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Cranes, Hoists, and Rigging

A Safety Training Manual

Lee Stinnett

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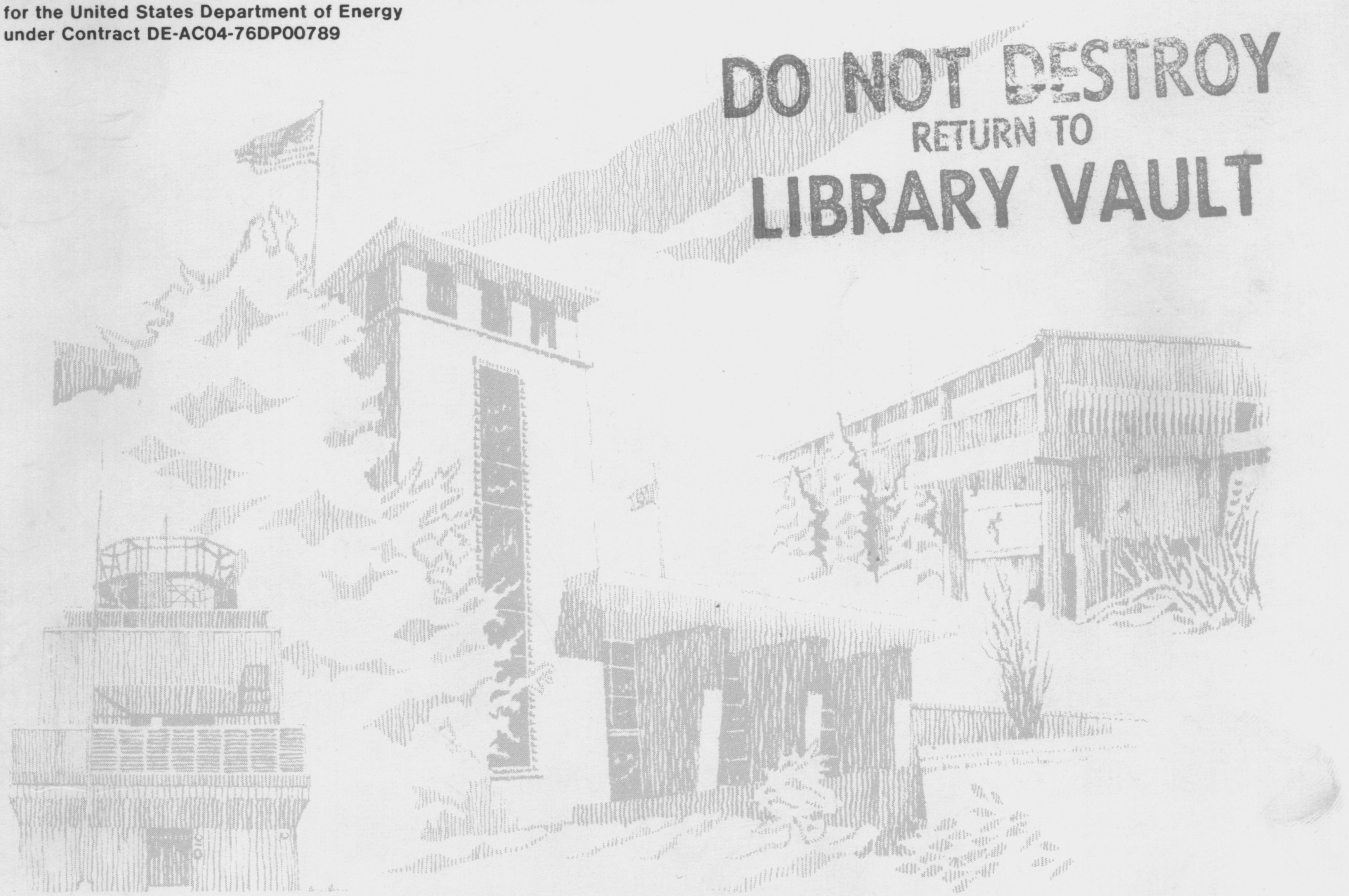

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Acknowledgments

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Introduction

Of Cranes, Hoists, and Rigging, the most important is . . .

Through the ages, since man first moved materials of significant weight or size or used them for building purposes, some type of handling equipment was used. Man's needs, ingenuity, and creativity produced such implements as levers (sticks), rollers (poles), and pullers (vines). Eventually, oxen, asses, camels, elephants, etc., were used to move material. But nothing of significance was created until the pulley and rope system provided man with a power advantage. Later, after the Industrial Revolution, steam provided the power and the impetus for developing machines that were the forerunners of the sophisticated heavy material-handling equipment used today.

The handling equipment discussed in this manual is the type that lifts, lowers, and locates (positions) heavy material—cranes and hoists.

The crane/hoist family of equipment may be as small as a single pulley/rope system handling several pounds, or as large as a marine crane system that recently (1985) hoisted a 5005-metric ton oil drilling rig from a barge and placed it on the seabed of England's North Atlantic offshore oil field. An equivalent "pick" would be a 6-ft-high solid pine board, 360 ft long and 160 ft wide (the dimensions of a football field).

The capacity of the cranes and hoists at Sandia National Laboratories in Albuquerque (SNLA) fits somewhere within the first 2% of the marine pick or lift described above. SNLA has several mobile cranes and more than 500 other types of cranes and hoists located in more than 100 buildings. As programs diversify and new projects are implemented, the quantity of these useful machines will undoubtedly increase.

The Department of Energy (DOE) and SNL have safety policies and directives that require the operators of heavy equipment to be trained and authorized. The Cranes, Hoists, and Rigging Safety Training Program, sponsored by the SNLA Safety Department, is an effort to fulfill those safety policy requirements. This manual will be used as a safety training aid and will be issued as a reference document for supervisors, operators, inspectors, and service personnel who use cranes or hoists during their regular duties.

The directives stipulate, in addition to training, that certain physical requirements must also be met by the operators of heavy material-handling equipment. The physical requirements listed in the referenced directives have been reviewed by the SNLA Medical Department (Appendix A). Therefore, to meet the imposed physical requirements prior to training, the following procedures shall be followed:

> Line managers shall nominate all of the individuals who operate cranes and hoists. The nomination forms will be sent to the Medical Department where the medical classification will be determined for each nominee.
>
> Those employees in Medical Classification I will be scheduled for the training course as space allows. SNLA employees who are assigned Medical Classifications II, III, or IV, and contract personnel may require a physical examination and the approval of the Medical Department in order to attend the course and to operate the material-handling equipment.

The Cranes, Hoists, and Rigging Safety Training course emphasizes the *safety* requirements when using this kind of heavy equipment. It does not cover the physical "hands-on" or "how-to" methods required to operate the equipment.

Safety at SNL is the responsibility of line management. Therefore, the training required to physically operate cranes and hoists is the responsibility of the first-line manager. The authorization to use material-handling equipment will be effective at the time the line manager signs the operator's card that is issued to each attendee at the Cranes, Hoists, and Rigging Safety Training Course.

Recertification of the physical qualifications and attendance of each operator at a Safety Review Seminar are required every three years.

This manual is not intended as a replacement for manufacturers' manuals, Federal Codes and Regulations, ANSI Standards, or DOE or SNL safety manuals and directives, but soley as a training manual and as quick reference for the more comprehensive documents listed in the References and Other Works Consulted.

Individuals who use, inspect, or service cranes or hoisting equipment should be familiar with the equipment manufacturers' manuals and the documents listed in the References. They must also be familiar with the definitions, general requirements, and inspection classifications and with the testing, maintenance, and operational guidelines contained in the following specific Subparts of *OSHA Safety and Health Standards*, 29 CFR Part 1910 and 29 CFR Part 1926:

Subpart H—Materials Handling, Storage, Use, and Disposal

1926.250	General Requirements for Storage
1910.30	Other Working Surfaces
1910.176	Handling Materials—General
1926.251	Rigging Equipment for Material Handling
1910.184	Slings

Subpart N—Cranes, Derricks, Hoists, Elevators, and Conveyors

1926.550	Cranes and Derricks
1926.551	Helicopters
1926.552	Material Hoists, Personnel Hoists, and Elevators
1926.553	Base-Mounted Drum Hoists
1926.554	Overhead Hoists
1926.556	Aerial Lifts

Copies of these Subparts are available for review in the Safety Department.

1. Cranes

Of Cranes, Hoists, and Rigging, the most important is . . .

A crane, by definition, is "an often-horizontal projection swinging about a vertical axis, a machine for raising, shifting, and lowering heavy weights by means of a projecting swinging arm, or with the hoisting apparatus supported on an overhead track."

This definition covers the tower, jib, gantry, bridge, mobile and all of the other various configurations of the crane. The words *crane* and *hoist* are usually used interchangeably. However, the crane is the supporting structure that holds the hoist that lifts or lowers the load. Hoists will be discussed in Section 2. Lifts and winches provide the same function and will be included in that section also.

1.1 Mobile Cranes

Refer to ANSI B30.5 and B30.5a.

Certain operational functions and safety precautions apply to all cranes, especially to mobile and to overhead cranes and hoists. Refer to Overhead Bridge Cranes (Section 1.2) and apply any function to mobile cranes that may be pertinent but that is not included in this section.

A mobile crane is a wheeled, four-point, supported structure consisting of a transporting vehicle (carrier) having rubber tires, steel tracks (as on a military tank), or steel wheels (as used on rail cars); a boom (a lattice or telescoping boxed steel structural member that provides the lifting height); outriggers (a term borrowed from the marine community that means "a spar or projecting beam," which, when the four outrigger pads are in the extended position, support the weight of the "crane" and the weight of the load or "pick"); an auxiliary power plant; a power drum; head sheaves; a load block; a hook; and wire ropes. The drum, wire rope, boom head sheaves, and load block act as a hoist or winch.

Mobile lattice boom cranes may use a jib. The boom is raised, lowered, and supported by pendants, gantry, mast, bail, etc. The "gantry" and "jib" are not to be confused with gantry- or jib-type cranes, and "pendants" should not be confused with the pendants on overhead cranes or hoists.

Hydraulic mobile cranes may have a boom extension and jib and occasionally even use a telescopic jib. The boom is raised and lowered by the action of the hydraulic boom hoist cylinders.

This "truck type" carrier must not be confused with the ordinary commercial truck chassis. It is specially designed for crane service and the heavy loads these cranes are required to withstand.

Carrier-mounted cranes are also commonly referred to as "Truck Cranes", "Conventional Cranes", "Friction Cranes", "Mobile Cranes", etc.

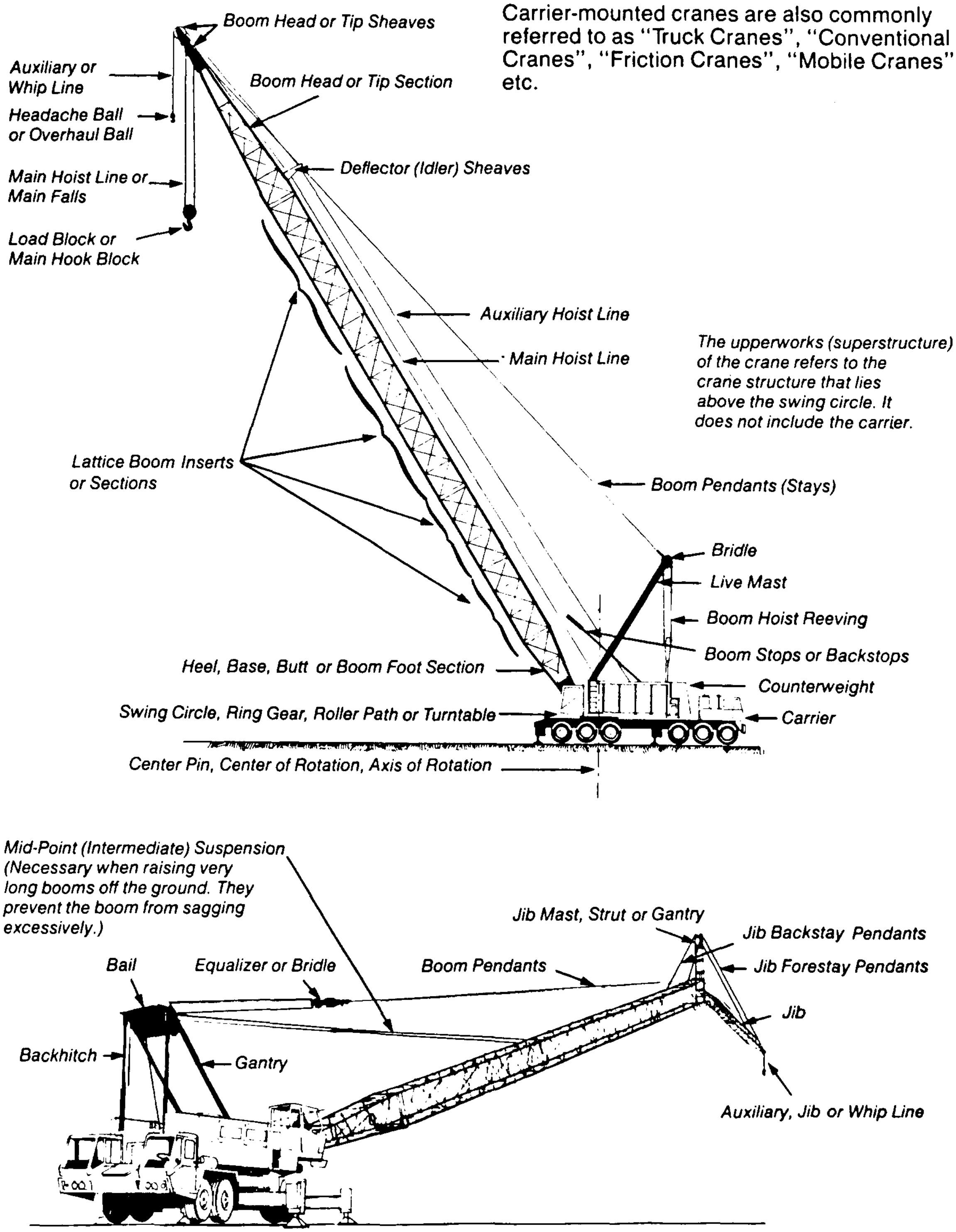


Figure 1. Carrier-Mounted Lattice Boom Cranes[1]

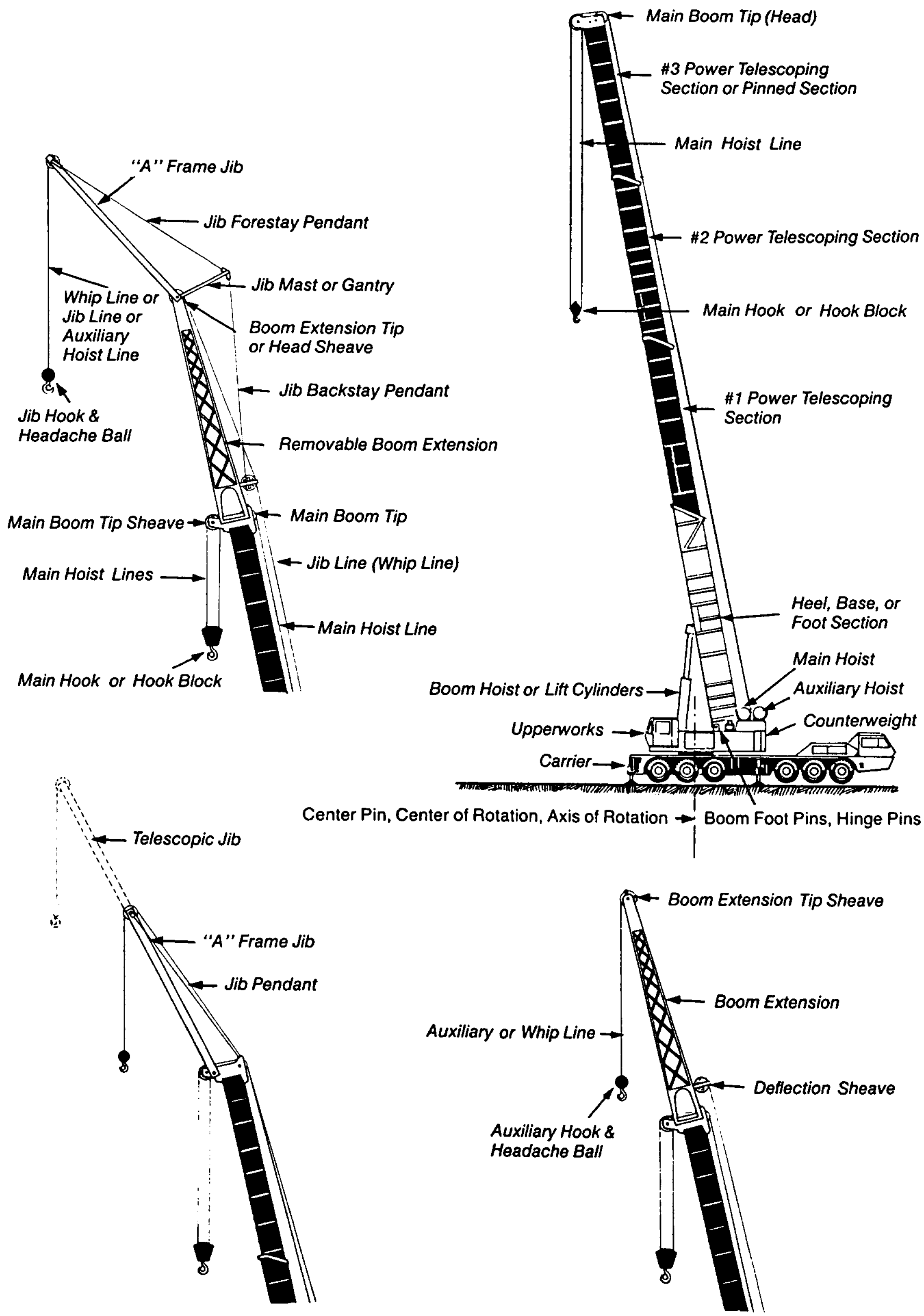


Figure 2. Carrier-Mounted Telescopic Boom Cranes[1]

Many accidents occur with mobile cranes. An average of one mobile or tower crane accident happens daily in the United States and Canada. Following are some of the causes of these accidents.

- The load was too heavy.
- The crane was not level on the outriggers.
- The outriggers were improperly positioned.
- The crane was driven into electric wires with the boom up.
- The load block was pulled up into the boom tip or jib tip sheaves. (This is called "two-blocking.")
- Incorrect signals were given or the signals were not understood.
- The fastenings were not the correct type or were the wrong size.
- The equipment failed from fatigue or damaged parts.
- The boom was raised too high.
- The boom snapped back over the carrier cab because the hoist cable broke.
- The ground was not firm or the cribbing was improperly stacked.
- The operator was not trained to operate the crane.
- A supervisor did not approve the crane setup or rigging.
- A supervisor made the decision to make the pick against the judgment of the crane operator.
- The urgency to complete the job overrode good judgment.

According to investigators, most of the accidents are caused by operator error, although many are the result of poor planning, lack of site supervision, and mismanagement. Most of these accidents could have been circumvented if everyone associated with the job had been alert, knowledgeable, and safety-cautious.

Following are some actions that, if done properly, would reduce hazards and possibly eliminate accidents.

1.1.1 Inspection

Inspections shall be made by the authorized operator in accordance with the manufacturer's recommendations and the requirements listed below.

The inspection of mobile cranes is divided into two general classifications: *Frequent* Inspections and *Periodic* Inspections.

Frequent Inspections

Frequent Inspection means that the crane is inspected before each daily use. The items that should be inspected are

1. All control mechanisms for maladjustments that interfere with proper operation
2. All control mechanisms for excessive wear of components and contamination by lubricants or other foreign matter
3. All safety devices for malfunctions
4. All hydraulic hoses, particularly those that flex in the normal operation of crane or carrier functions
5. Crane hooks for deformations or cracks (Hooks with cracks or having more than 15% in excess of normal throat opening, or more than a 10° twist from the plane of the unbent hook, shall be taken out of service. For additional information, see Section 3.4.1, The Hook.)
6. The load cable

   Note: One of the most important preoperational inspections to be made on any crane is the rope inspection. Refer to Section 3.1, Wire Ropes, for inspection criteria.
7. Wire rope reeving for compliance with the crane manufacturer's specifications
8. Hydraulic system for proper oil level
9. Tires for recommended inflation pressure
10. Fuel, oil, and cooling fluid levels
11. Carrier cab and crane cab windows missing, broken, cracked, or dirty
12. Fire extinguishers in place and serviced recently.

See Appendix B for the Field Inspection Check Sheet, Mobile Cranes.

Periodic Inspections

Periodic Inspections are normally completed by Plant Engineering Operations Field Inspectors in accordance with Plant Engineering procedures. This applies to all craning and hoisting items discussed in the following sections.

Mobile cranes must be load tested annually. They must be inspected and load tested after cable replacement if the crane has been idle for six months or more, if the boom has been repaired, or if the crane has been in an accident. The test load shall not exceed 110% of the rated load. A Plant Engineering Operations Field Inspector observes and certifies the load tests, which are performed by Plant Maintenance personnel.

1.1.2 Operations

The operator shall ensure that the following items are satisfactory before every crane setup or use.

1. The site location must have a firmly packed earth base, or heavy hardwood mats or cribbing must be used under the outrigger pads.
2. The outriggers shall be fully extended for all picks.
3. The crane setup must be level within a 1% grade so that the centerline of the boom will not be off vertical more than 3°. ***This is critical!*** The load rating of the crane must be decreased by 50% if the centerline of boom is more than 3° off vertical.

   The crane's center of rotation will be located more than 4 ft away from a vertical plane through the center of gravity (CG) of the pick if an 80-ft boom is 3° off vertical.
4. The counterweight swing area must be barricaded if the operation is being done in an area where personnel may be injured during the rotation of the crane.
5. The boom swing area must be barricaded if the operation is being done in an area that is populated by individuals other than the craning crew members.
6. The weight of all auxiliary handling devices such as the load block (including the hook), cable, slings, and lift-devices shall be considered a part of the weight to be hoisted. Also, the weight of the jib must be included if the pick is done by the boom tip. Refer to Section 3.5.1 for determining the weight of loads.
7. The weight of the load must be known or determined as accurately as possible. To determine the weight of the load if it is unknown, see Section 3.5.1.
8. The CG of the load must be known or determined as accurately as possible. Refer to Section 3.5.2 to determine the CG of the load if it is unknown.
9. The load radius (number of feet measured horizontally from the crane's pivot point to the sheave shaft in the load block or to the whip line) must be measured. This figure and the total weight of the pick are necessary to use the crane's load charts.
10. A sufficient number of taglines should be used so that control of the load being moved is maintained. A minimum of two taglines should be used on loads that are horizontally long and slender, large and bulky, loads that have a large wind-catching surface, or any item that needs a restricted rotational momentum.
11. The crane operator shall take signals from only one competent individual. Refer to Section 3.5.6 and to Chart A—Mobile Crane Hand Signals—following the appendixes.

Other items that the operator must be aware of are as follows:

1. A jib is attached to the boom to increase height, not radius.
2. Lift capacity decreases as the boom or jib tip radius increases.
3. The load radius changes if the load pickup point is changed from the main boom tip to the jib tip.
4. Rotation-resistant wire rope should not be used in a multipart hoisting system because the wire rope may be crushed on the drum. However, spin-resistant wire rope may be used, which is ideal for hoisting systems rigged with an odd number of parts where the load block has a tendency to twist.
5. Wire rope should be reeved instead of laced on a multipart system.
6. If a jib is used, it must have a positive stop to prevent its rotating to less than 5° within the straight line of the boom. Cable-type belly-slings are not approved as a positive stop.
7. Modifications shall not be made to any part of a mobile crane unless approved by the manufacturer and by Plant Engineering.
8. The maximum ballast or counterweight approved by the manufacturer of the crane shall not be exceeded.
9. All worn or damaged parts of a mobile crane must be replaced with the manufacturer's original equipment or must be approved by the manufacturer.
10. Beware of the wind during craning operations. Use taglines. Never make a full-capacity lift if it is windy. Stop operations if the wind speed exceeds 30 mph. Stop the operation if the load presents a large wind-catching surface and the wind velocity is gusting or is in the range exceeding 15 mph.

11. Cranes in transit shall move only when the boom is lowered to its horizontal traveling position and the hook is restrained from swinging.
12. Do not raise the boom when the crane is in transit.

Observe the following safety precautions when working near electrical transmission lines:

- Treat all wires and electrical equipment as "hot" until you have reliable information to the contrary.
- Cranes shall not be operated near electrical transmission lines unless the radius of the boom/jib tip is farther away from the nearest line by the radial limits stated in Table 1.
- The high line voltage at Kirtland Air Force Base does not exceed 350 kV as of this date. Should it ever increase, or when in doubt as to the line voltage, do not operate a crane if the boom/jib tip radius is within 45 ft of the transmission line.

  The best safety advice is this: If the crane is required to perform work within the radial limits shown above, request the utility company to de-energize the transmission line.
- If a crane must be positioned such that the boom or jib tip could penetrate the radial limit, a signalman must be used whose only duty is to watch and warn the crane operator if the hoist ropes are approaching the radial limits.
- Do not rely on ground rods for safety. A person touching the crane or load will still draw enough current to void even the best ground rods.
- Do not rely on proximity warning devices, hook insulators, insulating boom guards, swing-limit stops, or other similar devices. Each type has serious limitations or they fail.
- Do not allow anyone standing on the ground to touch the load, crane, or the crane hook until the signalman indicates that it is safe to do so.
- Avoid using taglines except when it is possible for the load to spin into the power line or within the radial limit. *Do not use a wet or damp rope for a tagline.*

  Note: Although all ropes will conduct electricity, dry polypropylene provides better insulating properties than most commercially available rope.
- Slow down the operating cycle of the machine by reducing hoisting, booming, swinging, and travel speeds.
- Exercise caution when working near overhead lines having long spans as they tend to swing laterally in the wind.
- Exercise caution when traveling the crane because uneven ground can cause the boom to weave or bob into the lines.
- The operator must not leave the crane if the boom, when lowered, can enter the radial limits shown above.
- In the event that a crane contacts energized electrical lines, ***do not panic!*** Stay in the cab. Instruct all other personnel to stay away from the crane, ropes, and load and to seek assistance from the electrical authorities. The ground around the crane will be "hot." Try to separate the crane from the electrical wire by at least 20 ft. If the line and crane or ropes appear to be welded to the electrical line, do not move the crane. If it is absolutely urgent to get off the crane, operators must jump away from the crane as far as possible, then shuffle away from the crane a substantial distance without lifting their feet off the ground.
- Every incident involving contact with a live line must be reported to the proper electrical authority and safety inspector so that inspections and repairs can be made to prevent any damaged power line from falling at a later date.
- The crane must be thoroughly inspected for possible damage caused by the electrical contact. Wire rope must be replaced if it touched an electrical line since the arc is usually of sufficient power to either weld, melt, or badly pit the rope.

Table 1. Electrical Line Radial Limits

Voltage (kV)	Clearance (ft)
Up to 50	10
50 to 200	15
200 to 350	20

1.1.3 Maintenance

A log book in which the miles traveled and the total crane operating time is recorded for each separate operation shall be maintained within the carrier cab of the mobile crane. Also, the mileage and date serviced must be recorded in the log book, which must be available for audit by DOE and SNL Safety Engineers.

The carrier vehicle and crane should be maintained in accordance with the crane manufacturer's service manual. The service requirements may depend on the data recorded in the log book, which is to be kept up to date in the crane or carrier cab.

Before adjustments and repairs are started on any mobile crane, the following precautions shall be taken as applicable:

- The crane shall be placed where it will cause the least interference with other equipment, personnel, or operations in the area.
- The boom shall be lowered to the ground or placed on cribbing, or otherwise be secured against dropping.
- The load block shall be lowered to the ground or otherwise secured against dropping.
- All controls shall be in the *Off* position, and all operating features shall be secured from inadvertent motion by brakes, pawls, or other means.
- The power plant shall be stopped or disconnected at the power takeoff.
- The starting means shall be rendered inoperative.
- The hydraulic oil pressure from all hydraulic systems shall be relieved before loosening or removing hydraulic components.

Warning or *Out of Order* signs shall be placed on crane controls during the down time. The signs shall be removed only by the individual who placed them on the controls.

After service or repairs have been completed, the crane shall not be returned to service until all guards have been replaced, trapped air removed from the hydraulic system, safety devices reactivated, tools and service equipment removed, and the *Warning* or *Out of Service* signs removed.

1.2 Overhead Bridge Cranes

Refer to ANSI B30.2 or ANSI B30.17.

Certain operational functions and safety precautions apply to all cranes, especially to mobile and to overhead cranes and hoists. Refer to the Mobile Crane section above and apply any function to overhead cranes that may be pertinent but is not included in this section.

The overhead crane—also known as a "bridge" crane—is a wheeled, four-point, supported crane structure containing one or more trolleys and hoists. The bridge spans the distance between the supporting rails and travels forward and in reverse, and parallel to the rails that normally are supported by building members or columns. Overhead cranes are controlled by a cab-mounted operator, an operator using the pendant, or by an operator using a radio-controlled system.

1.2.1 Inspection

Inspections shall be made by the authorized operator in accordance with the manufacturer's recommendations and the requirements listed below.

The inspection of overhead cranes is divided into two general classifications: *Frequent* Inspections and *Periodic* Inspections.

Frequent Inspections

Frequent Inspection means that the crane is inspected before each daily use. The items that should be inspected are

1. All functionally operating mechanisms for maladjustments that interfere with proper operation
2. All limit switches, without a load on the hook, at the beginning of each work shift
3. Leakage in lines, tanks, valves, pumps, and other parts of air or hydraulic systems
4. Deformed or cracked hooks
5. Hoist ropes (refer to Section 3.1).

See Appendix C for the Field Inspection Check Sheet, Overhead Bridge Cranes.

Periodic Inspections

Cranes shall be load tested biennially, when the wire rope cables are replaced, or if the hoisting system is repaired or changed. Test loads shall not exceed 125% of the rated load.

Care shall be taken during the loading, hoisting, and maneuvering of the test load in order to provide a safe environment for employees within the test area.

1.2.2 Operations

Overhead or bridge cranes shall be operated only by personnel trained and authorized to operate the equipment. This not only includes the operators but also the maintenance and test personnel and inspectors if they operate cranes to perform their duties.

Operators of overhead cranes shall have the same physical qualifications required for mobile crane operators listed in Section 1, Cranes.

The operator should make sure that there is plenty of clearance for movement of the load, that the intended transit path is clear of personnel, and that the destination site is ready to receive the load.

Note: Refer to Section 3, Rigging, for information on slings, fastenings, and the proper rigging procedures. Ensure that the rigging is correct and the load is rigged properly before any load is raised.

The hook must be positioned directly over the load's center of gravity. See Section 3.5.2 to determine the location of the CG if it is unknown.

A crane or trolley shall never be used to move a load sideways or endways by pulling it to a position under the hook.

After the rigging is attached to the hook, the operator should apply slight tension to the load with the hoist controls. The lifting ring or slings must be seated in the bottom of the hook. Raise the load slightly and make sure the hoist brake holds.

Whenever the load is lowered sufficiently to make the ropes slack, the operator should check before raising the load again to be sure that the load cable is reeved properly on the power drum and that the rigging is secure.

A sufficient number of taglines should be used so that control of the load being moved is maintained. A minimum of two taglines should be used on loads that are horizontally long and slender, large and bulky, or on any item that needs a restrictive rotational momentum.

Lift the load slowly to prevent cables, chains, and slings from being shock-loaded. Sudden starts, stops, or reverses must be avoided.

Raise the load only high enough to clear obstructions.

Do not move any load over individuals.

The moving crane operation demands complete attention. The operators, tagline handlers, signalers, etc., must give their full attention during the crane operation.

Operators of radio-controlled cranes shall activate the crane's radio signals only when the crane can be completely observed or when another person is giving signals. *Watch the crane or signaler until the crane is completely stopped. Never let the bridge bumpers act as the brake.*

Refer to Signaling (Section 3.5.6) and to Chart B—Overhead Bridge Crane and Hoist Hand Signals—following the appendixes. These signals are the same for all the cranes and hoists discussed in the following sections.

Never leave a load suspended. If a delay occurs, move the load to the nearest free area and set it down on the floor or ground.

Be alert for any variations of the crane/trolley/hoist functions during the running operations, such as cables out of the drum guides, cables slipping, jerky cable movements, travel problems, unusual noises, etc.

If any malfunction or unusual occurrence is evident, secure the load, leave the hook and rigging attached but slack, tape a *Warning*, *Out of Service*, or *Do Not Operate* sign with the operator's name on the pendant, and call Plant Maintenance for service.

When the crane/hoist is no longer required, raise the hook to a position near the supporting structure, "park" it in a location that will prevent it from interfering with other shop or lab activities, and secure the pendant or other controls out of the way of personnel.

1.2.3 Maintenance

A preventive maintenance program should be based on the crane manufacturer's recommendations. Records should be kept readily available for audit; computer records are adequate.

Before adjustments and repairs are made on a crane, the following precautions shall be taken as applicable.

1. The crane to be repaired shall be moved to a location where it will cause the least interference with other cranes and operations in the area.
2. All controllers shall be placed in the *Off* position.
3. The main switch (crane disconnect) shall be de-energized and locked, tagged, or flagged in the de-energized position.

4. Effective markings and barriers shall be used where service work will create a hazardous area on the floor beneath the crane.
5. Only trained personnel shall work on energized equipment when adjustments and tests are required.
6. After adjustments and repairs have been made, the crane shall not be restored to service until all guards have been reinstalled, safety devices reactivated, and service tools and equipment removed.

1.3 Trolley

Refer to ANSI B30.2.

A trolley is a wheeled accessory that supports a hoist. When it is a part of a bridge crane, it travels on the bridge laterally to the directional movement of the bridge. When it is suspended from a monorail, it travels along the I-beam.

The trolley on an overhead crane or other type of supporting structure will be inspected, serviced, and load tested as a part of that unit.

The bridge shall have stops at the limits of travel of the trolley. Also, the trolley shall be provided with bumpers and rail sweeps with the same conditions applied as those stated for overhead cranes.

The inspection sheets for the trolley and various hoists are

- Field Inspection Check Sheet, Electric or Pneumatic Hoists (Appendix D)
- Field Inspection Check Sheet, Chain Hoists (Appendix E).

1.4 Monorail

Refer to ANSI B30.11.

A monorail is a horizontal structural member, usually an I-beam, that supports a trolley and hoist. A monorail crane can exist in its own entity or be part of an overhead, gantry, jib, or wall crane.

The trolley and hoist on a monorail crane shall be inspected, serviced, and load tested in accordance with the appropriate and applicable requirements stated above in Section 1.2, Overhead Bridge Cranes.

The same Field Inspection Check Sheets referred to in Section 1.3 apply to monorail cranes.

1.5 Gantry Cranes

Refer to ANSI B30.2 and ANSI B30.17.

A gantry crane is a structure consisting of two A-frames or vertical support members that connect the monorail, trolley, and hoist. A gantry crane may be stationary or it may be mobile by having wheeled castors or by being on wheels and rails. The monorail of the gantry or portal crane can be extended outside the vertical support members. This configuration allows the hoist to travel outside the rails, which increases the work area of the crane. Another crane of this type is called a semigantry crane, which appears to be a combination of a bridge crane and a gantry crane. The bridge portion runs on a rail supported by the steel framework of the building; the gantry portion runs on rail supported by the ground or floor of the building.

The trolley and hoist on a gantry crane should be inspected, serviced, and load tested in accordance with the appropriate and applicable requirements stated above in Overhead Bridge Cranes (Section 1.2).

The same Field Inspection Check Sheets referred to in Section 1.3 apply to gantry cranes.

1.6 Jib Cranes

Refer to ANSI B30.11.

A jib crane is a structure consisting of a monorail, trolley, and hoist that rotates around, and is supported by, a vertical stationary monolith. A guy wire or steel rod is attached to the column above the swivel and to the free end of the monorail. This tension member usually contains a turnbuckle used to level the monorail.

The trolley and hoist on a jib crane should be inspected, serviced, and load tested in accordance with the appropriate and applicable requirements Section 1.2, Overhead Bridge Cranes.

The same Field Inspection Check Sheets referred to in Section 1.3 apply to jib cranes.

1.7 Wall Cranes

Refer to ANSI B30.2.

Depending on the source of definition, the "wall" crane has two different configurations. The stationary type of wall crane consists of a hoist and trolley mounted on a horizontal I-beam that rotates on a bearing plate affixed to a building structure. The free end of the I-beam is supported by a steel rod or guy wire attached to the same structure several feet above the bearing plate.

The mobile type of wall crane is a semi-jib crane mounted on two rails, one above the other in a vertical plane, which are attached to the building structure. The wall crane can move along the wall much like the bridge crane.

A wall crane may be used inside or outside depending upon the need and the structural facilities available.

The trolley and hoist on a wall crane should be inspected, serviced, and load tested in accordance with the appropriate and applicable requirements in Section 1.2, Overhead Bridge Cranes.

The same Field Inspection Check Sheets referred to in Section 1.3 apply to wall cranes.

1.8 Tower Cranes

A tower or hammerhead crane consists of a structural monolith, a horizontal monorail or jib, and a hoisting system. The jib is attached to the top of the monolith and carries the trolley, hoist, and counterweight. Tower cranes are either of fixed (stationary tower) or slewing (tower rotates) configuration.

