Chapter 20

Rigging (Seamanship)

This chapter describes the different types of blocks used in shipboard rigging and their nomenclature and maintenance. It also discusses the requirements for inspecting standing rigging. Also included are the formulas that are used to compute the safe working load and breaking strain for fiber, synthetic, and wire rope, hooks, shackles, and turnbuckles.

SECTION I - BLOCKS AND TACKLES

DESCRIPTION OF BLOCKS

20-1. A block consists of one or more pulleys or sheaves fitted in a wood or metal frame. Each block has one or more straps of steel or rope that strengthen the block and, in most cases, support the sheave pin. By inserting a hook or shackle in the strap, the block itself may be suspended or a load applied to the block. If the block has a becket to which the fall is spliced, the becket is also secured to the strap. A block with a rope led over the sheave is convenient in applying power by changing the direction of the pull. Used in conjunction with rope and another block, it becomes a tackle and increases the power applied on the hauling part (described later in this chapter).

DETERMINE THE SIZE OF BLOCK TO USE WITH FIBER LINE

20-2. The size of a block is found by measuring the length of the cheek of that block. The constant is 3 and the circumference of the line is the line size. The circumference of the line to be used will determine the size of the block needed. Blocks for fiber lines come in the following sizes: 4, 5, 6, 7, 8, 10, 12, and 14 inches.

Formula: LS X C = SB

Determine the size block to use for a 3 1/2-inch fiber line.

Example:

Line size to be used is 3 1/2 inches.

3 1/2 inches (LS) times a constant of 3.

3 1/2 X 3 = 10 1/2 inches

The closest sizes are 10-inch and 12-inch blocks. Go to the next larger size to select the 12-inch block. Blocks are designed for use with a certain size of rope. Therefore, they should never be used with rope of a larger size. Rope bent over a small sheave will be distorted, and any great strain applied will damage it and may even result in the rope wearing on the frame.

DETERMINE THE SIZE OF BLOCK TO USE WITH WIRE ROPE

20-3. It is impossible to give an absolute minimum size for wire rope sheaves because of the factors involved. However, experience has shown that the diameter of a sheave should be at least 20 times the diameter of the wire rope. An exception to this is a 6 X 37 wire and other flexible wire for which smaller sheaves can be used because of their greater flexibility. The construction of the wire rope has a great deal to do with determining the minimum diameter of sheaves to be used (Figure 20-1). The stiffer the wire rope, the larger the sheave diameter required.

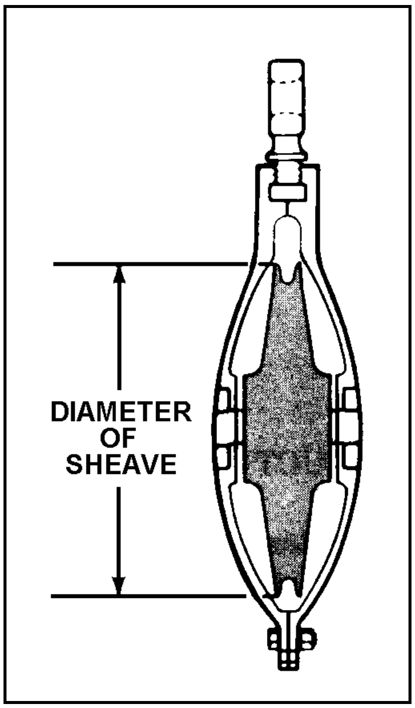

Figure 20-1. Wire Rope Block

COMMON CARGO BLOCKS

20-4. The three types of cargo blocks most frequently seen on ships are the diamond, oval, and roller bearing. Figure 20-2 shows the diamond block and roller bearing block. Each of these blocks are described below.

- **Diamond block.** A single-sheave diamond block is shown in Figure 20-2, but there may be many more, depending on the use of the block. Sheaves of this type of block are usually bushed with a high-grade bronze alloy, and the pins are equipped with grease fittings. Sheave bushings should be lubricated with hard graphite grease (such as Federal Specification VV-G-671, grade 0).
- **Oval Block.** Oval blocks are built to the same specifications as diamond blocks except that the cheeks are oval instead of diamond shaped. The most common use of these two blocks is for topping lifts of cargo booms.
- **Roller Bearing Block.** Head, heel, and many of the fairlead blocks are of the roller bearing type. These blocks have cast steel cheeks and sheaves. The sheaves are equipped with roller bearing assemblies. The pin is provided with a grease fitting. Roller bearing blocks are used where high-speed operation is essential.

