Chapter 9: Ropes, Knots, Bends, and Hitches

Chapter Overview

Rope is the foundation upon which successful rope rescue activities are built; therefore, extra attention should be paid to materials, construction methods, environments, storage practices, cleaning methods, and recordkeeping efforts. Carefully chosen and properly cared for ropes are crucial to the safety and efficacy of rescue activities. An understanding of the types of ropes available and the materials used to construct them will make it easier to determine which rope is best for a specific application. This knowledge will also help users take the necessary steps to care for the ropes.

Understanding the terminology used to refer to ropes and knots is crucial to the rescuer’s ability to execute skills and communicate with team members. Additionally, demonstrated knowledge and execution of various knots is imperative to a rescuer’s ability to safely perform rope rescue activities. Severe problems and hazards can result from poor rope choices, improperly applied techniques, and damaged equipment. Real-world testing and regular inspections must be included as part of any rope rescue program in order to ensure that all equipment is fit for service.

Objectives and Resources

**Knowledge Objectives**

After studying this chapter, you should be able to:

 List the materials used to create rope. (NFPA 1006: 5.2.4, pp. 148–150)

 Describe the characteristics of rope construction and how it impacts performance. (NFPA 1006: 5.2.4, pp. 150–152)

 List the considerations to weigh when selecting rope for a task.

 Describe the anatomy of a knot. (NFPA 1006: 5.2.4, pp. 157–158)

 Identify the purpose of knots in a rope rescue system. (NFPA 1006: 5.2.4, p. 159)

 Describe the specific knots utilized in rope rescue systems. (NFPA 1006: 5.2.4, pp. 160–172)

 Describe the practices to follow for the proper storage of ropes.

 Describe the practices to follow for the inspection and maintenance of ropes. (NFPA 1006: 5.2.3, pp. 172–180)

 Describe how to identify and remove damaged rope from service. (NFPA 1006: 5.2.3, pp. 175–178)

**Skill Objectives**

After studying this chapter, you should be able to:

 Select the appropriate rope for a rescue task. (NFPA 1006: 5.2.4, pp. 152–157)

 Tie an overhand knot. (NFPA 1006: 5.2.4, p. 160)

 Tie a barrel knot. (NFPA 1006: 5.2.4, p. 161)

 Tie a figure 8 stopper knot. (NFPA 1006: 5.2.4, p. 161)

 Tie a figure 8 on a bight. (NFPA 1006: 5.2.4, p. 162)

 Tie a figure 8 follow-through. (NFPA 1006: 5.2.4, p. 163)

 Tie a double figure 8 loop. (NFPA 1006: 5.2.4, p. 164)

 Tie a high-strength bowline. (NFPA 1006: 5.2.4, p. 165)

 Tie an interlocking long-tail bowline. (NFPA 1006: 5.2.4, p. 165)

 Tie an inline figure 8. (NFPA 1006: 5.2.4, p. 166)

 Tie a butterfly knot. (NFPA 1006: 5.2.4, p. 167)

 Tie a figure 8 bend knot. (NFPA 1006: 5.2.4, p. 168)

 Tie a grapevine bend. (NFPA 1006: 5.2.4, p. 169)

 Tie a ring bend. (NFPA 1006: 5.2.4, p. 170)

 Tie a Prusik hitch. (NFPA 1006: 5.2.4, p. 171)

 Tie a clove hitch. (NFPA 1006: 5.2.4, p. 172)

 Bag a rope. (NFPA 1006: 5.2.3, p. 175)

 Clean a rope. (NFPA 1006: 5.2.3, pp. 178–180)

 Dress rope ends. (NFPA 1006: 5.2.3, p. 180)

Support Materials

 Dry-erase board and markers or chalkboard and chalk

 LCD projector, slide projector, overhead projector, and projection screen

 PowerPoint presentation or slides

 **Navigate for Students**

 **Advantage**

 Each printed textbook comes with an access code that unlocks several valuable teaching and learning assets including:

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Reading and Preparation

Review all instructional materials, including *Rope Rescue: Principles and Practice,* Fifth Edition, Chapter 9 and all related presentation support materials.

Chapter Presentation Overview

Pre-lecture

I. You Are the Rescuer

Small-Group Activity/Discussion

Purpose

The purpose of this activity is to introduce students to concepts surrounding the understanding and management of water rescue incidents.

Instructor Directions

1. Direct students to read the “You Are the Rescuer” scenario found at the beginning of Chapter 9 (p. 148).

2. You may assign students to a partner or a group. Direct them to review the discussion questions at the end of the scenario and prepare a response to each question. Facilitate a class dialogue centered on the discussion questions.

3. You may also assign this as an activity and ask students to turn in their comments on a separate sheet of paper.

Lecture

I. Introduction

A. Review the learning objectives.

B. Rope is the foundation of any rope rescue activity.

C. Many kinds of rope are used for rescue tasks; however, each kind of rope contains different materials and is constructed in a specific manner according to its performance characteristics.

D. The ideal performance characteristics to specify when choosing a rope depend on the specific need and environment for which the rope will be use. The following should be considered before choosing a rope:

1. Whether it will be used for personal loads or rescue loads

2. Whether it should excel in force absorption or stability for managing loads

3. How durable the sheath needs to be

4. How soft and easy to tie it should be

5. Whether it will be exposed to high heat or flame

E. Choosing the correct rope for a job will make the task easier and safer to accomplish, whereas a poorly chosen rope can result in severe problems or hazards for rescuers.

II. Fibers Used to Make Rope

**A. Natural fibers**

1. For many years, ropes made of natural fibers, such as sisal, hemp, and manila, were standard. About the time of World War II, mass production of rope made of synthetic fibers, such as nylon or polyester, began.

2. Currently, synthetic fiber ropes are considered standard for situations in which the safety of a person is “on the line.”

3. National organizations such as the International Association of Fire Fighters, the International Society of Fire Service Instructors, and the National Fire Protection Association (NFPA) have all condemned the use of natural fiber rope in life-safety applications because natural fiber ropes experience the following issues:

a. Show low resistance to abrasion

b. Have a limited ability to absorb shock loading

c. Degrade in strength even with the best care

d. Can rot without outward visible signs

e. Have lower breaking strengths than ropes of the same diameter made of synthetic fibers such as nylon or polyester

f. Do not have strands that are continuous along the rope’s entire length because natural fibers are never more than a few feet long

**B. Synthetic fiber ropes**

1. Synthetic fiber ropes have several important advantages over natural fiber ropes:

a. Synthetic fiber ropes do not rot.

b. Synthetic fiber ropes do not age as quickly.

c. Synthetic fiber ropes can be made into more advanced rope designs than natural fibers.

