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"Fiber Line, Wire Rope, and Scaffolding"

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Chapter 7

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Chapter 7

Fiber Line, Wire Rope, and Scaffolding

Topics

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Overview

As a Seabee Builder Petty Officer you will be put in charge, from time to time, of two important construction tasks. These tasks are setting up rigging to hoist loads and building ***scaffolding*** to support work above your crew's reach. You as crew leader will be expected to direct your crew in the correct performance of these tasks and above all in the safety of yourself and your crew. Safety is paramount while doing any job, but it is especially important when hoisting heavy loads and when working at heights on scaffolding.

This chapter presents information on how to use ***fiber line***, ***wire rope***, and timber in rigging and erecting ***hoisting*** devices, such as ***shear legs***, ***tripods***, blocks and tackles; and different types of scaffolds and ladders. It will also give you formulas for determining the safe working load of these materials.

Objectives

When you have completed this chapter, you will be able to do the following:

1. Determine use, breaking strength, and care of ***lines*** and rope used for rigging
2. Determine use, breaking strength, and care of wire rope used for rigging
3. Identify components and operating characteristics of block and tackle units
4. Understand hoisting, hand signals used in lifting loads, and safety rules of lifting
5. Determine proper use of wood and prefabricated metal scaffolding

Prerequisites

None

This course map shows all of the chapters in Builder Basic. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on this course map.

1.0.0 FIBER LINE

Fiber line is made from either natural or synthetic fiber. Natural fibers, which come from plants, include manila, sisal, and hemp. The synthetic fibers include nylon, polyester, and polypropylene,

1.1.0 Natural Fiber Ropes

The two most commonly used natural fiber ropes are manila and sisal, but the only type suitable for construction rigging is a good grade of manila. High quality manila is light cream in color, smooth, clean, and pliable. The quality of the line can be distinguished by varying shades of brown; Number 1 grade is very light in color, Number 2 grade is slightly darker, Number 3 grade is considerably darker. The next best line making fiber is sisal. Sisal fiber is similar to manila, but lighter in color. This type of fiber is only about 80 percent as strong as manila fiber.

1.2.0 Synthetic Fiber Ropes

Synthetic fiber rope, such as nylon and polyester, has rapidly gained wide use by the Navy. It is lighter in weight, more flexible, less bulky, and easier to handle and store than manila line. It is also highly resistant to mildew, rot, and fungus. Synthetic rope is stronger than natural fiber rope. For example, nylon is about three times stronger than manila. When nylon line is wet or frozen, the loss of strength is relatively small. Nylon rope will hold a load even though several strands may be frayed. Ordinarily, the line can be made reusable by cutting away the chafed or frayed section and splicing the good line together.

1.3.0 Fabrication of Line

The fabrication of line consists essentially of three twisting operations. First, the fibers are twisted to the right to form the ***yarns***. Next, the yarns are twisted to the left to form the strands. Finally, the strands are twisted to the right to form the line. *Figure 7-1* shows how the fibers are grouped to form a three strand line.

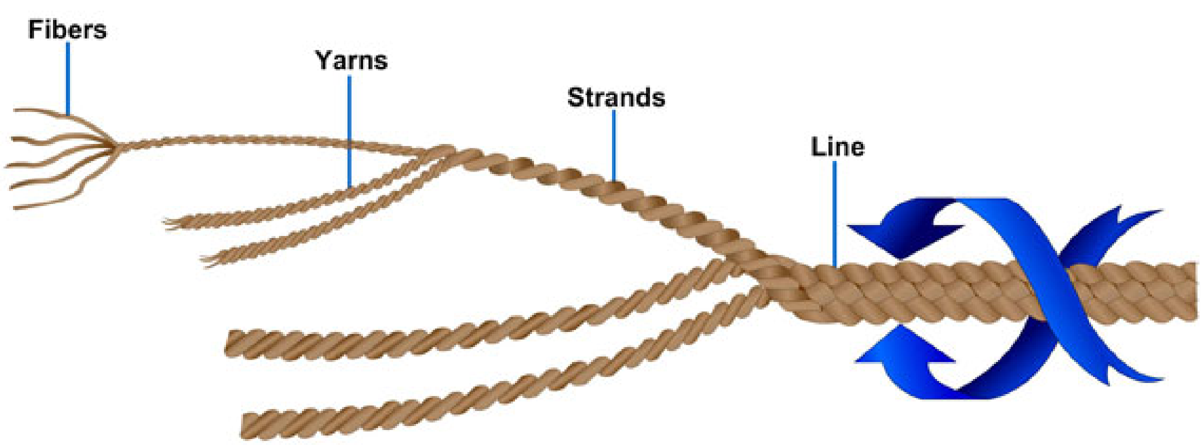


Figure 7-1 – Fiber groupings in a three-strand line.

The operation just described is the standard procedure, and the resulting product is known as a right-laid line. When the process is reversed, the result is a left-laid line. In either instance, the principle of opposite twists must always be observed. The two main reasons for the principle of opposite twists are to keep the line tight to prevent the fibers from unlaying with a load suspended on it and to prevent moisture penetration.

1.3.1 Types of Line Lays

There are three types of fiber line lays: hawser-laid, shroud-laid, and cable-laid lines. Each type is illustrated in *Figure 7-2*.

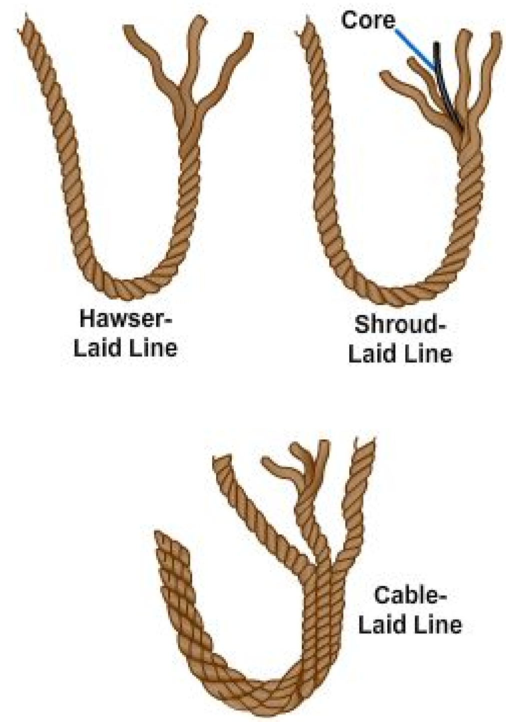
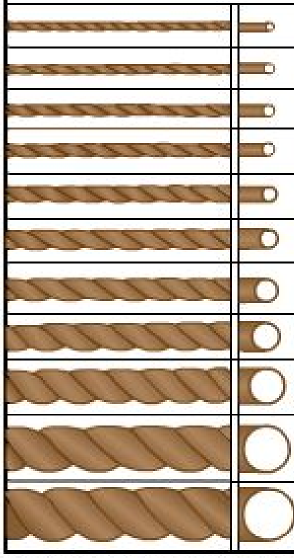


Figure 7-2 – Fiber line lays.

Hawser-laid line generally consists of three strands twisted together, usually in a right hand direction. A shroud-laid line ordinarily is composed of four strands twisted together, usually in a right hand direction around a center strand, or core, which is usually of the same material, but smaller in diameter than the four strands. Shroud-laid line is more pliable and stronger than hawser-laid line, but it has a strong tendency toward kinking. In most instances, it is used on ***sheaves*** and drums. This not only prevents kinking, but also makes use of its pliability and strength. Cable-laid line usually consists of three right-hand, hawser-laid lines twisted together in a left hand direction. It is especially safe to use in heavy construction work; if cable-laid line untwists, it will tend to tighten any regular right-hand screw connection to which it is attached.

1.3.2 Size Designation

Line that is 1 3/4 inches or less in circumference is called small stuff. The size is usually designated by the number of threads, or yarns, that make up each strand. You may use from six to 24 thread strands, but the most commonly used are nine to 21 thread strands, as shown in *Figure 7-3*. You may hear some small stuff designated by name without reference to size. One such type is marline; a tarred, two strand, left-laid hemp. Marline is the small stuff you will use most for seizing. When you need something stronger than marline, you will use a tarred, three-strand, left-laid hemp called houseline.



MANILA LINE			
Some Commonly Used Sizes	* Circumference		Thread
	Inches	Millimeters	
	3/4	19.05	6
	1	25.40	9
	1 1/8	28.58	12
	1 1/4	31.76	15
	1 1/2	38.10	21
	1 3/4	44.45	24
	2	50.80	
	3	76.20	
	4	101.6	
	5	127.0	
	6	152.4	

* Size is designated by the circumference

Figure 7-3 – Some commonly used sizes of manila line.

Line larger than 1 3/4 inches in circumference is generally size designated by its circumference in inches. A six-inch manila line, for instance, is constructed of manila fibers and measures six inches in circumference. 12 inches is about the largest manila carried in stock. Anything larger is used only on special jobs.

If you have occasion to order line, you may find that the catalogs, is designate it and you order it by diameter. The catalog may also use the term rope rather than line.

Pull rope yarns for temporary seizing, whippings, and lashings from large strands of old line that has outlived its usefulness. Pull your yarn from the middle, away from the ends, or it will get fouled.

1.4.0 Strength of Fiber Line

Overloading a line poses a serious threat to the safety of personnel, not to mention the heavy losses likely to result through damage to material. To avoid overloading, you must know the strength of the line with which you are working. This involves three factors: breaking strength, safe working load (SWL), and ***safety factor***.

Breaking strength refers to the tension at which the line will part when a load is applied. Rope manufacturers determine breaking strength through tests and provide tables with this information. In the absence of manufacturers' tables, a rule of thumb for finding the breaking strength of manila line is the formula:

$$BS = C^2 \times 900$$

BS equals the breaking strength in pounds and C equals the circumference in inches. To find BS, first square the circumference, then multiply the value obtained by 900. For example, with a three inch line you will get a BS of 8,100 pounds as follows:

$$BS = 3 \times 3 \times 900 = 8,100$$

The breaking strength of manila line is higher than that of sisal line because of the difference in the two fibers. The fiber from which a particular line is constructed has a definite bearing on its breaking strength. The breaking strength of nylon is almost three times that of manila line of the same size.

The best rule of thumb for breaking strength of nylon is as follows:

$$BS = C^2 \times 2{,}400$$

The symbols in the rule are the same as those for fiber line. For the 2 1/2 inch nylon line:

$$BS = 2.5 \times 2.5 \times 2{,}400 = 15{,}000 \text{ pounds}$$

Briefly defined, the safe working load of a line is the load that can be applied without damaging the line. Note that the safe working load is considerably less than the breaking strength. A wide margin of difference between breaking strength and safe working load is necessary. This difference allows for such factors as additional strain imposed on the line by jerky movements in hoisting or bending over sheaves in a pulley block.

You may not always have a chart available to tell you the safe working load for a particular line. Here is a rule of thumb that will adequately serve your needs on such an occasion:

$$SWL = C^2 \times 150$$

In this equation, SWL equals the safe working load in pounds, and C equals the circumference of the line in inches. Simply take the circumference of the line, square it, and then multiply by 150. For a 3 inch line:

$$SWL = 3 \times 3 \times 150 = 1{,}350 \text{ pounds}$$

The safe working load of a three inch line is equal to 1,350 pounds.

If a line is in good shape, add 30 percent to the SWL derived by means of the preceding rule; if it is in bad shape, subtract 30 percent from the SWL. In the example given above for the three inch line, adding 30 percent to the 1,350 pounds gives you a safe working load of 1,755 pounds. On the other hand, subtracting 30 percent from 1,350 pounds leaves you with a safe working load of 945 pounds.

Remember that the strength of a line decreases with age; use; and exposure to excessive heat, boiling water, or sharp bends. Especially with used line, give these and other factors affecting strength careful consideration and make proper adjustment in determining the breaking strength and safe working load capacity of the line. Manufacturers of line provide tables that show the breaking strength and safe working load capacity of line. Those tables are very useful in your work. You must remember that the values given in manufacturers' tables apply only to new line used under favorable conditions. For that reason, you must progressively reduce the values given in manufacturers' tables as the line ages or deteriorates with use.

Keep in mind that a strong strain on a kinked or twisted line will put a permanent distortion in the line. *Figure 7-4* shows what frequently happens when pressure is applied to a line with a kink in it. The kink that could have been worked out is now permanent, and the line is ruined.

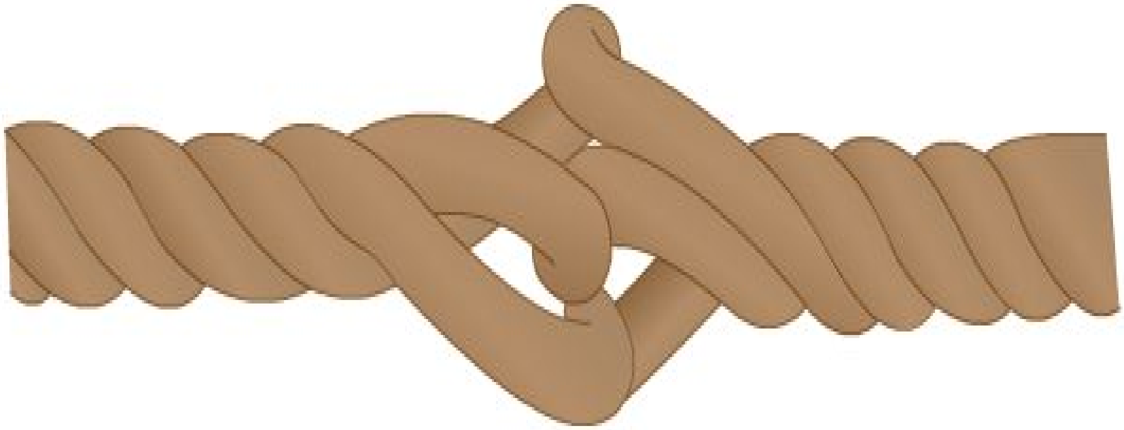


Figure 7-4 – Results of a strong strain on a line with a kink in it.

The safety factor of a line is the ratio between the breaking strength and the safe working load. Usually, a safety factor of four is acceptable, but this is not always the case. In other words, the safety factor should never be less than three; it often must be well above four, possibly as high as eight or ten. For the best, average, or unfavorable conditions, the following safety factors may often be suitable:

- Best conditions (new line): four
- Average conditions (line used, but in good condition): six
- Unfavorable conditions (frequently used line, such as running rigging): eight

1.5.0 Handling and Care of Lines

If you expect the fiber line you work with to give safe and dependable service, make sure it is handled and cared for properly. Study the precautions and procedures given here and carry them out properly.

Cleanliness is part of the care of fiber line. Never drag a line over the deck or ground, or over rough or dirty surfaces. The line can easily pick up sand and grit, which will work into the strands and wear the fibers. If a line does get dirty, use only water to clean it. Do not use soap because it will remove oil from the line, which weakens it.

Avoid pulling line over sharp edges because the strands may break. When you encounter a sharp edge, place chafing gear; such as a board, folded cardboard, or canvas, or part of a rubber tire between the line and the sharp edge to prevent damaging the line.

Never cut a line unless you have to. When possible, use knots that you can easily untie.

Fiber line contracts, or shrinks, when it gets wet. If there is not enough slack in a wet line to permit shrinkage, the line is likely to become overstrained and weakened. If a taut line is exposed to rain or dampness, make sure the line, while still dry, is slacked to allow for shrinkage.

Inspect line carefully at regular intervals to determine whether it is safe. The outside of a line does not show the condition of the line on the inside. Untwisting the strands slightly allows you to check the condition of the line on the inside. Mildewed line gives off a musty odor. A trained observer can usually spot broken strands or yarns immediately. Look carefully to ensure there is no dirt or sawdust-like material inside the line. Dirt or other foreign matter inside reveals possible damage to the internal structure of the line.