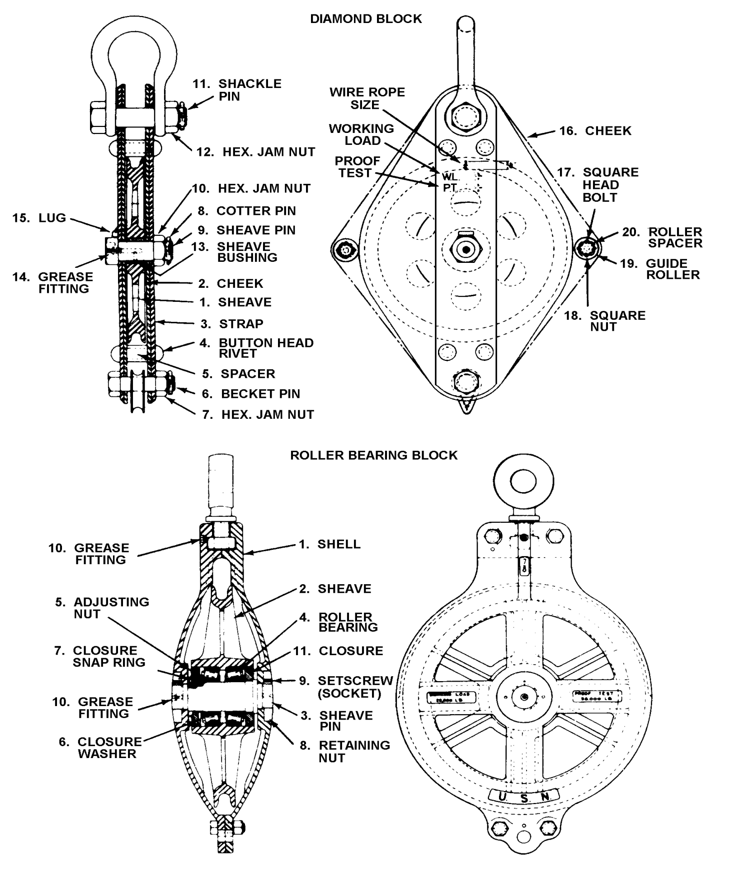

Figure 20-2. Common Cargo Blocks

NAMING A BLOCK

20-5. Regardless of type, a cargo block is usually named for its location in the cargo rig. The block at the head of the boom through which the whip runs is called the head block. The block at the foot, which fairleads the wire to the winch, is the heel block. A small single-sheave block in the middle of most booms is called the slack wire block because it prevents slack in a whip from hanging down in a bight. Blocks in the topping lift are upper and lower topping lift blocks. A fairlead block, called a check block, is permanently fixed by welding or bolting one cheek to a bulkhead, davit, and so on. Another fairlead block is a snatch block, which is cut at the swallow (the hole the line reeves through), hinged on one side, and fitted with a hasp on the other. This permits the block to be opened and clamped on a line rather than reeving the end of the line through. Tail blocks are single blocks usually used alone with a whip or as a runner.

Note: When ordering a block, five things must be specified: wood or metal, size, type rig (with or without becket), and number of sheaves.

TYPES OF RIGS

20-6. Blocks may be single, double, treble, and so on. That is, they may be fitted with one, two, three, or more sheaves, respectively. When used in a tackle, one of the blocks must be fitted with a becket to which one end of the line is spliced. When the hook, shackle, and swivel are fitted on the blocks they are called rigs. Figure 20-3 shows various types of rigs and fittings.

COMBINATIONS OF BLOCKS AND TACKLES

20-7. Tackles are designated in two ways. One is the number of sheaves in the blocks that are used to make the tackle, such as single whip, gun tackle, or twofold purchase. The other designation is according to the purpose for which the tackle is used, such as yard tackles, stay tackles, or fore-and-aft tackles. Only the most commonly used combinations found aboard ship are shown in Figure 20-4, page 20-6, and described as follows.

- **Single Whip.** Consists of one single-sheave block fixed to a support with a rope passing over the sheave.
- **Runner.** Consists of a single block, but the block is free to move. One end of the rope is secured to the support with the weight attached to the block.
- **Gun Tackle.** Consists of two single blocks. It takes its name from the use made of it in hauling muzzle-loading guns back into battery after the guns are fired and reloaded.
- **Luff Tackle (Jigger).** Consists of a double and a single block.
- **Twofold Purchase.** Consists of two double blocks.

