Rope


Life-Safety Rope

Life-safety rope is further broken down into light use (formerly called one person) and general use (formerly called two person). Light-use rope is used for light-use loads and escape. General-use rope is used for light-use loads, general-use loads, and escape. All life-safety rope must conform to the requirements of NFPA 1983, which defines life-safety rope as “rope dedicated solely for the purpose of supporting people during rescue, fire fighting, or other emergency operations, or during training evolutions.” Only rope of block creel construction using continuous-filament virgin fiber for load-bearing elements (commonly called static kernmantle) is suitable for life-safety applications.

Life-safety rope is usually purchased in 100 to 600 ft. (30 to 186 m) lengths depending upon local needs. It is usually 11 or 12.5 mm in diameter and should be of the kernmantle type. Kernmantle is a German word meaning core and sheath.

The red sheath and white core in a piece of kernmantle rope

The core (kern) is made up of continuous fibers, usually nylon, that run the entire length of the rope. The core provides about 75% of the rope’s strength and carries the majority of the working load. The core is protected by a sheath (mantle) made of tightly woven nylon or other synthetic fiber that provides the remainder of the rope’s strength. The sheath protects the core from abrasion, dirt, and the effects of sunlight, which can weaken nylon with prolonged exposure.

Some life-safety rope is designed to include components with electric current-carrying capabilities. Ropes of this type must comply with the requirements of Class I, Division 1, hazardous locations of American National Standards Institute/Underwriters Laboratories (ANSI/UL) 913, Standard for Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II, and III, Division 1, Hazardous (Classified) Locations.
NFPA 1983 specifies that the minimum breaking strength for light-use life-safety rope is 4,500 lb. (20 kilonewtons [kN]); and for general-use life-safety rope, 9,000 lb. (40 kN). The maximum working load for life safety rope is defined as the maximum amount of weight that may be supported by the rope in use. The maximum safe working load for escape rope is 200 lb. (91 kg); light-use life-safety rope 300 lb. (136 kg); and general-use life-safety rope, 600 lb. (272 kg). These figures result from dividing the respective minimum breaking strengths by 15. This provides an adequate margin of safety for both rescuers and victims suspended from ropes.

According to NFPA 1983, all life-safety rope must elongate (stretch) from a minimum of 1% to a maximum of 10% when loaded at 10% of its rated breaking strength. Elongation helps to reduce the shock of impact on both rescuers and their anchor systems in falls. However, this elasticity is a disadvantage when someone is trying to tension, raise, or lower heavy loads.

**Non-Life-Safety**
Non-life-safety (utility) rope is used for hoisting equipment and securing objects in place, not for supporting rescuers or victims. Any life-safety rope that fails to pass inspection or has been impact loaded should be destroyed immediately. However, in this context, “destroy” means that it is altered in such a manner that it cannot be mistakenly used as a life-safety rope. This could include disposing of the rope or removing the manufacturer’s label and cutting the rope into shorter lengths to be used as non-life-safety (utility) rope.

Some departments color-code their rope storage bags to aid in rope identification. Some departments dye the last few inches of each piece of rope to identify its status. Often, the ends of life-safety rope are dyed green, training rope yellow, and utility rope red. Once a life-safety rope has been retired, it can be cut into shorter lengths and the ends cut off, resealed, and remarked in red for utility use.

**Throwline**
Also called *accessory cord*, throwline is rope that is smaller in diameter than life-safety rope. It is usually synthetic rope of about 6 or 8 mm in diameter. Accessory cord is used for lashing litters and for forming prusik loops. NFPA 1983 specifies that the minimum breaking strength for throwline is 3,000 lb. (13 kN).

**Webbing**
Webbing is used extensively in rescue to construct anchor systems and harnesses, to package and secure victims, and to lash rescue components together. Webbing is preferable to rope for constructing a harness because it lies flat against the body and provides better support. Because of its strength and pliability, webbing is an excellent material to use for slings; it loses very little strength when bent around a carabiner. Webbing is relatively inexpensive, lightweight, and easy to tie, and it can be cut into short lengths for many uses. Although there are different methods by which webbing is made, webbing used in rescue applications is most often spiral weave or shuttle-loom tubular nylon.
Webbing is available in various widths from 1 to 2 in. (25 to 50 mm). The 1 in. (25 mm) size is most commonly used for lashing and has a 4,000 lb. (1,818 kg) breaking strength.

