6-1. INTRODUCTION. Section I of this chapter discusses blocks which are among the most important fittings used aboard ship on the deck, in the engine department, and in other operations. Section II covers elements of wire rope rigging which cargo handlers in a terminal service company must know. It details the care and use of wire rope, procedures for computing the safe working load and breaking strength, and inspection and handling. Section III covers marlinespike seamanship, which is a general term for handling and caring for fiber line and wire rope used aboard ship or in other marine operations.

6-2. COMPONENTS OF WOODEN BLOCKS. A wooden block, as shown in Figure 6-1, consists of one or more sheaves (pulleys). Each block has one or more steel straps which strengthen the block and support the sheave pin. Personnel may suspend the block or apply a load by means of a hook or shackle inserted in the top of the strap. The strap may continue through the block and form a projection, called the becket, to attach another line. The becket usually has a thimble to prevent chafing of the line. The front of the block is called its face and the sides of the shell are called cheeks. The opening between the top of the sheave and the block where the line is passed through the block is called the swallow. The breech is the opening between the bottom of the sheave and the block and serves no definite purpose. Line is never passed through the breech of a block except for a small tail line used to keep the block from bouncing on the deck. The entire wooden portion of a block is called the shell; it protects the sheave and line.

6-3. COMPONENTS OF METAL BLOCKS. Metal blocks have basically the same part as wooden blocks. The metal block has bolts to hold its cheeks together and a metal shell. The parts of a metal block are shown in Figure 6-2. This figure shows the diamond and roller bearing block.
6-4. TYPES OF BLOCKS. There are several different types of blocks, each with a particular use. Wooden and metal blocks are of the same design except for the head or heel block which is only metal. These blocks are explained below and illustrated in Figure 6-3.
- The single-sheave block has only one sheave and may or may not have a hook or becket.
- The multiple-sheave block contains two or more sheaves. It also may or may not have a hook or becket.
- A fixed-hook block is a single- or multiple-sheave block with a stationary hook attached to the top of the strap.
- A swivel-hook block is a single- or multiple-sheave block with a swivel hook that allows the lock to move in the direction of the load.
- The snatch block has a hinged cheek on one side and differs from all the other blocks. The advantage of a snatch block over the other types is that it can be opened and a bight of line placed over the sheave without passing the end of the line through the swallow. The snatch block also has a swivel hook. The primary function of the snatch block is to change the direction of the load or pull.
- The head or heel block has a cast metal shell, roller bearings, and a grease fitting in the sheave pin. The cargo runner can pass over these blocks at the head and heel of the cargo boom. These high-speed blocks must be lubricated every time they are used. A good winch operator can pass the cargo runner over the sheaves of these blocks at a rate of 500 feet per minute.

a. Blocks are named according to the purpose for which they are used, the places they occupy, or from a particular shape or type of construction. According to the number of sheaves, blocks are designated as single, double, or triple. A traveling block is attached to the load being lifted and moves as lifting occurs. A standing block is fixed to a stationary object.
b. Every tackle system contains a fixed block attached to some solid support and may have a traveling block attached to the load (see Figure 6-4). The single rope leaving the tackle system is called the fall line. Personnel apply the pulling force to the fall line which may be led through a leading block.

6-5. SIZES OF BLOCKS. Users can determine the size of blocks by measuring the length of the cheek in inches. Blocks are designated for use with a specific line size. Bending line over a sheave that is too small causes distortion and strain, resulting in the line wearing on the shell. Personnel can use line smaller than that designated for a sheave with no damage, but should never use line of a larger size.

a. To determine the size wooden block to use with line of a known size, personnel may follow these formulas:

\[
3 \times \text{circumference of line} = \text{shell size} \\
2 \times \text{circumference of line} = \text{sheave size}
\]

b. The size metal block to use with wire rope depends on the diameter of the sheave. The sheave is never less than 20 times the diameter of the wire. For example, personnel can determine the size block to use with 3/4-inch wire rope as follows:

\[
\frac{3/4 \text{ inch} \times 20 = 60}{14} = 15\text{-inch block}
\]

6-6. MAINTENANCE OF METAL BLOCKS. Personnel must frequently disassemble metal blocks in cargo-handling rigs and other blocks that are in continuous use and inspect them for wear. Blocks used only occasionally seldom need to be disassembled if they are kept well lubricated.

a. To remove the sheave from a diamond or oval block, personnel take out the cotter pin, remove the hexagonal nut from the sheave pin, and drive out the sheave pin. For a diamond block, personnel must loosen all bolts holding the cheeks together and remove one before the sheave will slide out. With an oval block, it is necessary only to loosen the bolts.

b. To disassemble a roller bearing block, personnel loosen the set screws and remove the retaining nuts. Next, they take out the bolt holding the shell together and remove the shell,
closure snap rings, adjusting nut, closure washer, and closure. The sheave pin and the bearings from the sheave are removed last.

6-7. TACKLE USES AND TYPES. A block with a line led over the sheave makes applying power by changing the direction of the pull easier. Used with line and another block, it becomes a tackle and increases the power applied on the hauling part. Tackles are designated according to their uses and the number of sheaves in the blocks that are used to make the tackle. The various types of tackle are rove with different size blocks and all have a limited lifting capacity depending on the number of sheaves, the size blocks and the size line used. The tackles are named for their use or from their makeup. The most commonly used tackles are explained below and illustrated in Figure 6-5.

- A single whip tackle consists of a single fixed block with a line passed over its sheave. This tackle has no mechanical advantage.
- The gun tackle, named for its use on old sailing ships to haul the cannons back to their gun port after firing, consists of one single-sheave fixed block and one single-sheave movable block.
- The luff tackle is made up of one double-sheaved block and one single-sheaved block.
- The twofold purchase is made up of two double-sheaved blocks.
- The double luff tackle is made up of one double-sheaved block and one triple-sheaved block.
- The threefold purchase is made up of two three-sheaved blocks.
6-8. **REEVING TACKLES.** Personnel reeving tackles reeve each type differently. If a tackle is rove improperly, too much friction and possible binding of the falls can result when lifting or lowering a load, creating a safety hazard. It is important to use the proper method of reeving each type of tackle up to and including a threefold purchase.

a. In reeving triple blocks (see Figure 6-6), personnel should put hoisting strain at the center of the blocks to prevent them from inclining under the train. If the blocks do incline, the rope will drag across the edges of the sheaves and the shell of the block and cut the fibers.

b. The reeving of each type of tackle is explained in subparagraphs (1) through (5) and illustrated in Figure 6-6, with the exception of single whip and runner tackles. Single whip tackle offers no mechanical advantage and runner tackle has a 2 to 1 mechanical advantage.