Slewing means "to turn, as a ship's spar, about a fixed point." The slewing ring can be located at the top or at the bottom of the vertical monolith or tower section. Tower cranes can also be classified as mono, inner and outer, and telescopic. The main types of jibs used on tower cranes are saddle, luffing, fixed, and rear-pivoted luffing. Saddle jibs are supported by pendants in a horizontal or near-horizontal position and the load hook is suspended from a trolley that moves along the jib to alter the hook radius. Luffing jibs are pivoted at the jib foot and are supported by luffing cables much like the boom on mobile cranes. The jib can be raised or lowered. Fixed-luffing jibs are also mounted on pivots at the jib foot but, unlike the luffing jibs, they are held by jib pendants at a fixed angle. Tower cranes are either self-erecting (climbing crane) or are erected by using mobile cranes. Tower cranes may also be crawler-mounted, truck-mounted, trailer-mounted, or rail-mounted.

With the exception of the luffing, slewing, and fixed jib configurations, all tower cranes have a counterweight, on the end of the monolith that is opposite the end that carries the trolley. Instead of having a counterweight, the luffing, slewing, and fixed jib configurations are counter-supported with a system of wire rope and pulleys attached to the top rear of the monolith and at the top of the base slewing ring. These three cranes have the slewing ring at the bottom of the monolith, and the entire unit rotates.

Pillar and portal cranes are similar to tower cranes in that they have booms, pendants, gantrys, etc. The pillar crane is a fixed crane consisting of a vertical member held in position at the base to resist an overturning moment, normally with a constant-radius revolving boom supported at the outer end by a tension member.

The portal crane consists of a rotating superstructure with operating machinery and boom, all mounted on a gantry. The crane and gantry assembly may be fixed or mobile. An opening for traffic is normally provided between the gantry legs or columns.

SNLA has no tower, portal, or pillar cranes, but should the need to know about these cranes ever arise, refer to the following standards:

ANSI B30.3—Hammerhead Tower Cranes
ANSI B30.4—Portal, Tower, and Pillar Cranes

1.9 Polar Cranes

A polar crane is similar to a bridge crane except that instead of traveling on linear tracks, it travels on a circular track. This type of crane is used in round structures, such as the gate houses at Hoover Dam and nuclear reactor cells. Polar cranes, like all cranes in reactor areas, are subject to the inspection and testing requirements of the *Reactor Development Technology Standard*, RDT F 8-6T, January 1980 or later issue. This document was issued by the Office of Nuclear Energy Programs, U.S. Department of Energy.

1.10 Skyhook Cranes

In the event any SNLA organization is ever involved with material handling by helicopter, refer to

ANSI B30.12—Handling Loads Suspended from Rotorcraft

All cranes can be hazardous, but the most dangerous are the mobile and tower cranes.

2. Hoists

Of Cranes, Hoists, and Rigging, the most important is . . .

A hoist is defined as "an apparatus for hoisting." Hoist (vb) means "to raise into position by or as if by means of tackle." Tackle is defined as "a ship's rigging, or an assemblage of ropes and pulleys arranged to gain mechanical advantage for hoisting and pulling."

- Hoist operators must be trained and authorized before operating any type of hoisting equipment
- Hoist operators shall meet the physical qualification requirements referred to in the Introduction.

There are three basic types of hoists: electric, pneumatic, and hand-operated. Hydraulic hoists are used to operate lifts, jacks, elevators, etc.

The safe operation of an overhead hoist involves more than pulling the hand chain of a chain-operated hoist or depressing the *Up* or *Down* buttons on a pendant of a powered hoist. Emphasis is placed on the fact that the use of overhead hoists is subject to certain hazards that cannot be met by mechanical means, but only by the exercise of intelligence, care, common sense, training, and experience in anticipating the motions that will occur as a result of operating the controls.

Before operating a hoist, the operator

- Shall become familiar with all operating controls of the hoist, the warnings on the hoist, safe hoisting practices, and the operator's portion of the manual provided by the hoist manufacturer
- Shall report promptly to the supervisor any repairs or adjustments that are necessary or any defects that are known
- Shall not operate a hoist that bears an *Out of Order* sign or a "red tag"
- Shall not adjust or repair a hoist unless qualified to perform maintenance on it
- Shall not use the chain or wire rope as a ground for welding
- Shall not touch the chain or wire rope with a welding electrode.

Before raising the load, the operator shall be assured of the following:

- The hoist rope or chain shall not be wrapped around the load.
- The load shall be attached to the load hook by suitable rigging (see Section 3, Rigging, for the proper way to rig loads).
- The sling or other device shall be properly seated in the saddle of the hook. The hook latch shall not be allowed to support any part of the load.
- The load shall not be applied to the tip of the hook.
- The chains or wire rope shall not be kinked or twisted or the multiple-part chains of wire ropes shall not be twisted about each other.
- The hoist hook shall be centered over the CG of the load.
- The load shall not be heavier than the rated load marked on the hoist or load block (except during authorized load tests).
- A load-limiting device shall not be used to measure the maximum load to be raised.
- Specific attention shall be given to the rigging and balancing of the load to prevent slipping or dropping of the load (see Section 3, Rigging).

When moving the load, the operator

- Shall not engage in any activity that will divert attention while operating the hoist (other associated personnel or casuals shall not engage in any activity that will divert attention from the safe operation of the loaded hoist)
- Shall respond to signals from only one designated and qualified person, except for STOP signals (see Chart B for the standard hoist hand signals)
- Shall not raise or lower a load with the hoist until all personnel are clear of the load
- Shall make sure that the transit path is clear of all obstacles before moving the load

- Shall not leave a suspended load unattended
- Shall not transport loads over people
- Shall not carry persons on the hook or on the load
- Shall avoid swinging a load or load hook when traveling the hoist
- Shall move powered hoists slowly into engagement with a load and shall avoid shock-loading
- Shall not use quick reversals of direction to stop the motion of trolleys or cranes
- Shall not raise a load more than a few inches before determining if it is well balanced, stable, and the brake holds
- On wire rope hoists, shall not lower the load below the point where less than two wraps of rope remain on each anchorage of the hoist drum
- Shall avoid contact between trolleys or between trolley and rail stops on trolley-mounted hoists
- Shall not use standard limit devices as a normal means of stopping the hoist; these devices are for emergency use only.

When parking the load, the operator

- Shall lower the load slowly and carefully, ensuring that it shall not bind the rigging or prevent its removal from the load after it is positioned
- Shall exercise care when removing a sling from under a positioned load
- Shall leave the load block hook above head level when the hoist is not in use.

Inspections shall be made by the authorized operator before every hoisting job.

Refer to ANSI B30.7 and B30.16 for details not covered in this manual.

2.1 Electric Hoists

An electric hoist is usually operated by push-button controls on a pendant or by pull ropes that control the up or down movement of the load. The electric hoist is the basic mechanical power unit used to raise or lower loads that are handled by overhead, monorail, gantry, and jib cranes. The hoist system on a mobile crane consists of the power drum, sheaves, blocks or pulleys, and the wire rope cable. The hoist on overhead cranes is very similar to that on mobile cranes in that drums, cable, sheaves, and load blocks are used. The hoists used on gantry, jib, wall, monorail, etc., are usually smaller systems than those used on overhead cranes and consist of an integral motor and drum arrangement with a chain or wire rope cable and a load block.

2.1.1 Inspection

Frequent Inspection means that the hoist is inspected by the operator before every job. The items that should be inspected are as follows:

1. All functional operating mechanisms for maladjustment and interference with proper operation
2. All limit devices without a load on the hook (see Section 2.1.3.1, Operational Tests)
3. Leakage in lines, valves, and other parts of air systems
4. Hooks in accordance with Section 3.4.1
5. Hoist rope in accordance with Section 3.1
6. Rope or load chain reeving for compliance with the hoist manufacturer's recommendations.

If any of these items are questionable, call the Plant Engineering Operations Field Inspector. Call Maintenance for items that need to be serviced

See Appendix D for the Field Inspection Check Sheet, Electric or Pneumatic Hoists.

2.1.2 Operations

- Before initial daily use, the operator must perform the Frequent Inspections listed in Section 2.1.1.
- The weight of the load or "pick" must be known by the operator and should not exceed the rated load limit marked on the hoist. Refer to Section 3.5.1 to determine the weight of a load if it is unknown.
- For information on the proper methods to rig the load for pickup by the hoist, refer to Section 3, Rigging.
- Do not operate hoist with twisted, kinked, or damaged rope.
- Do not operate a damaged or malfunctioning hoist.
- Do not lift people or lift loads over people.
- Do not operate wire rope hoist if the rope is not properly seated in the grooves on the drum.

- Do not remove or obscure warning labels.
- When the load is ready to move, operate the hoist slowly and carefully to determine if the rigging is satisfactory, if the weight is within the proper limits, if the hook is located over the center of gravity (CG), and if the brake holds the load. See Section 3.5.2.
- When the hoist is not being used, the hook should be raised and the hoist "parked" out of the way of personnel.

2.1.3 Testing

2.1.3.1 Operational Tests

Hoists shall be tested operationally by raising and lowering the load block or hook; the operation of the brakes shall be tested, and the trip-setting of limit devices shall be determined by test under no-load conditions. Actuating mechanisms shall be located so that they will trip the limiting devices in sufficient time to stop motion without damage to any part of the hoisting mechanism.

2.1.3.2 Load Testing

If a hoist was not load tested by the manufacturer, it shall be tested with a load of a least 125% of the load rating before being placed in operation.

Hoists shall be load tested every other year in the same manner described above for overhead cranes.

2.1.4 Maintenance

Electrical hoisting equipment and any associated auxiliary electrical equipment shall be serviced according to the manufacturer's service manual and the following requirements:

- The Preventive Maintenance Program shall be based on the hoist manufacturer's recommendations.
- Replacement parts shall be at least equal to the original manufacturer's specifications.
- The service technician shall review the Field Inspection Check Sheets before servicing the hoist.

Before adjustments and repairs are made, the following precautions should be taken, as applicable:

- The main or emergency switch on the line feeding the hoist shall be locked in the *Open* position, except as necessary to perform the required electrical service.
- Where service work creates a hazardous area on the floor beneath the hoist, effective markings and barricades shall be used.
- After adjustments and repairs have been made, the hoist shall not be returned to service until all guards have been replaced, safety devices reactivated, tools and service equipment removed, and *Warning* or *Out of Service* signs removed.

2.2 Pneumatic Hoists

2.2.1 Inspection

Inspections are the same as those required for electric hoists in Section 2.1.1.

See Appendix D for the Field Inspection Check Sheet, Electric or Pneumatic Hoists.

2.2.2 Operations

Operational requirements for pneumatic hoists are the same as those given in Section 2.1.2 for electric hoists.

2.2.3 Testing

All testing, including load testing, is the same as required for electric hoists (Section 2.1.3).

2.2.4 Maintenance

Pneumatic hoisting equipment and any associated auxiliary equipment shall be serviced according to the manufacturer's service manual and the following requirements:

- The Preventive Maintenance Program shall be based on the hoist manufacturer's recommendations.
- Replacement parts shall be at least equal to the original manufacturer's specifications.
- The service technician shall review the Field Inspection Check Sheets before servicing the hoist.
- The valve on the airline feeding the hoist shall be turned off, except as required to perform required service.

2.3 Chain Hoists

A chain hoist is powered by the operator pulling on a chain that raises or lowers the hook depending on the part of chain that is pulled. The load may be supported by chain or wire rope.

2.3.1 Inspection

See Section 2.3, Chain Hoists, for information on inspection and the care and use of chains.

The inspection criteria for chain hoists are the same as those specified for electric hoists given in Section 2.1.1.

See Appendix E for the Field Inspection Check Sheet, Chain Hoists.

2.3.2 Operations

Chain hoists shall be operated only by hand power, with no more than one operator per hand chain.

The operational criteria for chain hoists are the same as those specified for electric hoists given in Section 2.1.2.

2.3.3 Testing

All testing, including load testing, is the same as that required for electric hoists (Section 2.1.3).

2.3.4 Maintenance

Hand-powered hoisting equipment and any associated auxiliary equipment shall be serviced according to the manufacturer's service manual and the following requirements:

- The Preventive Maintenance Program shall be based on the hoist manufacturer's recommendations.
- The service technician shall review the Field Inspection Check Sheets before servicing the hoist.
- Replacement parts shall be at least equal to the original manufacturer's specifications.

2.4 Base-Mounted Drum Hoists

Refer to ANSI B30.7.

Drum-mounted hoists, winches, and windlasses perform the same basic function. A winch, by definition, is "a powerful machine with one or more drums on which to coil a rope, cable, or chain for hauling or hoisting." A winch is usually hand-powered, but can also be powered electrically. A windlass is defined as "a steam or electric winch with horizontal or vertical shaft and two drums used to raise a ship's anchor." A base-mounted drum hoist consists of a base, power unit, drums, and a cable or chain and is mounted on a foundation or other supporting structure. It is used primarily to raise or lower loads, or to pull loads or apply tension to wire rope cables that are used for functions other than hoisting.

Base-mounted drum (BMD) hoists are used at the cable sites and on test towers. A hand-powered winch is also used at the New Cable Site. It is possible that sometime in the future some aquatic program may require the use of a windlass near the West Test Tower.

2.4.1 Inspection

Two general classifications of inspections are designated: *Frequent* and *Periodic*. These inspections are similar to those mentioned in Section 1.1.1 for Cranes and in Section 2.1.1 for Hoists. In addition, the items listed below shall be inspected.

Frequent Inspection

Frequent Inspection means that the hoist is inspected before every job. Items that should be inspected frequently are

1. All control mechanisms for maladjustments or excessive wear that interfere with proper operation
2. All limit switches or limiting devices for malfunctions at the beginning of each work shift
3. Air or hydraulic systems for deterioration or leakage
4. Load-carrying wire ropes for excessive wear and distortion (see Section 3.1.2 for inspection criteria for wire ropes)
5. Electrical apparatus for malfunctions, signs of excessive deterioration, and dirt and moisture accumulation
6. The diameter of the drum flange, which shall extend a minimum of 1/2 in. beyond the top layer of rope at all times.

See Appendix F for the Field Inspection Check Sheet, Base-Mounted Drum Hoists.

2.4.2 Operations

Operators of base-mounted drum hoists must meet the training and physical qualifications listed in the Introduction.

2.4.2.1 Operational Tests

New and altered hoists shall be tested to ensure compliance with the following.

- Raising and lowering shall be done by each drum.
- Clutches, brakes, and pawls shall be operated.
- Limit switches and locking and safety devices shall be operated.

Trip-setting limit switches and limiting devices shall be determined by tests under no-load conditions. Tests shall be conducted first under slow speed and then with increasing speeds up to maximum speed. Actuating mechanisms shall be located so that they will trip the switches or limiting devices in time to stop motion without damage to any part of the hoisting equipment.

Operators shall not engage in any practice that might divert attention while actually engaged in operating the BMD hoist.

Operators shall be familiar with the equipment and its proper care. They shall test all controls at the start of a new shift, and if adjustments or repairs are necessary they shall report the same promptly to the supervisor or request service from Maintenance.

The operator shall respond to signals from only one qualified person during hoisting operations. See Chart C (following the appendixes) for the proper hand signals.

Whenever there is doubt as to safety, the operator shall stop the operations, secure the load, and consult with the supervisor.

Before leaving the hoist unattended, the operator shall

1. Secure the load
2. Disengage the clutches
3. Place the handles of controls in the *Off* position
4. Open the main switch or stop the engine
5. Engage the manual locking devices in the absence of automatic holding equipment.

If there is a *Warning* sign on the switch or engine starting controls, the BMD hoist operator shall not close the switch or start the operations until the sign has been removed by the individual who "red-tagged" the hoist.

If a power failure occurs during operations, the hoist operator shall

1. Set all brakes or locking levers
2. Move all clutch or other power controls to the *Off* or *Neutral* positions
3. Park the suspended load under brake control, if possible.

2.4.2.2 Handling the Load

No hoist shall be loaded beyond the rated load or line pull except during load tests.

If rotation-resistant wire rope is used with a design factor less than 5, but in no case less than 3.5, the following special provisions apply:

1. For each such lifting assignment
   - A qualified person shall direct the lift.
   - A qualified person shall ascertain that the wire rope is in satisfactory condition both before and after lifting (see Section 3.1.2 under Rigging).
   - Operations shall be conducted in such a manner and at such speeds as to minimize dynamic or shock load effects.
2. Each lift under these provisions shall be recorded in the hoist inspection record and such prior uses shall be considered before permitting another lift with the same equipment.
3. Provisions in Section 2.4.2.1 are not intended to permit duty cycle or repetitive lifts to be made with an operating design factor less than 5.

2.4.2.3 Moving the Load

- Care must be taken to ensure that the hoist cables are not kinked or twisted.
- Care must be taken to prevent sudden acceleration or deceleration of the moving load.
- Before moving the load, if there is a slack rope condition, the operator shall determine that the wire rope is properly seated on the drum.
- Each time a load approaches the maximum rated load, the operator shall test the load brakes by raising the load slightly and applying the brakes.
- No BMD hoist power drum shall be rotated in the lowering direction beyond the point where less than two wraps of rope remain on the drum.

- When loads are lowered for long distances, the operator shall check the thermal capacity of the brakes and motors as outlined by ratings or charts provided by the manufacturer for both repetitive and intermittent operation. Where maximum rated loads are being lowered for long distances, power controlled lowering is usually necessary to reduce the demand on the brake. Additional cooling may be required on fluid transmissions or torque converters.

2.4.2.4 Holding the Suspended Load

The operator shall not leave the controls while the load is suspended, unless the precautions stated below are taken:

1. If the load must remain suspended for any considerable length of time, a pawl or other equivalent means, rather than the brake alone, shall be used to hold the load.
2. The operator may leave the controls provided that before leaving another qualified individual shall establish the requirements for "dogging" the hoist.
3. BMD hoists, when holding anchor lines or applying static tension, are not considered to be holding suspended loads. However, before the operator leaves the controls, the operator and a qualified individual shall establish the requirements for braking, "dogging" the hoist, furnishing notices, setting up barricades, and shall take whatever other precautions necessary to provide a safe area.

2.4.3 Testing

If a base-mounted drum hoist was not line-pull tested by the manufacturer, it shall be tested with a load of at least 110% of the load rating before being placed in operation.

BMD hoists shall be line-pull tested at 110% every other year.

BMD hoists that have had load-sustaining parts altered, replaced, or repaired shall be load tested before being returned to operational status.

2.4.4 Maintenance

Base-mounted drum hoists shall be included in the Preventive Maintenance Program. Maintenance shall be based on the manufacturer's recommendations.

2.4.4.1 Maintenance Procedures

Before adjustments and repairs are started on a BMD hoist, the following precautions shall be taken:

- If electrically powered, the main or emergency switch must be locked in the *Open* position.
- If mechanically powered, the power plant must be stopped and disconnected at the takeoff.
- The power plant starting mechanism shall be rendered inoperative.
- The drum pawls must be engaged, or other means provided to prevent load ropes from inadvertently rotating the mechanism.
- *Warning* or *Out of Order* signs or "red tags" shall be placed on the power controls. These signs shall be removed only by the individual who placed them on the equipment at the beginning of the service period.

2.4.4.2 Adjustments and Repairs

- Any hazardous condition disclosed by the Frequent Inspections shall be corrected before the operation of the hoist is resumed.
- Adjustments shall be maintained to ensure correct functioning of components.
- Replacement parts shall be at least equal to the original manufacturer's specifications.

2.4.4.3 Lubrication

Lubricants shall be applied in accordance with the manufacturer's recommendations.

- Lubricating systems should be checked to ensure proper delivery of lubricant.
- All rotating machinery shall be stopped, where feasible, while lubricants are being applied and protection is provided unless the hoist is equipped for automatic or remote lubrication.

After adjustments, repairs, and service have been performed, the hoist shall not be returned to service until all drum pawls have been disengaged, guards installed, limiting devices reactivated, and the service tools, equipment, and warning signs removed from the work site.

3. Rigging

Of Cranes, Hoists, and Rigging, the most important is . . .

Rigging, by definition, is "lines and chains used aboard a ship, especially in working sail and supporting masts and spars." Another important part of craning, it appears, was borrowed from the marine community.

Rigging hardware, defined for use by this manual, includes all crane parts from, and including, the drum to the load. Drums and sheaves were covered in the Crane section. The hook and other hardware used in crane rigging, as well as special design items, will be discussed later (Section 3.4, The Hook and Under).

In construction and industry, *rigging* is the paraphernalia that is hung on the hook and holds the load. This consists of slings (wire rope, wire mesh, chain, or synthetic web), fastenings (clevises, shackles, plate grips, magnetic grips, tongs, rings, links, hooks, swivels, thimbles, clamps, etc.), strong backs, and spreader and equalizer beams. The weight of the rigging and the load block, hook, and cable hanging from the boom tip sheave must be added to the weight of the load, especially when the operation concerns a critical or a close-to-rated load-limit "pick." If a jib is attached to the boom but is not being used, its weight must also be included in the pick.

For additional or more comprehensive information refer to the *Rigging Manual*, the appropriate ANSI Standard, or other documents listed in the References section, including the Hoisting and Rigging Equipment section in the SNL *Safety Manual.*

3.1 Wire Ropes

One of the definitions of *machine* is "an assemblage of parts that transmit forces, motion, and energy onto another in a predetermined manner." A wire rope is an assemblage of parts. It transmits force (tension); it transmits motion (as in a hoisting condition); and it transmits energy (the energy of the power plant). It does so in a predetermined manner (as it is reeved). It also stores resilient energy. A wire rope cable in high tension contains a tremendous amount of energy. A wire rope is indeed a *machine.*

Wire rope consists of three basic parts: the *wire*, several of which make up a *strand*, and several strands, in turn, are wrapped around a *core*. The strand also contains a core called the "center." These parts move in relation to one another as the rope twists, coils, and turns. Another important element of wire rope is the lay length. A rope's "lay length" or "rope lay" is the linear distance necessary for one strand to revolve around the core.

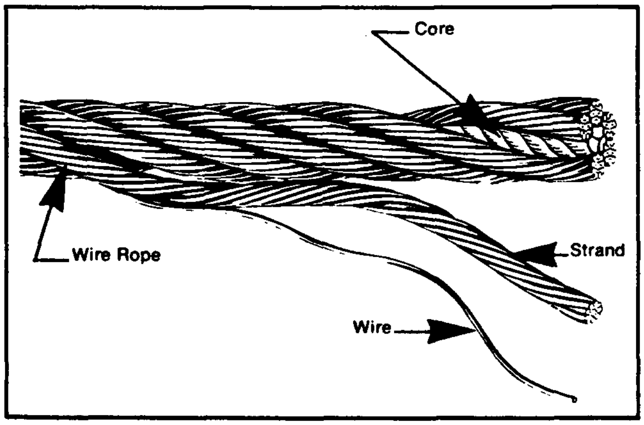


Figure 3. Elements of Wire Rope[2]

Other important features of wire ropes are "Lang Lay" and "Regular Lay," and "right lay," "left lay," or "alternate lay." In Lang Lay ropes, the wires in the strands and strands in the ropes are laid in the same direction. In Regular Lay ropes, the strand wires are laid in one direction and the strands in the rope are laid in the opposite direction.

A right-lay Regular Lay wire rope is one in which the individual wires in the strand rotate to the left about the center of the strand while the strands rotate to the right about the core, similar to a conventional screw thread. This wire rope configuration, unless otherwise stated, is understood to be the "standard" wire rope.

A left-lay Regular Lay wire rope is just the opposite. Its strands rotate to the left about the core while the wires in the strands rotate to the right about the strand's center.

A right-lay Lang Lay wire rope consists of strands that rotate to the right about the core while the wires in the strand also rotate to the right about the strand's center.

A left-lay Lang Lay wire rope contains strands that rotate to the left about the core while the wires in the strand also rotate to the left about the strand's center.

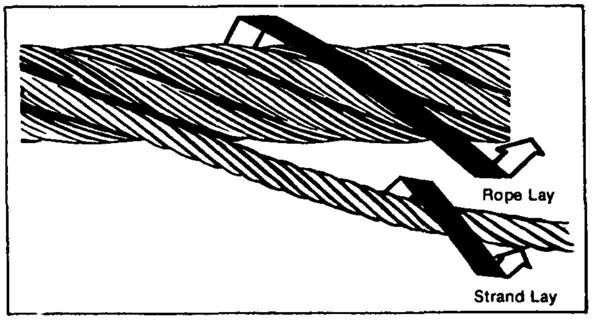
Lang Lay wire rope should not be used on overhead cranes, single-part hoist lines, or with swivel-end terminals.

An alternate-lay wire rope contains three right-lay and three left-lay strands of either Regular Lay or Lang Lay construction. The right- and left-lay strands alternate about the core.

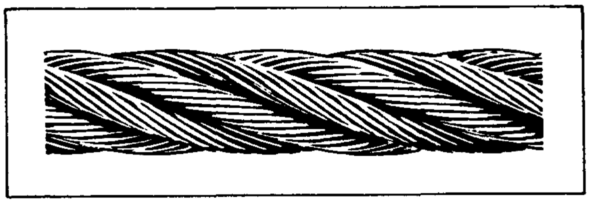
Another wire rope configuration is the Herringbone or Twin-Strand construction. This rope consists of a combination of right-hand and left-hand-laid strands—usually two pairs of the right-hand strands (Lang Lay) and two single left-laid strands (Regular Lay). The two single left-laid strands are separated by the pairs of right-hand strands. This configuration provides some of the stability of a Regular Lay rope while retaining most of the bending characteristics of Lang Lay wire rope.

Most of the wire ropes manufactured and now available are *preformed*, which means that during the manufacturing process the wires and strands are formed in a helical pattern in such a way that they fit into their position in the finished rope. Preforming individual wires removes the tendency of the wires and strands to unravel. Preformed wire ropes

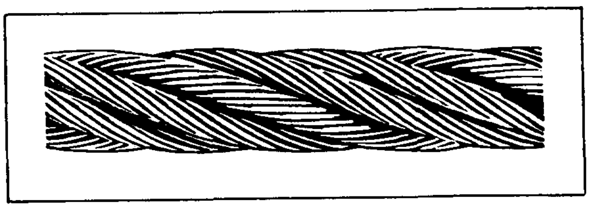
- Have ends that do not untwist
- Can be cut without applying seizings (ends wrapped) before the cutting operation
- Are free from liveliness and twisting tendencies, which make installation and handling easier
- Are less likely to kink or foul
- Have increased resistance to bending fatigue
- Have strands that carry an equal share of the load
- Cause less wear on sheaves and drums
- Have wires, when broken, that lie flat with the broken ends only slightly separated from the strand. For this reason, preformed rope requires very careful inspection.



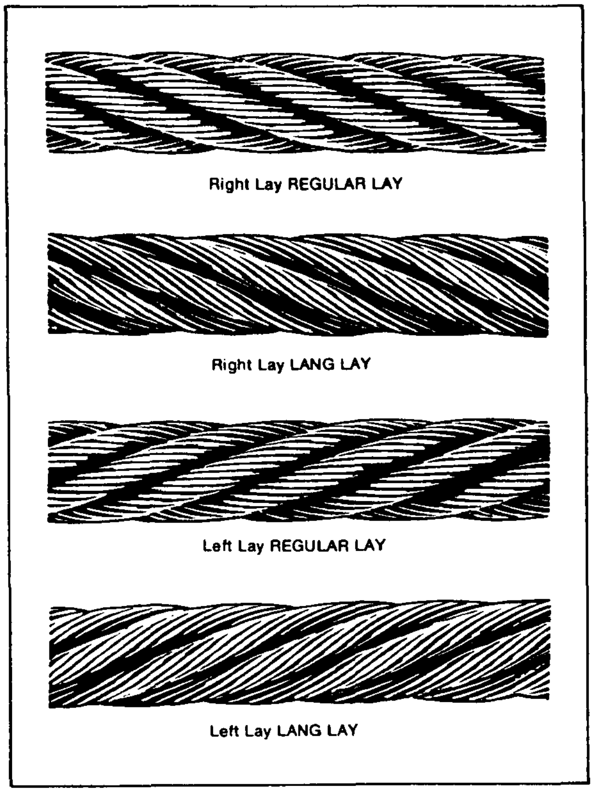
(a) Lang Lay Rope—Wires and Strands Laid in Same Direction



(b) Alternate Lay Rope



(c) Herringbone or Twin Strand



(d) Rope Lay

Figure 4. The Various Lays of Wire Rope[2]

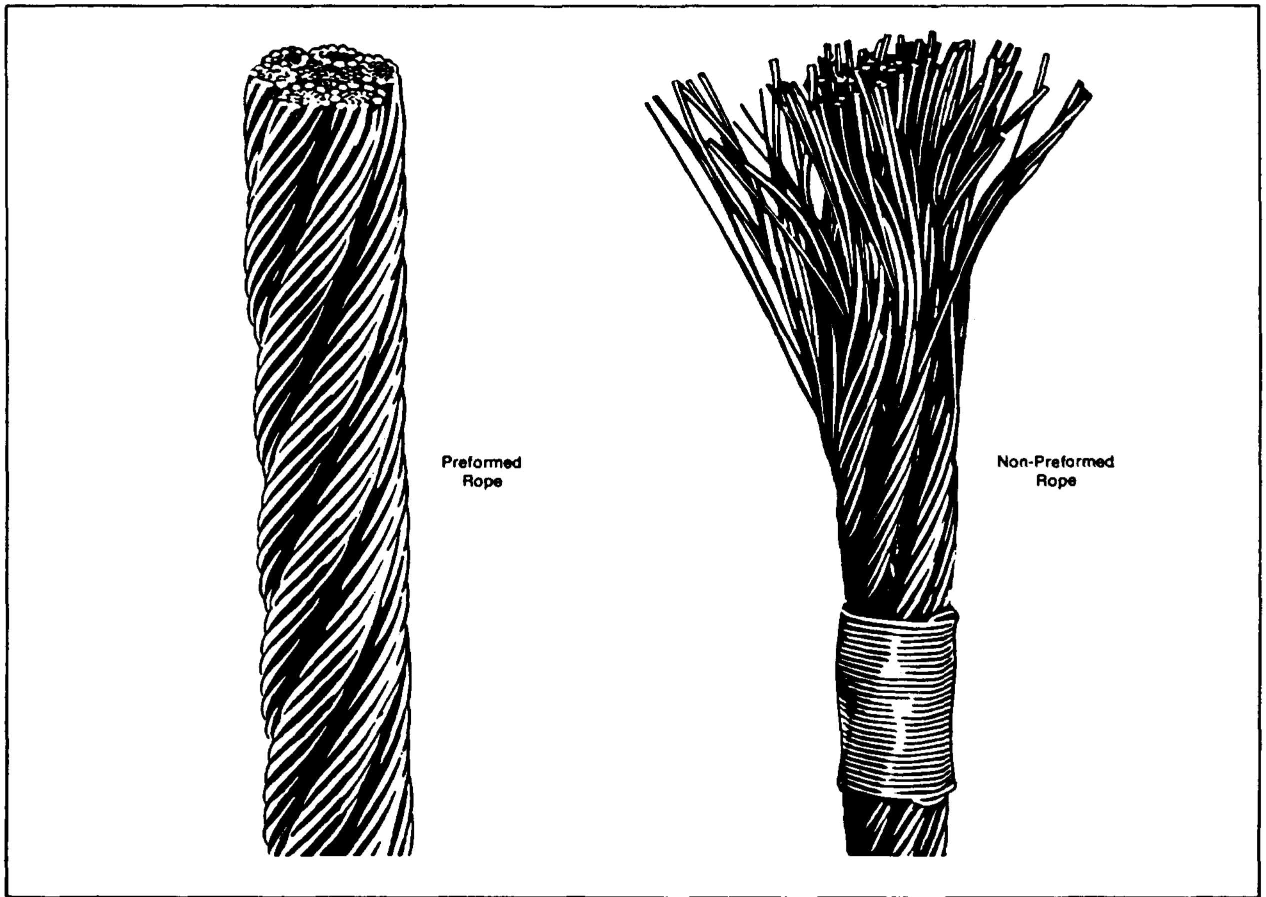


Figure 5. Effect of Preforming on a Wire Rope[2]

Six requirements must be considered when selecting a wire rope for use on a crane or hoist:

1. The rope should possess sufficient strength to take the maximum load that may be applied, with a design factor (factor of safety) of at least 5 to 1, and 10 to 1 when used to carry personnel.
2. The rope should withstand repeated bending without failure of the wires from fatigue.
3. It should resist abrasion.
4. It should withstand distortion and crushing.
5. It should resist rotation.
6. It should resist corrosion.

To elaborate further, wire rope service requirements and design characteristics are

- *Strength.* The wire rope must develop sufficient strength to support the load plus the necessary design factor. The strength of a wire rope depends on its size, construction, type of core, and grade of the rope.
- *Resistance to bending fatigue.* The wire rope must have the ability to bend over small sheaves or wind onto relatively small drums without the wires breaking at too fast a rate because of bending fatigue.

  Strands containing a large number of small wires offer greater resistance to bending fatigue than those containing a few large wires.

  Lang Lay construction provides greater fatigue resistance than Regular Lay construction.

  Preforming increases the wire rope's resistance to bending fatigue.
- *Resistance to abrasion.* The wire rope is subjected to wear from abrasion as it passes through operating sheaves or comes in contact with stationary objects. Large outer wires are better able to withstand abrasive wear than small wires. Lang Lay construction provides greater resistance to wear than Regular Lay construction.

  Refer to Figure 6 for comparison of abrasion and fatigue resistance factors.

- *Resistance to crushing.* Some wire ropes distort or flatten when they are forced to operate under heavy tension in grooves that do not provide ample support or on drums where multiple-lay winding occurs.

  An independent wire rope core (IWRC) provides greater support for strands under heavy bearing pressures and Regular Lay is more resistant to crushing than Lang Lay wire ropes. The coarser wire rope constructions provide greater resistance to flattening on drums.

- *Resistance to rotation.* The wire rope may rotate as the load is applied. This can be undesirable for load control and might lead to rapid deterioration of the wire rope.

  Special rotation-resistant constructions are available for specific applications. Regular Lay provides greater stability than Lang Lay, and wire ropes with an IWRC twist less than those with fiber cores.

- *Resistance to corrosion.* Wire rope may corrode if in contact with corrosive elements, or it may rust when exposed to atmospheric conditions over a long period of time.

  Galvanized or stainless steel wire offers excellent protection against corrosion. Special lubricants can also inhibit the development of rust.

Other factors to be considered when selecting wire rope are

Grades

To meet the demand for varying degrees of strength, toughness, abrasion resistance, and corrosion resistance, wire rope is manufactured in the following grades:

- Grade 120/130 Special Improved Plow Type II (XXIP)—Used for special installations where maximum rope strength is required.
- Grade 115/125 Special Improved Plow Type I (XIP)—Used for special applications where breaking strengths somewhat higher than those obtained with Grade 110/120 are desired and where other conditions such as sheave and drum diameters are favorable for its use.
- Grade 110/120 Improved Plow (IPS)—Has a good combination of tensile strength, wearing qualities, and excellent fatigue-resistant properties. These steels have high strength, are tough, ductile, and highly wear-resistant, and are drawn to 110/120 long tons/in^2 or to 246,000 to 268,000 psi.
- Grade 100/110 Plow—Has lower tensile strength and resistance to wear than Grade 110/120 but retains high fatigue-resistant properties. Can be used where strength is secondary to wear resistance.

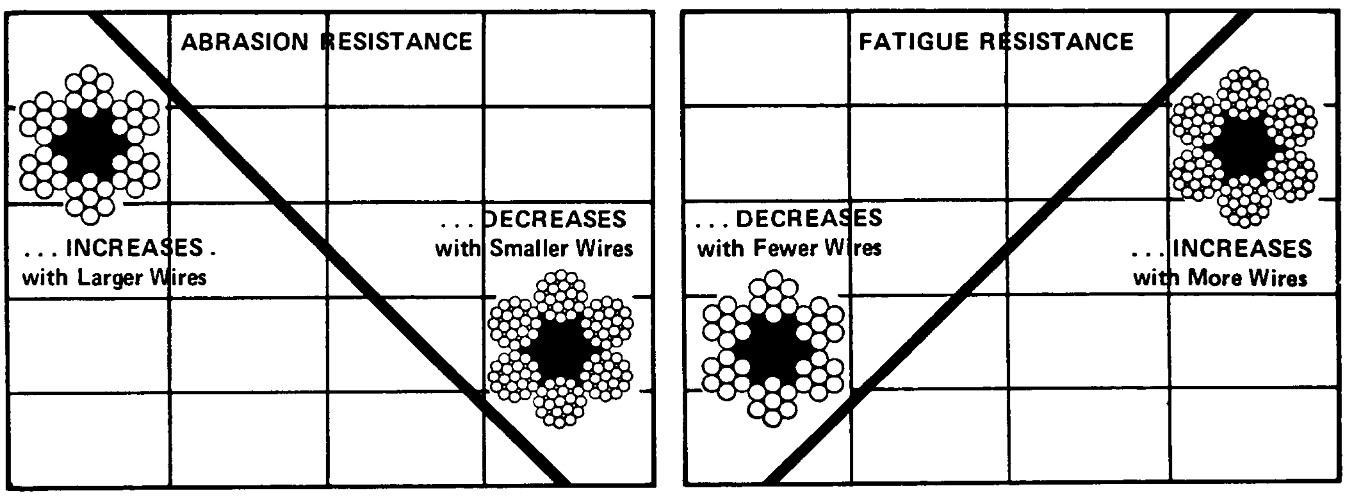


Figure 6. Abrasion and Fatigue Resistance[3]

Strand Classifications

- Round Strand Ropes
- Flattened (Triangular) Strand Ropes
- Locked Coil Ropes
- Concentric Strand Ropes

There are four common configurations of Round Strand Wire Rope:

- *Ordinary*—The wires are all the same size.
- *Seale*—The larger diameter wires are used on the outside of the strand to resist abrasion; the smaller wires are inside to provide flexibility.
- *Warrington*—The alternate wires are large and small to combine great flexibility with resistance to abrasion.
- *Filler Wire*—The very small wires fill in the voids between the outer and inner rows of wires so as to provide good abrasion, crushing, and fatigue resistance.

