angles of the right triangle in figure D–1 according to a long-established convention. Conventionally, sides *a* and *b* (generally referred to as the legs of the triangle) are the two perpendicular sides that meet at the 90-degree angle of a right triangle. Side *c* (the hypotenuse) is the side opposite the right angle. Angle *A* faces side *a* and angle *B* faces side *b*. The right angle faces side *c*.

The trigonometric functions relate the ratio of any two sides of a right triangle to either of the angles that are **not** the right angle. Using the labels for the sides and angles from the triangle in figure D–1, we define the three common trigonometric functions as:

- The **sine** (sin) of angle ***A*** equals the length of side *a* divided by the length of side *c* (opposite side over the hypotenuse).
- The **cosine** (cos) of angle *A* equals the length of side *b* divided by the length of side *c* (adjacent side over the hypotenuse).
- The **tangent** (tan) of angle *A* equals the length of side *a* divided by the length of side *b* (opposite side over the adjacent side).

Written as mathematical formulas, these functions are:

$\sin(A) = a \div c$

$\cos(A) = b \div c$

$\tan(A) = a \div b$

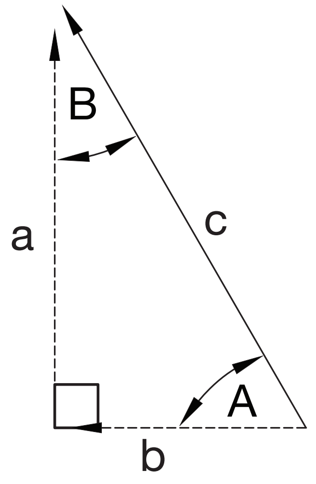


Figure D–1—A right triangle with conventional labels for the sides and angles.

Using the equations above, if you know the length of one side and at least one angle, you can determine all the remaining legs and angles of the triangle.

Examples:

$a = c \text{ x } \sin(A)$

$b = c \text{ x } \cos(A)$

$c = b \div \cos(A)$

$B = \cos\text{-}1(a \div c)$

$A = \tan\text{-}1(a \div b)$

$a = b \text{ x } \tan(A)$

There is a second trio of trigonometric functions that are the **reciprocals** of the first three and flip the ratios of the sides:

Cotangent (cot)

Secant (sec)

Cosecant (csc)

Cotangent is the reciprocal of the tangent; it is the ratio of the adjacent side to the opposite side in a right triangle.

Secant is the reciprocal of the cosine; it is the ratio of the hypotenuse to the side adjacent to a given angle in a right triangle.

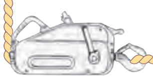
Cosecant is the reciprocal of the sine; it is the ratio of the hypotenuse to the side opposite a given angle in a right triangle.

Written as mathematical formulas, these functions are:

$\cot(A) = 1 \div (\tan(A)) = b \div a$

$\sec(A) = 1 \div (\cos(A)) = c \div b$

$\cos(A) = 1 \div (\sin(A)) = c \div a$



Again, if you know the length of one side and at least one angle, you can use these trigonometric functions to determine all the remaining legs and angles of the triangle:

$b = a \times \cot(A)$

$c = b \times \sec(A)$

$c = a \times \csc(A)$

Scientific calculators enable you to look up the sine, cosine, and tangent of any angle. Some calculators also offer cotangent, secant, and cosecant. For those that don't offer the latter functions, you can find them by calculating the corresponding function value and then pressing the "1/×" key. For example, applying the 1/× key to the cos() function results in cos-1() or sec(). After you determine the three legs of the triangle, we advise applying the Pythagorean theorem ($a^2 + b^2 = c^2$) to check the solutions. If the values you determined with the trigonometric functions hold true to the Pythagorean theorem, you made no computing errors and the values are correct.

Table D–1 lists values in 15-degree increments for the six trigonometric functions described above for angles from 0 to 90 degrees.

Table D–1—Trigonometric functions for angles from 0 to 90 degrees

Angle *A* (degrees)	sine *A* $= a \div c$	cosine *A* $= b \div c$	tangent *A* $= a \div b$	cotangent *A* $= b \div a$	secant *A* $= c \div b$	cosecant *A* $= c \div a$
0	0.000	1.000	0.000	Infinite	1.000	Infinite
15	0.259	0.966	0.268	3.732	1.035	3.864
30	0.500	0.866	0.577	1.732	1.155	2.000
45	0.707	0.707	1.000	1.000	1.414	1.414
60	0.866	0.500	1.732	0.577	2.000	1.155
75	0.966	0.259	3.731	0.268	3.863	1.035
90	1.000	0.000	Infinite	0.000	Infinite	1.000

Two final reminders from geometry:

- The sum of the angles in a triangle is 180 degrees. Because one of the angles in a right triangle is 90 degrees, the sum of the other two angles is 90 degrees. If you know one angle, you can find the other angles by subtracting the known angle from 90 degrees.
- $(\sin(A))^2 + (\cos(A))^2 = 1$. If you know the value of one of those functions for a particular angle, you can calculate the other.

Vector Diagrams and Some of their Practical Applications

For the following situations, we selected an angle known as the "angle of concern" (AoC) that is usually the easiest one for riggers to visualize. Because these situations involve right triangles, it is easy to link the results to the appropriate alternative angle.

Figure D–2 provides a key to the symbols used in the diagrams for this appendix and appendix E.

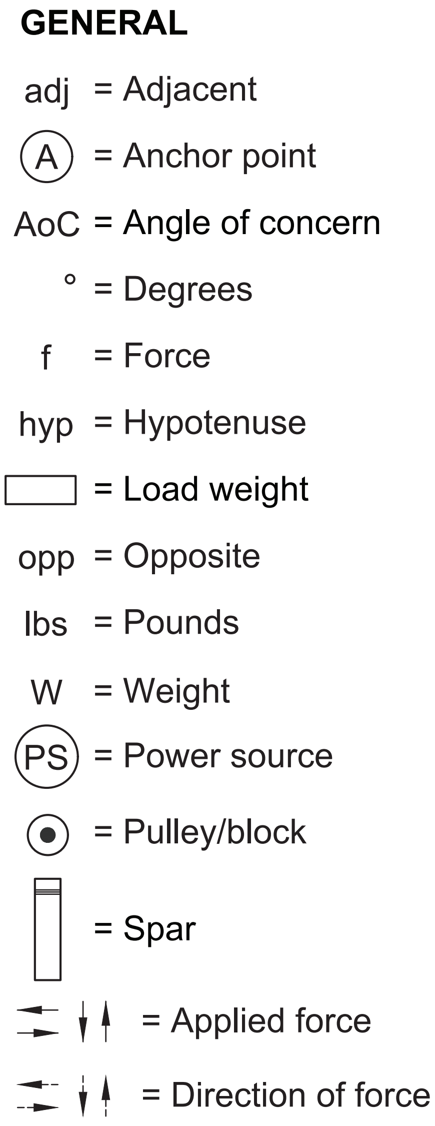


Figure D–2— Symbols used in a vector diagram.

Situation 1—Guy Lines

The purpose of a guy line is to apply lateral force to a spar in order to counteract other forces acting on the spar (figure D–3). In this situation, the AoC is the angle between the spar and the guy line. Table D–2 shows the percent of applied lateral force produced by a given angle.

Table D–2—Applied lateral force of a guy line on a spar

Angle of concern	Percent
90	100
75	97
72	95 (ground anchor located at least 3x the spar height)
64	90 (ground anchor located at 2x the spar height)
60	87
45	71
30	50
15	26

Bottom line: The distance between the base of a spar and an anchor point should be at least twice the distance between the ground and the attachment point on the spar. For example, a power pole is likely to lean from the lateral load imposed by the wires it supports if the anchor point of the guy lines on the pole is too close to the pole.

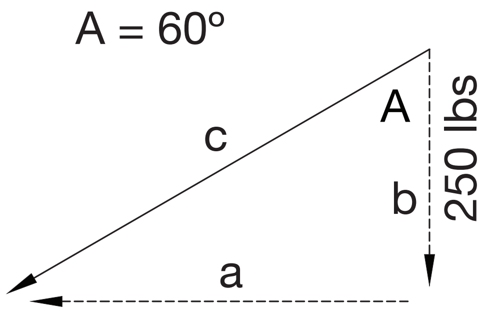


Figure D–3—A guy line used to apply lateral force to a spar.

Situation 2—Sling Angles

The AoC is the corner angle where the sling arm attaches to the load (figure D–4). Table D–3 shows the tension in each sling arm as a percentage of the actual load weight.

Table D-3—Tension in each sling arm as a percentage of the actual load weight

Angle of concern	Percentage
90	50
75	52
60	58
45	71
30	100
15	193
5	574

Bottom line: If the corner angle of a sling leg is never less than 30 degrees, the tension in each leg will not exceed the load weight.

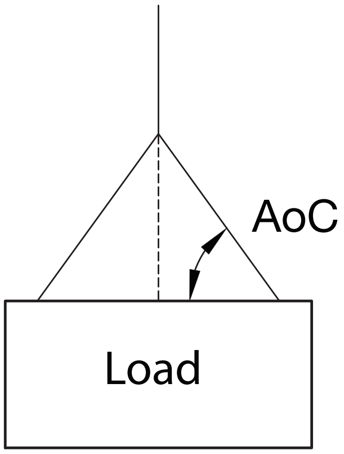


Figure D–4—The angle of concern on a sling.

Situation 3—Horizontal Pulls

The AoC is the angle between the desired direction of pull and the line applying the force (figure D–5). Table D-4 shows the percentage of applied horizontal force that acts in the desired direction of pull.

Table D-4—Percentage of applied horizontal force that acts in the desired direction of pull

Angle of concern	Percentage
90	0
75	26
60	50
45	71
30	87
15	97
0	100

Bottom line: As a rule of thumb, lines should run as parallel to the desired direction of pull as possible and should not exceed an AoC of more than 30 percent.

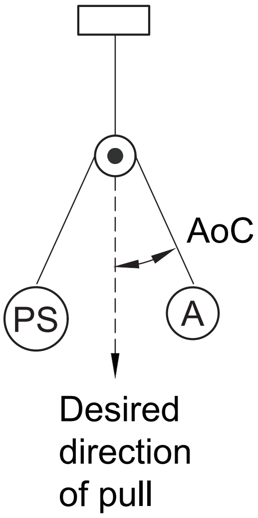


Figure D–5—View from above of a rigging configuration set up for a horizontal pull.

Situation 4—Aerial Suspension Lines

A suspended line requires tension. A flatter line (i.e., a line with less deflection or sag) requires more tension, which in turn lowers the payload the line can carry.

Figure D–6 shows two different AoC:

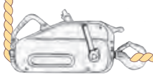
- AoC-A is the angle between a horizontal line drawn between the two pulleys and one side of the line carrying the load.
- AoC-B is the angle where the two sides of the line meet at the load (sometimes called the central angle).

Table D–5 shows the percentage of applied force that actually lifts the load and the percentage of tension created in the line by the load for aerial suspension lines.

Table D–5—Percentages of applied force that actually lifts the load and the tension created in the line by the load for aerial suspension lines

AoC-A	AoC-B	Percentage of applied force	Tension created in the line by the load
90	0	100	50
75	30	97	52
60	60	87	58
45	90	71	71
30	120	50	100
15	150	26	193
5	170	9	574

Bottom line: Ideally, AoC-A should be more than 60 degrees, or AoC-B should be less than 60 degrees.



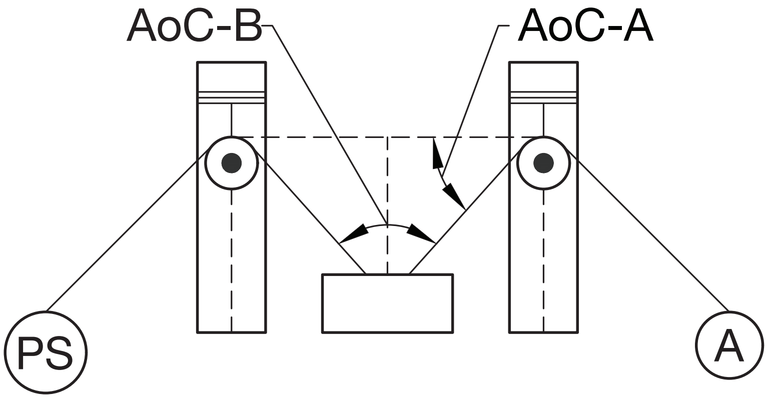


Figure D–6—Aerial suspension lines.