(1) **Gun tackle.** Place two single-sheave blocks about 3 feet apart with the hooks or straps facing outboard and both blocks in the same position, either on their face or cheek. Next, they should run the line through the first and second block, then splice it to the becket of the first block. Gun tackle has a 2 to 1 mechanical advantage.

(2) **Luff tackle.** Position one single- and one double-sheave block in the same manner as with the gun tackle. Run the line through one of the sheaves of the double-sheave block first and then to the sheave of the single-sheave block. Next, run the line through the other sheave of the double-sheave block and splice the line to the becket of the single-sheave block. This tackle offers a 3 to 1 mechanical advantage.

(3) **Twofold purchase.** Position two double-sheave blocks in the same manner as with the luff tackle. Reeve the line through the top or bottom block, stay in sequence, and never cross from one side to the other. After reeving the tackle, splice the standing line to the becket. Twofold tackle has a 4 to 1 mechanical advantage.
(4) **Double luff tackle.** Obtain a double- and a triple-sheave block. Place the blocks 3 feet apart with the hooks or straps facing outboard and position the blocks so that one is face down and the other cheek down. When reeving a tackle that has one block with more sheaves than the other, always start with the block with the most sheaves. In this instance, start reeving through the center sheave, keeping the line parallel. Never cross from one side to the other. Double luff tackle has a 5 to 1 mechanical advantage.

(5) **Threefold purchase.** Place two triple-sheave blocks 3 feet apart, with the hooks or straps facing outboard, positioning the blocks so one is face down and the other is cheek down. Start reeving in the center sheave of one block and finish in the center sheave on the other. Then splice the standing part to the becket. This tackle offers a 6 to 1 mechanical advantage.

6-9. **MECHANICAL ADVANTAGE.** The mechanical advantage of a tackle refers to the relationship between the load being lifted and the power required to lift it. In other words, if a load of 10 pounds requires 10 pounds to lift it, the mechanical advantage is one. If a load of 50 pounds requires only 10 pounds of power to lift it, the mechanical advantage is 6 to 1 or 5 units of weight lifted for each unit of power applied.

a. The mechanical advantage of a tackle is determined by counting the number of parts of the falls at the movable block. The gun tackle in Figure 6-6 has a mechanical advantage of two. This tackle is rove to a disadvantage as are most vertical lifts. For a horizontal pull, the block with the cargo hook attached should be connected to the load, making it the movable block. This tackle would then be rove to an advantage which would be increased by one. Since most lifts in this test are vertical, the tackle is rove to a disadvantage unless otherwise stated.

b. To ascertain the amount of power required to lift a given load by means of a tackle, cargo handlers should determine the weight of the load to be lifted and divide this figure by the mechanical advantage. For example, lifting a 600-pound load by a single luff tackle, cargo handlers first determine the mechanical advantage gained with this type of tackle by counting the parts of the falls at the movable block. By dividing the weight to be lifted by the mechanical advantage it is possible to determine the pounds of power required to lift a certain amount of weight.

6-10. **FRICTION.** A certain amount of the force applied to a tackle is lost through friction. Friction occurs in a tackle when lines rub against each other or against the frame or shell of the block, and pass over the sheaves. This loss in efficiency of the block and tackle (roughly 10 percent of the load per sheave) must be added to the weight being lifted to
determine the total weight. For example, to determine the total weight of a load when lifting a load of 500 pounds with a twofold purchase, personnel use the following formula and compute:

\[ TW = W \times (1 + \text{Friction}) \text{ or } (1 + F) \]

\[ TW = 500 \times (1 + .4) \]

\[ TW = 500 \times 1.4 \]

\[ TW = 700 \text{ pounds} \]

6-11. BREAKING STRESS AND SAFE WORKING LOAD. The following paragraphs explain the procedures used to determine breaking stress and safe working loads for blocks and tackle loads. The symbols used in the formula for computations are as follows:

- \( W \) = Weight
- \( TW \) = Total weight
- \( SHP \) = Strain on hauling part
- \( BS \) = Breaking stress
- \( SWL \) = Safe working load
- \( MA \) = Mechanical advantage
- \( SF \) = Safety factor

a. The formulas for computing BS and SWL are as follows:

\[ TW = W \times (1 + F) \]

\[ SHP = TW \div MA \]

\[ BS = SHP \times SF \]

EXAMPLE 1: SHP = TW ÷ MA

**Step 1.** Determine the friction. See paragraph 6-10

**Step 2.** Determine the total weight. See paragraph 6-10.

**Step 3.** Determine the SHP.

**Step 4.** Compare the SHP to Table 6-1. Select an SWL that exceeds the computed SHP for the block and tackle.

EXAMPLE 2: BS = SF x SHP

**Step 1.** Determine the friction for the block and tackle.

**Step 2.** Determine the total weight to be lifted.
**Step 3.** Determine the SHP of the block and tackle.

**Step 4.** Apply the BS formula to compute the BS of the block and tackle.

**Step 5.** Compare the BS to the figures shown in Table 6-1. It is desirable that the SWL of the line used be greater than the computed BS for the block and tackle.

**NOTE:** The safety factor for the hauling part is always 5. Tackle that involves the lifting or lowering of humans uses a safety factor of 8.