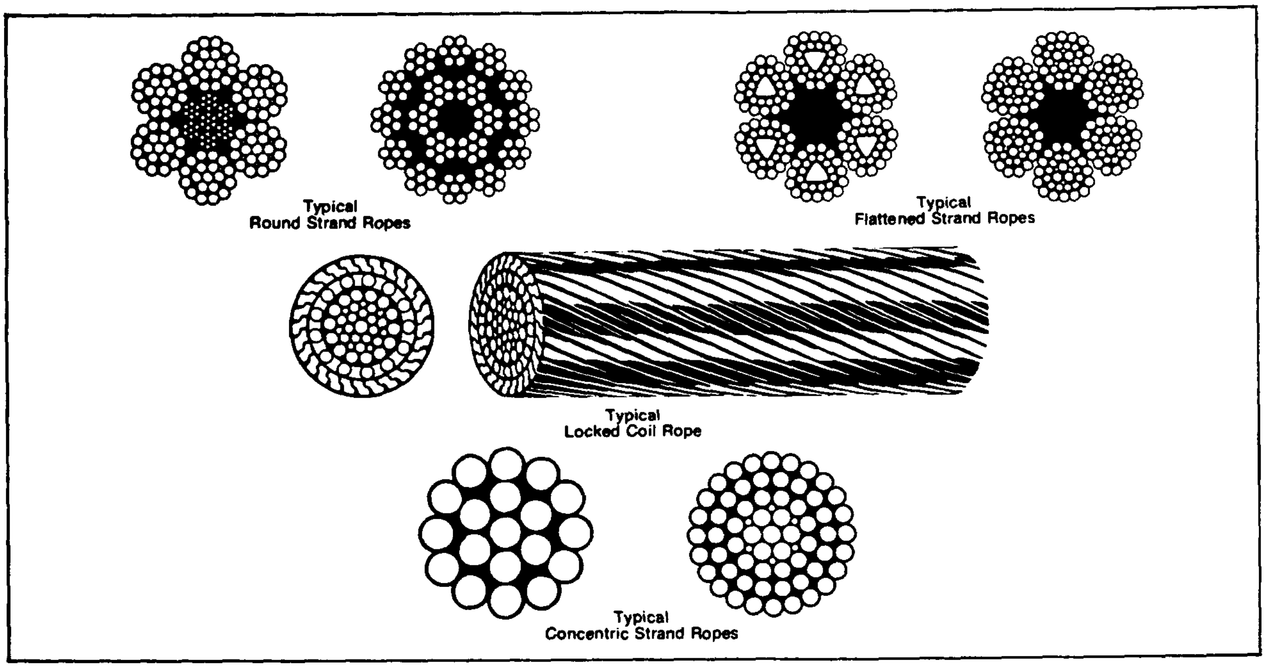


Figure 7. Strand Classification Configurations[2]

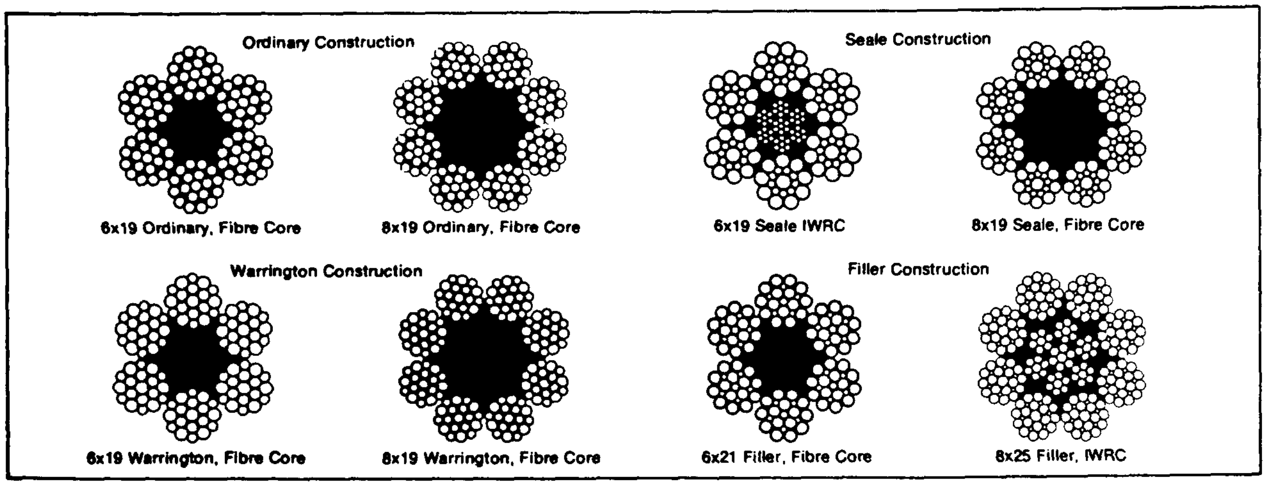


Figure 8. Wire Rope Construction[2]

As the number of wires per strand increases, combinations of Filler Wire, Seale, and Warrington patterns are used to provide certain characteristics. The combination of rope classifications and strand constructions produces varying degrees of resistance to bending fatigue and abrasion. The effect of varying constructions can best be shown by using, as examples, the most commonly used rigging wire ropes:

Basic 19 Class Strands

- *19 Class Seale*—Seale patterns always have the same number of outer and inner wires. The outer wires are fairly large and provide good abrasion resistance.
- *19 Class Warrington*—Outer wires are in two sizes and are alternately supported by the crowns and voids of the inner layer. This type of construction is ideal for small-diameter ropes or for intermediate layers when building large-diameter strands of many wires.
- *25 Class Filler Wire*—Filler wires are used to prevent the outer wires from crowding into the voids between the inner wires. The Filler construction has good abrasion and fatigue-resistance characteristics.

Basic 37 Class Strands

- *31 Class Warrington Seale*—The 19-Wire Warrington strand is enclosed by an outer layer of 12 large-diameter wires resting in the voids between the 12 wires of the inner layer. This construction provides similar abrasion resistance to 25-Wire Filler, but increases flexibility from additional internal wires.
- *41 Class Seale Filler Wire*—The 41-Wire Filler strand comprises a 17-wire inner Seale strand with an outer layer of 16 wires and a layer of 8 filler wires to prevent crowding of the outer wires. This construction is recommended for larger diameter ropes where more flexibility is required.
- *49 Class Seale Filler Wire*—The 49-Wire Filler Seale strand comprises a conventional 33-Wire Filler strand with an outer layer of 16 large-diameter wires resting between the 16 wires of the inner layer. This construction is ideal for large-diameter ropes where the requirement is maximum flexibility.

The 18×7 Rotation-Resistant Construction Round Strand Wire Rope consists of an outer layer of 12 strands laid Right Lay over an inner layer of 6 strands laid Left Lay around a fiber core. All of the strands contain 7 wires.

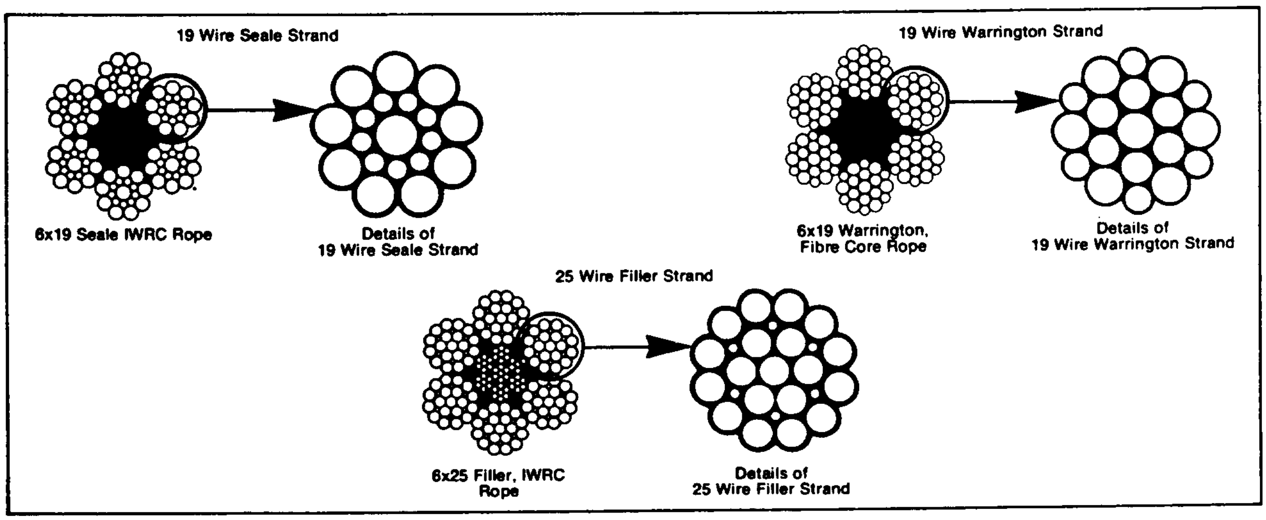


Figure 9. Basic 19 Class Strand Construction[2]

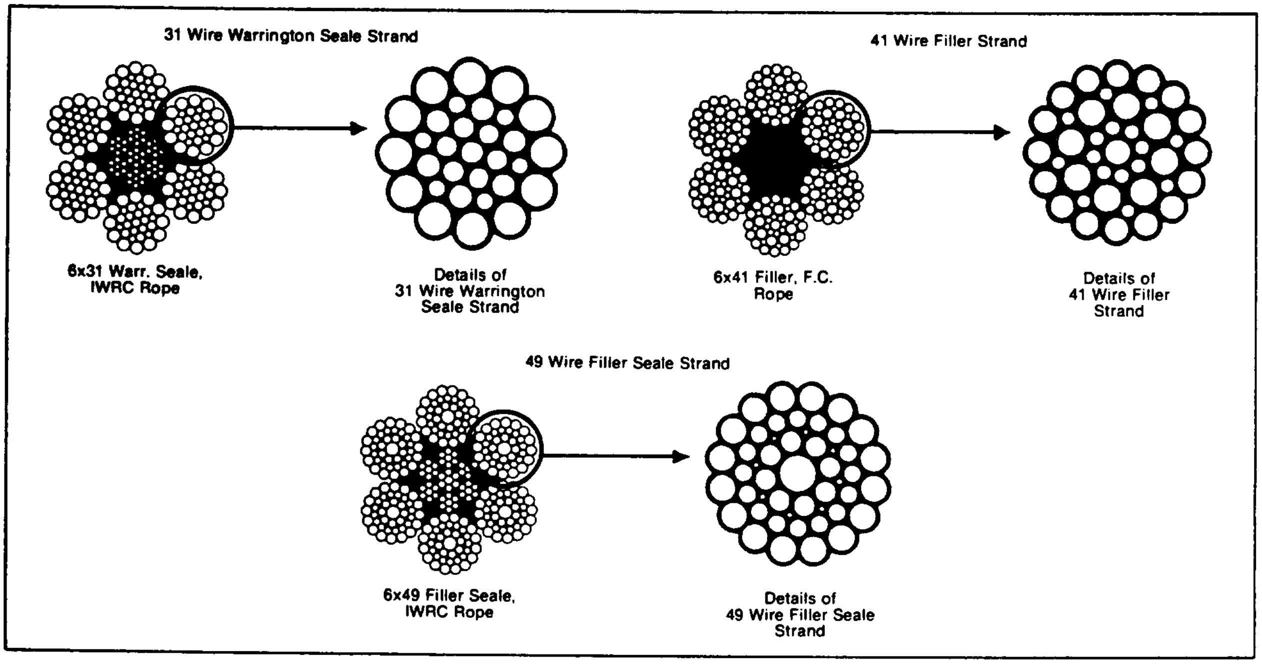


Figure 10. Basic 37 Class Strand Construction[2]

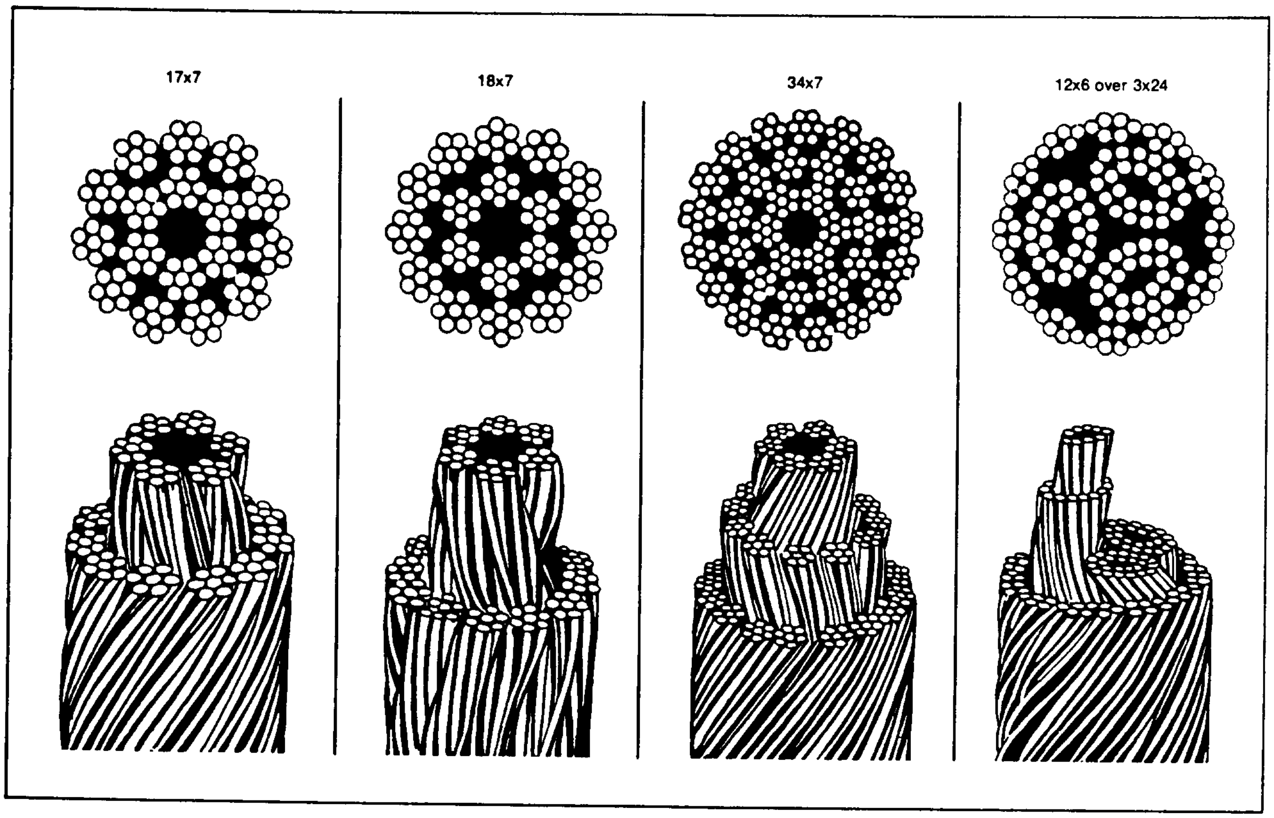


Figure 11. Typical Multistrand Rotation-Resistant Constructions[2]

Rotation-resistant ropes require special handling before, during, and after installation:

- Do not twist or turn the rope, as core slippage may result.
- When seizing an end, ensure that the entire cross section of the rope is firmly secured.
- Before cutting a rotation-resistant rope, secured seizings of annealed wire should be placed on both sides of the point where the cut is to be made.
- Seizings for these ropes should be a short distance apart, and the length should be at least equal to 1-1/2 to 2 times the diameter of the rope.
- There should be three seizings on each side of the cut for ropes up to 1 in. diameter, and four seizings on each side when the diameter of the rope is over 1 in.
- If thimbles are required, use a larger size than specified for the same size of wire rope, to prevent core slippage.
- Optimum rotation-resistant characteristics may be obtained by using a design factor of 8 or 10 to 1.
- Rotation-resistant ropes should not be used for boom or pendant (standing) cables.

The third element of wire rope construction is the core. The core forms the heart of the rope and is the component around which the main rope strands are laid. The core supports the strands and is intended to keep them from jamming against each other under normal loads and flexings.

There are two basic types of cores:

- *Fiber Cores*—Adequate for many types of service by providing maximum flexibility and elasticity to the wire rope. Fiber cores are made of natural fibers such as sisal or manila or from man-made fibers such as polypropylene or nylon.
- *Wire Cores*—Increases the resistance of wire ropes to abuse as they do not yield to the compressive action of the outer strands as do fiber cores. There are three types of wire cores: independent wire rope core (IWRC), steel strand core, and armored core.

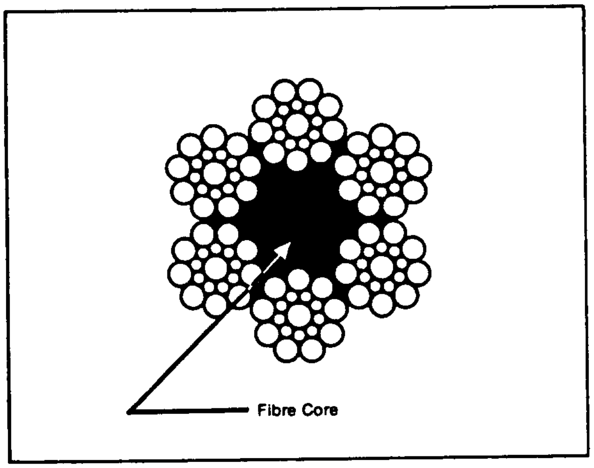


Figure 12. Fiber Core Ropes[2]

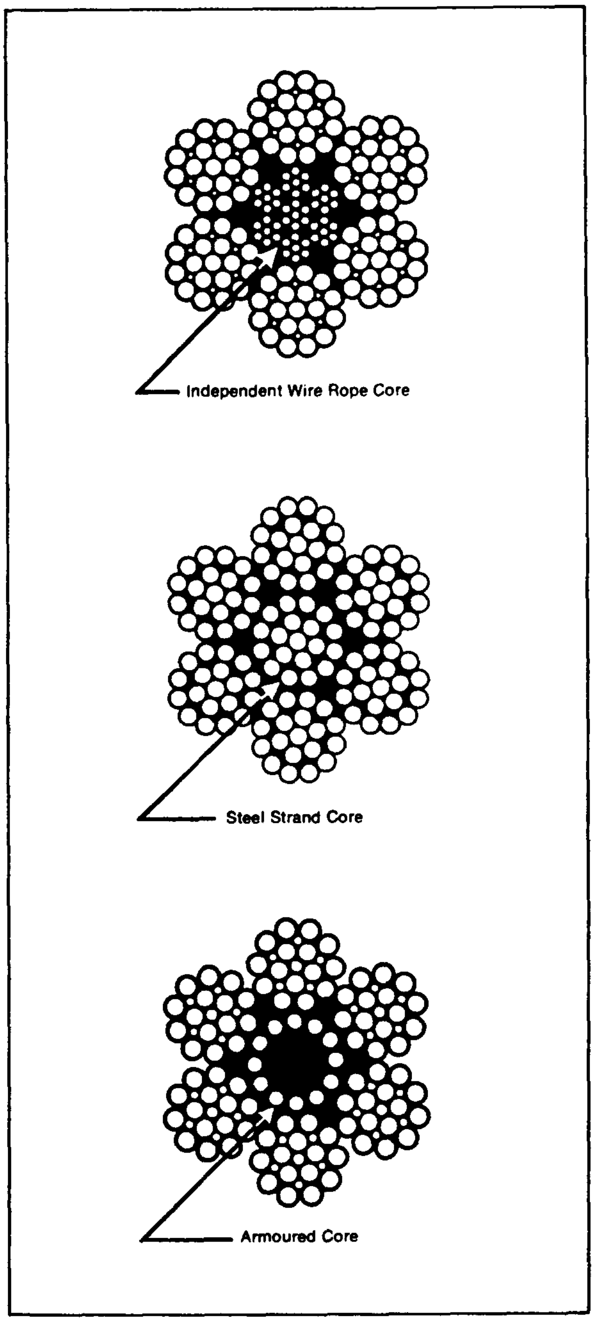


Figure 13. Wire Core Ropes[2]

Design Factors for Wire Rope

To guard against failure of a wire rope in service, the actual load on the rope should be only a fraction of the breaking or failure load. In its simplest form, the Design Factor is defined as

$$\text{Design Factor} = \frac{\text{Catalog Strength of the Rope}}{\text{Maximum Safe Working Load}} .$$

To find the maximum safe working load, divide the catalog breaking strength of the rope by the design factor. The wire ropes supplied as rigging on mobile cranes must possess design factors as follows:

- Live or running ropes that wind on drums or pass over sheaves
  3.5 to 1 under operating conditions
  3.0 to 1 when erecting the boom
- Pendants or standing ropes
  3.0 to 1 under operating conditions
  2.5 to 1 when erecting the boom.

The hoisting or rigging ropes on cranes other than those that are mobile must possess a design factor of 5 to 1.

When cranes are used to lift people, the design factor is 10 to 1.

The design factor accounts for the following variables:

- Reduced capacity of the rope below its catalog strength due to wear, fatigue, corrosion, and abuse
- End fittings and splices that are not as strong as the rope itself
- Extra loads imposed by acceleration and inertia (starting, stopping, swinging, and jerking of the load)
- Increased line pull (load on the rope) due to friction of the rope passing over sheaves
- Inaccuracies in the weight of the load
- Inaccuracies in the weight of the rigging
- Reduced strength of the rope due to bending over sheaves.

These variables, although not complete, are sufficient to indicate why a design factor is required and why it must *never* be lowered.

To determine the maximum safe working load (MSWL) in tons, the diameter, grade, core type, and classification of the rope selected must be known. Consult the crane or hoist manufacturers' manuals, Engineering Standards, or the *Rigging Manual* listed in the References.

3.1.1 End Fittings and Connections

End attachments and how they are assembled to wire rope greatly affect safety. Since many end attachments develop less than the full strength of the rope, safety practices require that the craftsman making the attachment

- Select the correct fittings and connections
- Properly install the fittings and connections
- Evaluate the connections for safe load capacity.

Forged fittings, which may be stamped "load-rated," are the only type recommended.

The various types of fittings and connections used depend on the factors of the installation:

- *Zinc (Spelter) Socket.* This socket is efficient for permanent terminal attachments and is recommended for use on all standing ropes and where severe service conditions exist. Only trained and properly qualified personnel are permitted to make these connections.
- *Swaged Socket.* This socket also makes efficient and permanent attachments. These attachments are made by compressing a steel sleeve over the rope with a hydraulic press. Properly made swaged sockets provide an efficiency of 100% of the wire rope.

  When inspecting the spelter of swaged connections, examine the rope closely for corrosion at the socket. Corroded wire is very susceptible to fatigue. One broken wire is sufficient cause to reattach the connection or replace the rope.
- *Cappel Socket.* When properly installed and frequently inspected, this socket gives 100% efficiency. It is made with interlocked wedges, which afford a holding power equal to the strength of the wire rope.
- *Wedge Socket.* This socket is probably the simplest device used for anchoring an end connection to wire rope. The efficiency, however, is only 70% of the rope strength.

  Do not attach the dead end of the cable to the live length of the rope with a clip.

  Wedge socket anchorages should not be used on rotation-resistant ropes because of the small radius of the wedge socket and the possibility of severe core slippage.
- *Spliced Eye Connection.* The SNLA Safety Department recommends that extreme caution be taken when selecting this type of connection because it is almost impossible to determine what kind of splice is used when it is covered by serving wire or pressed metal sleeves. The spliced eye connection has several configurations in three basic groups. These groups of Spliced Eye connections are Flemish Eye, Tucked Eye, and Fold Back Eye.

  The best and most secure splice is the Flemish Eye Plus Pressed Metal Sleeve. It develops almost 100% of the catalog strength of wire rope. Again, it is almost impossible to determine what type of splice exists when it is covered by serving wire or pressed metal sleeves. The Flemish Eye is made by separating the wire rope strands into two groups, forming the core into a basic eye, and then weaving the two groups of strands around the core from separate sides and then together until the strands have covered the core and have been interweaved.

  The Tucked Eye can develop only 70% of the rope strength and tends to come free as the rope unwinds. Consequently, it should not be used for hoisting loads.

  The Fold Back Eye splices are made by bending the rope to the eye dimension and securing the dead end of the rope to the live length by means of a steel or aluminum sleeve.

  It is strongly recommended that these two splices never be used for overhead hoisting since improper swaging or split sleeves will result in complete failure without warning.
- *Collet Connection.* The Collet connection is similar to the Fold Back Eye connection except that instead of the sleeve being swaged onto the rope, it takes the form of a split collet, sleeve and nut arrangement. Safety recommends that this type of connection not be used.
- *Cable Clip Connection.* The most common clips used are (1) the Crosby or the U-bolt and saddle type and (2) the double saddle or fist grip type. The fist grip clip is also called the safety clip.

  U-bolt clips must have the U-bolt section on the dead or short end of the rope and the saddle on the live or long end of the rope. See Figure 14 for the correct installation of U-bolt or cable clips.
- *Cable clips shall never be reused.*
- Never use clips to directly connect two straight lengths of rope. Use clips to form eyes on the end of each rope and connect the two thimbles together. See Figure 15 for proper method of joining two wire ropes.
- Double saddle clips (Figure 16) or fist grip clips are preferable to the U-bolt clips.
- The cable clip nut torque must be rechecked monthly after the rope has been in operation and until it has earned its "construction stretch."

- Still greater efficiency can be obtained by using long, double base clamps (Figure 17), which should be at least six rope diameters in length. These clamps obtain a greater clamping force on the rope without damaging it, and rope life and safety increase accordingly.

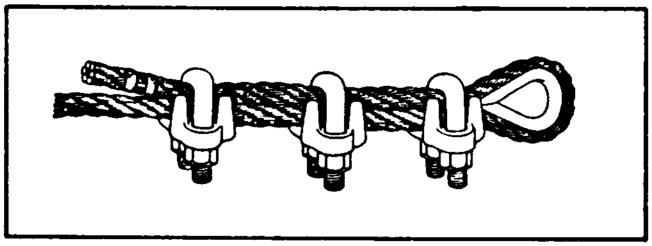


Figure 14. Cable Clips[2]

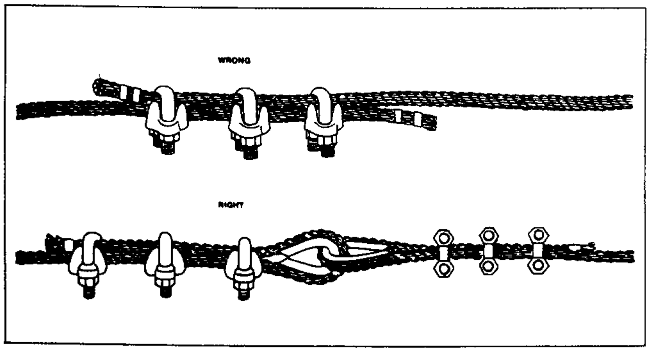


Figure 15. Proper Method of Joining Two Wire Ropes[2]

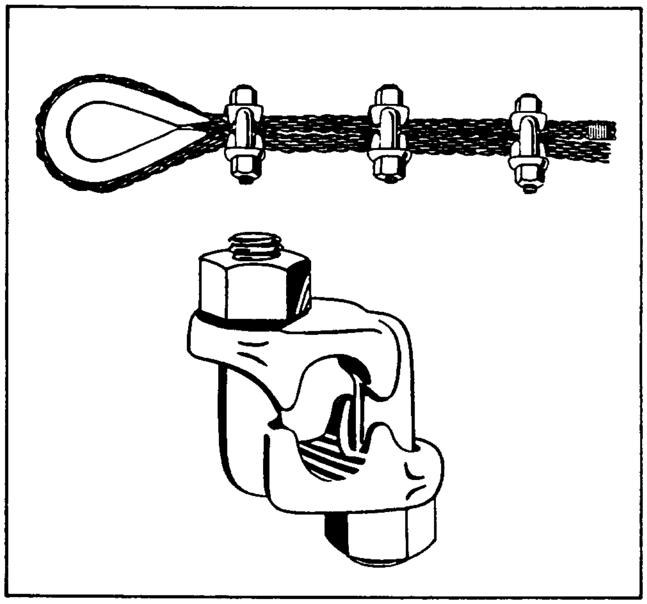


Figure 16. Double Saddle Clips[2]

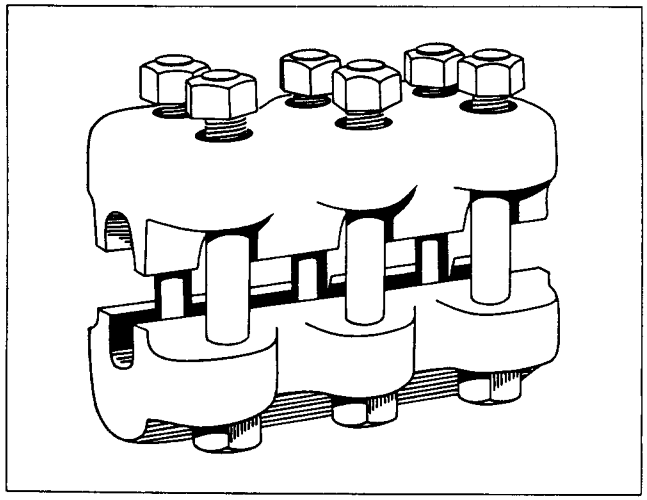
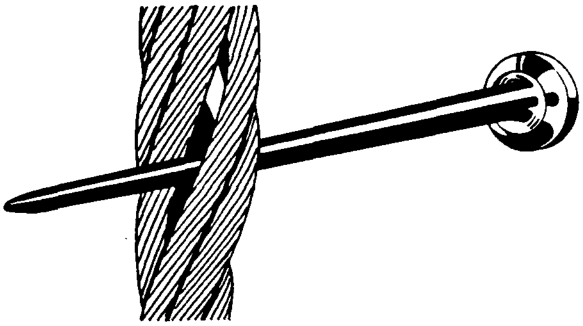


Figure 17. Double Base Clamp[2]

3.1.2 Inspection

The single most important operational check to be made on hoisting and rigging equipment is the rope and rigging inspection. All wire rope in continuous service should be observed during normal operation and visually inspected on a weekly basis. The strands of the wire rope should be separated to provide a view of the rope's interior. A marlin spike or similarly shaped tool should be used to separate the strands. Refer to Figure 18 for the proper method of opening a wire rope for internal inspection.



To open a rope, insert marlin spike beneath two strands and rotate to lift strands and provide view of interior.

Figure 18. Proper Method of Opening up a Wire Rope[2]

Factors such as abrasion, wear, fatigue, corrosion, improper reeving, and kinking are often of greater significance in determining the usable life of wire rope than are strength factors based on new rope conditions.

A record of each rope, its inspections, its defects, and deficiencies should be kept to determine the rate of degradation and when to replace the rope. Include the date of installation, size, construction, length, type of wear or abuse found during inspections, and length of service.

See Appendix G for the Field Inspection Check Sheet, Wire Rope.

The following conditions are sufficient reasons to question seriously the rope's safety features. If there is any doubt as to the rope's integrity, call the Plant Engineering Operations Inspector or request Maintenance to replace it with a new one.

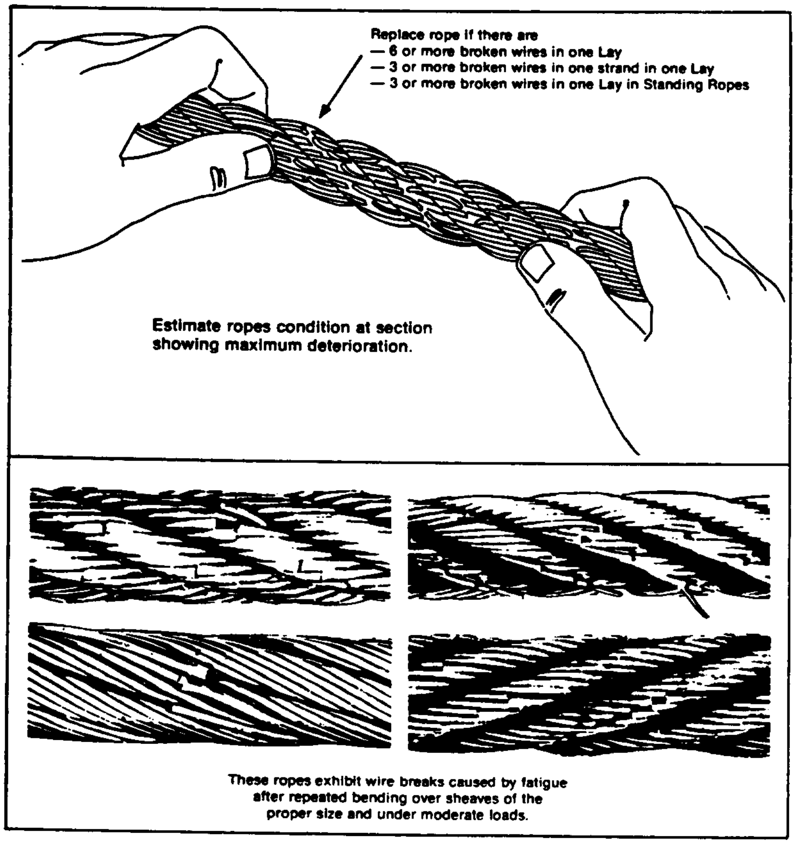
3.1.2.1 Broken Wires

The rope must be replaced

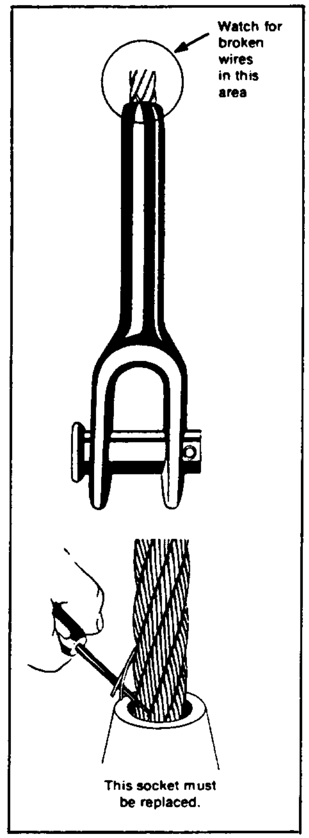
- If in running ropes, there are more than five randomly distributed broken wires in one lay length, or more than two broken wires in one strand in one lay length
- If in pendants or standing ropes, there are more than two broken wires in one lay length
- If in any rope, there are one or more broken wires near an attached fitting

  (Breaks near attached fastenings, such as sockets, are usually the result of fatigue stresses. The end fastenings should be replaced to eliminate the fatigued area. Six to eight feet should be cut off the rope before the new attachment is made.)
- If in running ropes, there is any evidence of wire breaks in the valleys between strands

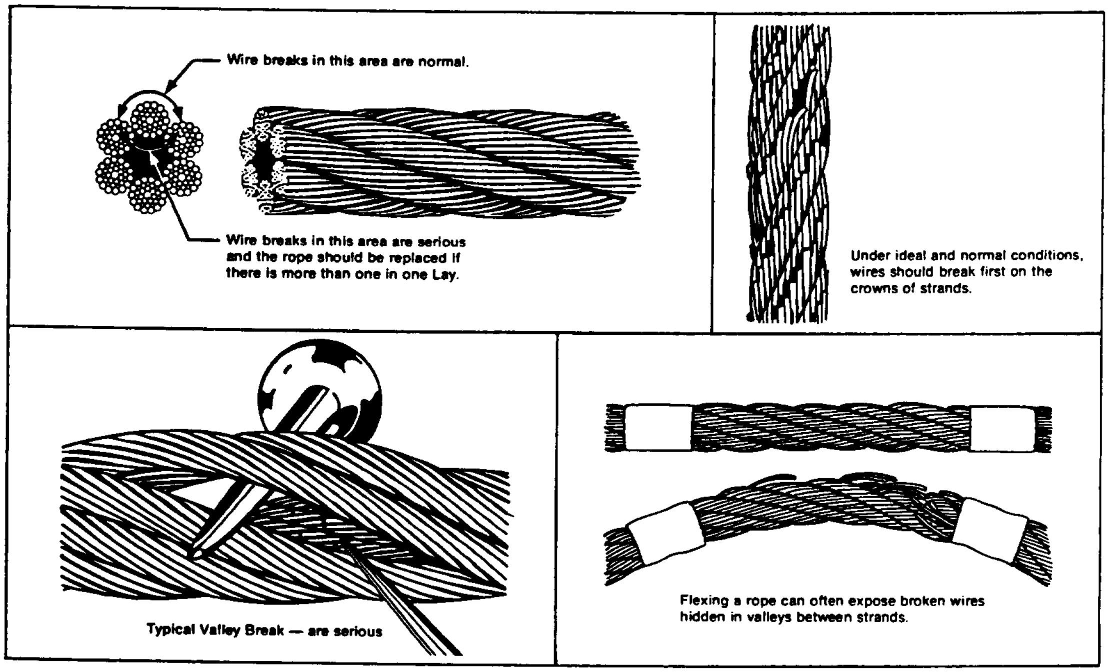
  (Breaks occurring on crowns of outside wires indicate normal deterioration. Breaks in valleys between strands indicate an abnormal condition, possibly fatigue or breakage of other wires not readily visible. More than one of these valley breaks in one lay length should be cause for replacement.)