Webbing is available in rolls of up to 1,000 ft (300 m) in length and a variety of colors. A system of color-coding webbing to identify its length greatly aids in constructing rescue systems. For example, if all pieces of red webbing are 20 ft. (6 m) in length, it is easy to select the proper piece of webbing to construct a seat harness or to secure a victim in a litter. The following is a recommended color-coding system for rescue webbing:

<table>
<thead>
<tr>
<th>Color</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green</td>
<td>5 ft. (1.5 m)</td>
</tr>
<tr>
<td>Yellow</td>
<td>12 ft. (3.5 m)</td>
</tr>
<tr>
<td>Blue</td>
<td>15 ft. (4.5 m)</td>
</tr>
<tr>
<td>Red</td>
<td>20 ft. (6.0 m)</td>
</tr>
<tr>
<td>Black</td>
<td>25 ft. (7.5 m)</td>
</tr>
</tbody>
</table>

If a department’s webbing consists of only one or a few colors, the ends of each piece should be dyed according to the chart to identify its length. Most webbing is constructed of nylon, but regardless of the constituent material, it is produced in two basic forms: flat and tubular.

**Flat Webbing**
Flat webbing is constructed of a single layer of material, and it is similar to that used in automobile seat belts. While not as expensive as tubular webbing, flat webbing is stiffer and more difficult to tie into knots. Flat webbing is mainly used in rescue work for straps and harness.

**Tubular Webbing**
Because tubular webbing is more supple and easier to tie, it is the most commonly used webbing in rescue work. Its tubular shape can be seen if it is viewed from the end while the two edges are squeezed toward each other.

There are two types of tubular webbing: edge-stitched and spiral weave. Edge-stitched webbing is formed by folding a piece of flat webbing lengthwise and stitching the edges together. Because of abrasion, edge-stitched webbing can become unstitched, but edge-stitched webbing that is lock stitched is not as prone to this occurrence.

Also known as shuttle-loom construction, spiral weave tubular webbing is the type most preferred in rescue work. Spiral weave webbing is constructed by weaving the tube as a unit, and it is so named because the threads spiral around the tube as it is being woven.

**Harness**
There are two general types of life-safety harness used in rescue operations: (1) those identified in NFPA 1983 as Class I, Class II, and Class III, and (2) a variety of improvised harnesses.
Note: Ladder belts are no longer classified as life-safety harness. They are intended only as a positioning device for a person on a ladder or as an emergency escape belt.

**Class I Harness**
Also known as a *seat harness*, this type of harness fastens around the waist and around thighs or under the buttocks and is intended to be used for emergency escape with a load of up to 300 lb. (1.33 kN).

**Class II Harness**
This type of harness fastens around the waist and around the thighs or under the buttocks and may be used in rescues with up to a 600 lb. (2.67 kN) load. Class I and Class II harness may appear to be identical; the difference between them is in their rated working loads that can be determined only by reading the label on the harness.

**Class III Harness**
Also known as *full-body harness*, this type of harness fastens around the waist, around the thighs or under the buttocks, and over the shoulders. It is designed to support a 600 lb. (2.67 kN) load and may consist of more than one component.

*Improvised Harness*
In the absence of a manufactured harness, rescuers may have to construct a life-safety harness using the equipment available on scene—rope, webbing, and carabiners. The most common types of improvised harness are the rescue knot, Swiss seat, and Swiss seat with shoulder harness.
**Rescue knot.** The rescue knot has the advantage of needing only the rescue rope and does not require webbing or hardware. It can be tied onto a conscious or unconscious victim. The rescue knot is tied as follows:

Step 1: Tie a double-loop figure 8 on the end of the rope.
Step 2: Slip legs into the loops formed by the knot, and pull up the loops until they are snug just below the buttocks. Place the standing part of the rope over one shoulder.
Step 3: Form a half hitch around the upper torso, just below the armpits.
Step 4: Form a small bight in the standing part, and pass it down and behind part of the half hitch.
Step 5: Pass the bight up in front of the half hitch and through the loop formed when the bight was passed behind the half hitch.
Step 6: Pass the loose end of the rope up through the bight. An upward pull on the standing part of the rope will cause the small bight to snap over and complete the knot.
Step 7: Tie off the loose end with an overhand safety.