2. Polyolefins (polypropylene and polyethylene)

a. Common in recreational boating activities and in commodity ropes, such as hardware store utility rope, twine, clothesline, and other nonspecialty commercial products

b. Because they float, rescuers may come across polypropylene ropes in water rescue throw bags.

c. These are among the least expensive of ropes, but because of their low tensile strength, low abrasion resistance, and low melting point, they should not be used for direct loading in life-safety operations.

d. Advantages of polyolefin ropes include the following:

i. Do not absorb water

ii. Float (specific gravity of 0.91); consequently, they are useful in activities on the water

iii. Have good chemical resistance (pH 2 to 12)

e. Disadvantages include the following:

i. Have relatively low tensile strength (6 to 6.5 grams per denier [gpd] breaking tenacity)

ii. Have poor abrasion resistance

iii. Have low melting points (150°F to 200°F [65.6°C to 93.3°C])

iv. Have poor shock-absorbing (shock-loading) capability

v. Have poor resistance to damage from sunlight

3. Polyester

a. Fibers are found in a number of life-safety applications; however, because polyester does not handle shock loading as well as nylon, it generally is not found in dynamic climbing ropes.

b. Advantages of polyester rope include the following:

i. High-tensile strength even when wet (7 to 10 gpd breaking tenacity)

ii. Good abrasion resistance

iii. Resistant to damage from acids (pH of 3.5 to 7.5)

iv. Lower elongation than nylon

c. Disadvantages of polyester rope include the following:

i. Inability to handle shock loading as well as nylon (12 percent to 15 percent elongation at break)

ii. Susceptible to damage from alkalis

iii. Inability to float (specific gravity of 1.38)

iv. “Slipperiness” of material can make for fast descents

4. Nylon

a. The two most commonly used in life safety ropes are nylon 6 and nylon 6,6.

i. Of the two, nylon 6 is preferred for higher elongation properties (and lower cost) while nylon 6,6 is preferred where greater durability and lower elongation characteristics are desired.

b. Advantages of nylon rope include the following:

i. Optimum breaking tenacity (7.8 to 10.4 gpd)

ii. Balanced shock-loading capability (15 percent to 28 percent elongation at break)

iii. Resistant to damage from alkalis (pH 6.5 to 10.5)

c. Disadvantages of nylon rope include the following:

i. It may lose 10 percent to 15 percent of its strength when wet (regained when dry).

ii. Susceptible to certain strong acids

iii. Does not float (absorbs water)

5. UHMPE (extended chain, high-modulus polyethylene)

a. UHMPE is a polyethylene yarn, known by brand names such as Spectra and Dyneema.

b. Gained initial popularity in this market in the form of slings and runners for climbing; now incorporated into ropes and other products

c. Advantages of HMPE ropes include the following:

i. Have high-tensile strength (30 to 35 gpd breaking tenacity)

ii. Float (0.97 specific gravity)

iii. Do not absorb water

d. Disadvantages of HMPE ropes include the following:

i. Have a low melting point (about 150°F to 200°F [65.6°C to 93.3°C])

ii. Have poor shock-absorbing capability (2.7 percent to 3.5 percent elongation at break)

iii. Are very slippery; therefore, special knots may be required to hold when tied

e. Denier

i. Denier is a weight-per-unit-length measure of any linear material such as yarn

ii. The measurement is a numeric representation of the weight in grams (g) of 9000 meters of the material. The smaller the number, the finer the yarn. The tensile strengths of yarns are often rated as grams per denier (gpd).

iii. While denier is still being used by some manufacturers, *tex* is a term increasingly being used. Tex is defined as the mass in grams per 1000 meters. The commonly used unit is decitex, abbreviated dtex, which is the mass in grams per 10,000 meters.

6. Aramids

a. An aramid is a particular type of polyamide that has been altered to increase heat resistance.

b. Para-aramid fibers such as Kevlar, Twaron, and Technora excel in heat resistance (where UHMPE is lacking) while still offering exceptionally high strength-to-weight ratios, but they do not float, they absorb water, and they are easily damaged by repeated flexing.

c. Advantages of aramid ropes include the following:

i. Are resistant to high temperatures (350°F [176.7°C] working limit)

ii. Have high-tensile strength (18 to 26.5 gpd breaking tenacity)

iii. Are resistant to organic solvents

d. Disadvantages of aramid ropes include the following:

i. Are easily damaged by continued small radius flexing (as in knotting)

ii. Have poor shock-loading capability (1.5 percent to 3.6 percent elongation at break)

e. Are sensitive to chlorine and some acids and bases

III. Rope Construction

**A. Laid**

1. Laid construction means that small fiber bundles of material are twisted and then combined in larger bundles, usually in groups of three, which are twisted around one another in the opposite direction. Construction resembles the designs of older types of rope made of natural fibers.

2. Disadvantages

a. When loaded, the fibers in laid rope tend to untwist slightly, causing inherent spin and kinking as a descender spirals down the twist of the strands.

b. Laid rope tends to be very stretchy, and it also tends to kink unless handled carefully.

c. The load-bearing fibers are not covered by a sheath, so they are exposed to potential damage by abrasion during use.

3. Ropes of laid construction have been displaced in most high-angle work by other designs.

**B. Plaited**

1. Plaited rope usually consists of bundles of fibers plaited together.

2. Plaited ropes tend to be soft and pliable, but they are prone to picking (snagging and pulling out of fiber bundles).

**C. Braided**

1. The two types of braid used in the construction of braided rope are as follows:

a. Solid (single) braid (clothesline braid)

i. Constructed entirely of a single weave of three or more fiber bundles

ii. Because the load-supporting fiber bundles in single-braid construction are vulnerable to destruction when the rope is being used, single-braid ropes have limited use in critical safety operations.

b. Hollow-braid rope

i. Similar in appearance to solid braid, but sometimes has a filler, such as scrap yarn or filament plastic; typically is found in inexpensive hardware store–type rope

ii. Though often quite similar in appearance to life safety rope, it does not have the same performance specifications.

**D. Double braid**

1. A double-braid rope is essentially a rope constructed of a solid braid covered with a hollow braid.

2. One braid acts as the rope core; the second braid is constructed around it to act as a sheath and to help protect the inner braid.

3. Double-braid ropes are typically woven loosely to maintain softness and flexibility, but this also increases their susceptibility to picking, abrasion, contamination, and sheath slippage.

**E. Kernmantle**

1. Rope design

a. Central core of fibers that supports the major portion of the load on the rope

b. Woven sheath that covers core and supports a lesser portion of the load

c. The amount of material in the core versus sheath is not directly proportional to the amount of load that is taken by each.

2. Kernmantle ropes are prized for their balance, strength, ease of handling, and resistance to damage.

3. Braiding machines

a. Kernmantle ropes used for life safety applications are typically made on a braiding machine that carries yarn-filled bobbins around and around a core material in a serpentine pattern to form a braided sheath around the strength-giving core.

b. The following factors influence rope performance:

i. The amount and type of yarn committed to each part of the rope

ii. The angle at which the braided yarns are wound on the sheath

iii. The tension at which the braid is applied

4. Static and low-stretch kernmantle

a. Static

i. When applied to kernmantle rope, a type of rope with very low stretch (no more than 6 percent elongation at 10 percent of its rated minimum breaking strength)

1 Created by a rope core of fiber bundles that are nearly parallel to one another

2 Some static ropes have so little stretch that what there is results largely from the inherent stretch of the core fiber.

b. Low stretch

i. At type of kernmantle rope with a little more stretch than static kernmantle ropes (no less than 6 percent and no more than 10 percent elongation at 10 percent of its rated minimum breaking strength)

1 Most low-stretch ropes have more twist in each core strand to provide additional mechanical elongation to the inherent stretch of the core fiber.

c. Pros and cons

i. Causes a more abrupt stop when catching a fall, which subjects the climber’s body, the equipment in the system, and the anchors to greater impact loading than would a dynamic rope

ii. Protected from damage by abrasion, dirt and grit as a result of thicker sheath

iii. Stiff and not as easy to handle as a dynamic kernmantle rope with its thinner sheath