### Table 6-1. Line strength table

<table>
<thead>
<tr>
<th>SIZE IN INCHES</th>
<th>MANILA*</th>
<th>SISAL*</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWL</td>
<td>BS</td>
<td>SWL</td>
</tr>
<tr>
<td>1</td>
<td>200</td>
<td>1,000</td>
</tr>
<tr>
<td>1 1/2</td>
<td>450</td>
<td>2,250</td>
</tr>
<tr>
<td>2</td>
<td>800</td>
<td>4,000</td>
</tr>
<tr>
<td>2 1/2</td>
<td>1,250</td>
<td>6,250</td>
</tr>
<tr>
<td>3</td>
<td>1,800</td>
<td>9,000</td>
</tr>
<tr>
<td>3 1/2</td>
<td>2,450</td>
<td>12,250</td>
</tr>
</tbody>
</table>

* This table is computed in pounds for new line. For line that has been used these figures will decrease. Old line may have only 60 percent of the strength shown in pounds for a given size of line.

b. To determine the SWL for a line of known size to be rove into a tackle, personnel should use one of the following formulas as appropriate, where "C" denotes circumference and "D" denotes diameter. The formulas for manila and nylon will give the SWL in pounds. The formulas for wire rope will be in tons.

<table>
<thead>
<tr>
<th>Line Type</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manila line:</td>
<td>SWL = C² x 200</td>
</tr>
<tr>
<td>Three strand nylon line:</td>
<td>SWL = C² x 500</td>
</tr>
<tr>
<td>2-in-1 braided nylon line:</td>
<td>SWL = C² x 600</td>
</tr>
<tr>
<td>Extra improved plow steel wire rope:</td>
<td>SWL = D² x 10</td>
</tr>
<tr>
<td>Improved plow steel wire rope:</td>
<td>SWL = D² x 8</td>
</tr>
<tr>
<td>Plow steel wire rope:</td>
<td>SWL = D² x 7</td>
</tr>
<tr>
<td>Mild steel wire rope:</td>
<td>SWL = D² x 6</td>
</tr>
</tbody>
</table>
c. If personnel are unsure which type of wire rope they are using, they must always use the formula for mild steel when figuring the SWL. This will ensure ultimate safety since the different strengths of wire rope cannot be identified visually.

Section II. Wire Rope

6-12. CARE AND USE OF WIRE ROPE. Wire rope is made of steel except for its core which is likely to be fiber. The grades of wire rope in descending order of strength are: Extra improved plow, improved plow, plow, and mild plow steel. Of these four grades, the Army uses improved plow steel extensively and plow steel to a lesser extent. The manufacturer stamps the grade on the reel. Because the grade of wire rope is not visually apparent, it should always be considered as plow steel when in doubt.

6-13. MAKEUP OF WIRE ROPE. The basic unit of wire rope is the individual wire. Wires are laid together to form strands. The number of wires in a strand varies according to the purpose for which the rope is intended. Strands are laid around a core to form the wire rope itself. With preformed plow steel wire rope, the core may be hemp or polypropylene, a synthetic fiber. The core is a foundation to keep the wire rope round, to act as a shock absorber when the wire rope contracts under strain, and to serve as a reservoir for lubricant. Figure 6-7 shows a cross section of wire rope.

6-14. CLASSIFICATION. Wire rope is classified by the number of strands, number of wires per strand, strand construction, and type of lay.

a. Strands and Wires. Standard wire rope has six strands. The present commercial classifications group wire ropes according to weight, flexibility, and strength. The 6 x 19 classification has 6 strands and 19 wires per strand. The 6 x 37 classification has 6 strands and 37 wires in each strand (see Figure 6-7). Rope of numerous small wires is more flexible, but less resistant to external abrasion. Wire rope of a smaller number of larger wires is less flexible but more resistant to abrasion. Two ropes of the same size have the same strength even though, for example, one is 6 x 19 and the other is 6 x 37.
b. **Strand Construction.** In most wire rope used today, the wires and strands are preformed. Preforming means presetting wires in the strands into a permanent corkscrew form which they will have in the completed rope. As a result, preformed wire rope does not have the internal stresses found in nonpreformed wire rope, does not untwist as readily as nonpreformed wire rope, and is more flexible.

c. **Types of Lay.** Lay refers to the direction of winding of the wires in the strands and the strands in the rope. Both may be wound in the same direction or in opposite directions.

(1) In regular lay, the strands and wires are wound in opposite directions. Most common is the right regular lay in which the strands are wound right and the wires wound left. This lay is used in marine operations.

(2) In lang lay, the strands and wires are wound in the same direction. This type of wire rope is used on the blades of bulldozers and scrapers.

**6-15. MEASUREMENT.** Whatever its grade, wire rope is usually measured by its diameter. Figure 6-8 shows the correct method of measuring the diameter of wire rope. To measure wire rope correctly, personnel should place it in the caliper so that the outermost points of the strands will be touching the jaws of the caliper.

**6-16. SAFE WORKING LOAD AND BREAKING STRENGTH.** The SWL and BS formulas are listed in the paragraphs below.

a. Formulas for determining the SWL of several grades of wire rope have constants that are not to be confused with safety factors. For example, the formula for the SWL in STONs (2,000 pounds) for extra improved plow steel wire rope is diameter squared multiplied by 10, or SWL = D^2 x 10. The formula to find the SWL of 1-inch, 6 x 19, extra improved plow steel wire rope is as follows: SWL = D^2 x 10 = 1 x 1 x 10 = STONs.

b. A figure relatively constant in marine operations, especially for new wire rope, is the SF, which is 5. The SF is used with the SWL to find the BS.

\[
BS = \text{SWL} \times 5
\]

BS = 10 x 5 = 50 STONs

c. The formulas for improved plow steel, plow steel, and mild plow steel (6 x 19 wire rope) are as follows:
Improved plow steel:  \[ SWL = D^2 \times 8 = \text{STONs} \]
BS = SWL x SF = STONs

Plow steel:  \[ SWL = D^2 \times 7 = \text{STONs} \]
BS = SWL x SF = STONs

Mild plow steel:  \[ SWL = D^2 \times 6 = \text{STONs} \]
BS = SWL x SF = STONs

6-17. INSPECTION OF WIRE ROPES. Wire ropes should be inspected frequently and replaced if frayed, kinked, worn, or corroded. The frequency of inspection depends on how often the rope is used. Wire rope used 1 or 2 hours a week requires less frequent inspection than one used 24 hours a day.

a. Common causes of wire rope failures are as follows:

- Using rope of incorrect size, construction, or grade.
- Allowing rope to drag over obstacles.
- Operating over sheaves and drums of inadequate size.
- Overwinding or crosswinding on drums.
- Operating over sheaves and drums that are out of alignment.
- Permitting rope to jump sheaves.
- Subjecting rope to moisture or acid fumes.
- Permitting rope to untwist.
- Using kinked rope.

b. Carefully inspect weak points and points of greatest stress. Worn or weak spots show up as shiny, flat spots on the wires. If the outer wires have been reduced in diameter by one-half, the wire rope is unsafe.

c. Inspect broken wires, since they show where the greatest stress occurs. If individual wires are broken next to each other, unequal load distribution at this point will make the rope unsafe. Broken wires are called fishhooks. To determine the extent of damage to the wire rope, users can slide a finger along one strand of wire for one complete turn, equal to the length of one wire rope lay. Next, count the number of fishhooks. If six or more fishhooks are discovered, the wire rope is unsafe and should be replaced immediately.

