



STUDENT MANUAL

HEAVY EQUIPMENT & RIGGING SPECIALIST TRAINING

MODULE 1-2 :

RIGGING BASICS

Unit Objective

After completing this unit, you will understand the role of the Heavy Equipment and Rigging Specialist (HERS) and interaction with the Structures Specialist (StS)

Also we will explain the basic concepts and components used to rig and lift debris during US&R incidents.

Acknowledgements

The California Office of Emergency Operations, Heavy Equipment and Rigging Curriculum Committee originally developed this module in 1998 thru 2000. The main contributing members of that committee were: B.K. Cooper, Cooper Crane; Tom Clark, CATF-4, StS; David Hammond, CATF-3, StS. Additional contributors were Alan Fisher, MATF-1, StS/HERS and Jay Coon, CATF-7, HERS

Many of the illustrations and much of the information found in this manual concerning rigging connection devices were borrowed from publications and presentations given by The Crosby Group. They have been supportive of the FEMA US&R HERS training since 2000, and this support is greatly appreciated

Enabling Objectives

You will:

- Identify common engineering and rigging terms
- Identify wire rope terms, configuration, lay, strengths, inspection items, and strength;
- Discuss types and configurations of slings;
- Describe various devices used with rigging; and
- Identify the FEMA US&R Task Force, Rigging Cache

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Enabling Objectives

- Identify common engineering & rigging terms
- Identify wire rope terms, configuration, lay, strengths, inspection items, capacity
- Discuss types and configurations of slings
- Describe various devices used with rigging
- Identify the FEMA US&R Rigging Cache

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I. Introduction & References

Much of what is to be covered in this section can be found in the following materials.

- *Bob's Overhead Crane and Rigging Handbook*, available from Pellow Engineering Services, Inc. (877)-473-5569.
- *Wire Rope Users Manual*—published by the Wire Rope Technical Board

The manual may be obtained through Crane Institute of America at www.craneinstitute.com or by calling 1-800-832-2726.

- Also useful is the companion reference:

Wire Rope Sling Users Manual—published by the Wire Rope Technical Board

Handout References include the following:

- Crosby's *User's Guide Lifting* (which can be obtained by calling 1-800-777-1555). This guide will be used as a quick reference tool
- SIGNAL-RITE Rigging Card, available from www.signal-rite.com. This guide may be used as a quick reference, during field exercises

II. Introduction to Rigging

Wire Rope and other rigging can provide a relatively quick solution to many problems that occur in US&R

- Rigging can be installed quickly from readily available materials
- Rigging may be a “Quick and Dirty” way to increase safety, reduce risk, in an area for immediate rescue
- The Failure Mode of Rigging is usually SUDDEN and without warning

If rigging systems are used for other than vertical lifting, (such as stabilizing a structure) additional forces will be generated every time the cable changes direction.

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Course References

- **Bob's Crane & Rigging Handbook**
 - Pocket and full-sized versions
 - Pellow Engineering Services, 877-473-5569
- **Wire Rope Users Manual**
- **Wire Rope Sling Users Manual**
 - Wire Rope Tech Board
 - Crane Institute of America
 - <http://www.craneinstitute.com/>

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Course References (continued)

- **Crosby's User's Guide Lifting**
 - 16-panel version, June 1999 or later
 - Will refer to guide during this hour
 - thecrosbygroup.com or 1-800-777-1555
- **Signal-Rite Rigging Card**
 - www.signal-rite.com
 - It may be used as a guide for Crane Hand & Verbal Signals in the field exercises

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Introduction to Rigging

- Rigging materials connect loads to lifting equipment
- Understanding range of items available helps you know various advantages and limitations of each
- Dynamic behavior of loads that are lifted needs to be respected

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Introduction (continued)

The StS will normally be able to calculate these forces, generated by change in direction. This is all about Trigonometry, and working together with the HERS, competent solutions can be developed.

Because of these issues and its sudden failure mode, rigging should only be used for stabilization of structures when there are no other practical solutions

Common Terms and Concepts

Forces are given in the following units:

- 1 Kip, or 1k = 1,000 lb or 1 kilo-pound
- 1 Ton, or 1T = 2,000 lb = 2k
- 1 Metric Ton, or 1T = 2,200 lb (actually 2,204.6 lb). Most excavators are rated in metric tons.
- 1 Long Ton = 2,240 lb

Stresses are the total force acting on an object (pulling on a wire rope, pushing on a post, etc.) divided by the object's cross-sectional area.

The force per unit area = psi, ksi, psf, tons/sq ft, etc.

- The force per unit area = psi, ksi, psf, tons/sq ft.
- The Breaking strength is the same as the Ultimate strength—the force at which the object breaks, buckles, or totally fails.
- The Working Capacity, Design Capacity, or the working load limit (W L L), is the breaking strength divided by the Safety Factor (SF), or the Design Factor (term used by Crosby).

III. Wire Rope Basics

Wire rope is made of several strands made from many high-strength steel wires laid together.

Strands are laid together to form a rope, usually around a central core.

The core may be fiber or an additional independent wire rope or wire strand. The number of strands, number of wires per strand, type of material, and nature of the core will depend on the intended purpose of the rope. The more wires and strands, the more flexible the rope.

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Introduction (continued)

- Most rigging systems are all about **TRIGONOMETRY** and **FORCE VECTORS**
- HERS and StS can work together to the benefit of Rescue Team
 - Most engineers know little about rigging, but understand accounting for forces
 - Most riggers know rigging, but appreciate someone else doing the arithmetic

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Common Terms

- **Force** is given in
 - 1 Kip or 1k = 1,000 (kilo) lbs
 - 1 Ton or 1T = 2,000 lbs = 2k
 - 1 Metric Ton or 1T = 2,200 lbs (2,204.6)
 - 1 Long Ton = 2,240 lbs
- **Stress** = Force/Area
 - Force per unit area = psi, ksi, psf, tons/sq ft

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Common Terms – used in Rigging

- **Breaking Strength** = Ultimate Strength
- **Working Capacity** = Design Strength = Breaking Strength / S.F.
 - Crosby uses Working Load Limit = W L L = Ultimate Strength / Design Factor
- **Safety Factor (SF) for Wire Rope**
 - SF = 5 for lifting applications (6 in Canada)
 - SF = 3 for other general structural uses
 - SF = 10 when lifting people

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Wire Rope Terms

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Wire Rope Size

The size of a wire rope should be measured across the diameter at its widest point. Measure the “crowns,” not the “flats.”