A shrinking of circumference of the line is usually a sure sign that too much strain has been applied to the line.

For a thorough inspection, examine a line at several places along its length.

CAUTION

Only one weak spot anywhere in a line makes the entire line weak.

As a final check, pull out a couple of fibers from the line and try to break them. Sound fibers show a strong resistance to breakage.

If an inspection discloses any unsatisfactory conditions in a line, make sure to destroy the line or cut it up into small pieces as soon as possible. This precaution prevents the defective line from being used for hoisting.

Test your Knowledge (Select the Correct Response)

1. How many grades of manila lines are there?

   A. One
   B. Two
   C. Three
   D. Four

2. What term is line that is 1 3/4 inches or less in circumference called?

   A. Small stuff
   B. Hawser
   C. Rope
   D. Tarred line

2.0.0 WIRE ROPE

During the course of a project, Seabees often need to hoist or move heavy objects. Wire rope is used for heavy duty work. The following paragraphs discuss the characteristics, construction, and use of many types of wire rope. We will also discuss the safe working load, use of attachments and fittings, and procedures for the care and handling of wire rope.

2.1.0 Construction

Wire rope consists of three parts; wires, strands, and core, as shown in *Figure 7-5*. In the manufacture of rope, a number of wires are laid together to form the strand. Then a number of strands are laid together around a core to form the rope.

The basic unit of wire rope construction is the individual wire, which may be made of steel, iron, or other metal, in various sizes. The number of wires to a strand varies, depending on the purpose for which the rope is intended. Wire rope is designated by the number of strands per rope and the number of wires per strand. Thus a 1/2 inch 6 X 19 rope will have 6 strands with 19 wires per strand; but it will have the same outside diameter as a 1/2 inch 6 X 37 wire rope, which will have 6 strands with 37 wires of much smaller size per strand. Wire rope made up of a large number of small wires is flexible, but the small wires are easily broken, so the wire rope does not resist external abrasion. Wire rope made up of a smaller number of larger wires is more resistant to external abrasion but is less flexible.

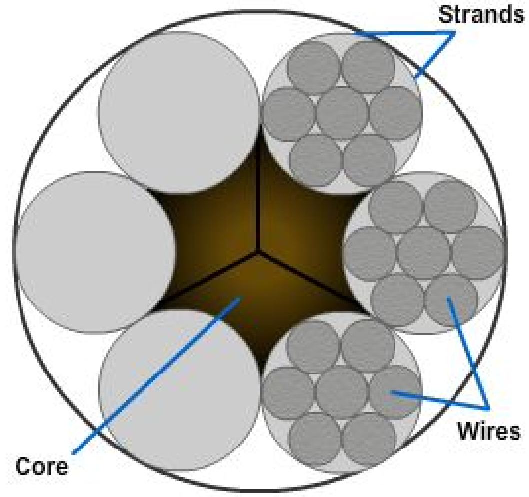


Figure 7-5 – Parts of wire rope.

The core is the element around which the strands are laid to form the rope. It may be a hard fiber; such as manila, hemp, plastic, paper, or sisal; a wire strand, or an independent wire rope. Each type of core serves the same purpose, to support the strands laid around it.

A fiber core offers the advantage of increased flexibility. Also, it serves as a cushion to reduce the effects of sudden strain and acts as a reservoir for the oil to lubricate the wires and strands to reduce friction between them. Wire rope with a fiber core is used in places where flexibility of the rope is important.

A wire strand core not only resists heat more than a fiber core, but also adds about 15 percent to the strength of the rope. On the other hand, the wire strand makes the rope less flexible than does a fiber core.

An independent wire rope is a separate wire rope over which the main strands of the row are laid. It usually consists of six seven-wire strands laid around either a fiber core or a wire strand core. This core strengthens the rope more, provides support against crushing, and supplies maximum resistance to heat.

Wire rope may be made by either of two methods. If the strands or wires are shaped to conform to the curvature of the finished rope before laying up, the rope is called preformed. If they are not shaped before fabrication, the rope is called non-preformed. When cut, preformed wire rope tends not to unlay, and it is more flexible than non-preformed wire rope. With non-preformed wire rope, twisting produces a stress in the wires; and when it is cut or broken, the stress causes the strands to unlay.

WARNING

In non-preformed wire, unlaying is rapid and almost instantaneous, which could cause serious injury to someone not familiar with it.

The main types of wire rope used by the Navy consist of 6, 7, 12, 19, 24, or 37 wires in each strand. Usually, the rope has six strands laid around a fiber or steel center. Two common types of wire rope, 6 X 19 and 6 X 37 ropes, are illustrated in views A and B of *Figure 7-6*, respectively. The 6 X 19 type of rope, having six strands with 19 wires in each strand, is commonly used for rough hoisting and skidding work where abrasion is likely to occur. The 6 X 37 wire rope, having six strands with 37 wires in each strand, is the most flexible of the standard six-strand ropes. For that reason, it is particularly suitable when small sheaves and drums are to be used, such as on cranes and similar machinery.

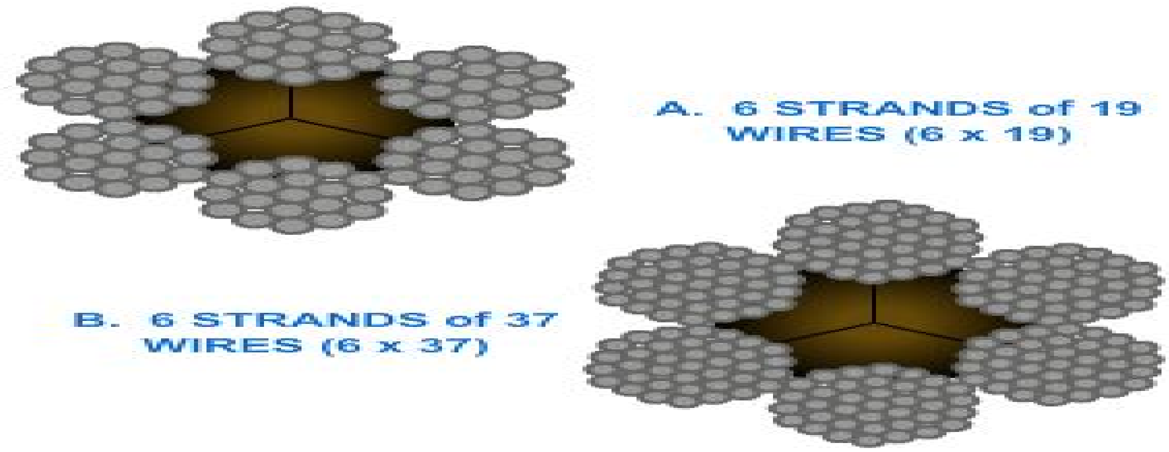


Figure 7-6 – Two common types of wire rope.

2.2.0 Grades of Wire Rope

Wire rope is made in a number of different grades. Three of the most common are mild plow steel, plow steel, and improved plow steel.

Mild plow steel rope is tough and pliable. It can stand up under repeated strain and stress and has a tensile strength of from 200,000 to 220,000 pounds per square inch (psi). Plow steel wire rope is unusually tough and strong. It has a tensile strength, or resistance to lengthwise stress, of 220,000 to 240,000 psi. This rope is suitable for hauling, hoisting, and logging. Improved plow steel rope is one of the best grades of rope available, and most, if not all, of the wire rope in your work will probably be made of this material. It is stronger, tougher, and more resistant to wear than either plow steel or mild plow steel. Each square inch of improved plow steel can withstand a strain of 240,000 to 260,000 psi.

2.3.0 Measuring Wire Rope

The size of wire rope is designated by its diameter. The true diameter of a wire rope is the diameter of a circle that will just enclose all of its strands. Correct and incorrect methods of measuring wire rope are illustrated in *Figure 7-7*. In particular, note that the correct way is to measure from the top of one strand to the top of the strand directly opposite it. The wrong way is to measure across two strands side-by-side. Use calipers to take the measurement. If calipers are not available, an adjustable wrench will do.

To ensure an accurate measurement of the diameter of a wire rope, always measure the rope at three places, at least 5 feet apart. Use the average of the three measurements as the diameter of the rope.

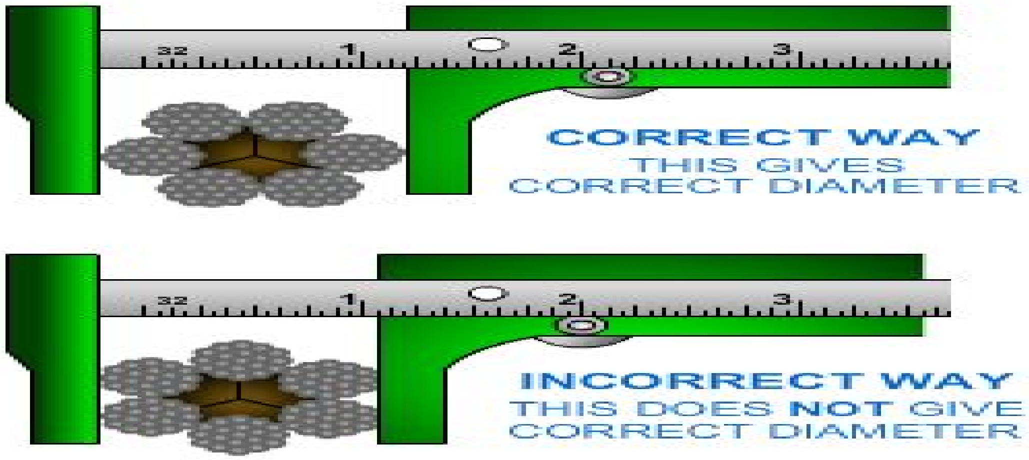


Figure 7-7 – Correct and incorrect methods of measuring wire rope.

2.4.0 Safe Working Load

The term safe working load (SWL), in reference to wire rope, means the load that can be applied and still obtain the most efficient service from and prolong the life of the rope. Most manufacturers provide tables that show the safe working load for their rope under various conditions. In the absence of these tables, you must apply a formula to obtain the SWL. There are rules of thumb you can use to compute the strength of wire rope. The one recommended by the Naval Facilities Engineering Command (NAVFAC) is:

$$SWL = D^2 \times 8$$

D represents the diameter of the rope in inches, and SWL represents the safe working load in tons. This particular formula provides an ample safety margin to account for such variables as the number, size, and location of the sheaves and drums on which the rope runs. It also includes dynamic stresses, such as the speed of operation and the acceleration and deceleration of the load. All can affect the endurance and breaking strength of the rope. Let's work an example. Suppose you want to find the SWL of a two inch rope. Using the formula above, your figures would be:

$$SWL = 2^2 \times 8 = 4 \times 8 = 32$$

The answer is 32, meaning that the rope has a SWL of 32 tons.

It is very important to remember that any formula for determining SWL is only a rule of thumb. In computing the SWL of old rope, worn rope, or rope that is otherwise in poor condition, you should reduce the SWL as much as 50 percent, depending on the condition of the rope. Use the manufacturer's data concerning the breaking strength (BS) of wire rope if available. But if you do not have that information, one rule of thumb recommended is:

$$BS = C^2 \times 8{,}000 \text{ pounds}$$

Wire rope is measured by the diameter (D). To obtain the circumference (C) required in the formula, multiply D by pi (π), which is approximately 3.1416. Thus, the formula to find the circumference is:

$$C = D \times \pi$$

2.5.0 Wire Rope Failure

Wire can fail due to any number of causes. Here is a list of some of the common causes of wire rope failure.

- Using the incorrect size, construction, or grade of wire rope
- Dragging rope over obstacles
- Having improper lubrication
- Operating over sheaves and drums of inadequate size
- Overriding or cross winding on drums
- Operating over sheaves and drums with improperly fitted grooves or broken flanges
- Jumping off sheaves
- Subjecting it to acid fumes
- Attaching fittings improperly
- Promoting internal wear by allowing grit to penetrate between the strands
- Subjecting rope to severe or continued overload

2.6.0 Handling and Care of Wire Rope

To render safe, dependable service over a maximum period of time, wire rope must have the care and upkeep necessary to keep it in good condition. In this section, we'll discuss various ways of caring for and handling wire rope. Not only should you study these procedures carefully, you should also practice them on your job to help you do a better job now. In the long run, the life of the wire rope will be longer and more useful.

2.6.1 Coiling and Uncoiling

Once a new reel has been opened, it may be either coiled or faked down like line. The proper direction of coiling is counterclockwise for left-laid wire rope and clockwise for right-laid rope. Because of the general toughness and resilience of wire, it occasionally tends to resist being coiled down. When this occurs, it is useless to fight the wire by forcing down a stubborn turn; it will only spring up again. If it is thrown in a back turn, as shown in *Figure 7-8*, it will lie down properly. A wire rope, when faked down, will run right off like line; but when wound in a coil, it must always be unwound.

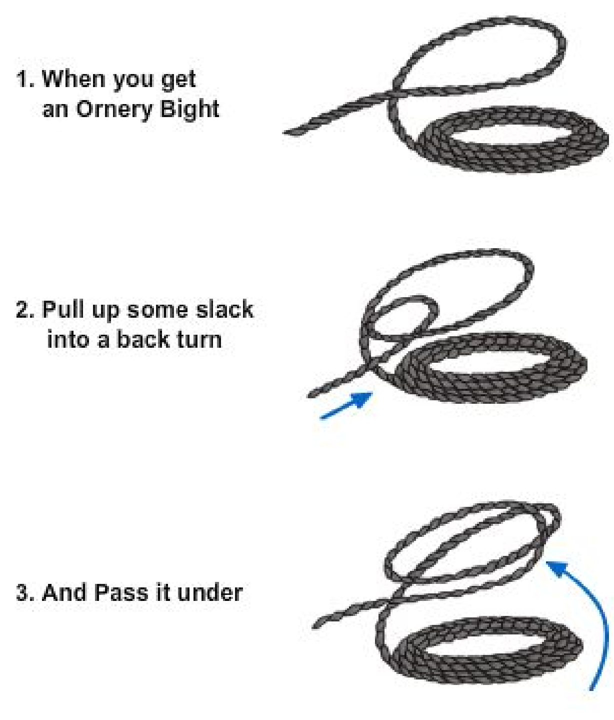


Figure 7-8 – Throwing a back turn to make wire lie down.

Wire rope tends to kink during uncoiling or unreeling, especially if it has been in service for a long time. A kink can cause a weak spot in the rope, which will wear out more quickly than the rest of the rope. A good method for unreeling wire rope is to run a pipe or rod through the center and mount the reel on drum jacks or other supports so the reel is off the ground or deck as shown in *Figure 7-9*. In this way, the reel will turn as you unwind the rope, and the rotation of the reel will help keep the rope straight. During unreeling, pull the rope straight forward, as shown in *Figure 7-9*, and try to avoid hurrying the operation. As a safeguard against kinking, never unreel wire rope from a stationary reel.

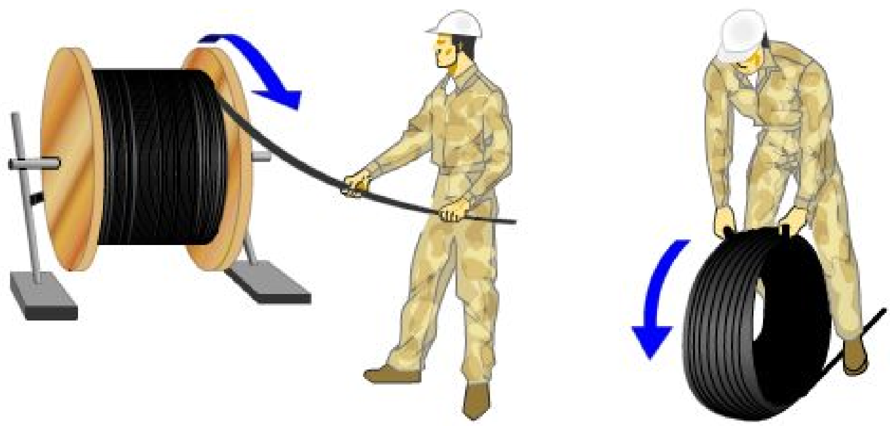


Figure 7-9 – Unreeling wire rope (left) and uncoiling wire rope (right).