IV. Performance Characteristics

**A. While material and construction are important, what is more important are the performance characteristics that the combination of these factors produce in the rope that you intend to use.**

**B. The starting point for evaluating or classifying rope is the relevant standards that apply to your intended use, examples of which include the following:**

1. NFPA

2. American National Standards Institute (ANSI)

3. ASTM International (ASTM)

4. Union of International Alpine Associations (UIAA)

5. EuroNorm (EN)

V. Rope Selection

**A. When choosing a rope, consider at least the following specifications:**

1. Diameter. Compatibility with other gear is especially important.

2. Minimum breaking strength. Be sure it is rated in accordance with an appropriate standard test method.

3. Elongation. Too much results in a bouncy rope, but too little can exacerbate forces.

4. Abrasion resistance. More tightly woven ropes tend to be more abrasion resistant.

5. Hand. A soft hand is great for tying knots, but this feature is juxtaposed with abrasion resistance.

6. Color. Consider visibility in your field of work and possible color-coding schemes.

7. Length. Needs will vary depending on your response area and type.

**B. You can only compare specifications between ropes if they are measured according to the same test methods and reporting criteria.**

**C. NFPA 2500 (1983) refers to test methods from Cordage Institute standard CI 1801, so this text will focus most on these standards.**

**D. Diameter**

1. Measurements

a. It is essential to know the actual diameter of life safety ropes as they are accurately measured and reported.

b. The diameter of commodity ropes is sometimes reported based on mass per unit length; precision is less important.

c. Life safety rope diameter is measured more precisely thank.

2. NFPA 2500 (1983)

a. Ropes certified to NFPA 2500 (1983) are measured for diameter using calipers at several points across the length of the rope; there is a limit to how much the values can vary.

b. Using the correct diameter of rope for auxiliary equipment is essential to ensure compatibility and proper performance.

3. Grippability

a. With this class of equipment, rescuers should not be relying on barehand rope techniques.

b. The grippability of even a 12.5-mm (1/2-in.) rope is not adequate to ensure safety for rescue purposes.

c. Rescuers should rely on auxiliary equipment to hold fast to the rope such as connectors, braking devices, rope grabs, and other gear.

4. Ranges

a. Rescue ropes: 9.5 mm to 13 mm (3/8 in. to ½ in.)

b. Personal escape ropes: 7-mm to 9-mm (9/32-in. to 7/20-in.)

c. NFPA rating-related ranges:

i. G rating: 11 mm and 16 mm (7/16 in. and 5/8 in.)

ii. T rating: between 9.5 mm and 12.5 mm (3/8 in. and ½ in.)

iii. E rating: 7.5 mm and 9.5 mm (19/64 in. and 3/8 in.)

5. Webbing

a. Per NFPA, webbing can now be used in place of rope for escape systems

b. Webbing is of a flat construction, rather than round, so diameter measurement is necessarily across the wide, flat surface.

c. It should not be assumed that a 1-inch webbing really has 1-inch of thickness to protect against abrasion.

6. Choosing a rope

a. The best choice for the application will depend first on the descenders, rope grabs, and other components with which it will be used.

b. A rope with large enough diameter to provide adequate durability and an appropriate minimum breaking strength is also important.

i. Choosing too large a diameter could limit compatibility with other gear, as well as the overall additional weight when transporting gear to a rescue site.

ii. Most rescue teams select 7/16-inch (11.1-mm) or 1/2-inch (12.7-mm) static or low-stretch kernmantle ropes for their main rescue lines.

iii. Each team should make its own decision based on such factors as rescue needs, environment, and the nature of their team.

7. Large-diameter ropes

a. Overall strength of very-large-diameter ropes should be viewed in light of safety factors relative to the entire system and its ability to maximize overall safety.

b. Pitfalls of large-diameter ropes

i. Higher cost (more material used in the rope)

ii. Greater weight (more difficult to carry to a rescue site)

iii. Handling problems (additional weight of hanging rope on the system)

iv. Incompatibility with other equipment (most equipment is designed for 11- to 12.7-mm (7/16- to ½-in.) rope)

**E. Breaking strength**

1. Breaking strength

a. The force at which an item will break

2. Manufacturer’s reports

a. The only way to know the actual strength of any item is to break it, and no two samples of any item are going to break at exactly the same force, so it is difficult to provide a reasonably accurate and reliable figure upon which to base load ratio calculations.

b. When publishing breaking strengths for life-safety equipment, it is important that the manufacturer publish a figure in which the rescuer can have a high degree of confidence.

c. The information that is of most value to the rescuer is the minimum, or lowest, strength at which equipment is reasonably likely to fail.

3. MBS and 3-Sigma

a. Minimum breaking strength (MBS)

i. The minimum, or lowest, strength at which equipment is reasonably likely to fail

b. 3-Sigma

i. Common method for calculating a reliable and repeatable MBS rating

ii. Rope strength is measured by wrapping the rope several times around a bollard (or short post) and pulling to failure.

iii. A minimum of five samples are tested, and then an MBS is calculated by subtracting three times the standard deviation from the mean (average) of the test result numbers. That result, or lower, is what the manufacturer should advertise.

iv. Using the 3-sigma method helps to ensure that some 99.87 percent of ropes made to this exact same design should have a breaking strength above the 3-sigma rating.

v. The manufacturer’s quality assurance program is what maintains that continuity.

4. Comparing information

a. When reviewing breaking strengths and comparing products, be sure you are comparing similar information.

b. Some manufacturers do not use the 3-sigma method to determine the MBS.

c. Some manufacturers that are not building and marketing gear to CI1801, ASTM F32, or NFPA 2500 (1983) standards may have other ways to determine breaking strength.

d. Other variations in standards and testing exist and should also be taken into consideration when comparing the specs of different types or brands of rope.

5. Strength

a. While strength is important, higher strength often is achieved by using materials that hardly stretch at all.

i. This lack of stretch means poor energy absorption if an unexpected force is suddenly applied to the system.

ii. Special care must be taken when rigging with a very-low-stretch rope.

b. Another way to increase strength in a kernmantle rope of a given diameter is to put less yarn in the sheath and more yarn in the core.

i. Can result in a strong rope with a soft hand

ii. Can also make a rope with little sheath to protect the core from cuts, dirt, chemicals, and abrasions

6. NFPA 2500 (1983) classifications and MSBs

a. G-Rated (General use): MBS value of at least 40 kN (8992 lbf)

b. T-Rated (Technical use): MBS value is at least 20 kN (4496 lbf)

c. E-Rated (Escape use): MSB of 13.5 kN (3034 lbf)

d. Rescuers using T-rated rope are expected to be more thoroughly trained and capable of ensuring that they maintain adequate safety margins while using this type of rope.

**F. Elongation**

1. Elongation and force absorption

a. Ropes that offer high impact-force absorption, such as dynamic climbing rope, are typically also high in elongation, and vice-versa.

b. NFPA 2500 (1983) does not specify force absorption characteristics of ropes, but it does call for measurement of elongation (i.e., between 1 percent and 10 percent).

c. Ropes that are lower in elongation are more stable for lowering and raising, but cause a more abrupt stop when catching a fall. This results in greater impact loading than would a dynamic climbing rope.

d. Rescue ropes are primarily intended to be used with a relatively low fall factor.

i. With a sufficient length of rope already in play, the limited range of falls that can be reasonably anticipated in rescue situations do not warrant a high force-absorption capability; stability for lowering and raising is more important in this case.

e. Ropes that are less dynamic and have less ability to elongate offer greater control during rescue operations.