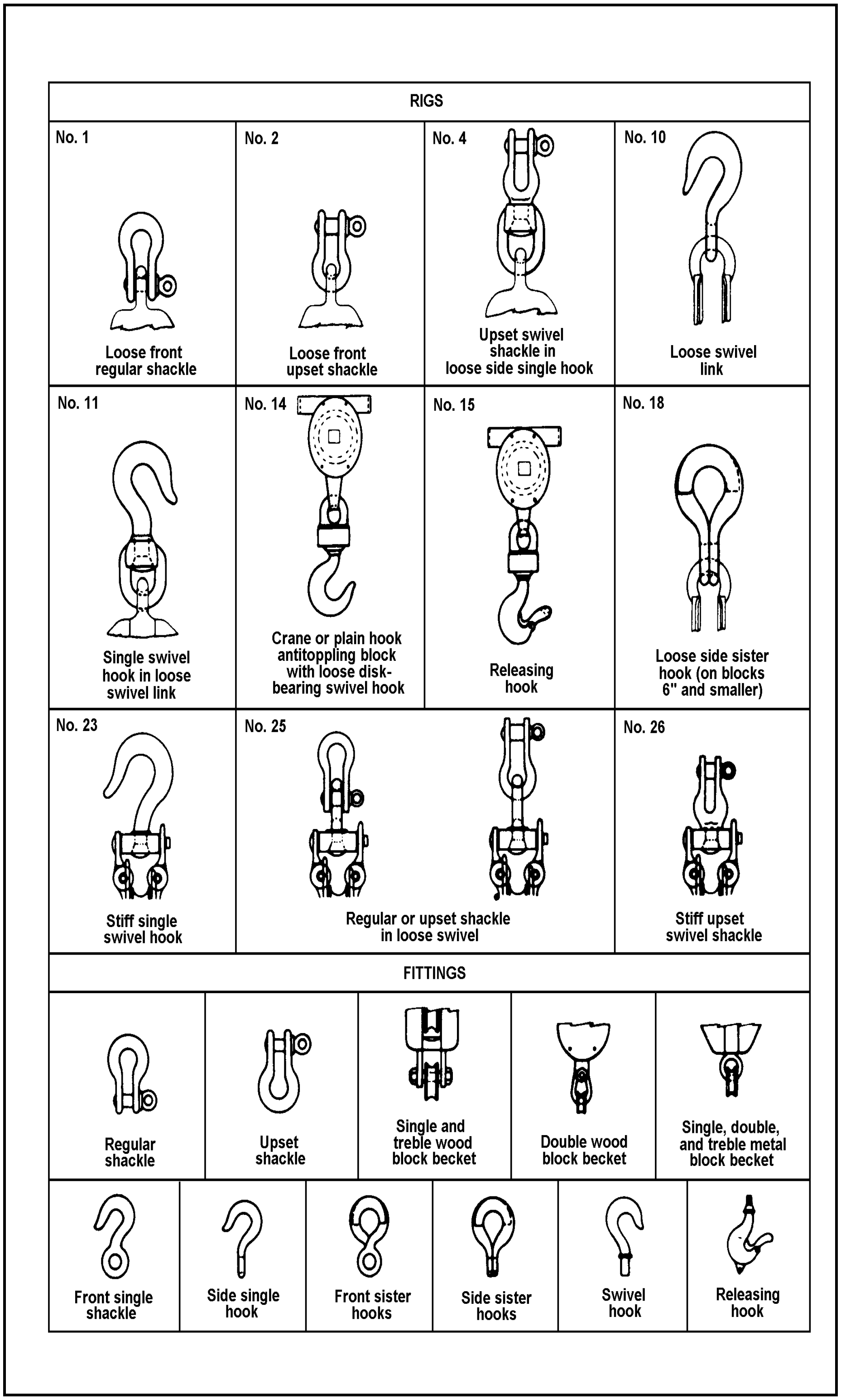

Figure 20-3. Various Rigs and Fittings

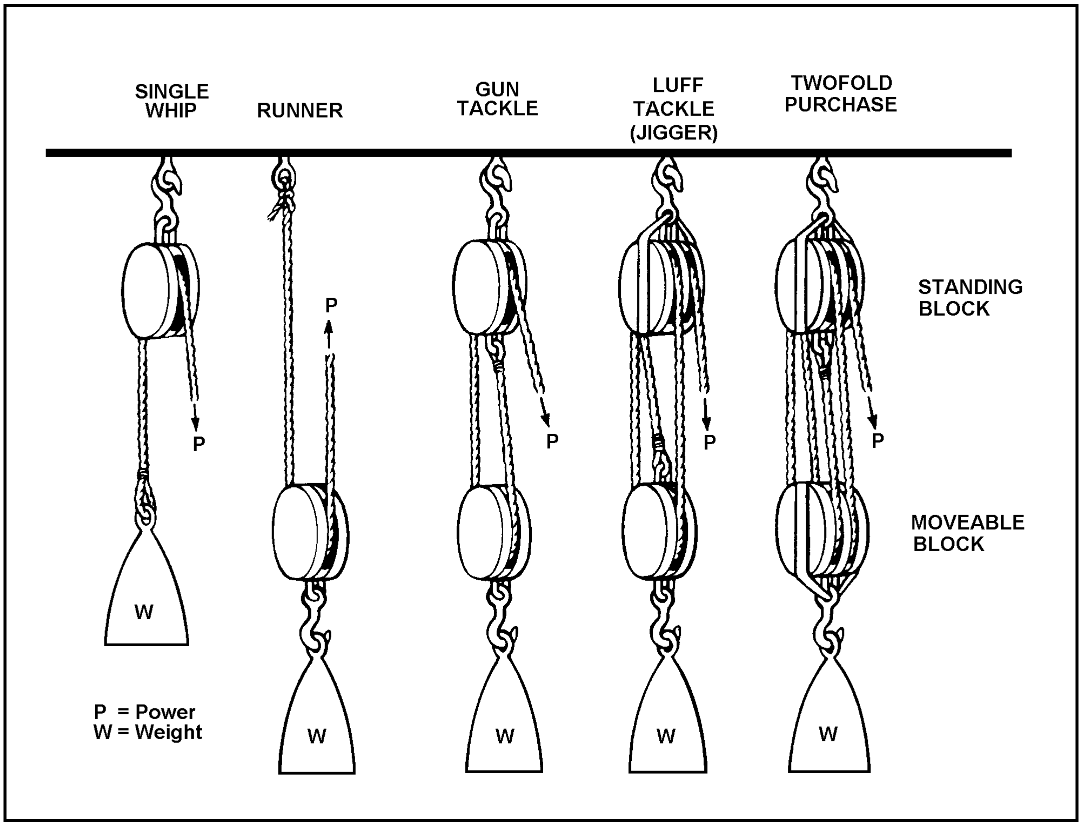

Figure 20-4. Blocks and Tackles

REEVING BLOCKS AND TACKLES

20-8. The preferred method of reeving multiple sheave blocks is referred to as the "right-angle method of reeving". With this method, one block (usually the head block) rests on the edge of its plates and cheeks, and the other block rests on its cheek. The sheaves are at right angles to each other (Figure 20-5). The advantages of using the right-angle method of reeving are that it reduces the chances of the rope chafing or of the blocks turning.

REEVING A DOUBLE LUFF TACKLE

20-9. A double luff tackle consists of a triple sheave and a double sheave block. The right-angle method of reeving is shown in Figure 20-6.

REEVING A THREEFOLD PURCHASE

20-10. The same method used to reeve a threefold purchase is used in reeving the double luff tackle (see Figure 20-7). After the line has been reeved through the last sheave, the final step is to make an eye-splice around the thimble and then bolt it into the becket.