To uncoil a small coil of wire rope, simply stand the coil on edge and roll it along the ground or deck like a wheel or hoop, as illustrated in *Figure 7-9*. Never lay the coil flat on the deck or ground and uncoil it by pulling on the end because that practice can kink or twist the rope.

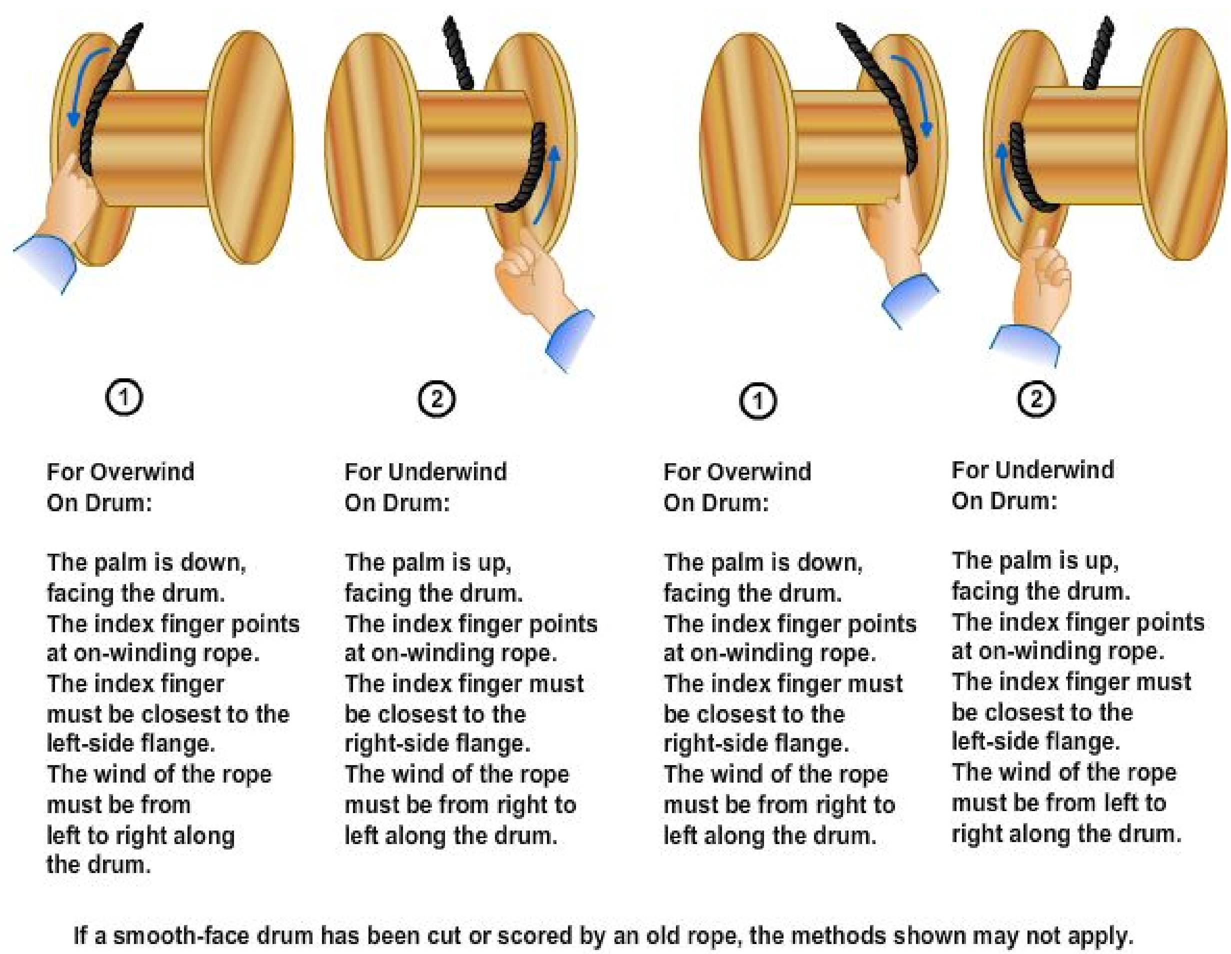


Figure 7-10 – Drum windings diagram for selecting the proper lay of rope.

To rewind wire rope back onto a reel or a drum, you may have difficulty unless you remember that it tends to roll in the direction opposite the lay. For example, a right-laid wire rope tends to roll to the left.

Carefully study *Figure 7-10*, which shows drum-winding diagrams selecting the proper lay of rope. When putting wire rope onto a drum, you should have no trouble if you know the methods of overwinding and underwinding shown in the illustration. When you run wire rope off one reel onto another or onto a winch or drum, run it from top to top or from bottom to bottom, as shown in *Figure 7-11*.

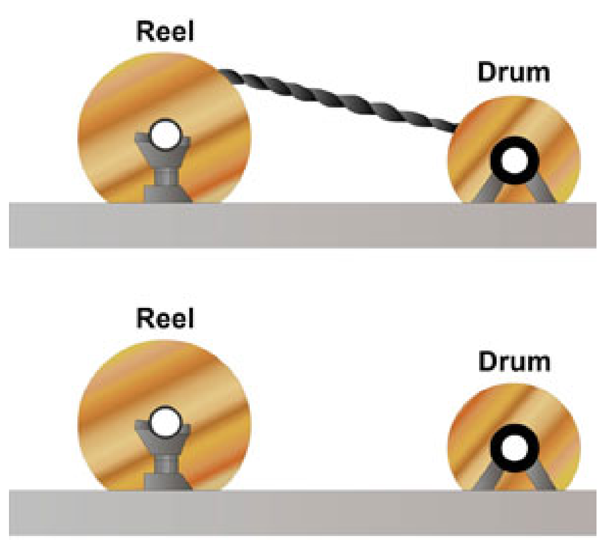


Figure 7-11 – Transferring wire rope from reel to drum.

2.6.2 Kinks

If a wire rope should form a loop, never try to pull it out by putting strain on either part. As soon as you notice a loop, uncross the ends by pushing them apart. See steps 1 and 2 in *Figure 7-12*. This reverses the process that started the loop. Now, turn the bent portion over and place it on your knee or some firm object and push downward until the loop straightens out somewhat. See step 3 in *Figure 7-12*. Then, lay the bent portion on a flat surface and pound it smooth with a wooden mallet. See step 4 in *Figure 7-12*.

If a heavy strain has been put on a wire rope with a kink in it, the rope can no longer be trusted. Replace the wire rope altogether.

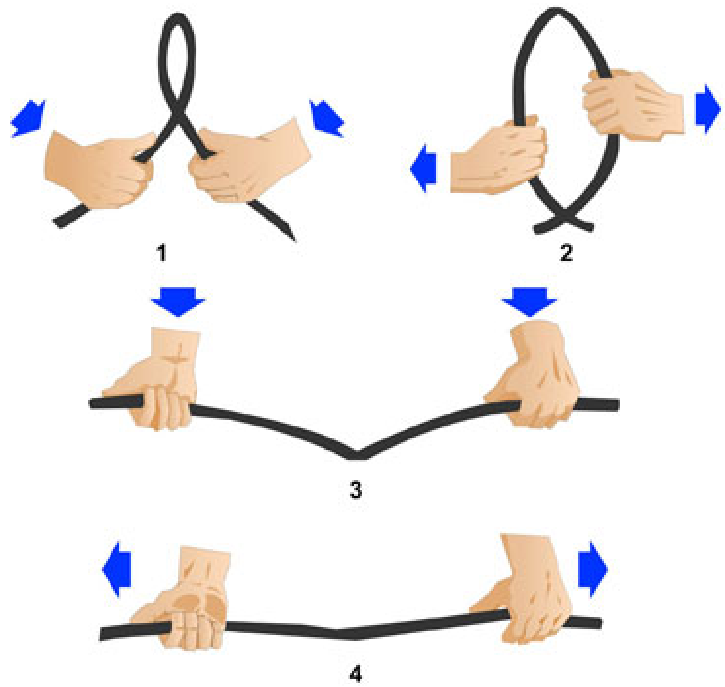


Figure 7-12 – The correct way to take out a loop in wire rope.

2.6.3 Lubrication

Clean used wire rope at frequent intervals to remove any accumulation of dirt, grit, rust, or other foreign matter. The frequency of cleaning depends on how much the rope is used. However, rope should always be well cleaned before lubrication. The rope can be cleaned with wire brushes, compressed air, or steam.

WARNING

Do not use oxygen in place of compressed air; it becomes very dangerous when it comes in contact with grease or oil.

The purpose is to remove all old lubricant and foreign matter from the valleys between the strands and from the spaces between the outer wires. This gives newly applied lubricant ready entrance into the rope. Wire brushing affords a good opportunity to find any broken wires that may otherwise go unnoticed.

Wire rope is initially lubricated by the manufacturer, but this initial lubrication isn't permanent and the user must make periodic reapplications. Each time a wire rope bends and straightens, the wires in the strands and the strands in the rope slide upon each other. To prevent the rope from wearing out from this sliding action, a film of lubricant is needed between the surfaces in contact. The lubricant also helps prevent corrosion of the wires and deterioration of fiber centers. A rusty wire rope is a liability! With wire rope, just as with any machine or piece of equipment, proper lubrication is essential to smooth, efficient performance.

The lubricant should be a good grade of lubricating oil, free from acids and corrosive substances. It must also be of a consistency that will penetrate to the center of the core, yet heavy enough to remain as a coating on the outer surfaces of the strands. Two good lubricants for this purpose are raw linseed oil and medium graphite grease. Raw linseed oil dries and is not greasy to handle. Graphite grease is highly resistant to saltwater corrosion. Of course, you may obtain and use other commercial lubricants. One of the best is a semi-plastic compound that is thinned by heating before being applied. It penetrates while hot, then cools to a plastic filler, preventing the entrance of water.

One method of applying the lubricant is by using a brush. Remember to apply the coating of fresh lubricant evenly and to work it in well. Another method involves passing the wire rope through a trough or box containing hot lubricant, shown in *Figure 7-13*. In this method, the heated lubricant is placed in the trough, the rope passes over a sheave, through the lubricant, and under a second sheave. Hot oils or greases have very good penetrating qualities. Upon cooling, they have high adhesive and film strength around each wire.

Figure 7-13 – Trough method of lubrication.

As a safety precaution, always wipe off any excess when lubricating wire rope. This is especially important where heavy equipment is involved. Too much lubricant can get on brakes or clutches, causing them to fail. The motion of machinery can throw excess oil onto crane cabs and catwalks, making them unsafe to work on.

2.6.4 Storage

Wire rope should not be stored in places where acid is or has been kept. The slightest trace of acid coming in contact with wire rope damages it at that particular spot. Many times, wire rope that has failed has been found to be acid damaged. The importance of keeping acid or acid fumes away from wire rope must be stressed to all hands.

It is especially important that wire rope be cleaned and lubricated properly before it is placed in storage. Corrosion of wire rope during storage can be virtually eliminated if the lubricant film is applied properly beforehand and if adequate protection is provided from the weather. Bear in mind that rust, corrosion of wires, and deterioration of the fiber core greatly reduce the strength of wire rope. It is not possible to state exactly the loss of strength that results from these effects. It is certainly great enough to require close observance of precautions prescribed for protection against such effects.

2.6.5 Inspection

Inspect wire rope at regular intervals, the same as fiber line. In determining the frequency of inspection, carefully consider the amount of use of the rope and the conditions under which it is used.

During an inspection, examine the rope carefully for fishhooks, kinks, and worn, corroded spots. Usually, breaks in individual wires are concentrated in those portions of the rope that consistently run over the sheaves or bend onto the drum. Abrasion or reverse and sharp bends cause individual wires to break and bend back. These breaks are known as fishhooks. When wires are only slightly worn, but have broken off squarely and stick out all over the rope, the condition is usually caused by overloading or rough handling. Even if the breaks are confined to only one or two strands, the strength of the rope may be seriously reduced. When 4 percent of the total number of wires in the rope have breaks within the length of one lay of the rope, the wire rope is unsafe. Consider a rope unsafe when three broken wires are found in one strand of 6 by 7 rope, six broken wires in one strand of 6 by 19 rope, or nine broken wires in one strand of 6 by 37 rope.

Overloading a rope also reduces its diameter. Failure to lubricate the rope is another cause of reduced diameter, since the fiber core will dry out and eventually collapse or shrink. The surrounding strands are thus deprived of support, and the rope's strength and dependability are correspondingly reduced. Rope with a diameter reduced to less than 75 percent of its original diameter should be removed from service.

A wire rope should also be removed from service when an inspection reveals widespread corrosion and pitting of the wires. Pay particular attention to signs of corrosion and rust in the valleys, the small spaces between the strands. Since such corrosion is usually the result of improper or infrequent lubrication, the internal wires of the rope are then subject to extreme friction and wear. This form of internal, and often invisible, destruction of the wire is one of the most frequent causes of unexpected and sudden failure of wire rope. The best safeguard is to keep the rope well lubricated and to handle and store it properly.

2.7.0 Wire Rope Attachments

Many attachments can be fitted to the ends of wire rope to connect it to other wire ropes, pad eyes, or equipment. The attachment used most often to attach dead ends of wire ropes to pad eyes or like fittings on earthmoving rigs is the wedge socket, shown in *Figure 7-14*. Apply the socket to the bitter end of the wire rope as shown in the figure.

To configure a wedge socket and attach to wire rope, follow the steps listed below:

1. Remove the pin and knock out the wedge.
2. Pass the wire rope up through the socket and lead enough of it back through the socket to allow a minimum of six to nine inches of the bitter end to extend below the socket.
3. Replace the wedge, and haul on the bitter end of the wire rope until the bight closes around the wedge, as shown in *Figure 7-15*. A strain of the standing part will tighten the wedge. You need at least six to nine inches on the dead end, the end of the line that doesn't carry the load.

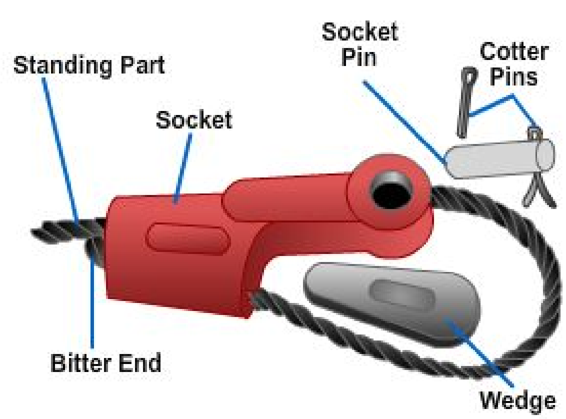


Figure 7-14 – Parts of a wedge socket.

4. Place one wire rope clip on the dead end to keep it from accidentally slipping back through the wedge socket. The clip should be approximately three inches from the socket. Use one size smaller clip than normal so that the threads on the U-bolt are only long enough to clamp tightly on one strand of wire rope. The other alternative is to use the normal size clip and hop the dead end back as shown in *Figure 7-15*. Never attach the clip to the live end of the wire rope.

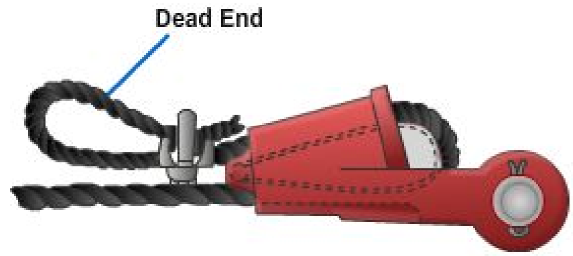


Figure 7-15 – Wedge socket attached properly.

