ROPES AND KNOTS

INTRODUCTION

There are several uses for ropes in the fire service, some of these are hoisting and lifting tools and equipment, hoisting and lowering fire fighters and victims, and tying objects off. These are just a few of the uses of ropes. Just as there are many uses of ropes, there are different types of ropes. In this handout, we will discuss the types of ropes (lines), rope terms and nomenclature, uses, basic rope care, and some common fire service knots.

The importance of being able to care for and handle ropes and knots cannot be over emphasized. While it would be rather ridiculous to expect a firefighter to be as adept as a sailor who may work with ropes constantly, it should be stressed that the speed and sureness required of a firefighter when they work with these "tools" are critical due to the emergency nature of their work. The success or failure of performing rescues, hoisting indispensable equipment, or perhaps saving his/her own life, can rest solely with his/her ability to handle ropes and to tie knots properly.

ROPE TERMS AND NOMENCLATURE

Before getting to deep into the subject, it is necessary to learn some of the most common terms used when dealing with ropes.

1. Anchor point: a secure or non-movable place or object to which the rope is attached.

2. Bend: one of the three types of knots.

3. Bight: A U-shaped bend in a piece of slack rope, where the rope changes direction 180 degrees and comes back on itself.

4. Bitter end: the part of the rope that is used in forming the knot. (Also known as working end or loose end.)

5. Breaking strength: usually 5 times the working strength.

6. Coil: a neatly prepared bundle of rope that will payout without kinking.

7. Crowning: weaving the end of the rope back into itself to avoid fraying the end.

8. Eye: weaving the end of the rope back into itself to form a loop like end.

9. Halyard: any rope through a block or a pulley.

10. Hitch: one of the three types of knots.

11. Hoisting line: rope which is used to raise or lower items.

12. Knot: specifically, one of the three types of ties we use with rope (all are generally called "knots") .

13. Life line: a rope generally reserved for the hoisting or lowering of human life.

14. Loop: rope completing a full circle, one of the three parts of knots.

15. Round turn: a rope making 1 and 1/2 turns around something, one of the three parts of a knot.

16. Running part: the part of the rope that is to be used for the work such as hoisting, pulling, or belaying.

17. Safety factor: usually in the range of 5 to 1.

18. Safety line: referring to the rope a firefighter uses during a search and rescue procedure.

19. Splice: to unite by interweaving the strands.

20. Standing part: the part of the rope between the working end and the running part.

21. Tag line: line used to remotely operate or steady an object that can't be reached by hand, i.e., hoisting a smoke ejector.

22. Whipping: a method of wrapping twine around the bitter end of a rope to prevent it from becoming unlaid. Sometimes known as "seizing".

23. Wickers: slivers of fiber ropes that stick out or can be found inside the wrap, occurs when the rope is bent and twisted severely or has been wet and dry a number of times.

24. Working end: part of the rope used in forming the knot.

BASIC KNOTS AND USES

Clove hitch: used to tie off hoses, extinguisher, and other tools when hoisting above ground or lowering, used in conjunction with a half hitch.

Half Hitch: used in conjunction with other knots for hoisting and lowering equipment, like axes, pike poles, sledge hammers, and as a safety knot.

Becket Bend: used to tie two ropes of unequal diameters together, can also be used to tie rope to cables, chains. Also known as sheet bend.

Bowline: most common used knot used for anchoring lines, tieing off ladders, smoke ejectors and other equipment for taking aloft.

Figure Eight: Used as a stopper knot or as a basis for the figure eight family of knots.

Figure Eight Follow Through: used to tie two ropes of the same Diameter together. Can also be used to tie around an object. Also known as the Double Figure of Eight.

Figure Eight on a Bight: used for an anchoring attachment and as a harness tie in. Preferred as the replacement for the bowline when using synthetic rope.

Double Loop Figure of Eight: used in the rescue knot for the leg holes.

Half Sheep Shank with A Safety: used to tighten a rope between two objects such as would be done as securing a danger zone for crowd control, securing a load guying a pole or wall.

Rescue Knot: used as a way of securing a victim or rescuer for hoisting or lowering.

USES OF ROPES

The use of ropes in the Fire Service are usually divided into three general categories:

1. Life lines
2. Haul lines
3. Utility lines

LIFE LINES: are ropes which are used in the raising or lowering of human life. Pulley systems, which are lifting objects off of human life would also be considered life lines. In short, if the failure of the rope will result in death or injury, then a life line quality rope should be used. Life lines should be reserved for life safety use only and identified as such.

HAUL LINES: are lines which are used in pulling, lifting and hauling any object or equipment not related to human life, and which failure would not result in injury or death to users or victims.