AoC-A should not be less than 30 degrees (or AoC-B should not be more than 120 degrees). As the suspension line flattens out (approaches the horizontal), the amount of force required to suspend the load increases dramatically. This also has the effect of dramatically increasing the tension in the line and increasing the lateral load on the spars. For example, towers for power lines (especially interstate transmission lines) are very tall to accommodate a significant amount of sag in the lines. This reduces tension in the lines and the lateral load on the adjacent towers.

It is important to remember that the two primary purposes of aerial suspension systems are:

- To raise the load up off the ground to eliminate the force due to friction inherent in the act of pushing an object resting on the ground.
- To raise the load up high enough to clear any obstacles in the path the load must take.
  It is common to see systems that lift loads far higher than necessary to accomplish these two goals. The closer the load stays to the ground, the safer the system is and the less leverage it exerts on the spars.

Situation 5—Spars

It is critical to consider the effects of lateral force and the resultant "moment" when using spars. Most spars can withstand incredible compression forces, as long as the forces are directed straight down the length of the spar (figure D-7). To illustrate this, try compressing a 2 by 4 down its long axis. When a spar is subject to a lateral force, the load-capacity question becomes more complex. A lateral force (F) applied some height (r) above the ground induces a bending moment (which we can loosely describe as torque) at the base of the spar (figure D–8). Note that you determine a bending moment using the equation $r \times F = M$. As is evident in the equation, the higher the lateral load on the spar, the higher the magnitude of the bending moment. It is crucial to understand that the magnitude of a moment increases significantly as the value r increases, just as the efficacy of a pry bar increases significantly with its length. The higher the attachment of the lateral load on the spar, the greater the tilting force. The force exerted at the base is proportional to the lateral force times its attachment height on the spar. The exact effect depends upon the spar's diameter and how it is anchored at its base.

Bottom line: More height can provide better line deflection and, thus, better lifting capability. The tradeoff is an increase in the likelihood that the spar will rip out of the ground, bend, and/or break. Riggers often have to install guy lines to counteract these possibilities.

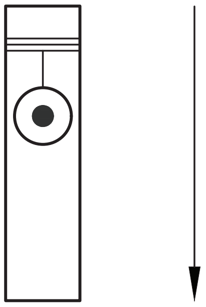


Figure D–7—Vertical force acting on a spar.

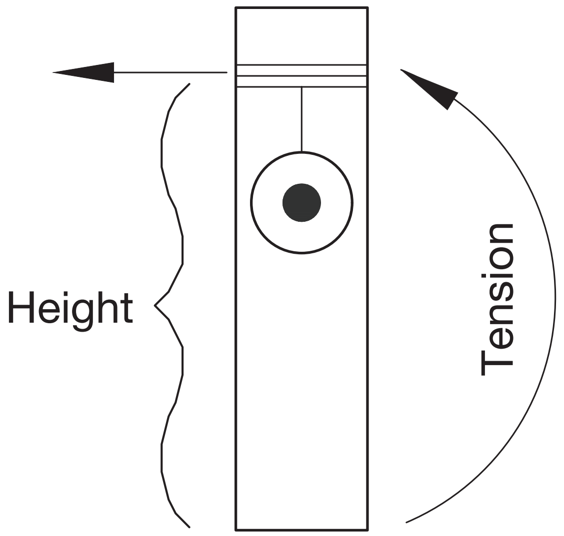


Figure D–8—Lateral force acting on a spar.

The Combined Effect of Line Tension and Angle on the Actual Loading of Components

Understanding the combined effect of line tension and angle on the loading of rigging components (including equipment, spars, and anchors) is an important aspect of understanding the forces in a rigging system. It explains the variations found in dynamometer readings at various locations in a rigging system. The following discussion relates to the orientation of lines attached to a pulley that is anchored at some height (*r*) on a spar.

If a suspended line crosses over a centered pulley 10 feet up on a spar and you tighten the line to 1,000 pounds, there is no vertical load on the pulley but the line weight (figure D–9).

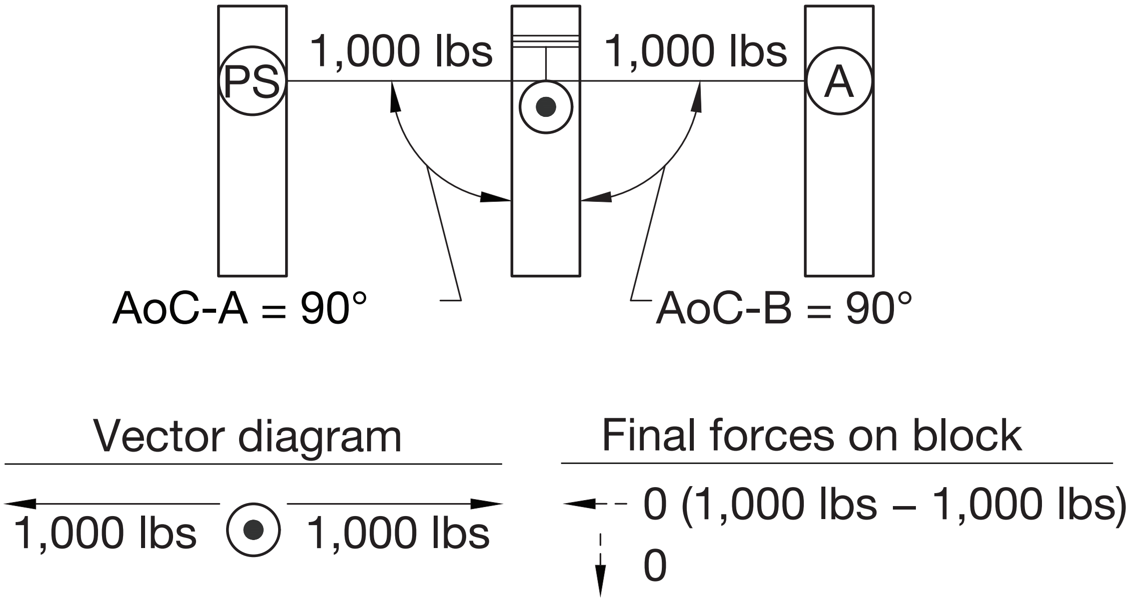


Figure D–9—Cancellation of opposing forces when lines enter and leave a block parallel to the ground.

If the lines approach the pulley at 45-degree angles, the resultant lateral force on the spar is zero because the two lines generate equal but opposite lateral forces that cancel each other out (figure D–10). Note, however, that there is a downward load of 1,414 pounds (707 + 707).

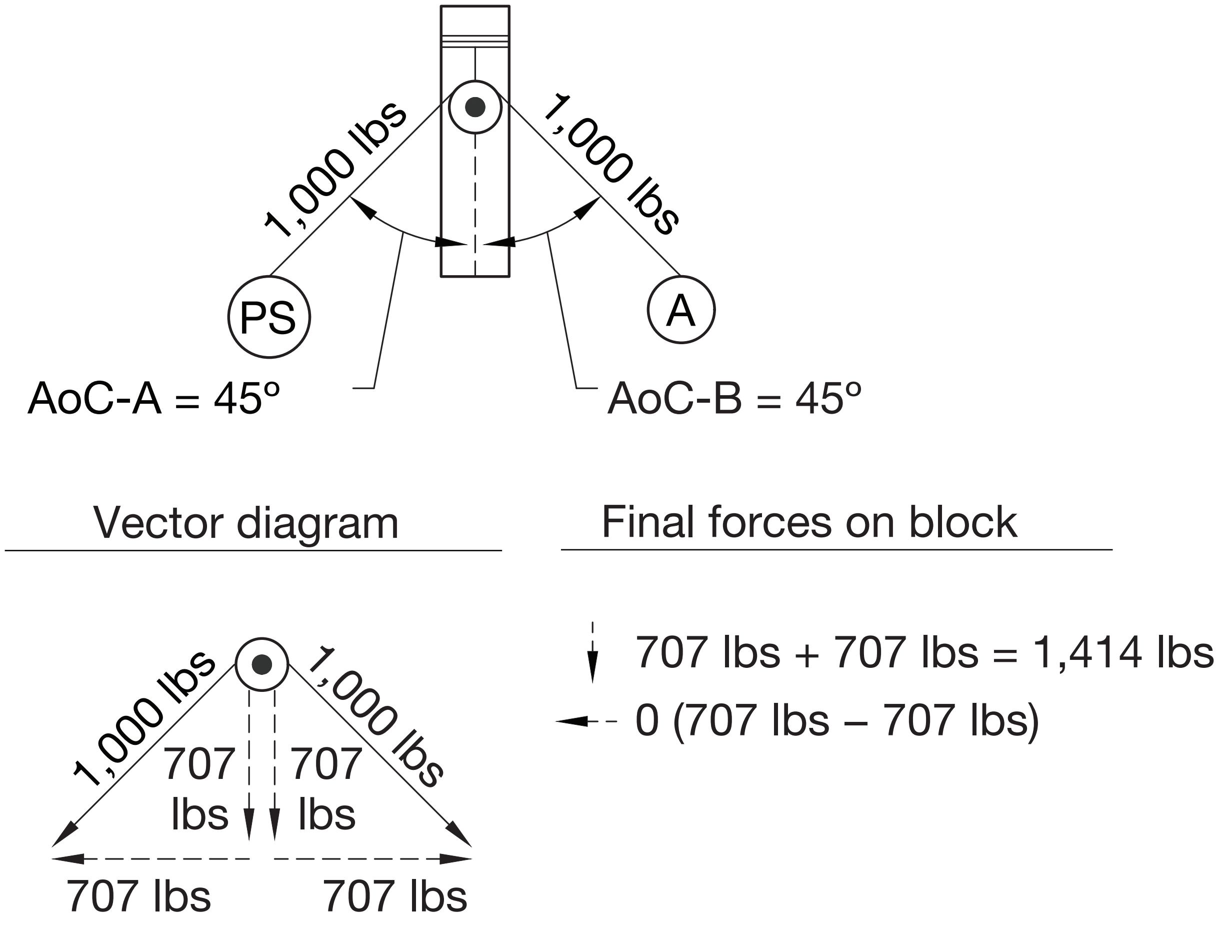


Figure D–10—Vertical and horizontal forces when lines enter and leave a block at the same angle.

If one side of a line approaches a fixed pulley at a 45-degree, angle and the other side approaches at a 20-degree angle (figure D–11), there will be a resultant lateral force of 365 pounds pulling to the left (707 pounds on the left minus 342 pounds on the right). This value multiplied by the height of the pulley is the bending moment exerted at the base of the spar. Think of it as a wooden lever of a certain length; if you raise the block higher, the spar becomes a longer lever exerting more force. One of three things can happen:

- The spar can bend under the load but will hold the load because the wood fiber absorbs the energy.
- A poorly rooted spar tree can tip over because the bending moment at the base of the tree exceeds the strength of the root system.
- The spar can break because the bending moment at the base exceeds the bending strength of the spar.

You can use guy lines to reduce the resultant lateral force on a spar and consequently reduce the magnitude of the bending moment at the base of the spar. Additionally, note that in figure D–11 there is an increased downward pull of 1,647 pounds (707 + 940).

Bottom line: If the angles AoC-A and AoC-B from figure D–10 are equal, the lateral forces on the spar will cancel each other out. If the angles are not equal (as shown in figure D–11), then the side with the greater angle will be the dominant lateral force on the spar, and the force will be in that direction. This lateral force will induce a bending moment that can cause or lead to one of the three failures listed above if you do not properly guy the spar. Similarly, the smaller the AoCs are, the less lateral force is generated to act on the spar. Figures D–10 and D–11 show a vertical orientation (a pulley hung on a spar), but the same principles apply to horizontal orientations.

If the tree is structurally sound and its base is securely anchored, it will flex some in response to lateral bending forces, but its inherent rigidity will prevent this movement from allowing those forces to equalize. Properly guying the tree can equalize the lateral bending forces and eliminate flexing. Failure to adequately cancel lateral forces may cause the tree to flex excessively and cause the trunk to fail.