The advantage of the wedge socket is that it is easy to remove; just take off the wire clip and drive out the wedge. The disadvantage of the wedge socket is that it reduces the strength of wire rope by about 30 percent. Of course, reduced strength means less safe working load.

To make an eye in the end of a wire rope, use new wire rope clips, like those shown in *Figure 7-16*.The U-shaped part of the clip with the threaded ends is called the U-bolt; the other part is called the saddle. The saddle is stamped with the diameter of the wire rope that the clip will fit. Always place a clip with the U-bolt on the bitter end, not on the standing part of the wire rope. If clips are attached incorrectly, the standing part or live end of the wire rope will be distorted or have mashed spots. An easy way to remember is never saddle a dead horse.

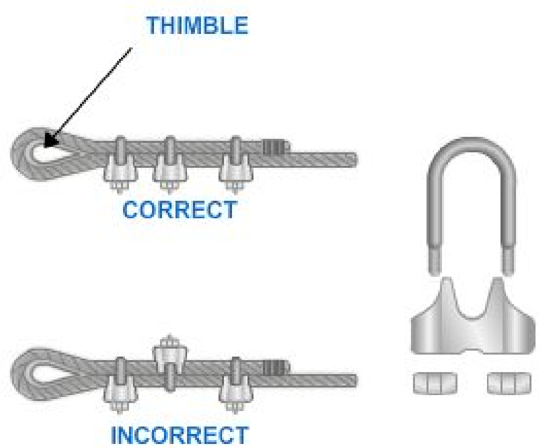


Figure 7-16 – Wire rope clips.

You also need to determine the correct number of clips to use and the correct spacing. Here are two simple formulas Remember D represents the diameter of the wire rope:

- Number of clips = 3 x D + 1
- Spacing between clips = 6 x D

Another type of wire rope clip is the twin-base wire clip, sometimes referred to as the universal or two-clamp, shown in *Figure 7-17*. Since both parts of this clip are shaped to fit the wire rope, correct installation is almost certain. This considerably reduces potential damage to the rope. The twin-base clip also allows for a clean 360° swing with the wrench when the nuts are being tightened. When an eye is made in a wire rope, a metal fitting (called a thimble) is usually placed in the eye, as shown in *Figure 7-16*, to protect the eye against wear. Clipped eyes with thimbles hold approximately 80 percent of the wire rope strength.

After the eye made with clips has been strained, retighten the nuts on the clips. Make occasional checks for tightness or damage to the rope caused by the clips.

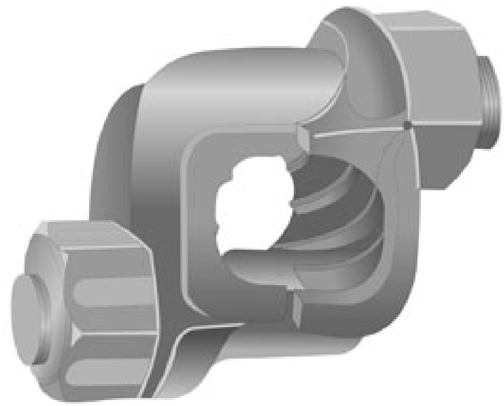


Figure 7-17 – Twin-base wire clip.

Test your Knowledge (Select the Correct Response)

3. Which of the following is not part of a wire rope?

   A. Wires
   B. Fibers
   C. Strands
   D. Core

4. **(True or False)** Once a new reel of wire rope has been opened, it may be either coiled or faked down like line.

   A. True
   B. False

5. **(True or False)** Rope that has its diameter reduced to less than 90 percent of its original diameter should be removed from service.

   A. True
   B. False

3.0.0 Block and Tackle

A block, shown in *Figure 7-18*, consists of one or more sheaves fitted in a wood or metal frame supported by a shackle inserted in the strap of the block. A tackle, as shown in *Figure 7-19*, is an assembly of blocks and lines used to gain a ***mechanical advantage*** in lifting and pulling.

In a tackle assembly, the line is ***reeved*** over the sheave(s) of blocks. The two types of tackle systems are simple and compound. A simple tackle system is an assembly of blocks in which a single line is used, as shown in view A of *Figure 7-19*. A compound tackle system is an assembly of blocks in which more than one line is used, as shown in view B of *Figure 7-19*.

Figure 7-18 – Fiber line block.

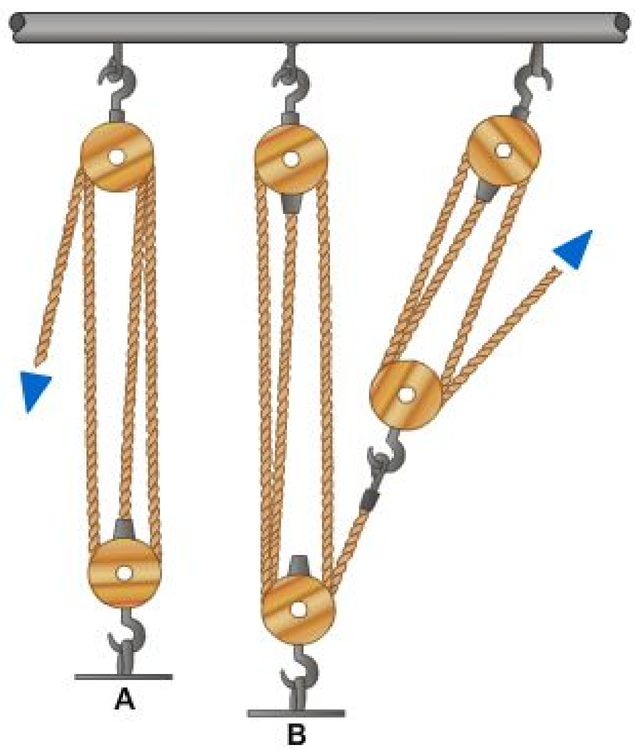


Figure 7-19 – Types of tackle: simple (view A) and compound (view B).

3.1.0 Tackle Terms

To help avoid confusion in working with tackle, you need a working knowledge of tackle vocabulary. *Figure 7-20* will help you organize the various terms.

A fall is a lie, either a fiber line or a wire rope, reeved through a pair of blocks to form a tackle. The hauling part is the part of the fall leading from one of the blocks upon which the power is exerted. The standing part is the end of the fall, which is attached to one of the beckets. The movable or running block of a tackle is the block attached to the object to be moved. The fixed or standing block is the block attached to a fixed object or support. When a tackle is being used, the movable block moves, and the fixed block remains stationary. The term two-blocked means that both blocks of a tackle are as close together as they will go. You may also hear this term called block-and-block. To overhaul is to lengthen a tackle by pulling the two blocks apart. To round in means to bring the blocks of a tackle toward each other, usually without a load on the tackle; this is the opposite of overhaul.

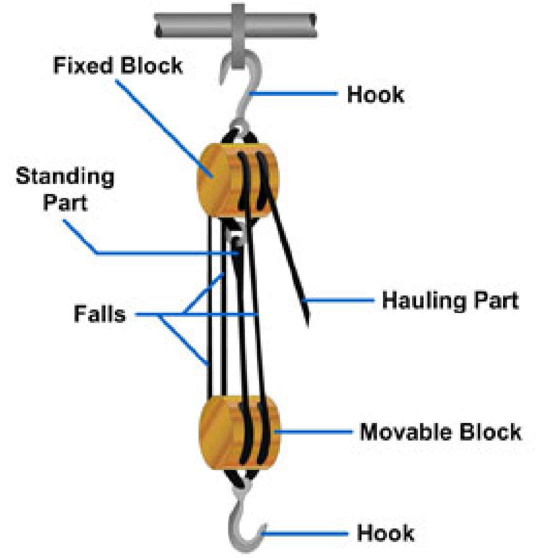


Figure 7-20 – Parts of a tackle.

Don't be surprised if your coworkers use a number of different terms for a tackle. For example, line and blocks, purchase, and block and falls are other typical names for tackle.

3.2.0 Block Nomenclature

The block(s) in a tackle assembly change(s) the direction of pull or mechanical advantage, or both. The name and location of the key parts of a fiber line block are shown in *Figure 7-21*.

The frame, or ***shell***, is made of wood or metal and houses the sheaves. The sheave is a round, grooved wheel over which the line runs. Ordinarily, blocks used in your work will have one, two, three, or four sheaves. Blocks can come with more than this number of sheaves; some come with 11 sheaves. The ***cheeks*** are the solid sides of the frame, or shell. The pin is a metal axle on which the sheave turns. It runs from cheek to cheek through the middle of the sheave. The becket is a metal loop formed at one or both ends of a block; the standing part of the line is fastened to this part. The straps hold the block together and support the pin on which the sheaves rotate. The swallow is the opening in the block through which the line passes. The breech is the part of the block opposite the swallow.

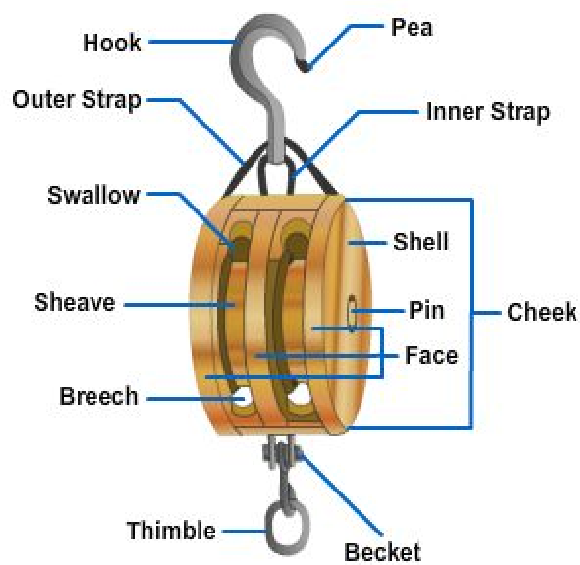


Figure 7-21 – Nomenclature of a fiber line block.

3.3.0 Construction of Blocks

Blocks are constructed for use with fiber line or wire rope. Wire rope blocks are heavily constructed and have a large sheave with a deep groove. Fiber line blocks are generally not as heavily constructed as wire rope blocks and have smaller sheaves with shallower wide grooves. Wire rope requires a large sheave to prevent sharp bending. Since fiber line is more flexible and pliable than wire rope, it does not require a sheave as large as the same size of wire rope.

Blocks fitted with one, two, three, or four sheaves are often referred to as single, double, triple, and quadruple blocks, respectively. Blocks are fitted with a number of attachments, the number depending upon their use. Some of the most commonly used fittings are ***hooks***, shackles, eyes, and rings. *Figure 7-22* shows two metal frame, heavy-duty blocks. Block A is designed for manila line, and block B is for wire rope.

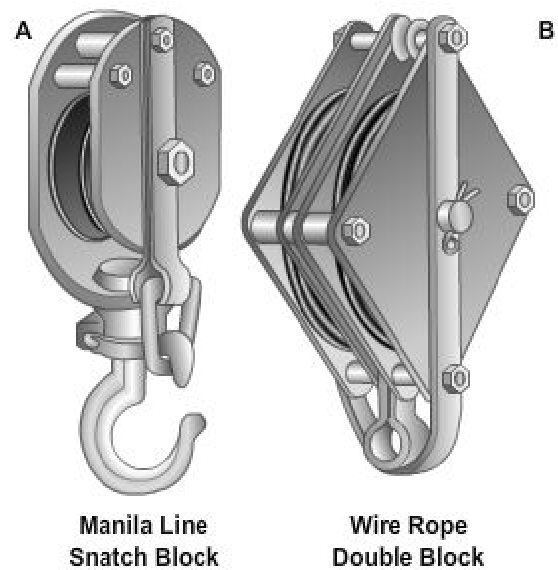


Figure 7-22 – Metal frame, heavy-duty blocks.

3.4.0 Ratio of Block Size to Line or Wire Size

The size of fiber line blocks is designated by the length in inches of the shell or cheek. The size of standard wire rope blocks is controlled by the diameter of the rope. The size of nonstandard and special purpose wire rope blocks is found by measuring the diameter of one of its sheaves in inches.

Use care in selecting the proper size line or wire for the block you are using. If a fiber line is reeved onto a tackle whose sheaves are below a certain minimum diameter, the line will be distorted and will soon wear badly. A wire rope too large for a sheave tends to be pinched and damage the sheave. The wire will also be damaged because of too short a radius of the bend. A wire rope too small for a sheave lacks the necessary bearing surface, puts the strain on only a few strands, and shortens the life of the wire.

With fiber line, the length of the block used should be about three times the circumference of the line. An inch or so either way doesn't matter too much; for example, a three inch line may be reeved onto an eight inch block with no ill effects. As a rule, you are more likely to know the block size than the sheave diameter. The sheave diameter should be about twice the size of the circumference of the line used.

Wire rope manufacturers issue tables that give the proper sheave diameters used with the various types and sizes of wire rope they manufacture. In the absence of these, a rough rule of thumb is that the sheave diameter should be about 20 times the diameter of the wire. Remember that with wire rope, diameter rather than circumference is important. Also remember that this rule refers to the diameter of the sheave rather than to the size of the block.

3.5.0 Snatch Blocks and Fairleads

A ***snatch block***, as shown in *Figure 7-22*, is a single sheave block made so that the shell opens on one side at the base of the hook to permit a rope or line to be slipped over a sheave without threading the end of it through the block. Snatch blocks are ordinarily used where it is necessary to change the direction of the pull on a line.

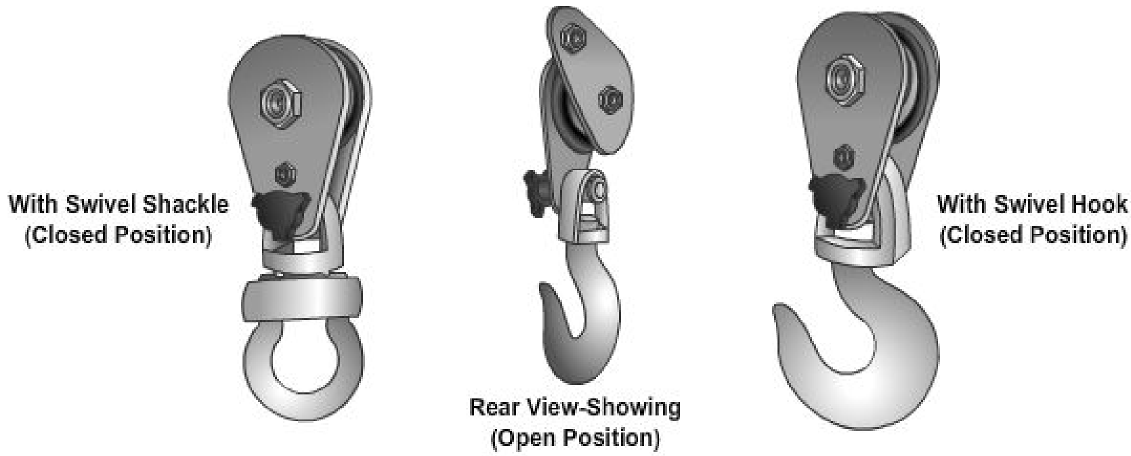


Figure 7-23 – Top dead end snatch blocks.

Figure 7-24 shows a system for moving a heavy object horizontally away from the power source using snatch blocks. This is an ideal way to move objects in limited spaces. Note that the weight is pulled by a single luff tackle, which has a mechanical advantage of three (mechanical advantage is discussed below). Adding snatch blocks to rigging changes the direction of pull but does not affect the mechanical advantage. It is, therefore, wise to select the proper rigging system to use based upon the weight of the object and the type and capacity of the power that is available.