6-18. HANDLING. There are different handling methods for wire rope. These methods are listed below.

a. Kinking. When loose wire rope is handled, small loops frequently form in the slack portion of the rope. If personnel apply tension to the rope while these loops are in position, the loops will not straighten out but will form sharp kinks, resulting in unlaying of the rope.
Personnel should straighten these loops out of the rope before applying a load. After a kink has formed in wire rope, it is impossible to remove it, and the strength of the rope is seriously damaged at the point where the kink occurs.

b. **Unreeling.** When removing wire rope from a reel or coil, personnel should be sure to rotate the reel or coil. If the reel is mounted, the wire rope may be unwound by holding the end and walking away from the reel. If a wire rope is in a small coil, personnel may stand the coil on end and roll it along the deck, barge, wharf, or ground. Remove any loops that may form, although rotating the reel or coil usually avoids causing loops to form.

c. **Seizing.** Personnel should seize (lash together) all wire rope before cutting it. If the ends of the rope are not properly secured, the original balance of tension is disturbed. Maximum use cannot be made on wire rope when some strands carry a greater load than others.

(1) Annealed wire is recommended for the seizing. Figure 6-9 shows how to seize wire rope. Personnel should tighten the turns of the annealed wire rope closely so that they do not have to tighten them when the ends are being twisted together. The ends should be twisted together at one end of the seizing so that the completed twist can be tapped into the groove between two strands where it is less likely to be knocked off.

(2) There are three formulas for determining the number and length of seizings and the space between them. When a calculation results in a fraction, the next larger whole number is used. The following formulas are based on a 3/4-inch diameter wire rope.

(a) The number of seizings required equals about three times the diameter of the rope. For example: $3 \times \frac{3}{4} = 2 1/4$ or 3 seizings. Because the rope will be cut, six seizings are required so that there will be three on each rope end after the cut.

(b) The length of a seizing should be equal to the diameter of the rope. For example: $1 \times \frac{3}{4} = 3/4$ or 1 inch.

(c) The seizings should be spaced a distance apart equal to twice the diameter. For example: $2 \times \frac{3}{4} = 1 1/2$ or 2 inches apart.
d. Cutting. Wire rope may be cut with a wire rope cutter, a cold chisel, a hacksaw, bolt clippers, or an oxyacetylene cutting torch. When cutting wire rope, personnel should follow the procedures outlined below.

(1) To seize the wire rope, insert it into the cutter with the blade between the two central seizings, close the locking device, then close the valve on the cutter. The handle should be pumped to build up enough pressure to force the blade through the rope.

(2) Use the bolt clippers on wire rope of fairly small diameter. Use the oxyacetylene torch on wire of any diameter. Cutting with the hacksaw and cold chisel is slower than cutting with the other tools and equipment.

e. Coiling. Personnel may need to take a length of wire rope from a reel and coil it down before using it. Small loops or twists will form if the wire rope is coiled in a direction opposite to the lay. To avoid loops, users should coil right lay wire rope clockwise and left lay wire rope counterclockwise. When a loop forms in the wire, they should put a back turn in as shown in Figure 6-10.

![Figure 6-10. Putting a back turn in wire rope](image)

f. Size of Sheaves and Drums. When a wire is bent over a sheave or drum, two things happen: Each wire is bent to conform to the curvature, and the wires slide against each other lengthwise because the inside arc of the rope against the sheave or drum is shorter than the outside arc. The smaller the diameter of the sheave or drum, the greater the bending and sliding. Personnel should keep this bending and moving of wires to a minimum.
to reduce wear. The minimum recommended sheave and drum diameter is 20 times the diameter of the rope. For example, for 5/8-inch rope: $20 \times \frac{5}{8} = 12 \frac{1}{2}$-inch sheave. If a 12 1/2-inch sheave is not on hand, personnel should use the next larger size, never a smaller size.

g. **Lubrication.** Wire rope is lubricated as it is manufactured. The lubricant generally does not last throughout the life of the rope, which makes relubrication necessary. Crater "C" compound is recommended, but personnel may use oil on hand rather than delay lubrication. Crater "C" compound should be heated before it is put on the wire rope. Personnel should use a brush if possible to apply lubricant. If a brush is not available, they may use a sponge or cloth, but they should look out for fishhooks or broken wires.

h. **Reversing Ends.** It is sometimes advisable to reverse or cut back ends to get more service from wire rope. The wear and fatigue on a rope frequently is more severe at certain points than at others. Reversing distributes stronger parts of the rope to the points getting wear and fatigue. To reverse ends, personnel remove the drum end, put it in the attachment, and then fasten the end taken from the attachment to the drum. Cutting back the ends has a similar effect, but not as much change is involved. In reversing ends, personnel should cut off short lengths of both ends to remove the sections with the greatest local fatigue.

i. **Storing.** Wire rope should be coiled on a spool for storage. Its grade, size, and length are noted on a tag attached to the rope or spool. Wire rope should be stored in a dry place to reduce corrosion. Personnel should not store it with chemicals or where chemicals have been stored because chemicals and their fumes can attack the metal. Personnel should always clean and lubricate wire rope before storing it.

j. **Cleaning.** Personnel can remove most of the dirt or grit on a used wire rope by scraping or steaming. Rust should be removed at regular intervals by wire brushing. Personnel must clean the rope carefully before lubricating to remove foreign material and old lubricant from the valleys between the strands and from the spaces between the outer wires. This permits the newly applied lubricant to freely enter the rope.