Wire Rope Core Types

Fiber core wire rope has a central fiber core, which is made from manila, sisal, jute, or polypropylene, and is impregnated with lubricant to aid and cushion the wire strands.

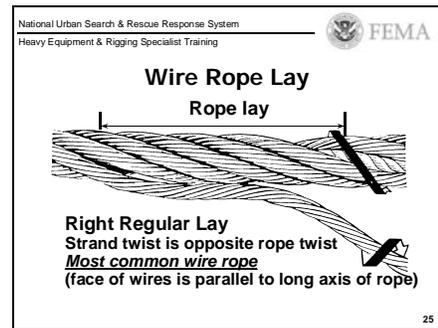
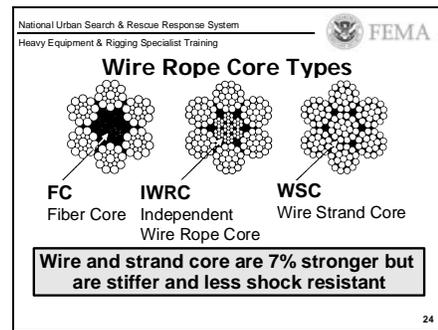
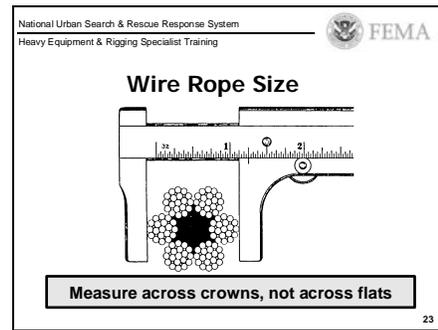
Wire core ropes have independent steel wire rope or strand cores (IWRC stands for Independent Wire Rope Core). WSC stands for Wire Strand Core, which is also independent, but is not included in the common designation. IWRC and WSC ropes have advantages over fiber core ropes:

- The additional strand increases rope strength, helps resist crushing, and provides better resistance to extreme heat.
- However, IWRC ropes are stiffer and less shock-resistant.

Wire Rope Lays

The lay refers to the direction of winding of the wires in the strands and to the strands in the rope. There are two basic lays: regular and lang.

In regular lay, the wires in each strand are laid in one direction, while the strands are laid in the opposite direction.





Wire Rope Lays (continued)

In this lay, the individual wires are able to resist crushing and distortion since wires are exposed over very short lengths. Right, regular lay is the most common type of wire rope. It can be easily recognized since the individual wires at the surface are aligned with the long axis of the rope.

In lang lay, the wires in strands, in addition to the strands in the rope, are laid in the same direction. This type of rope should not be used in single-part hoisting line because of its tendency to untwist, but lang lay wire ropes have superior resistance to abrasion.

Wire Strand Configuration and Rope Classification

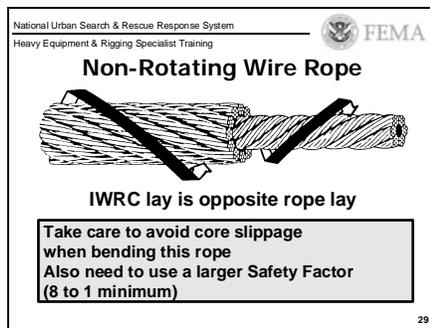
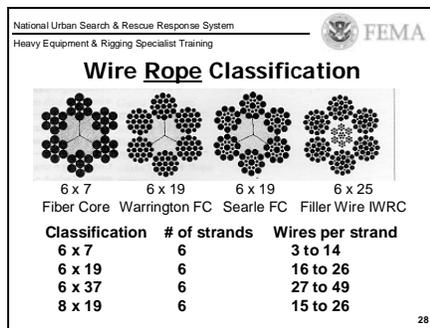
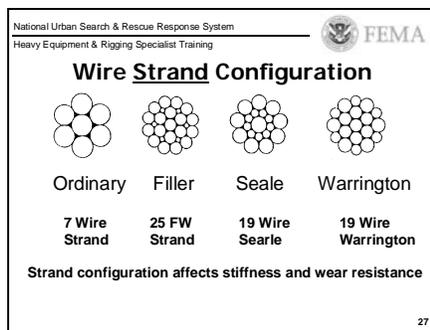
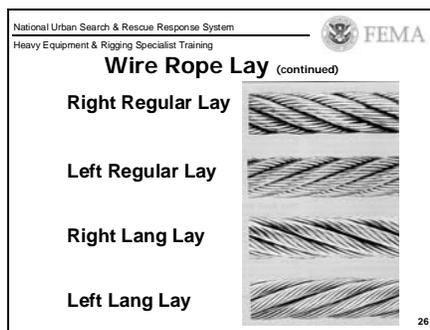
Strands are grouped according to the number of wires per strand. The number of wires and the pattern define the rope's characteristics. Within strands, the wires may be the same or different sizes.

The number of wires and the pattern define the rope's characteristics. Within strands, the wires may be the same or different sizes.

Non-Rotating Wire Rope

Non-rotating wire rope is used in single live hoists and is constructed with the lay on the IWRC being in the direction opposite to the lay of the outer layers.

Care must be taken to prevent core slippage, and therefore this type of rope should only be used in US&R as a last resort. Special care needs to be taken when bending it around a thimble, etc. Added seizings would be required to bind inner and outer strands together. Non-rotating wire rope has about 15 percent less strength than standard IWRC rope, and a larger safety factor is used.





Common Uses of Wire Rope

- 6 x 7 has larger wire and is not very flexible. It has good abrasion resistance and, therefore, is used on large-diameter sheaves and drums, as well as guy lines, ski tows, and tramways.
- 6 x 19 has the most diverse use since it has good flexibility and abrasion resistance. It is a good choice for most US&R rigging.
- The most common wire rope is improved plow steel, 6 x 19, filler wire, right regular lay (called 6 x 19).
- 6 x 37 is very flexible wire rope used on high-speed cranes, multiple reeving hoists, etc. It has a tendency to crush when used in multiple layers on drums.
- 8 x 19 is more flexible than 6-strand but has poor abrasion resistance. It is used in high-speed cranes and available in spin-resistant designs.