UTILITY LINES: are best classified as ropes used to lash or secure loads or rigging in place. As a general rule, life and haul lines are under live or active forces, while utility lines are under static or fixed forces. Seldom do utility lines have more than static, evenly applied forces on them.

PROPERTIES OF ROPES

TENSILE STRENGTH: This is the static force required to break the rope. It is not an indicator of how strong the rope is.

WORKING STRENGTH: Working strength is generally computed to 112 the current tensile strength of a rope. It is the maximum load, not force, which a rope can support without sustaining great damage. However, with each use the rope declines in strength, so tensile and working strength are never constant.

ENERGY ABSORPTION: This is the shock absorbing quality of rope, or how much force a rope can take suddenly without breaking. Steel cable for example, is high in tensile strength, but has little or no energy absorption and will snap when a very small weight is applied suddenly. It can easily be seen that elasticity is actually the measure of a rope's total ability and performance. However, the force applied should not exceed the rope's working strength. It should also be noted that if an elastic rope is loaded to 50% of its tensile strength 12 times in succession, it will fail; and after 70 loadings at only 25% of tensile strength. This is due to elastic fatigue. With a proper interval of rest, repeated loading can be accomplished safely.

SAFE LIFE: This is the total life of a rope as subj. etc to ultraviolet radiation, moisture, abrasion, and number of days in use. The most important of these is the compound abrasion and days in use. With natural fiber there is no safe life, since the rope starts to deteriorate from the moment it is made. Therefore, natural fiber ropes should never be used in conjunction with human life, since their life is totally unpredictable. However, with synthetic fiber or yarn, the rope's life is very predictable, particularly for static kernmantle rope.

Quite recently, research has shown that nylon rope deteriorates in direct proportion to the number of times it is used. The abrasion factor from this use being constant with nylon of laid construction. There is one exception, however--when a rope has been subjected to a force which will elongate it 20-30%, its useful life is finished and it should be retired no matter how new it is. In addition, once a rope sustains a load equal to 50% of its total tensile strength, it should be downgraded to a non safety rope.

STRENGTH OF APPLICATION: This is the tensile strength. less the percentage of knots or bends. Every angle potentially weakens a rope. For example, a rope rated at 10,000# tensile strength which is secured by a bowline to an object will fail at 60% or the rope's strength--in this case 6,000#. The strength of application does not, however affect the working strength as the percentage of tensile reduction is potential only, and the rope incurs no adverse affect.

CONSTRUCTION OF ROPE

The selection of a specific rope for a task is an extremely important item, critical many times to the operation. The following is a brief outline of properties and qualities of common rope materials.

LAID ROPE: Laid rope is the most common form of rope today. It is made by twisting a number of fibers into single strand and then "counter twisting" three strands into the finished rope. This structure is very strong, but is very prone to abrasion. In the twisting during construction, about 80-90% of the entire fiber count is exposed at the surface. This leaves only 10-20% of the rope protected. The most recent research has determined that even ropes which are mildly abraded have been found to be only partially intact. This greatly affects the energy absorption quality of the rope, since synthetic rope relies on its continuous fiber structure, which travels uninterrupted the entire length of a rope. (Natural fiber ropes are made of short, spliced fibers and therefore are not very elastic.)

On a 3-strand laid rope, the 3 strands only provide 2/3 of the total rope's strength. Failure of one of the 3 strands will cause the rope to lose 2/3 of its overall strength.

Since laid rope is produced by twisting, it has a nasty habit of kinking when force is applied. The structure is actually much like a giant helix. As force is applied, the helix tends to straighten out and unwinds a small amount. When this unwinding reaches its maximum, the rope is very brittle since it depends on the close support of the other strands for strength.

Because laid rope is a twisted product, it should not be used on devices which tend to additionally twist it, such as the life belt or sky genie. Whenever a man employs this device or those similar, the rope will kink and snarl rapidly below. When the same man is free of the wall he will spin so rapidly that, in many cases, he will become sick and possible black out. Most rescue devices now in use by the mountain rescue agencies employ a friction brake device called a brake bar. This tool has all the features of the life belt, yet does not twist the rope. It is also considered the best tool for lowering stretchers, men and equipment.

BRAIDED ROPE: This rope is formed by a weaving process which joins a dozen or more substrands into a solid braid. The finished rope is a rather loose weave and subject to heavy abrasion. Also, its elongation is excessive and is currently used only for ropes where dirt and grit are at a minimum. Braided rope, despite its drawbacks, is very good on capstan style winches due to its soft nature and large surface-contact area. Braid-on-braid ropes consist of two unconnected braids, reducing the total abrasions of fibers to 60%.

STATIC KERNMANTLE: Quite different from dynamic kernmantle used for mountaineering, this rope is a tight mass of synthetic fiber which is placed under tension in a woven jacket or sheath of like synthetic fiber.