**Section III. Marlinespike Seamanship**

6-19. **CHARACTERISTICS AND FIBER LINE.** To be able to work with fiber line, personnel must know its characteristics and properties. They must be able to handle and care for the line, and tie basic knots, bends, and hitches.
a. **Materials for Fiber Line.** Fiber line is made of either vegetable or synthetic fibers. Vegetable fibers include manila, sisal, hemp, cotton, and flax. Synthetic fibers include nylon, Dacron, polyethylene, and polypropylene. The Army primarily uses nylon synthetic fiber line, so this manual covers only that synthetic fiber.

(1) Manila is a strong fiber that comes from the leaf stems of the abaca plant, a part of the banana family. Varying in length from 4 to 15 feet in their natural state, the fibers have the length and quality which gives manila rope relatively high elasticity, strength, and resistance to wear and deterioration.

(2) Sisal is made from sisalana, a species of the agave plant. Although sisal is not used much in the Army, it is covered here because it is a good substitute for manila. Sisal withstands exposure to seawater very well.

(3) Hemp is a tall plant that has useful fibers for making rope and cloth. It was used extensively before manila was introduced. Now hemp's principal use is in fittings such as ratline and marline. Because hemp is absorbent, the fittings are tarred to make them more water-resistant.

(4) Nylon made from mineral products is waterproof, absorbs shocks, stretches, and resumes its original length. It also resists abrasion, decay, and fungus growth.

b. **Construction of Fiber.** Figure 6-11 shows how fiber line is made by twisting fibers into yarns, yarns into strands, and strands into the finished line. The fibers are twisted from left to right to spin the yarn. The yarn is twisted from right to left to form the strands. The strands are then twisted from left to right to lay or form the line.

c. **Size of Line.** Fiber line is measured by its circumference in inches with the exception of "small stuff" which is fiber line 1 3/4 inches or less in circumference. It has three strands and the number of threads it contains determines its size. Small stuff will range in size from 6 to 21 threads. To determine the number of threads, personnel count the number in one strand and then multiply it by three. Small stuff is used for lashing material and heaving lines. Fiber line between 1 3/4 and 5 inches in circumference is referred to as line, and line over 5 inches in circumference is referred to as hawser. Hawsers are used for mooring and towing.
d. **Strength of Fiber Line.** Manila is the standard line against which all other types of fiber line are measured. The measurement implies that all the other lines have the same circumference as the manila line against which each is measured. The strengths of the lines are as follows:

<table>
<thead>
<tr>
<th>TYPE LINE</th>
<th>STRENGTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-in-1 braided nylon</td>
<td>300 percent</td>
</tr>
<tr>
<td>Three-strand nylon</td>
<td>250 percent</td>
</tr>
<tr>
<td>Manila</td>
<td>100 percent</td>
</tr>
<tr>
<td>Sisal</td>
<td>80 percent</td>
</tr>
</tbody>
</table>

Three-strand nylon line will stretch 30 to 35 percent under an average load or a load that does not exceed the safety factor for that size line. Three-strand nylon line will stretch 40 percent without being damaged and will draw back to its original length.

e. **Useful Formulas.** To find the SWL and BS of the various lines, some useful formulas are listed below.

(1) The manufacturer states the size and BS of its lines and if available, crew members should use the manufacturer’s figures for determining the strength of line. If this information is not available, personnel should use the following formula and constant for type line to
compute the SWL and the BS: \( C^2 \times \text{constant} \) for type line = SWL (in pounds), where "C" denotes circumference in inches. Constants for type line are as follows:

<table>
<thead>
<tr>
<th>TYPE LINE</th>
<th>CONSTANT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sisal</td>
<td>160 percent</td>
</tr>
<tr>
<td>Manila</td>
<td>200 percent</td>
</tr>
<tr>
<td>Three-strand nylon</td>
<td>500 percent</td>
</tr>
<tr>
<td>2-in-1 braided nylon</td>
<td>600 percent</td>
</tr>
</tbody>
</table>

For example, to find the SWL of a 3-inch sisal: 

\[
3^2 \times 160 = 9 \times 160 = 1,440 \text{ pounds SWL}
\]

(2) In marine operations an SF of 5 is generally used for new line or line that is in good condition; old or worn line may have an SF of 3. As line ages and wears through use, the SF drops. If the SF is multiplied by the SW, the result is the BS of the fiber line. The BS is the amount of weight in pounds required to part the line. The BS of a line divided by the SF of 5 results in the SWL.

EXAMPLE 1: Find the BS of 3-inch manila line.

Solution: 

\[
C^2 \times \text{constant} = \text{SWL}
\]

\[
3^2 \times 200 = 9 \times 200 = 1,800 \text{ pounds}
\]

BS = SWL x SF = 1,800 x 5 = 9,000 pounds

EXAMPLE 2: Find the SWL for a 6-inch hawser that has a BS of 36,000 pounds.

Solution: 

\[
\frac{\text{SWL} \times \text{BS}}{\text{SF}} = \frac{36,000}{5} = 7,200 \text{ pounds}
\]

6-20. CORDAGE. In marine usage, cordage is a collective term that includes all cord, twine, line, and string made from twisted vegetable or synthetic fibers. Cord, string, and twine are loosely used to mean small line.

a. Cotton twine is similar to the string found in homes. It is used for temporary whippings and should be run through beeswax before use.

b. Sail twine is made of flax or of a better grade of cotton than that used in cotton twine. It is waxed during manufacture. Measured by the number of plies, sail twine comes in three
to seven plies. Like a yarn, a ply has a certain number of fibers in it. Sail twine is used for whippings.

c. Marline is tarred hemp. It is made of two yarns with fibers making up the yarns. Marline is used for whippings on lines 3 inches and larger.

6-21. INSPECTION OF LINES. The outside appearance of the line is not always a good indication of its internal condition. Therefore, it is necessary to inspect line inside as well as outside. Overloading a line may cause it to break with possible damage to materiel and injury to personnel. Before using unfamiliar line, or line that has been stored for a long period of time personnel should perform the following procedures.

a. Inspect line carefully at regular intervals to determine its condition. Untwist the strands slightly to open the line to examine the inside. Mildewed line has a musty odor and inside fibers have a dark, stained appearance. It is easy to identify broken strands of yarn. Dirt and sawdust-like material inside the line means that it has been damaged. If the line has a core, it should not break away in small pieces. If it does, the line has been overstrained. If the line appears to be satisfactory in all respects, pull out two fibers and try to break them. Sound fibers should offer considerable resistance to breakage.

b. When any unsatisfactory conditions are found, destroy the line or cut it in short pieces. Make sure that none of these pieces is long enough to permit its use. This not only prevents the use of line for hoisting, but saves the short pieces for miscellaneous use such as lashings, whippings, and seizings.