Wire Rope Grades

Improved Plow Steel (IPS) has been the standard for slings and general use for a long time. It is composed of wires whose tensile strength is 223 to 258 ksi. Extra Improved Plow Steel (EIPS) is 10 percent stronger, but less fatigue resistant, than IPS. EIPS is becoming the standard for slings. Extra Extra Improved Plow (EEIP) is 10 percent stronger, but less fatigue resistant, than EIPS. It is not used for slings because it requires special considerations for its terminations.

Canadian standards for wire rope are slightly different from those of the U.S. grading system.

Most Common Wire Rope

- Improved Plow Steel– breaking strength for 1: diameter = 45 tons
- 6 x 19 (6 x 21)
- Filler Wire (FW)
- Right regular lay
- Widely available

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Common Uses of Wire Rope

6 x 7	Regular lay: guy lines
6 x 19	Seale, regular lay: mines
6 x 19 (6 x 21)	Filler wire, regular lay: misc hoists, cranes, tackle blocks, mine hoists, elevators.
6 x 37	Regular lay: hoists, traction elevators
8 x 19	Non-rotating: single line hoists

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Wire Rope Grades – USA

- Improved Plow Steel (IPS) or Bethlehem Purple
 - Has been the standard for slings and general use
 - 223 to 258 ksi Ultimate Tensile Strength of wires
- Extra Improved Plow Steel (EIPS), Purple Plus
 - 10% stronger, but less fatigue resistant than IPS
 - Becoming the standard for slings
- Extra Extra Improved Plow (EEIP), Royal Purple
 - 10% stronger, but less fatigue resistant than EIPS
 - Not used for slings, requires special considerations
- For Canadian Grades, see Student Manual

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Most Common Wire Rope

- 6 X 19 (6 X 21) classification
- IWRC
- Bright, uncoated (not galvanized)
- Filler Wire (FW) construction
- Right regular lay
- IPS Breaking Strength, 1" diam = 45 Tons
- EIPS Breaking Strength, 1" diam = 52 Tons

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Wire Rope Inspection

Wire rope inspection should be done on a regular basis for the wire rope used on cranes and the slings that are dispatched with them. The Heavy Equipment and Rigging Specialist, however, should check all clearly observable ropes that are to be used during task force operations.

No assumptions should be made as to the frequency of previous inspections, and appropriate questions should be asked of the responding crane operators

.See Crosby's *User's Guide Lifting*, Panel 3, for detailed information regarding inspection.

- Replace rope if there are: (6 & 3 Rule)
 - ◆ 6 broken wires in one lay,
 - ◆ 3 broken wires in one strand in one lay, or
 - ◆ 3 broken wires in one lay in standing ropes.
- The 10 and 5 Rule may also be used

Important Inspection Items

- Kinks, bird caging, and a protruding core are easy to see adjacent slide
- Metal fatigue—wire fractures because of repeated passes over sheaves.
- Electric arc—reject wire rope with fused or annealed wires.
- Abrasion—from winding over drum, etc.;
- Corrosion—difficult to assess since it starts inside the rope and is not visible. If you can see rusting, reject the rope.

Important Inspection Items (continued)

- Diameter reduction/stretch—new wire rope is slightly oversized and expected to stretch less than 1 percent.
- Stretched rope will have a smaller diameter and longer lay.
- Crushed strands—too many layers on drum, no thimble

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Wire Rope Inspection

- Do on regular basis
- Check for
 - Broken wires—depends on location
 - Crushed strands
 - Kinks, bird caging, and protruding core
 - Stretch, diameter reduction
 - Abrasion and corrosion
 - Fatigue and electric arc
- See Crosby's *User's Guide Lifting*, Panel 3

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Wire Rope Inspection (continued)

Replace rope if there are:
 6 broken wires in one lay
 3 broken wires in one strand in one lay
 3 broken wires in one lay in Standing Ropes

Also 10 & 5 Rule

Estimate rope condition at section showing maximum deterioration

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Wire Rope: Discard Conditions

Kinks **Bird Cage** **Popped Core**

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Wire Rope: Discard Conditions

Core failure strands bind and take oval shape

Rope stretch reduce diameter and increase lay

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Wire Rope Cutting

When wire rope is to be cut, seizing is the best way to bind the ends in order to prevent un-laying. The number of seizings to be used is determined by multiplying the diameter by 3 and rounding off to the next highest number.

Example: For 1" rope use 3 seizings, and for ½" wire rope, use 2 seizings. The length of each seizing should be 1 to 1½ times the rope diameter, and spacing should be 2 times the diameter.

IV. Slings – Wire Rope, Synthetic & Chain

Slings, especially those used as chokers, are continually subjected to abuse because of abrasion, crushing, kinking, and overload.

Some authors of safety books suggest that the SF for slings be increased from the 5 to 1, normal for rigging, to 8 to 1. In US&R operations, it is assumed that the slings will either be newly constructed or carefully inspected.

It is therefore recommended that the 5 to 1 SF be maintained. One could argue that using a badly abused sling with even a 10 to 1 SF would be risky. **ABUSED SLINGS SHOULD BE DISCARDED.**

The standard wire rope sling is made from IPS or EIPS 6 x 19 or 6 x 37 construction wire rope with a Flemish eye mechanical splice.

There are slings made with mechanical splices and turnback eyes instead of Flemish eyes. Flemish eye, mechanical splice slings are strongly preferred.

Slings with hand-tucked eyes are available, but their capacity is not rated as highly as a Flemish eye mechanical splice.

The basic capacity of wire rope slings can be expressed as:

$$\text{Working Capacity} = D^2 \times 8.5 \text{ tons or } D^2 \times 17 \text{ kips}$$

(where D is the wire rope diameter)

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Wire Rope Cutting

Apply **SEIZING** at each side of cut
(may be done using soft wire and pliers)

**Number of seizings to be applied = 3 times
Diameter of rope to next whole number**

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Wire Rope Slings

- **Standard: IPS or EIPS 6 x 19 or 6 x 37**
- **Capacity based on end terminations**
 - **Hand Tucked** 80% Efficiency Factor (EF)
 - **Mechanical Splice** 95% EF
 - ◆ Returned loop – Generally not used for lifting
 - ◆ Flemish eye – Most common and strongly preferred
 - **Poured Sockets** 100% EF
 - ◆ Not used for field rigging often

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Wire Rope Slings (continued)

- **Additional wire rope sling styles**
 - Cable-laid wire rope slings
 - Braided multi-part slings
 - Grommet slings (endless)
 - Full capacity of wire rope is further reduced based on Nominal Splice Efficiency Use
 - Use manufacturers' tables for estimating capacity
 - Check sling tag for verification of capacity

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Additional Information about Wire Rope Slings

The capacity should be taken from a Crosby or similar rigging reference when deciding on what size sling to use. Before using any sling, verify the capacity by examining the capacity given on the tag attached to the sling.