![Completed rescue knot improvised harness](image)

**Swiss seat.** Also called a *hasty seat*, a Swiss seat is an improvised Class II harness made up of one large carabiner and a piece of webbing about 15 ft. (5 m) long. A Swiss seat is constructed as follows:

Step 1: If the webbing is not in the form of a loop, it must be made into one by buckling the ends together (if so equipped) or by tying the ends together with a water knot and overhand safeties.
Step 2: The point where the ends of the webbing are joined is placed at the small of the wearer’s back.
Step 3: The bights formed at each end of the loop are brought around to the front of the wearer and held there.
Step 4: Reaching between the wearer’s legs, a bight is formed in the middle of the lower part of the webbing, and it is brought forward.
Step 5: Reaching through the ends of the loop that came around each side, each leg of the bight coming between the wearer’s legs is pulled up through the loop ends.
Step 6: The newly formed bights are pulled up until the harness is snug, and the bights are snapped into a large carabiner.

**Swiss seat with shoulder harness.** If there is a possibility of the wearer inverting, an improvised shoulder harness can be constructed and linked to the Swiss seat. A slightly shorter loop of webbing is needed to form the shoulder harness as follows:
Step 1: Cross the loop over itself to form a figure 8.
Step 2: Slip the wearer’s arms through the ends of the figure 8, with the crossover point in the middle of the wearer’s upper back.
Step 3: Bring the ends together in front of the wearer’s chest and join by snapping them into the carabiner on the seat harness.

**Hardware**
In this context, the term hardware refers to the mechanical devices needed to fully and safely use life-safety rope and to construct mechanical advantage systems with rope. According to NFPA 1983, each type of hardware has a range of strength requirements depending upon its rating as an escape, light-use, or general-use device. For example, the minimum breaking strengths of carabiners range from 1,200 lb. (5 kN) to 9,000 lb. (40 kN). Ascent and rope grab devices must withstand from 1,100 lb. (5 kN) to 2,500 lb. (11 kN) without permanent damage to the device or the rope. Descent control devices must withstand from 1,100 lb. (5 kN) to 5,000 lb. (22 kN) without failure. Portable anchor devices must withstand from 1,100 lb. (5 kN) to 8,000 lb. (36 kN) without failure. The requirements for pulleys range from 1,100 lb. (5 kN) without damage to
6,000 lb. (19.5 kN) without failure. The most commonly used pieces of rescue hardware are load-bearing fasteners, ascending and descending devices, and pulleys.

**Load-Bearing Fasteners**

As the name implies, load-bearing fasteners connect rope and/or webbing together or to other objects and support the weight of rescuers, victims, and the equipment involved. The fasteners most often used in rescue work are carabiners, tri-links, rescue rings, swivels, and anchor plates.

**Carabiners.** A carabiner consists of an open metal loop with a hinged gate to close the opening. Some gates can be locked in the closed position, and others cannot. While carabiners are available in other metals, most are made of aluminum or steel. A variety of sizes and shapes are available, but most carabiners are either oval or some form of D shape. Large, D-shaped steel carabiners with locking gates are recommended for rescue work.

If nonlocking carabiners must be used in a life-safety situation, whether an actual incident or a training exercise, they should be used in pairs and should be snapped on with the gates opposite and opposed.

![A common type of carabiner](image1)

![Carabiners are available in different shapes](image2)

![Nonlocking carabiners reversed and opposed](image3)
If aluminum carabiners are used, they must be handled with care because they may develop invisible stress fractures if they are subjected to impact. These fractures may later cause the carabiner to fail under load. If possible, aluminum carabiners should not be used in rescue operations.