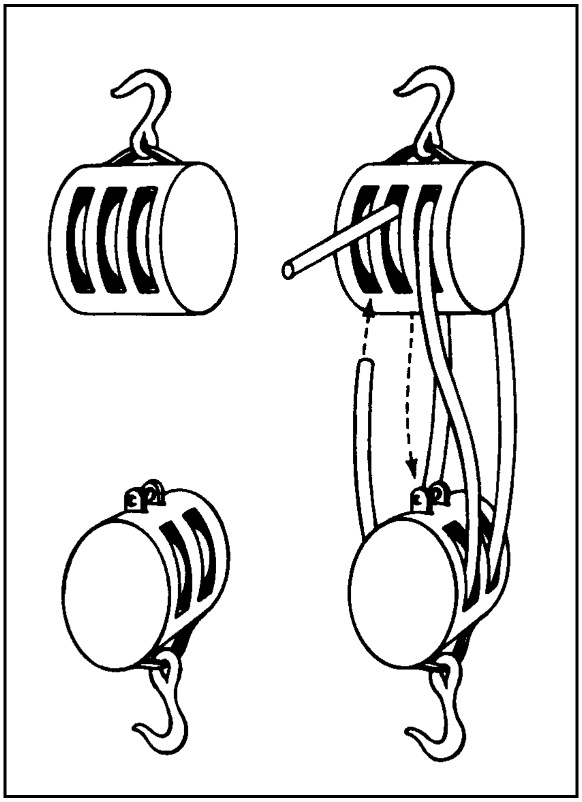

Figure 20-5. Blocks at Right Angles

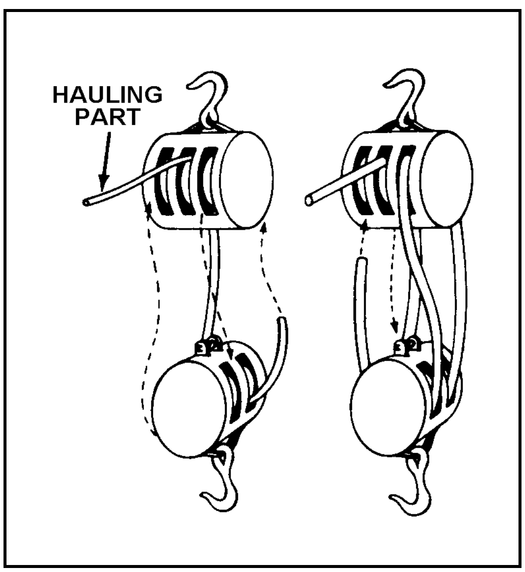

Figure 20-7. Reeving a Threefold Luff Tackle

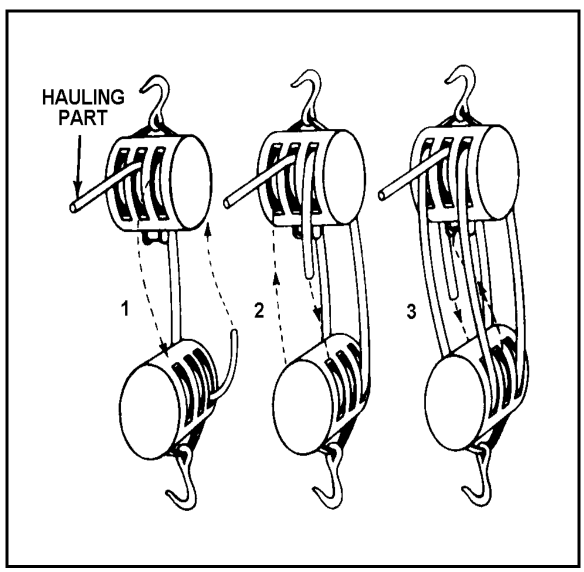

Figure 20-6. Reeving a Double Purchase

DETERMINING THE MECHANICAL ADVANTAGES OF TACKLES

20-11. The mechanical advantage of a simple tackle is determined by counting the number of parts of the moving lines at the moveable block. The moveable block is the block that is attached to the weight to be moved (see Figure 20-8). Friction is not considered in the following example: If a load of 10 pounds requires 10 pounds to lift it, the mechanical advantage is 1. If a load of 40 pounds requires only 10 pounds of power to lift it, then the mechanical advantage is 4 to 1, or 4 units of weight lifted for each unit of power applied.