The standard US&R task force cache has four wire rope slings which are IPS, Flemish eye, mechanical splice, 7/16" x 8 ft, 2400-lb choker capacity. Note that the capacity given is based on the use of the sling in a choker hitch. The effect of hitch type and sling angle is discussed later in this chapter.

Some specialized styles of wire rope slings have advantages for US&R activities.

- Cable laid slings are similar to braided slings in that they are made of multiple wire ropes grouped together. These are also more flexible than standard slings, but are not meant for fitting odd shaped loads and probably would not be used in US&R type situations.
- Braided multi-part slings are composed of multiple individual wire ropes that are interwoven to make a single sling. They are more flexible than similar capacity standard slings. These can fit odd shaped loads, such as rubble-sized concrete better than standard slings.
- Grommet slings are essentially loops of wire rope. They can be manufactured to shorter overall lengths than standard slings and are useful in situations calling for tight rigging.

Wire rope slings should be carefully inspected as discussed in the section on wire rope inspection.

Synthetic Web Slings -come in many configurations.

The slings that are constructed with metal or eye ends requiring sewing and, therefore, may be subject to more rapid degradation than the endless loop.

These slings are very lightweight, elastic, load hugging, and do not produce sparks. They may be made from nylon, polyester, aramid, kevlar, dacron, polyethylene, and nomex fibers and have varying resistance to harmful chemicals. They also tend to minimize twisting and spinning of the load, but some (nylon up to 10 percent) tend to stretch when loaded.

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Synthetic Sling Materials

- **Nylon—general purpose**
 - Unaffected by grease, oil, chemicals (except acids)
 - Loses 15% strength when wet
- **Polyester**
 - Unaffected by most chemicals, including mild acid
 - Disintegrates in sulfuric acid
- **Aramid, Kevlar, Dacron, Nomex—resistant to most weak chemicals**
- **High-density polyethylene—resistant to most chemicals**

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Synthetic slings should be purchased from reputable distributors and should not be used without the presence of the manufacturer's sewn-on tag (label). The label normally gives information on:

- Manufacturer's name, fiber type, and sling length; and
- Working loads limit for vertical, basket, and choker configuration

Nylon and Polyester web slings are made in different widths, from 1" to 12", but are generally used in widths of 2' to 4". They can be made with multiple plies; 1 to 4 are common. The standard task force cache has four nylon slings that are synthetic, heavy-duty, 3" x 6", type 3, flat eye, one-ply, 3,800-lb choker, Working Capacity.

Polyester Round Slings

One should avoid the following conditions:

- Sharp edges—Slings should always be protected from being cut by sharp corners, sharp edges, and highly abrasive surfaces. Use protective boots and wear pads or suitable sling protection.
- No knots—Slings should not be twisted, tied into knots, or joined by knotting.
- Prolonged sun exposure—Extended exposure of a sling to sun will degrade lifting capacity.
- Temperature—Nylon and polyester slings should not be used at temperatures in excess of 194 °F.
- The sling should fit the hook—On eye-and-eye type slings, the eyes should be of ample length to slip over the crane hook easily, thus reducing stress on stitching. Folding or bunching, which occurs when used on hooks, will reduce the load carrying capabilities.
- Use special shackles that are intended for synthetic slings.

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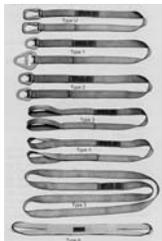


Synthetic Slings

- Must include manufacturer's sewn-on tag
- Provided with protective cover—seamless
- **Use Corner Protection**
- Need careful inspection
- Do stretch—up to 10%; polyethylene = 1%
- Very lightweight and easy to use
- Minimize twisting and spinning during lifting
- Capacity in *FOG*, not Crosby's *User's Guide*
- Use manufacturer's tag for capacity

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Nylon and Polyester Web Slings

- Unilink fittings
- Triangle and choker fittings
- Triangle fittings both ends
- Flat eye on both ends
- Twisted eye on both ends
- Endless (grommet)
- Endless with reverse eyes
- Note tag

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Notes on Nylon & Polyester Web Slings

- Can be made with multiple plies, 1 to 4
- Can be made from different classes of materials
- Can be made in different body widths
 - From 1" to 12", generally 2" to 4"
- Made in different lengths, usually even feet
- Standard TF cache has four 3" x 6', 1-ply, flat eye nylon web slings, 3,800-lb choker cap

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Polyester Round Slings

- Note adjuster for sling length
- Use manufacturer's tag for capacity
- Standard TF cache has
 - Four 10' 17,000-lb choker capacity = W L L
 - Four 20' 17,000-lb choker capacity = W L L
- 10 footer weighs 11 lb
- Similar cap wire rope 25 lb

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Endless Round Sling Capacity

The FEMA US&R cache contains eight endless, round, synthetic slings. They are the blue type, supplied in lengths of 20 ft and 10 ft (four of each length).

- They have an Working Capacity of 21,200 lb for vertical lift, 17,000 lb as a choker, and 42,400 lb when used in a basket configuration.
- All synthetic slings need careful inspection

Polyester Round Sling Discard Conditions

- Acid or caustic burns;
- Melting or charring of any part of the sling;
- Holes, tears, cuts or snags;
- Broken or worn stitching in load-bearing splices;
- Excessive abrasive wear;
- Knots in any part of the sling;
- Excessive pitting or corrosion, or cracked, distorted, or broken fittings; and
- Other visible damage that causes doubt as to the strength of the sling.

In addition, there are four other important reasons to remove slings from service:

- Any time you see warning yarns (frequently red),
- When there is distortion of the sling,
- When an identification tag contains any unreadable part
- Any time a sling is loaded beyond its rated capacity

Chain Slings

In most cases, chain slings are considered to be the least desirable type to use since they have disadvantages:

- Failure of single link = failure of sling,
- Give no warning of failure,
- Not suitable for impact loading,
- Are very heavy, and
- Are sometimes hard to identify (use only grade 8 or 10 with ID mark).