This construction results in an no-stretch, nokink rope such as braided or braid-on-braid, yet with 85% of the fibers protected by the woven sheath. Unlike braid-on-braid, the sheath on static kernmantle will not slide on the core, thus static kernmantle rope is the most abrasion-resistant rope yet developed. Abrasion will seldom ever exceed 20% of the entire fiber count.

Static kernmantle has less than 2% stretch under normal loads, yet if impacted, possesses very good energy absorption. For this reason, static kernmantle is very useful in the hauling or lowering of critical men or equipment loads or where a no-stretch, high strength rope is needed.

NATURAL FIBER ROPES, (Cotton, Hemp, Sisal, etc.): These ropes are all vegetable products and, as such, start to deteriorate from the day they are harvested. They have no safe life. Their use in rescue situations should be very limited and only on non-critical items. A human life should not be trusted to natural fiber ropes except as a last resort.

MANILA: Will not stretch, and hence will not absorb impact or shock load. Water, chemicals and heat will degenerate manila rapidly. Good abrasion resistance, good in sizes larger than 1/2" diameter for haul lines and utility line or sling, and should not be used as a life line unless the rope is new.

NYLON:(Dynamic or stretchable style) is good for all rigging, slings and life line where sudden or high impact loads are anticipated. Dynamic nylon has long been used as a protection lifeline for mountain climbers. This dynamic property will, however cause high stretch at rather low loads--as much as 10-20% at 200# and therefore may not be desirable for lowering loads where the load may be increased or decreased during the load or raise. Good heat and chemical resistance compared to manila. Fair abrasion resistance.

NYLON: (Static or nonstretchable) is best for life lines, as it possesses extreme strength, some impact or energy absorption and has proven ideal for raising and lowering men and variable loads. Good heat and chemical resistance. Excellent abrasion when in kernmantle construction. Good in laid and braid construction.

DACRON: Same as static nylon, except has less abrasion resistance and even less energy absorption. It is a good life line and rigging rope, however nylon does have an edge. Good chemical and heat resistance.

POLYETHYLENE/POLYPROPYLENE: Not desirable for rescue due to low strength, high stretch and low temperature resistance. Avoid for heavy rescue where weight or life is involved.

SISAL: Similar to manila, except it possesses overall weaker strength.

COTTON: Not an acceptable material for life line. Dependent upon smallness of diameter, may not be acceptable for slings or haul lines. Qualities much the same as manila.

ROPE CARE AND MAINTENANCE

In order to test the quality and relative strength of ropes, they should be inspected visually each month. Important conditions to be looked for on natural fiber ropes are:

* Surface abrasions, broken and brittle fibers, etc.
* Soft spots
* Wet or mildewed areas (possible discoloration)
* Internal abrasion
* Dirt or powdering along the strand axis
* Cuts to sheath to core, on kernmantle

Visual inspection should not be limited to the surface of the rope. The strands must be twisted apart and examined most carefully. If in doubt about the condition of a rope, take several lengths of fiber from the rope and run them across a fingernail. If they feel brittle and dry, the rope should be sent to be tested at once.

Each year, all ropes should be tested by static means to 10% above the rated working strength. Synthetic fiber ropes should be washed in warm water after use to rid them of abrasive dirt and grit.

DO'S AND DONT'S CONCERNING ROPE:

DO train frequently on rope uses and knots
DO keep ropes clean
DO test and inspect frequently
DO pad abrasion points rope may run over
DO identify rope type/classification

DON'T stand or step on rope, this drives dirt into the rope.
DON'T let oil, grease, acid or alkaline materials touch ropes
DON'T test rope more than its working strength, plus 10%
DON'T use strong cleaners or solvents on ropes

ROPE CARE

Improper care and use of your rope could result in a serious injury. It is very important to practice these hints on the use and care of your rope.

1. Always properly pad your rope at points of abrasion. Rope pads from softer materials are recommended as they will abrade rather than your rope. Canvas pads are excellent.

2. Tie off your rope so that sharp points or bends are avoided. When possible, use a second anchor point for added safety.

3. Never use a life-support rope to lift heavy objects or in any manner which subjects the rope to extreme loads. Loads under 1 00 pounds will result in NO permanent elongation of Blue Water ropes of 7/16" diameter and larger, thus no major change in the rope properties will occur. This information only applies to Blue Water ropes as other ropes could have completely different stress ratios.