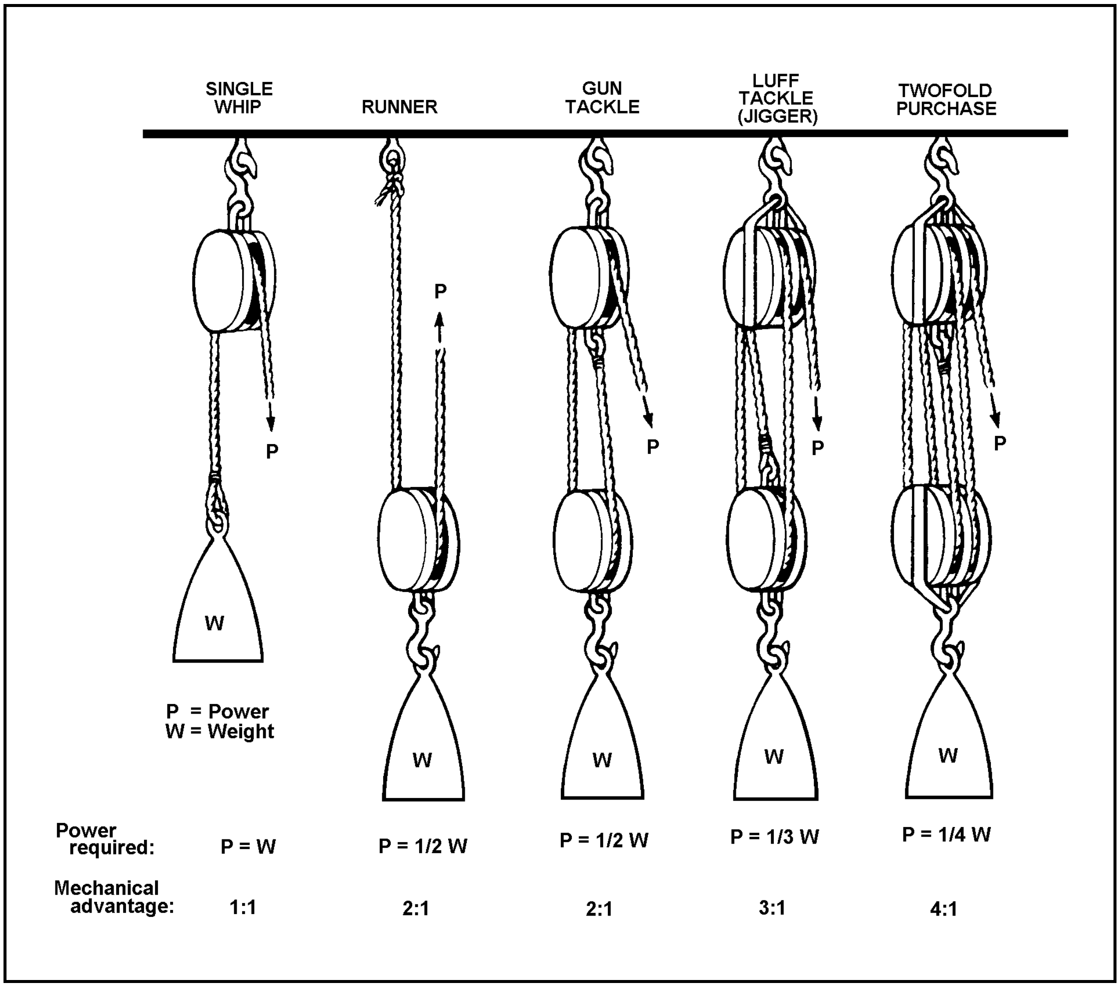

Figure 20-8. Mechanical Advantages of Tackles

SECTION II - COMPUTATIONS

COMPUTING FRICTION

20-12. A certain amount of the force applied to a tackle is lost through friction. Friction in a tackle is the rubbing of ropes against each other or against the frame or shell of a block, the passing of the ropes over the sheaves, and the rubbing of the pin against the sheaves. This loss in efficiency of the block and tackle must be added to the weight being lifted when determining the power required to lift a given load. Roughly 10 percent of the load must be added to the load for every sheave in the tackle. For example, what would be the loss of efficiency due to friction when picking up 500 pounds and using a twofold purchase?

Weight of load is 500 pounds.

10 percent of the weight of the load is 50 pounds.

With a twofold purchase there are four sheaves.

4 (sheaves) X 50 pounds (10 percent of weight) = 200 pounds loss in efficiency due to friction.