The snatch block used as the last block in the direction of pull to the power source is called the leading block. This block can be placed in any convenient location provided it is within 20 drum widths of the power source. This is required because the ***fairlead*** angle, or ***fleet angle***, cannot exceed 2° from the center line of the drum; therefore, the 20-drum width distance from the power source to the leading block will assure the fairlead angle. If the fairlead angle is not maintained, the line could jump the sheave of the leading block and cause the line on the reel to jump a riding turn.

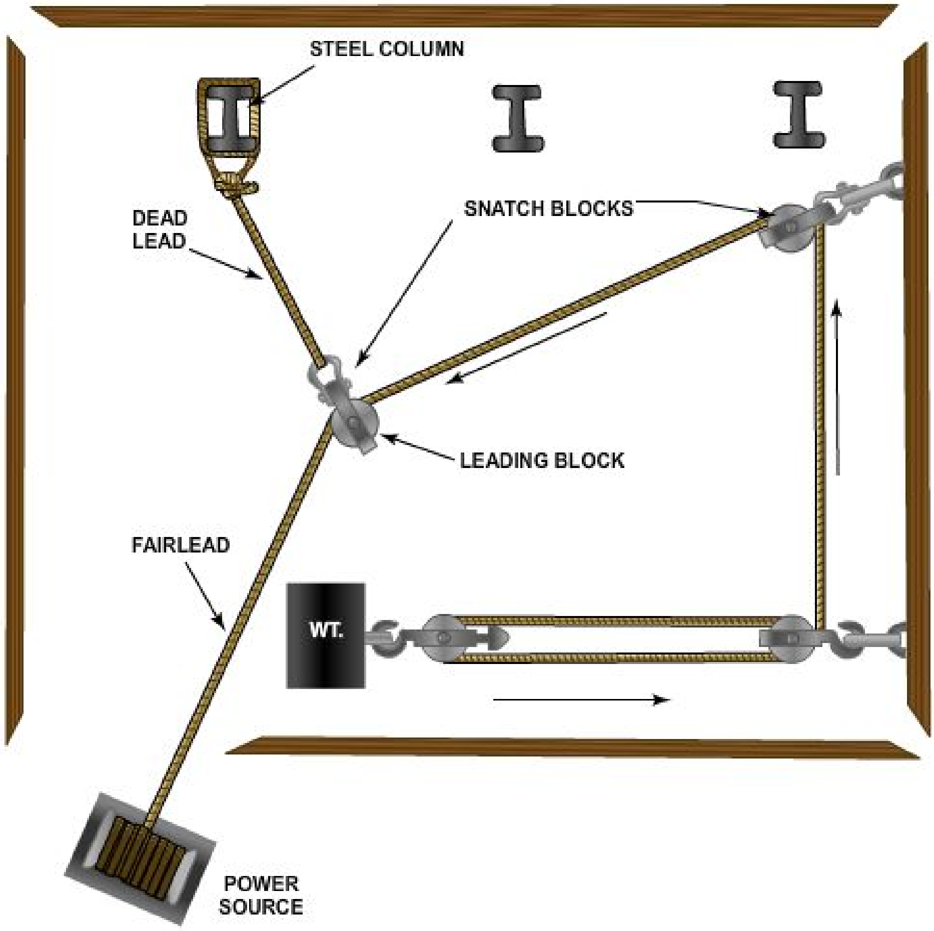


Figure 7-24 – Moving a heavy object horizontally along floor with limited access using snatch blocks and fairleads.

3.6.0 Mechanical Advantage

The mechanical advantage of a tackle is the term applied to the relationship between the load being lifted and the power required to lift it. If the load and the power required to lift it are the same, the mechanical advantage is one. If a load of 50 pounds requires only 10 pounds to lift it, then you have a mechanical advantage of five to one, or five units of weight are lifted for each unit of power applied.

The easiest way to determine the mechanical advantage of a tackle is by counting the number of parts of the falls at the running block. If there are two parts, the mechanical advantage is two times the power applied, disregarding friction. A gun tackle, for instance, has a mechanical advantage of two. Lifting a 200 pound load with a gun tackle requires 100 pounds of power, disregarding friction.

To determine the amount of power required to lift a given load by means of a tackle, determine the weight of the load to be lifted and divide that by the mechanical advantage. For example, if it is necessary to lift a 600 pound load by means of a single luff tackle, first determine the mechanical advantage gained by the tackle. By counting the parts of the falls at the movable block, you determine a mechanical advantage of three. By dividing the weight to be lifted, 600 pounds, by the mechanical advantage in this tackle, three, we find that 200 pounds of power is required to lift a weight of 600 pounds using a single luff tackle.

Remember, a certain amount of the force applied to a tackle is lost through friction. Friction develops in a tackle from the lines rubbing against each other or against the shell of a block. You must add an adequate allowance for the loss from friction. Roughly 10 percent of the load must be allowed for each sheave in the tackle.

3.7.0 Types of Tackle

Tackles are designated in two ways: first, according to the number of sheaves in the blocks used to make the tackle, such as single whip or twofold purchase; and second, by the purpose for which the tackle is used, such as yard tackles or stay tackles. In this section, we'll discuss some of the different types of tackle in common use; single whip, runner, gun tackle, single luff, twofold purchase, double luff, and threefold purchase. The purpose of the letters and arrows in *Figures 7-25* through *7-31* is to indicate the sequence and direction in which the standing part of the fall is led in reeving. You may want to refer to these illustrations when we discuss reeving of blocks in the next sections.

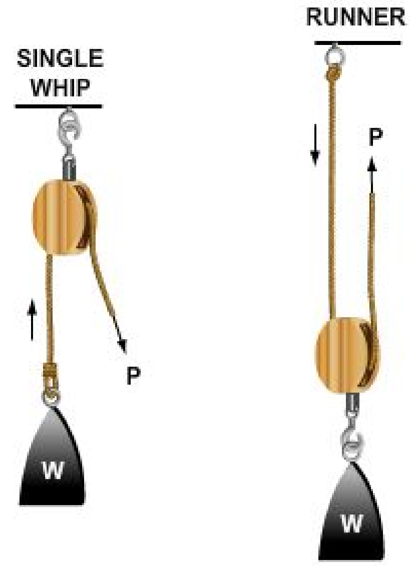


Figure 7-25 – Single-whip and runner tackle.

A single whip tackle consists of one single sheave block or tail block fixed to a support with a rope passing over the sheave as shown in *Figure 7-25*. It has a mechanical advantage of one. Lifting a 100 pound load requires a pull of 100 pounds plus an allowance for friction.

A runner, as shown in *Figure 7-25*, is a single sheave movable block that is free to move along the line on which it is reeved. It has a mechanical advantage of two.

A gun tackle is made up of two single sheave blocks as shown in *Figure 7-26*. This tackle got its name in the old days because it was used to haul muzzle-loading guns back into the battery after they had been fired and reloaded. A gun tackle has a mechanical advantage of two. To lift a 200 pound load with a gun tackle requires 100 pounds of power, disregarding friction.

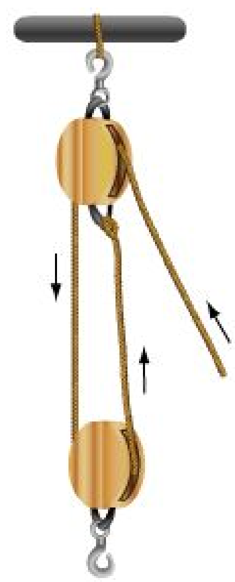


Figure 7-26 – Gun tackle.

By inverting any tackle, you always gain a mechanical advantage of one because the number of parts at the movable block increases. By inverting a gun tackle, for example, you gain a mechanical advantage of three, as shown in *Figure 7-27*. When a tackle is inverted, the direction of pull is difficult. You can easily overcome this by adding a snatch block, which changes the direction of the pull but does not increase the mechanical advantage.

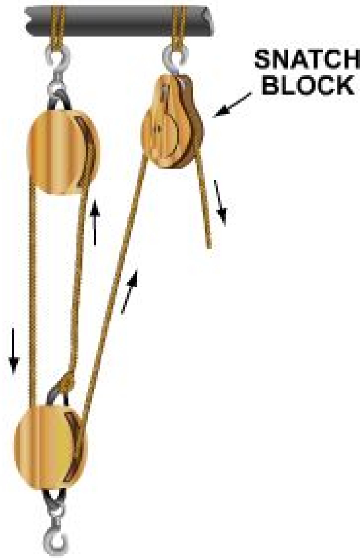


Figure 7-27 – Inverted gun tackle.

A single-luff tackle consists of a double and single block, as shown in *Figure 7-28*, and the double-luff tackle has one triple and one double block, as shown in *Figure 7-29*. The mechanical advantage of the single is three; the mechanical advantage of the double is five.

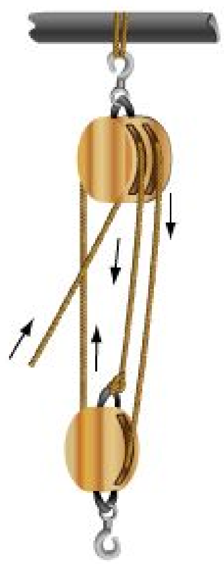


Figure 7-28 – Single-luff tackle.

Figure 7-29 – Double-luff tackle.

A twofold purchase consists of two double blocks, as shown in *Figure 7-30*, whereas a threefold purchase consists of two triple blocks, as shown in *Figure 7-31*. The mechanical advantage of the twofold purchase is four; that of the threefold is six.

Figure 7-30 – Twofold purchase.

Figure 7-31 – Threefold purchase.

3.8.0 Reeving Tackle

In reeving a simple tackle, lay the blocks a few feet apart. Place the blocks down with the sheaves at right angles to each other and the becket ends pointing toward each other.

To begin reeving, lead the standing part of the falls through one sheave of the block that has the greatest number of sheaves. If both blocks have the same number of sheaves, begin at the block fitted with the becket. Then pass the standing part around the sheaves from one block to the other, making sure no lines are crossed, until all sheaves have a line passing over them. Now, secure the standing part of the falls at the becket of the block containing the least number of sheaves, using a becket hitch for a temporary securing or an eye splice for a permanent securing.

With blocks of more than two sheaves, lead the standing part of the falls through the sheave nearest the center of the block. This method places the strain on the center of the block and prevents the block from toppling and the lines from being cut by rubbing against the edges of the block.

Falls are generally reeved through eight or ten inch wood or metal blocks in such a manner as to have the lower block at right angles to the upper block. Two three-sheave blocks are the usual arrangement, and the method of reeving these is shown in *Figure 7-32*. The hauling part must go through the middle sheave of the upper block, or the block will tilt to the side and the falls jam when a strain is taken.

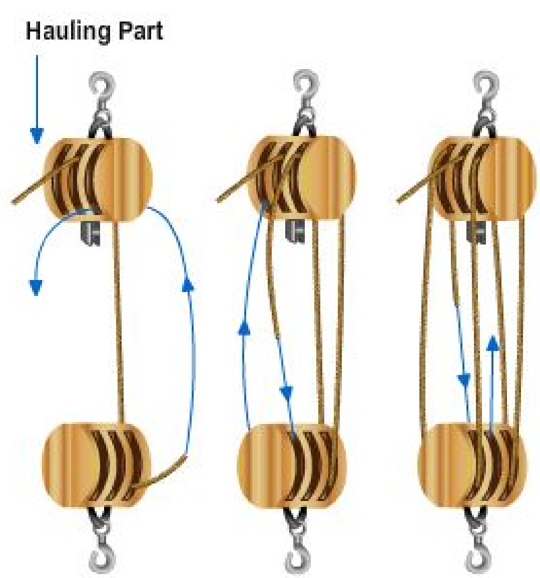


Figure 7-32 – Reeving a threefold purchase.

If a three and two-sheave block rig is used, the method of reeving is about the same as shown in *Figure 7-33,* but, in this case, the becket for the dead end must be on the lower, rather than the upper block.

Naturally, you must reeve the blocks before you splice in the becket thimble, or you will have to reeve the entire fall through from the opposite end.

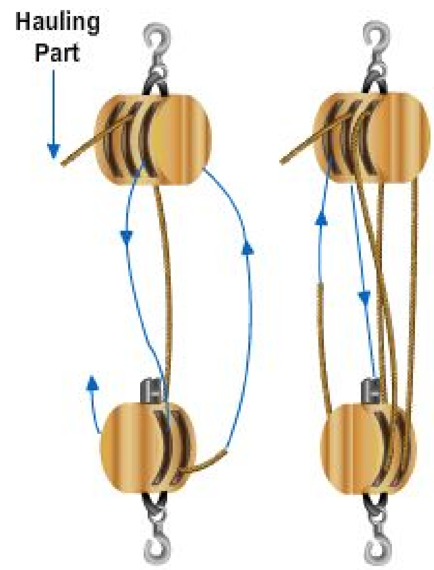


Figure 7-33 – Reeving a double-luff tackle.

3.9.0 Safe Working Load of Tackle

You know that the force applied at the hauling part of a tackle is multiplied as many times as there are parts of the fall on the movable block. Also, you must allow for friction, which adds roughly 10 percent to the weight to be lifted for every sheave in the system. If you are lifting a weight of 100 pounds with a tackle containing five sheaves, you must add 10 percent times five, or 50 percent, of 100 pounds to the weight in your calculations. In other words, you determine that this tackle is going to lift 150 pounds instead of 100 pounds.

Disregarding friction, the safe working load of a tackle should be equal to the safe working load of the line or wire used multiplied by the number of parts of the fall on the movable block. To make the necessary allowance for friction, multiply this result by 10, and then divide what you get by 10 plus the number of sheaves in the system.

Suppose you have a threefold purchase with a mechanical advantage of 6, reeved with a line that has a safe working load of two tons. Disregarding friction, 6 times 2, or 12 tons, should be the safe working load of this setup. To make the necessary allowance for friction, multiply 12 by 10, this gives you 120. This you divide by 10 plus 6, the number of sheaves in a threefold purchase, or 16. The answer is 7 1/2 tons safe working load.

3.9.1 Lifting a Given Weight

To find the size of fiber line required to lift a given load, use this formula:

$$C = \sqrt{15 \ x \ P}$$

C in the formula is the circumference, in inches, of the line that is safe to use. The number 15 is the conversion factor. P is the weight of the given load expressed in tons. The radical sign over 15 x P indicates you are to find the square root of that product.

To square a number means to multiply that number by itself. Finding the square root of a number means finding the number that, multiplied by itself, gives the number whose square root you are seeking. Most pocket calculators today have a square root function. Now, let’s determine what size fiber line you need to hoist a 5 ton load. First, circumference equals 15 times five, or:

$$C = 15 \times 5, \text{ or } 75$$

Next the number that multiplied by itself comes nearest to 75 is 8.6. A fiber line 8 1/2 inches in circumference will do the job.

The formula for finding the size of wire rope required to lift a given load is:

$C = 2.5 \times P$

C is the circumference, in inches, of the rope that is safe to use. The number 2.5 is the conversion factor. *P* is the weight of the given load expressed in tons. You work this formula in the same manner explained above for fiber line. One point you should be careful not to overlook is that these formulas call for the circumference of the wire. You are used to talking about wire rope in terms of its diameter, so remember that circumference is about three times the diameter, roughly speaking. You can also determine circumference by the following formula, which is more accurate than the rule of thumb:

$C = D \times \pi$

C is the circumference in inches; D is the diameter in inches. In using this formula, remember that π equals approximately 3.14.

3.9.2 Size of Line to Use in a Tackle

To find the size of line to use in a tackle for a given load, add one-tenth, 10 percent for friction, of its value to the weight to be hoisted for every sheave in the system. Divide the result you get by the number of parts of the fall at the movable block, and use this result as P in the formula.