(a) Rope Replacement Criteria Based on the Number of Broken Wires



(b) Broken Wires Near Fittings



(c) Broken Wires Inside a Rope

Figure 19. Broken Wires[2]

3.1.2.2 Worn and Abraded Wires

In a new rope each individual wire (with the exception of certain wires in the Flattened Strand and Locked Coil ropes) is a complete circle in cross section. Wear due to friction on sheaves, rollers, drums, etc., eventually causes the outer wires to become flat on the outside, reducing the circle to a segment that gradually becomes smaller as the "flat" increases. These worn areas are characterized by their bright appearance.

The rope must be replaced if this wear exceeds one-third of the diameter of the wire.

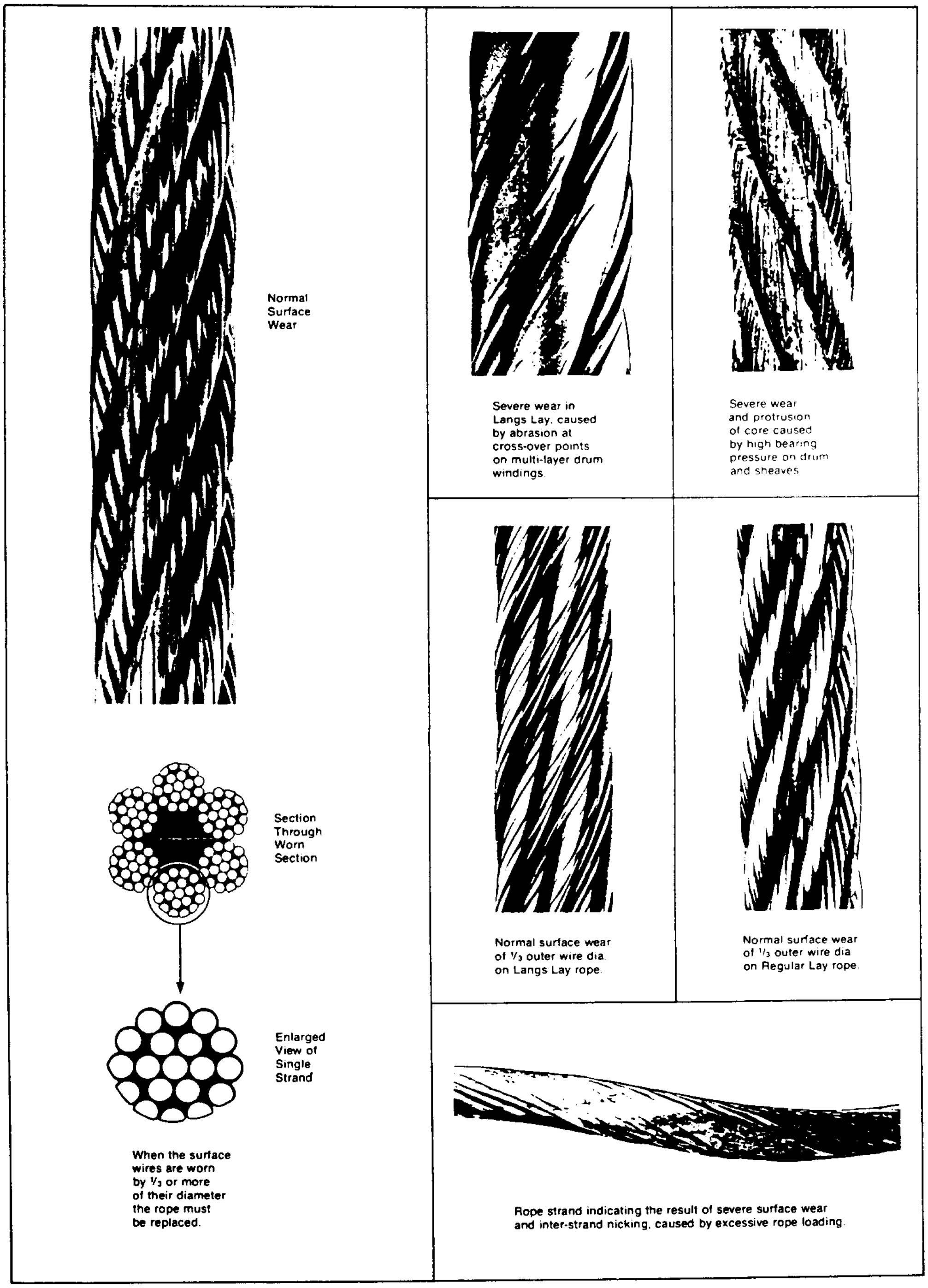


Figure 20. Worn and Abraded Ropes[2]

3.1.2.3 Reduction in Rope Diameters

Any marked reduction in rope diameter is a critical deterioration factor. It is often due to excessive abrasion of the outside wires, loss of core support, internal or external corrosion, inner wire failures, or a loosening of the rope lay. All ropes decrease in diameter after use, which is normal. The rope must be replaced if the diameter is reduced by more than

- 3/64 in. for rope diameters of up to and including 3/4 in.
- 1/16 in. for rope diameters of 7/8 to 1-1/8 in.
- 3/32 in. for rope diameters of 1-1/4 to 1-1/2 in.

3.1.2.4 Rope Stretch

Severe stretch or elongation of rope is also a deterioration factor. All steel ropes will stretch during their initial periods of use. This is known as "construction stretch." An elongation of 6 in. per 100-ft of rope can be expected in a six-strand rope and approximately 9 to 10 in. in an eight-strand rope.

Note: Look for lengthening of the lay length or a reduction in the rope diameter.

Excessive stretch beyond these dimensions should be cause for replacement. Sudden stretching after the rope has initially stabilized is also cause for replacement of the wire rope.

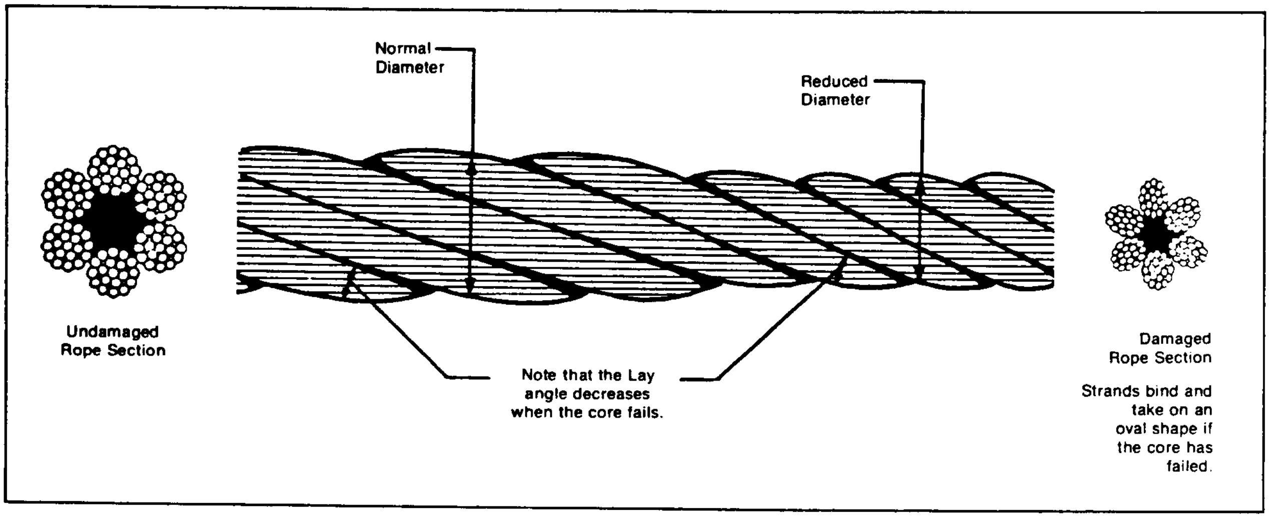


Figure 21. Reduction in Rope Diameter[2]

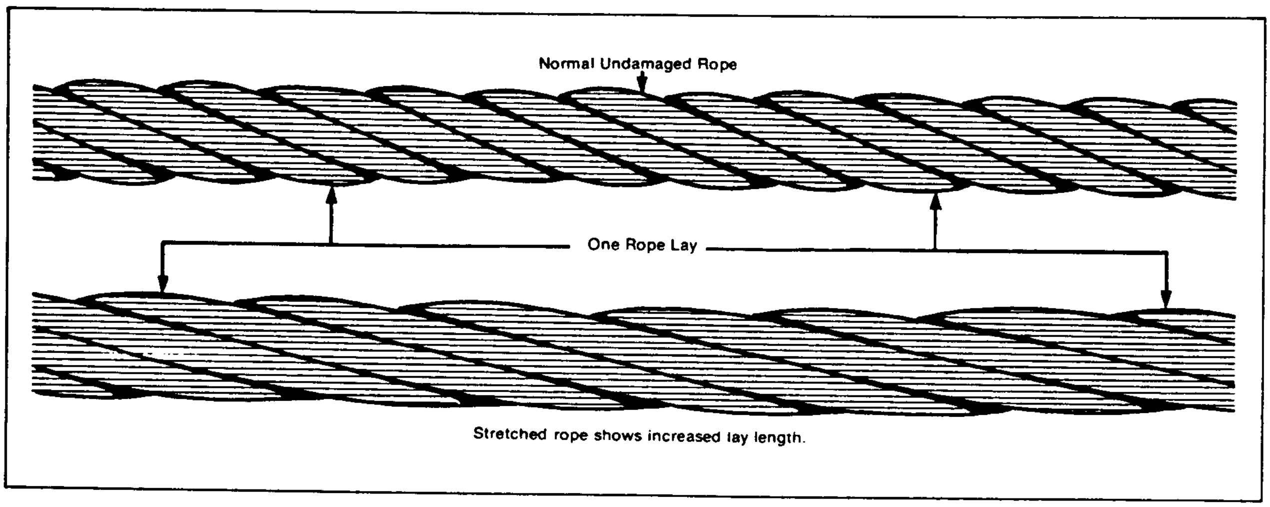


Figure 22. Rope Stretch[2]

3.1.2.5 Corrosion

Corrosion can be more dangerous than wear as more wires are affected by corrosion. Visual field inspections do not give even an approximate idea of the quality of a corroded rope. This is because corrosion frequently develops inside the rope before any evidence is visible on the rope surface. If corrosion is detected by the characteristic discoloration of the wires or if pitting is observed, then consideration must be given to replacing the rope. Noticeable rusting and the development of broken wires in the vicinity of attachments are also cause for replacement. If corrosion occurs at the base of the socket, it must be removed, about 6 to 8 ft of wire cut off, and the socket should then be reattached to the wire rope.

3.1.2.6 Insufficient Lubrication

A wire rope is supposedly lubricated internally by the saturated fiber core but this is not necessarily true. The lubricant usually dries out, leaks out, or is squeezed out of the rope. Where the grooves between the strands are filled with hard-packed grease or dirt, new lubricant cannot penetrate to prevent internal friction. Refer to Section 3.1.4.2, Lubrication. Also see Figure 18 for the proper way to examine the inside of a wire rope.

3.1.2.7 Damaged or Inadequate Splices

All splices must be closely examined for worn and broken wires, pinched or jammed strands, loose strands, cracked fittings, tucks drawing out, corrosion, etc. If any of these conditions are evident, then that section of the rope must be scrapped and a new splice made. If the serving wire is merely loose it may be replaced without replacing the wire rope section.

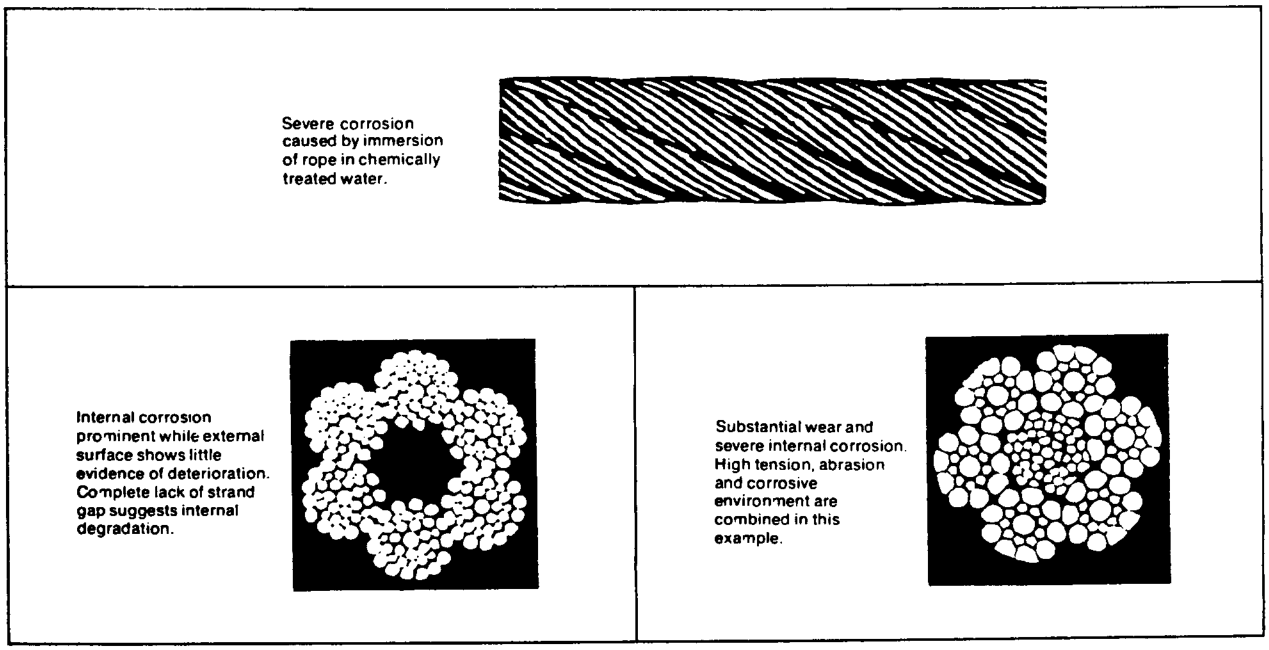


Figure 23. Rope Corrosion[2]

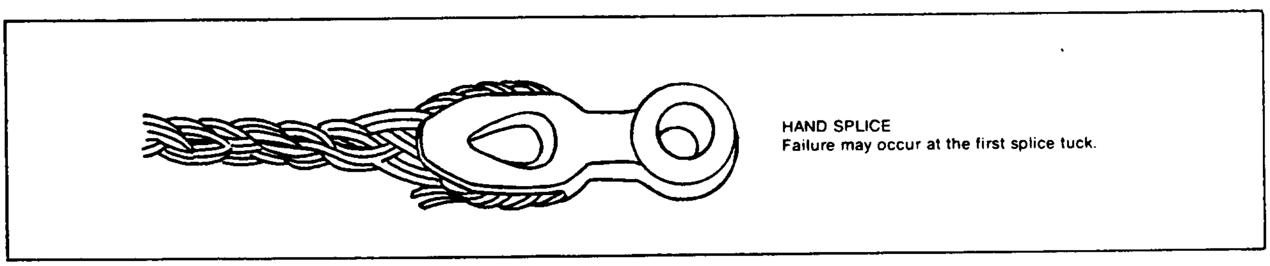


Figure 24. Damaged Splice[2]

3.1.2.8 Damaged End Fittings

If any of the conditions shown in Figure 25 exist, replace the fitting. Examine all thimbles closely for wear in the crown, for evidence of the throat biting into the rope, and for distortion or closure of the thimble.

3.1.2.9 Crushed, Jammed, and Flattened Strands

Replace the rope as these conditions are dangerous because of the severe wire deformation. These deficiencies occur when there are multiple layers on drums. Ropes with a large number of wires (e.g., 6×37) should never be used when multilayers are required. A rope with larger wires (e.g., 6×19 or 6×25) could be used but sheave and drum sizes must be increased accordingly to reduce fatigue due to bending. Also, independent steel wire core (IWRC) ropes should be used to reduce crushing.

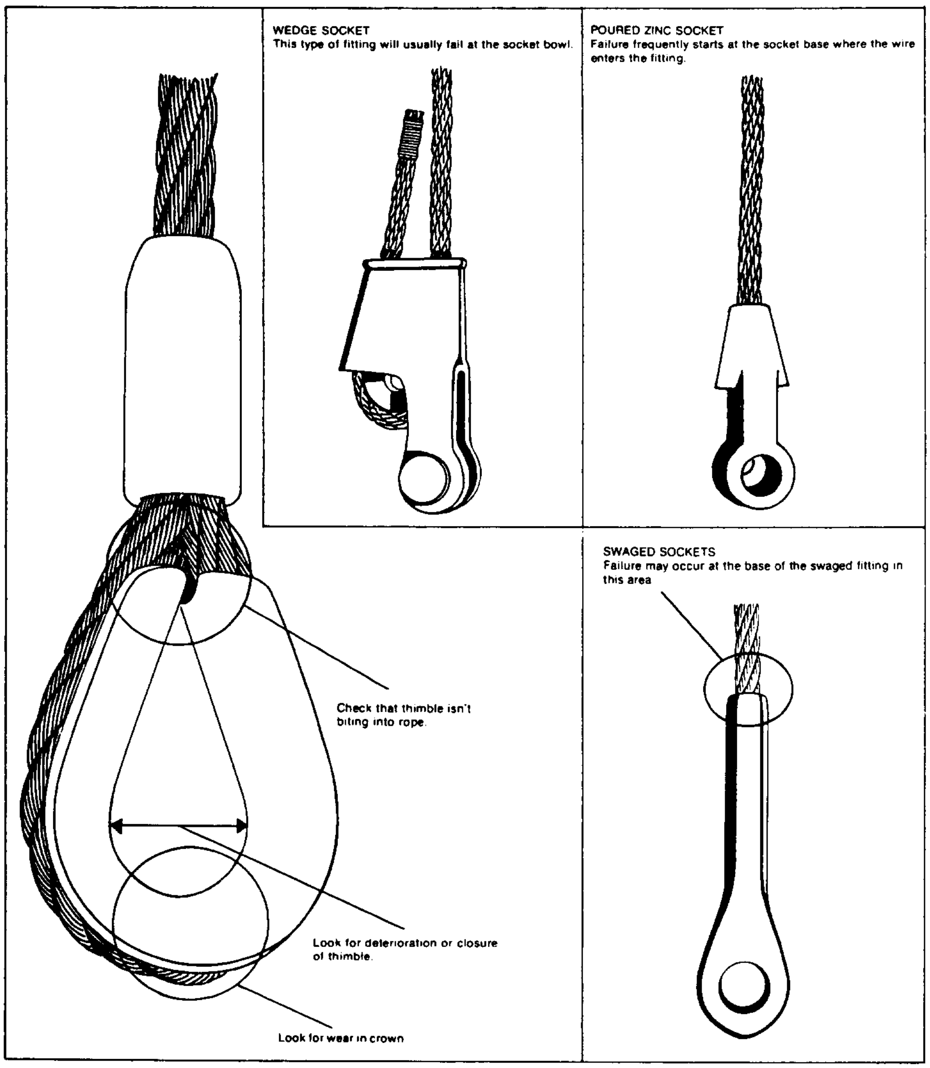


Figure 25. Damaged End Fittings[2]

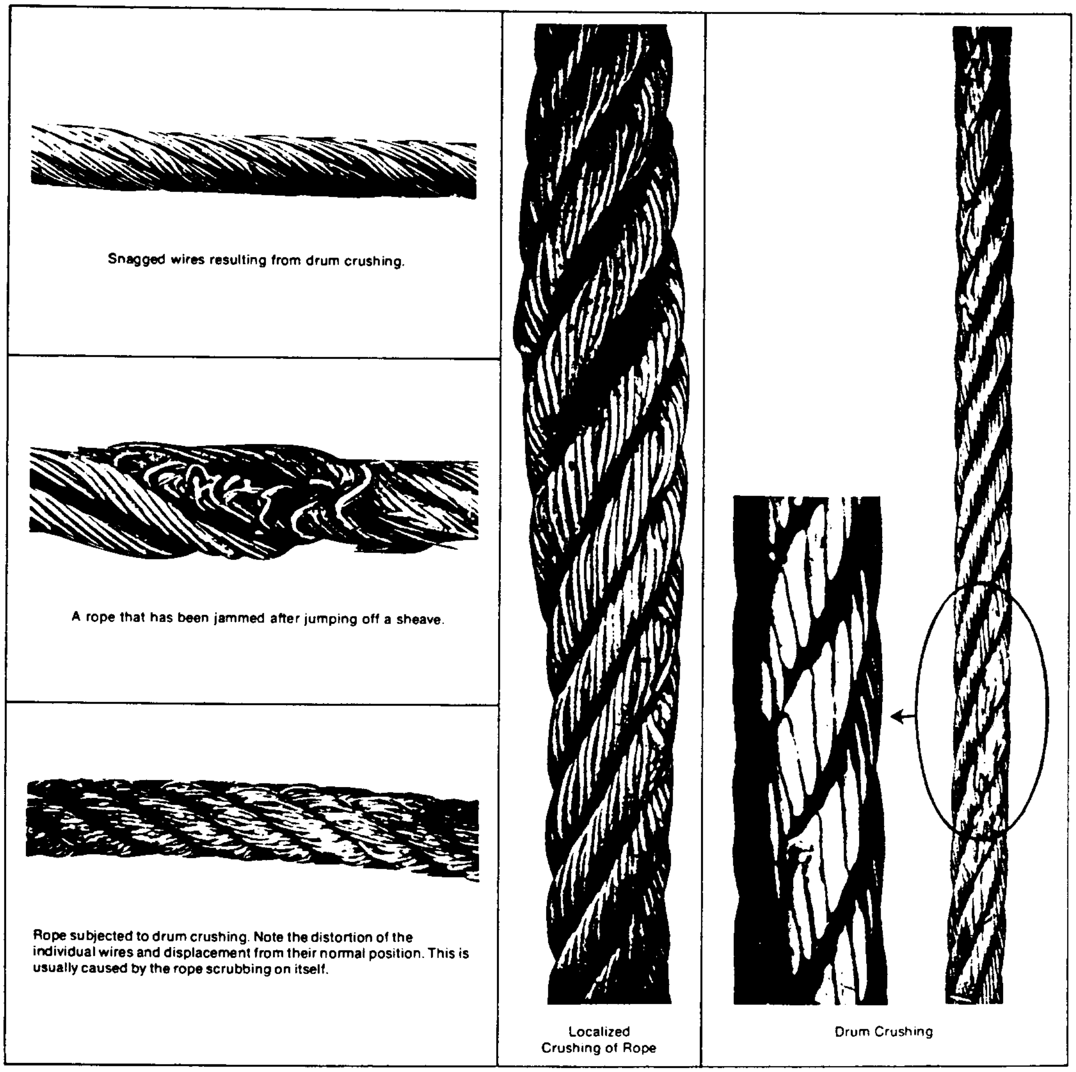


Figure 26. Crushed, Jammed, and Flattened Strands[2]

3.1.2.10 High Stranding and Unlaying

Replace the rope or renew the end connection to reset the rope lay. In cases such as this, excessive wear and crushing take place and the other strands become overloaded.

3.1.2.11 "Bird Cages"

Replace the rope or the affected section of the rope. A "bird cage" is caused by sudden release of tension and resultant rebound of rope from an overloaded condition.

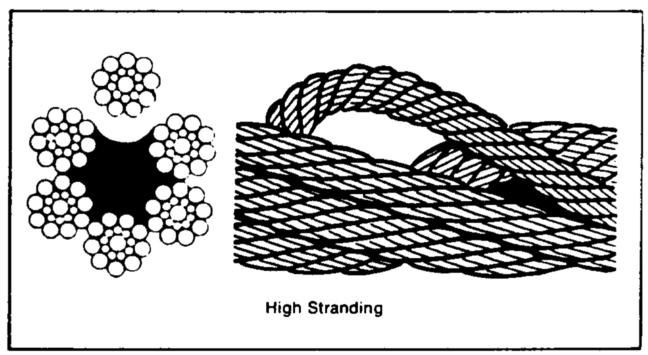


Figure 27. High Stranding[2]

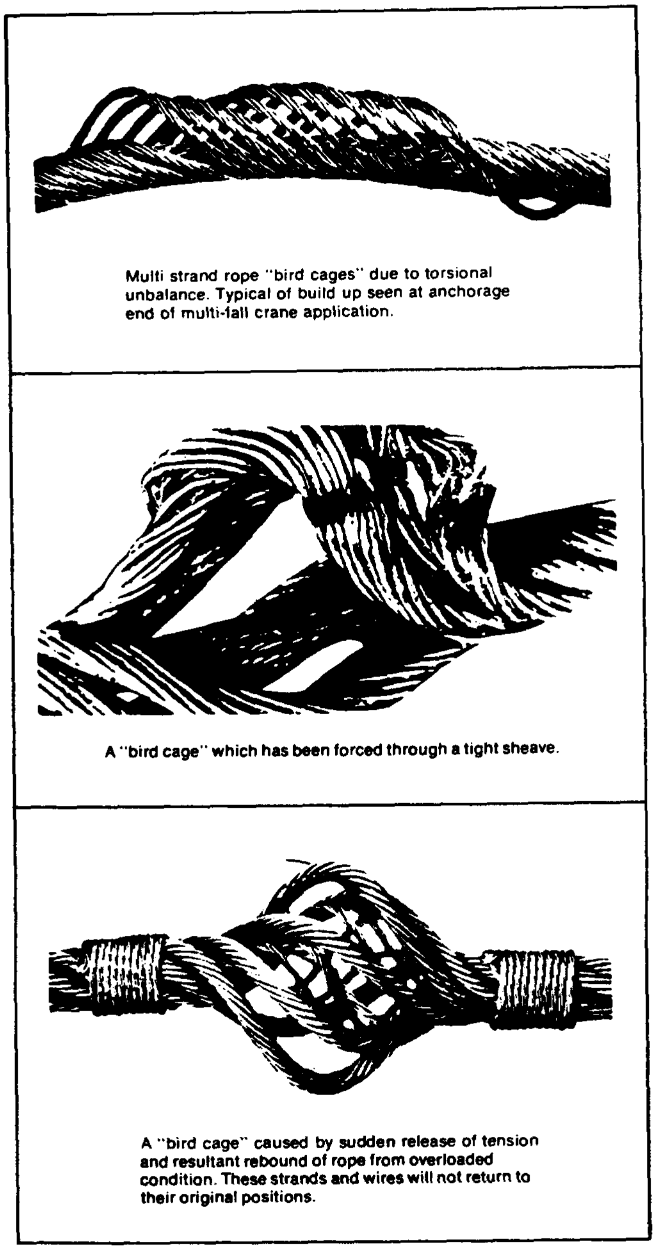


Figure 28. "Bird Cages"[2]

3.1.2.12 Kinks

Replace the rope or the affected section of the rope. Kinks are usually caused by faulty handling or reeving. The strands become doglegged and, when running on sheaves, are subject to excessive wear at the kink. Loading of the strands is no longer equal.

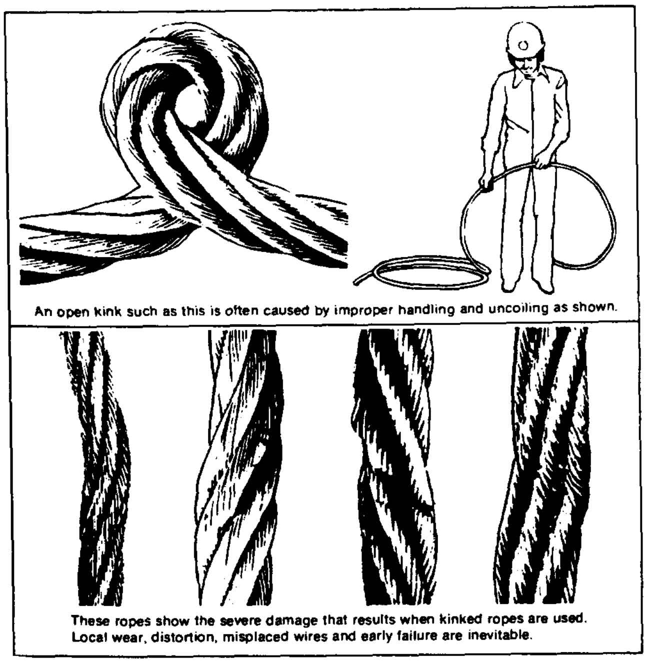


Figure 29. Rope Kinks[2]

3.1.2.13 Core Protrusion

Replace the rope. Core protrusion is a result of torsional unbalance created by shock loading.

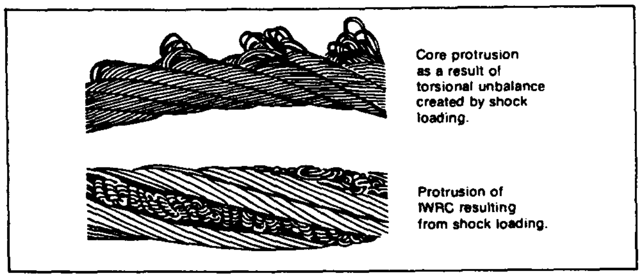
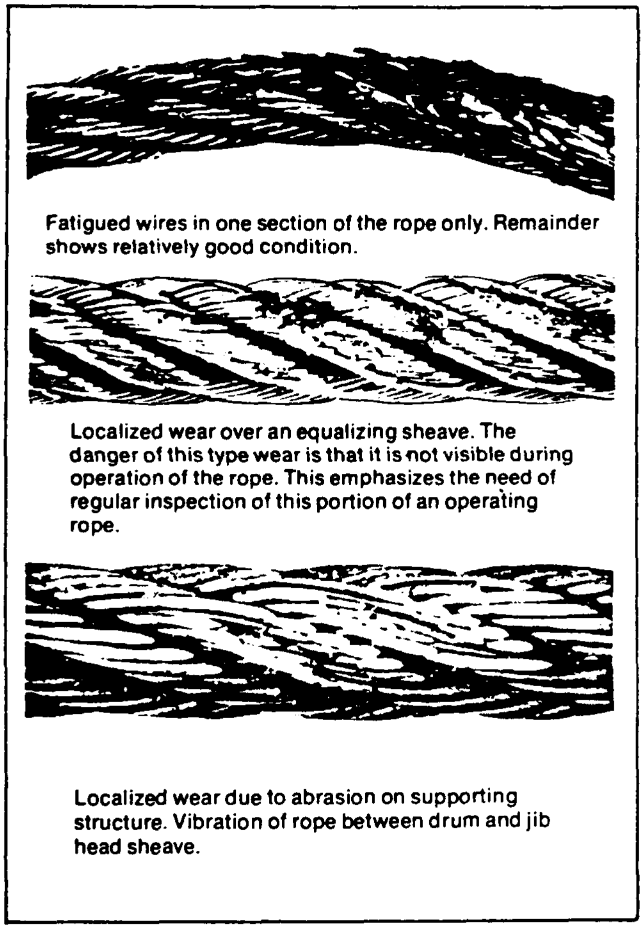


Figure 30. Core Protrusion[2]

3.1.2.14 Unbalanced Severely Worn Areas

This type of defect is caused by fatigued wires in only one section of the rope, localized wear over an equalizing sheave, or by vibration of rope between drum and jib head sheave. Remove the affected section.



Fatigued wires in one section of the rope only. Remainder shows relatively good condition.

Localized wear over an equalizing sheave. The danger of this type wear is that it is not visible during operation of the rope. This emphasizes the need of regular inspection of this portion of an operating rope.

Localized wear due to abrasion on supporting structure. Vibration of rope between drum and jib head sheave.

Figure 31. Unbalanced Severely Worn Areas[2]

3.1.2.15 Energy Damage

Remove the affected area or replace the rope if heat damage, torch burns, or electric arc strikes are evident. Gaps or excessive clearance between strands and bulges may also occur. These deficiencies are the result of core slippage or "turns" being put into or taken out of the rope. These usually occur in rotation-resistant rope constructions. These deficiencies also require that the wire rope be replaced.

Refer to Figure 32 for details of typical rope damage and to Table 2 for typical faults and possible causes of wire rope damage.

If the rope being inspected contains multilayers of strands, open it up and examine the inner strands. Particular attention should be paid to those areas close to the terminal fittings. Examine not only the length of rope that is in constant use, but also the rope that remains spooled and inoperative on the drum.

Examine all ropes, including the standing ropes, for possible deterioration caused by corrosion, abrasive dust, etc., and for damage during crane erection and dismantling procedures.

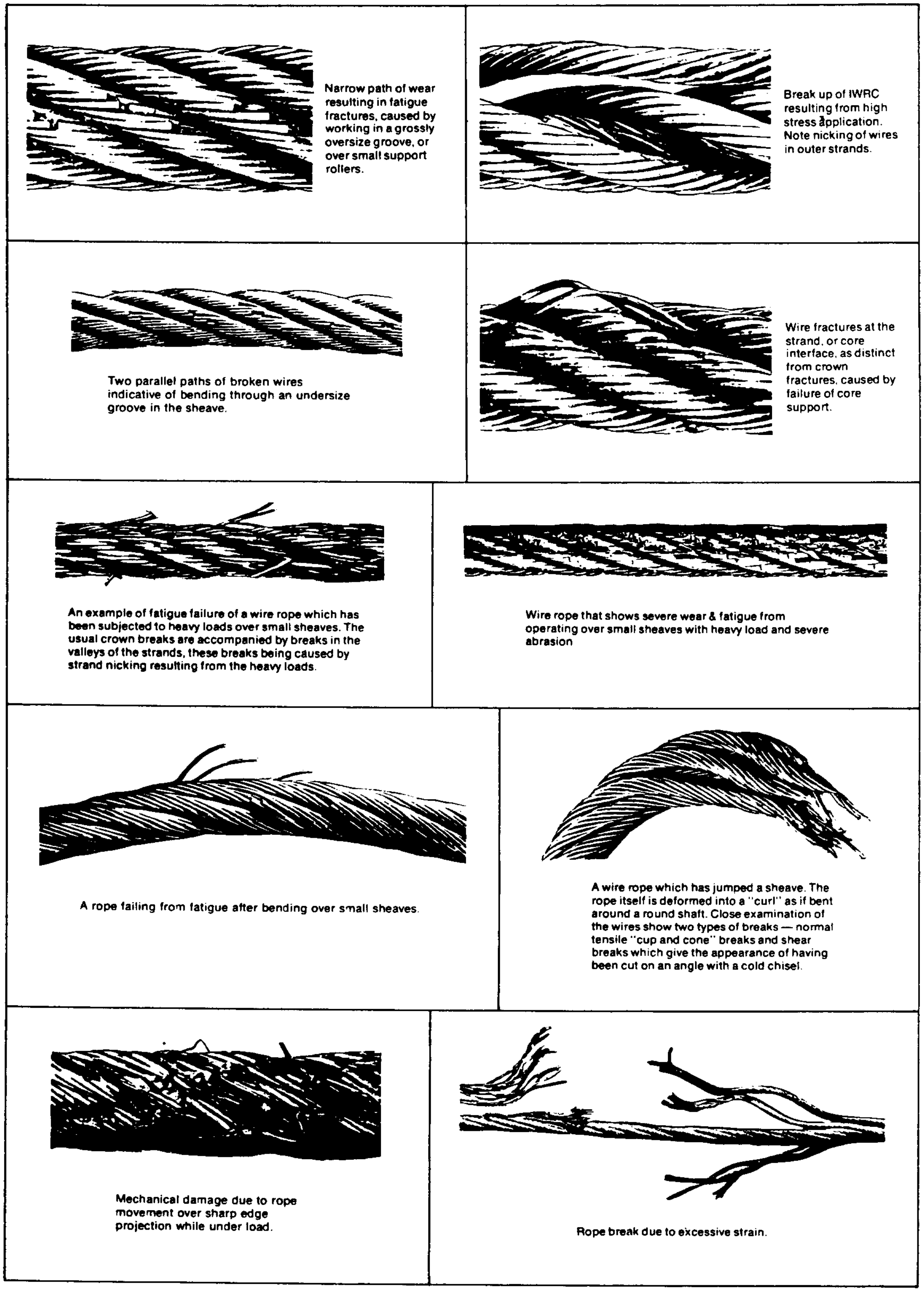


Figure 32. Typical Rope Damage[2]

Table 2. Faults And Possible Causes[2]

FAULT	POSSIBLE CAUSE
Accelerated Wear	Severe abrasion from being dragged over the ground or obstructions. Rope wires too small for application or wrong construction or grade. Poorly aligned sheaves. Large fleet angle. Worn sheaves with improper groove size or shape. Sheaves, rollers and fairleads having rough wear surfaces. Stiff or seized sheave bearings. High bearing and contact pressures.
Rapid Appearance of Broken Wires	Rope is not flexible enough. Sheaves, rollers, drums too small in diameter. Overload and shock load. Excessive rope vibration. Rope speed too high. Kinks that have formed and been straightened out. Crushing and flattening of the rope. Reverse bends. Sheave wobble.
Rope Broken Off Square	Overload, shock load. Kink. Broken or cracked sheave flange.
Strand Break	Overload, shock load. Local wear. Slack in 1 or more strands.
Corrosion	Inadequate lubricant. Improper type of lubricant. Improper storage. Exposure to acids or alkalis.
Kinks, Dog Legs, Distortions	Improper installation. Improper handling.
Excessive Wear in Spots	Kinks or bends in rope due to improper handling in service or during installation. Vibration of rope on drums or sheaves.
Crushing and Flattening	Overload, shock load. Uneven spooling. Cross winding. Too much rope on drum. Loose bearing on drum. Faulty clutches. Rope dragged over obstacle.
Stretch	Overload. Untwist of Lang Lay ropes.
Broken Wires or Undue Wear on One Side of Rope	Improper alignment. Damaged sheaves and drums.
Broken Wires Near Fittings	Rope vibration.
Burns	Sheave groove too small. Sheaves too heavy. Sheave bearings seized. Rope dragged over obstacle.
Rope Core Charred	Excessive heat.
Corrugation and Excessive Wear	Rollers too soft. Sheave and drum material too soft.
Distortion of Lay	Rope improperly cut. Core failure. Sheave grooves too big.
Pinching and Crushing	Sheave grooves too small.
Rope Chatters	Rollers too small.
Rope Unlays	Swivel fittings on Lang Lay ropes. Rope dragging against stationary object.
Crushing and Nicking	Rope struck or hit during handling.
High Stranding	Fittings improperly attached. Broken strand. Kinks, dog legs. Improper seizing.
Reduction in Diameter	Broken core. Overload. Corrosion. Severe wear.
Bird Cage	Sudden release of load.
Strand Nicking	Core failure due to continued operation under high load.
Core Protrusion	Shock loading. Disturbed rope lay. Rope unlays. Load spins.