2. CI elongation definitions

a. Static = Elongation > 1 percent < 6 percent when measured at 10 percent of minimum breaking strength (MBS)

b. Low stretch = Elongation > 6 percent < 10 percent when measured at 10 percent of MBS

3. NFPA 2500 (1983)

a. NFPA 2500 (1983) permits both static and low-stretch ropes, though there can be a noticeable difference in elongation between them.

b. When choosing ropes, it is important to balance specific rescue and rigging needs; low stretch can be achieved in a number of ways, though each method has its own disadvantages.

4. Elongation life-saving rope

a. Recognized by the NFPA but not classified as life safety rope by NFPA 1983

b. It is intended only for special-use applications where elongation between 10 percent is 25 percent is necessary in life-saving operations (e.g., basic fire-ground rescue operation where a rescuer is being lowered from a roof for a pickoff) where there is a high possibility of an impact load from a person suddenly jumping onto the rescuer.

c. They would not be used for other types of rope rescue such as lowering or hauling a litter, in mechanical advantage haul systems, or highlines.

**G. Abrasion resistance**

1. Abrasion resistance

a. In fiber technology, this generally refers to the ability of a yarn to resist surface wear when rubbed against another yarn of the same material.

b. Abrasion resistance is a difficult thing to quantify and is not presently measured in NFPA 2500 (1983).

2. Proposed test methods

a. Although a number of test methods have been proposed to measure this rope characteristic, each has its flaws (e.g., ropes that test well in a longitudinal test, where it is abraded up and down on a surface, may not perform as well in a test where abrasion occurs side-to-side, in a sawing fashion).

b. The test surface is also a challenge in terms of choice of abrasive material, heat build-up, embedding of fibers that then provide padding to the affected rope, wearing down of the abrasive surface, etc.

3. Real-world test methods

a. The best way to determine which ropes outlast others is by actual use in the environment and conditions under which it will be used.

b. Simply put, you will find that some ropes last longer than others as you use them. Do not be surprised if your experience differs from what other users report.

c. In addition to the influence of the equipment you use and your particular environment, you will also find that sheath material, braid, and sheath thickness all play a role in the outcome.

4. Sheath thickness

a. Determined by a number of factors, the most significant of which is the number of yarn bundles used in making the sheath

i. Most life safety ropes have either 16, 32, or 40 bundles in the sheath.

ii. Some dynamic climbing ropes may have up to 48, but this results in a very thin sheath.

b. Carrier

i. The piece of equipment that carries the bundles of sheath yarn around and around the core to form the outer braid during the manufacturing process

(i) The robustness of a sheath is referred to by saying that these are 16-, 32-, or 40-carrier ropes.

(ii) More bundles result in a smoother, more pliable, softer sheath, while fewer bundles contribute to toughness and durability.

**H. Hand**

1. Hand

a. How a rope feels in your hand

i. Influenced by such things as number of yarn bundles used to create the sheath, tightness of weave, and material

ii. In general, the softer the hand of the rope, the less abrasion resistant it will be.

2. Knotability

a. Measured by simply tying an overhand knot in the rope and measuring the remaining gap with a tapered plug gauge; the proportion of the gap to the diameter of the rope is called knotability.

i. A rope with a knotability rating of .5 would be found to have a measured gap of half the diameter of the rope.

ii. The lower the number, the easier it is to tie knots and work with the rope. The higher the number, the more durable it will be.

**I. Color**

1. A wide variety of colors is available, though generally speaking, extruded fibers such as polyester will sport brighter colors than dyed filament fibers like nylon.

2. Colors can serve a functional purpose (e.g., several ropes are used together, the different colors can help distinguish one line from another so that the rescuer immediately knows which rope to haul or lower).

3. Color coding

a. Color may also be used to indicate such things as truck, team, length, diameter, year of purchase, storage location, duty cycle, etc.

b. It is left to the discretion of the authority having jurisdiction (AHJ) whether, and how, color coding might be used. If used, care should be taken to ensure thorough training so that all personnel understand the protocol.

c. Whip end dip or end labels (i.e., write-on labels with a light adhesive on the back) can be used to color code the ends of ropes.

**J. Length**

1. There is no one standard rope length that is right for every agency. The best length of rope for your needs will depend several factors, including:

a. Response area

b. Types of operations

c. How personnel are trained

2. Additional factors to be considered include:

a. Measurement

i. Ropes may be measured in meters or in feet. Particular attention should be paid to the unit of measurement when purchasing rope and when working alongside another agency.

b. Weight and training levels

i. Longer ropes are heavier and more difficult to transport, so avoid erring toward very long ropes. Ropes too short for an operation require personnel to be trained to perform knot passes.

VI. Anatomy of a Knot

**A. Much of rope terminology comes from sailing and marine uses and can be a bit confusing when applied to land-based operations. For the purposes of rescue and rigging, it is best to keep things relatively simple.**

**B. Knot-tying instruction relies on knowledge of certain basic terminology:**

1. Line – a rope in use

2. Working end of a rope – the part of a rope where a knot is tied and a function underway as the working end of a rope

3. Running end – the free end that goes over the edge touches the ground

4. Standing part – the remaining length of the rope between the working end and the running end

5. Tail – the unused portion of rope remaining behind the working end

6. Bight – a U-shaped section of rope with parallel sides

7. Loop – the portion of rope formed into a circle with the ends crossing each other

8. Knot – generally used to refer to any kind of fastening made by tying rope or webbing together in a prescribed way

9. Bend – a class of knot that joins two ropes (or webbing pieces) together

10. Hitch – a manner of tying that requires some other object to maintain its shape

11. Backup (safety) knot – an extra tie—usually a simple overhand or double overhand—intended to provide secondary safety and prevent a primary knot from loosening, or to secure the tail of a rope

12. Stopper knot – bulky knot tied in the running end of the rope to prevent a device from accidentally running off the end

**C. Manufacturer-supplied eye termination**

1. Manufactured eye termination

a. A permanent formed loop in the end of a rope created by the rope manufacturer, as an alternative to a knot

i. The inside of the eye may be protected by a layer of fabric, metal, or other protective material, and the sewn part is often protected by material such as plastic tubing

ii. Such terminations make for quick rigging or facilitate hooking to connections such as the davits on some helicopters

iii. Some users specify their life safety ropes with permanent eye terminations supplied by the manufacturer

2. NFPA 2500 (1983) now has performance test standards for manufacturer-supplied eye terminations

a. Specifically, they are required to have a calculated MBS from a series of tests that is EITHER at least 85 percent of the certified rope’s calculated minimum breaking strength, OR

b. At least equal to the rated strength requirement for the host rope (20 kN [4496 lbf] for T, 40 kN [8992 lbf] for G, and 13.5 kN [3034 lbf] for E.)

c. Some rescuers believe that a rope marked to NFPA 2500 (1983) must meet the requisite test methods with the termination.

i. What this means is that if you purchase an NFPA-marked rope that is rated to 9000 pounds (4800 lg), it could have an end termination that is rated to only 7650 pounds (3500 kg).