4. Protect your rope from chemicals and excessive heat. Nylon is basically on inert material, but good common sense is still the key to the safe use of your rope and unknown chemicals. It is always a good idea to protect your rope from ALL chemicals as nylon is effected by acids and alkalies as well as oxidizing agents such as bleaching compounds, salt, acetone, benzene, chloroform, freon, gasoline, kerosene, lard, mineral oil, paints and pine oil DO NOT appreciably effect nylon. Watch out for battery acid as this is the most common chemical that comes into contact with safety ropes. Heat under 3500 F will not effect the strength of your rope but nylon begins to be effected by temperature over 4000 F. The layered construction of the kernmantle rope offers better protection against heat as compared to twisted ropes; the sheath yarns protect the load-bearing core strands for a certain period of time whereas the twisted ropes are affected immediately by excessive heat.

5. Keep your ropes clean as dirt will shorten the life of your rope through abrasion. Blue Water ropes should be washed in cold water with a mild soap or detergent. Fabric softener can be used to give better flexibility and a softer hand. DO NOT USE BLEACH. The rope should be air dried away from direct sunlight. DO NOT DRY YOUR ROPE IN HOME OR COMMERCIAL DRYERS as the heat is excessive and will tend to make your rope stiff. It is not harmful to store your rope wet since Blue Water ropes are not effected by water and will not rot or mildew.

6. Check your rope after each use. Look in particular for damage to the sheath caused by cuts or from rubbing against a rough surface. All Blue Water ropes are made using a colored sheath over white core strands which allows for a visible inspection of the rope to determine if excessive wear has occurred. Since the core strands contribute approximately 75% of the rope's tensile strength, very little strength is lost until the sheath is completely worn through and the white core strands can be seen. When this occurs, it is necessary to cut the rope at that point but the remainder of the rope should be satisfactory unless other damage is present. It is impossible to make an exact statement as to when a rope should be retired since there are so many variables. It is the responsibility of the user to know the history of each life-support rope and make the decisions to when a rope should be down-graded or retired from service.

Remember, a life is much more valuable than a piece of rope, so replace your rope if there is any doubt as to its condition.

ROPE - DO'S AND DON'TS

DO: Roll the rope off the reel, don't take it off over the end unless you want lots of kinks to work out. An old broom handle works well for this.

DO: Pad your rope at all points of contact that might abrade your rope.

DO: Wash your rope often with clean, cold water. A PMI rope washer is just the thing to use in your own yard. Dirt will cause wear on and in your rope and rappelling equipment. Allow to air dry before storing away. Use a mild soap if you wish don't use detergent, and NEVER use bleach.

DO: Inspect your rope for damage each time you rig it and again as you coil or bag it up. If the sheath becomes cut or worn to the inner core, or if you feel lumps or "mashie" places in the core, cut the rope at that point and inspect for damage elsewhere.

DON'T: Mistreat your rope. Walking or standing on ropes can damage them

DON'T: Use your PMI rope as a dynamic belay. Because of the low stretch qualities of this rope, a short fall could jerk a climber enough to injure or kill.

DON'T: Allow chemicals to come in contact with your rope. Remember that many common items contain strong chemicals. Some of these chemicals can weaken or severely damage the nylon. Keep away from batteries (acid), and products that contain benzene, phenol (pine oil cleaners). carbon tetrachloride, formaldehyde and gasoline. If you suspect chemical damage to your rope, cut it! If you wish to use a marker on your rope, use one with an ether or alcohol base as they do not appear to damage ropes.

DON'T: Overload your rope. Never use a safety rope to tow cars or lift heavy objects. Overloading can cause hidden damage without actually breaking the rope.

1/2 INCH STATIC KERN MANTLE ROPE

Made of 100% Dupont 707 Nylon Monofilament

SHEATH: Comprises approximately 25% of the strength of the rope. It will not slide on the core as will braid on braid and double braided rope.

TEMPERATURE RESISTANCE: Will maintain strength to 3000 F. Critical temperature is 3500 F. Melting point 4800 F.

ABRASION RESISTANCE: Three times more abrasion resistant than lay type ropes, single and double braided construction. The kernmantle sheath protects the inner core from damage, contamination and wear. The sheath can almost be destroyed and the rope will only lose 25% of its strength.

CHEMICAL RESISTANCE: Rope will not mildew; can be put away wet and stored if necessary. More resistant to most acid-alkaline-petroleum products than natural fiber ropes.

SERVICE LIFE: As long as the sheath remains intact, shielding the core from abrasion and contamination. Also as long as there is no shock load put on the rope, or stretched beyond its working load.

MAXIMUM AVERAGE STRENGTH: 1.5% at 200 pounds, 21 % at failure. Will stretch slightly more when wet.

MINIMUM TENSILE STRENGTHS: 7/16 - 6,500 pounds 1/2 - 7,600 pounds 9/16 - 10,500 pounds

Static kern mantle rope will stretch 20% more when it is wet and will come back to 100% when it dries.