3.1.3 Installation

The following should be observed when wire rope is to be installed on the drums of cranes, hoists, or on base-mounted drum hoists:

- Obtain the correct type of wire rope according to the manufacturer's recommendations.
- Determine if the wire rope to be installed is Right Lay or Left Lay.
- Keep the rope as clean as possible.
- Determine if the rope is to be wound over the drum or under the drum (depends on the rotation of the drum when power is applied).

  Visualize the drum from the rear, or from the opposite side of the drum from which the load cable leaves. If a Right Lay cable is to be installed, make a fist with the right hand (drum) and extend the forefinger (rope). For overwound installation keep the back of the fist up. For underwound installation turn the palm up. Install the rope, either over or under the drum, as indicated by the position of the fist and finger. Start the rope installation at the drum flange that is nearest the finger. For Left Lay cables, use the left hand and follow the same procedures.
- Unwind the rope from the reel in such a way that kinks or twists will not occur.
- Load the rope over the top of the drum if the rope uncoils from the top of the reel.
- Load the rope under the bottom of the drum if the rope uncoils from the bottom of the reel.
- Before cutting any wire rope, apply the correct number of seizings to both sides of the location of the cut. See Section 3.1.4.1, Seizing and Cutting Wire Rope.
- The diameter of the top layer of rope on the drum should always be less than the diameter of the drum flange by twice the diameter of the rope or 2 in., whichever is greater.

The correct length of rope to reeve on any drum is very important. A rope that is too short may unreel to the point of becoming unhooked or having the rope anchorage carry the load instead of the drum. Also, on overhead cranes, a rope that is too short may prevent loads that are lower than the floor level from being picked up. A rope that is too long can exceed the drum's spooling capacity, causing it to ride over one of the drum flanges.

With the hook at its lowest position there should be at least two full turns of rope on the drum, and the spooling capacity must not be exceeded when the hook is at its highest point. (See Section 2.4.1, Item 6.)

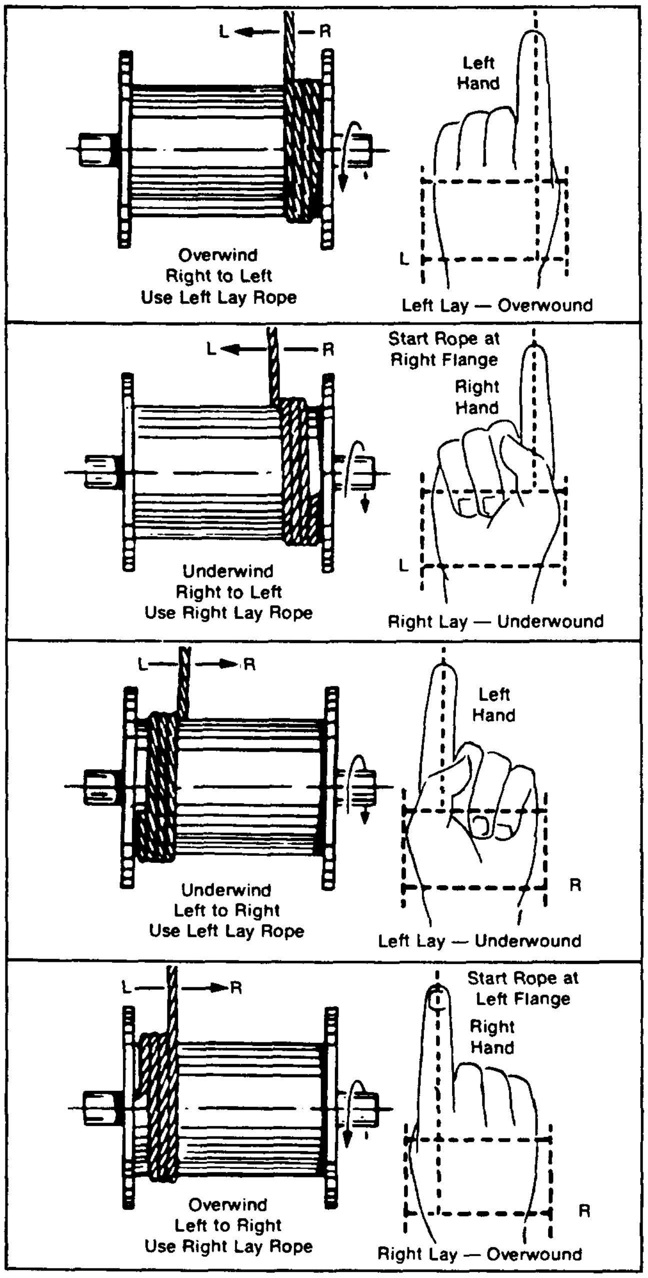


Figure 33. Application of Rope to Drum[2]

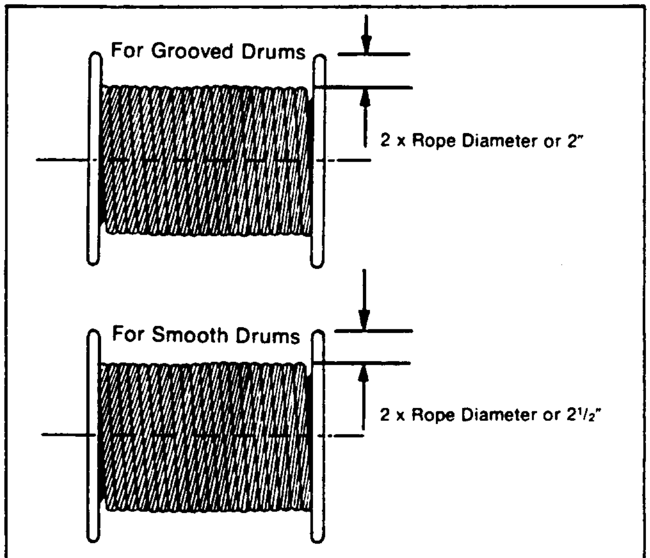


Figure 34. Maximum Drum Capacity[2]

3.1.3.1 Reeving

Reeving is the passing of a rope through a block or similar device. The size of the block, the rope size, and the number of sheaves per block must be determined in relation to the load to be lifted and the pull that can be applied to the lead line. The lead line is the rope that travels between the power drum and the sheave in the standing or head block. In reeving a pair of tackle blocks, one of which has more that two sheaves, the lead hoist line should lead from a center sheave of the head block to the power drum.

Reeving provides a mechanical advantage as the system (rope and blocks) acts as a "machine." The machine is not 100% efficient because the lead line pull must be increased to make up for the friction loss in the tackle or blocks. The friction is additive and varies from 3% to 10% of sheave load depending on the sheave bearings and how easily they rotate.

Care must be taken when passing the rope through the head block and the load block to ensure that the load block does not tilt during a nonlifting operation. "Lacing" is the term used when the load block tilts when raised with no load. This tilting results from the rope being passed through the blocks and over the sheaves in consecutive order.

A reeved system is called *symetrically* reeved; the laced system is called *unsymetrically* reeved.

To determine the number of parts of line in a system already reeved, imagine that the ropes between the head block and the load block have been neatly severed by a thin metal sheet. Count all the cut rope ends on one side of the metal sheet. That figure is the number of parts in the reeved system. The lead line, or the rope from the head block to the drum, is not cut or counted when determining the number of parts of line.

To gain enough mechanical advantage to lift a load that is too heavy for a one-part pick, certain facts must be known and calculations performed.

Three important calculations that every rigger must know are

- How to determine the number of parts of line required to make pick
- How to determine the maximum load that can be lifted with a given reeving arrangement
- How to determine the line pull needed when the load weight and number of parts of line are established.

The procedures for the three types of calculations follow.

1. How to determine the number of parts of line required to make a pick:
   - Determine the MSWL of the rope and the maximum pulling load to be applied to the lead line. Use the smaller of the two values in the following calculation:

     $$R = \frac{\text{Load to be Lifted}}{\text{MSWL (or desired lead line pull)}} \; .$$

   - Determine what type of sheave bearings are used.

     Find the R (value calculated above) in Figure 35 and read the parts of line required for the type of sheaves used. Always use the next higher whole figure for the number of rope parts.

2. How to determine the maximum load that can be lifted with a given reeving arrangement:
   - Determine the number of parts of line.
   - Determine what kind of sheave bearings is being used.
   - Determine *R* from Figure 35 by using the number of parts of line and type of sheave bearings just determined above.
   - Determine the MSWL of the rope and the maximum pulling load desired to be applied to the lead line. Use the smaller of the two values in the following calculation.

     Maximum Load = R×(MSWL) or (lead line pull) .

FACTORS TO ACCOUNT FOR SHEAVE FRICTION LOADS FRICTION FORCE = 5% of Sheave Load (Typical for bronze bushing sheaves and stiff roller bearing sheaves.)		
Number of Parts of Line N	Multiplication Factor F	Ratio R (R = N/F) = Actual Mechanical Advantage
1	1.05	.95
2	1.10	1.82
3	1.16	2.59
4	1.22	3.28
5	1.28	3.91
6	1.34	4.48
7	1.41	4.96
8	1.48	5.41
9	1.55	5.81
10	1.63	6.13
11	1.71	6.43
12	1.80	6.67
13	1.89	6.88
14	1.98	7.07
15	2.08	7.21
16	2.18	7.34
17	2.29	7.42
18	2.41	7.47
19	2.53	7.51
20	2.65	7.55

FACTORS TO ACCOUNT FOR SHEAVE FRICTION LOADS FRICTION FORCE = 3% of Sheave Load (Typical for good roller bearing sheaves.)		
Number of Parts of Line N	Multiplication Factor F	Ratio R (R = N/F) = Actual Mechanical Advantage
1	1.03	.97
2	1.06	1.89
3	1.09	2.75
4	1.13	3.54
5	1.16	4.31
6	1.20	5.00
7	1.23	5.69
8	1.27	6.30
9	1.31	6.87
10	1.35	7.41
11	1.39	7.91
12	1.43	8.39
13	1.47	8.84
14	1.51	9.27
15	1.56	9.62
16	1.61	9.94
17	1.65	10.30
18	1.70	10.59
19	1.76	10.80
20	1.81	11.05

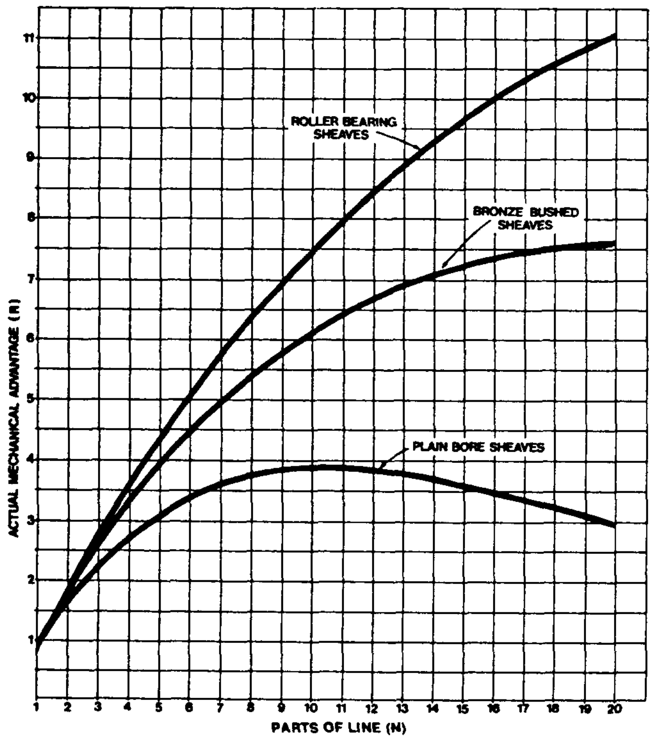


Figure 35. True Mechanical Advantage Chart[2]

3. How to determine the line pull needed when the load weight and number of parts of line are established:
   - Determine the type of sheave bearings.
   - Determine the load weight.
   - Determine the number of parts of line.
   - Calculate the lead line pull with following formula:

     $$\text{Line Pull} = \frac{\text{Load Weight}}{\text{R}}.$$

   - Ensure that the required line pull does not exceed the rated safe working load (MSWL) of the wire rope.

Always use a shackle block as the upper or head block and a hook block as the lower or load block.

If the blocks have *equal* numbers of sheaves, the dead end of the rope should be fastened to the becket of the head block. If the blocks have *unequal* numbers of sheaves, the rope should be fastened to the becket of the block having the least number of sheaves.

It is important that blocks and reeved systems be of sufficient size and capacity to carry the loads to which they will be subjected. If the hook on a set of blocks shows signs of opening up, this is an indication that the blocks are being overloaded. The hook will usually begin to bend at approximately 70% of the maximum block strength. The best way to avoid overloads is to know exactly how reeved systems work, use the previously mentioned calculations, and appreciate just how much friction affects the total load.

3.1.4 Operations

Wire rope, as a machine, requires the same careful use, handling, and regular maintenance that the crane or other equipment does for satisfactory performance, long life, and adequate safety.

Precautions that should be taken to meet these requirements are as follows:

- Ensure that the correct type and size of rope is used.
- Inspect regularly the entire length of each wire rope.
- Never overload a wire rope.
- Minimize shock loading. Pick up slowly when hoisting and stop slowly when lowering a load.
- Avoid sudden loading in cold weather.
- Take extra special precautions or use a larger rope if
  —the exact weight of load is unknown
  —shock loading is a possibility
  —conditions are abnormal or severe
  —hazards exist that might endanger personnel.
- Protect wire rope from sharp corners or edges.
- Avoid dragging rope.
- Avoid rolling loads with ropes.
- Store all unused or spooled rope in a clean dry area.
- Always store reels of wire rope on the reel edges, never on the ends or sides of the reel.
- Never use wire rope that has been kinked or crushed, or has other abnormalities.
- Avoid reverse bends and prevent loops from being pulled tight and kinking.
- Ensure that the drums and sheaves are the correct diameter.
- Repair or replace faulty guides and rollers.
- Ensure that the sheaves are aligned.
- Never wind more than the proper amount of rope on any drum.
- Replace sheaves that are deeply worn or have scored grooves, cracks, broken rims, or worn or damaged bearings.
- Ensure that the rope ends are properly seized.
- Thimbles should be used in all wire rope eye fittings.
- Watch for local or isolated wear.
- Check for abnormal line whip and vibration.
- Ensure that the rope spools properly on the drum.
- Never allow the rope to cross-wind over itself.
- Ensure that new ropes do not bind in sheaves.
- Lubricate ropes regularly according to the rope manufacturer's recommendations.

Where rope deterioration is excessive at one end, the life of the rope may be extended by turning the rope end for end. This must be done before the deterioration becomes too severe.

3.1.4.1 Seizing and Cutting Wire Rope

When wire rope is to be cut, it is best to seize it on both sides of the cut before the cut is made so that the cut wires won't splay. Preformed wires do not splay, but tight seizing will help to hold the core securely in place.

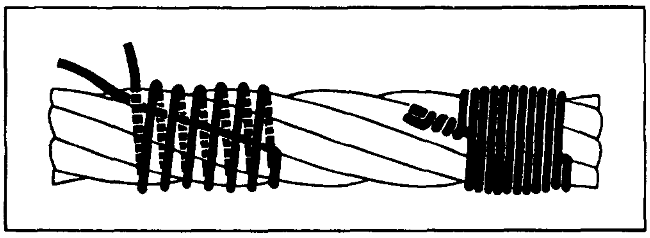
For ropes larger than 1-in.-diameter, use a soft, annealed seizing wire. Place one end in a valley between strands and coil the wire around the rope and over the end in the valley.

For ropes smaller than 1-in.-diameter, wind the seizing wire around the rope, bring the two ends of the wire together, and twist.

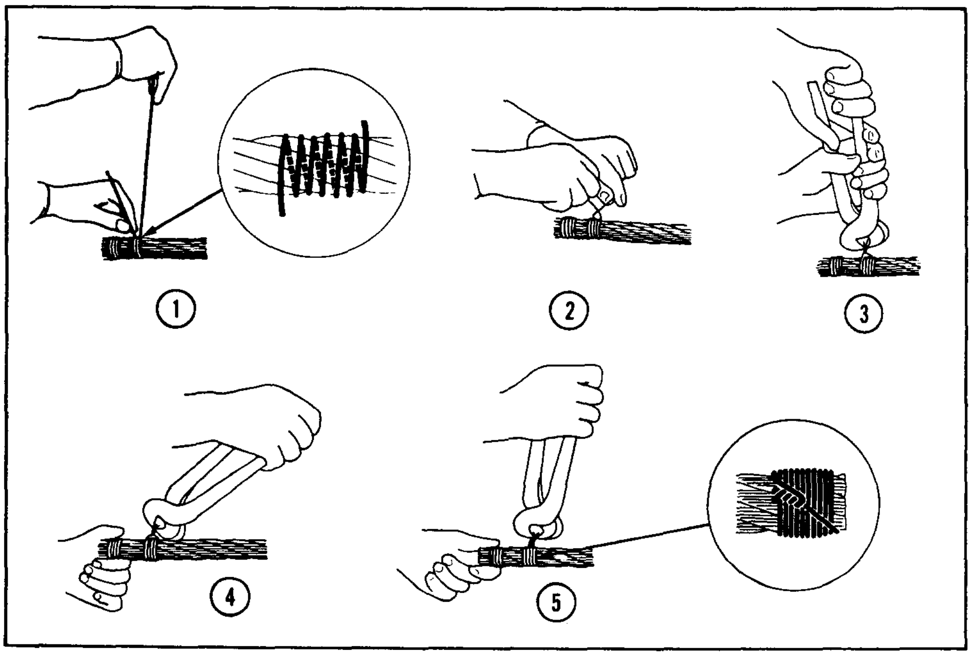
The number of seizings required should be separated from each other by approximately the diameter of the rope.

Figure 36 shows how the seizings are made differently on wire ropes with less than and more than 1-in. diameters.

Table 3 shows the recommended number of seizings and the size of the seizing wire that should be used to secure the ends of cut wire rope.



(a) Larger than 1 in. Diameter



(b) Smaller than 1 in. Diameter

Figure 36. Proper Method of Seizing Ropes[2]

Table 3. Seizing Data[2]

RECOMMENDED NUMBER OF SEIZINGS AND SIZE OF SEIZING WIRE OR STRAND						
Rope Diameter (Inches)	MINIMUM NUMBER OF SEIZINGS				Approx. Diam. of Seizing (Inches)	
	6 and 8 Strand Ropes Round and Flattened Strand		Non-Rotating Ropes Round & Flattened Strand		Stranded Ropes	
	Reg. Lay, F.C.	Lang Lay, F.C. Reg. Lay, Steel Core Lang Lay, Steel Core	Groups	Seizings Per Group	Wire	Strand
3/32 & smaller	2	2	2	3	.020	
1/8 — 1/4	2	3	2	3	.024	
5/16 — 1/2	3	4	2	3	.032	
9/16 — 7/8	3	4	2	3	.040	1/16
15/16 — 1 1/2	3	4	3	3	.080	3/32
1 9/16 — 2	4	5	3	3	.106	1/8
Larger than 2	4	5	3	3	.128	5/32

3.1.4.2 Lubrication

Wire rope will deteriorate rapidly if not regularly lubricated. The following will be curtailed if a regular lubricating program is followed:

- Corrosion and pitting. Pits can cause internal nicking as the wires move against one another.
- Wires becoming embrittled.
- Frictional wear. Since wires in a rope move relative to one another during operation, they are subject to frictional wear. Lack of lubrication will cause the frictional wear to increase.
- Weathering. Ropes not in regular use and standing ropes are vulnerable to weathering out of the internal lubricant. Moisture seeps in and both core and wires deteriorate.

A rope should be scrubbed clean and be dry before a fairly viscous light oil is applied (sprayed would be best) to allow it to soak into the inside of the rope. The oil used should meet the wire rope manufacturer's specification.

Note: Never apply used crankcase oil to a wire rope. Do not use WD-40 as a lubricant on a wire rope.

Good lubricants have the following characteristics:

- corrosion resistant
- water repellent
- penetrating ability
- chemically neutral
- high-pressure flow characteristics
- adhesiveness and an affinity for steel
- plastic coating
- temperature stability

3.1.4.3 Wire Rope Storage

Wire ropes should be stored in coils or on reels in a clean, dry indoor area. If stored on a reel, the reel must be placed such that the centerline is horizontal. Reels should be rolled 180° every six months to prevent the lubricating fluid from dripping or pooling in the lower layers of the rope's core.

The stored rope must be kept away from heat and steam and must never be allowed to rest for any long period of time on concrete or ash floors. The lime, sulphur, and ash can cause corrosion pits, which act as stress raisers.

3.2 Chains

For general construction rigging, never use a chain when it is possible to use wire rope. The failure of a single link in a chain can result in a serious accident. Wire rope, on the other hand, is frequently composed of 114 wires or more, all of which must fail before the rope breaks. Wire rope provides a reserve strength and many opportunities to notice hazards and perhaps prevent an accident; chains do not.

Chains will stretch a little under excessive loading. Should a weld be defective, the chain will break with no warning.

Chains are less resistant to sudden stresses or shock loads than wire rope and can break with no warning under such conditions.

There are certain jobs, however, for which chains are better suited than wire rope. Chains withstand rough handling, do not kink, are easily stored, have dead flexibility and, when used as slings, grip the load well. They are much more resistant to abrasion and corrosion than wire rope, and are particularly well suited as slings in high-temperature environments and for lifting rough loads such as heavy castings, which have sharp rough edges.

3.2.1 Grades

For the highest degree of safety, ensure that only chains stamped with an *8* is used for hoisting operations. It may be stamped with letters in addition to the 8, such as CA-C8, HA800, A-8, A8A, P8, G8, or W8. Whether it is stamped with 8, 80, or 800 makes no difference; it is the only grade of chain that may be used for overhead lifting. If a chain is marked with a *T*, it is approved for overhead lifting, since T is used by the International Standards Organization (ISO) for Grade 8 chain.

3.2.2 Strength

The maximum safe working loads for new alloy steel chain when used as a single vertical sling are shown in Table 4.

Alloy steel chain can be used in environments up to 500°F without reducing the safe working load. However, the safe working load limit is reduced 10% for each additional 100°F up to 1000°F. In addition, the safe working load of the chain at ambient temperature is permanently reduced by 10% after 900°F and by 15% after 1000°F.

Table 4. MSWL for "A" Type Alloy Steel Chain[2]

MAXIMUM SAFE WORKING LOAD "A" TYPE ALLOY STEEL CHAIN SINGLE VERTICAL SLING	
Chain Size (Inches)	Capacity (Pounds)
1/4	3,250
3/8	6,600
1/2	11,250
5/8	16,500
3/4	23,000
7/8	28,750
1	38,750
1 1/8	44,500
1 1/4	57,500
1 3/8	67,000
1 1/2	80,000
1 3/4	100,000

Table 5. Effect of Heat on Chain and Safe Working Load[2]

EFFECT OF HEAT ON SAFE WORKING LOAD		
CHAIN TEMPERATURE	REDUCTION OF SAFE WORKING LOAD LIMIT WHILE HEATED*	PERMANENT REDUCTION IN SAFE WORKING LOAD LIMIT**
500°F	None	None
600°F	10%	None
700°F	20%	None
800°F	30%	None
900°F	40%	10%
1000°F	50%	15%

* While chain is at temperature in first column.
** When chain is used at room temperature after being used at temperature shown in first column.

3.2.3 Inspection

All chains used regularly should be thoroughly inspected on a link-by-link basis at least once a month. Under no circumstances should a chain be used for hoisting unless it has been closely examined for defects or wear.

Whenever a chain is subjected to shock or impact loads, it must be immediately inspected before being put back into service.

It is recommended that every chain carry a small metal identification tag bearing a serial number and its safe working load.

Every link must be inspected to the following guidelines:

- Clean the chain thoroughly in a solvent solution.
- Lay chain on a clean surface or hang it up. Use a magnifying glass to aid in the inspection.
- Look for elongated or stretched links. Elongation should be determined by measuring all new chains in sections of 1 to 3 ft with a caliper and remeasuring them during each subsequent inspection. If the inspection reveals a stretch of more than 3% (approximately 1/32 per inch), the chain must be removed from service.
- Look for bent, twisted, or damaged links that often occur when the sling is used to lift a load having unprotected sharp edges.
- Look for cracked links. The presence of any crack, regardless of its size, means that the chain is not safe.
- Look for gouges, chips, scores, or cuts in each link. If they are deep or large in area, the chain should be removed from service.
- Look for small dents, peen marks, and bright polished surfaces on the links. These marks indicate that the chain has been work-hardened or fatigued.
- Look for lifted fins at welds. They are evidence of severe overloading and the chain must be destroyed.
- Look for severe corrosion, material loss, or pitting.
- Be particularly careful in determining link wear at the point where each link bears on the others. Safety practices recommend that the chain be replaced when its diameter has been reduced by 2.5% (0.00625 in. for a 1/4-in. chain).

3.2.4 Care and Use

- Use only alloy steel chain marked with an *8* and never exceed the rated safe working load.
- Inspect the chains regularly and destroy those that are defective.
- Know the weight of all loads to avoid accidental overload.
- Avoid impact or shock loading.

- Store chains where they will not be damaged or corroded.
- Never shorten a chain by twisting or knotting it, or by using nuts and bolts.
- When wrapping chain around sharp corners use pads to prevent damage to the links.
- Never use links that are not approved, or makeshift fasteners formed from bolts, rods, etc.
- Never use repair links, mechanical coupling links, or low-carbon steel repair links to splice broken lengths of alloy steel chain.
- Never use a chain when the links are locked, stretched, or without free movement.
- Never hammer a chain to straighten the links or to force links into position.
- Avoid crossing, twisting, kinking, or knotting a chain.
- Never use the tip of a chain hook to carry a load.
- Never weld alloy steel chain links.
- Inspect each link regularly for wear, nicks, gouges, stretch, localized bending, and shearing.
- Make sure the chain is of the correct size and grade for the load.
- Make sure all attachments and fittings are of a type, grade, and size suitable for service with the chain used.
- Make sure that alloy steel chains are never annealed or heat-treated.

3.3 Fiber Ropes

Fiber ropes are made from natural or synthetic fibers. The natural fibers come from plants and include manila, sisal, and hemp. The synthetic fibers include nylon, polypropylene, and the polyesters.

Natural Fiber Ropes

- Manila—The only natural fiber suitable for construction. The six grades of manila ropes most commonly used are
  —Yacht Rope
  —Bolt Rope
  —Number 1 Grade
  —Number 2 Grade
  —Number 3 Grade
  —Hardware Store Rope
- Sisal—These fibers are less durable and lower in strength than manila fibers.

Note: Qualified safety-approved life saving equipment, which may contain natural fiber or synthetic rope, is approved for rescue work by the Safety Department.

Natural fiber ropes may be used for taglines except when they are wet or if the "pick" is near electrical lines.

Synthetic Fiber Ropes

- Nylon (braided nylon rope provides the highest possible strength of the synthetic fiber ropes)
- Polyester (Dacron, Terylene)
- Polypropylene
- Polyethylene

Note: With the exception of synthetic slings (which are discussed in a later section), Safety does not recommend and will not approve the use of slings made of synthetic or natural fiber ropes.

All ropes will conduct electricity when they are wet. However, polyester, polyethylene, and polypropylene ropes all have good and consistent insulating properties under conditions of low or high humidity. Nylon is *not* recommended where insulation against high voltages is required.

Note: Use only dry fiber ropes for taglines—never use wire ropes. Always use taglines when the pick is near electrical lines.

3.4 The Hook and Under

3.4.1 The Hook

Refer to ANSI B30.10.

Hooks are made in many different configurations. There are load hooks and there are sling hooks. The types most normally used with load blocks are the eye, shank, clevis, and duplex (double) hooks. If the load block should have a duplex hook, both hooks must share the weight of the load. The selection of the sling hook depends on the type of pick to be made. Sorting, clevis, eye, shank, grab, foundry, and plate are some of the hooks available. See Section 3.4.4, Hardware.

The primary "hook" is the load or hoisting hook and it must have a safety latch. Hooks used as part of the end fittings on slings are considered secondary hooks and normally do not (but should) have safety latches.

Hook material shall have sufficient ductility to deform permanently before failure. Proof-test loads for hooks shall be conducted at 200% of the rated load and held for 15 seconds. The permanent increase in throat opening during proof-load testing shall not exceed 0.5% or 0.010 in., whichever is greater.

The manufacturer's identification should be shown on the hook in a low-stress, nonwearing area.

3.4.1.1 Inspection

Inspection of hooks should be conducted with no less attention than that accorded other parts of the rigging family. Record keeping should be as much a part of the inspection requirements as it is with the Frequent and Periodic Inspections.

Frequent Inspections require visual examinations at least monthly. Periodic Inspections under normal service should be made annually. Hooks in regular service should be frequently inspected visually for distortion (bending, twisting, or increased throat opening), wear, cracks, severe nicks, gouges, damaged or malfunctioning latch, and hook attachment and securing means.

During Periodic Inspections, the distortion should be measured and recorded. Load block hooks should be inspected every five years by x ray, dye penetrant, magnetic flux, or other flaw-detection methods.

Hooks with any of the following deficiencies shall be removed from service:

- Cracks
- Wear exceeding 10% of the original dimension
- A bend or twist exceeding 10° from the plane of the unbent hook
- An increase in throat opening exceeding 15% for nonlatched hooks and 8% for latched hooks.

3.4.1.2 Maintenance

Damaged, corroded, or bent hooks shall be repaired or replaced. If repairs can be made to a hook, they must be performed by the manufacturer.

3.4.2 Slings

Refer to ANSI B30.9.

All slings shall be inspected prior to use and at least annually by the person in charge or other designated individual.

Slings require special attention because they are almost always subjected to severe wear, abrasion, impact loading, crushing, kinking, and overloading. They also merit special attention because seemingly insignificant changes in sling angle (hitches) drastically affect the loading imposed on the sling legs.

Slings should be load tested after purchase (for compliance and for establishment of base test data) and shall be tested thereafter in accordance with the requirements of Article 4.6.3.2 of the SNL *Safety Manual* (SAND81-1807) and ANSI B30.9.

The *Safety Manual* specifies that "load proof-testing is required when visual inspections find excessive abrasion, wear, or reduced cross section of any type of rigging equipment. In addition, rigging equipment used in areas of frequent stress or exposure to heat, fumes, acids, or other chemicals must be load tested annually. It is recommended that all other rigging equipment be load tested every four years."

ANSI B30.9 specifies that slings shall be load proof-tested at 200% of the rated load. Any master link to which multiple leg slings are connected shall be proof loaded to 2 times the force applied by the combined legs.

See Appendix H for the Load Test Record Sheet for all slings.

When using slings, exercise extreme caution because unknown loads and stresses will develop under less-than-ideal circumstances with less-than-perfect equipment.

The term *sling* includes a wide variety of configurations for all fiber ropes, wire ropes, chains, wire meshes, and webs. The most commonly used types of slings will be considered here because improper application can affect the safety of the pick.

3.4.2.1 Wire Rope Slings

Refer to the Wire Rope section above and to ANSI B30.9, Chapter 9-2, for additional information about wire rope.

Properly fabricated wire rope slings are the safest type available for general use. They do not wear as rapidly as fiber rope or synthetic slings and they are not susceptible to the weak-link ailment of chains. The true condition of wire rope slings can be determined by inspection because the appearance of broken wires clearly indicates the extent of fatigue, wear, abrasion, corrosion, etc.

It is recommended that all wire rope slings used at SNLA be made of improved plow steel (IPS) or, better, with independent wire rope cores (IWRC) to reduce the possibility of the rope being crushed in service. However, fiber core wire rope slings are acceptable.

Plant Maintenance no longer fabricates wire rope slings on Telecon or Plant Engineering Change Request orders. Therefore, all required wire rope slings must be purchased from commercial sources to specified requirements. Safety approves of this action and will not tolerate any wire rope slings made with clips, by the hand-tucked method, or any other method made by staff or lab personnel.

Note: It is recommended that all eyes in wire rope slings be equipped with thimbles, that the eyes be formed with the Flemish Splice, and the splice be secured by swaged or pressed mechanical sleeves or fittings.

This method produces an eye that develops almost 100% of the catalog strength of the rope and provides some reserve strength should the mechanical sleeve or fitting fail or loosen.

Note: Be very cautious when lowering a wire-rope-sling rigged load to a rest position if it will be raised again without adjusting the rigging. If a wire rope sling becomes slack, it can twist when the tension is relieved and the thimble may rotate up and over the tip of the hook. When the hook is raised, the thimble, which now rests on the hook latch, will pull free, thus creating a safety hazard.

The maximum safe working load (MSWL) limit and identification numbers shall be conspicuously marked on each sling. If the data cannot be marked on the sling, it shall be stamped on a metal tag that is attached to the sling.

Inspection of Wire Rope Slings

Frequent Inspection

Wire rope slings shall be visually inspected before initial daily use. Check for

- Distortion such as kinking, crushing, unstranding, "bird-caging," strand displacement, or core protrusion
- General corrosion
- Broken or cut wires (do not inspect a sling by passing bare hands over the wire rope body)
- Number, distribution, and type of visible broken wires
- Abrasion or scraping
- Evidence of heat damage
- End attachments.

Periodic Inspection

Inspection should be based on frequency of sling use, severity of service conditions, and the nature of lifts being made. Periodic Inspection should include

- Entire length of sling, splices, end attachments, and fittings
- Broken wires (10 in one rope lay, or 5 in one strand in one rope lay)
- Severe abrasion or scraping
- Kinking, crushing, "bird-caging," or other distortion
- Heat damage
- End attachments (for cracking, deformation, or extensive wear)
- Severe corrosion.

See Appendix I for the Field Inspection Check Sheet, Wire Rope Slings.

Use of Wire Rope Slings

Choose wire rope slings having suitable characteristics for the type of load, hitch, and environment in accordance with the appropriate tables.

When a wire rope sling is rigged as a basket, the *diameter* of the bend where a sling contacts the load can be a limiting factor on sling capacity. Standard D/d ratios (D is the diameter of the bend; d is the diameter of the wire rope sling) are applied to determine efficiency of various sling constructions.

As a general policy and one easily remembered, the SNLA Safety Department recommends that no pick be made with wire rope slings when the diameter of the load will produce a D/d ratio that is less than 20 for mechanically spliced, single-part wire rope slings.

For example: A 1/2-in. (d) wire rope sling can safely hoist a load that has a 40-in. diameter (D).

D = 20 divided by 1/2-in. = 20 × 2-in. = 40-in.

The D/d ratio also affects the choker hitch and, therefore, the rated capacity of IWRC and fiber core wire rope must be reduced according to the angle of choke that results when the sling is drawn tight at the eye nearest the load and then is pulled against the thimble in an arc toward the load. This configuration is one that might be used to shift, turn, rotate, or control a load, or when the pull is against the choke in a multileg lift. See Figure 37 for choker angles.

The percentages of choker hitch rated capacity adjustment, or choker efficiency figures, are shown in Table 6. They should be used in the Single Choker Hitch and Double Choker Hitch "rule-of-thumb" formulas shown in Section 3.5.5 for Safe Working Loads.