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Endless Round Sling Capacity
Working Load Limit in Pounds

COLOR	Wt #/ft	Vertical	Choker	Basket
Purple	0.2	2,650 lb	2,120	5,300
Black	0.25	4,000	3,200	8,000
Green	0.3	5,300	4,240	10,600
Yellow	0.4	8,400	6,720	16,800
Tan	0.55	10,600	8,500	21,200
Red	0.6	13,200	10,560	26,400
White	0.9	16,800	13,400	33,600
Blue	1.0	21,200	17,000	42,400
Grey	2.15	31,000	24,800	62,000

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Chain Slings

- Use only alloy grade 8 or 10 with ID mark
- Avoid use where possible (opinion?)
 - Failure of single link = failure of sling
- Usually give no failure warning
- Not suitable for impact loading
- Take rough handling, resistant to abrasion
- No kinks
- Resistant to corrosion
- Have Safety Factor of 4

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Chain Slings (continued)

However, they have the following advantages:

- Take very rough handling,
- Resist abrasion,
- Do not kink,
- Are relatively resistant to corrosion and most chemicals, and

Are more easily adjustable (sling length, etc).

They can also be configured around concrete slabs in combination with wire rope chokers to provide for specially aligned lifting in critical situations. It is important that US&R operations use only alloy hoist slings that can be clearly identified as grade 8 or 10.

Chain slings are normally provided with ID tags that specify the Working Load Limit. The ID tag should be attached to the master link.

In addition to the tag, you should be able to read the chain type marks on the master link and other chain links. Grade 8 alloy hoist chain will be marked with an: "A," "T," "8," "80," or "800." Grade 10 is marked with a 10 or 100.

In US&R operations, it is intended that we use chain only to bind a load, not for lifting, except when all other alternatives are not available.

Chain Sling Problems

Chain slings should be checked for stretch (indicates having been severely overloaded), twisted links, and gouged links.

Observe the following safety tips:

- Keep shock loading to a minimum.
- Never shorten a chain by tying knot or by boxing links together.
- Use only alloy hoist slings, grade 8 or 10.
- Grade 10 is 25 percent stronger than grade 8.
- Never use homemade links or repaired links.
- If links bind on each other, the chain is over-stretched.
- Always use softeners on sharp corners.
- Inspect the chain for wear, cracks, or stretch after cleaning chain.

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**Chain Sling Capacities (Lbs.)
(Working Load Limit = W L L)**

- Crosby User's Guide for Lifting, Panel 7
3/4" vertical leg sling = 28,300 lbs = 14 Tons
2 - 3/4" legs at 60 deg. = 49,000 lbs = 24.5 Tons
- Grade 10 is 25% stronger than Grade 8
See Crosby's Users Guide, Panel 7A (5/8" max)
2 - 5/8" legs at 60 deg. = 39,100 lbs = 19.5 Tons

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Chain Sling Identification

Chain Links Master Link
ID Tag

Two types of alloy lifting chain
Grade 8: has mark A, T, 8, 80, or 800
Grade 10: has mark 10 or 100

Use only alloy lifting chain for US&R lifting

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Chain Sling Problems

Chain stretch Twisted links Gouged links

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Chain Sling Capacity

The value for Working Load Limit for alloy chain slings can be determined as follows (with SF of 4 to 1):

Working Load Limit = $D^2 \times 24$ tons (vertical hitch, if identified with A, T, 8, 10, 80)

See examples in the Crosby *User's Guide Lifting*, Panel 7, grade 8, and Panel 7A, grade 10.

Effects of Hitch Types and Sling Angles

The basic capacity of a sling with an eye at each end is its capacity when used in a vertical (straight) configuration.

That value can be doubled for basket slings (with near 90-degree legs).

The basic value is reduced to about 75 percent for a choker sling. In practice, any sling being used will have a tag on it on which the capacity for the different types of hitches is given. For preliminary sizing, use the capacities given on the Crosby folding rigging card, Panel 5

Example: What is WLL or 3/4" vertical wire rope sling?

What is WLL for same as choker?

(9,800lb & 7,200lb)

Sling Angle

When slings are configured such that the legs have an angle less than 90 degrees from horizontal, the force in the sling increases.

As the angle decreases, a larger and larger horizontal force is exerted on the connectors in the direction perpendicular to the load, which illustrates that when loads (forces) are resisted at angles other than straight on, greater forces are generated in the resisting elements (cables).

Furthermore, additional forces are generated at 90 degrees to the original load (even though the load has not changed). This is similar to what happens with raker shores, when the horizontal force needed to restrain a wall must be provided by a diagonal timber. The raker's capacity must be greater than the required horizontal force.

The tension load in the sloped cable is related to the vertical load that needs to be carried, by the ratio of length (L) of the cable to the height (H) from load to hook

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Chain Sling Capacities (Lbs.) (Working Load Limit = W L L)

- Crosby User's Guide for Lifting, Panel 7
3/4" vertical leg sling = 28,300 lbs = 14 Tons
2 - 3/4" legs at 60 deg. = 49,000 lbs = 24.5 Tons
- Grade 10 is 25% stronger than Grade 8
See Crosby's Users Guide, Panel 7A (5/8" max)
2 - 5/8" legs at 60 deg. = 39,100 lbs = 19.5 Tons

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Sling Hitch Types

Vertical
1 X cap

Basket
2 X cap

Choker
3/4 X cap

Capacities assuming sling angle = 90 deg (vertical)

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Sling Angle

- Measured from horizontal
- Preferably 60 deg
- At least 45 deg
- Never less than 30 deg
- Load capacity is reduced from full sling capacity by ratio of H/L

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Example: If a 1,000 lb load is lifted by a 2 leg sling, with a length (L) of 10 ft and a height of 7 ft the force in the sling is 700 lb (500 x 10/7) (707 for 45deg)

Similar to a 45-degree raker that is resisting a 500-lb horizontal force from a building has a 700-lb force acting on the axis of the raker, and an additional force of 500 lb is acting upward on the wall surface