COMPUTING BREAKING STRENGTH AND SAFE WORKING LOAD

20-13. When working with line, it is essential that you do not overload it because doing so is dangerous and costly. An overloaded line may part and injure someone in the vicinity. Even if it does not part, its useful life is shortened every time it is overloaded. For these reasons, you need to know a line's breaking strength and safe working load.

20-14. The manufacturer's data gives the BS of a line, but to learn the line's SWL, you must apply an SF. An SF is a number by which the BS is divided to find the range in which it is safe and economical to operate the rope. Table 20-1 shows, even under the best of conditions, that the allowance for safety is considerable.

Table 20-1. Safety Factor of Line

Line	Working Conditions		
	Best	Average	Poor
Manila	5	10	15
Nylon Polyester	3	4	6

Polypropylene Polyethylene	5	6	8

USEFUL FORMULAS FOR LINES

20-15. When the manufacturer states the size and BS of its lines, use these figures for determining the strength of line. If this information is not available, then use the rule of thumb to compute the SWL and the breaking strength.

20-16. The following rules of thumb give only approximate results. However, the error will be on the side of safety because of the constants used in the formula.

Type of line	Constant
Sisal	160
Manila	200
Three-strand nylon	500
2-in-1 braided nylon	600

With "C" meaning circumference in inches, the formula for SWL in pounds is:

C^2 X constant for line = SWL

3-inch sisal:
3 X 3 X 160=
9 X 160 =
1,440 pounds SWL

3-inch manila:
3 X 3 X 200 =
9 X 200 =
1,800 pounds SWL

3-inch, three-strand nylon:
3 X 3 X 500=
9 X 500 =
4,500 pounds SWL

3-inch, 2-in-1 braided nylon:
3 X 3 x 600 =
9 X 600 =
5,400 pounds SWL

20-17. An SF of 5 is generally used in marine operations. Multiply this by the SWL to find the BS of a fiber line. This is the amount of weight in pounds required to part the line. If you are given the BS of a line, divide it by the safety factor 5 to find the SWL.

Note: The safety factor of 5 is valid when using new line or line that is in good condition. As line ages and wears through use, the safety factor drops. Old line may have a safety factor of 3.

SWL AND BS FOR WIRE ROPE

20-18. Useful formulas for determining the SWL of several grades of wire rope have constants 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 (D^2) times 10

or

$SWL = D^2 X 10$

20-19. To find the SWL of 1-inch, 6 X 19, extra improved plow steel wire rope:

$SWL = D^2 x 10$
= 1 X 1 X 10
= 10 STONs

20-20. A figure relatively constant in marine operations, especially for new wire rope, is the SF of 5. It is used with the SWL to find the breaking strength or strain:

BS = SWL X 5
= 10 X 5
= 50 STONs

20-21. The formulas for improved plow steel, plow steel, and mild plow steel (6 X 19 wire rope) are as follows:

Improved plow steel and plow steel:

$SWL= D^2 X 7$ = STONs

BS = SWL X SF = STONs

Mild plow steel:

$SWL= D^2 X 6$ = STONs

BS = SWL X SF = STONs

COMPUTING THE BREAKING STRENGTH OF A BLOCK AND TACKLE

20-22. Breaking strength determines the ultimate strength of the block and tackle. When computing the breaking strength of a block and tackle think of this as the load that your line should be expected to handle on a regular basis. Computing the correct breaking strength will safeguard expensive equipment and also protect the lives of personnel.

DETERMINING BREAKING STRESS

20-23. Perform the following steps to determine breaking stress.

- **Step 1.** Determine the friction for the block and tackle.
- **Step 2.** Determine the total weight to be lifted.
- **Step 3.** Determine the strain on the hauling part of the block and tackle.
- **Step 4.** Apply the breaking stress formula to compute the breaking stress of the block and tackle.

Note: The SF for the hauling part is always 5. The formula is SF X SHP = BS for the block and tackle.

- **Step 5.** Compare the breaking stress to the figures shown in the line strength table (see Table 20-2). The SWL of the line used should be greater than the computed BS for the block and tackle.

Example:

Determine the breaking strain for a twofold block and tackle that is going to be used to lift a 500-pound weight.

Determine the minimum size manila line that has an SWL capable of making the lift.

PROCEDURE

20-24. Friction is computed at 10 percent per sheave.

- **Step 1.** Determine the friction. For a block and tackle, 10 percent times the number of sheaves equals the percent of friction. Using a twofold purchase, there are four sheaves, giving a loss of efficiency of 40 percent.
- **Step 2.** Determine the total weight to be lifted. The original weight to be lifted is 500 pounds. There is a 40 percent loss of efficiency that must be added to that weight to be lifted (40 percent X 500 = 200 pounds). The formula for total weight is:

  W + F = TW

  500 + 200 = 700 pounds total weight to be lifted.

- **Step 3.** Determine the SHP. The mechanical advantage for a twofold purchase is 4.

Formula is:

TW ÷ MA = SHP

700 ÷ 4 = 175 pounds SHP

- **Step 4.** Compare the SHP to the line strength shown in Table 20-2. Select an SWL that exceeds the computed SHP for the block and tackle. You would use 1 1/2-inch manila line, which has an SWL of 450 pounds for making the lift.