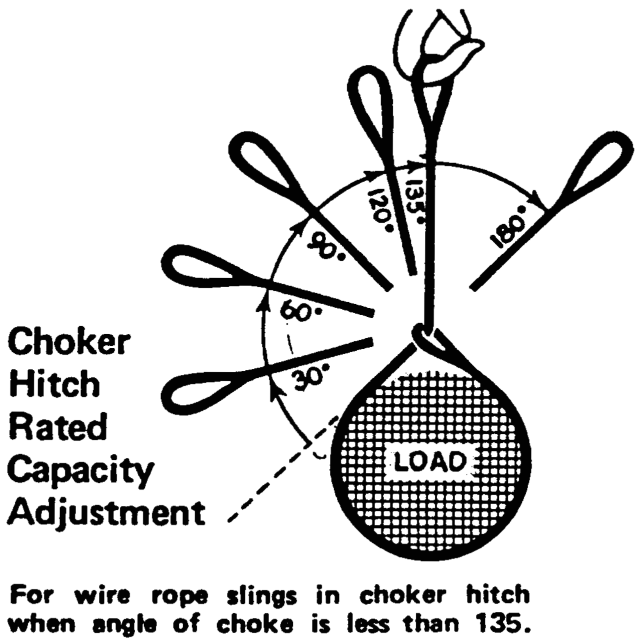


Figure 37. Choker Angles[4]

Table 6. Choker Efficiency Percentages

Choker Hitch Rated Capacity Adjustment Data

Angle of Choke (°)	Reduce Sling Rated Capacity by (%)
120–180	100
90–119	87
60–89	74
30–59	62
0–29	49

- Weight of load shall be within the rated load capacity of the sling.
- Slings shall not be shortened or lengthened by knotting, by wire rope clips, or other methods not approved by the sling manufacturer.
- The sling shall be hitched in a manner providing control of the load.
- All portions of the human body shall be kept from between the sling and the crane hook or hoist hook.
- Personnel shall stand clear of the suspended load.
- Personnel shall not ride the sling or load.
- Shock loading shall be avoided.
- Sharp corners in contact with the sling shall be padded.
- Slings shall be stored in a manner that will prevent damage, corrosion, wear, kinking, heat damage, or moisture accumulation.
- Sling legs shall not be twisted or kinked.
- The sling load shall be seated firmly in the hoist hook.
- Personnel shall be alert for snagging of the load while it is being raised.
- In a basket hitch, the load should be balanced to prevent slippage.
- The sling's legs should support their individual share of the load.
- Multiple leg slings shall be selected and used for specific angles.
- Slings shall not be dragged over abrasive surfaces.
- In a choker hitch, slings shall be long enough so that the choker fitting chokes on the wire rope body and never on the fitting.
- Do not use degreasing or solvent liquids on fiber core wire rope slings.
- Care should be taken to minimize sling rotation.

See Tables 14, 15, 16, and 17 (Section 3.5.5) for the MSWLs for wire rope sling hitches.

3.4.2.2 Metal Mesh Slings

Refer to ANSI B30.9, Chapter 9-3.

Wire or chain mesh slings are well adapted for use where the loads are abrasive, hot, or tend to cut fabric slings and wire ropes. They grip the load firmly without stretching and can withstand temperatures of up to 550°F. They have smooth flat bearing surfaces, they conform to irregular shapes, they do not kink or tangle, and they resist corrosion.

For handling materials that could damage the mesh, or for handling loads with finishes that the mesh could damage, the sling can be coated with rubber or plastic.

Inspection of Metal Mesh Slings

Frequent Inspection

Metal mesh slings shall be visually inspected before each daily use. Inspection criteria shall be

- Distortion such as kinking, crushing, etc.
- General corrosion

- Broken or cut wires or links
- Abrasion or scraping
- Evidence of heat damage
- End attachments.

Periodic Inspection

Inspection should be made annually unless severity of service, environmental conditions, and the nature of lifts being made require more frequent inspections.

Metal mesh slings shall be removed from service if the following deficiencies are visible:

- Broken weld or broken brazed joint along the sling edge
- Broken wire or link in any part of the mesh
- Reduction in wire or link diameter of 25% due to abrasion or 15% due to corrosion
- Lack of flexibility due to distortion of the mesh
- Distortion of the choker fitting when the depth of the slot is increased by more than 10%
- Distortion of either end fitting when the width of the eye opening is decreased by more than 10%
- A 15% reduction of the original cross-sectional area of metal at any point around the hook opening of end fitting
- Visible distortion of either end fitting out of its plane
- Cracked end fitting.

See Appendix J for the Field Inspection Check Sheet, Wire Mesh Slings.

Use of Wire Mesh Slings

Choose wire mesh slings having suitable characteristics for the type of load, hitch, and environment in accordance with the appropriate tables.

- Weight of load shall be within the rated load capacity of the sling.
- Do not shorten or lengthen slings by methods not approved by the manufacturer.
- The sling shall be hitched in a manner providing control of the load.
- Personnel shall stand clear of the suspended load.
- Personnel shall not ride the sling or load.
- Shock loading shall be avoided.
- Sharp corners in contact with the sling shall be padded.
- Slings shall be stored in a manner that will prevent damage, corrosion, moisture, heat, or kinking.
- In a choker hitch, slings shall be long enough so that the choker fitting chokes on the wire mesh and never on the other fitting.
- Slings should not be pulled from under a load when the load is resting on the sling.
- Personnel shall be alert for snagging of the load while it is being raised.
- In a basket hitch, balance the load to prevent slippage.
- Mesh slings used in pairs should be attached to a spreader beam.
- A sling in which the spirals are locked or without free articulation shall not be used.
- Slings shall not be dragged over abrasive surfaces.
- Never hammer a sling to straighten a spiral or cross rod or to force a spiral into position.

Refer to Table 18 (Section 3.5.5) for the MSWLs for wire mesh sling hitches.

3.4.2.3 Chain Slings

Refer to ANSI B30.9, Chapter 9-1.

Chain slings find application in areas where the primary requirements are ruggedness, abrasion resistance, and high temperature resistance. Because of their susceptibility to sudden failure, however, they should not be used if it is possible to use wire rope or other materials.

The only chain suitable for overhead lifting is fabricated from alloy steel and identified by a number 8 stamped on each link.

Inspection of Chain Slings

Frequent Inspection

Chain slings shall be visually inspected before each initial daily use. The sling shall to be subjected to Periodic Inspection if it exhibits any of the deficiencies mentioned below.

- Chain and attachments shall be inspected for wear, nicks, cracks, breaks, gouges, stretch, bends, weld splatter, discoloration from excessive temperature, and throat opening of hooks.
- Chain links and attachments should hinge freely and seat properly without evidence of permanent distortion.

- Latches on hooks should hinge freely and seat properly without evidence of permanent distortion.

Periodic Inspection

Complete link-by-link inspections of the slings shall be performed annually.

- Each link and each attachment shall be examined individually, taking care to expose inner link surfaces of the chain and attachments to inspect for the items defined under Frequent Inspection.
- Worn links should not exceed values shown in Table 7 or the value specifically recommended by the manufacturer.
- Sharp transverse nicks and gouges should be removed by grinding, and the depth of the gouge or ground-out portion should not exceed the values shown in Table 7.
- Hooks should be inspected in accordance with the requirements in The Hook (Section 3.4.1) and ANSI B30.10.
- Latches should seat properly, rotate freely, and show no permanent distortion.
- Chain slings should be load tested at 200% of the rated capacity in accordance with the requirements of the SNL *Safety Manual* (SAND81-1807) and ANSI B30.9, Chapter 9-1.

Table 7. Maximum Allowable Wear

Nominal Chain or Coupling Link Size (in.)	Maximum Allowable Wear of Cross-sectional Diameter (in.)
9/32	3/64
3/8	5/64
1/2	7/64
5/8	9/64
3/4	10/64
7/8	11/64
1	12/64
1-1/4	16/64

See Appendix K for the Field Inspection Check Sheet, Chain Slings.

Use of Chain Slings

Any hazardous condition disclosed by the inspection results shall be corrected before use of the chain sling is resumed.

Padding should be used with chain slings to protect the chains and also to protect the material being moved.

Care should be taken when a chain sling is used in the "single choker hitch" configuration. Place the hook around the chain instead of the tip of the hook in a link of the chain. If the chain hook is placed with the tip in a link, the capacity is reduced by 25%. Also, there is a good possibility that the hook will be ruined by the spreading of the throat opening.

Care should also be taken when a chain sling is used in the "single basket hitch" configuration. Again, do not place the hook's tip in a link of the chain, for the same reason given above. Instead, place the hook in the master link. This hookup will not reduce the capacity and will not damage the hook.

Mechanical coupling links or carbon steel repair links shall not be used to repair or replace broken links of alloy chain.

- Slings having suitable characteristics for the type of load, hitch, and environment shall be selected in accordance with Table 4 (Section 3.2.2) and Table 19 (Section 3.5.5). The chain manufacturer shall be consulted about reduced working load limits if the chain becomes heated to a temperature in excess of 600°F, or if the chain sling is to be used in temperatures lower than −40°F.
- The weight of the load shall be within the rated load of the sling.
- Chain slings shall not be shortened or lengthened by knotting, twisting, or by other methods not approved by the sling manufacturer.
- Slings that appear to be damaged shall not be used unless inspected and accepted as usable under the requirements of the Periodic Inspection.
- The sling shall be hitched or rigged in a manner providing control of the load.
- Personnel shall stand clear of the suspended load.
- Personnel shall not ride the load or sling.
- Shock or impact loading shall be avoided.

- Chain slings shall not be pulled from under a load when the load is resting on the sling.
- Chain slings should be stored in an area where they will not be subjected to mechanical damage, corrosive action, moisture, extreme heat, or kinking.
- Twisting and kinking the legs of the sling shall be avoided.
- The load shall be applied to the center of the bowl of the hook to prevent loading of the tip.
- During lifting, with or without a load, personnel shall be alert for possible snagging.
- In a basket hitch, the load should be balanced to prevent slippage.
- All of the legs of the sling should support the load so that it remains under control, with each leg carrying its share of the weight.
- Slings should not be dragged on the floor or over an abrasive surface.
- Slings should be long enough so that the rated load is adequate when the angle of the legs is taken into consideration.
- When used in a choker hitch arrangement, slings shall be selected to prevent the load developed on any portion of the sling from exceeding the rated load of the sling components.

Refer to Table 19 (Section 3.5.5) for the MSWLs for chain sling hitches.

3.4.2.4 Synthetic Web Slings

Refer to the *Recommended Standard Specification for Synthetic Web Slings*, Web Sling Association, 1978 issue or later, and to ANSI B30.9, Chapter 9-5.

There are a number of advantages in using synthetic web slings for rigging purposes:

- They are relatively soft and the width causes less tendency to mar or scratch finely machined, highly polished or painted surfaces and they have less tendency to crush fragile objects than do wire rope, chain, or wire mesh slings. Their softness precludes cuts, punctures, or skin abrasions, and the occurrence of a bruise by a free-swinging web sling is minimal.
- Synthetic web slings are flexible and they tend to mold themselves to the shape of the load.
- They are not affected by moisture and certain chemicals.
- They are rust-proof; therefore, they do not stain the pick.
- They are nonsparking and can be used safely in explosive atmospheres.
- They are stable and minimize twisting and spinning during lifting.
- They are lightweight, which permits ease of rigging.
- Synthetic web slings are elastic and stretch under load more than either wire rope or chain, and thus are able to absorb heavy shocks.

There are also a number of disadvantages:

- Web sling stretch may be a disadvantage.
- They are subject to ultraviolet degradation.
- They can be cut easily by sharp edges.
- They can be damaged by high temperature.
- They are easily abraded.
- They are easily soiled.

During picks where sling stretching must be kept to a minimum, a web sling of larger load capacity or a polyester sling should be used.

There are three basic configurations and six types of web slings:

- *Standard Eye and Eye Sling.* Eyes are provided at each end of the sling. Eye widths may vary. Type I has a triangle end fitting on one end and a slotted triangle choker fitting on the other. Type II has triangle fittings on both ends.
- *Twisted Eye Sling.* This type of sling is similar to the standard eye and eye sling but the webbing of the eye is twisted about 90° to the plane of the sling body. Eye widths may vary. Type IV has loop eyes that are turned right angle to the plane of the sling body. Type VI has two reversed eyes that are formed by using multiple widths of webbing constructed edge to edge, overlapped by wear pads.
- *Endless or Grommet Sling.* This sling is constructed to form a continuous belt. It is suitable for vertical, bridle, choker, or basket hitches. Wear can be evenly distributed because the load contact points can be shifted with every pick. Type V is a continuous loop formed by joining the ends of the webbing together with a splice.

Web slings can be obtained with protective devices such as buffer strips of leather, edge guards, sleeve or sliding tube-type wear pads, reinforcing strips, and coatings. Coatings can be colored for safety or for load-rating purposes.

Inspection of Synthetic Web Slings

Frequent Inspection

Web slings shall be visually inspected before each initial daily use. A web sling shall be removed from service if damage is visible and shall be returned to service only when approved by an authorized inspector or the manufacturer. The sling shall be subjected to Frequent Inspection if it exhibits any of the deficiencies listed below.

- 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
- Cracked, distorted, broken, or excessively pitted or corroded fittings
- Other visible damage that causes doubt as to the strength of the sling.

Periodic Inspection

Periodic Inspections shall be conducted at least annually by inspecting the slings in accordance with the requirements of the Frequent Inspections.

Web slings should be load tested at 200% of the rated capacity in accordance with the requirements of the SNL *Safety Manual* (SAND81-1807) and ANSI B30.9, Chapter 9-1.

See Appendix L for the Field Inspection Check Sheet, Synthetic Web Slings.

Use of Synthetic Web Slings

- Care must be taken to select the correct web sling according to the maximum safe working load rating, type of webbing material, type of hitch to be used, and the weight of the pick.
- The weight of load shall be within the rated load capacity of the sling.
- Slings shall not be shortened or lengthened by knotting or other methods not approved by the sling manufacturer.
- Slings that appear to be damaged shall not be used unless inspected and accepted in accordance with the requirements shown under Frequent Inspection.
- The sling shall be hitched in a manner providing control of the load.
- Sharp corners in contact with the sling should be padded with material of sufficient strength to minimize damage to the sling and to the load.
- All portions of the human body should be kept from between the sling and the load, and from between the sling and the crane hook or hoist hook.
- Personnel should stand clear of the suspended load.
- Personnel shall not ride the sling of the load.
- Shock or impact loading should be avoided.
- Slings should not be pulled from under a load when the load is resting on the sling.
- Slings should be stored in a cool, dry, and dark place to prevent environmental damage.
- Twisting and kinking the legs shall be avoided.
- The load shall be applied to the center of the bowl of the hook to prevent loading of the tip.
- In a basket hitch, the load should be balanced to prevent slippage.
- During lifting, with or without a load, personnel shall be alert for possible snagging.
- The sling's legs should contain or support the load from the sides above the center of gravity when using a basket hitch.
- Slings should be long enough so that the rated load capacity is adequate when the angle of the leg is taken into consideration.
- Slings should not be dragged on the floor or over an abrasive surface.
- In a choker hitch, slings shall be long enough so that the choker fitting chokes on the webbing and never on the other fitting or stitching.
- Nylon and polyester slings shall not be used at temperatures exceeding 194°F.
- When nylon or polyester web slings are extensively exposed to sunlight or ultraviolet light resulting in loss of strength, the sling manufacturer should be consulted for recommended inspection procedures.

See Tables 20, 21, or 22 (Section 3.5.5) for the MSWLs for the various types of synthetic web slings and hitches.

3.4.2.5 Fiber Rope Slings

Slings made of synthetic or natural fiber ropes shall not be used for hoisting.

3.4.3 Lifting Devices

Refer to ANSI B30.20, Below the Hook Lifting Devices.

Everything that must be moved by a crane or hoist cannot be hoisted by sling alone because of shape, type of material, or potential damage. Special design items such as "strong backs" (SNL designs many of these), spreader beams, equalizer beams, drum turners, vacuum and magnetic lifters, clamps, tongs, etc., fall in this category. Many of these devices will never be used at SNL because there is no need for such specifically designed items. However, if a special lifting device is required, refer to the referenced ANSI standard for inspection, operation, and maintenance criteria.

Should a pick have shoulderless eye bolts as its only attachment points, it is recommended that one of the following lifting devices be used instead of a multileg sling in a bridle hitch configuration.

3.4.3.1 "Strong Backs"

All of the SNL specially designed "strong backs" are designated as *H* items. They are designed to be attached to a load at certain attachment points, which makes the handling and packaging easier, safer, and reduces the chance of damage to the load.

Special types of lifting devices such as "C" hooks (to transport rolls of paper), drum turners (to handle 50-gal drums), and lifting beams (similar to the spreader bar) may be used in the Print Shop, Foundry, or Metal Storage Area.

3.4.3.2 Spreader Beams

Spreader beams (Figure 38) are used to support long loads during lifts. They eliminate the hazard of the load tipping, sliding, or bending, also the possibility of low sling angles and the tendency for the slings to crush the load.

3.4.3.3 Equalizer Beams

Equalizer beams (Figure 39) are used to equalize the load in sling legs and to keep equal loads on dual hoist lines when making tandem lifts. The hook location in the equalizer beam can be shifted in relation to the center of gravity in order to keep the pick level.

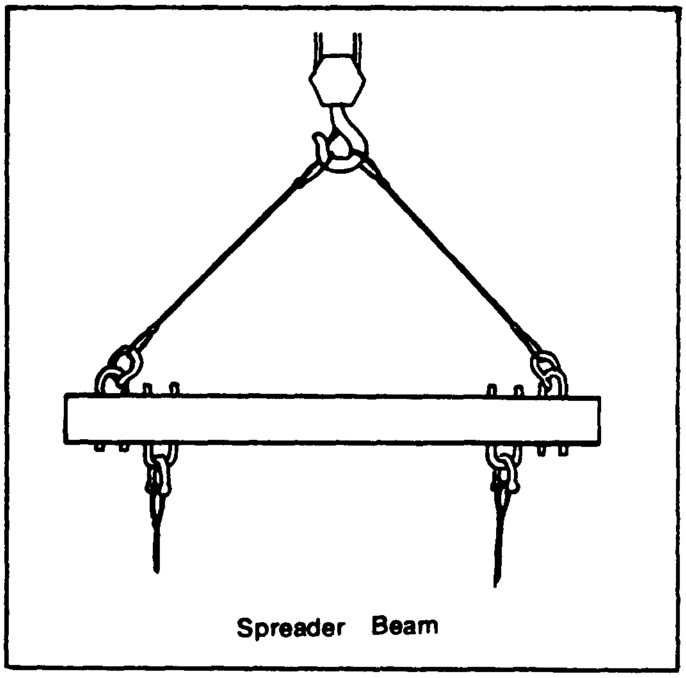


Figure 38. Spreader Beam[2]

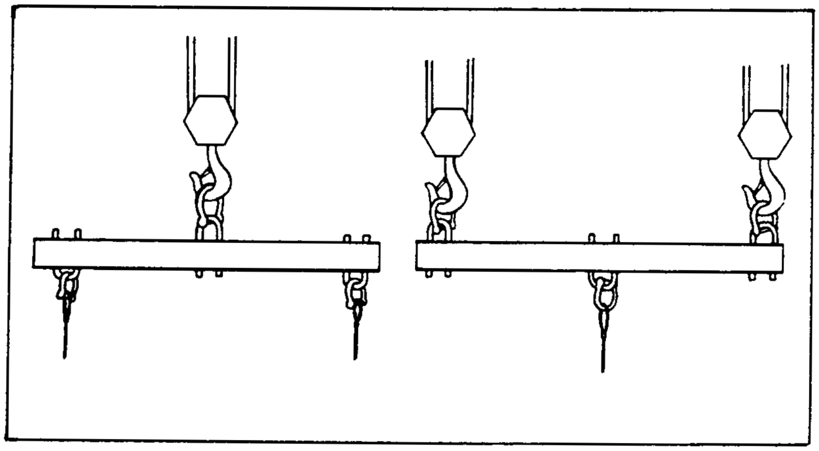


Figure 39. Equalizer Beam[2]

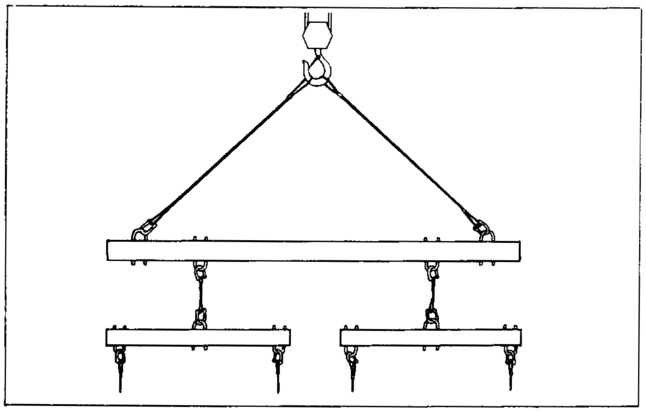


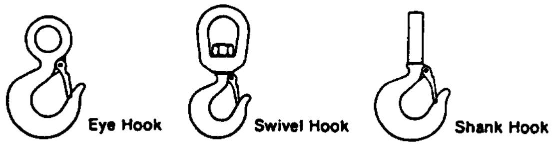
Figure 40. Combination Spreader/Equalizer Beam[2]

3.4.4 Hardware

Rigging hardware consists of the interface items that promote easy rigging practices with the assurance of safer handling. Hardware items are hooks, rings, links, swivels, shackles, clevises, turnbuckles, and eye bolts. The configuration of these items can be seen in the following tables.

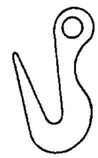
Table 8. MSWL/Hooks[2]

EYE HOOKS, SHANK HOOKS, SWIVEL HOOKS
FORGED ALLOY STEEL
(SAFETY FACTOR = 5)



Throat Opening (Inches)	Maximum Safe Working Load (Pounds)
5/8	600
11/16	800
1	1,500
1 1/16	2,000
1 1/8	2,500
1 1/4	4,000
1 3/8	4,500
1 13/32	5,000
1 1/2	5,500
1 17/32	6,000
1 11/16	6,800
1 25/32	8,000
1 7/8	8,400
1 15/16	10,000
2 1/16	10,400
2 1/8	11,000
2 1/4	12,500
2 5/16	13,000
2 1/2	16,000
2 9/16	18,000
3	19,200
3 1/16	20,000
3 3/8	24,000
3 7/16	26,000
4	33,400

TYPICAL SORTING HOOK
FORGED ALLOY STEEL



I.D. of Eye	1 1/4"
Opening at Top of Hook	2 13/16"
Safe Working Load 2 1/2" From Tip	2 Tons
Safe Working Load at Bottom of Hook	7 1/2 Tons

CHAIN GRAB HOOKS
(CLEVIS TYPE AND EYE TYPE)
FORGED ALLOY STEEL

Throat Opening (Inches)	For Size of Chain (Inches)	Maximum Safe Working Load (Pounds)
11/32	1/4	2,750
7/16	5/16	4,300
1/2	3/8	5,250
9/16	7/16	7,000
21/32	1/2	9,000
25/32	5/8	13,500
15/16	3/4	19,250
1 1/16	7/8	26,000
1 3/16	1	34,000

CHAIN SLIP HOOKS
(CLEVIS TYPE AND EYE TYPE)
FORGED ALLOY STEEL
(SAFETY FACTOR = 4)

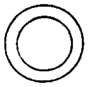
Throat Opening (Inches)	For Size of Chain (Inches)	Maximum Safe Working Load (Pounds)
15/16	1/4	2,750
1 1/16	5/16	4,300
1 5/16	3/8	5,250
1 9/16	7/16	7,000
1 11/16	1/2	9,000
2	5/8	13,500
2 1/8	3/4	19,250
2 3/4	7/8	26,000
3	1	34,000

SLIDING CHOKER HOOKS
FORGED ALLOY STEEL
(SAFETY FACTOR = 5)

Throat Opening (Inches)	For Rope Size (Inches)	Maximum Safe Working Load (Pounds)
1/2	1/4 - 5/16	1,500
5/8	3/8	2,600
7/8	1/2	3,400
1 1/8	5/8	5,100
1 1/8	3/4	8,000
1 7/16	7/8 - 1	15,000
1 3/4	1 1/8 - 1 1/4	23,000
2 3/16	1 3/8 - 1 1/2	30,000

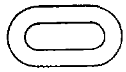
Table 9. MSWL/Rings, Links/Swivels[2]

RINGS
— Weldless Construction
— Forged Alloy Steel



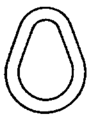
Stock Diameter (Inches)	Inside Diameter (Inches)	Maximum Safe Working Load (Pounds)
7/8	4	7,200
7/8	5 1/2	5,600
1	4	10,800
1 1/8	6	10,400
1 1/4	5	17,000
1 3/8	6	19,000

END LINKS
— Weldless Construction
— Forged Alloy Steel



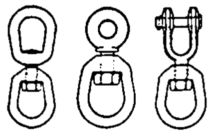
Stock Diameter (Inches)	Inside Width (Inches)	Maximum Safe Working Load (Pounds)
5/16	1/2	2,500
3/8	9/16	3,800
1/2	3/4	6,500
5/8	1	9,300
3/4	1 1/8	14,000
7/8	2	12,000
1	2 1/4	15,200
1 1/4	2 1/2	26,400
1 3/8	2 3/4	30,000

PEAR SHAPED LINKS
(Sling Links)
— Weldless Construction
— Forged Alloy Steel



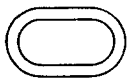
Stock Diameter (Inches)	Inside Length (Inches)	Maximum Safe Working Load (Pounds)
3/8	2 1/4	1,800
1/2	3	2,900
5/8	3 3/4	4,200
3/4	4 1/2	6,000
7/8	5 1/4	8,300
1	6	10,800
1 1/4	7 3/4	16,750
1 3/8	8 1/4	20,500

SWIVELS (ALL TYPES)
— Weldless Construction
— Forged Alloy Steel



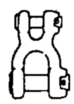
Stock Diameter (Inches)	Max. Safe Working Load (Pounds)
1/4	850
5/16	1,250
3/8	2,250
1/2	3,600
5/8	5,200
3/4	7,200
7/8	10,000
1	12,500
1 1/8	15,200
1 1/4	18,000
1 1/2	45,200

MASTER LINKS
— Weldless Construction
— Forged Alloy Steel



Stock Diameter (Inches)	Inside Width (Inches)	Maximum Safe Working Load (Pounds)
1/2	2 1/2	3,250
5/8	3	4,400
3/4	2 3/4	7,000
1	3 1/2	16,500
1 1/4	4 3/8	25,000
1 1/2	5 1/4	35,500
1 3/4	6	44,500
2	7	57,500

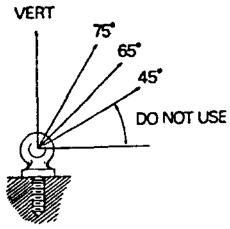
DOUBLE CLEVIS LINKS
— Weldless Construction
— Forged Alloy Steel



Small Pin Diameter (Inches)	Large Pin Diameter (Inches)	Maximum Safe Working Load (Pounds)
5/16	1/2	3,250
7/16	5/8	6,600
9/16	11/16	8,750
5/8	3/4	11,250

Table 10. MSWL/Eye Bolts/Turnbuckles/Shackles[2]

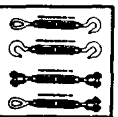
EYE BOLTS
— Shoulder Type Only
— Forged Carbon Steel



Stock Diameter (Inches)	SAFE WORKING LOADS (LBS) CORRESPONDING TO ANGLE OF PULL				
	Vertical	75°	60°	45°	Less than 45°
1/4	500	Reduce Vertical Loads By 45%.	Reduce Vertical Loads By 65%.	Reduce Vertical Loads By 75%.	NOT RECOMMENDED
5/16	800				
3/8	1,200				
1/2	2,200				
5/8	3,500				
3/4	5,200				
7/8	7,200				
1	10,000				
1 1/4	15,200				
1 1/2	21,400				

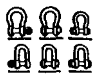
Note: S.W.L. for plain (shoulderless) eye bolts are same as for shoulder bolts under vertical load. Angular loading is not recommended.

TURNBUCKLES
— Weldless Construction
— Forged Alloy Steel



End Fitting, Stock Diameter (Inches)	SWL of Any Combination of Jaw End Fittings, Eye End Fittings and Stub End Fittings (Lbs)	SWL of Any Turnbuckle Having a Hook End Fitting (Lbs)
1/4	500	400
5/16	800	700
3/8	1,200	1,000
1/2	2,200	1,500
5/8	3,500	2,250
3/4	5,200	3,000
7/8	7,200	4,000
1	10,000	5,000
1 1/4	15,200	5,000
1 1/2	21,400	7,500
1 3/4	28,000	—
2	37,000	—
2 1/2	60,000	—
2 3/4	75,000	—

SHACKLES (ALL TYPES)
— Weldless Construction
— Forged Alloy Steel



Stock Diameter (Inches)	Inside Width At Pin (Inches)	Max. Safe Working Load Single Vertical Pull (Pounds)
3/16	3/8	665
1/4	15/32	1,000
5/16	17/32	1,500
3/8	21/32	2,000
7/16	23/32	3,000
1/2	13/16	4,000
5/8	1 1/16	6,500
3/4	1 1/4	9,500
7/8	1 7/16	13,000
1	1 11/16	17,000
1 1/8	1 13/16	19,000
1 1/4	2 1/32	24,000
1 3/8	2 1/4	27,000
1 1/2	2 3/8	34,000
1 3/4	2 7/8	50,000
2	3 1/4	70,000
2 1/2	4 1/8	100,000
3	5	150,000
3 1/2	5 3/4	200,000
4	6 1/2	260,000

Please observe the following safety precautions when *rigging any pick with selectable hardware items.*

- Refer to Section 3.4.1, The Hook, for additional information concerning load block hooks and hook deficiencies.
- Grab hooks shall be removed from service when the portions of the hook that form the throat are not parallel.
- Select hardware items of adequate size to ensure that the MSWL is not exceeded.
- All hoisting hooks, except the grab and sorting type, should be equipped with safety latches.
- Always rig the pick so that the load is carried by the bowl or crown of the hook—never by the tip of the hook.
- Never replace a shackle pin with a bolt.
- Never use a shackle if the inside width at the pin exceeds the values listed in the MSWL table for shackles.
- All shackle pins must be straight.
- All shackle screw pins must be seated tightly.
- Cotter pins must be used with all round pin shackles.
- Shackles worn in the crown of the pin by more than 10% of the original diameter should be destroyed.
- Never allow a shackle to be pulled at an angle. The legs can be pulled apart and the capacity will be reduced tremendously.
- Centralize the load on the pin by using suitable washers for spacers.
- Do not use screw pin shackles if the pin can roll under the load and unscrew.
- All turnbuckles used in hoisting or rigging operations should be of weldless construction and fabricated from alloy steel.
- Hook end fittings should be fitted with safety latches.
- If turnbuckles are used in applications where vibration or sling twist is present, lock the frame to the end fittings with wire to prevent it from turning and loosening.
- Do not use lock nuts or jam nuts to prevent the turnbuckle end fittings from turning. They are not effective and add greatly to the load on the screw threads.
- When tightening a turnbuckle, do not apply more torque to it than would be applied to a bolt of equal size.
- Turnbuckles should be inspected frequently for cracks in the end fittings, especially at the neck of the shank, for deformed end fittings, for deformed and bent rods and frame, for cracks and bends around the internally threaded portion, and for signs of thread damage.
- All eye bolts and ring bolts used for hoisting should be of forged alloy steel and equipped with shoulders or collars.
- Shoulderless eye bolts may be used only for vertical lifting.
- The MSWLs of eye bolts and ring bolts that have shoulders are severely reduced if they are loaded at an angle.
- When installed, the shoulder of the eye bolt must contact a flat surface and the nuts must be properly torqued.
- Washers may have to be used to ensure that the eye bolt shoulders are firmly in contact with the flat surface.
- The tapped holes for ring bolts should have a minimum depth of 1-1/2 times the bolt diameter and must be a tight fit for the threaded shank of the bolt.
- Never insert the point of a hook in an eye bolt; always use a shackle.
- When using bridle slings, one single leg only should be attached to each eye bolt.
- Do not use a sling reeved through an eye bolt or reeved through a pair of eye bolts.
- The eye of a shouldered bolt should be at right angles to the plane of the leg of a bridle sling. If not, the eye part of the bolt can bend. It may be necessary to place shims under the collar in order to provide the correct orientation of the bolt's eye.
- Spreader beams are preferred to bridle slings provided the pick is made with vertical slings attached to the eye or ring bolts.
- The above precautions apply to ring bolts; the MSWLs are generally the same as for the eye bolts.
- Rings, links, and swivels, like all other hoisting and rigging fittings, must be of forged alloy steel to provide the highest degree of safety.

- The same precautions mentioned above for shackle pins apply to the pins used in links and swivels.
- Never use a C-clamp of any size or quality as a hardware fitting or lifting device for hoisting.

3.5 Duties of the Rigger

3.5.1 Calculating the Load Weight

The most important step in any rigging operation is determining the weight of the load to be hoisted. If this information cannot be obtained from shipping papers, design specifications, catalog data, or from other dependable sources, it must be calculated.

Caution: Shipping papers and other documents can be in error. It may be wise to compare the identified or stated weight with an estimated or calculated weight.

Before estimating the weight of any load, the material, shape, and dimensions must be determined. Then, by calculating the volume of the load, the rigger or operator can multiply the volume by the material's weight per cubic foot to find the estimated weight of the load.

Some loads will contain material for which the weight must be calculated based on square feet rather than cubic feet. Examples of this type of material are glass, corrugated steel sheet, carpeting, and metal studs.

The following tables should be reviewed to find the estimated weight of material, either by volume or surface area, to use in the weight-per-volume or weight-per-area calculations.

Table 11. Weights of Materials Based on Volume[2]

Material	Approximate Weight Lbs. Per Cubic Foot	Material	Approximate Weight Lbs. Per Cubic Foot
METALS		**TIMBER, AIR-DRY**	
Aluminum	165	Cedar	22
Brass	535	Fir, Douglas, seasoned	34
Bronze	500	Fir, Douglas, unseasoned	40
Copper	560	Fir, Douglas, wet	50
Iron	480	Fir, Douglas, glue laminated	34
Lead	710	Hemlock	30
Steel	490	Pine	30
Tin	460	Poplar	30
MASONRY		Spruce	28
Ashlar masonry	140-160	**LIQUIDS**	
Brick masonry, soft	110	Alcohol, pure	49
Brick masonry, common (about 3 tons per thousand)	125	Gasoline	42
Brick masonry, pressed	140	Oils	58
Clay tile masonry, average	60	Water	62
Rubble masonry	130-155	**EARTH**	
Concrete, cinder, haydite	100-110	Earth, wet	100
Concrete, slag	130	Earth, dry (about 2050 lbs. per cu. yd.)	75
Concrete, stone	144	Sand and gravel, wet	120
Concrete, stone, reinforced (4050 lbs. per cu. yd.)	150	Sand and gravel, dry	105
ICE AND SNOW		River sand (about 3240 lbs. per cu. yd.)	120
Ice	56	**VARIOUS BUILDING MATERIALS**	
Snow, dry, fresh fallen	8	Cement, portland, loose	94
Snow, dry, packed	12-25	Cement, portland, set	183
Snow, wet	27-40	Lime, gypsum, loose	53-64
MISCELLANEOUS		Mortar, cement-lime, set	103
Asphalt	80	Crushed rock (about 2565 lbs. per cu. yd.)	90-110
Tar	75		
Glass	160		
Paper	60		

Table 12. Weights of Materials Based on Surface Area[2]

Material	Approximate Weight Lbs. Per Square Foot
CEILINGS	
(Per Inch of Thickness)	
Plaster board	5
Acoustic and fire resistive tile	2
Plaster, gypsum-sand	8
Plaster, light aggregate	4
Plaster, cement sand	12
ROOFING	
Three-ply felt and gravel	5.5
Five-ply felt and gravel	6.5
Three-ply felt, no gravel	3
Five-ply felt, no gravel	4
Shingles, wood	2
Shingles, asbestos	3
Shingles, asphalt	2.5
Shingles, 1/4 inch slate	10
Shingles, tile	14
PARTITIONS	
Steel partitions	4
Solid 2" gypsum-sand plaster	20
Solid 2" gypsum-light agg. plaster	12
Metal studs, metal lath, 3/4" plaster both sides	18
Metal or wood studs, plaster board and 1/2" plaster both sides	18
Plaster 1/2"	4
Hollow clay tile 2 inch	13
3 inch	16
4 inch	18
5 inch	20
6 inch	25
Hollow slag concrete block 4 inch	24
6 inch	35
Hollow gypsum block 3 inch	10
4 inch	13
5 inch	15.5
6 inch	16.5
Solid gypsum block 2 inch	9.5
3 inch	13
MASONRY WALLS	
(Per 4 Inch of Thickness)	
Brick	40
Glass brick	20
Hollow concrete block	30
Hollow slag concrete block	24
Hollow cinder concrete block	20
Hollow haydite block	22
Stone, average	55
Bearing hollow clay tile	23

Material	Approximate Weight Lbs. Per Square Foot
FLOORING	
(Per Inch of Thickness)	
Hardwood	5
Sheathing	2.5
Plywood, fir	3
Wood block, treated	4
Concrete, finish or fill	12
Mastic base	12
Mortar base	10
Terrazzo	12.5
Tile, vinyl 1/8 inch	1.5
Tile, linoleum 3/16 inch	1
Tile, cork, per 1/16 inch	0.5
Tile, rubber or asphalt 3/16 inch	2
Tile, ceramic or quarry 3/4 inch	11
Carpeting	2
DECKS AND SLABS	
Steel roof deck 1 1/2" — 14 ga.	5
— 16 ga.	4
— 18 ga.	3
— 20 ga.	2.5
— 22 ga.	2
Steel cellular deck 1 1/2" — 12/12 ga.	11
— 14/14 ga.	8
— 16/16 ga.	6.5
— 18/18 ga.	5
— 20/20 ga.	3.5
Steel cellular deck 3" — 12/12 ga.	12.5
— 14/14 ga.	9.5
— 16/16 ga.	7.5
— 18/18 ga.	6
— 20/20 ga.	4.5
Concrete, reinforced, per inch	12.5
Concrete, gypsum, per inch	5
Concrete, lightweight, per inch	5-10
MISCELLANEOUS	
Windows, glass, frame	8
Skylight, glass, frame	12
Corrugated asbestos 1/4 inch	3.5
Glass, plate 1/4 inch	3.5
Glass, common	1.5
Plastic sheet 1/4 inch	1.5
Corrugated steel sheet, galv.	
— 12 ga.	5.5
— 14 ga.	4
— 16 ga.	3
— 18 ga.	2.5
— 20 ga.	2
— 22 ga.	1.5
Wood Joists — 16" ctrs. 2 x 12	3.5
2 x 10	3
2 x 8	2.5
Steel plate (per inch of thickness)	40

3.5.2 Determining Center of Gravity

The definition of *center of gravity* or *center of mass* is "the point at which the entire weight of a body may be considered as concentrated so that if supported at this point the body would remain in equilibrium in any position."