V. Wire Rope Terminations

Socket Terminations

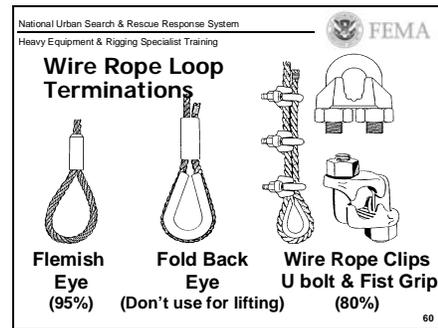
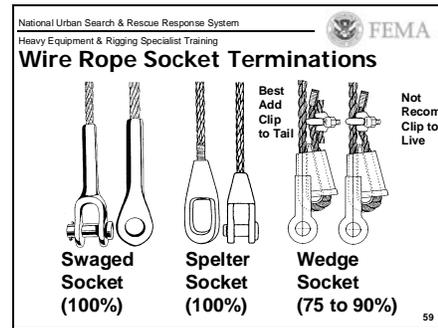
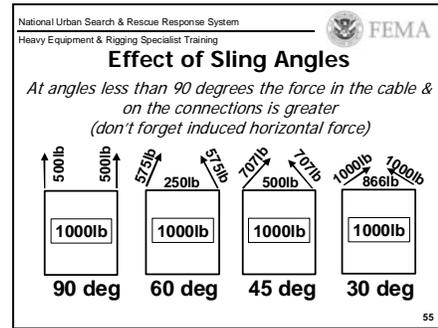
Sockets are used for most wire rope terminations on a crane. The most common types are swaged, spelter, and wedge sockets. Swaged sockets are made in a shop and are found at the ends of pendants; they should only be used on standing ropes. Wedge sockets may be installed in the field and are normally used to attach the whip line to the ball. All wire rope slings, tiebacks, etc., need some sort of loop (eye) to be formed.

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Sling Terminations

Prefabricated slings come with swaged or Flemish eyes that only reduce the capacity of the assembly by 5 percent. Broken wires at or near eye fittings are a cause for concern and will require a **re-do** of the eye or rejection of the rope. During US&R operations, wire rope termination loops may need to be made using cable clips.

Eyes made using cable clips can develop 80 percent of the wire rope strength. First grips clips may also be used but are much less available. Clips should come from reliable manufacturers and should be installed according to the manufacturer's recommendations (found on package)





Cable Clips

Three or more clips are used for rope size 1/2" and greater. The number used is equal to the rope diameter times 3 + 1, raised to the next whole number. See Crosby's *User's Guide Lifting*, Panel 16.

The use of thimbles in all constructed eyes is highly recommended

Clip Installation

Clips are installed by placing the U-bolt over the dead end of the rope (never saddle a dead horse) with the first clip being placed farthest from the loop and tightened (hopefully a thimble will be placed in the loop). The second clip is placed near the loop, and the remaining clips are equally spaced between the first two.

Clip Installation – Splicing & Proper Torque

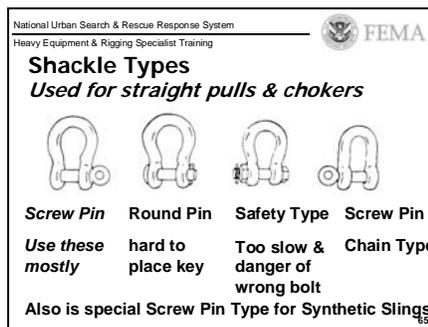
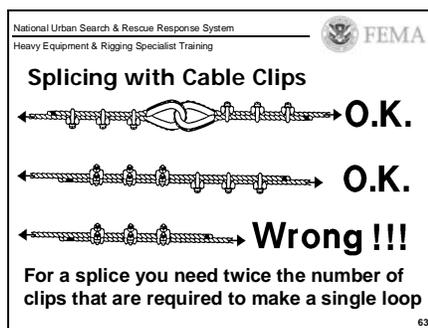
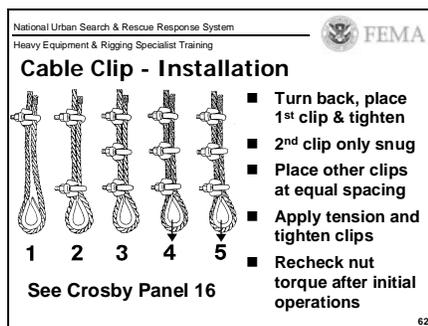
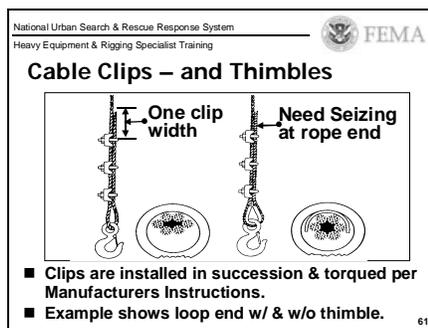
All clips should be sequentially tightened, using a torque wrench. The proper torque is printed on the package and is given on Panel 16, Crosby *User's Guide Lifting*.

For a splice, you need twice the number of clips that are required to make a single loop.

VI. Shackles, Hooks, & Eye Bolts/Nuts

Screw pin shackles are most commonly used, and they provide the best method of attaching loads and constructing chokers.

- Shackles are available in carbon steel or alloy steel. For use in lifting, both should be forged, quenched, and tempered.
- Special, flat bow shackles are available for use with synthetic slings—they keep the sling fibers from bunching up at the center of the bow.
- NEVER REPLACE A PIN WITH A BOLT





Shackles need to be installed so that the pin cannot roll under load.

- The size is based on the diameter of steel in bow, and leading manufacturers stamp the load capacity into the steel.
- The screw pin is 1/8 inch greater than the nominal shackle size for those within the 1/2" to 1 1/2" range.

Screw pin shackles may be side loaded .

- At 90 degrees there is a 50% loss in capacity.
- The screw pin may be point loaded by another shackle or a wire rope sling eye, as long as long as the load is reasonable centered.

Shackle Orientation

- Orient shackles on hooks for best sling alignment
- When a shackle is used to interconnect two slings the alignment should be at 0 or 90 degrees, as shown in adjacent slide

Connecting Slings to Shackles

The diameter of the shackle and its pin must be greater than the wire rope diameter, if there is not thimble in the eye.

- Shackles must be wide enough to prevent bunching of synthetic slings.
- As previously mentioned, flat bow shackles are available for use with synthetic slings—they keep the sling fibers from bunching up at the center of the bow.