Note: The information in Table 20-2 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 strength shown in pounds for a given size of line.

Table 20-2. Line Strength Table
(Safety factor of 5)

Size in (inches)	Manila		Three-strand Nylon		2-in-1 Braided Nylon	
	SWL (pounds)	BS	SWL (pounds)	BS	SWL (pounds)	BS
1	200	1,000	500	2,500	600	3,000
1 ½	450	2,250	1,125	5,625	1,350	6,750
2	800	4,000	2,000	10,000	2,400	12,000
2 ½	1,250	6,250	3,125	15,625	3,750	18,750
3	1,800	9,000	4,500	22,500	5,400	27,000
3 ½	2,450	12,250	6,125	30,625	7,350	36,750
4	3,200	16,000	8,000	40,000	9,600	48,000
4 ½	4,050	20,250	10,125	50,625	12,150	60,750
5	5,000	25,000	12,500	62,500	15,000	75,000
5 ½	6,050	30,250	15,125	75,625	18,150	90,750
6	7,200	36,000	18,000	90,000	21,600	100,800
6 ½	8,450	42,250	21,125	105,625	25,350	126,750
7	9,800	49,000	24,500	122,500	29,400	147,000
7 ½	11,250	56,250	28,125	140,625	33,750	168,750
8	12,800	64,000	32,000	160,000	38,400	192,000
8 ½	14,450	72,250	36,125	180,625	43,350	216,750

COMPUTING SAFE WORKING LOAD FOR HOOKS, SHACKLES, AND TURNBUCKLES

20-25. Calculated or predicted design loads are compared to a baseline strength in computing the safety factor for hooks, shackles, and turnbuckles. All hooks, shackles, and turnbuckles will be tested before being used.

COMPUTE THE SWL OF A HOOK

20-26. The diameter of a hook is measured where the inside of the hook starts its arc. The constant for a hook is 2/3.

Formula:

D^2 X C = SWL of hook in STONs

- **Step l.** Measure diameter of the hook to be used.
- **Step 2.** Use the constant of 2/3.
- **Step 3.** Apply the formula to determine the SWL of the hook in STONs.

Example:

Determine the SWL of a 3-inch hook.

D^2 X C = SWL in STONs

(D^2 = 3 X 3 = 9),(C = 2/3)

9 X 2/3 = 6 STONs SWL

COMPUTE THE SWL OF A SHACKLE

20-27. Measure the diameter of the shackle at its side. The constant for shackles is 3.

Formula:

D^2 X C = SWL in STONs

- **Step l.** Measure the diameter at the side of the shackle.
- **Step 2.** Use the constant of 3.
- **Step 3.** Apply the formula to determine the SWL in STONs for a shackle.

Example:

Determine the SWL of a shackle that has a diameter of 2 inches.

D^2 X C = SWL in STONs

$(D^2 = 2 X 2 = 4), (C = 3)$

4 X 3 = 12 STONs SWL

COMPUTE THE SWL OF A TURNBUCKLE

20-28. To determine the SWL for turnbuckles, measure the diameter of the threaded rod (Figure 20-9) and check the SWL in Table 20-3.

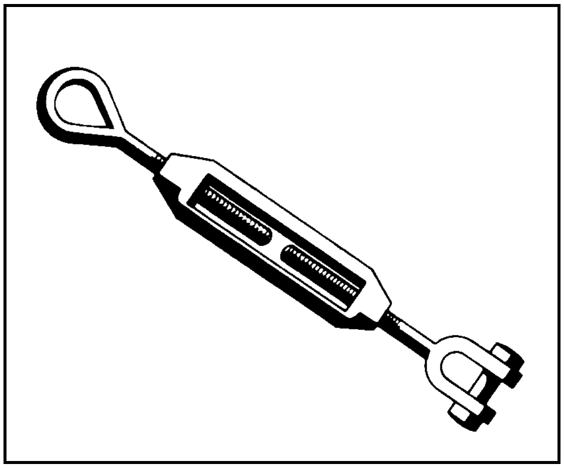

Figure 20-9. Threaded Rod on Turnbuckle

Table 20-3. Turnbuckle Rod SWL Table

Values in STONs (2,000 pounds)	
Rod diameter (in inches)	**SWL (in STONs)**
1/2	.9
5/8	1.5
7/8	2.2
1	3.1
1 1/8	5.1
1 1/4	6.6

SECTION III - BLOCK MAINTENANCE AND RIGGING

MAINTENANCE AND OVERHAUL OF BLOCKS

20-29. Blocks, like other equipment exposed to the elements, will become useless if they do not receive proper maintenance. The bearing and bushing will wear if they are not properly lubricated. The shells and accessories will deteriorate if they are not properly preserved. Maintenance for the fiber rope and the wire rope blocks is discussed as follows.

FIBER ROPE BLOCKS

20-30. These types of blocks should be disassembled periodically and inspected and lubricated. A mixture of white lead and tallow, or graphite and grease, should be used.

20-31. To disassemble a block, remove the becket bolt and becket, pry off the keeper, and drive out the pin. To loosen the strap in the frame, tap the bottom with a hammer. Then if you cannot pull it out by hand, insert a marlinespike in the U of the strap and drive it out by tapping on the marlinespike with the hammer. Figure 20-10 shows a disassembled block.