6-22. UNCOILING NEW LINE. New Line is coiled, bound, and wrapped in burlap for protection. Since the burlap covering protects the line during storage and prevents tangling, it should not be removed until the line is to be used. To open, personnel strip back the burlap wrapping and look inside the coil for the end of the line. It should be at the bottom of the coil. If it is not, turn the coil over so that the end will be at the bottom. Pull the end of line up through the center. As line comes up through the coil it will unwind in a counterclockwise direction. Nylon is handled differently from natural fiber line. Nylon comes on reels and to uncoil it, personnel should place the reel on stands or jacks.

6-23. WHIPPING LINE. Personnel must never cut a line or leave the end of a line dangling loose without a whipping to prevent it from unlaying. A line without whipping will unlay of its own accord. Whenever a line or hawser has to be cut, whippings should be put on first, on each side of the cut. To prevent fraying, a temporary or plain whipping can be put on with
any type cordage, even rope yarn. Figure 6-12 shows one of the several methods that can be used for putting a temporary whipping on a line.

![Figure 6-12. Plain or temporary whipping](image)

a. To make a temporary whipping, personnel should-

- Lay the end of the whipping along the line and bind it down with three or four round turns.
- Lay the other end the opposite way.
- Bind this end with a bight of the whipping.
- Take a couple more turns.
- Take the bitter of the whipping and pull it tight.

b. A permanent whipping, as its name implies, is put on to stay. One way to fasten a permanent whipping is with a sewing palm and needle. Sewing palms are made for both right- and left-handed people. The width of the permanent whipping should equal the diameter of the line. Two whippings are recommended. The space between the two whippings should be six times the width of the first whipping. The needle is threaded with sail twine, doubled (Figure 6-13 shows a single strand for clearness). When putting on permanent whipping, personnel should-

- Put the needle through the middle of a strand so that it comes out between two strands on the other side.
- Wind the turns toward the bitter end. (The number of turns or the width of the whipping will depend on the diameter of the line.)
- Push the needle through the middle of a strand so that it comes out between two strands again.
- Go up and down between strands to put a cross-seizing between each pair of strands.
- Pull each cross-seizing taut before taking the next one.
- Ensure the thread comes out through the middle of a strand the last time it is pushed through, so that the strand will hold the end of the twine after it is knotted and cut.

![Diagram of whipping](image)

**Figure 6-13. Making a permanent whipping**

**6-24. KNOTS, BENDS, AND HITCHES.** Each of the three terms-knot, bend, and hitches-has a specific definition. The choice of the best knot, bend, or hitch to use depends largely on the job it has to do. In a knot, a line is usually bent or tied to itself, forming an eye or a knob or securing a cord or line around an object, such as a package. A good knot must be easy to tie, must hold without slipping, and must be easy to untie. In its noun form, a bend ordinarily is used to join the ends of two lines together. In its verb form, bend means the act of joining, bent is the past tense of bend. A hitch differs from a knot and a bend in that it ordinarily is tied to a ring, around a spar or stanchion, or around another line. It is not merely tied back on itself to form an eye or to bend two lines together. This portion of the manual explains why a given type is used and also gives the efficiency or strength of many of the knots, bends, and hitches.
WARNING: Tying a knot, bend, or hitch in a line weakens it because the fibers are bent sharply, causing the line to lose varying degrees of efficiency or strength. Never tie a knot on which you are not willing to stake your life. A general rule to follow, then, is to use a knot, bend, or hitch for temporary work and a splice for permanent work because it retains more of the line's strength.

a. **Overhand Knot.** The overhand knot shown in Figure 6-14 is the basis for all knots. It is the simplest and the most commonly used. Personnel may use this knot to prevent the end of a line from untwisting, to form a knot at the end of a line, or to be part of another knot. When tied to the end of a line, this knot will prevent the line from running through a block, hole, or other knot.

![Figure 6-14. Overhand knot](image)

b. **Figure Eight Knot.** This knot shown in Figure 6-15 forms a larger knot at the end of a line than an overhand knot forms. It also prevents the end of the line from running through a block. Personnel can easily tie this knot by forming an overhand loop in the line and passing the running end under the standing part, up the other side, and through the loop. They can tighten the knot by pulling on the running end and the standing part.

![Figure 6-15. Figure eight knot](image)

c. **Square Knot.** Personnel use the square knot to tie two lines of equal size together so that they will not slip. Figure 6-16, shows that in the square knot the end and standing part of one line comes out on the same side of the bight formed by the other line. This knot will not hold if the lines are wet or are of unequal sizes. It tightens under stain but can be untied by grasping the ends of the two bights and pulling the knot apart. Its strength is .45 percent.
To avoid a "granny" or a "fool's knot" which will slip, personnel should follow this procedure: Pass the end in your right hand over and under the part in your left hand as illustrated in Figure 6-16. With your right hand, take the end that was in your left hand and pass the end under and over the part in your left hand.

**Figure 6-16. Square knot**

**d. Bowline.** The bowline is used to make a temporary eye in the end of a line. For permanent use, put an eye splice on the line. A bowline will not slip or jam and unties easily. One use of a bowline is for tying a heaving line or messenger to a hawser and throwing it to a pier where line handlers can pull the hawser to the pier. To tie a bowline (see Figure 6-17), hold the standing part with your left hand and the running end with your right. Flip an overhand loop in the standing part, and hold the standing part and loop with the thumb and fingers of your left hand. Using your right hand, pass the running end up through the loop, around the standing part, and down through the loop. Its strength is 60 percent.

**Figure 6-17. Bowline**

e. **French Bowline.** A French bowline is used as a sling for lifting an injured person. For this purpose one loop is used as a seat and the other loop is put around the body under the arms, with the knot drawn tight at the chest. Even an unconscious person can be hoisted safely in a properly secured French bowline, because the weight applied will keep the two loops tight so that the individual will not fall out. Personnel must not allow the loop under the person's arms to catch on any projections. The French bowline may also be used if a person is working alone and needs both hands free. The two loops of the knot can be
adjusted to the required size. Figure 6-18 shows the step-by-step procedure for tying the French bowline.