$C = \sqrt{15 \ x \ P}$

For example, let's say you are trying to find the size of fiber line to reeve in a threefold block to lift 10 tons. There are six sheaves in a threefold block. Ten tons plus one tenth for each of the six sheaves, a total of six tons, gives you a theoretical weight of 16 tons to be lifted. Divide 16 tons by six, the number of parts on the movable block in a threefold block, and you get about 2 2/3. Using this as P in the formula you get:

$C = \sqrt{15 \ x \ 2 \ \ 2/3}$

$= \sqrt{40}$

or about 6.3

The square root of 40 is about 6.3, so it will take a line of about 6 1/2 inches in this purchase to hoist 10 tons safely. As you seldom find three-sheave blocks that will take a line as large as 6 1/2 inches, you will probably have to rig two threefold blocks with a continuous fall, as shown in *Figure 7-34*. Each of these will have half of the load. To find the size of the line to use, calculate what size fiber line in a threefold block will lift five tons. It works out to about 4 1/2 inches.

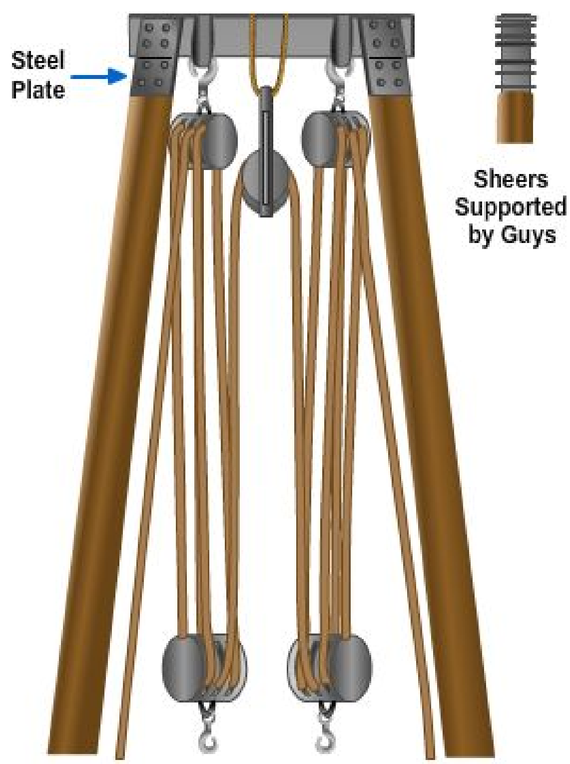


Figure 7-34 – Rigging two tackles with continuous fall.

3.10.0 Tackle Safety Precautions

In hoisting and moving heavy objects with blocks and tackle, stress safety for people and materials.

Always check the condition of blocks and sheaves to make sure they are in safe working order before using them on a job. See that the blocks are properly greased. Also, make sure that the line and sheave are the right size for the job.

Remember that you must not use sheaves or drums that have become worn, chipped, or corrugated because they will damage the line. Always find out whether you have enough mechanical advantage in the amount of blocks to make the load as easy to handle as possible.

Sheaves and blocks designed for use with fiber line must not be used for wire rope since they are not strong enough for that service, and the wire rope does not fit the sheave grooves. Also, sheaves and blocks built for wire rope should never be used for fiber line.

3.11.0 Hooks and Shackles

Hooks and shackles are handy for hauling or lifting loads without tying them directly to the object with a line or wire rope. They can be attached to wire rope, fiber line, or blocks. Shackles should be used for loads too heavy for hooks to handle.

Hooks should be inspected at the beginning of each workday and before lifting a full rated load. *Figure 7-35* shows where to inspect a hook for wear and strain. Be especially careful during the inspection to look for cracks in the saddle section and at the neck of the hook.

When the load is too heavy for you to use a hook, use a shackle. Shackles, like hooks, should be inspected on a daily routine and before lifting heavy loads.

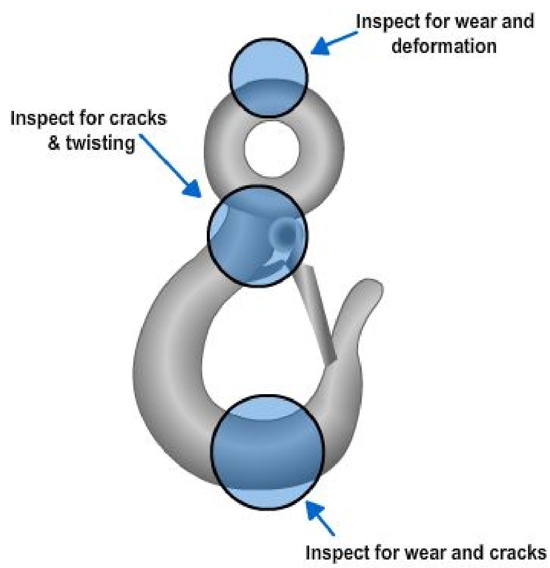


Figure 7-35 – Hook inspection.

Figure 7-36 shows the area to look for wear.

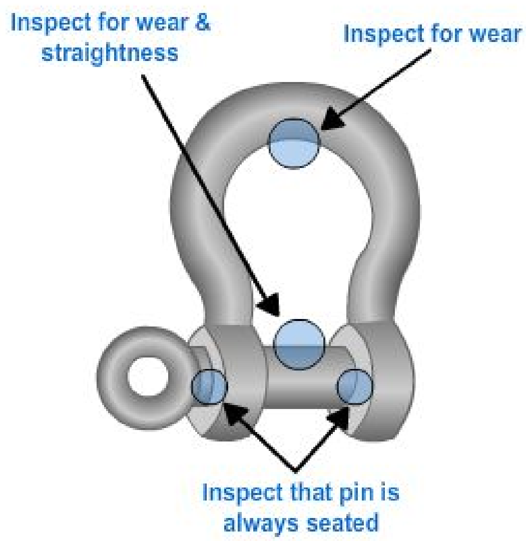


Figure 7-36 – Shackle inspection.

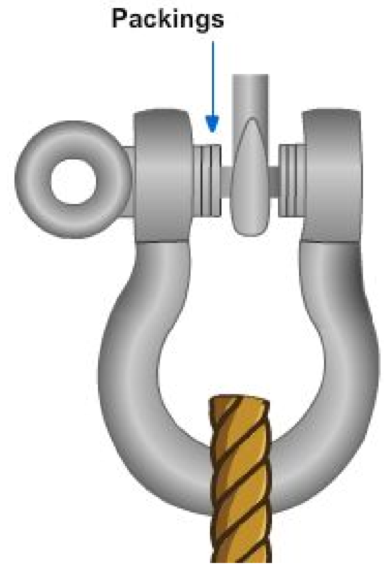


Figure 7-37 – Packing a shackle with washers.

You should never replace the shackle pin with a bolt. Never use as shackle with a bent pin, and never allow the shackle to be pulled at an angle; doing so will reduce its carrying capacity. Packing the pin with washers centralizes the shackle as shown in *Figure 7-37*.

If you need a hook or shackle for a job, always get it from Alpha Company. This way, you will know that it has been load tested.

Mousing is a technique often used to close the open section of a hook to keep slings, straps, and so on, from slipping off the hook as shown in *Figure 7-38*. To some extent, it also helps prevent straightening of the hook. Hooks may be moused with rope yarn, seizing wire, or a shackle. When using rope yarn or wire, make 8 to 10 wraps around both sides of the hook. To finish off, make several turns with the yarn or wire around the sides of the mousing, and then tie the ends securely as shown in *Figure 7-38*.

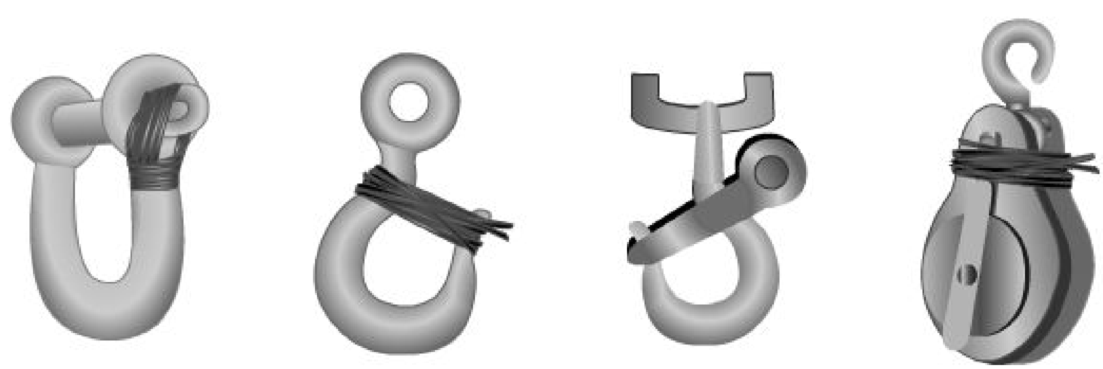


Figure 7-38 – Mousing.

Shackles are moused when there is danger of the shackle pin working loose and coming out because of vibration. To mouse a shackle, simply take several turns with seizing wire through the eye of the pin and around the bow of the shackle. *Figure 7-38* shows what a properly moused shackle looks like.

Test your Knowledge (Select the Correct Response)

6. How many types of tackle systems exist?

   A. Two
   B. Three
   C. Four
   D. Five

7. When using fiber line, the length of the block should be about how many times the circumference of the line?

   A. Two
   B. Three
   C. Four
   D. Five

8. What are the components of a single luff tackle?

   A. One triple and one double block
   B. Two double and one single block
   C. One double and one single block
   D. Two double blocks

4.0.0 HOISTING

Lifting any load safely takes two personnel, an equipment operator and a signalman. In the following paragraphs, we will discuss the importance of the signalman and a few of the safety rules all hands engaged in hooking on must observe.

4.1.0 Signalman

One person and one person only should be designated as the official signalman for the operator of a piece of hoisting equipment, and both the signalman and the operator must be thoroughly familiar with the standard hand signals. When possible, the signalman should wear some distinctive article of dress, such as a bright-colored helmet. The signalman must maintain a position from which he or she can see the load and the crew working on it and the operator can see him or her.

Figure 7-39 shows the standard hand signals for hoisting equipment. Some of the signals shown apply only to mobile equipment; others to equipment with a boom that can be raised, lowered, and swung in a circle. The signalman uses two-arm hoist and lower signals when he or she desires to control the speed of hoisting or lowering. The one-arm hoist or lower signal allows the operator to raise or lower the load. To dog off the load and boom means to set the brakes so as to lock both the hoisting mechanism and the boom hoist mechanism. The signal is given when circumstances require that the load be left hanging motionless.

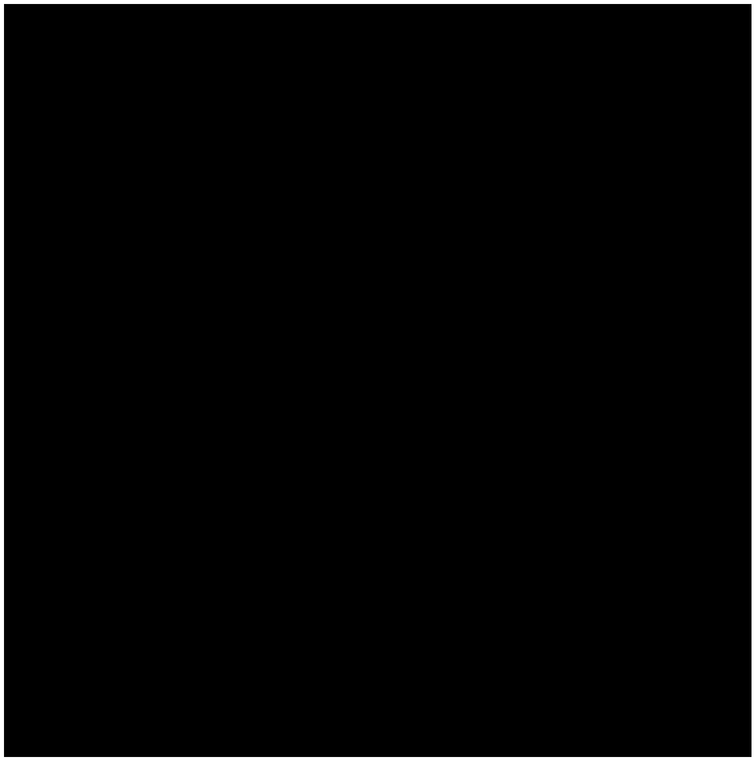


Figure 7-39 – Hand signals.

With the exception of the emergency stop signal, which may be given by anyone who sees a necessity for it, and which the operator must obey instantly, only the official signalman gives the signals. The signalman is responsible for making sure that members of the crew remove their hands from slings, hooks, and loads before giving a signal. The signalman should also make sure that all persons are clear of bights and snatch block lines.

4.2.0 Attaching a Load

The most common way of attaching a load to a lifting hook is to put a sling around the load and hang the sling on the hook as shown in *Figure 7-40*.

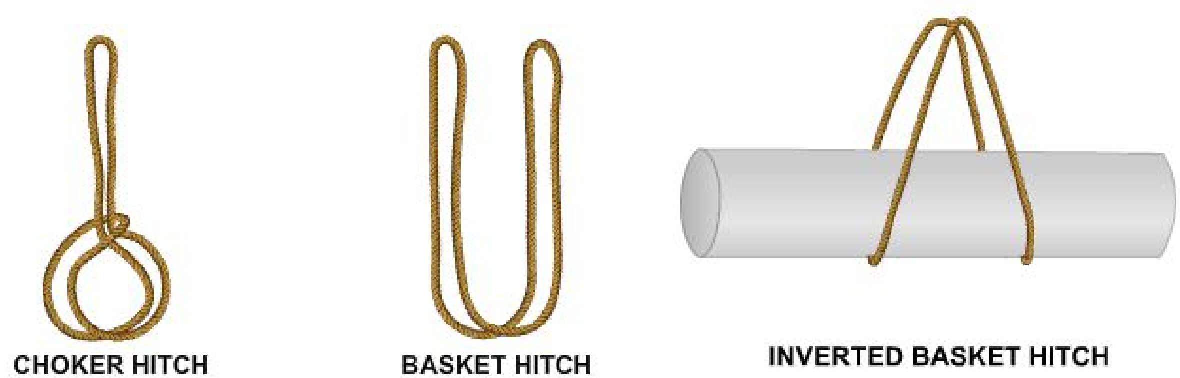


Figure 7-40 – Ways of hitching on a sling.

A sling can be made of line, wire, or wire rope with an eye in each end, also called a strap, or an endless sling, shown in *Figure 7-41*. When a sling is passed through its own bight or eye, or shackled or hooked to its own standing part, so that it tightens around the load like a lasso when the load is lifted, the sling is said to be choked, or it may be called a choker, shown in *Figures 7-40* and *7-41*. A two-legged sling that supports the load at two points is called a bridle, shown in *Figure 7-42.*

Figure 7-41 – Ways of hitching on straps.

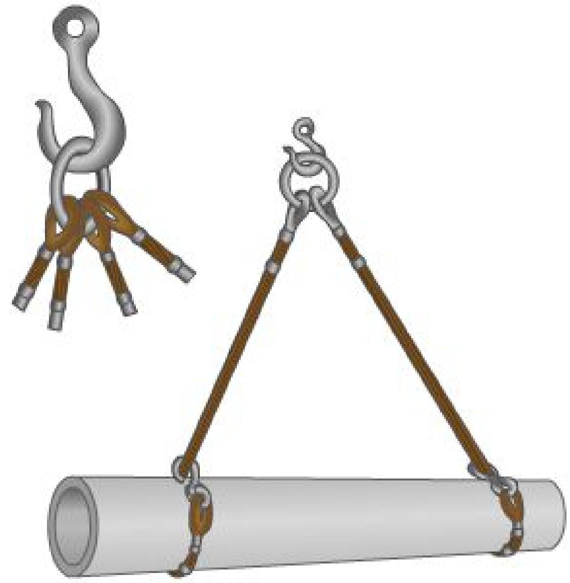


Figure 7-42 – Bridles.