VII. Knots

**A. While elimination of knots is a lofty goal, anyone who works at height will quickly learn that knots are indispensable for joining together many elements in the rope rescue system.**

**B. Among other functions, knots are used in the rope rescue environment for the following:**

1. Anchoring

2. Tying ropes together

3. Tying webbing together

4. Tying loops in rope and webbing

5. Tying people directly into ropes

6. Creating certain belay systems

7. Dealing with emergency situations (e.g., devising an emergency seat harness)

8. Backing up other knots

9. Keeping rope ends from pulling out of equipment

10. Ensuring personal safety (e.g., preventing a rappeller from rappelling off the end of a rope)

11. Creating emergency ascenders

12. Tying safety lines

13. Improvising when other elements of a system fail

14. Extricating oneself from unexpected difficulties

**C. Expectations**

1. The rope rescuer must be able to tie knots correctly, confidently, and without hesitation.

2. They must be well versed in the ways these knots are used, and competent to select the appropriate knot for a given application; if rescuers go into the rope rescue environment without these knot skills, they may be a danger to themselves, to a rescue subject, and to their fellow rescuers.

3. An aspiring rope rescuer should own at least two lengths of rope, each several feet (or a couple of meters) long, with which they can practice tying knots.

4. Every operations-level rescuer should be able to tie knots under stress, in the dark, when cold, using only one hand, and with diminished physical ability.

**D. Qualities of a good knot**

1. Although knots vary in their specific use, all good knots have certain characteristics in common:

a. They are relatively easy to tie.

b. It is easy to determine whether they have been tied correctly.

c. Once tied correctly, they remain tied.

d. They have a minimal effect on rope strength.

e. They are relatively easy to untie after loading.

2. Every knot diminishes the strength of rope to some degree.

a. This strength reduction is the result of sharp bends and pinching – generally speaking, the sharper the bends or the tighter the pinch, the less efficient is the knot.

b. Some knots, such as bowlines, have sharper bends, resulting in greater strength loss than knots that have more open bends, such as the figure 8.

3. Ultimately, the strength of knots, along with other elements of a high-angle system, must be taken into consideration when deciding on a rope load ratio or a system safety factor for a rope.

4. An improperly tied knot, or incorrect application of a knot, could result in serious injury or death.

**E. Removing knots**

1. Knots should be removed from a rope before the rope is put away and stored, for the following reasons:

a. Leaving a knot loaded and tied in a rope over a long period may cause permanent strength loss in the rope.

b. Knots left in a rope over a long period tend to set and become more difficult to untie.

**F. Completing the knot**

1. Knots should be well-dressed.

a. The end result should be neat and clean, with only as large a loop as necessary, and without a lot of extra tail.

b. Rope strands should be aligned correctly and to pull the ends down so the knot is compact to help prevent the knot from coming apart or capsizing and to ensure that it maintains its best performance.

2. It is good practice to back up most knots with a safety knot.

a. While an overhand knot if often used as a safety knot, a more secure backup is the double overhand knot.

b. When used, the backup should be tied as close as possible to the knot it is backing up.

3. For clarity, many knots in this manual are not shown with safety knots. However, it should be assumed that safety knots are an appropriate addition to most knots used for life safety applications.

VIII. Specific Knots for the Rope Rescue Environment

**A. Overhand knot**

1. An overhand knot is a type of stopper knot (i.e., a type of knot tied into the running end of a rope to prevent the line from feeding through a device.

2. Usually used in lowering or rappelling so that the rescuer does not inadvertently let the rope run completely through the device in the event that the rope length is insufficient

3. See Skill Drill 9-1: Tying a Simple Overhand Knot

**B. Barrel knot**

1. Can be transformed from an overhand knot

2. The barrel knot is tied by following the first two steps of tying an overhand knot, then looping it two more times:

a. Form a bight and bring the working end under itself

b. Bring the working end back into the bight and under itself for a total of three times

c. Pull the working end and standing part to tighten

**C. Figure 8 family of knots**

1. Many authorities experienced in the rope rescue environment prefer the figure 8 family of knots because for the following reasons:

a. More likely to be tied correctly

b. More likely to be remembered

c. Easier to tell quickly if it is tied correctly

d. Remains stable if loading on it comes from a direction different from that intended

e. More likely to remain tied after repeated loading and unloading

f. Less likely to invert and become untied when pulled across an obstruction or when the tail of the knot is pulled

g. More efficient (stronger) than a bowline

2. Figure 8 stopper knot

a. The figure 8 stopper knot is a type of stopper knot.

b. See Skill Drill 9-2: Figure 8 Stopper Knot

c. If two lines require a stopper knot, the figure 8 can be utilized to create a stopper knot by the following:

i. Tying a stopper knot in each line

ii. Tying a stopper knot together into both lines

3. Figure 8 on a bight

a. The figure 8 is also a good choice to form a loop (i.e., bight) in the end of a rope.

b. The figure 8 on a bight knot is easy to remember if you visualize the bight as one strand of rope and tie it just as the simple figure 8 is tied.

c. See Skill Drill 9-3: Tying a Figure 8 on a Bight

d. A figure 8 on a bight is used as a secure loop in a rope for clipping into with safety lines, anchor lines, persons being lowered, or similar situations.

e. Be careful that you tie a figure 8 on a bight and not an overhand on a bight.

4. Figure 8 follow-through

a. A figure 8 follow-through may be used when it is not possible to pass a simple loop over the end of an object, when a knot needs to be tied after the rope is looped around something, such as a structural beam or a tree.

b. See Skill Drill 9-4: Tying a Figure 8 Follow-Through Knot

c. Tip for tying a figure 8 follow-through knot

i. The figure 8 follow-through always begins with the tying of a simple figure 8 knot as a foundation well back from the end of the rope.

ii. After the simple figure 8 has been tied, pass the end of the rope around the anchor point, then follow back through, parallel to the first knot. Follow every contour of the first knot with both rope ends going in the same direction.

iii. Do not confuse this knot with the figure 8 bend.

5. Double figure 8 loop

a. The double figure 8 loop, also known as bunny ears, is a variation on the versatile figure 8.

b. This is a useful knot for sharing a load between two anchors, among other things.

c. See Skill Drill 9-5: Tying a Double Figure 8 Loop

6. Optional approach: bowline knots

a. A high-strength bowline provides a more secure loop than a single bowline and is usually easier to untie after being loaded; it, too, should be tied with a safety knot at the tail.

b. See Skill Drill 9-6: Tying a High-Strength Bowline

c. An interlocking long-tail bowline is an interesting variation on this theme.

i. It is useful as a tie-in for vertical litter lowers and raising operations; when used in this fashion, it brings the main line and the belay line to a single point, such as the main attachment point on a litter bridle, at the same time provides tails to back up the subject and the litter tender.

ii. See Skill Drill 9-7: Tie an Interlocking Long-Tail Bowline.