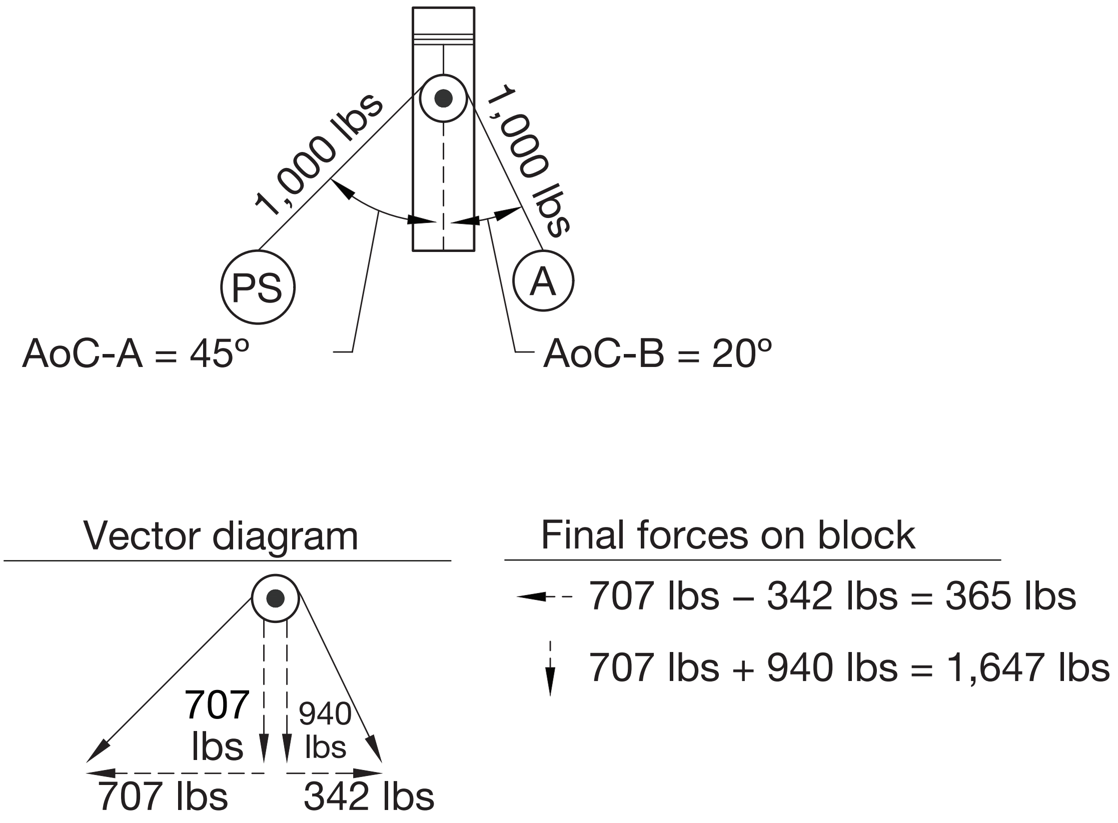


Figure D–11—The effects of lines entering and leaving a block at different angles.

Appendix E: Calculating Force Vectors and Line Tension

Calculating force vectors is primarily an academic exercise; you do not generally calculate them in the field. However, trigonometry is valuable as a basis for developing useful generalizations, such as those listed in "Appendix D: The Effects of Angles on Forces," and on rare occasions when conditions change in the field and you have to accomplish an unexpected task with the equipment at hand. We present the material in this appendix as a reference rather than as a recommended way to design systems because there are so many other important, variable, and less precise physical factors in any system (such as anchor strength, spar bending strength, etc.). As a result, relying primarily on calculated force vectors can give a false sense of security. The major emphasis in design must always focus on the "weak link" concept presented earlier in the text ("Appendix D: The Effects of Angle on Forces" has additional information about force vectors).

Triangles and Associated Trigonometric Functions

When a force applies directly to an object, the line tension equals the force applied (there is no force dissipated in a lateral direction). In this situation, the force vector is a straight line because it is unidirectional (figure E–1). However, when you support or move an object in a direction different from the force applied to it (such as gravity), the force required to support or move the object is usually different than the applied force. The magnitude of the directed force depends on the AoC.

To illustrate how the forces on rigging lines vary with the AoC, consider the task of supporting the 500-pound log shown in figure E–1.

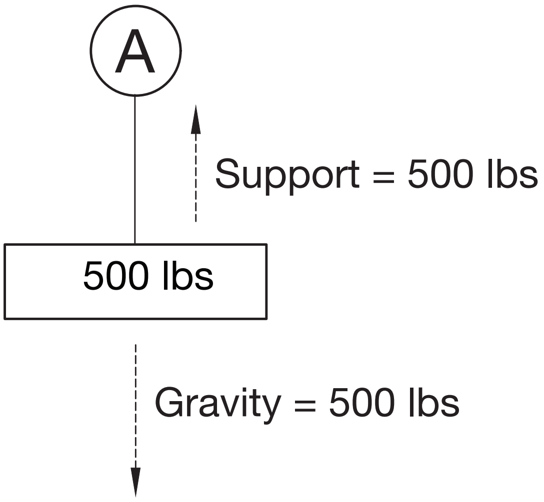


Figure E–1—Gravity applies a force of 500 pounds to a suspended log, so the cable suspending the log has 500 pounds of strain on it.

Gravity pulls down on the log with 500 pounds of force. The line supporting the log opposes the force of gravity with 500 pounds of lift. The potential issue with the support shown is that the log could pivot about the point where the support line attaches to the log. The log would be more stable with the line attached at two points, as shown in figure E–2.

With two lines supporting the log against gravity, each line carries 250 pounds of lift in the vertical direction. However, each cable running from the center connection to the anchor and one end of the log has 500 pounds of tension on it; the force of gravity for each half of the log. This results from the 60-degree angle between the gravity force vector and the cable (applied force vector). The horizontal directed force vector(s) of 433 pounds is the force with which the log pushes out on the suspending cables.

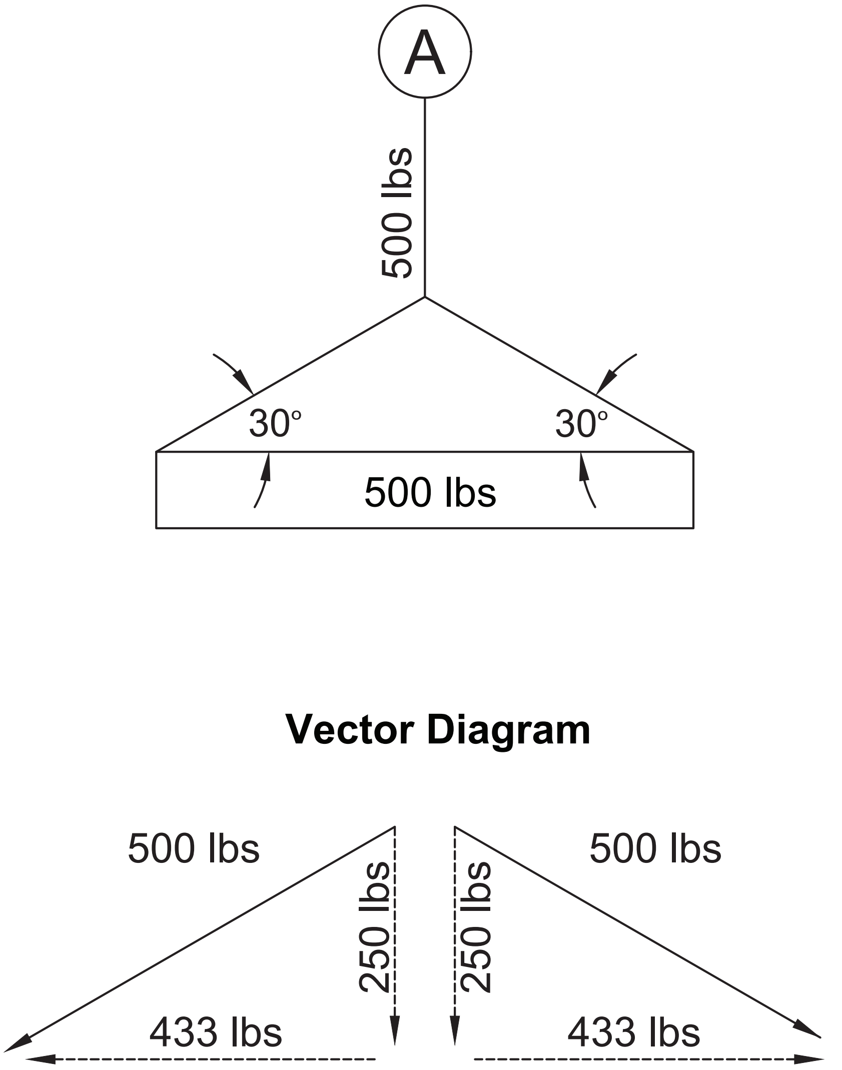


Figure E–2—A 500-pound log suspended by two cables, each with an angle of concern of 60 degrees from the vertical gravity vector.

Referring to the definitions of trigonometric functions and the information we have, angle *A* is the angle between the gravity force vector (side *b*) and the rigging cable (side *c*). Angle *A* is 60 degrees (figure E–3). Referring to the list of equations in the "Introduction to Vectors and Trigonometric Functions" section in "Appendix D: The Effects of Angles on Forces," the secant function is the equation that solves for side *c* when we know side *b* and angle *A*:

$c = b \times \sec(A)$

From the table of values for trigonometric functions and specific angles, sec(60) = 2.

Therefore, side $c = 250 \times 2$, or 500.

Because the lengths of the sides represent forces, applied force *c* = directed force *b* × 2 = 500 pounds

Gravity sets the direction of the vectors in most examples in this guide. It may be the applied force vector (represented by the hypotenuse of the right triangle) or it may be a directed force vector (represented by one of the legs of the right triangle).

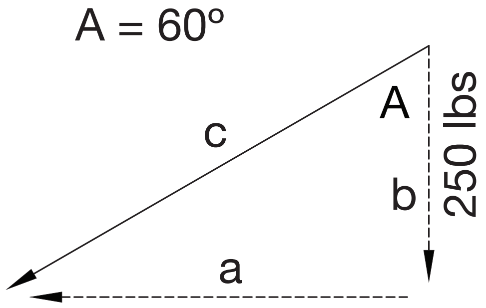


Figure E–3—The sides of a triangle representing applied and directed forces are labeled to match the sides and angles used to define the trigonometric functions and to solve for unknown terms.

Using Cosecants to Calculate Line Tension With Direct Vertical Line Suspension Systems That Have Various Sling Angles

The following examples of sling lines suspending loads show one line attached to a load at two points. The formula for calculating line tension (below) extends the number of attachment points for sling lines, but assumes the sling lines will all have the same angle to the attachment point of the main suspension line.

(Load in pounds) ÷ (number of lines) × csc(AoC) = line tension

Example 1:

Two independent lines suspending a load from two anchors (figure E–4).

csc(90) = 1

1,000 pounds ÷ 2 × 1 = 500 pounds

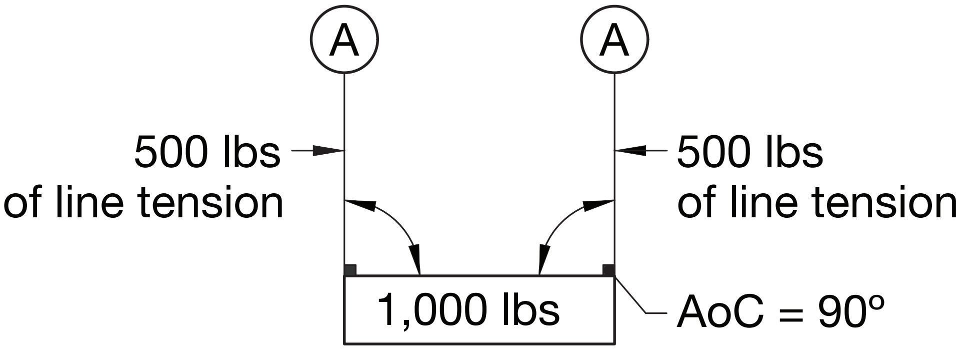


Figure E–4—The line tension with two suspending lines equals half the load weight in each line.

Example 2:

A sling attached to a single suspending line and to a load with a corner angle of 60 degrees (figure E–5).

csc(60) = 1.1547

1,000 pounds ÷ 2 × 1.1547 = 577 pounds

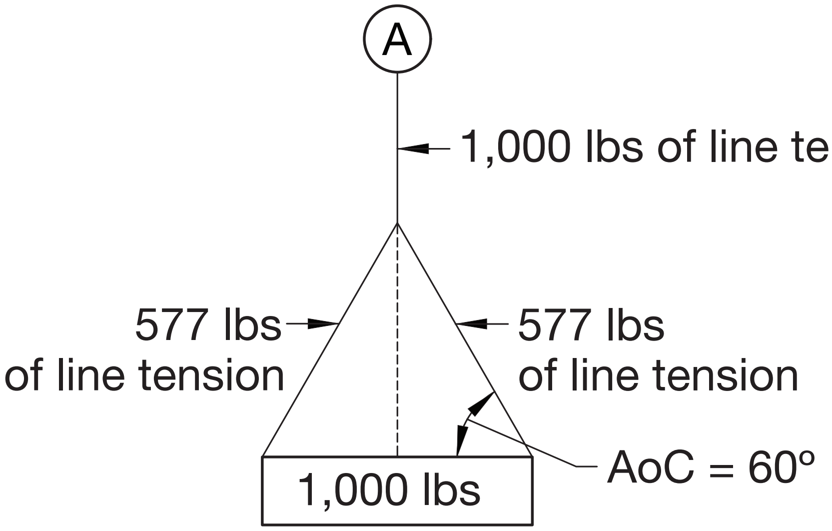


Figure E–5—As the sling angle (angle of concern) decreases, the line tension in each leg increases (577 pounds in each leg).