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Shackle at Hook or Choker
Washers can be used as spacers at hook - hangs more evenly

YES - pin can't roll under load **NO - moving rope can unscrew pin**

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Loading of Shackles

ANGLE OF SIDE LOAD	LOSS OF W.L.L.
NONE IN LINE	NONE
45 DEGREE	30% LOSS
90 DEGREE	50% LOSS

Loading at an Angle
No Side Load for Round Pin Shackle

Point Loading is O.K.
As long as load is centered, use washers

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Shackle Orientation & Alignment

Orientate shackle for best sling alignment **Proper Alignment** **Incorrect**

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Connection of Slings to Shackles

Diameter of Shackle must be greater than Wire Rope diameter, if no Thimble in Eye **Shackle must be large enough to avoid pinching Synthetic Slings**

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Shackle Working Load Limit for carbon steel and alloy steel shackles are listed in Crosby's *User's Guide Lifting*, Panel 12, or they can be expressed in terms of the bow diameter (D).

For Carbon Steel: (SF = 6 to 1)

$$SWL = D^2 \times 8.5 \text{ tons or } D^2 \times 17 \text{ kips (1 kip = 1,000 lb)}$$

For Alloy Steel: (SF = 5 to 1)

$$SWL = D^2 \times 12.5 \text{ tons or } D^2 \times 25 \text{ kips}$$

Shackles should be carefully inspected for wear on the bow or on the bolt, as well as gouges and other cuts that reduce cross-section. These defects can cause shackle failure and/or damage to slings.

Hooks – Identification & Angle Marks

Hooks are used to receive the load from one or more slings. Hooks are available in Carbon Steel or Alloy Steel

- Use Alloy Steel Hooks by leading manufacturers that have an A or C embossed in the hook to identify type of steel. For use in Lifting, both types should be Forged, Quenched and Tempered
- The included angle between two slings supported by a hook must be no greater than 90 degrees – or listed strength will be reduced. Hooks should have forged in angle limit marks.
- WLL for hooks are also shown in Crosby's *User's Guide Lifting*, Panel 12, which is shown at the top of this page

Hook Latches and Minimum Sling Size

All hooks used for lifting **Must have Functioning Latches**. The slings must sit in the base of the hook and clear the latch – **Do Not Foul the Latch**

- The length of the sling end loop must be two times the width of the bottom of the hook

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Crosby Panel 12 Shackles & Hooks

Best to use Forged-Quenched & Tempered
 W.L.L. is stamped into Shackle/Hook body
 (S.F. = 6/1 - Carbon & 5/1 - Alloy Shackles – 4.5/1 Hooks)₇₀

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Hook I.D. & Angle Marks

- Crosby Hooks have forged-in information
 - W L L & C for Carbon, and A for Alloy Steel
- Slings must sit on base of Hook & clear latch
 - Included angle of 2 slings must not exceed 90 deg
 - Most slings have forged-in max. angle marks

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Hook Latches & Min. Sling Size

Latches are required to retain slings & must be working

L of Slings must be 2 times width of Hook

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Improper Hook Loading

As shown in the adjacent slide, hooks must fit into eyes or other connections, such that they are loaded at the bottom of the hook and it remains upright

Also all slings must be placed within the middle of the bottom of the hook and not foul the latch

Shackles placed on Hooks

As shown in adjacent slide, shackles placed on hooks must be of adequate width so as to clear the width of the hook, and bear on the bottom of the hook

Shackle pins may bear on a hook, as shown in the slide. If there is too much space either side of the pin, and unwanted movement will occur, washers may be used to fill the space and center the pin

Eye Bolts

These devices have limited reliability and are not preferred for use in US&R.

Forged steel eye bolts with shoulders could be used for vertical pulls provided that they pass through steel or concrete and have a washer and double nut on the far side. They are available from leading manufacturers with SWL stamped into the steel.

The WWL of Eye Nuts screwed to drilled-in expansion anchors is limited by the capacity of the anchor. Working Load Limit, in pounds, for quenched and tempered eye bolts are shown in the Crosby *User's Guide Lifting*, Panel 14.

See FEMA Structural Collapse Technician, SCT04, Student Manual, Part c, Anchor Systems for information about the installation and strength of Eye Bolts when used with drill-in concrete anchors

The FEMA US&R Rigging Cache includes: 8 eye nuts, 1/2" (type 3a). The working load limit for the eye not threaded onto this anchor is about 2,000lb for a vertical pull. It is not recommended to pull on this type of anchor at an angle

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Improper Hook Loading, Fouling of Latch

Do not Tip Load, Side Load, or Back Load Hoist Hooks | **Correct! Sling in Base of Hook** | **Incorrect! Sling fouled on Latch**

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Shackles placed on Hooks

Use large enough Shackles | **Point Loading is O.K. As long as load is centered, use washers**

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Eye Bolts – US&R use Eye Nuts in Conc.

Eye bolts must have shoulders tight

Load vert. if possible only as shown | **Best to use Shackle** | **No use Hook**

See SCT04 for Eye Nuts & Swivel Hoist Rings

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Eye Bolt - Quenched & Tempered

Working Load Limit at Various Angles - in Pounds

Shank Diameter	W L L (LBS) based on angle		
	Vertical	60 deg	45 deg
1/4	650	420	195
3/8	1,550	1000	465
1/2	2,600	1,690	780
5/8	5,200	3,380	1,560
3/4	7,200	4,680	2,160
1	13,300	8,645	3,990
1 1/4	21,000	13,600	6,300
	100%	65%	30%

Crosby User's Guide, Panel 14, S.F.= 5/1

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of more than 15 degrees off vertical.

VII. Other Rigging Tools

Portable Cable Winch—Hoist (Come-Along)

These devices come with rated capacity from 0.5 to 6 tons and weigh from 7 to 35 pounds. Few manufacturers publish the SF incorporated in their rated capacity, so one needs to use these devices with extreme caution.

- One manufacturer lists an SF of 3 and notes that the handle will bend when overloaded (as a warning).
- In most cases, the length of the handle and one's ability to move it provide an overload limit device.

NEVER USE A HANDLE EXTENDER (“cheater pipe”).

Other devices are preferable; however, these could be used to pull cable ends together initially in order to apply the final tension with a more reliable tightener.