7. Inline figure 8

a. The inline figure 8 is used to create a loop in the middle of the rope, to create handholds for a haul line, and to create an additional anchor point.

b. The inline figure 8 should be loaded in only one direction; otherwise, it can capsize and fail.

c. See Skill Drill 9-8: Tying an Inline Figure 8

8. Butterfly knot

a. A butterfly knot (a lineman’s knot) provides a secure loop in the middle of a rope.

b. Unlike some similar knots, such as the inline figure 8, the butterfly knot can be loaded in multiple directions.

c. Be aware that mistying can result in a “false butterfly,” an inferior knot prone to slipping.

d. See Skill Drill 9-9: Tying a Butterfly Knot

9. Figure 8 bend knot

a. Bend – as applied to knots, the joining of two ropes

b. A figure 8 bend is used to join two ropes or the two ends of one rope for the purposes of connecting two pieces of rope or creating a loop of rope by joining the two ends of one rope.

c. See Skill Drill 9-10: Tying a Figure 8 Bend Knot

d. Tips for tying a figure 8 bend knot

i. First, try tying this knot using two ropes of different colors. This will make it easier to distinguish the different strands of rope.

ii. Note that the figure 8 bend always begins with the tying of a simple figure 8 knot as a foundation.

iii. Follow the contour of the first knot exactly, with the rope ends approaching from opposite directions.

10. Optional approach: grapevine knot

a. Another knot that can be used to join two rope ends securely to form a longer rope or to form a loop is the grapevine knot (also known as the double fisherman’s knot).

b. Loops of rope have a variety of uses, including the creation of Prusik hitches

c. This knot is very secure, but it may be more difficult to learn and to tell whether it is tied correctly and can be difficult to untie after it is loaded, particularly in softer hand ropes.

d. See Skill Drill 9-11: Tying a Grapevine Knot

e. The grapevine knot is best used to join rope ends of a similar diameter. It should not be used for webbing, for ropes of greatly unequal diameters, or for materials that may tend to untie or creep back through the bends of the knot. For ropes of unequal diameter, a double sheet bend could be considered.

11. Ring bend (water knot)

a. The ring bend (water knot), also known as the overhand bend, is used only for webbing – never rope.

b. The ring bend is used to join two pieces of webbing or the two ends of one piece of webbing for the following purposes:

i. Forming a longer piece (joining two pieces of webbing)

ii. Forming a loop (tying together the two ends of one piece of webbing)

c. Make sure the webbing follows flat through the knot

i. A twist in the webbing inside the knot will allow the knot to slip at relatively low loads.

ii. Because webbing is flat, it allows the strands to overlay itself with a smooth contour, which is a big part of what secures the bend in place. Because rope does not have this same quality, a ring bend in rope can come out much more easily.

d. When tying a ring bend, first try tying it using two pieces of webbing of different colors. This will make it easier to distinguish the different pieces of webbing as you tie.

e. See Skill Drill 9-12: Tying a Ring Bend

**D.** Hitches

1. Hitch

a. A knot that attaches to or wraps around an object or rope in such a way that when the object or rope is removed, the knot falls apart (e.g., Prusik hitch, the clove hitch)

2. Prusik hitch

a. The Prusik hitch is a sliding friction hitch that works well as a lightweight, soft rope grab for ascending, belaying, and progress-capture.

b. This hitch, when loosened, can be slid up and down the rope – yet, when it is under tension, the hitch will not slide.

c. See Skill Drill 9-13: Tying a Prusik Hitch

3. Clove hitch

a. A clove hitch is used for anchoring to rounded anchor points, such as litter rails.

b. See Skill Drill 9-14: Tying a Clove Hitch

c. This method assumes that the rescuer has use of the working end of the rope, so that they can pass the end around the object to which they are hitching, such as a litter rail.

4. Additional hitches

a. The Münter hitch is used for one-person belays.

b. The Trucker’s hitch is a handy hitch that every rescuer should know and can be used to increase tension.

c. The girth hitch may be used with webbing and a fixed object.

d. Many knots are known by different names depending on the region and the rescue organization.

IX. Care of Ropes

**A. A rope’s performance, how long it lasts, and its safety still depend on how well it is cared for.**

**B. The condition of a rope ultimately depends on its history: the age of the rope, the conditions to which it has been subjected, and the care it has received.**

**C. If a rope is owned and used by only one person, that person probably knows the history of the rope. However, if more than one person is using the rope, there has to be a system for tracking the rope’s history.**

1. The common way of tracking a rope’s history is to keep a rope history log.

2. Each rope should have its own log.

**D. Keeping a rope history log**

1. Each rope must have its own log card with pertinent information on the manufacturer, diameter, design, tensile strength, date of purchase, and critical data.

2. The log card should have enough space to allow rope technicians to note each time the rope was used and for what activity.

3. Specific entries must be made whenever the rope was subjected to abuse that could affect its performance or safety.

4. It is essential that entries for each rope be made every time ropes are returned to storage after use.

**E. Identification and marking of ropes**

1. Each rope must have its own log card with pertinent information on the manufacturer, diameter, design, tensile strength, date of purchase, and critical data.

2. The log card should have enough space to allow rope technicians to note each time the rope was used and for what activity.

3. Specific entries must be made whenever the rope was subjected to abuse that could affect its performance or safety.

4. It is essential that entries for each rope be made every time ropes are returned to storage after use.

**F. Storing ropes**

1. A life safety rope must be stored in a place of its own where it is protected from harm. Rope can be damaged in any number of ways, including the following:

a. Age. All fibers used in life safety ropes degrade over time.

b. Leaving it in sunlight. Although some research indicates minimal loss of strength of life safety rope due to sunlight exposure, this is likely the result of the core being protected from direct sunlight by the sheath. Despite the fact that most fibers used in life safety ropes have UV stabilizers in them, nylon, polyester, and other polymers degrade with prolonged exposure to sunlight.

c. Exposing it to potentially harmful substances. Any chemical exposure, including vehicle exhaust, fumes or residues from storage batteries, and other substances, can be damaging to rope.

d. Leaving it on the floor.

i. Concrete floors leach alkaline, which is especially harmful to polyester, but they may also contain damaging substances from materials used in sealants and from acids used in cleaning.

e. Storing it in areas of high temperature.

i. Prolonged exposure to temperatures higher than humans can tolerate promotes rope degradation.

f. Contaminating it with dirt and grit.

i. Dirt and grit work into the core and damage the yarn.

ii. Avoid needlessly dragging a rope on the ground, and clean it periodically.

**G. Bagging ropes**

1. One of the most convenient ways of storing, transporting, and protecting a rope is called bagging. Some of the advantages of bagging include the following:

a. The bag helps protect the rope from damage while keeping it clean.

b. You can usually flake rope into a bag quicker than you can coil it.

c. A bag with a shoulder strap or pack straps is a convenient way to carry the rope.

d. A bagged rope is easy to deploy.

i. Simply secure the upper end of the rope and drop the bag over the edge.

ii. In most cases, the rope flakes out of the bag without tangles.

iii. Secure the bottom end of the rope to the bottom of the bag so that the bag is not lost when you drop it.

2. See Skill Drill 9-15: Bagging a Rope

3. Coiling

a. Before bagging became common practice, coiling commonly was used for storing and transporting ropes.

b. The specific type of coil depends on the circumstances or environment in which the rope is to be used.

c. Some basic types of coils include the mountaineer coil, caver’s coil, and butterfly coil.

X. How Ropes Are Damaged

**A. Harmful substances**

1. Some common substances can destroy or cause deterioration in certain kinds of rope; many strong chemicals can be damaging to both nylon and polyester rope.