Example 3:

A sling attached to a single suspending line and to a load with a corner angle of 30 degrees (figure E–6).

csc(30) = 2

1,000 pounds ÷ 2 × 2 = 1,000 pounds

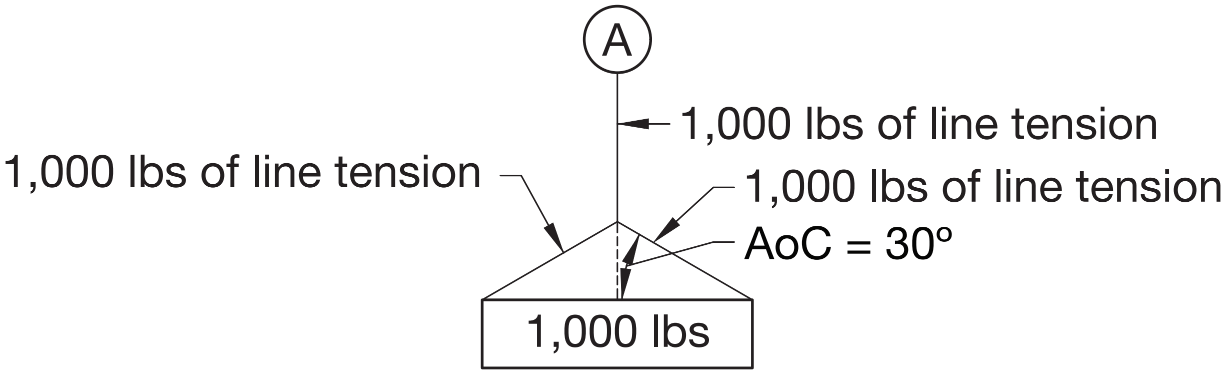


Figure E–6—At a sling angle of 30 degrees, the line tension in each leg equals the total load weight.

Example 4:

A sling attached to a load with a corner angle of 5 degrees and then to a single suspending line (figure E–7).

csc(5) = 11.474

1,000 pounds ÷ 2 × 11.474 = 5,737 pounds

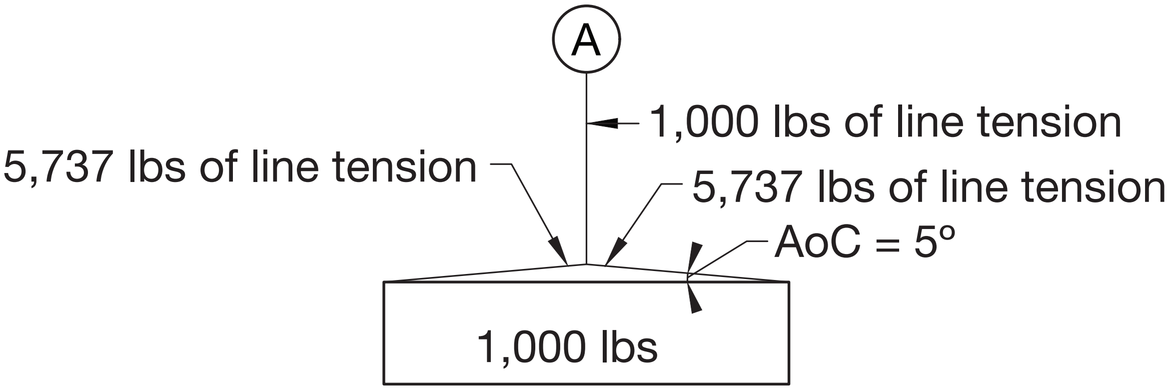


Figure E–7— As the sling angle decreases, line tension in each leg of the sling increases dramatically (here more than five times the load weight).

Influence of Cable Angle on Forces

In the vertical mode, the setup in example 4 could be a line running through an elevated pulley where you want to calculate the total downward force exerted on the pulley, anchor strap, and anchor point, as well as the lateral force applied to the anchor point. In the horizontal mode, this could be a mechanical advantage setup for dragging an object where you want to calculate the total force exerted on the object (and attaching components).

In examples 1 through 4, the AoC is between the two trees in the line to the load. The magnitude opposite is the downward load of the pulley and the adjacent side is the lateral load on the pulley.

Using Sines and Cosines to Calculate Line Tension in Mechanical Advantage Systems

The following examples of sling lines suspending loads show the line tension with forces applied at varying angles. The formulas (below) calculate the resultant line tension when forces are applied at a given angle.

Lateral force: applied force × sin(AoC)

Downward force: applied force × sin(AoC)

Example 5:

In figure E–8, the force (500 pounds) in each line applies directly to the anchor point.

AoC = 0 degrees

sin(AoC) = 0

500 pounds × 0 = 0

cos(AoC) = 1

500 pounds × 1 = 500 pounds

The lateral force applied to the block by each line is 0 pounds. The downward or outward force applied to the block by each line is 500 pounds. So, the total load on the block and anchor strap is 500 pounds (left line) plus 500 pounds (right line), equaling 1,000 pounds of line tension.

If all lines are parallel in a direct pull, no force is lost in a lateral vector.

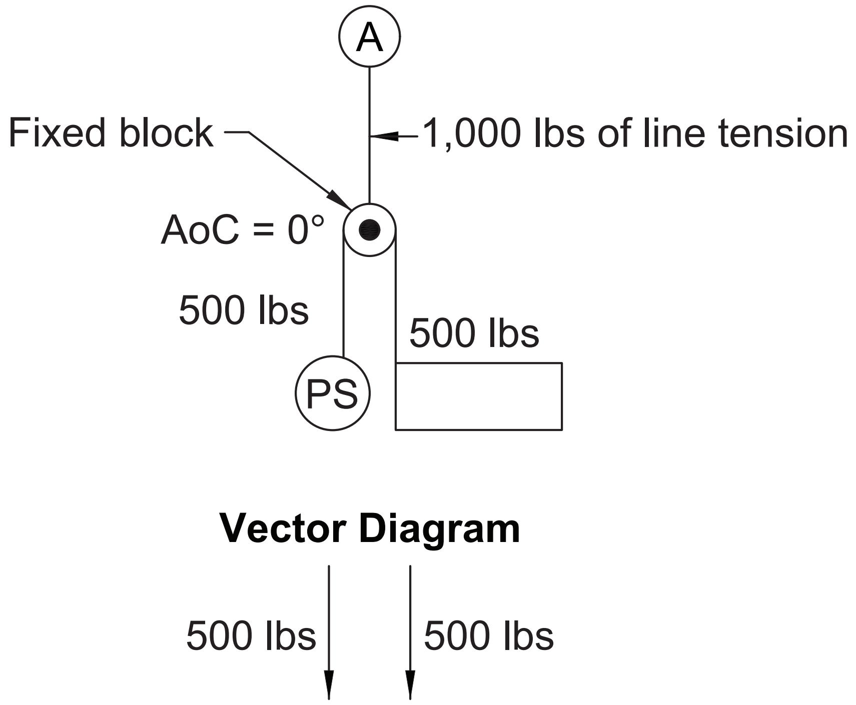


Figure E–8—When all lines are parallel in a direct pull, no force is lost in a lateral vector.

Example 6:

In figure E–9, the force (500 pounds) in the left line applies at a 15-degree angle and the block is anchored in place in the position shown.

AoC = 15 degrees

sin(AoC) = 0.25882

500 × 0.25882 = 129

cos(AoC) = 0.96593

500 × 0.96593 = 483

The lateral force applied to the block by the left line is 129 pounds. The downward or outward force applied to the block by the left line is 483 pounds. The right side is unchanged from example 1, so the total downward load on the block and anchor strap is 483 pounds (left line) plus 500 pounds (right line), equaling 983 pounds of line tension.

As the AoC increases, it introduces a lateral force component that decreases the in-line force generated.

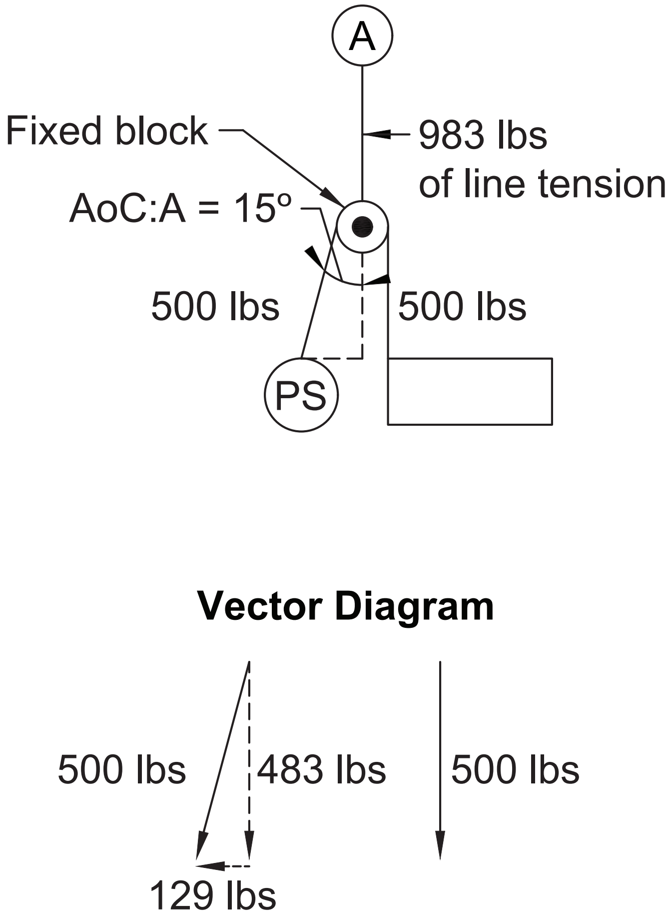


Figure E–9—As the sling angle increases, it introduces a lateral force component that decreases the in-line force generated.

Example 7:

In figure E–10, the force (500 pounds) in the left line applies at a 30-degree angle and the block is anchored in place in the position shown.

AoC = 30 degrees

sin(AoC) = 0.5

500 x 0.5 =250

cos(AoC) = 0.866

500 x 0.866 = 433

The lateral force applied to the block by the left line is 250 pounds. The downward or outward force applied to the block by the left line is 433 pounds. So, the total load on the block and anchor strap is 433 pounds (left line) plus 500 pounds (right line), equaling 933 pounds of line tension.

As the AoC increases to 30 degrees, the lateral force is now half the applied force and the in-line force continues to decrease.

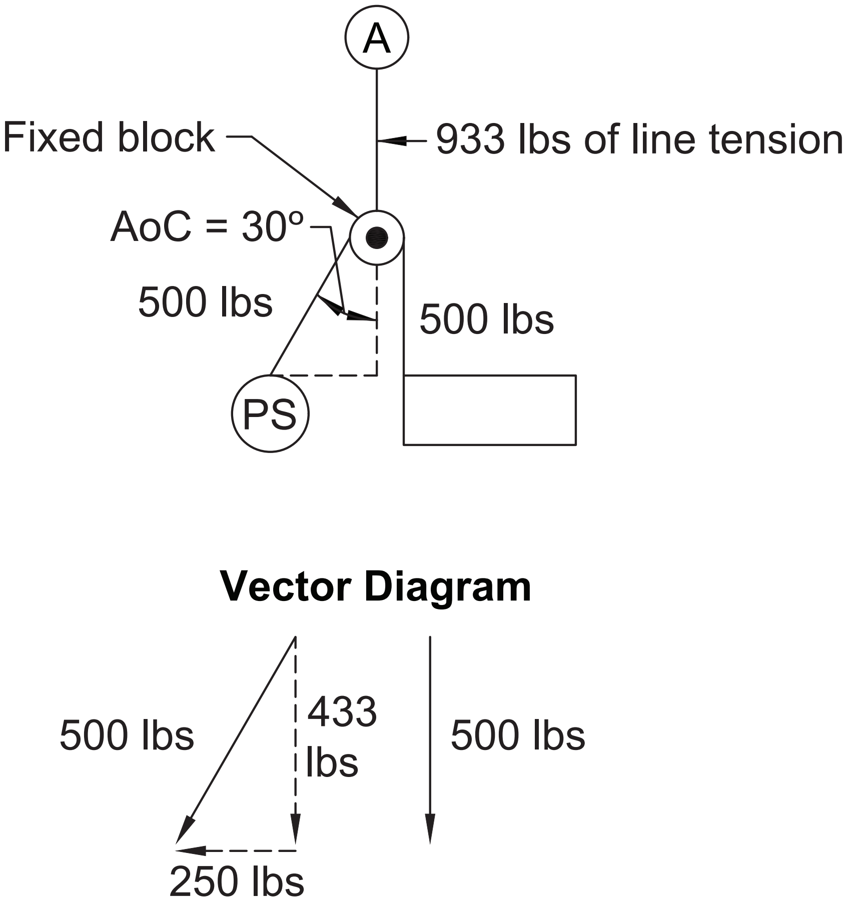


Figure E–10—As the sling angle increases to 30 degrees, the lateral force is half the applied force and the in-line force continues to decrease.