4.3.0 Safety Rules

The following safety rules must be given to all hands engaged in hooking on. They must be strictly observed.

- The person in charge of hooking on must know the safe working load of the rig and the weight of every load to be hoisted. The hoisting of any load heavier than the safe working load of the rig is absolutely prohibited.
- When a cylindrical metal object, such as a length of pipe, a gas cylinder, or the like, is hoisted in a choker bridle, give each leg of the bridle a round turn around the load before hooking or shackling it to its own part or have a spreader bar placed between the legs. The purpose of this is to ensure that the legs of the bridle will not slide together along the load, upsetting the balance and possibly dumping the load.
- The point of strain on a hook must never be at or near the point of the hook.
- Before the hoist signal is given, the person in charge must be sure that the load will balance evenly in the sling.
- Before the hoist signal is given, the person in charge should be sure that the lead of the whip or falls is vertical. If it is not, the load will take a swing as it leaves the deck or ground.
- As the load leaves the deck or ground, the person in charge must watch carefully for kinked or fouled falls or slings. If any are observed, the load must be lowered at once for clearing.

- Use tag lines to guide and steady a load when there is a possibility that the load might get out of control.
- Before any load is hoisted, inspect it carefully for loose parts or objects that might drop as the load goes up.
- Clear all personnel from and keep them out of any area that is under a suspended load, or over which a suspended load may pass.
- Never walk or run under a suspended load.
- Do not place or leave loads at any point closer than four feet eight inches from the nearest rail of a railroad track or crane truck, or in any position where they would impede or prevent access to fire-fighting equipment.
- When materials are being loaded or unloaded from any vehicle by crane, the vehicle operators and all other persons, except the rigging crew, should stand clear.
- When materials are placed in work or storage areas, provide dunnage or shoring, as necessary, to prevent tipping of the load or shifting of the materials.
- All crew members must stand clear of loads that tend to spread out when landed.
- When slings are being heaved out from under a load, all crew members must stand clear to avoid a backlash, and to avoid a toppling or a tip of the load, which might be caused by fouling of a sling.

4.4.0 Shear Legs

The shear legs are formed by crossing two timbers, poles, planks, pipes, or steel bars and lashing or bolting them together near the top. A sling is suspended from the lashed intersection and used as a means of supporting the load tackle system, as shown in *Figure 7-43*. In addition to the name shear legs, this rig is often simply called a shears. It has also been called an A-frame.

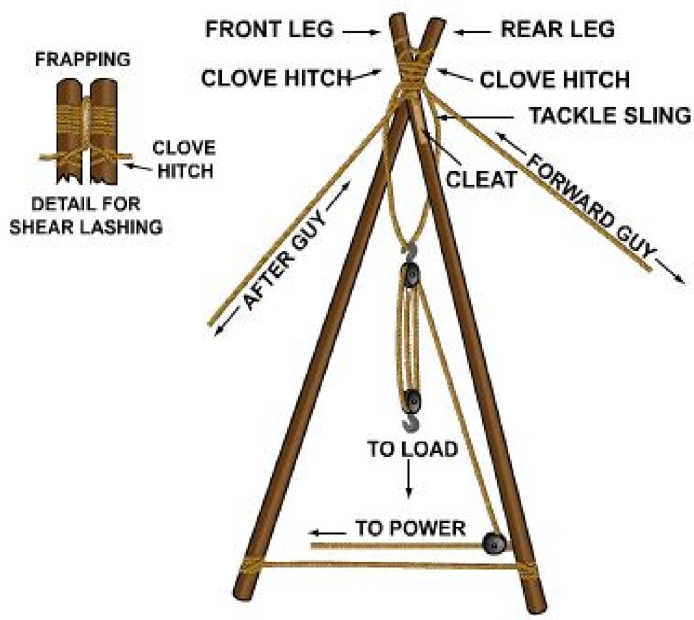


Figure 7-43 – Shear legs.

The shear legs are used to lift heavy machinery and other bulky objects. They may also be used as end supports of a cableway and highline. The fact that the shears can be quickly assembled and erected is a major reason why they are used in field work.

A shears requires only two guy lines and can be used for working at a forward angle. The forward guy does not have much strain imposed on it during hoisting. This guy is used primarily as an aid in adjusting the drift of the shears and in keeping the top of the rig steady in hoisting or placing a load. The after guy is a very important part of the shears' rigging, as it is under considerable strain when hoisting. It should be designed for strength equal to one-half the load to be lifted. The same principles for thrust on the spars or poles apply, the thrust increases drastically as the shear legs go off the perpendicular.

The following are the steps for rigging the shears:

- Place your two spars on the ground parallel to each other and with their butt ends even.
- Put a large block of wood under the tops of the legs just below the point of lashing, and place a small block of wood between the tops at the same point to facilitate handling of the lashing.
- Separate the poles a distance equal to about one-third the diameter of one pole.
- As lashing material, use 18 or 21 thread small stuff. In applying the lashing, first make a clove hitch around one of the legs.
- Take about eight or nine turns around both legs above the hitch, working towards the top of the legs. Remember to wrap the turns tightly so that the finished lashing will be smooth and free of kinks.
- To apply the frapping, also known as tight lashings, make two or three turns around the lashing between the legs.
- With a clove hitch, secure the end of the line to the other leg just below the lashing as shown in *Figure 7-43*.
- Cross the legs of the shears at the top, and separate the butt ends of the two legs so that the spread between them is equal to one-half the height of the shears.
- Dig shallow holes, about one foot (30 cm) deep, at the butt end of each leg. The butts of the legs should be placed in these holes in erecting the shears. Placing the legs in the holes will keep them from kicking out in operations where the shears are at an angle other than vertical.
- Form the sling for the hoisting falls. To do this, take a short length of line, pass it a sufficient number of times over the cross at the top of the shears, and tie the ends together.
- Reeve a set of blocks and place the hook of the upper block through the sling, and secure the hook by mousing the open section of the hook with rope yarn to keep it from slipping off the sling.
- Fasten a snatch block to the lower part of one of the legs, as indicated in *Figure 7-43*.
- Secure the guys, one forward guy and one after guy, next to the top of the shears. Secure the forward guy to the rear leg and the after guy to the front leg using a clove hitch in both instances. If you need to move the load horizontally by moving the head of the shears, you must rig a tackle in the after guy near its anchorage.

4.5.0 Tripods

A tripod consists of three legs of equal length that are lashed together at the top as shown in *Figure 7-44*. The legs are generally made of timber poles or pipes.

Materials used for lashing include fiber line, wire rope, and chain. Metal rings joined with short chain sections are also available for insertion over the top of the tripod legs.

Compared to other hoisting devices, the tripod has a distinct disadvantage: it is limited to hoisting loads only vertically. Its use will be limited primarily to jobs that involve hoisting over wells, mine shafts, or other such excavations. A major advantage of the tripod is its great stability. In addition, it requires no guys or anchorages, and its load capacity is approximately one-third greater than shears made of the same size timbers. *Table 7-1* gives the load-carrying capacities of shear legs and tripods for various pole sizes.

Figure 7-44 – Tripod.

Table 7-1 – Load Carrying Capacities of Shear Legs and Tripods

Pole Size (Inches)	Length (Feet)	Working Capacity (Tons) Shear Legs (2) Poles	Working Capacity (Tons) Tripods (3) Poles
6 x 6	20	8	13
	25	5	7
	30	3	5
8 x 8	25	12	18
	30	8	13
	40	5	7
	50	3	5
10 x 10	20	35	52
	25	26	39
	30	17	26
	40	10	15
	50	7	10
12 x 12	30	35	52
	40	21	31
	50	14	21
	60	10	15

4.5.1 Rigging Tripods

The strength of a tripod depends largely on the strength of the material used for lashing, as well as the amount of lashing used. The following procedure for lashing applies to a line three inches in circumference or smaller. For extra heavy loads, use more turns than specified in the procedure given her. For light loads, use fewer turns than specified here.

As the first step in the procedure, take three spars of equal length and place a mark near the top of each to indicate the center of the lashing. Now, lay two of the spars parallel with their tops resting on a skid or block. Place the third spar between the two, with the butt end resting on a skid. Position the spars so that the lashing marks on all three spars are in line. Leave an interval between the spars equal to about one-half the diameter of the spars. This will keep the lashing from being drawn too tightly when you erect the tripod.

With the three inch line, make a clove hitch around one of the outside spars; put it about four inches above the lashing mark. Then make eight or nine turns with the line around all three spars as shown in view A of *Figure 7-45*. In making the turns, remember to maintain the proper amount of space between the spars.

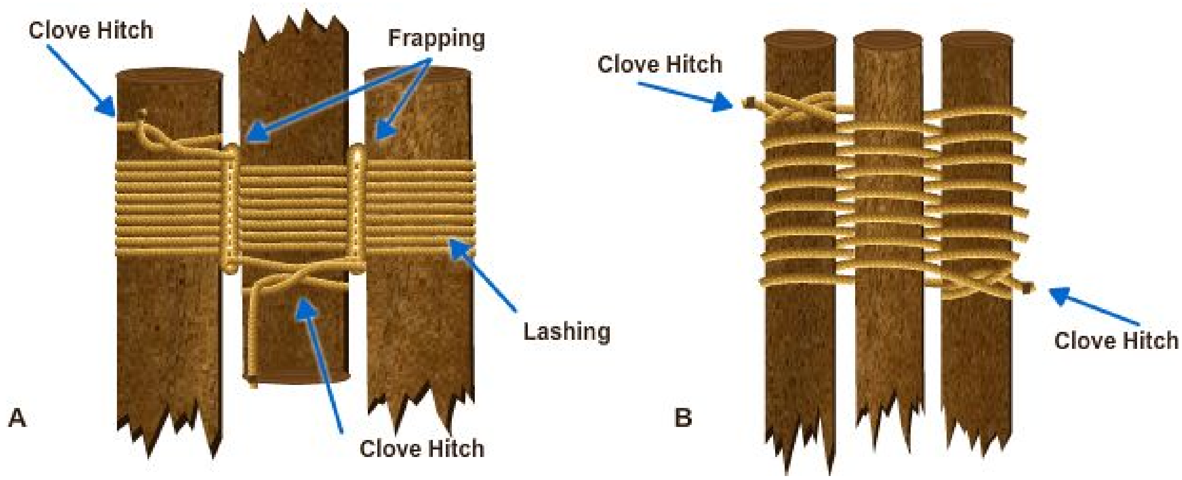


Figure 7-45 – Lashings for a tripod.

Now, make one or two close frapping turns around the lashing between each pair of spars. Do not draw the turns too tightly. Finally, secure the end of the line with a clove hitch on the center spar just above the lashing; as shown in view A of *Figure 7-45*.

There is another method of lashing a tripod that you may find preferable to the method just given. You may use it in lashing slender poles up to 20 feet in length, or when some means other than hand power is available for erection.

First, place the three spars parallel to each other, leaving an interval between them slightly greater than twice the diameter of the line to be used. Rest the top of each pole on a skid so that the end projects about two feet over the skid. Then line up the butts of the three spars, as indicated in view B of *Figure 7-45*.

Next, make a clove hitch on one outside leg at the bottom of the position the lashing will occupy, which is about two feet from the end. Now, proceed to weave the line over the middle leg, under and around the other outside leg, under the middle leg, over and around the first leg, and so forth, until completing about eight or nine turns. Finish the lashing by forming a clove hitch on the other outside leg as shown in view B of *Figure 7-45*.

4.6.0 Erecting Tripods

In the final position of an erected tripod, it is important that the legs be spread an equal distance apart. The spread between legs must be no more than two-thirds or less than one-half the length of the leg. Small tripods, or those lashed according to the first procedure given in the preceding section, may be raised by hand. The following are the main steps:

- Raise the top ends of the three legs about 4 feet, keeping the butt ends of the legs on the ground.
- Cross the tops of the two outer legs, and position the top of the third or center leg so that it rests on top of the cross.
- You can readily attach a sling for the hoisting tackle by first passing the sling over the center leg, and then around the two outer legs at the cross. Place the hook of the upper block of a tackle on the sling, and secure the hook by mousing.
- You can now complete the raising operation. Raising an ordinary tripod, requires a crew of about eight. As the tripod is being lifted, spread the legs so that when it is in the upright position, the legs will be spread the proper distance apart.
- After getting the tripod in its final position, lash the legs near the bottom with line or chain to keep them from shifting, as shown in *Figure 7-44*.
- Where desirable, you can lash a leading block for the hauling part of the tackle to one of the tripod legs, as shown in *Figure 7-44*.

In erecting a large tripod you may need a small ***gin pole*** to aid in raising the tripod into position. The following are the steps in that procedure:

- To erect a tripod lashed according to the first procedure described in the preceding section, first raise the tops of the legs far enough from the ground to permit spreading them apart.
- Use guys or tag lines to help hold the legs steady as you raise them.
- With the legs clear of the ground, cross the two outer legs and place the center leg so that it rests on top of the cross.
- Attach the sling for the hoisting tackle. Here, as with a small tripod, simply pass the sling over the center leg and then around the two outer legs at the cross.

Test Your Knowledge (Select the Correct Response)

9. What two individuals are responsible for making a safe lift or hoist?

   A. Equipment operator and division chief
   B. Equipment operator and site supervisor
   C. Signalman and equipment operator
   D. Signalman and division chief

10. **(True or False)** A shears requires a minimum of three guy lines.

   A. True
   B. False

11. **(True or False)** A tripod is limited to hoisting only vertical loads.

A. True
B. False

5.0.0 SCAFFOLDING

As the working level of a structure rises above the reach of crew members on the ground or deck, temporary elevated platforms, called scaffolding, are erected to support the crew members, their tools, and materials.

There are two types of scaffolding in use today, wood and prefabricated. The wood types include the swinging scaffold, which is suspended from above, and the pole scaffold, which is supported on the ground or deck. The prefabricated type is made of metal and put together in sections, as needed.

5.1.0 Swinging Scaffold Construction

The simplest type of a swinging scaffold consists of an unspliced plank made from 2 x 8 inch (minimum) lumber. Place hangers between six and 18 inches from the ends of the plank. Ensure the span between hangers does not exceed 10 feet. Make sure also to secure the hangers to the plank to stop them from slipping off. *Figure 7-46* shows the construction of a hanger with a ***guardrail***. The guardrail should be made of 2 x 4 inch material between 36 and 42 inches high. Construct a midrail, if required, of 1 x 4 inch lumber.

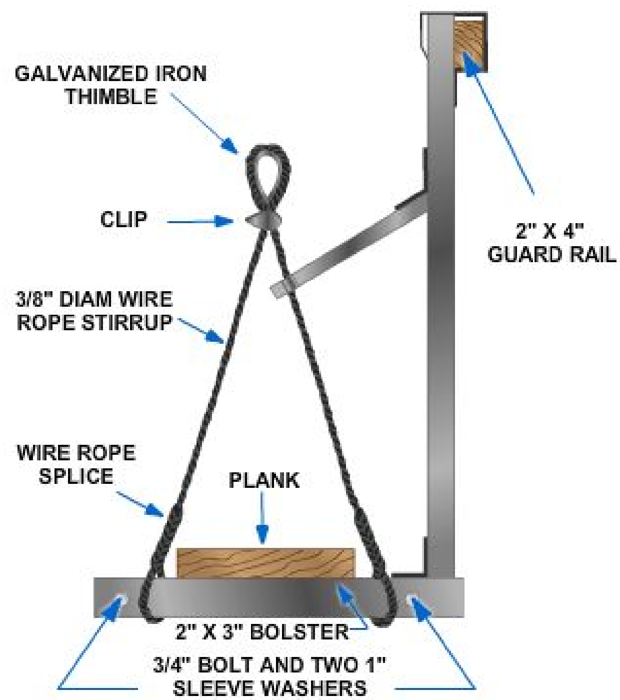


Figure 7-1 – Typical hanger to use with plank scaffold.