2. Avoid any contact with a chemical unless you know for sure it is harmless to rope fiber.

**B. Overloading a rope**

1. Overloading a rope causes internal damage that could endanger those using the rope in the future.

2. Damage from overloading (e.g., towing vehicles and lifting heavy objects) usually occurs when a rope is used in activities for which it was not intended and when the load greatly exceeds the rope’s safe working load.

3. A separate set of ropes, for utility use only, must be used to avoid overloading a rope.

4. Utility lines must be stored separately from life safety ropes and be distinctly marked, for example, “utility line – not for life-safety operations.”

**C. Damage from falling objects**

1. Objects such as rocks or tools that fall on the rope, particularly when it is under load, can do serious damage.

2. Any time heavy or sharp objects fall directly on a rope, the rope should be retired, even if damage is not readily apparent.

3. When the rope has been used in a rock fall zone, it should be inspected for damage.

**D. Abrasion**

1. One of the most common means of destroying a rope or shortening its life is abrasion.

2. This kind of damage usually is avoidable.

3. Damage from abrasion commonly occurs when the rope is under tension and is lowered and raised across a rock or over the edge of a building. This often happens when a person is doing “bouncy” rappels or ascending, causing the rope to “saw” back and forth across a rock or hard object.

**E. Thermal damage**

1. Thermal damage results when two pieces of synthetic material rub together; this is very destructive to rope and can cut a line as surely as a knife.

2. Thermal damage usually occurs when one rope runs across another rope or across webbing, or when one line moves quickly across one spot in a second line that remains stationary.

3. Thermal damage can occur in the following situations:

a. Two ropes under tension with one remaining stationary while the other, being lowered, runs across the first.

b. A loaded rope running across an anchor rope or webbing also under load

c. A rappeller holding a rope against the seat harness webbing while performing a rapid rappel

4. Thermal damage to ropes can happen quickly, without warning, and can be catastrophic; some ways to prevent thermal damage between ropes include the following:

a. Rigging ropes so that they do not make contact and create heat fusion

b. Holding ropes away from each other with pulleys or edge rollers

c. Padding a stationary rope where another rope runs across it

d. Making sure never to place a moving rope and a stationary rope in the same edge protection device, such as edge rollers (separate rollers or devices are used)

5. If both ropes are moving constantly so that one spot is not subjected to heat build-up, destruction is less likely.

a. For example, in a Münter hitch, the rope is running across itself, but all surfaces are moving. Therefore, when used correctly, the Münter hitch is not likely to cause thermal damage.

**F. Rope damage through “flash” rappels**

1. All rappel devices operate through friction of the rope across the device; this results in heat build-up that increases with the speed of the rappel.

2. Fast rappels must be avoided because they can damage rope through heat build-up.

3. “Flash” rappels also indicate poor technique or lack of control (or both) on the part of the rappeller.

**G. Rotation of ropes**

1. In ropes in frequent use that are always anchored on the same end, the handling characteristics eventually change because of sheath milking at the lower end.

a. This can be observed either as a “bunching” of the sheath over the core at the end of the rope, or as a flattening as the sheath protrudes beyond the core.

2. When a rope is used for many rappels, the ends of the rope should be alternated as anchors to help prevent a change in handling characteristics.

**H. Strength loss through knots**

1. All knots reduce the overall strength of a rope, but some knots cause a greater loss than others.

2. The general rule is this: Knots with tight bends, such as bowlines, cause greater strength loss than knots with more open bends (e.g., the figure 8 family of knots).

3. Effects of bending a rope

a. Whenever a rope is placed under load in a sharp bend, some strength is lost.

i. The rope fibers on the outside of the bend receive a greater share of the load, and those on the inside of the bend receive very little of the load or none at all.

b. Common situations in which ropes undergo this kind of stress include ropes that have knots or kinks when they run over a sharp bend (e.g., a carabiner or small-diameter pulley).

c. The 4:1 rule

i. Rope users have traditionally estimated rope strength loss and system efficiency based on a D:d ratio. The D:d is the ratio of the diameter (D) of the bend divided by the overall diameter (d) of the rope.

ii. As a rule of thumb for modern nylon and polyester life safety ropes, when a bend in a rope becomes less than the diameter of the rope itself, strength begins to be significantly affected.

iii. This ratio is difficult for users initiated by wire rope and natural fiber ropes to comprehend. With those products, acceptable D:d ratios have historically been in the 6:1, 10:1, or even 25:1 range. Synthetic fiber ropes are a different matter altogether.

iv. When it comes to system efficiency, higher ratios will yield better system performance, particularly in systems where rope is moving around a bend, such as in a pulley.

1 Very small pulleys mean low efficiencies as the rope turns around them.

v. As a standard guide, most rope users recommend a D:d ratio of at least 4:1 for optimum system efficiency.

vi. To choose a pulley using the 4:1 rule, compare the diameter of the rope with the diameter of the pulley sheave.

1 If the diameter of the rope is 1/2 inch (1.3 cm), the diameter of the pulley sheave should be at least 2 inches (5.1 cm).

XI. Inspecting a Rope

**A. Rope inspection is an ongoing process that is performed before, during, and after rope use.**

**B. Rope is inspected in two ways: by look and by feel.**

1. Ropes should be inspected thoroughly after each use by looking and feeling along every inch of its length.

2. T-CHAPS should be used when inspecting ropes.

XII. Establishing Responsibility for Life Safety Ropes

**A. As with other life-safety devices, such as breathing apparatus, ropes used by a team must be assigned a chain of responsibility.**

1. Someone must be responsible for knowing where they are, how they have been used, who has used them, and what condition they are in.

2. Someone must be responsible for inspecting them after each use, for keeping a log for each rope, and, when appropriate, for removing them from service.

**B. Retiring a rope**

1. The tests currently available for reliably measuring rope strength destroy the rope; therefore, it is essential to be able to determine whether a rope should be retired.

2. That ability is the result of education in rope use and construction combined with experience and good judgment.

3. Compared with many other types of equipment, rope is an inexpensive tool. The cost of replacing a rope is certainly less than that of a severe injury or loss of life.

XIII. Washing Rope

1. Using a rope when it is dirty shortens its life.

2. A rope should be washed only if it is in obvious need because overwashing can cause the rope to stiffen or shrink, or both.

3. Soiling obviously affects the appearance of the rope, but the most serious effect is hidden.

a. Particles of grit and dirt can eventually work their way into the core of the rope and damage the load-supporting yarn as it stretches and flexes.

b. Dirt on the surface of a rope accelerates wear on hardware such as rappel devices, much as sandpaper would.

c. Aluminum particles also are damaging to rope.

i. The metal particles are forced into the rope as it runs through metal hardware such as rappel devices.

**B. Rope-washing devices**

1. Commercial devices specifically designed for washing ropes are available.

a. Some operate very much like the hose-washing devices used by fire departments.

b. One model has a built-in brush to help scrub away the surface dirt.

2. Rope-washing devices are most effective against larger particles of dirt; for deeper cleaning, additional steps may be warranted.

**C. Cleaning ropes with a washing machine**

1. Front-loading washing machines are the best choice, as the agitator in top-loading machines can become entangled with the rope, causing potential damage to both the rope and the machine.

a. This hazard can be reduced somewhat by placing the rope in a mesh rope-washing bag. Close the bag securely before placing the bagged rope in the machine.

b. If a mesh bag is not available, coiling the rope can help to prevent tangling (e.g., chain coil).