Example 8:

In figure E–11, the force (500 pounds) in the left line applies at a 45-degree angle and the block is anchored in place in the position shown.

AoC = 45 degrees

sin(AoC) = 0.70711

500 × 0.70711 = 353

cos(AoC) = 0.70711

500 × 0.70711 = 353

The lateral force applied to the block by the left line is 353 pounds. The downward or outward force applied to the block by the left line is 353 pounds. So, the total load on the block and anchor strap is 353 pounds (left line) plus 500 pounds (right line), equaling 853 pounds of line tension.

As the AoC increases to 45 degrees, the lateral force now equals the in-line force produced by the same line.

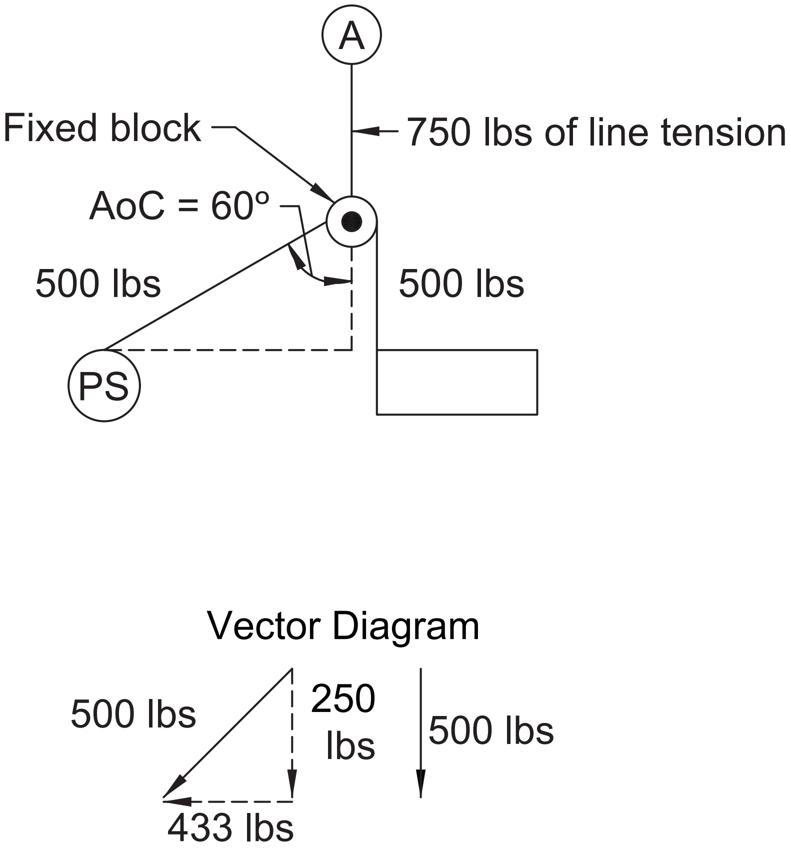


Figure E–11—As the sling angle increases to 45 degrees, the lateral force equals the in-line force produced by the same line.

Example 9:

In figure E-12, the force (500 pounds) in the left line applies at a 60-degree angle and the block is anchored in place in the position shown.

AoC = 60 degrees

sin(AOC) = 0.866

500 x 0.866 = 433

cos(AoC) = 0.5

500 x 0.5 = 250

The lateral force applied to the block by the left line is 433 pounds. The downward or outward force applied to the block by the left line is 250 pounds. So the total load on the block and anchor strap is 250 pounds (left line) plus 500 pounds (right line), equaling 750 pounds of line tension.

As the AoC increases to 60 degrees, the lateral force applied is greater than the inline force, which now reduces to 50 percent.

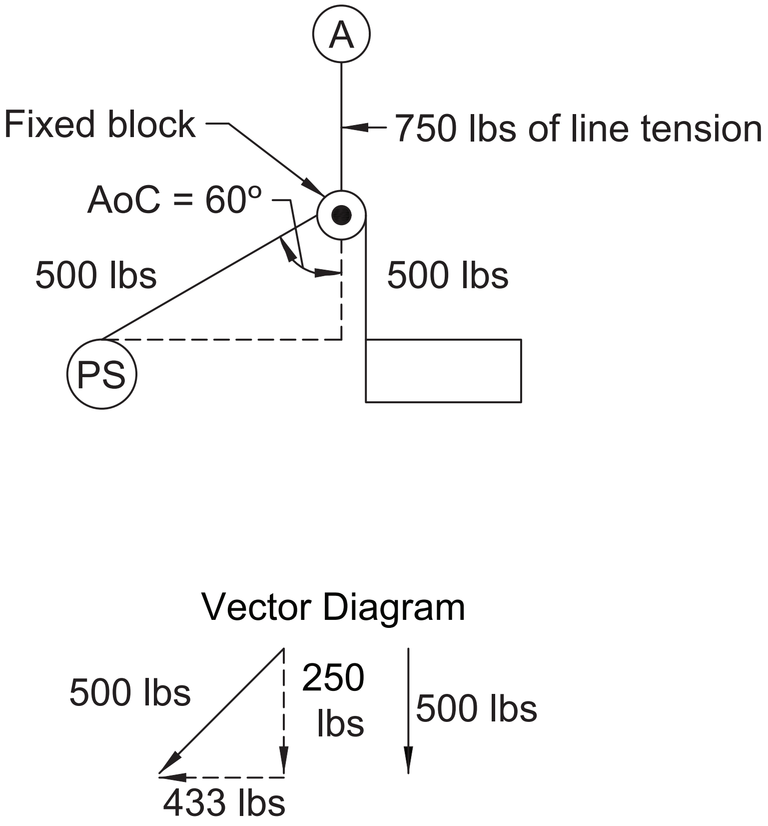


Figure E–12—As the sling angle increases to 60 degrees, the lateral force applied is greater than the in-line force, which reduces to 50 percent.

Example 10:
In figure E–13, the force (500 pounds) in the left line applies at a 75-degree angle, the force in the right line applies at a 0-degree angle, and the block is anchored in place in the position shown.

AoC = 75 degrees

sin(AoC) = 0.96593

500 × 0.96593 = 483

cos(AoC) = 0.25882

500 × 0.25882 = 129

The lateral force applied to the block by the left line is 483 pounds. The downward or outward force applied to the block by the left line is 129 pounds. So, the total load on the block and anchor strap is 129 pounds (left line) plus 500 pounds (right line), equaling 629 pounds of line tension.

As the AoC increases to 75 degrees, the majority of applied force in that leg is lost to lateral force. If the right leg AoC is also 75 degrees, then the total inline force would be 25 percent of the force generated in figure E-7.

By maximizing the angle of concern between the load and the power source, you can decrease the tension on the line supporting the block and lifting the weight by 30 percent (or more) when compared with having the power source directly below the block and an AoC of 0 degrees.

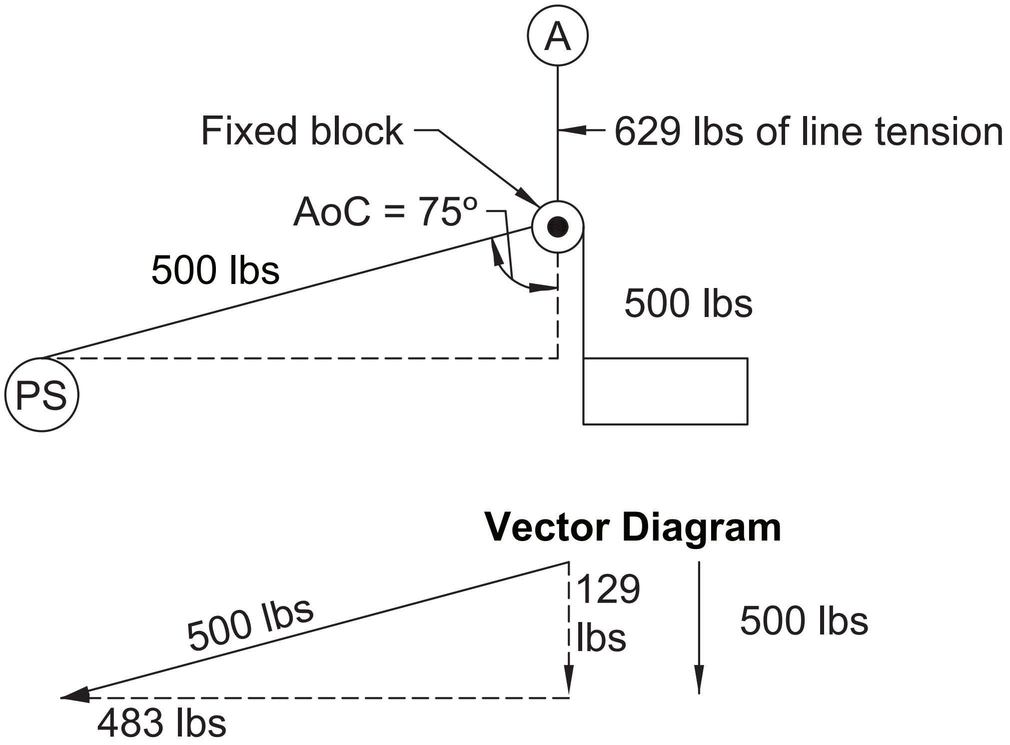


Figure E–13—As the deflection angle increases to 75 degrees, the majority of applied force in that leg is lost to lateral force.

Influence of Cable Angle on Guy Lines

You can use the same calculation method used for line tension in mechanical advantage systems to illustrate the importance of calculating guy-line angles. In this case, the basic setup is as follows: you attach one end of a guy line to a ground anchor and attach the other end at some elevated point on a spar, to counteract opposite forces acting on the spar. In this case, you want to maximize the lateral force—the exact opposite of figure E–13.

You attach a guy line to a spar or tree and apply 500 pounds of line tension (figure E–14). Using the illustration in figure E-14 with a line force of 500 pounds, you can construct a table of the actual lateral forces generated at varying angles (table E-1).

Table E-1—Lateral forces generated at varying angles using a line force of 500 pounds

Angle of concern	Lateral force (pounds)	Percent of applied force
90°	500	100
75°	483	97
60°	433	86
45°	353	71
30°	250	50
15°	129	26

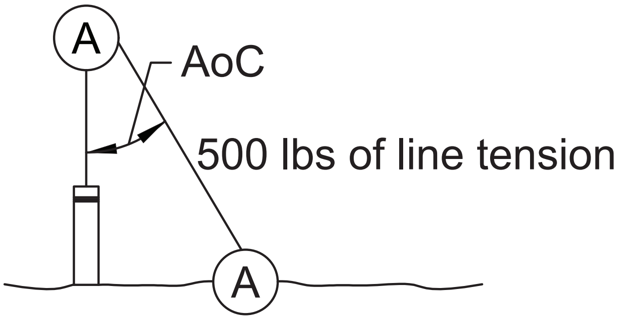


Figure E–14—A guy line applying 500 pounds of line tension to a tree.

Influence of Cable Angles (Deflection or Sag) With a Load Suspended Between Two Anchor Points

The following examples are variations of cable angles and are useful for demonstrating several important points. The examples specifically address the forces associated with various deflections or sags in an aerial line used to suspend a load and are applicable to a double highline or a skyline. We use cosecants for these calculations.