**Note:** There is no practical way to field test the reliability of a carabiner after impact. So, a good rule of thumb is that if a carabiner was dropped from waist height onto a hard surface, it should not be used in a life-safety application until it has been lab tested.

Carabiners are strongest when loaded in line with their major axis and near the spine. They are weakest when loaded in line with their minor axis across the gate. They are designed to be loaded in one direction only. If a multidirectional load must be supported, carabiners should never be connected to each other. Instead, a tri-link, rescue ring, or figure-8 plate should be used to avoid torsional stress.

**Tri-links.** Tri-links are similar to carabiners, but they have a screw-type locking sleeve to close the opening, and they are usually triangular or semicircular in shape. Tri-links are specifically designed to handle multidirectional loads.
Rescue rings. As the name implies, rescue rings are steel rings specifically designed for rescue applications; that is, they meet NFPA 1983 specifications for load-bearing devices. Rescue rings are also designed to be used when a multidirectional load must be supported.

Swivels. Applied at the point of attachment to the anchor, these devices prevent the twists that sometimes develop in the rope used in mechanical advantage systems. Without swivels, the twists in the rope can add a significant amount of friction to the system. Only swivels specifically approved for life-safety applications should be used in these situations.
Anchor plates. Anchor plates are devices used to attach multiple anchors to a single point. They may also be used as the point of attachment for litter harnesses and other multiple loads. In either application, anchor plates help rescuers to organize and manage multiple attachments and reduce tangling and jamming. Only steel anchor plates should be used in rescue operations.

Ascending Devices
These devices are designed to allow someone to climb (ascend) a fixed vertical rope. However, ascenders are not designed to stop a falling load. In drop tests, these devices caused serious damage to the rope or severed it at approximately one third of the rope’s rated strength. When used for their intended purpose, ascenders do little or no damage to the rope on which they are applied. Cams and handled ascenders are two basic types of ascending devices used in rescue work.

Cams. These devices can be used as ascenders and in hauling systems. Cam devices consist of a metal frame that surrounds the rope and is the base for the pivot pin of a lever having a serrated cam on one end and a loop on the other. For a cam device to be applied to a rope, the device must be disassembled by removing the pivot pin and cam lever. The rope is then slipped into the frame, and the device is reassembled in the reverse order of disassembly. The load is attached to the device through the loop at the exposed end of the cam lever. When a load is applied, the lever pivots and forces the cam against the rope within the frame.
There are two basic types of cam devices: free running and spring loaded. In the free-running type, the cam does not engage the rope unless and until a load is applied to the other end of the lever. In the spring-loaded type, the spring keeps the cam in contact with the rope at all times, regardless of whether or not a load is applied.

**Handled ascenders.** These devices also operate with a form of cam, but they are significantly different from the cam devices previously described. Handled ascenders are not designed to be used in hauling systems but are intended only to support the weight of one person. Normally used in pairs, handled ascenders consist of either a right-handed or a left-handed metal frame that surrounds the rope and incorporates some form of handle. Unlike other cam devices, handled ascenders do not have to be disassembled to be applied to the rope, and they are designed with a cam release that allows them to be applied to the rope with one hand. In operation, with the climber’s weight on the foot loop attached to the lower ascender, the top one is pushed up the rope as far as the climber can reach. When the climber puts weight on the foot loop of the upper ascender, the cam engages the rope and allows the climber to ascend. The lower ascender is then pushed up to the top one, and the sequence is repeated until the climber reaches the desired elevation.

![A typical handled ascender](image)

**Descending Devices**
Sometimes called rappel devices, descenders are devices that function by creating friction on the rope being descended. They are designed to allow a person to descend a fixed vertical rope at a safe and controlled rate, and they may also be used to control the rate of descent of rescuers,
litters, and equipment. The most common types of descending devices used in rescue are figure-8 plates, Q-8 plates, rappel racks, and belay plates.