2. The following guidelines can be used in washing ropes:

a. Use gentle, nondetergent soaps and follow package directions for their use.

i. Specially fabricated low-pH rope soap is a good choice to gently remove dirt, oil, grease, soot, smoke, and grime.

ii. A gentle cleaner, such as Woolite or Ivory Snow laundry soap, can be used with synthetics.

iii. Do not use dishwashing liquid detergent, as the grease-cutting solvents degrade fiber treatments.

b. Some ropes have had an additional chemical “dry” treatment to prevent the rope from picking up water.

i. This is particularly useful in areas where wet ropes may freeze.

ii. Some of these treatments are easily removed with soapy water, and such ropes should be cleaned only with plain water.

c. Do not use bleaches or bleach substitutes.

d. Use the “cold water” setting.

e. Rinse thoroughly to remove all traces of soap.

f. Carefully dry the rope without heat. Hang the rope loosely out of direct sunlight and allow it to air dry.

**D. Fabric softeners**

1. Some people use a small amount of fabric softener during the rinse cycle to give the rope sheath a soft feel.

2. The benefits of using fabric softener include the following:

a. Better performance

b. Decreased stiffness; easier to tie knots

c. Decreased presence of lubricants; helps the yarns load more evenly, which may raise the tensile strength slightly in older, well-washed ropes

3. Always use fabric softener diluted according to manufacturer’s instructions.

**E. Special cleaning problems**

1. Despite careful handling, ropes may become spotted with oil, grease, or mildew.

a. While not demonstrably destructive, the substance can stain clothing or high-angle gear.

2. Petroleum substances may cause other contaminants to stick to the rope.

3. These substances often can be removed by soaking the rope in cool, soapy water and scrubbing the affected areas with a fingernail brush.

4. Do not use strong, solvent-based cleaners, as many solvents that loosen grease and grime also dissolve nylon.

5. Contact the rope’s manufacturer for specific types of cleaning problems.

XIV. Dressing Rope Ends

**A. Frayed ends have a sloppy, unprofessional appearance, become snagged, and eventually grow in size.**

**B. The most effective method of cutting nylon or polyester rope is to use an electric hot cutter to melt the rope in two.**

**C. Before the rope is cut, the spot where it is to be severed should be firmly taped.**

**D. Electric hot cutters are less effective on aramid ropes, which do not melt.**

1. If you are cutting an aramid rope, or if you need to cut a nylon or polyester rope without a hot cutter, the following steps should be taken:

a. Firmly tape the spot to be cut to prevent fraying.

b. Cut down through the center of the tape.

c. Immediately fuse the cut ends. For fibers that melt, heat from a lighter or other small flame can be used. Alternatively, a coating material such as whip end dip may be used.

d. Taper the fused end slightly. It should not be the shape of a mushroom, because the rope end could get snagged when pulled through hardware or rock.

XV. Summary

 **Rope is the foundation of any rope rescue activity. Choosing the correct rope for the task will make the task easier and safer to accomplish.**

 **Ropes may be made of natural or synthetic fibers. Synthetic fiber ropes are considered standard for situations in which the safety of a person is “on the line.”**

 **Synthetic fiber ropes include polyolefins, polyester, nylon, UHMPE, and aramids. Each type of fiber has its advantages and disadvantages.**

 **The selection of a rope depended upon what the rope is made of and how it is made. Rope construction methods include laid, plaited, braided, and kernmantle.**

 **When choosing a rope, consider the rope’s diameter, minimum breaking strength, range of elongation, abrasion resistance, the feel of the rope itself (hand), color, and length.**

 **Knot-tying instruction relies on knowledge of certain basic terminology, including bight, hitch, loop, running end, standing part, turn, and the working end.**

 **Knots are used in the rope rescue environment for tasks from anchoring to backing up other knots to creating emergency ascenders.**

 **It is good practice to back up most knots with a safety knot. When used, the backup should be tied as close as possible to the knot it is backing up.**

 **The lifespan of a rope depends upon the care, inspection, and maintenance of this vital piece of equipment and should be documented.**

 **A rope should be washed only if it shows dirt. Overwashing can cause the rope to stiffen or shrink, or both.**

 **Commercial devices specifically designed for washing ropes are available but may not get the surface of the rope completely clean.**

 **Washing machines can thoroughly and effectively clean rope. However, the machines must be used carefully, and certain specific precautions must be taken.**

 **Ropes rinsed with a fabric softener solution that is mixed according to the fabric softener manufacturer’s directions should perform better than ropes washed only with soap and water.**

 **Do not use strong, solvent-based cleaners when cleaning rope. Many solvents that loosen grease and grime also dissolve nylon.**

 **The most effective method of cutting synthetic fiber rope is to use an electric hot cutter.**

Post-lecture

I. After-Action Review

Individual/Small-Group Activity/Discussion

On Scene

This activity is designed to help the student understanding how to approach a fire investigation. This activity incorporates both critical thinking and the application of basic trench rescue knowledge.

Purpose

To allow students an opportunity to develop responses to critical thinking questions.

Instructor Directions

1. Direct students to read the “On Scene” questions located in the After-Action Review section at the end of Chapter 9 (p. 182).

2. Direct students to read and individually answer the discussion questions. Allow approximately 10 minutes for this part of the activity. Facilitate a class review and discussion of the answers, allowing students to correct responses as needed.

3. You may also assign these as individual activities and ask students to turn in their comments on a separate piece of paper.

Answers

1. To reach a civilian caught on a bridge abutment, a rescue must lead climb beyond their anchor point. What type of rope should be used?

Use a dynamic rope that is designed to absorb the force of a potential lead climbing fall.

2.What are the important considerations for select­ing a rope for a given task?

Diameter; compatibility with other components; minimum breaking strength; elongation; abrasion resistance; hand; color; length

3.When might an aramid rope be desirable over a polyester rope?

In case the rope will be exposed to high temperatures.

4. Name at least one tie that can be used for each of the following: *Form a loop in the end of a line*

 Join two ropes – double sheet bend; grapevine; figure 8 bend

 Form a safety knot – barrel knot; overhand; figure 8

 Create a friction hitch – Prusik hitch

II. Lesson Review

Discussion

Note: Facilitate the review of this lesson’s major topics using the review questions as direct questions or slides. Answers are found throughout this lesson plan.

1. Identify various types of fibers used to make synthetic ropes. (Lecture II B)

2. Identify various types of construction method used to manufacture ropes. (Lecture III A-E)

3. Define *breaking strength.* (Lecture V E)

4. Define *working end of a rope.* (Lecture VI B)

5. What are the qualities of a good knot? (Lecture VII D)

6. Why are figure 8 family knots preferred in the rope rescue field? (Lecture VIII C)

7. What factors ultimately impact the condition of a rope? (Lecture IX B)

8. Identify they ways in which a rope can be damaged. (Lecture X A–H)

9. What information must be tracked through a chain of responsibility? (Lecture XII A)

10. Discuss the benefits of using fabric softener when washing ropes. (Lecture XIII D)

III. Assignments

Lecture

A. Advise students to review materials for a quiz (determine the date/time).

B. Direct students to read the next chapter in *Rope Rescue: Principles and Practice,* Fifth Edition, as listed in your syllabus (or reading assignment sheet) to prepare for the next class session.