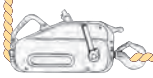
CSC(AoC) = hyp ÷ opp

You can use this information on guy line tension and lateral force to stabilize spars supporting double highlines or skylines. Figures E-15 through E-21 are examples of double highlines that may require guy lines on the spars.

The basic design is a 1,000-pound load lifted by a cable anchored at one end and passing up through a block on a spar, back down to the load, back up through a block on a second spar, and down to an anchored power source. The basic formula for calculating line tension required in this type of system is:

csc(AoC) × load ÷ 2 = force (tension in the line) required to suspend the load

We provided the procedure for calculating the forces on the spar blocks in figures E–9 through E–13.



Example 11:

In figure E–15, the spars are very close together and the suspension lines are essentially vertical. The proximity of the two spars would preclude any lateral movement, so this is just to illustrate a point.

csc(90) = 1

1 × 1,000 pounds ÷ 2 = 500 pounds

The force required to suspend the load is 500 pounds per line.

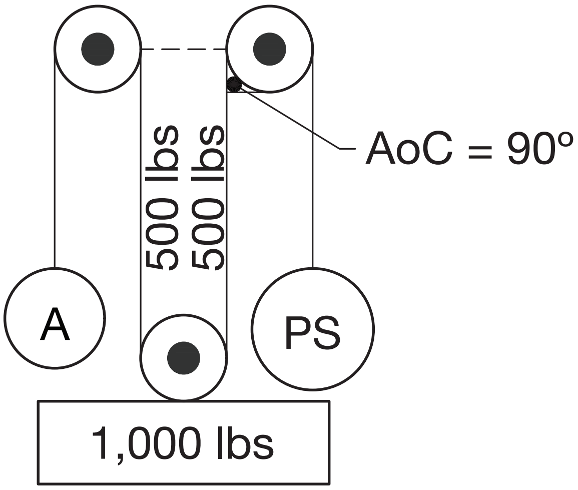


Figure E–15—A power source applying 500 pounds of force can suspend a 1,000-pound load.

Example 12:

In figure E–16, the spars are farther apart, and the distance between the spars creates an AoC of 75 degrees.

csc(75) = 1.0353

1.0353 × 1,000 pounds ÷ 2 = 518 pounds

The force required to suspend the load is 518 pounds per line.

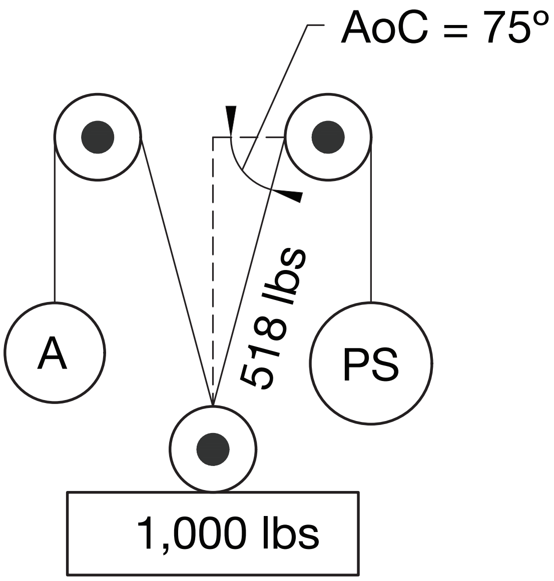


Figure E–16—As the deflection angle decreases to 75 degrees, the rigging system must apply more force to suspend the load.

Example 13:

In figure E–17, the distance between the spars creates an AoC of 60 degrees.

csc(60) = 1.1547

1.1547 × 1,000 ÷ 2 = 577

The force required to suspend load is 577 pounds per line.

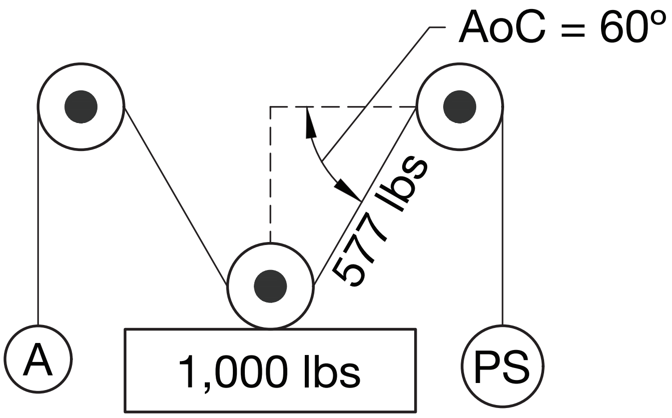


Figure E–17—As the deflection angle decreases to 60 degrees, the rigging system must apply even more force to suspend the load.

Example 14:

In figure E–18, the distance between the spars creates an AoC of 45 degrees.

csc(45) = 1.4142

1.4142 × 1,000 ÷ 2 = 707

The force required to suspend the load is 707 pounds per line.

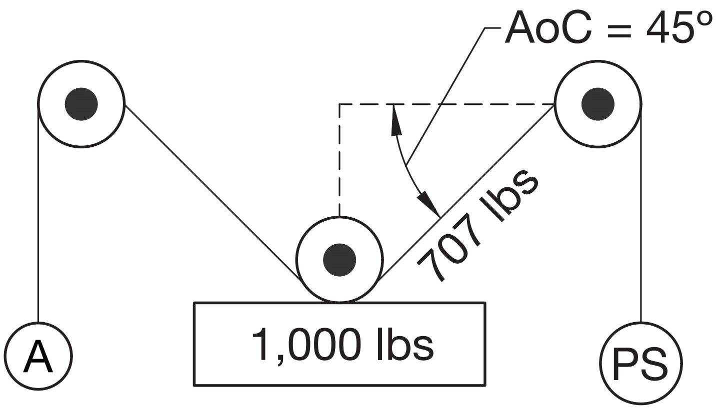


Figure E–18—As the deflection angle decreases to 45 degrees, the rigging system must apply almost half as much force to suspend the load.

Example 15:

In figure E–19, the distance between the spars creates an AoC of 30 degrees.

csc(30) = 2.0

2.0 × 1,000 ÷ 2 = 1,000

The force required to suspend the load is 1,000 pounds per line.

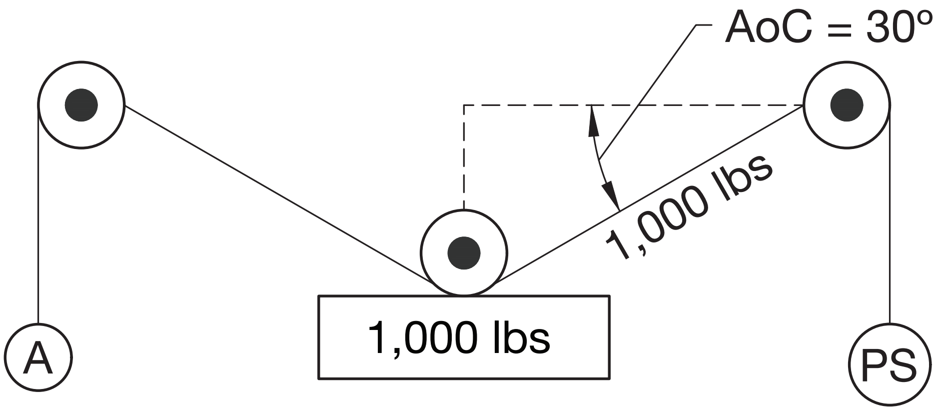


Figure E–19—At a deflection angle of 30 degrees, essentially all mechanical advantage is neutralized, and the force required to suspend the load equals the load weight.

Example 16:

In figure E–20, the distance between the spars creates an AoC of 15 degrees.

csc(15) = 3.8637

3.8637 × 1,000 ÷ 2 = 1,932

The force required to suspend the load is 1,932 pounds per line.

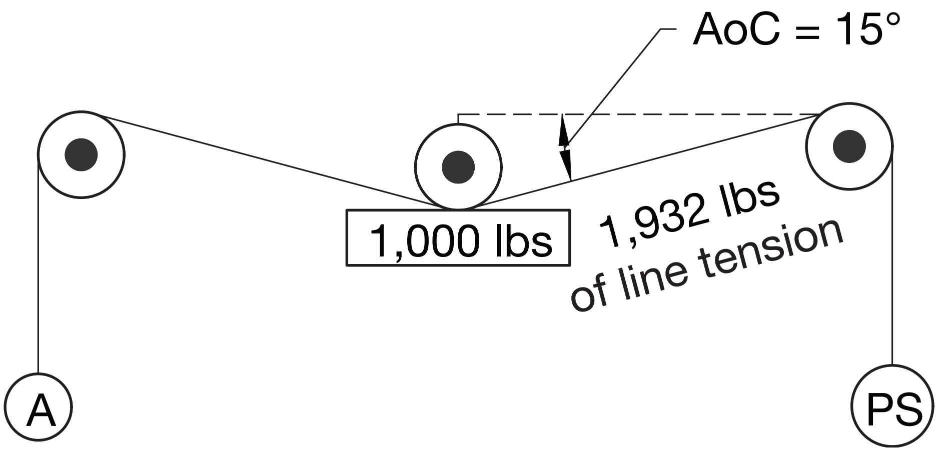


Figure E–20—As the deflection angle decreases to 15 degrees, the rigging system requires almost twice the load weight to support the load.

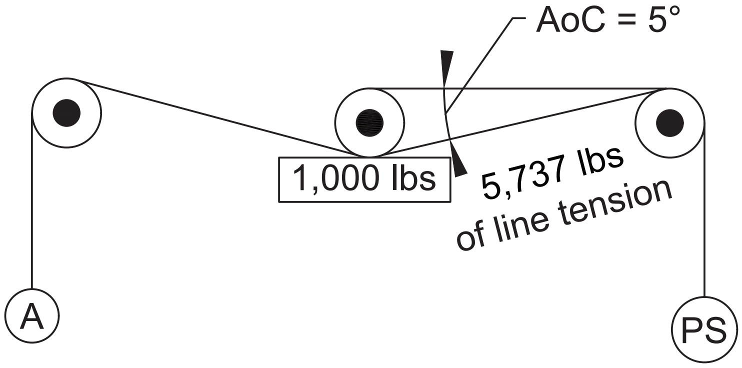
Example 17:

In figure E–21, the distance between the spars creates an AoC of 5 degrees.

csc(5) = 11.474

11.474 × 1,000 ÷ 2 = 5,737

The force required to suspend the load is 5,737 pounds per line.



Vector diagram (right block)

Vector diagram (guy diagram)

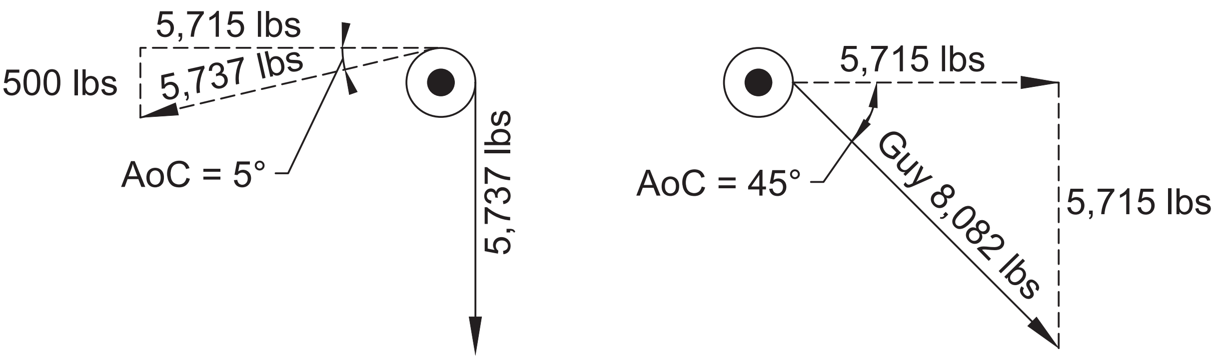


Figure E–21— At a deflection angle of 5 degrees, the rigging system requires almost six times the load weight to support the load.

There are other forces in figures E-15 through E-21 that are not readily apparent, but you must take them into account. For example, the right block in figure E-21 is subject to 5,737 pounds of line tension from the load and is also subject to 5,737 pounds of tension from the power source below it. These forces cannot simply be added because they are vectors in different directions. However, the vector sum of the two forces is 8,460 pounds if the block is allowed to float (figure E–22). Whatever device secures the block must be able to withstand this force.

As illustrated in figure E-21, there is a lateral force of 5,715 pounds on the spar supporting the right block that a guy line must balance with an equal force. Table E-1 lists the relationship between guy line angles and the percentage of the line tension that translates into lateral force. For example, a guy line with an angle of 45 degrees attached at the height of the right block on its spar would require a tension of 8,082 pounds to balance the lateral force on the line supporting the 1,000 pound load with an AoC of 5 degrees.