**Figure-8 plates.** Also called rescue-eights, these devices consist of a double-ring of steel or anodized aluminum, with one ring larger than the other. In operation, the smaller ring is attached to the user’s harness by a carabiner, and the rope being descended is looped through the larger ring and around the waist of the figure-8 plate. If the bight in the rope looped through the figure-8 plate slips, it can slide to the top of the ring and form a girth hitch. To undo the girth hitch, the user must be able to ascend far enough to relieve the tension on the hitch in order to slip the rope back into position. On some figure-8 plates, appendages called ears have been incorporated into the larger ring. The ears are intended to prevent the rope from slipping out of place and forming a girth hitch at the top of the ring.

![Rope applied to a figure-8 plate](image1) ![A typical figure 8 with ears](image2)

**Q-8 plates.** The ears on Q-8 plates are positioned on one side of the larger ring. The position of the ears makes tying off under load easier and safer than with conventional figure-8 plates.

**Rappel racks.** Also called brake bar racks, these devices consist of an elongated U-shaped rod with an eye on one end, a nut (stopper) threaded onto the other end, and six friction bars in between. The friction bars are penetrated by the longer leg of the rack only at one end. Each bar has a groove machined into it near the unattached end so that it can align parallel to the other bars when in place across the rack.

Many consider rappel racks superior to figure-8 plates for rappelling in several ways. By varying the number and spacing of bars engaged, rappel racks allow the amount of friction applied to the rope to be adjusted during descent. This provides greater control of the rate of descent than is possible with figure 8s. Because the rope passes straight through a rappel rack, there is less of a tendency for the rope to twist. On long rappels, they generate less heat, which protects the rope from heat damage.
Belay plates. Frictioning devices of all sorts can be used for belaying (applying a friction brake to) a single-person load; however, belay plates are designed specifically for this purpose and may do it better than devices designed for other uses. Most often used with single-person loads, belay plates are intended to allow a rescuer’s rate of descent to be controlled and stopped if the rescuer falls or the main line fails. A belay plate consists of a metal plate with two or more holes or slots in it. In operation, a bight of the belay line is passed through the belay plate and attached to an anchor with a carabiner. When the running part of the rope is pulled, more friction is added to the rope, and the rescuer’s progress can be slowed or stopped.

Other Rope Rescue Hardware
In this category of rope rescue hardware are various types of pulleys. Also included are edge rollers because they serve the same purposes and share many of the characteristics of pulleys, so they are discussed in this section.
**Pulleys.** Pulleys are used to change the direction and point of application of a rope in a way that protects the rope from damage and keeps friction to a minimum. In rescue, they are most often used as part of a mechanical advantage system for raising rescuers, victims, and equipment. Rescue pulleys are all-metal construction and consist of one or more sheaves (wheels), an axle with a bearing or bushing, and two side plates. The types most often used in rescue are single- and double-sheave pulleys. The diameter of the sheaves should be three to four times the diameter of the rope to which they are applied. This prevents putting the rope into too tight a turn, which would increase friction and might damage the rope.

**Components of a rescue pulley**

**Single-sheave pulleys.** Single-sheave pulleys are the simplest pulleys used with rescue rope. They consist of the components described earlier with only one sheave. While the side plates are designed to meet, they are not connected; each can pivot in either direction around the axle. Pivoting them in opposite directions opens up the pulley and allows it to be applied to a rope at any point in its length. This saves having to thread the pulley onto the rope from one end.
**Double-sheave pulleys.** Double-sheave pulleys are similar to single-sheave types, but as the name implies, they have two sheaves instead of one. In addition, the sheaves are separated by a plate that also separates the two side plates. Double-sheave pulleys are much more versatile than single-sheave types because they are adaptable to a variety of operational demands such as constructing mechanical advantage systems.

While known by other names, self-tending pulleys have an internal cam that allows the rope to pass freely through in one direction only. When released, the cam engages and prevents the rope from moving.

**Edge rollers.** These devices are also all-metal construction and designed to reduce friction and thereby protect rope from damage when it must be pulled over sharp edges such as cornices or parapet walls. While there are a variety of different designs available, they all incorporate one or more rollers, similar to wide sheaves, and they are capable of conforming to the shape of the edge over which the rope must be pulled. When edge rollers are not available, any substantial padding (such as a folded salvage cover) can be used.