The center of gravity (CG) can be easily determined if the shape of the load is geometrically formed and the mass is homogeneous. The determination of the CG for items that are combinations of geometric shapes and nonhomogeneous masses is more difficult.

The rigger (and the operator) must know two important things about the load—its weight and its CG—before a pick can be rigged so that it will remain level and stable during the hoisting operation.

Consider the CG of the following described shapes, all made of homogeneous material:

- The CG of a ball or sphere is at the center, where all radial elements emanating therefrom are of the same length.
- The CG of a cube or rectangular polyhedron (box) is located at the center of each shape midway between the top and the bottom surface, midway between both end surfaces, and midway between both sides. Also, it can be determined by the intersection of two lines passing through two different sets of corners that are the farthest apart diagonally.
- The CG of a cylinder or pipe is on the centerline midway between each end.
- The CG of a pyramid or cone is on the centerline at a point one-fourth of the dimension from the large end to the apex.

The CG can be calculated for odd size items by considering the various shaped parts individually and calculating the location of the CG using a mathematical relationship that is similar to a child's seesaw or teeter-totter. This relationship can be used for areas, volumes, and weight or mass. On a work sheet, draw a letter *J* about 6 in. high. Visualize that it can also have a depth dimension. This means the shape can have either area, volume, or mass depending upon the item you have in mind (see Figure 41).

Before starting the following exercise, estimate the location of the CG of the "J" by drawing a 1/4-in. circle on the work sheet. Divide the "J" into various shapes, and assign a letter to each one. Calculate the area of each shape determined above. Determine the location of the CG of each shape by drawing lines from one corner to the corner diagonally opposite. The CG is located at the intersection of the two lines.

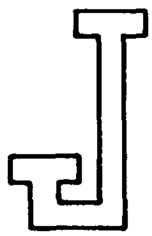


Figure 41. "J" Sketch

Draw a vertical line at the left edge of the "J," about 8 in. long, and mark this line with a "Y." Also, draw a horizontal line at the bottom edge of the "J," about 6 in. long, and mark this line with an "X." Measure the horizontal distances from each individual CG to the *Y* line using a scale of 1/4 in. = 1 ft. Multiply the area of each lettered shape times its scaled dimension to the *Y* line. Add the sums just calculated, which are in cubic feet. Add the various areas of the lettered shapes and divide this sum into the total cubic feet. The resultant dimension, which is in feet, determines the location of the CG of the "J" measured from the *Y* line. Draw this line parallel to the *Y* line.

Do the same type of calculations in a vertical manner from the *X* line. The resultant dimension determines the location of the CG of the "J" measured from the *X* line. Draw this line parallel to the *X* line.

The CG of the "J" is located at the intersection of the two lines.

Using the same game plan, assign a depth dimension to each lettered shape and then calculate the volume of each shape. Multiply the various volumes times the CG-to-*Y* dimensions, and continue the calculations as done above for area. Calculate the *X* to CG dimension and locate the CG of the "J" shape's volume.

Again, using the same game plan, assign a weight-per-cubic-feet to the "J" and calculate the weight of each lettered volume. Multiply the weight of each volume times the CG-to-*Y* dimension, and determine the location of the CG from the *Y* line. Determine the location of the CG from the *X* line.

Compare the various locations of the three calculated centers of gravity of the "J" shape.

Although the above geometric and mathematical exercise is academic, it does serve to establish a mental method for quickly determining the location of the CG of odd-shaped items.

The material handled at Sandia National Laboratories is seldom neatly shaped and homogeneous. But it will probably be packaged in crates that are either cubed- or rectangular-shaped boxes. Other items of various sizes, shapes, and weight are frequently moved by hoist. And the CG of any item may not be at the same location when the same item is hoisted the next time, because of what may have been done to it in the meantime.

From a practical viewpoint the CG of the items that do not have rigging or lifting lug features, or have the CG or lifting instructions marked on the container, must be determined by the "hunt 'n *pick*" method. The rigger, when using this method, must be able to judge or guess the location of the CG fairly accurately so that the hook can be placed directly over it. Adjustments may be necessary after the operator hoists the pick only high enough to determine if the load will remain level and stable.

Note: Remember that any pick where the CG of the load is above the hook or lift points will be unstable.

3.5.3 Selection of Hitch

The tables in Section 3.5.5 on Determining the Safe Working Loads indicate various hitch configurations. The selection of the hitch depends on the type of sling to be used and the type of material, shape, and weight of the load.

Every lift uses one of three basic hitches:

1. *Straight* or vertical hitches are made by using a sling to connect a lifting hook to a load. The full-rated lifting capacity of the sling may be used, but it must not be exceeded. A tagline should be used to prevent load rotation, which may damage the sling.

   When two or more slings are attached to the same lifting hook, the total hitch becomes, in effect, a lifting bridle.

2. *Choker* hitches reduce the lifting capability of a sling since this method of rigging affects the ability of the wire rope components to adjust during the lift. A choker is used when the load will not be seriously damaged by the sling body—or the sling damaged by the load—and when the lift requires the sling to fit snugly against the load.

3. *Basket* hitches distribute a load equally between the two legs of a sling—within limitations shown in a later section. Capacity of a sling used in a basket is affected by the bend, or curvature, where the sling body comes in contact with the load just as any wire rope is affected and limited by bending action, as over a sheave.

The various hitches used in rigging are

- *Single Vertical Hitch.* The total weight of the load is carried by one leg, the angle of the lift is vertical or 90°, and the weight lifted can equal the maximum safe working load (MSWL) of the sling and fittings.

  The single vertical hitch must not be used for lifting loose material, long material, or any material that will be difficult to balance. Use this type of hitch only on items equipped with eye bolts or shackles. Taglines should be used whenever a single vertical hitch is used to make the pick.

- *Bridle Hitch.* Two, three, or four single hitches can be used together to form a bridle hitch for lifting a load that has lifting lugs or attachments. A bridle hitch provides excellent load stability when the load is distributed equally among the legs, when the hook is directly over the center of gravity of the load and the load is raised in a level position. It may be necessary to adjust the leg lengths with turnbuckles. The use of a bridle sling requires that the sling angles be determined very carefully to ensure that the individual legs are not overloaded.

  Note: When hoisting a rigid load using a bridle sling having more than two legs, it is possible for two of the legs to carry the full load while the other legs only balance it.

- *Single Basket Hitch.* This is a method of hoisting a load with a single sling by hooking one end of the sling to the hoist hook, inserting the sling through the load, and securing the other end of the sling to the hoist hook. This hitch cannot be used on a load that is difficult to balance because the load can tilt and slip on the sling.

- *Double Basket Hitch.* Two single slings are used in the single basket hitch configuration to make a double basket hitch. The two slings must be placed under the load so that it is properly balanced. The angle between the load and the sling leg should be approximately 60° or greater to avoid slippage. Proper balance must be maintained in order to make a successful pick.

- *Double-Wrap Basket Hitch.* This hitch can be made by using one single sling, which is wrapped around the load, or by using two single slings wrapped around the load and spaced apart so that each leg will be about 60° from the horizontal. This method is excellent for handling loose material, pipe, rods, or other types of long, slender, smooth material.

- *Single Choker Hitch.* This hitch is made by using a single sling with one eye inserted through the other eye. The loop encircles the load or the hook on one end of the sling is hooked around the vertical length of the sling, thus encircling the load. Or, in place of a hook, a "choker" is placed on the vertical length of the sling and the loose-end eye is hooked onto the choker. The choker slides along the sling and can be used in any position. Single choker hitches are not suitable for handling long, loose types of material.

The single choker hitch can be doubled to provide twice the capacity, or it can be used to turn a load. To turn a load, the choker is made by placing both eyes of the sling on top of the load with the eyes pointing in the direction opposite to the direction of turn. The center of the sling is passed around the load, through both eyes and up to the hook. As the hook is raised, the load is turned. Adjustments can be made to perform continuous turnings of the load.

The diameter of the bend where the sling contacts the load should keep the point of choke against the sling *body* and never against a splice or the base of the eye. When a choke is used at an angle of less than 135°, the sling's rated capacity must be adjusted downward.

A choker hitch should be pulled tightly before a lift is made, *not pulled down during the lift*. It is also dangerous to use only one choker hitch to lift a load that might shift or slide out of the choke.

Refer to Table 6 (Section 3.4.2.1) for choker efficiencies when using wire rope slings.

- *Double Choker Hitch.* This hitch consists of two single chokers attached to the load and spread apart to provide load stability. As with the single choker hitch, these chokers do not completely grip the load. The loads are less likely to tip but the double choker hitches are better suited for handling loose bundles, pipes, and rods.

  The choker hitch efficiencies in Table 6 also apply to the double choker hitch, for the same reasons given above for the single choker hitch.

- *Double-Wrap Choker Hitch.* This hitch consists of a sling that is wrapped completely around the load (the end that is wrapped passes under the load twice) before being hooked onto the vertical part of the sling. An eye and eye sling can also be used by wrapping the sling around the load, passing one eye through the other one, and hooking it over the hoist hook.

- *Endless Sling Hitch.* The endless or grommet sling can be used to rig vertical hitches, basket hitches, choker hitches, and all combinations of the basic hitch configurations.

3.5.4 Determining Sling Angle

The rated capacity of any sling depends on its size, hitch configuration, and the angles formed by the legs of the sling with a horizontal plane. If possible, when using other than the single vertical hitch, rig the pick so that the sling angles are greater than 45°.

Examples:

A 2-leg bridle hitch sling is attached to a 1000-lb load at 60°. The tension in each leg is 577 lb. Should the sling angle be 5° less than the assumed angle of 60°, an error of 5.7% results, causing the tension in each leg to be 610 lb.

The same hitch is used on the same load but the sling angles are 45°. The tension in each leg of the hitch is 707 lb. Should the sling angle be 5° less than the assumed angle of 45°, an error of 9.1% results, causing the tension in each leg to be 778 lb.

The same hitch is used on the same load but the sling angles are 30°. The tension in each leg of the hitch is 1000 lb. Should the sling angle be 5° less than the assumed angle of 30°, an error of 18.3% results, causing the tension in each leg to be 1180 lb.

Safety recommends that all bridle hitches be rigged at 60° or more to eliminate a potential hazard that might be created by too much tension in the bridle legs.

3.5.5 Determining the Safe Working Load

Because of the severe service expected of slings, errors in determining load weight, and the effect of sling angle on the loading, it is recommended that all safe working loads be based on a design factor of at least 5 to 1.

After the pick weight, CG, and hitch configuration are determined, refer to the appropriate tables that follow for the maximum safe working load according to the type of sling used.

Table 13. Hand-Tucked Spliced-Eye Efficiencies[2]

Rope Diameter	Efficiency
1/4" and Smaller	95%
5/16" — 3/4"	90%
7/8" — 1"	85%
1 1/8" — 1 1/2"	80%
1 5/8" — 2"	75%
2 1/8" and Larger	70%

The following "rules of thumb" may be used to estimate the loads for the most common sling hitches. Each of the rules for a given hitch, material, and size is based on the MSWL of the single vertical hitch for that type of sling. Efficiencies of the end fittings should also be used when determining the capacity of the sling combination.

Historically, chain, rope, and web sling angles have been measured from the vertical, from between the sling legs, and from the horizontal. The following dimensions are obtained by measuring from the horizontal plane only.

Bridle Hitch. The rule of thumb for 2-, 3-, and 4-leg bridle hitches is: Safe working load of the bridle hitch equals the safe working load of a single vertical hitch times the head room between the hook and the load divided by the length of the sling legs times two, or

$$SWL(bh) = SWL(svh) \times (H/L) \times 2 .$$

It is wrong to assume that a 3- or 4-leg hitch will safely lift a load equal to the safe load on one leg multiplied by the number of legs in the hitch for the reason stated above in the Note under Bridle Hitches (Section 3.5.3).

Single Basket Hitch. The rules of thumb for the single basket hitch are

For vertical legs:

$$SWL(sbh) = SWL(svh) \times 2 .$$

For inclined legs:

$$SWL(sbh) = SWL(svh) \times (H/L) \times 2 .$$

Double Basket Hitch. The rules for the double basket hitch are

For vertical legs:

$$SWL(dbh) = SWL(svh) \times 4 .$$

For inclined legs:

$$SWL(dbh) = SWL(svh) \times (H/L) \times 4 .$$

Double-Wrap Basket Hitch. The safe working loads for the double-wrap basket hitch, depending on the configurations, are the same as for the single basket hitch or for the double basket hitch.

Single Choker Hitch. The rules for the single choker hitches are

For sling angles of 45° or more:

$$SWL(sch) = SWL(svh) \times (0.70) \times (\text{choker efficiency}).^*$$

For sling angles of 45° or less, see Note below.

The SWL for this angle hitch is the SWL of a single vertical hitch times the head room between the choker or sling hook and the load divided by the length of the inclined leg.

$$SWL(sch) = SWL(svh) \times (H/L) .$$

Double Choker Hitch. The rules for the double choker hitches are as follows.

For choker angles of 45° or more:

$$SWL(dch) = SWL(svh) \times (0.70) \times (H/L) \times 2 \times (\text{choker efficiency}).^*$$

For choker angles of 45° or less, see Note below.

Safe working load of the double choker hitch equals the SWL (svh) multiplied by the head room (A) from the choker or sling hook to the load divided by the length of the leg (B) from the choker to the load multiplied by the head room (H) between the hoist hook and the load divided by the length of inclined leg (L) from hoist hook to the load multiplied by two, or

$$SWL(dch) = SWL(svh) \times (A/B) \times (H/L) \times 2 .$$

Note: Sling angles of less than 45° should not be used. However, if the pick cannot be made with the approved sling angles, use the formulas as indicated above. Use extra precaution during the hoisting operation under these conditions.

Double-Wrap Choker Hitch. The safe working loads, depending on the configuration, are the same as for the single choker hitch or the double choker hitch.

Endless or Grommet Slings. The safe working loads, depending on the configuration, are twice the values for the previous sling configurations.

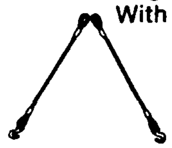
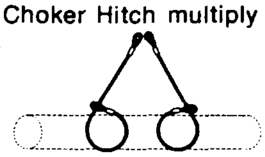
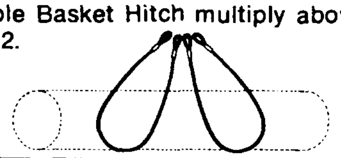
Consult the load rated capacity tables to obtain the single vertical hitch maximum safe working loads for the various types and configurations of slings. Note that the formulas shown above give results similar to the values shown in the columns for the Single Choker Hitch and Single Basket Hitch.

*Refer to Table 6 for choker efficiency percentages.

Table 14. 6×19 Wire Rope Slings/IWRC[2]

WIRE ROPE SLINGS
6 x 19 Classification Group, Improved Plow Steel, IWRC

MAXIMUM SAFE WORKING LOADS — POUNDS (Safety Factor = 5)

Rope Diameter (Inches)	Single Vertical Hitch 	Single Choker Hitch 	Single Basket Hitch (Vertical Legs) 	2-Leg Bridle Hitch & Single Basket Hitch With Legs Inclined   60°	45°	30°
3/16	650	480	1,300	1,100	900	650
1/4	1,150	860	2,300	2,000	1,600	1,150
5/16	1,750	1,300	3,500	3,000	2,500	1,750
3/8	2,550	1,900	5,100	4,400	3,600	2,550
7/16	3,450	2,600	6,900	6,000	4,900	3,450
1/2	4,700	3,500	9,400	8,150	6,650	4,700
9/16	5,700	4,200	11,400	9,900	8,050	5,700
5/8	7,100	5,300	14,200	12,300	10,000	7,100
3/4	10,200	7,650	20,400	17,700	14,400	10,200
7/8	13,750	10,300	27,500	23,800	19,400	13,750
1	17,950	13,450	35,900	31,100	25,400	17,950
1 1/8	22,750	17,000	45,500	39,400	32,200	22,750
1 1/4	28,200	21,200	56,400	48,800	39,900	28,200
1 3/8	34,800	26,100	69,600	60,300	49,200	34,800
1 1/2	41,300	31,000	82,600	71,500	58,400	41,300
1 5/8	48,600	36,400	97,200	84,200	68,700	48,600
1 3/4	55,900	41,900	111,800	96,800	79,000	55,900
1 7/8	65,400	49,000	130,800	113,300	92,500	65,400
2	72,600	54,500	145,200	125,700	102,700	72,600
2 1/4	90,300	67,600	180,600	156,400	127,700	90,300
2 1/2	111,800	83,700	223,600	193,600	158,100	111,800
2 3/4	131,100	98,200	262,200	227,000	185,400	131,100
				If used with Choker Hitch multiply above values by 3/4.  For Double Basket Hitch multiply above values by 2. 		

Note: Table values are for slings with eyes and thimbles in both ends, Flemish Spliced Eyes and mechanical sleeves.
Hand tucked spliced eyes — reduce loads according to table 13.
Eyes formed by cable clips — reduce loads by 20%.

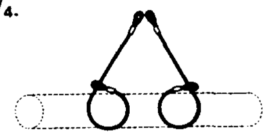
Table 15. 6×37 Wire Rope Slings/IWRC[2]

WIRE ROPE SLINGS
6 x 37 Classification Group, Improved Plow Steel, IWRC

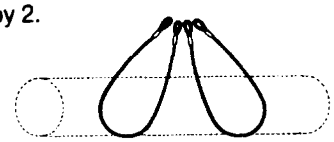
MAXIMUM SAFE WORKING LOADS — POUNDS (Safety Factor = 5)

Rope Diameter (Inches)	Single Vertical Hitch 	Single Choker Hitch 	Single Basket Hitch (Vertical Legs) 	2-Leg Bridle Hitch & Single Basket Hitch With Legs Inclined  60°	45°	30°
1/4	1,050	800	2,100	1,800	1,500	1,050
5/16	1,700	1,300	3,400	2,950	2,400	1,700
3/8	2,350	1,750	4,700	4,100	3,300	2,350
7/16	3,200	2,400	6,400	5,550	4,500	3,700
1/2	4,300	3,200	8,600	7,450	6,100	4,300
9/16	5,350	4,000	10,700	9,250	7,550	5,350
5/8	6,900	5,200	13,800	11,950	9,750	6,900
3/4	9,500	7,100	19,000	16,450	13,400	9,500
7/8	13,000	9,750	26,000	22,500	18,400	13,000
1	17,000	12,750	34,000	29,450	24,000	17,000
1 1/8	21,000	15,750	42,000	36,400	29,700	21,000
1 1/4	26,200	19,650	52,400	45,400	37,000	26,200
1 3/8	32,000	24,000	64,000	55,400	45,200	32,000
1 1/2	39,500	29,600	79,000	68,400	55,900	39,500
1 5/8	45,400	34,000	90,800	78,600	64,200	45,400
1 3/4	52,000	39,000	104,000	90,000	73,500	52,000
1 7/8	61,000	45,750	122,000	105,700	86,300	61,000
2	66,600	49,950	133,200	115,400	94,200	66,600
2 1/4	86,400	64,800	172,800	149,600	122,200	86,400
2 1/2	105,300	79,000	210,600	182,400	148,900	105,300
2 3/4	126,000	94,500	252,000	218,200	178,200	126,000

If used with Choker Hitch multiply above values by 3/4.



For Double Basket Hitch multiply above values by 2.

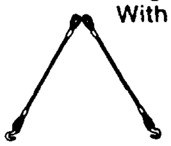


Note: Table values are for slings with eyes and thimbles in both ends, Flemish Spliced Eyes and mechanical sleeves.

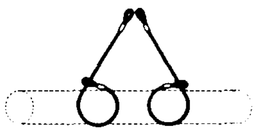
Hand tucked spliced eyes — reduce loads according to table 13.
Eyes formed by cable clips — reduce loads by 20%.

Table 16. 6×19 Wire Rope Slings/Fiber Core[2]

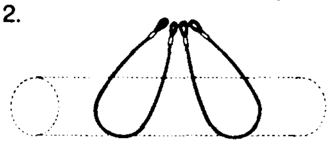
WIRE ROPE SLINGS
6 x 19 Classification Group, Improved Plow Steel, Fibre Core

Rope Diameter (Inches)	MAXIMUM SAFE WORKING LOADS — POUNDS (Safety Factor = 5)					
	Single Vertical Hitch 	Single Choker Hitch 	Single Basket Hitch (Vertical Legs) 	2-Leg Bridle Hitch & Single Basket Hitch With Legs Inclined  		
				60°	45°	30°
3/16	600	450	1,200	1,050	850	600
1/4	1,100	825	2,200	1,900	1,550	1,100
5/16	1,650	1,250	3,300	2,850	2,350	1,650
3/8	2,400	1,800	4,800	4,150	3,400	2,400
7/16	3,200	2,400	6,400	5,550	4,500	3,200
1/2	4,400	3,300	8,800	7,600	6,200	4,400
9/16	5,300	4,000	10,600	9,200	7,500	5,300
5/8	6,600	4,950	13,200	11,400	9,350	6,600
3/4	9,500	7,100	19,000	16,500	13,400	9,500
7/8	12,800	9,600	25,600	22,200	18,100	12,800
1	16,700	12,500	33,400	28,900	23,600	16,700
1 1/8	21,200	15,900	42,400	36,700	30,000	21,200
1 1/4	26,200	19,700	52,400	45,400	37,000	26,200
1 3/8	32,400	24,300	64,800	56,100	45,800	32,400
1 1/2	38,400	28,800	76,800	66,500	54,300	38,400
1 5/8	45,200	33,900	90,400	78,300	63,900	45,200
1 3/4	52,000	39,000	104,000	90,000	73,500	52,000
1 7/8	60,800	45,600	121,600	105,300	86,000	60,800
2	67,600	50,700	135,200	117,100	95,600	67,600
2 1/4	84,000	63,000	168,000	145,500	118,800	84,000
2 1/2	104,000	78,000	208,000	180,100	147,000	104,000
2 3/4	122,000	91,500	244,000	211,300	172,500	122,000

If used with Choker Hitch multiply above values by 3/4.



For Double Basket Hitch multiply above values by 2.

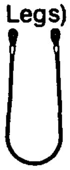
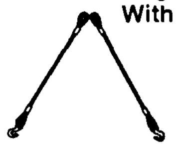
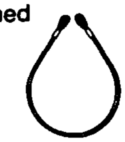


Note: **Table values are for slings with eyes and thimbles in both ends, Flemish Spliced Eyes and mechanical sleeves.**
Hand tucked spliced eyes — reduce loads according to table 13.
Eyes formed by cable clips — reduce loads by 20%.

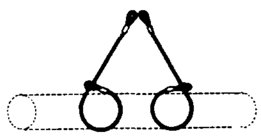
Table 17. 6×37 Wire Rope Slings/Fiber Core[2]

WIRE ROPE SLINGS
6 x 37 Classification Group, Improved Plow Steel, Fibre Core

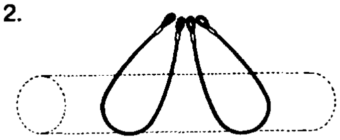
MAXIMUM SAFE WORKING LOADS — POUNDS (Safety Factor = 5)

Rope Diameter (Inches)	Single Vertical Hitch 	Single Choker Hitch 	Single Basket Hitch (Vertical Legs) 	2-Leg Bridle Hitch & Single Basket Hitch With Legs Inclined   60°	45°	30°
1/4	1,000	750	2,000	1,750	1,400	1,000
5/16	1,600	1,200	3,200	2,750	2,250	1,600
3/8	2,200	1,650	4,400	3,800	3,100	2,200
7/16	3,000	2,250	6,000	5,200	4,250	3,000
1/2	4,000	3,000	8,000	6,900	5,650	4,000
9/16	5,000	3,750	10,000	8,650	7,100	5,000
5/8	6,400	4,800	12,800	11,100	9,050	6,400
3/4	8,900	6,700	17,800	15,400	12,600	8,900
7/8	12,100	9,100	24,200	21,000	17,100	12,100
1	15,800	11,900	31,600	27,400	22,300	15,800
1 1/8	19,600	14,700	39,200	33,900	27,700	19,600
1 1/4	24,400	18,300	48,800	42,300	34,500	24,400
1 3/8	29,800	22,400	59,600	51,600	42,100	29,800
1 1/2	36,000	27,000	72,000	62,400	50,900	36,000
1 5/8	42,200	31,700	84,400	73,100	59,700	42,200
1 3/4	48,400	36,300	96,800	83,800	68,400	48,400
1 7/8	56,800	42,600	113,600	98,400	80,300	56,800
2	62,000	46,500	124,000	107,400	87,700	62,000
2 1/4	80,400	60,300	160,800	139,300	113,700	80,400
2 1/2	98,000	73,500	196,000	169,700	138,600	98,000
2 3/4	117,200	87,900	234,400	203,000	165,700	117,200

If used with Choker Hitch multiply above values by 3/4.

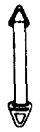
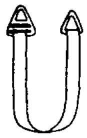
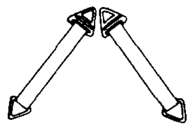
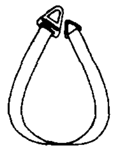


For Double Basket Hitch multiply above values by 2.

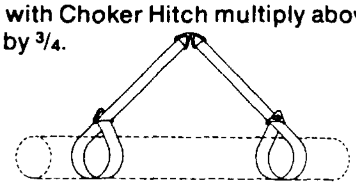


Note: **Table values are for slings with eyes and thimbles in both ends, Flemish Spliced Eyes and mechanical sleeves.**
Hand tucked spliced eyes — reduce loads according to table 13.
Eyes formed by cable clips — reduced loads by 20%.

Table 18. Wire Mesh Slings[2]

METAL (WIRE OR CHAIN) MESH SLINGS						
	MAXIMUM SAFE WORKING LOADS — POUNDS (Safety Factor = 5)					
Sling Width (Inches)	Single Vertical Hitch 	Single Choker Hitch 	Single Basket Hitch (Vertical Legs) 	2-Leg Bridle Hitch & Single Basket Hitch Non Vertical Legs  		
				60°	45°	30°
HEAVY DUTY CLASSIFICATION (10 GAUGE MESH)						
2	1,500	1,100	3,000	2,600	2,100	1,500
3	2,700	2,000	5,400	4,700	3,800	2,700
4	4,000	3,000	8,000	6,900	5,600	4,000
6	6,000	4,500	12,000	10,400	8,500	6,000
8	8,000	6,000	16,000	13,800	11,300	8,000
10	10,000	7,500	20,000	17,300	14,100	10,000
12	12,000	9,000	24,000	20,800	17,000	12,000
MEDIUM DUTY CLASSIFICATION (12 GAUGE MESH)						
2	1,350	1,000	2,700	2,300	1,900	1,350
3	2,000	1,500	4,000	3,500	2,800	2,000
4	2,700	2,000	5,400	4,700	3,800	2,700
6	4,500	3,400	9,000	7,800	6,400	4,500
8	6,000	4,500	12,000	10,400	8,500	6,000
10	7,500	5,600	15,000	13,000	10,600	7,500
12	9,000	6,750	18,000	15,600	12,700	9,000
LIGHT DUTY CLASSIFICATION (14 GAUGE MESH)						
2	900	700	1,800	1,600	1,300	900
3	1,400	1,000	2,800	2,400	2,000	1,400
4	2,000	1,500	4,000	3,500	2,800	2,000
6	3,000	2,250	6,000	5,200	4,200	3,000
8	4,000	3,000	8,000	6,900	5,700	4,000
10	5,000	3,750	10,000	8,600	7,100	5,000
12	6,000	4,500	12,000	10,400	8,500	6,000

If used with Choker Hitch multiply above values by 3/4.



For Double Basket Hitch multiply above values by 2.

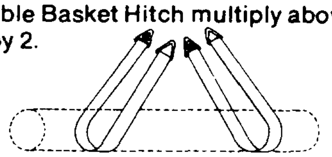
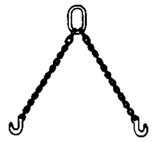
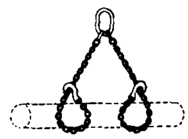
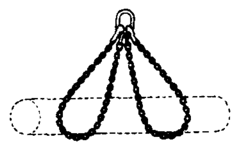


Table 19. Alloy Steel Chain Slings[2]

CHAIN SLINGS (ALLOY STEEL)						
	MAXIMUM SAFE WORKING LOADS — POUNDS*					
Chain Size (Inches)	Single Vertical Hitch 	Single Choker Hitch 	Single Basket Hitch (Vertical Legs) 	2-Leg Bridle Hitch & Single Basket Hitch With Legs Inclined  		
				60°	45°	30°
1/4	3,250	2,440	6,500	5,600	4,600	3,250
3/8	6,600	4,950	13,200	11,400	9,300	6,600
1/2	11,250	8,400	22,500	19,500	15,900	11,250
5/8	16,500	12,400	33,000	28,600	23,300	16,500
3/4	23,000	17,200	46,000	39,800	32,500	23,000
7/8	28,750	21,500	57,500	49,800	40,600	28,750
1	38,750	29,000	77,500	67,100	54,800	38,750
1 1/8	44,500	33,400	89,000	77,000	63,000	44,500
1 1/4	57,500	43,000	115,000	99,500	81,000	57,500
1 3/8	67,000	50,000	134,000	116,000	94,500	67,000
1 1/2	80,000	60,000	160,000	138,000	113,000	80,000
1 3/4	100,000	75,000	200,000	173,000	141,000	100,000
				If used with Choker Hitch multiply above values by 3/4.  For Double Basket Hitch multiply above values by 2. 		

*Chain slings have a Factor of Safety of 4.

Table 20. Nylon Web Slings, 6000 lb/in. Width[2]

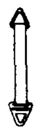
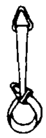
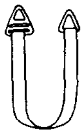
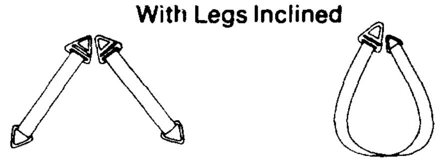
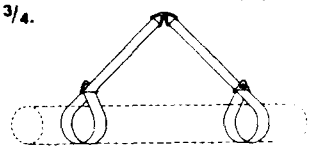
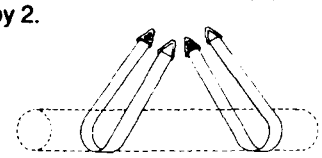
NYLON WEB SLINGS (6000 lb/in Material)						
Web Width (Inches)	MAXIMUM SAFE WORKING LOADS — POUNDS (SAFETY FACTOR = 5) (Eye & Eye, Twisted Eye, Triangle Fittings, Choker Fittings)					
	Single Vertical Hitch 	Single Choker Hitch 	Single Basket Hitch (Vertical Legs) 	2-Leg Bridle Hitch & Single Basket Hitch With Legs Inclined 		
				60°	45°	30°
1	1,200	900	2,400	2,080	1,700	1,200
2	2,400	1,800	4,800	4,160	3,400	2,400
3	3,600	2,700	7,200	6,240	5,100	3,600
4	4,800	3,600	9,600	8,300	6,800	4,800
5	6,000	4,500	12,000	10,400	8,500	6,000
6	7,200	5,400	14,400	12,500	10,200	7,200
7	8,400	6,300	16,800	14,550	11,900	8,400
8	9,600	7,200	19,200	16,600	13,600	9,600
9	10,800	8,100	21,600	18,700	15,300	10,800
10	12,000	9,000	24,000	20,800	17,000	12,000
11	13,200	9,900	26,400	22,900	18,650	13,200
12	14,400	10,800	28,800	25,000	20,400	14,400
				If used with Choker Hitch multiply above values by 3/4.  For Double Basket Hitch multiply above values by 2. 		
Note: For Safe Working Loads of Endless or Grommet Slings, Multiply Above Values by 2.						

Table 21. Nylon Web Slings, 8000 lb/in. Width[2]

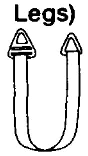
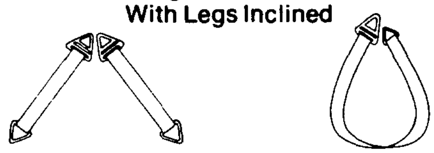
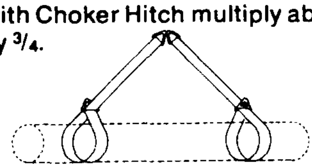
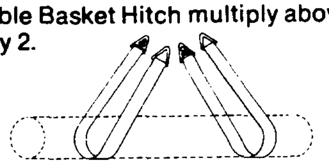
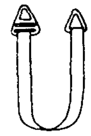
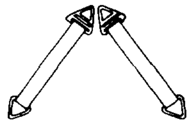
NYLON WEB SLINGS (8000 lb/in Material)						
Web Width (Inches)	MAXIMUM SAFE WORKING LOADS — POUNDS (SAFETY FACTOR = 5) (Eye & Eye, Twisted Eye, Triangle Fittings, Choker Fittings)					
	Single Vertical Hitch 	Single Choker Hitch 	Single Basket Hitch (Vertical Legs) 	2-Leg Bridle Hitch & Single Basket Hitch With Legs Inclined 		
				60°	45°	30°
1	1,600	1,200	3,200	2,770	2,260	1,600
2	3,200	2,400	6,400	5,550	4,520	3,200
3	4,800	3,600	9,600	8,300	6,800	4,800
4	6,400	4,800	12,800	11,100	9,050	6,400
5	8,000	6,000	16,000	13,850	11,300	8,000
6	9,600	7,200	19,200	16,600	13,600	9,600
7	11,200	8,400	22,400	19,400	15,800	11,200
8	12,800	9,600	25,600	22,200	18,100	12,800
9	14,400	10,800	28,800	25,000	20,400	14,400
10	16,000	12,000	32,000	27,700	22,600	16,000
11	17,600	13,200	35,200	30,500	24,900	17,600
12	19,200	14,400	38,400	33,300	27,200	19,200
				If used with Choker Hitch multiply above values by 3/4.  For Double Basket Hitch multiply above values by 2. 		
Note: For Safe Working Loads of Endless or Grommet Slings, Multiply Above Values by 2.						

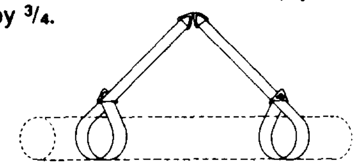
Table 22. Dacron Web Slings, 5000 lb/in. Width[2]

DACRON WEB SLINGS
(5000 lb/in Material)

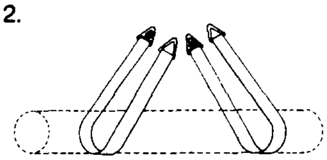
MAXIMUM SAFE WORKING LOADS — POUNDS (SAFETY FACTOR = 5)
(Eye & Eye, Twisted Eye, Triangle Fittings, Choker Fittings)

Web Width (Inches)	Single Vertical Hitch 	Single Choker Hitch 	Single Basket Hitch (Vertical Legs) 	2-Leg Bridle Hitch & Single Basket Hitch With Legs Inclined  		
				60°	45°	30°
1	1,000	750	2,000	1,730	1,400	1,000
2	2,000	1,500	4,000	3,460	2,830	2,000
3	3,000	2,250	6,000	5,200	4,250	3,000
4	4,000	3,000	8,000	6,950	5,650	4,000
5	5,000	3,750	10,000	8,660	7,070	5,000
6	6,000	4,500	12,000	10,400	8,500	6,000
7	7,000	5,250	14,000	12,100	9,900	7,000
8	8,000	6,000	16,000	13,850	11,300	8,000
9	9,000	6,750	18,000	15,600	12,700	9,000
10	10,000	7,500	20,000	17,350	14,100	10,000
11	11,000	8,250	22,000	19,100	15,500	11,000
12	12,000	9,000	24,000	20,800	17,000	12,000

If used with Choker Hitch multiply above values by 3/4.



For Double Basket Hitch multiply above values by 2.



Note: For Safe Working Loads of Endless or Grommet Slings, Multiply Above Values by 2.

3.5.6 Signaling

The rigger frequently has multiple responsibilities such as rigging the pick, barricading the craning site, holding the tagline, and giving signals to the crane operator. To give and receive signals, the operator and rigger must understand thoroughly the same set of signals, which can vary according to the type of equipment being used for the hoisting operation. The signals between a mobile crane operator and the rigger are much more comprehensive than those required between an overhead crane operator and the rigger or a coworker.

Refer to Chart A for signals that are pertinent for mobile crane operation, to Chart B for signals that should be used during overhead crane operations, and to Chart C for signals used with base-mounted drum hoists.

A Final Word About Safety

Of Cranes, Hoists, and Rigging, the most important is . . .

Craning, as used in today's sophisticated construction, industry, and military, marine, and research and development activities consists of many elements, each as important as the other. Every wire, strand, rope, link, sling, boom, sheave, block, hook, fastener, drum, power plant, carrier, hydraulic line, safety device, barricade, and tagline is important. Every rigging, inspection, operation, and maintenance function is important. But we now reach the one element of craning, not yet emphasized, that is *the most important:* the human element.