Figure 6-18. Tying a French bowline

f. **Half Hitch.** The half hitch is used to back up other knots, and is tied with the short end of the line. Personnel should not tie two half hitches by themselves; instead, they should take two round turns so that the strain will be on the line, not the hitches. Then they tie the hitches (see Figure 6-19).
g. **Clove Hitch.** The clove hitch is the best knot for tying a line to a ring, a spar, or anything that is cylindrical. It will not jam or pull out and has a strength of 55 to 60 percent (see Figure 6-20).

h. **Stopper Hitch.** A slight defect of a clove hitch is that it can slide along the cylindrical object to which it is tied. To guard against this, personnel should use a stopper hitch (commonly called a rolling hitch) which is illustrated in Figure 6-21. This figure shows fiber rope; with wire rope, personnel would use a small chain.
(1) When tying, personnel should take a turn around the line with the stopper as in the first view, pull tight, and take another turn. This turn must cross the first turn (first view) and then pass between the first turn and the stopper (second view). This completes the stopper hitch itself, but it must be stopped off in one of several ways.

(2) Personnel can take two or more turns with the lay of the line and then seize the stopper to the line with marline. Another method is to tie a half hitch directly above the stopper hitch. A third method is to tie a half hitch above the rolling hitch (third view), and then take a couple of turns against the lay, and seize the stopper to the line.

6-25. SPLICING THREE-STRAND FIBER LINE. Splicing is a method of permanently joining the ends of two lines or of bending a line back on itself to form a permanent loop or an eye. If two lines are to be spliced, strands on an end of each line are unlaid and interwoven with those of the standing part of the line. Small stuff can be spliced without a fid, which is a tapering length of hard wood used in splicing larger lines. A knife is used to cut off the ends of the strands.
a. **Short Splice.** The short splice is as strong as the rope of which it is made. However, the short splice increases the diameter of the rope and can be used only where this increase in diameter will not affect operation. The splice is frequently used to repair damaged ropes or where two ropes of the same size are to be joined together permanently. Damaged parts of the rope are cut out and the sound sections are spliced. Personnel should follow these steps:

1. Untwist one end of each line five complete turns. Whip or tape each strand. Bring these strands tightly together as in Figure 6-22, view 1, so that each strand of one line alternates with a strand of the other line. Put a temporary whipping on the lines where they join to keep them from suddenly coming apart. Do this procedure with small lines until you are skilled enough to hold them together while you tuck.

   ![Figure 6-22. Short splice](image)

2. Starting with either line, tuck a round of strands in the other line. Then, using the strands of the other line, tuck a round in the first line. Make sure to tuck in one direction, the reverse and tuck in the other direction. When making a round of tucks, regardless of the direction, face where the lines are butted so you will always tuck from right to left. Pull each strand as required to tighten the center of the splice.

3. Tuck two more rounds in each direction. After tucking in one direction and reversing and tucking in the other direction, pull the strands as required to strengthen the center of the splice. When finished with three rounds of tucks in each direction, cut off any excess length on the strands.
NOTE: To have a smoother splice, you may cut off one-third of the circumference of each strand before making the second round of tucks and another third before the third round.

(4) When the splice is completed, cut off the excess strands as before. Lay the splice on the deck and roll it with your foot to smooth out and tighten the splice.

b. **Eye Splice.** When a permanent loop is to be put in the line, personnel should use an eye splice which has a strength of 90 to 95 percent. (Compare this with the strength of a bowline which is 60 percent.) Personnel should follow these steps:

(1) Unlay (untwist) the strands in the end of the line four or five times and splice them into the standing part of the line by tucking the unlaid strands from the ends into the standing part. Whip or tape the ends of the strands. An original round of tucks, plus two more complete rounds, is enough. If the line parts, it will likely part in the eye rather than in the splice, so three rounds are as effective as a greater number.

(2) Always whip or tape the ends of the strands before starting, otherwise, they will unlay and be troublesome. Seize large lines at the point where unlaying stops to avoid trouble working with them. For lines with up to 21 threads, you can open the strands in the standing part with your fingers. Use the fid for larger lines.

(a) Figure 6-23 shows how to make the first two tucks. Separate the strands in the end and hold them up as shown in the first step. Place the three unlaid strands against the standing part where they will be tucked, forming the desired eye. The middle strand facing you always tucks first. Put a reverse twist on the standing part so that you can raise the strand under which you will make the first tuck. Pick up the stand to be tucked, and tuck it under the strand raised. Always tuck from right to left or with the lay of the line.
Figure 6-23. Making eye splices

(b) Be sure to keep the next strand, in step two, on the side of the line that is towards you. Tuck that strand next. Put it over the strand under which the first one is tucked, and tuck it under the next one.

c) Now turn the incomplete eye over as shown. Check the third strand to be sure that it has not unlaid more. If it has, twist it back to where it should be. Take the last strand, put it across the standing part, turn its end back toward you, put it under the strand over which the first tuck was made, and tuck it in a direction toward you. This results in the third tuck going to where the second came out and coming out where the first tuck went in. After this round of tucks, there is a strand in each lay.

d) Pull each of the three strands tucked backward at about a 45-degree angle to the eye to tighten the splice.

(3) The first round of tucks is the key to making a perfect eye splice; the rest is easy. Starting with any strand, simply tuck each one over and under two more times. None of the last two rounds requires an over and back tuck. However, always tuck from right to left. As required, pull the tucked strands away from the eye and twist the splice and line to tighten them.
(4) After finishing the splice, bend the end of each strand back toward the splice and, using a knife, cut it off, up, and away, leaving 1/4-inch tip.