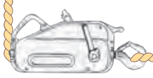
Most of the time, you won't have to calculate vector forces, but we include the methodology here for two reasons:

- It is handy to have the reference information in case you need it.
- It illustrates the importance of paying attention to the AoC.

The examples given here are artificial in that the block is fixed on the tree and the only forces we examine are the downward ones. In reality, the block attaches to a strap and automatically aligns itself with the final force vector formed by the two lines. In the vertical mode, if you calculate the downward forces, taking into account the movement provided by a strap, the effect on the resultant forces turns out to be minimal and is not worth the effort. Obviously though, the longer the strap, the more the angles change, as do the magnitude and direction of the final force vector.

Figure E-21 introduces the concept of a final force vector. The example is in the vertical mode, but the calculations apply in the horizontal mode as well. If the block can move, it will try to orient itself in line with the forces acting on it. The example in figure E-22 uses the line force calculations from example 17 and shows how the block will swing 42.5 degrees (half of the angle between the load and the power source) to center itself. Figure E-22 shows the force component vectors for the load and power source lines that are in line with the block's supporting strap and the lateral forces at right angles to it. The tension on each line produces a force of 4,230 pounds in line with the supporting strap, and the sum of the two inline forces is 8,460 pounds. This is the force the strap holding the block must support.

Figure E–22 illustrates the concept of final force vector, which operates in a two–dimensional, vertical plane. The methods of calculation apply equally to setups in a horizontal plane. However, the calculations quickly become complicated with an elevated block because the forces then act in both a vertical plane and a horizontal plane (three dimensions). Once you calculate the vertical force vectors, the angle at which the lines enter the block in the horizontal plane influences the lateral forces. This type of setup requires guy lines to keep the spar or tree from toppling.



To calculate the exact forces specifically, it is generally best to calculate the tension for a load suspended in the middle of a skyline and consider that as the peak tension. A quick method in the field is to take physical measurements and the tangent of an angle:

Tangent of an angle = (length of opp) ÷ (length of adj)

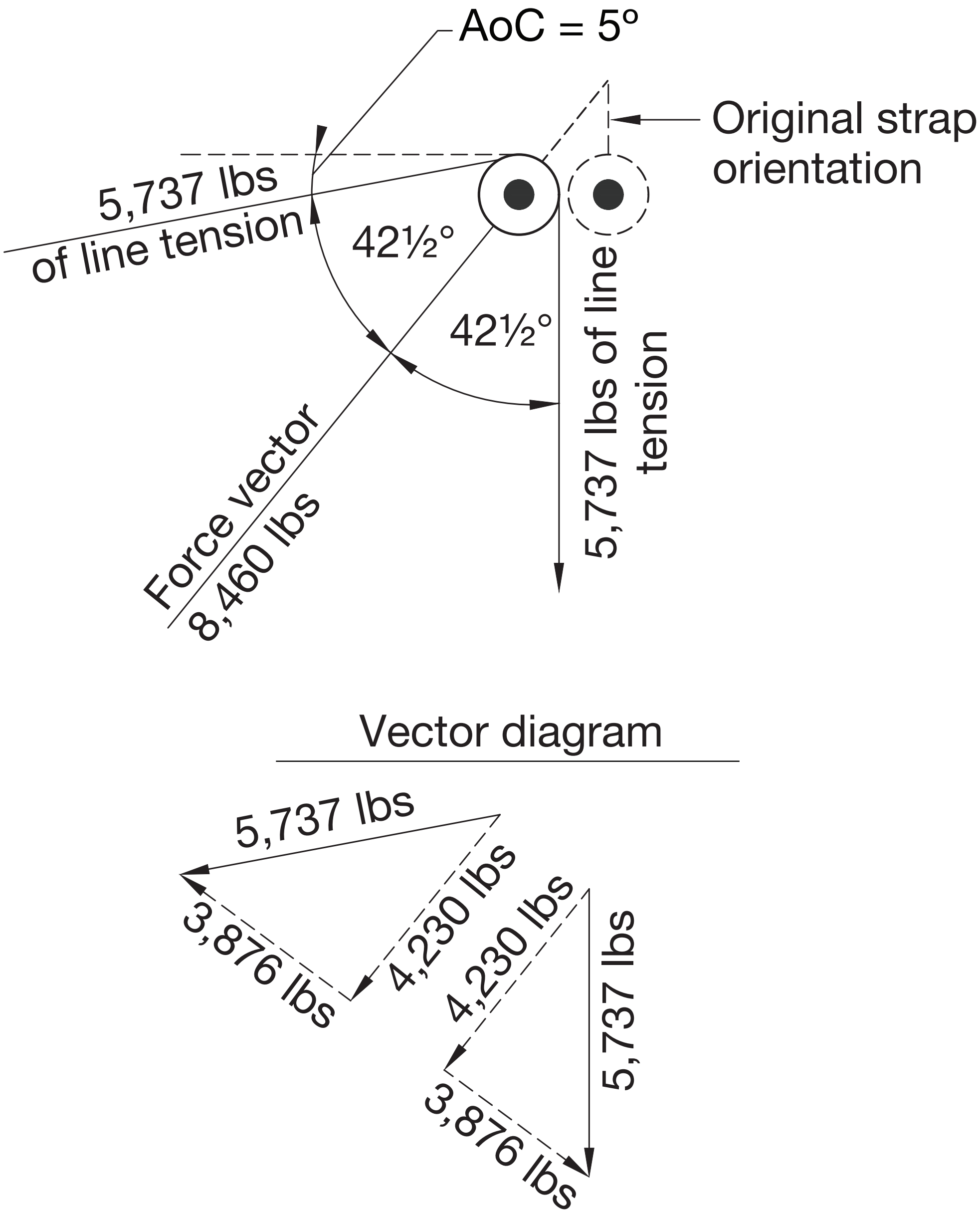


Figure E–22—The importance of the final force vector direction with regard to placing a guy line.

The value of determining the orientation of the final force vector is that it allows you to orient the guy line in the optimum position (exactly opposite the direction of the force vector). Using a skyline to move a load along on a carriage involves the same principles.

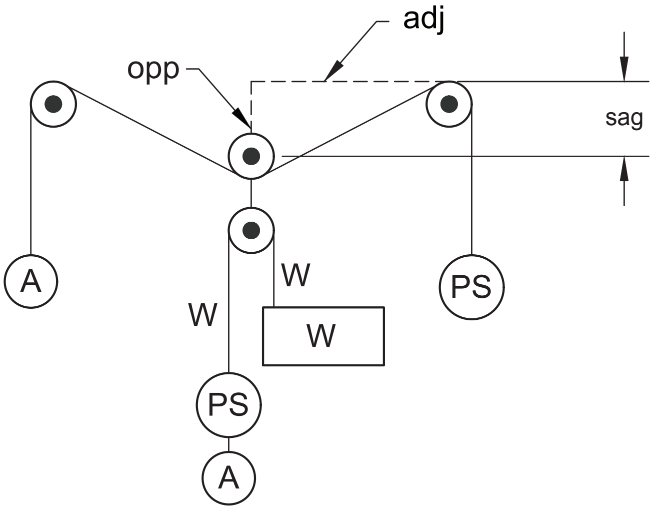
In figure E–23, opp is the sag at the center point of the skyline, and adj is one-half the horizontal distance between the two elevated blocks. You can look up the tangent value in the tables to determine the AoC and can calculate as described in figure E–22. Once you calculate that angle, take half the suspended weight and divide that by the sine of the angle you determined above or multiply it by the cosecant of that angle to determine the tension in the skyline.

Distance between the two blocks = 100 ft

Sag = 25 ft
W = 100 lbs
Tan A = sag ÷ adj distance   Tan A = 25 ft ÷ (½ x 100 ft)   Tan A = 0.50
A = 26.6 degrees

Because the lower center block has 2 lines with W tension (assuming that the angle between the power source and the weight is zero for simplicity), the total weight on the skyline is 2W and each side of the skyline supports 1W.

csc = line tension ÷ 100
csc(26.6) = 2.233
Line tension = 100 x csc(26.6) = 100 x 2.233
Line tension = 223.3 lbs
Lateral force - cos(26.6) x line tension = 200 lbs



Vector diagram

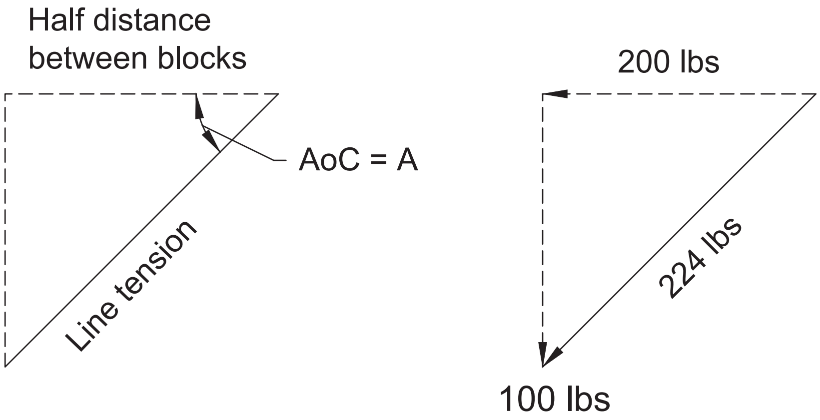


Figure E–23— Moving a load along a skyline involves the same principles and calculations as illustrated in the diagrams throughout this appendix.

Alternate Methods for Estimating Angles of Concern

You can use the estimated length of two sides of the triangle encompassing the AoC to estimate the angle degrees (figure E–24):

- **30 degrees:** the adjacent side of the angle is 1.7 times the length of the opposite side (if it is 2 times the length, the actual angle is 26 degrees).
- **45 degrees:** the adjacent side of the triangle equals the length of the opposite side.
- **60 degrees:** the adjacent side of the triangle is 0.6 times the length of the opposite side.

You can easily measure the corner angle in a sling setup using a clinometer or a compass that has a second needle for measuring slope angle. If you use a clinometer, remember that the trigonometry factors printed on the clinometer are cosine values.

If you have difficulty measuring an AoC, remember that the sum of the two non-90-degree angles in a right triangle has to equal 90 degrees, so measuring the other angle and subtracting it from 90 provides the AoC. Also, if you can visualize a line parallel to one side of the AoC, where the line crosses the point of the opposing angle, the angles are equal on opposite sides of the diagonal line, essentially creating a parallelogram (figure E–25).

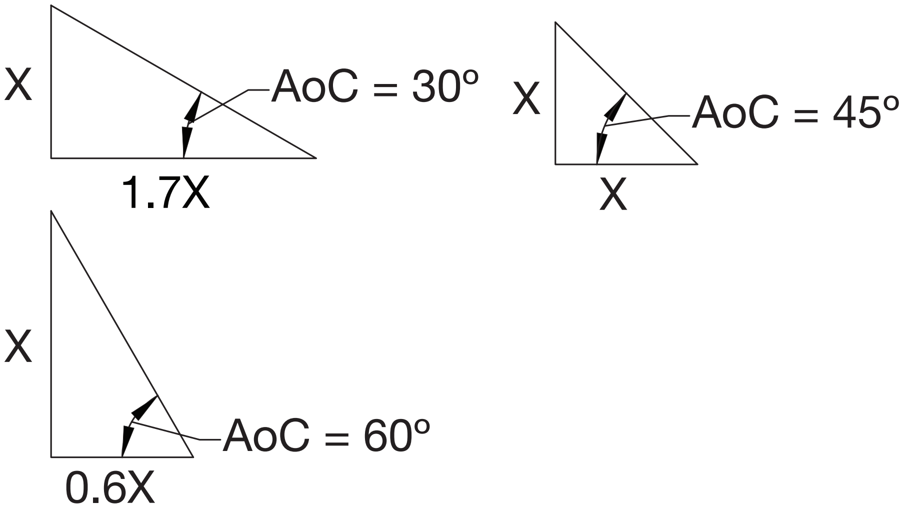


Figure E–24—Relative triangle side lengths with given angles.