Chain Hoists, Falls, and Ratchet Levers

- These devices have rated capacities of up to 6 tons, which, in some cases, can be achieved with a 100-lb pull.
- Use devices which are rated for lifting applications not just “pullers.”
- These tighteners have large (up to 10 ft) take-up capacities but are relatively heavy and expensive.
- They are strongly preferred when adjustment under load is required.

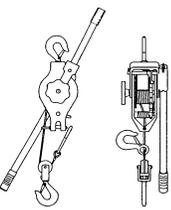
Chain falls and chain hoists can be very useful when awkward and uneven loads and situations are encountered

- They may be used to adjust sling lengths for awkwardly shaped loads
- They may be used to balance and level odd shaped loads when slings cannot be positioned to fully capture the center of gravity
- They may be used to better maneuver a load, especially when access is an issue

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Portable Cable Winch-Hoist (Come-Along)



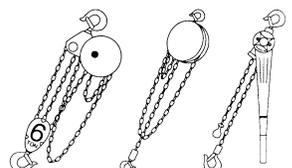
- 0.5 to 6 ton capacity
- Weigh 7 to 35 pounds
- Large take-up
- Safety Issues
 - SF may be 1.5 to 2.0
 - Inspect Carefully
 - DO NOT use Handle Extender

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Chain Hoists, Falls, & Ratchet Levers



Up to 6 ton wt to 80 lb Up to 5 ton wt to 84 lb Up to 6 ton wt to 46 lb

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Chain falls and chain hoists useful for awkward loads and situations



- Used to adjust lengths
- Used to maneuver load
- Access to operate is issue

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Chain Hoists and Falls Safety Issues

- Use the proper type and capacity.
- Inspect the hoists and falls for wear.
- If it takes two, the load is too great.
- Use only the handle that is provided.

Grip Hoists

Grip hoists are a special type of cable come-along, sometimes referred to as an “endless” come-along. They use a length of wire rope that is pulled through two sets of gripping jaws. These devices are rated for either overhead lifting of materials (5 to 1) or for lifting of people (10 to 1). They are very useful, but the standard cache does not include any at this time.

Turnbuckles

These are probably the most commonly used tightening devices. They are available in many sizes and come configured with eye, jaw, and hook ends.

Length of take-up for turnbuckles varies depending on the length purchased and can vary from 4 to 24 inches. They can be difficult to tighten near SWL and may require lubrication. (Keep the WD-40 handy.)

The listed size is based on the diameter of the threaded ends.

The Working Load limits are listed in tables and are based on SF = 5 to 1. Hook-end turnbuckles have significantly lower strengths. The WLL can be expressed as:

$$SWL = D^2 \times 5 \text{ tons or } D^2 \times 10 \text{ kips}$$

(See Crosby *User's Guide Lifting*, Panel 13.)

Turnbuckles should be carefully inspected for:

- Cracks or bends on the turnbuckle body,
- Cracks or bends on each end fitting, and
- Damaged threads.

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Chain Hoists and Fall Safety Issues

Use proper type and capacity
Inspect for wear

If it takes two, load is too great

Use only the handle provided

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Grip Hoists

- Not in cache
- Very handy if available
- Use their own special wire rope
- Don't use it for anything else

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Turnbuckles

Eye **Jaw** **Hook**

Hook end is from 1/2 to 2/3 as strong as EYE
S.F.=5, Take-up = 24"max, Need Inspect

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Turnbuckle - Working Load Limit in 1000lbs - Kips - not Tons

Type	3/8	1/2	5/8	3/4	1	1 1/4
Hook	1.0k	1.5k	2.25k	3.0k	5.0k	6.5k
Eye	1.2k	2.2k	3.5k	5.2k	10k	15.2k
Jaw	1.2k	2.2k	3.5k	5.2k	10k	15.2k

See Crosby Guide, Lifting, Panel 13

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VIII. FEMA US&R Task Force Rigging Cache

Rigging items are in the rescue cache and are intended to comprise a minimum, lightweight cache. It is expected that the cache will be augmented with rigging provided by the local crane company.

- 2 cable pullers and/or chain hoists
- 4 chain slings, 10' and 20' (grade 8 or 10)
- 8 – 1 ¼" shackles (for synthetic slings)
- 8 – 5/8" shackles (alloy)
- 4 wire rope slings, 7/16" x 8"
- 4 synthetic slings with eyes
- 8 synthetic, endless, round slings, 10' and 20'
- 8 synthetic sling wear protectors
 - ◆ 12" x 18" with Velcro (makes 6" x 18" sleeve)
- 8 turnbuckles, 1" x 12", take-up, jaw-jaw
- 4 swivel hoist rings, ½"
- 8 eye nuts, ½" (type 3a)
- Torque wrench ½" x 250 lb with ¾" sockets
- 25 – ½" x 5 ½" wedge anchors
- 25 – ½" x 7" wedge anchors

Summary and Review

US&R rigging design considerations have been presented.

- Rigging may be used to lift, pull, and tieback.
- However, the failure mode is CATASTROPHIC.

We have discussed that wire rope comes in many configurations, but a 6 x 19, grade improved plow rope will serve most needs for US&R operations. The rope may have a fiber or a wire core, but the SWL is approximately the same for either.

We discussed making end loops (eyes) in wire rope using U-bolt clips, but we should be sure to use clips and other fittings that are made by reputable manufacturers.

We discussed slings and stated that, although wire rope slings are most common, synthetic and chain slings have properties that make them useful for some applications.

We, also pointed out that wire rope and all other rigging hardware need to be inspected for obvious flaws, signs of abuse, and so forth. This responsibility should be assumed by each task force Heavy Equipment & Rigging Specialist.

<p>National Urban Search & Rescue Response System Heavy Equipment & Rigging Specialist Training</p> <p> FEMA</p> <p>Review Enabling Objectives</p> <ul style="list-style-type: none">■ Review interaction between HERS and StS<ul style="list-style-type: none">● Review Common Rigging Terms■ Identify wire rope terms, configuration, lay, strengths, inspection items, capacity■ Discuss types and configurations of slings■ Describe various devices used with rigging■ Information for student review<ul style="list-style-type: none">● Crosby's <i>User's Guide Lifting</i>, - 16 Panel● Signal-Rite Rigging Card● US&R Task Force Rigging Cache <p style="text-align: right;">86</p>
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