6-26. PUTTING AN EYE IN WIRE ROPE. This paragraph discusses how to put both a temporary eye and a permanent eye in wire rope. A temporary eye can be put in wire rope by using wire rope clips or by using a field expedient known as a "hasty eye" or "Molly Hogan" splice. A liverpool splice is the accepted method for putting a permanent eye in the end of a wire rope. With the proper equipment, and a bit of practice, a liverpool splice can be put in wire rope in less than 15 minutes.

a. Splicing Tools. With the exception of the wire cutters, Figure 6-24 shows the tools needed for splicing. The marlinespike is used for opening the strands in the standing part of the wire rope and for working the strands to be spliced into the standing part. The wire cutters are used for cutting the strands after the splice is complete. The hydraulic wire rope cutter is used to cut the length of wire rope that will be spliced. A thimble is used to keep the wires from moving and the rigger's vise from crushing them when a soft eye is made. After the soft eye is spliced, the thimble is removed. When an eye is to have a thimble as a permanent part, the thimble is the size of the eye desired.
b. **Temporary Eye.** A temporary eye may be put in wire by using wire rope clips. Figure 6-25 shows the correct way of using these clips. As the illustration shows, a wire rope clip consists of two parts: the U-bolt and the roddle, the part into which the U-bolt is inserted. Personnel should always put the U-bolt over the bitter end and the roddle on the standing part. This procedure protects the live or stress-bearing end of the rope against
crushing. The roddle protects the rope and, therefore, should always be placed against the live end.

(1) To obtain maximum strength from the temporary eye splice, use the correct size and number of wire clips, and the correct spacing between them. Size is stamped on the roddle between the two holes. Personnel may use the following formula to determine the number of clips: $3 \times \text{diameter of wire rope} + 1 = \text{number of clips}$. For example, the number of clips needed for 1-inch wire rope is: $3 \times 1 + 1 = 4$. To determine the correct space between clips, multiply the diameter of the rope by six. For example, the space between clips to be put on 1-inch rope is: $6 \times 1 = 6$ inches. Measure the space from the center of one clip to the center of the next one. If the calculation for either the number or the space results in a fraction, round off to the next higher whole number.

(2) The improved type of wire rope clips shown in Figure 6-26 has a few advantages over the older type. Both halves are identical and provide a bearing surface for both parts of the rope. Thus, it cannot be put on wrong and does not distort the wire. It also allows a full swing with a wrench.

c. **Hasty Eye (Molly Hogan) Splice.** Occasionally it becomes necessary to construct a field expedient, called the hasty eye or Molly Hogan splice. This splice can be quickly made, but it is limited to about 70 percent of the strength of the wire rope. It should not be used to lift heavy loads. This splice can be used only when working with preformed wire rope. To make a hasty eye splice, personnel should follow these steps:

(1) Using a marlinespike, screwdriver, or, if necessary, a nail, separate the wire rope into two three-strand sections. These sections should be unlaid four times the diameter of the desired eye. If you want a 1-foot diameter eye, unlay the sections back 4 feet.

(2) Use the two sections to form a loop of the desired diameter for the eye.

(3) Lay the strands back around each other to form the eye.

(4) After the strands have been laid back around each other and the eye has been formed, seize the wire to complete the splice.
d. Liverpool Splice. The Liverpool splice is the easiest and most common of the wire splices to make. It is the primary splice used when a permanent eye is required. Personnel should follow these instructions:

(1) **Forming the eye.** To find the distance, the strands should be unlaid for an eye splice; then, multiply the diameter of the wire by 36 inches. (For example, to determine the distance of a 5/8-inch wire rope: multiply 5/8 x 36/1 = 180/8 = 22 1/2 or 23 inches.) Measure off that distance on the wire rope and put a seizing at that point. Cut the end seizing and carefully unlay the strands. Whip the ends of each strand with either sail twine or friction tape. Form the desired size eye and put the eye in the rigger's vise with the unlaid strands to your right as you face the vise. Stretch out the standing part of the wire, clamp and lash it and you are ready to start.

**NOTE:** When splicing wire, always insert the marlinespike against the lay of the wire, and make sure not to shove it through the core. The core must be on the left-hand side of the spike.

(2) **Making the first tuck of strands one, two, and three.** In the Liverpool splice, the first strand goes under three strands, the second strand goes in the same opening but only under two strands, and the third strand goes in the same opening but only under one strand. All of the strands go in at the same point, but come out at different places (Figure 6-27). At this time, run the spike behind the three strands under which the first three are tucked, but above the first three tucked strands. Holding the marlinespike at a 90-degree angle to the standing part, turn the spike counterclockwise about one fourth of a turn and insert the core through the standing part. This is called "dipping the core." Make sure that the core is inserted under the marlinespike. Pull the core down and run it down into the splice.

(3) **Tucking strands four, five, and six.** Remember that the core was last between strands three and four and that the strands are numbered clockwise. To tuck strand four, put the marlinespike under the strand to the left of where one, two, and three were tucked through the standing part. Turn the marlinespike counterclockwise around the standing part and tuck the strand. Pull it tight and run it down with the spike. Tuck strand four around the same strand four times. Lock each tuck in place by holding the strand down and running the spike up. Push the marlinespike under the next higher strand on the standing part and tuck strand five around it four times, using the same procedure as with strand four. Then tuck strand six four times. This completes strands four, five, and six.

(4) **Running the core up.** Burying the core in the center of the splice in the standing part is called "running the core up." Part of the core is run up and the excess is cut off. This is
done before each of the first strands is tucked three more times. Run the spike under the same three strands under which number one strand was passed. With the spike in your left hand and the core in your right hand, move the spike to the left and down, and pull up the core with your right hand to tighten it. Then move the spike back to the right. Next run up the core into the center of the splice and cut off the excess.

(5) **Tucking strands one, two, and three.** To finish the splice, tuck number three, two, and one. Each is tucked three times in a row, ending up with an overall total of four tucks for each. To avoid kinking the strands on the last tucks, insert the spike and run it up the wire. Follow the spike up with the strand, shove it under the spike, and pull taut. Keeping a strain on the strand, work the spike and strand back around and down together. Hold the strand there and work the spike back up the wire. Follow up with the strand and take the last tuck. Work the strand back down and hold it there. Before pulling out the spike, run it back up until the strands of the standing wire bind the working strand in place. Make the second and third tucks with the remaining strands in the same way.

(6) **Completing a splice.** Remove the wire from the vise, use a hammer to pound the splice into shape, and cut off the ends of the tucking strands close to the splice.
Figure 6-27. Tucking strands of a Liverpool splice