There are no functions involving cranes, hoists, and rigging that a crane operator, inspector, mechanic, rigger, supervisor, manager, engineer, or onlooker is not involved with in some way. The materialistic element of craning, in terms of value engineering, is *move material.* The functions of the human element are twofold: *provide safety* and *operate cranes.*

The rigger who rigs a pick incorrectly or signals incorrectly, the operator who fails to take the time to set up the crane correctly or operates it unsafely, the mechanic who merely adjusts a subsystem rather than replace its badly worn parts, the inspector who overlooks a well-worn or damaged part, or the supervisor who does not review a crane setup or the rigging before a pick—all are derelict in their duties and responsibilities should an accident occur.

Remember, during the planning stage of craning or any other hazardous type of work, safety must be considered to be just as important as the necessary physical functions required to complete the job.

Remember that a good safety program is no accident, so give crane safety a lot of thought. Your life may depend on it!

References

[1]*Mobile Crane Manual*, 1982 ed (Toronto, Ont: Construction Safety Assn of Ontario).

[2]*Rigging Manual*, ed D. E. Dickie (Toronto, Ont: Construction Safety Assn of Ontario, October 1975).

[3]*Tech Report*, Report No 102 (St. Joseph, MO: Wire Rope Corp of America, Inc.).

[4]*WIRECO Wire Rope Slings* (St. Joseph, MO: Wire Rope Corp of America, Inc.)

Other Works Consulted

The American Society of Mechanical Engineers
ANSI/ASME Standards:
B30.2 —Overhead and Gantry Cranes (Top Running Bridge, Single or Multiple Girder, Top Running Trolley Hoist)
B30.2a —Addenda to ANSI/ASME B30.2
B30.5 —Mobile and Locomotive Cranes
B30.5a —Addenda to ANSI/ASME B30.5
B30.7 —Base-Mounted Drum Hoists
B30.9 —Slings
B30.10 —Hooks
B30.11 —Monorails and Underhung Cranes
B30.16 —Overhead Hoists (Underhung)
B30.17 —Overhead and Gantry Cranes (Top Running Bridge, Single Girder, Underhung Hoist)
B30.20 —Below-the-Hook Lifting Devices

Bob DeBenedictis, Inc. *Crane and Rigging Safety Manual.* SNL Plant Engineering-Sponsored Crane Safety Seminar, "Overhead Crane Technical Symposium." Sandia National Laboratories, Kirtland Air Force Base, NM. Feb 10-11, 1986.

Crane Inspection and Certification Bureau. Mobile Crane Training Manual. UNM/ASSE-Sponsored Crane Safety Seminar, "Mobile Crane and Rigging Considerations." Kirtland Air Force Base, NM. Jan 31, 1986.

———. Crane Safety Conferences. Las Vegas, NV. First, Second, Third, Fourth Conferences, Nov 1979, 1980, 1981, 1982, respectively. Sixth Conference, Nov 1984.

Crane Handbook. 1975. Toronto, Ont: Construction Safety Assn of Ontario.

Crane Manufacturers Association of America, Inc.
CMAA Specification #70, Revised 1983
CMAA Specification #74
(CMAA is an affiliate of the Materials Handling Institute)

Crane Technical Training and Inspection, Inc. *Crane and Rigging Training Manual.* Overhead Cranes and Rigging Training Course. Norfolk, VA. Aug 28-30, 1985.

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US Dept of Energy. 1984. *Safety Manual—Industrial Safety, Fire Prevention, Environmental Health.* SAND81-1807, Revised. Albuquerque, NM: Sandia National Laboratories.

———. May 1980. *DOE Hoisting and Rigging Manual.* Idaho Falls, ID: EG&G.

———. *Manual for Use, Inspection, and Maintenance of Hoisting Equipment.* SLA-74-0206. Albuquerque, NM: Sandia Laboratories.

———. 1973. *Rigging Equipment Manual—Design, Fabrication, Inspection, Use, and Testing.* SLA-73-0564. Albuquerque, NM: Sandia Laboratories.

US Dept of Labor. Training Course 100-19, "Cranes and Material Handling." Gulfport, MS. Nov 27– Dec 5, 1985.

———. Occupational Safety and Health Administration. Safety and Health Standards:
Subpart H—Materials Handling, Storage, Use, and Disposal
Subpart N—Cranes, Derricks, Hoists, Elevators, and Conveyors

APPENDIX A

Medical Memorandum

Sandia National Laboratories

Albuquerque, New Mexico 87185

date: January 21, 1986

to: Lee Stinnett, 3442

from: L. R. Clevenger, M.D., 3320

subject: Medical Considerations for Proposed Training Program for Employees Required to Use Cranes and Hoists

I have reviewed the ANSI standard recommendations regarding medical qualifications for operators.

All employees at Sandia National Laboratories have been through a pre-placement medical examination and have been assigned to one of four medical classifications. Employees with significant medical problems including severe impairment of vision, hearing, color deficiency and physical defects will typically be in medical class II or medical class III if indefinite work restrictions have been required.

Accordingly, it is reasonable to consider the following scheme for purposes of approving employees to participate in the training course and be allowed use of heavy material handling equipment.

Supervisors should review the medical classification of employees who require such approval as an initial step. Interpretation of these classifications may be summarized as follows:

> Medical Class I - there are no medical contraindications to such an employee participating in the training program and may be assumed to be qualified to operate heavy material handling equipment.
>
> Medical Class II - employees in this category may have a medical problem which should be reviewed prior to approval for this program. Names of employees should be routed to the Medical Organization for an initial chart review and/or physical examination if indicated.
>
> Medical Class III - employees in this category will typically have indefinite medical work restrictions and these should be carefully reviewed by the line

organization supervisor to determine whether these will place the employee in an unsafe working condition should he operate heavy material handling equipment. Specific questions regarding interpretation of these restrictions should be directed to the Medical Organization.

Medical Class IV - employees in this category are typically highly disabled, however, indefinite work restrictions should be reviewed in a manner similar to those employees in Medical Class III.

This approach would maintain privacy of medical information while at the same time meeting the recommendations of the ANSI standard B30.5-1982.

LRC:3320:lm

APPENDIX B

Field Inspection Check Sheet, Mobile Cranes

Field Inspection Check Sheet, Mobile Cranes

Equip ID: Operator: Date:

I. Frequent Inspections:	Check	Action
1. All control mechanisms for maladjustment interfering with proper operation.		
2. All control mechanisms for excessive wear of components and contamination by lubricants or other foreign matter.		
3. All safety devices for malfunction.		
4. Load Cable.		
5. Boom cable.		
6. Wire rope cable reeving for compliance with the crane manufacturer's specifications.		
7. Electrical apparatus for malfunctioning, signs of excessive deterioration, dirt, and accumulation of moisture.		
8. Hydraulic system for proper oil level.		
9. Tires for recommended inflation pressure.		
10. Fuel, oil, and coolant levels.		
11. Windshield and cab windows are not cracked, missing, or dirty.		
12. Fire extinguisher(s) in place and recently serviced.		

APPENDIX C

Field Inspection Check Sheet, Overhead Bridge Cranes

Field Inspection Check Sheet, Overhead Bridge Cranes

Equipment ID: Operator: Date:

I. Frequent Inspections	Check	Action
* All functional operating mechanisms for maladjustment and interference with proper operation		
* Limit devices for operation		
* Air lines, valves and other parts for leakage		
* Hooks for damage, cracks, or excessive throat opening		
1. Deformed (gouges, nicks, abrasions, etc.)		
2. Welded or reshaped		
3. Chemically damaged		
4. Cracked		
5. Throat opening (in excess of 15%)		
6. Twist (in excess of 10 degrees)		
7. Hook latch operation		
* Wire Rope		
1. Wire rope distortion (kinking, crushing, unstranding, bird caging, core protrusion, main strand displacement, clips, etc.)		
2. General corrosion, end fittings		
3. Broken or cut strands		
4. Number, distribution, and type of visible broken wires (12 randomly distributed broken wires in one lay or four broken wires in one strand in one lay)		
* Wire rope cable or chain reeving		

APPENDIX D

Field Inspection Check Sheet, Electric or Pneumatic Hoists

Field Inspection Check Sheet, Electric or Pneumatic Hoists

Equipment ID: Operator: Date:

I. Frequent Inspections	Check	Action
* All functional operating mechanisms for mal--adjustment interfering with proper operation		
* Limit devices for operation		
* Air lines, valves and other parts for leakage		
* Hooks for damage, cracks, or excessive throat opening		
1. Deformed (gouges, nicks, abrasions, etc.).		
2. Welded or reshaped.		
3. Chemically damaged.		
4. Cracked.		
5. Throat opening (in excess of 15%).		
6. Twist (in excess of 10 degrees).		
7. Hook latch operation		
* Hoist wire rope cable		
1. Wire rope distortion (kinking, crushing, unstranding, bird caging, core protrusion, main strand displacement, clips, etc.)		
2. General corrosion, end fittings		
3. Broken or cut strands		
4. Number, distribution, and type of visible broken wires (12 randomly distributed broken wires in one lay or four broken wires in one strand in one lay)		
* Wire rope cable or chain reeving		

APPENDIX E

Field Inspection Check Sheet, Chain Hoists

Field Inspection Check Sheet, Chain Hoists

Equipment ID: Operator Date:

I. Frequent Inspections	Check	Action
* All functional operating mechanisms for maladjustment and interference with proper and safe operation		
* Hooks for damage, cracks, or excessive throat opening		
1. Deformed (gouges, nicks, abrasions, etc.).		
2. Welded or reshaped.		
3. Chemically damaged.		
4. Cracked.		
5. Throat opening (must not exceed 15%).		
6. Twist (must not exceed 10 degrees).		
7. Hook latch operation.		
* Load chain		
A. <u>Welded Link Chain</u>		
1. Test the hoist under load by lifting and lowering it. The chain should feed smoothly into and out of the sprockets.		
2. If the chain binds, jumps, or is noisy, call Maintenance for service.		
B. <u>Roller Chain</u>		
1. Test the hoist under load in lifting and lowering directions. The chain should feed smoothly into and away from the sprockets.		
2. If the chain binds, jumps, or is noisy, call Maintenance for service.		
3. Check the chain for twist. Have the chain replaced if the twist in any 5' section exceeds 15 degrees.		

APPENDIX F

Field Inspection Check Sheet, Base-Mounted Drum Hoists

Field Inspection Check Sheet, Base-Mounted Drum Hoists

Equipment ID: Operator: Date:

I. Frequent Inspections	Check	Action
* Control mechanisms for maladjustment or excessive wear interfering with safe operations		
* Limit devices/switches for malfunction		
* Oil levels and grease points		
* Deterioration or leakage in air or hydraulic systems		
* Electrical apparatus for malfunctioning, signs of excessive deterioration, and dirt and moisture accumulation		
* Inspect load carrying ropes for excessive wear and distortion		
1. Wire rope distortion (kinking, crushing, unstranding, bird caging, core protrusion, main strand displacement, clips, etc.).		
2. Broken or cut strands.		
3. Number, distribution, and type of visible broken wires (6 randomly distributed broken wires in one lay or three broken wires in one strand in one lay).		
4. Severly corroded or broken wires at end connections.		
5. Severely corroded, cracked, bent, worn, or improperly applied end connections.		
6. Care shall be taken when inspecting sections in contact with saddles or sheaves where rope travel is limited.		
7. Care shall be taken when inspecting sections of rope near terminal ends where corroded or broken wires may protrude.		
* Wire rope reeving on drums		

APPENDIX G

Field Inspection Check Sheet, Wire Rope

Field Inspection Check Sheet, Wire Rope

Equipment Type: Equipment ID: Location:

Wire Rope Function: (1) (2) (3) (4)

Wire Rope Description: (1) (2) (3) (4)

Date of Inspection	Wire Rope Function Code	Measured Diameter of Rope	Measured Rope Lay	Excessive Wire Wear (1/3 Diam.)	Wire Damage Type	Core Damage Type

End Attachments			Condition of Drum	Condition of Sheaves				
Broken Wires	Corrosion of Wire	End Fitting Condition						

APPENDIX H

Load Test Record Sheet, Wire Rope, Mesh, Chain, and Web Slings

Load Test Record Sheet, Wire Rope, Mesh, Chain, and Web Slings

RIGGING EQUIPMENT LOAD TEST

SLINGS RECORD SHEET

Division ______ Location ____________________ Date __________

Test Requester ___________________________ Extension __________

Test Operator ____________________________ Test Date __________

Load Test Results	Item No.	Control No.	Rigging Equipment Description (Load rating, type, length, etc)
	1		
	2		
	3		
	4		
	5		
	6		
	7		
	8		
	9		
	10		
	11		
	12		
	13		
	14		
	15		
	16		
	17		
	18		
	19		
	20		

ANSI B30.9 requires all slings to be load tested at two times the load rating indicated on the equipment and ANSI B30.20 requires all under-the-hook lifting devices to be load tested at 125% of the rated load.

Instructions or comments:

APPENDIX I

Field Inspection Check Sheet, Wire Rope Slings

Field Inspection Check Sheet, Wire Rope Slings

Sling ID: Inspector: Date:

	Check	Action
I. Frequent Inspections:		
1. Distortion such as kinking, crushing, unstranding, bird caging, strand displacement, or core protrusion.		
2. Corrosion, pitting, heat damage.		
3. Broken or cut wires: Number and distribution per rope lay (10) or per strand (5) per rope lay.		
4. Abrasion and scraping evidence.		
5. Latches should hinge freely and seat properly.		
6. End attachments.		
II. Periodic Inspections		
1. Is the rated capacity of the sling legible?		
2. Inspect entire length of sling, splices, end attachments and fittings.		
3. Broken wires. (10 in one rope lay, or 5 in one strand in one rope lay).		
4. Severe abrasion or scraping.		
5. Kinking, crushing, bird caging, or other distortion.		
6. Severe corosion, pitting, or heat damage.		
7. Replace end attachments if cracked, gouged, or worn excessively. Replace hooks if wear exceeds 10%, if bend or twist exceeds 10 degrees, if throat opening exceeds 15% for nonlatched and 8% for latched hooks.		
8. Date of last load test. ________. Wire Rope slings should be load tested at least every four years.		

APPENDIX J

Field Inspection Check Sheet, Wire Mesh Slings

Field Inspection Check Sheet, Wire Mesh Slings

Sling ID: Inspector: Date:

I. Frequent Inspections:	Check	Action
1. Distortion such as kinking, crushing, twisting, holes in mesh, etc.		
2. Corrosion.		
3. Broken or cut wires, rods, or links.		
4. Abrasion and scraping evidence.		
5. Evidence of heat damage.		
6. End attachments.		
II. Periodic Inspections		
1. Is the rated capacity of the sling legible?		
2. Broken weld or brazed joint along the sling edge.		
3. Broken wire or link in any part of the mesh.		
4. Reduction in wire or link diameter of 25% due to abrasion or 15% due to corrosion.		
5. Lack of flexibility due to distorted mesh.		
6. Distortion of the choker fitting so the depth of the slot is increased by more than 10%.		
7. Distortion of either end fitting so the width of the eye opening is decreased by more than 10%.		
8. A 15% reduction of the original cross-sectional area of metal at any point around the hook opening of the end fitting.		
9. Cracked or visibly distorted end fitting out of its plane.		
10. Date of last load test. ________. Wire mesh slings should be load tested at least every four years.		

APPENDIX K

Field Inspection Check Sheet, Chain Slings

Field Inspection Check Sheet, Chain Slings

Sling ID: Inspector: Date:

	Check	Action
I. Frequent Inspections:		
1. Chain and attachments for wear, nicks, cracks, breaks, gouges, stretch, bends, weld splatter, discoloration from excessive temperatures, and throat opening of hooks.		
2. Chain links and attachments should hinge freely and seat properly without evidence of permanent distortion.		
3. Hook latches should hinge freely and seat properly without evidence of permanent distortion.		
II. Periodic Inspections		
1. Is chain sling identified with an 8 or a T?		
2. Is the rated capacity of the sling legible?		
2. Each link and each attachment shall be examined for wear that reduces the cross-sectional area. Refer to Table 6 in Section III.D.2.c. for allowable cross-sectional wear.		
3. Worn links should not exceed values shown in Table 6 or the value which is specifically recommended by the manufacturer.		
4. Sharp transverse nicks and gouges may be removed by grinding. The depth of the ground portion should not exceed the values shown in Table 6.		
5. Hooks should be inspected for: Cracks, wear exceeding 10% of the original dimension, a bend or twist exceeding 10 degrees from the plane of the unbent hook, throat opening exceeding 15% for nonlatched and 8% for latched hooks. The portions of a grab hook that form the throat should be parallel. Latches should seat properly, rotate freely, and show no permanent distortion.		
6. Date of last load test. _________. Chain slings should be load tested at least every four years.		

APPENDIX L

Field Inspection Check Sheet, Synthetic Web Slings

Field Inspection Check Sheet, Synthetic Web Slings

Sling ID: Inspector: Date:		
I. Frequent Inspections:	Check	Action
1. Acid or caustic burns.		
2. Melting or charring of any part of the sling.		
3. Holes, tears, cuts, or snags.		
4. Broken or worn stitching in load bearing splices.		
5. Excessive abrasive wear in load bearing area.		
6. Knots in any part of the sling.		
7. Cracked, distorted, broken or excessively pitted or corroded fittings.		
8. Excessive abrasive wear within the eyes.		
II. Periodic Inspections		
1. Is the rated capacity of the sling legible?		
2. Periodic inspections should be conducted annually by inspecting the sling in accordance with the requirements of the the Frequent Inspections list shown above.		
3. Date of last load test. ________. Web slings should be load tested at least every four years.		

APPENDIX M

Authorization to Operate Heavy Equipment

Authorization to Operate Heavy Equipment

Heavy equipment operators who have met the physical qualifications required by the B-30 Series of ANSI Standards and who have attended the safety training course, *Cranes, Hoists, and Rigging*, or who have qualified to operate equipment other than cranes and hoists, shall be issued a card similar to that shown below. The card authorizes the individual to operate the equipment identified by the initials of the authoritarian. Listed equipment not authorized shall be hole-punched.

All operators are required to be recertified every three years.

```
|<------------3-3/8"------------>|
|                                |
|                                |
 -------------------------------     -------
|   SANDIA NATIONAL LABORATORIES |        ^
|  ____________________E-No.______|       |
|  _  is authorized to operate: ___|      |
||_|-BACKHOE/DIGGER        DOZER-|_||     |
||_|-MOBILE CRANE          HOIST-|_||   2-1/8"
||_|-ROAD GRADER         MANLIFT-|_||     |
||_|-LOADER         BRIDGE CRANE_|_||     |
||_| AUGER ______FORKLIFT TRUCK |_||      |
|  _________________  __________  |       |
|_____AUTHORITARIAN___RENEW DATE_|   _____V
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CHART A

Mobile Crane Hand Signals

Mobile Crane Hand Signals

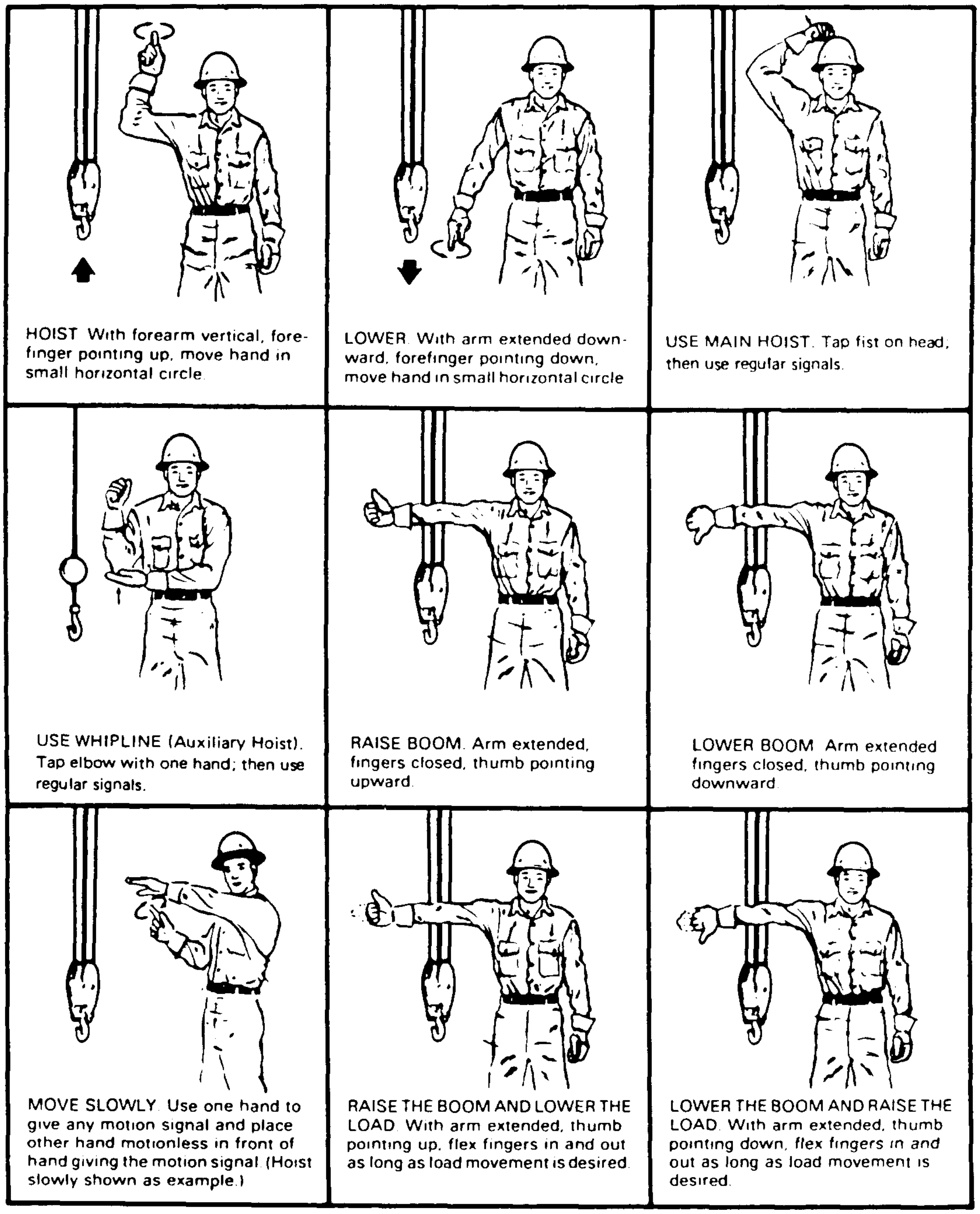
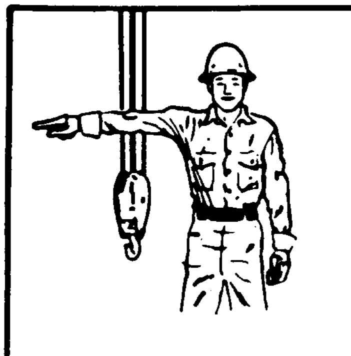
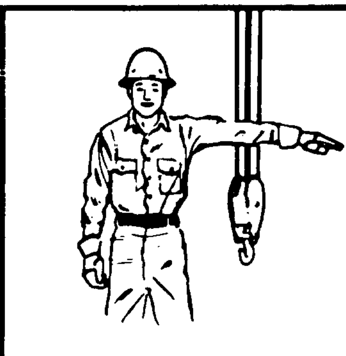


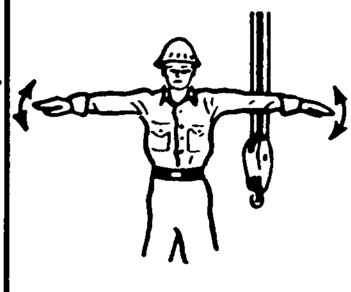
Chart A. Mobile Crane Hand Signals



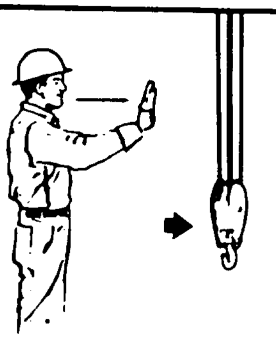
SWING. Arm extended, point with finger in direction of swing of boom.



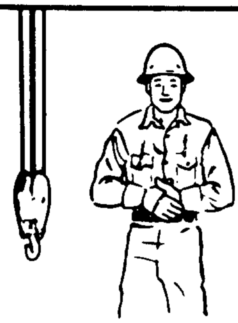
STOP. Arm extended, palm down, move arm back and forth horizontally.



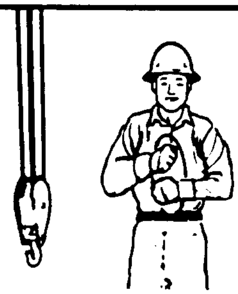
EMERGENCY STOP. Both arms extended, palms down, move arms back and forth horizontally.



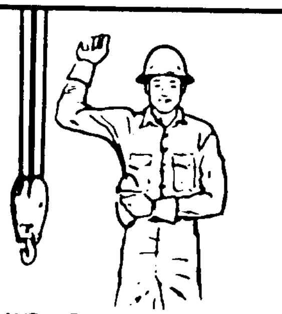
TRAVEL. Arm extended forward, hand open and slightly raised, make pushing motion in direction of travel.



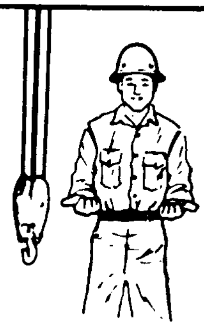
DOG EVERYTHING. Clasp hands in front of body.



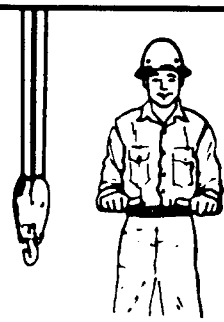
TRAVEL (Both Tracks). Use both fists in front of body, making a circular motion about each other, indicating direction of travel, forward or backward. (For land cranes only.)



TRAVEL. (One Track) Lock the track on side indicated by raised fist. Travel opposite track in direction indicated by circular motion of other fist, rotated vertically in front of body (For land cranes only.)

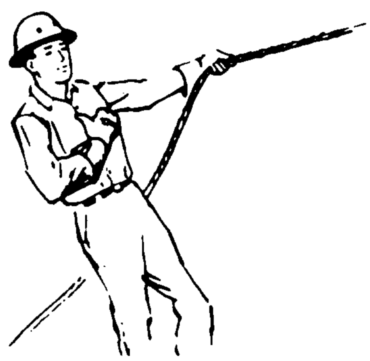


EXTEND BOOM (Telescoping Booms). Both fists in front of body with thumbs pointing outward.

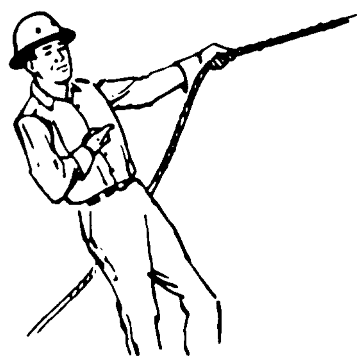


RETRACT BOOM (Telescoping Booms). Both fists in front of body with thumbs pointing toward each other.

Chart A. Continued



EXTEND BOOM (Telescoping Boom). One Hand Signal. One fist in front of chest with thumb tapping chest.



RETRACT BOOM (Telescoping Boom). One Hand Signal. One fist in front of chest, thumb pointing outward and heel of fist tapping chest.

Chart A. Concluded

CHART B

Overhead Bridge Crane and Hoist Hand Signals

Overhead Bridge Crane and Hoist Hand Signals

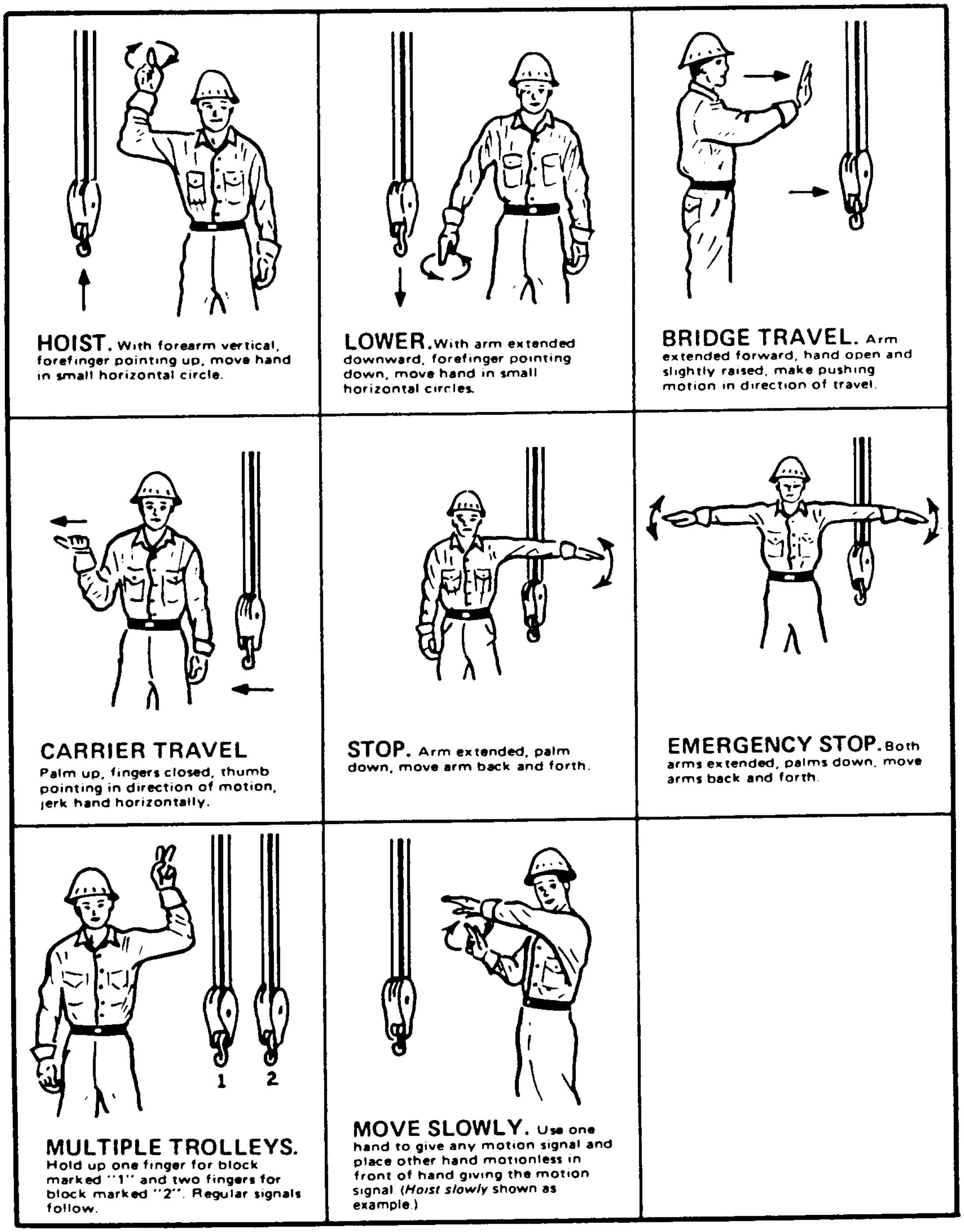


Chart B. Overhead Bridge Crane and Hoist Hand Signals

CHART C

Base-Mounted Drum Hoist Hand Signals

Base-Mounted Drum Hoist Hand Signals

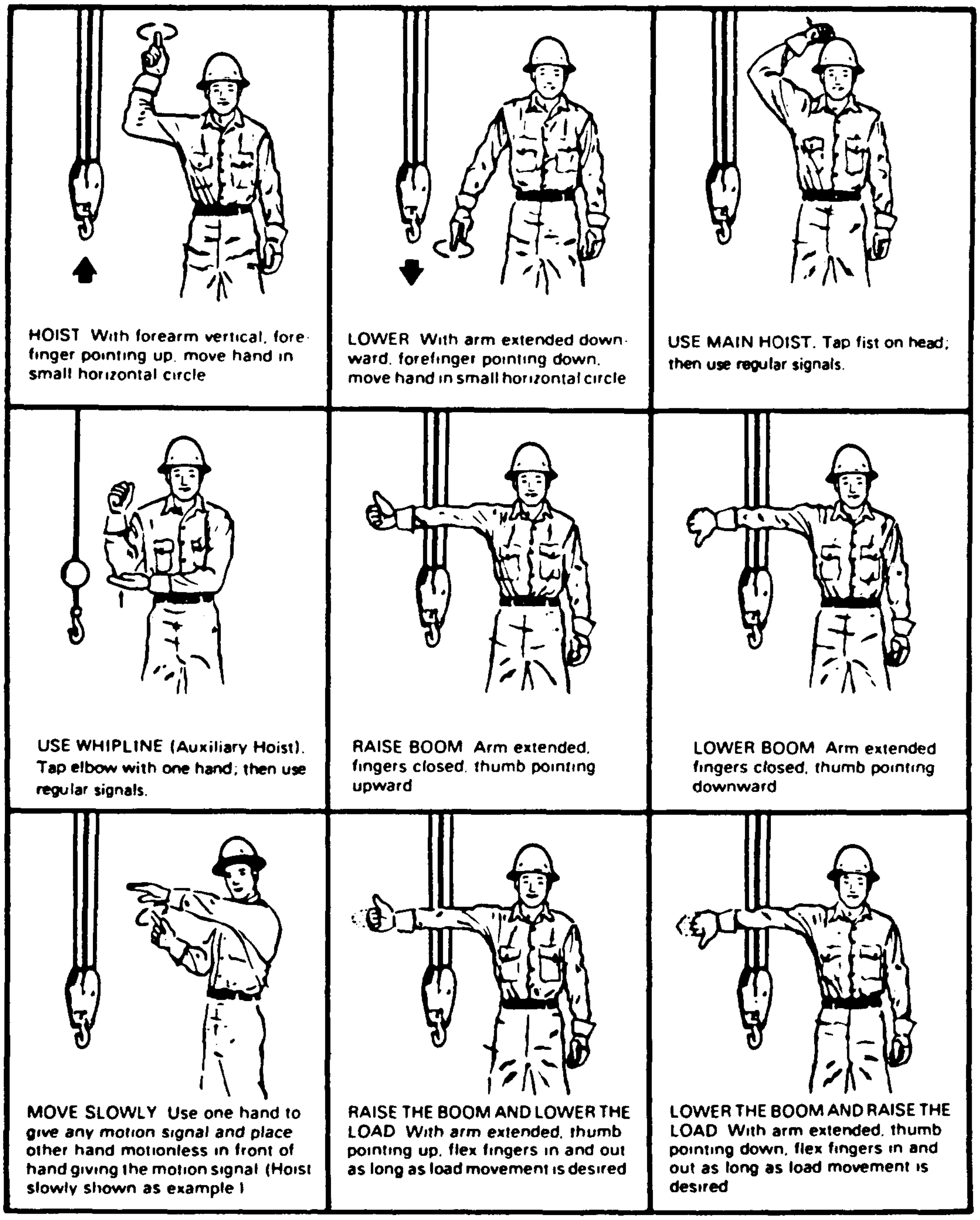


Chart C. Base-Mounted Drum Hoist Hand Signals

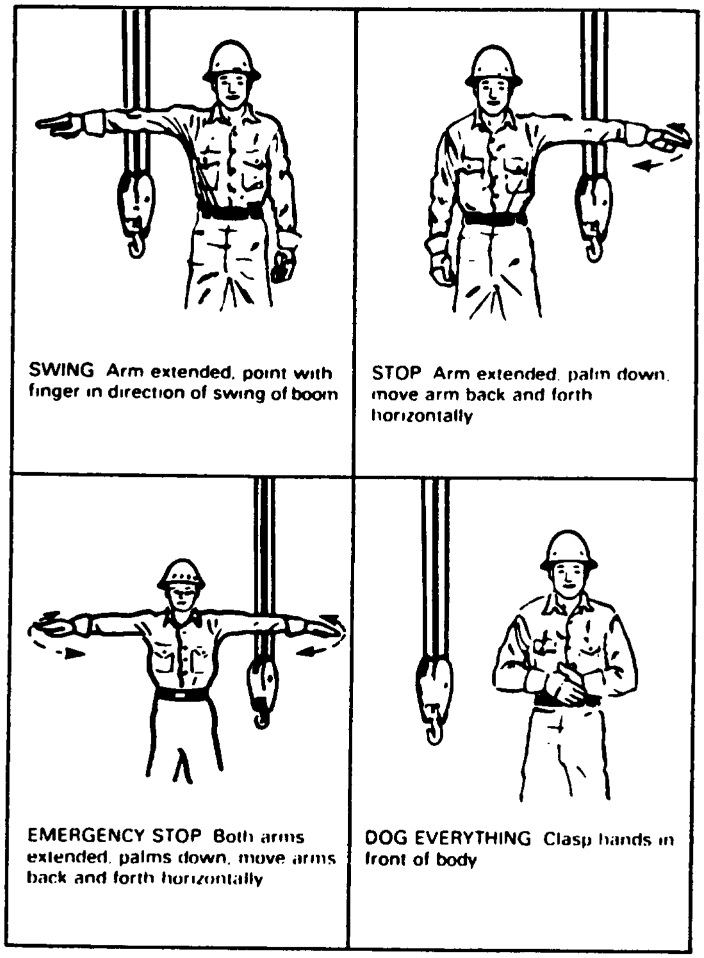


Chart C. Concluded

DISTRIBUTION:

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8024	P. W. Dean
3141	S. A. Landenberger (5)
3151	W. L. Garner (3)
3154-1	C. H. Dalin (28)
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