Suspend swing scaffolds by wire or fiber line secured to the outrigger beams. Suspension ropes require a minimum safety factor of six. The blocks for fiber ropes should be the standard six inch size consisting of at least one double block and one single block. The sheaves of all blocks should fit the size of rope used.

Space the outrigger beams no more than the hanger spacing and construct them of no less than 2 x 10 inch lumber. The beam should not extend more than six feet beyond the face of the building. The inboard side should be nine feet beyond the edge of the building and securely fastened to the building.

Figure 7-47 shows a swinging scaffold you can use for heavy work with block and tackle.

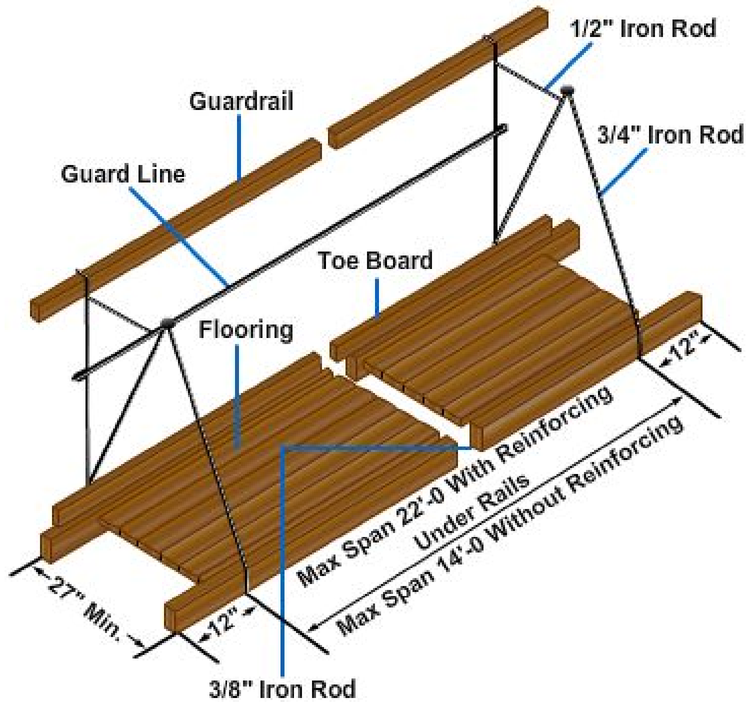


Figure 7-47 – Swinging scaffold.

5.2.0 Pole Scaffold Construction

The poles on a job-built pole scaffold should not exceed 60 feet in height. If higher poles are required, an engineer must design the scaffolding.

- All poles must be setup perfectly plumb.
- The lower ends of poles must not bear directly on a natural earth surface. If the surface is earth, a board footing two inches thick and six to 12 inches wide, depending on the softness of the earth, must be placed under the poles.
- If poles must be spliced, splice plates must not be less than four feet long, not less than the width of the pole wide, and each pair of plates must have a combined thickness not less than the thickness of the pole. Adjacent poles must not be spliced at the same level.
- A ledger must be long enough to extend over two pole spaces, and it must overlap the poles at the ends by at least four inches. Ledgers must be spliced by overlapping and nailing at poles, never between poles. If platform planks are raised as work progresses upward, the ledgers and logs on which the planks previously rested must be left in place to brace and stiffen the poles. For a heavy-duty scaffold, ledgers must be supported by cleats, nailed or bolted to the poles, as well as by being nailed themselves to the poles.
- A single log must be set with the longer section dimension vertical, and logs must be long enough to overlap the poles by at least three inches. They should be both face nailed to the poles and toe nailed to the ledgers. When the inner end of the log butts against the wall, as it does in a single-pole scaffold, it must be supported by a 2 x 6 inch bearing block, not less than 12 inches long, notched out the width of the log and securely nailed to the wall. The inner end of the log

should be nailed to both the bearing block and the wall. If the inner end of a log is located in a window opening, it must be supported on a stout plank nailed across the opening. If the inner end of a log is nailed to a building stud, it must be supported on a cleat, the same thickness as the log, and nailed to the stud.

- A platform plank must never be less than two inches thick. Edges of planks should be close enough together to prevent tools or materials from falling through the opening. A ***toe board*** on each side of scaffold will prevent tools and materials from being accidently kicked over the side. A plank must be long enough to exceed over three logs, with an overlap of at least six inches, but not more than 12 inches.

5.3.0 Prefabricated Scaffold Erection

Several types of scaffolding are available for simple and rapid erection; one of these types is shown in *Figure 7-48*. The scaffold uprights are braced with diagonal members, and the working level covered with a platform of planks. All bracing must form triangles and the base of each column requires adequate footing plates for bearing area on the ground or deck. The steel scaffolding is usually erected by placing the two uprights on the ground or deck and inserting the diagonal members. The diagonal members have end fittings that permit rapid locking in position.

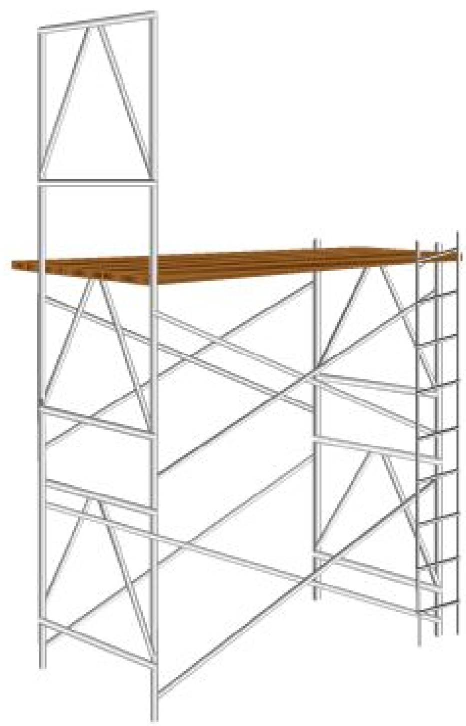


Figure 7-48 – Assembled prefabricated independent-pole scaffolding.

In tiered scaffolding, shown in *Figure 7-49*, the first tier is set on steel bases on the ground, and a second tier is placed in the same manner on the first tier with the bottom of each upright locked to the top of the lower tier. A third and fourth upright can be placed on the ground level and locked to the first set with diagonal bracing. The scaffolding can be built as high as desired, but high scaffolding should be tied to the main structure. Where necessary, scaffolding can be mounted on casters for easy movement.

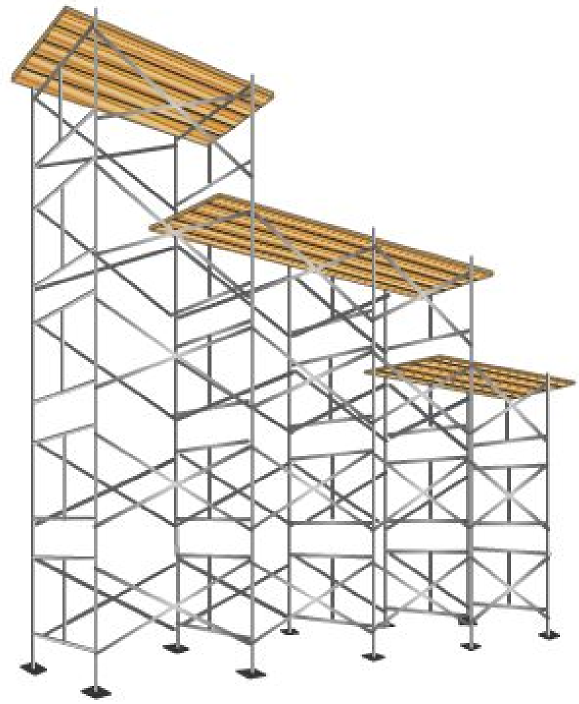


Figure 7-49 – Tiered scaffolding.

Prefabricated scaffolding comes in three categories: light, medium, and heavy duty. Light duty has nominal two inch outside diameter steel tubing bearers. Posts are spaced no more than six to ten feet apart. Light-duty scaffolding must be able to support 25 pounds per square foot loads.

Medium duty scaffolding normally uses two inch outside diameter steel tubing bearers. Posts should be spaced no more than five to eight feet apart. If 2 1/2 inch outside diameter steel tubing bearers are used, posts are to be spaced six to eight feet apart. Medium duty scaffolding must be able to support 50 pounds per square foot loads.

Heavy duty scaffolding should have bearers of 2 1/2 inch outside diameter steel tubing with the posts spaced not mare than six feet to six feet six inches apart. This scaffolding must be able to support 75 pounds per square foot loads.

To find the load per square foot of a pile of materials on a platform, divide the total weight of the pile by the number of square feet of platform it covers.

5.4.0 Bracket Scaffolding

The bracket, or carpenter's scaffold, shown in *Figure 7-50*, is built of a triangular wood frame with not less than 2 x 3 inch lumber or metal of equivalent strength. Each bracket is attached to the structure in one of four ways: (1) a bolt, at least 5/8 inch, that extends through to the inside of the building wall; (2) a metal stud attachment device; (3) welded to a steel tank; or (4) hooked over a secured supporting member.

The brackets must be spaced no more than eight feet apart. No more than two persons should be on any eight foot section at any one time. Tools and materials used on the scaffold should not exceed 75 pounds.

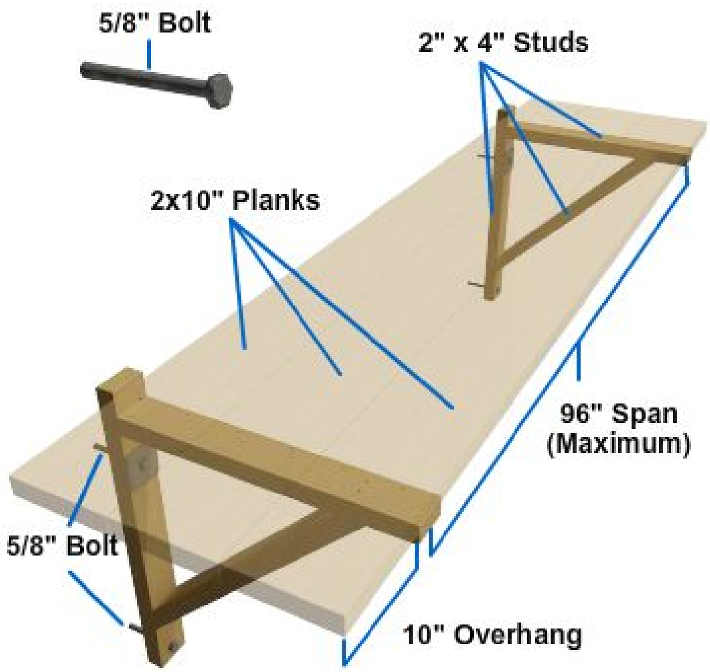


Figure 7-50 – Carpenter's portable bracket for scaffolding.

The platform is built of at least two 2 x 10 inch nominal size planks. The planks should extend between six and twelve inches beyond each support.

5.5.0 Scaffold Safety

When working on scaffolding or tending others on scaffolding, observe all safety precautions. Builder petty officers must not only observe the safety precautions themselves, but must also issue them to their crew and ensure that the crew observes them. The following is a listing of the minimum safety precautions that must be followed.

- Always keep scaffolds clear of accumulations of tools, equipment, materials, and rubbish.
- Do not use a scaffold for the storage of materials in excess of those currently required for the job.
- Tools not in immediate use on scaffolds must be stored in containers to prevent tools left adrift from being knocked off. Tool containers must be lashed or otherwise secured to the scaffolds.
- Throwing objects to or dropping them from scaffolds is absolutely prohibited. Always use hand lines for raising or lowering objects that you cannot pass hand to hand.
- A standard guardrail and toe board should be provided on the open side of all platforms five feet or more above ground; otherwise, safety belts tied off to safety lines must be used.
- No person should remain on a rolling scaffold while it is being moved.

- Maintain all scaffolds in safe condition, and do not alter or disturb them while in use. Personnel must not use damaged or weakened scaffolds.
- Access to scaffolds must be by standard stairs or by fixed ladders only.
- When scaffolding is being dismantled, clean it and make it ready for storage or use. Never store scaffolding that is not ready for use.

Summary

Two materials can be used for rigging; fiber line and wire rope. Each of these materials has its uses, which factor in the breaking strength of the material. Care of fiber line and wire rope differs; it is important to understand these differences so you can properly care for them.

Block and tackle units increase the mechanical advantage of force used to hoist a load. The various components in use and how they are reeved determine the operating characteristics of block and tackle units. Calculating of the size and number of components to use is critical in maintaining the safety of the crew and the load being worked with.

Shear legs and tripods can be used for hoisting heavy loads. It is important for the well-being of the crew that there is a good understand of hand signals used in lifting loads, and safety rules of lifting.

Scaffolding is an important tool used when work rises above a level that can be reached by the crew from the ground. Scaffolding can be built from wood, or assembled from prefabricated metal scaffolding. In either case, the Builder chief petty officer must ensure that crewmembers follow safety precautions whenever they work on scaffolding.

Trade Terms Introduced in this Chapter

Cheeks	In general, the side of any feature, such as the side of a dormer.
Fairlead	A device such as a ring or a block of wood with a hole in it, through which cable or rope is led for alignment.
Fiber line	A thread-like structure of a plant that contributes to stiffness or strength.
Fleet Angle	In hoisting gear, the included angle between the rope, in its position of greatest travel.
Gin pole	An upright guy pole with hoisting tackle and foot-mounted snatch block. Used for vertical lifts.
Guardrail	(1) A horizontal rail of metal, wood, or cable fastened to intermittent uprights of metal, wood, or concrete around the edges of platforms or along the lane of a highway. (2) The rail that separates traffic entering or exiting through side-by-side automatic doors.
Hoisting	(1) Any mechanical device for lifting loads. (2) An elevator. (3) The apparatus providing the power drive to a drum, around which cable or rope is wound in lifting or pulling a load.
Hooks	(1) Any bent or curved device for holding, pulling, catching, or attaching. (2) A terminal bend in a reinforced bar. (3) Slang term for a crane.
Lines	Strands of natural or synthetic fiber twisted together, sometimes referred to as rope.
Mechanical advantage	The ratio of the weight lifted by a machine divided by the force applied.
Mousing	Turns of cordage around the opening of a block hook.
Reeved	Threading or placement of a working line.
Safety factor	The ratio of ultimate load, moment, or shear of a structural member to the working load, moment, or shear, respectively, assumed in design.
Scaffolding	A temporary structure for the support of deck forms, cart ways, and/or workers, such as an elevated platform for supporting workers, tools, and materials. Adjustable metal scaffolding is frequently adapted for shoring in concrete work.
Shear legs	A hoisting device constructed from two or more poles fastened near their apex, from which a pulley is hung to lift heavy loads
Sheaves	A grooved wheel used to support cable or change its direction

	of travel. (pronounced shiv)
Shell	The outer portion of a hollow masonry unit when laid. The outer section of a block.
Snatch block	A pulley or block with a side that can be opened to receive a rope or line.
Toe board	A vertical barrier at floor level erected along exposed edges of a floor opening, wall opening, platform, runway, or ramp to prevent falls of materials.
Tripods	A three legged, adjustable stand for an instrument.
Wire rope	A rope formed of wires wrapped around a central core; a steel cable.
Yarns	A continuous strand of twisted threads of natural or artificial material such as wool or nylon, used in making carpets.

Additional Resources and References

This chapter is intended to present thorough resources for task training. The following reference works are suggested for further study. This is optional material for continued education rather than for task training.

Navy Occupational Safety and Health (NAVOSH) Program Manual for Forces Afloat, Volume I, Office of the Chief of Naval Operations (OP-45), Washington, D.C., 1989.

Safety and Health Requirements Manual, EM 385-1-1, U.S. Army Corps of Engineers, Washington, D.C. 1981.