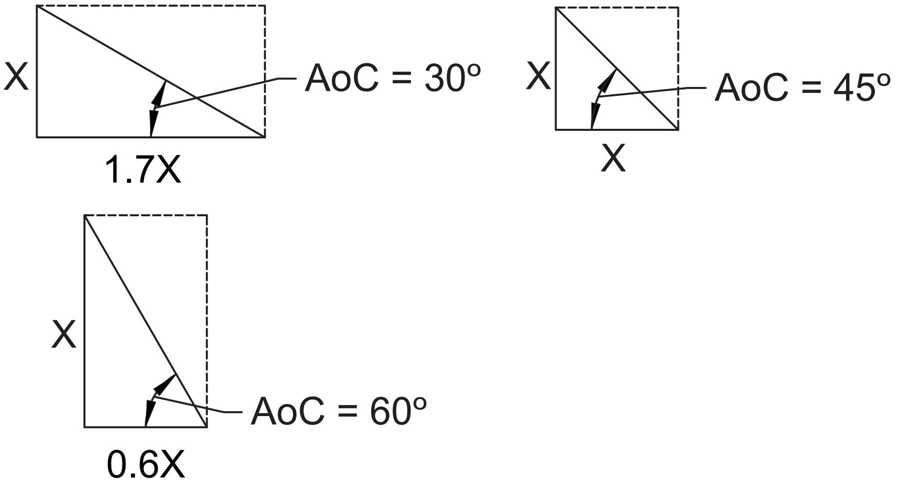


Figure E–25—Determining the angle of concern using a parallelogram.

Appendix F: Stock Animals

Using horses and mules (stock animals) to assist in rigging dates back to the early American pioneer days. Stock animals still have applications in rigging today. With the recent availability of high-strength ropes, we predict greater opportunities for riggers to use stock animals in specialized rigging applications, such as ground-skidding logs and rocks or hauling lifting lines on a cable rigging project. While riggers don't often use stock animals, these animals may be the preferred method for moving materials under certain conditions. Only experienced stock handlers who are thoroughly familiar with draft applications should work on these trail rigging projects. While handlers can train almost any stock animal to draft, trail rigging projects are not good on-the-job training opportunities for these animals. Handlers should only use gentle, well-trained animals with properly fitted harness components.

Stock Animal Applications

Most rigging using stock animals involves ground-skidding logs, although some riggers use animals to pull stone boats to move rock and other materials. The most critical factors to consider before using stock animals for skidding are the size of the load and the type of ground to be traversed. Riggers can also use stock animals for applications where they must haul substantial material uphill to the trail site by repeatedly raising the necessary loads with a skyline. A stock animal may replace a power capstan or chain saw winch for some operations.

Examples of rigging applications using stock animals include:

- Skidding log waterbars from the cutting location to the installation site
- Clearing out jack-strawed blowdown segments cut with crosscut saws along wilderness trails
- Skidding locally acquired replacement logs used for a cabin restoration project
- Skidding a stone boat to move gravel or rock from its source to its intended location on a trail
- Raising building material, such as rock, along a skyline from a source below the trail

> “Successfully using stock animals for rigging applications depends heavily on crews using the proper equipment for the job.”

Equipment

The internet, books, and other sources provide extensive information about quality draft horse equipment. Successfully using stock animals for rigging applications depends heavily on crews using the proper equipment for the job. For this reason, we recommend seeking the advice of reputable draft horse equipment suppliers for information about harness and tack needs. We only provide some basic considerations in this appendix.

Harnesses

A harness is a series of leather, nylon, or synthetic belting fitted to a horse or mule that enables the animal to pull a vehicle or load. Selecting the right harness and maintaining it properly increases its useful life and can prevent a disastrous mishap that could harm the animal.

Harnesses come in several styles and three sizes:

- Pony (800 pounds or less)
- Regular horse (800 to 1,400 pounds)
- Draft horse (1,400 pounds and up)

Suppliers often recommend that you fit the stock animal with a D-ring harness for the kind of work required in most trail rigging projects. The advantage of a correctly adjusted D-ring harness is that it maintains the proper angle of the traces to the stock animal's shoulder via the collar and hames, whether the rear trace to the load is high or low. This is especially helpful for skidding logs in broken country. By maintaining the traces to the hames attachment on the collar at a 90-degree angle, the animal's shoulders receive an even load distribution. Without this feature, the load could place uneven pressure on the collar that could make the animal sore.

Caring for a Harness

Checking the components of a harness regularly not only protects a crew's investment, but also ensures the safety of the stock animal and crew.

To care for a harness:

- Check for broken or worn stitching.
- Clean the harness frequently with mild soap, whether the harness is leather or synthetic. Disassemble all the parts to clean the harness. For leather harnesses, also apply leather conditioner.
- Check for rot, mildew, or tears in leather or synthetic materials.
- Inspect beneath the locations where buckles fasten.
- Inspect all hardware for cracks or bending.
- Check and replace the hame straps as needed.

Collars

A collar is a large, padded leather or synthetic cushion placed around the animal's neck, enabling the animal to pull the load with its shoulders. While you can adjust harnesses to fit several animals of the same weight class with different configurations, you cannot adjust the collars. A work collar is a very personal piece of equipment that is sized to fit the individual animal's neck and shoulders. Seek professional help to select the proper style and size for an individual animal. Even a well-made collar will hurt the animal if it does not fit properly. Use a collar pad to wick sweat away from the animal and keep it off the collar.

Hames

Hames come in pairs and attach to each side of the collar to properly align the load to the animal's shoulders. Manufacturers often make hames of tubular steel. They are sized to and should be considered part of the collar. Trail rigging requires the use of heavy-duty work hames that are designed for heavy pulling and are equipped with a draft adjustment feature. You usually order them two sizes larger than the collar. They are the correct size when their full length naturally fits behind the rim of the collar, and they often have an extra piece of wear leather stitched to the rim of the collar to protect the collar. A harness that is either too long or too short for a collar can chafe or make an animal sore.

Traces

Traces are wide (often 2½ inches), thick leather or synthetic straps attached to the hames. They run along each side of the animal and enable the animal to pull the load. The back ends of the traces have short pieces of elongated chain that hook onto the singletree. The traces carry the weight of the load, so it is critical that they be structurally sound. Because it is hard to guarantee the quality of leather, we recommend using only 2-inch by 5-ply polypropylene for traces used in trail rigging applications.

Singletrees

A singletree is a horizontal bar directly behind the animal's rear hoofs that attaches the load to the traces of the harness. Singletrees vary in length, thickness, material, and construction, depending on the need. The size of the animal determines the length of the singletree. The singletree must be long enough that the traces just clear the side of the animal. Because the singletree holds the entire weight of the load, you should inspect it frequently, particularly a singletree made of wood. Steel singletrees are more durable for trail rigging applications.

Some riggers attach a quick-release hook to the singletree. You activate this emergency manual release using a small-diameter rope lanyard that is within easy reach. If you use the manual release, the release should be equipped with an automatic braking system so that the detached load cannot rapidly descend the skyline, possibly injuring workers below.

General Procedures

When ground-skidding, the closer the load is to the singletree the better. Likewise, the singletree must have only a couple of inches of clearance from the animal's heels. This enables the animal to exert some lifting power to the load as it leans into the collar. Properly rigging a change-of-direction block can facilitate the optimum angle of the rope attached to the singletree.

Safety

- Never leave a stock animal untied or unattended.
- Keep unauthorized personnel away from stock animals.
- Never stand between a load and a stock animal.
- Check all equipment and ensure that it is in good repair.
- Beware of items that could startle a stock animal.
- Use fly net or repellent to protect stock animals.
- Always know where the lines are in relation to a stock animal's feet.

Notes

About the Authors and the Illustrator

David E. Michael has more than 40 years of experience applying rigging principles in the woods and teaching others about rigging. The U.S. Department of Agriculture, Forest Service, volunteer groups, and the traditional skills community recognize Michael nationally for his expertise in traditional tools and techniques. He has received numerous regional and national awards. For 25 years, Michael has contributed his knowledge and skills as a subject matter expert to numerous projects for the Forest Service, National Technology and Development Program.

Michael worked in the logging industry during college and, after military service, he joined the Forest Service. During his career on seven national forests in four regions, he learned numerous local rigging techniques. His work in engineering, recreation, and wilderness management—primarily building remote trail bridges and constructing and maintaining trails—provided him with ample opportunities to learn and perfect the art of rigging.

Michael retired in 2011 from his position as the manager of the Tahoe National Forest Trails and Off-Road Vehicle Program after a 33-year career with the Forest Service. He and his wife, Marci, now live in the Missouri Ozarks, where he continues to learn, teach, and consult about rigging and traditional skills.

Jedadiah J. Talbot's first exposure to trail work in college opened his eyes to the possibilities in the conservation field. He has worked extensively with various conservation corps, private trail contractors, nonprofit groups, and State and Federal agencies. In 2004, he established Off the Beaten Path (now known as OBP Trailworks, LLC)—a business that specializes in training trail skills, contracting trail work, backcountry construction, and low-impact forestry operations. Talbot's philosophy synthesizes traditional historic practices with innovative modern tools and techniques. His passion for understanding and developing safe and creative rigging practices matches his desire to teach and inspire others who wish to pursue conservation-based work. To date, Talbot has facilitated more than 100 trail skills workshops to groups of all ages and experience levels.

John S. Glenn began volunteering for the Forest Service in 2000. His primary work from May through November each year was to clear trees in wilderness areas using a crosscut saw. After attending a rigging and climbing course presented by the California State Parks Advanced Trails Program, Glenn began to use rigging extensively for trail work and for removing hazard trees. He received the Forest Service National Traditional Skills and Minimum Tool Leadership Award in 2006 and was named the Forest Service National Individual Volunteer of the Year in 2010.

Alice Webber studied at the Fine Art Conservancy of Purchase College, State University of New York. After spending her final college semester focused on field and conservation biology, she began her career as a crewmember in the southern California desert. Webber has continued her work as a trail crew leader, skills trainer, and trails supervisor with various nonprofit and outdoor organizations across the country. The combination of her background in drawing and empirical knowledge of rigging-based trail work made her uniquely qualified to provide the illustrations for this manual.

About NTDP

The U.S. Department of Agriculture, Forest Service, National Technology and Development Program, provides Forest Service employees and partners with practical, science-based solutions to resource management challenges. We evaluate, design, and develop new technologies, products, and systems to solve problems and deliver solutions.

Library Card

Michael, D. E.; Talbot, J. J.; Glenn, J. S. Rigging for trail work: principles, techniques, and lessons from the backcountry 2024. 2223–2806–NTDP. Tech. Rep. Missoula, MT: U.S. Department of Agriculture, Forest Service, National Technology and Development Program. 176 p.

Rigging is the use of specialized tools to safely move heavy objects from one location to another without causing undue strain on the body of a rigging crewmember. When used properly, rigging greatly expands the options and efficiency of trail construction and maintenance activities—from simple, repetitive work projects involving minor forces (e.g., moving trail materials from one location to another) to complicated scenarios involving massive forces that require the use of mechanical advantage (e.g., moving bridge timbers, big rocks, or large trees).

An effective approach to safe rigging techniques must include a thorough understanding of the basic principles of force, movement, and environmental sensitivity, and on selecting good, quality rigging components. This manual describes fundamental concepts of force and movement, explains various rigging configurations and their uses, and provides information about selecting and caring for quality rigging equipment.

The manual is designed primarily for U.S. Department of Agriculture, Forest Service trail maintenance and bridge construction work, but the principles of rigging can be used on many resource projects. Riggers can use this manual as a reference in the field and rigging instructors and employees can use it to prepare a job hazard analysis (JHA). Though written information cannot prevent accidents, understanding the information in this manual, along with applied field experience, can help you to work safely with trail rigging systems.

Keywords: anchors, backcountry, blocks, braking systems, fiber ropes, hoists, job hazard analysis, JHA, knots, mechanical advantage, rigging, safety at work, slings, spars, spar trees, trail construction, trail maintenance, trail rigging, winches, wire rope, working load limit, WLL

Contact Information

Contact the National Technology and Development Program (NTDP) for additional technical information:

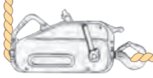
USDA Forest Service
National Technology and Development Program
Phone: 406–329–3978 or 909–599–1267
Email: SM.FS.wo_mtdc_pubs@usda.gov

Find electronic copies of NTDP documents on the internet at:

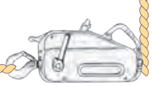
Search NTDP:
<https://www.fs.usda.gov/t-d/index.php>

Forest Service and Bureau of Land Management employees can search NTDP documents, CDs, DVDs, and videos on their internal computer networks at:

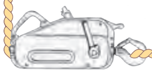
Search NTDP: <https://fsweb.wo.fs.fed.us/ntdp/>



Notes



Notes



This page left intentionally blank.

Produced by
U.S. Department of Agriculture, Forest Service
National Technology and Development Program

2223–2806–NTDP