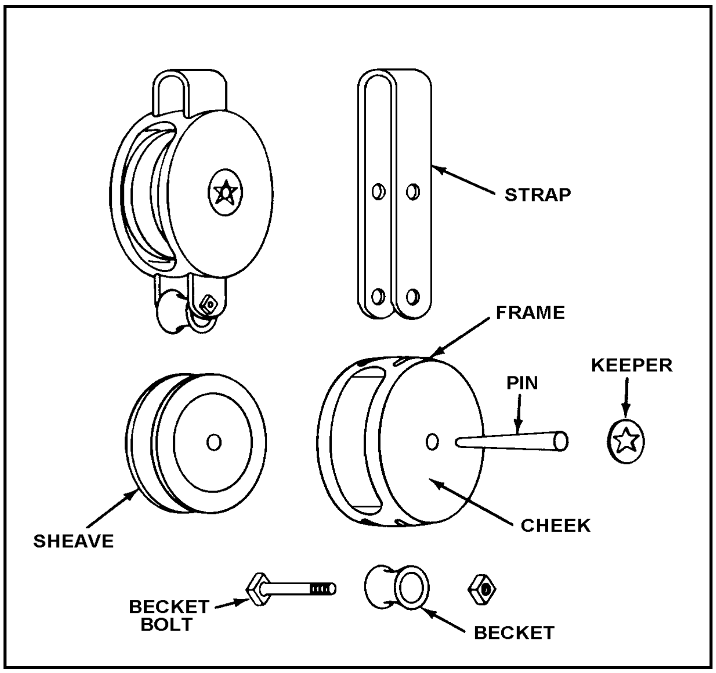

Figure 20-10. A Disassembled Block

20-32. Inspect the frame of the block for any cracks or splits and for any signs of the sheave wearing on the frame. If there are any worn spots on the inside of the frame, check the pin to see if it is bent. Check the hooks or shackles for any sign of distortion. A bent pin or a distorted hook or shackle is no longer is safe. Dropping a wooden block can split its frame. Never paint a wooden block because a coat of paint could hide a split. Instead, use clear shellac or varnish or several coats of linseed oil. Metal in constant use is subject to fatigue. Frequently and carefully inspect blocks in running rigging for any signs of distortion or wear. Immediately replace any doubtful block and, if the cost warrants, send it to a shipyard for testing.

20-33. Inspect and replace any suspected wooden blocks. Many parts for blocks are available separately--for example, rigs for wire rope blocks. Before replacing an entire block, consult the supply officer to see if you can get a replacement for any part that is defective.

WIRE ROPE BLOCKS

20-34. These types of blocks used in cargo handling rigs and others in continuous use should be disassembled frequently and inspected for wear. However, those used only occasionally seldom need to be disassembled if they are kept well lubricated. Two types of wire rope blocks are the diamond and oval blocks and the roller bearing block. Refer back to Figure 20-2, page 20-3, to do the following:

Diamond and Oval Blocks

20-35. To remove the sheave from a diamond or oval block, take out the cotter pin (8) and remove the hexagon nut (10) from the sheave pin (9). Drive out the sheave pin. For a diamond block it is necessary to loosen all bolts holding the cheeks together and to remove one before the sheave will slide out. With an oval block it is necessary only to loosen the bolts.

Roller Bearing Blocks

20-36. To disassemble a roller bearing block, loosen the setscrews (9) and remove the retaining nuts (8). Take out the bolts holding the shell together and remove the shell. Remove the closure snap rings (7), adjusting nut (5), closure washer (6), and closure (11). Now remove the pin, then the bearings from the sheave.

STANDING RIGGING

20-37. Standing rigging, usually of 6- X 19-inch galvanized, high-grade plow steel wire rope, is used to support the masts. The fore and aft supports are called stays and the supports running athwartships are shrouds. Stays and shrouds are set up at the lower end with turnbuckles. Vibration often causes turnbuckles to back off. To prevent this, keepers are installed on most turnbuckles in standing rigging. The effectiveness of shrouds and stays is reduced considerably if they are allowed to become slack. Inspect standing rigging periodically and tightened if necessary. Use the following procedure when considerable adjustments are required.

- Slacken all stays and shrouds so that no unbalanced forces are applied to the mast.
- Take up the slack as uniformly as possible until sag is substantially eliminated from all stays and shrouds, and turnbuckles are handtight. Measure the distances between the ends of the turnbuckle bolts.
- Tighten each turnbuckle so that it is shortened by a distance equal to l inch for each 60 feet of stay length.

Insulators should present clean surfaces. They should not be painted, tarred, varnished, or coated in any way. All electrical grounds on standing rigging should be inspected periodically for excessive deterioration at points of contact between different metals.

INSPECTIONS OF RIGGING

20-38. A weekly inspection of all booms and their rigging and associated fittings is conducted by the mate and boatswain. Whenever a boom is to be used for hoisting or lowering a load equal to its rated capacity, as shown on the heel of the boom, the chief mate should be notified. He will make a thorough inspection of the boom and its associated fittings and rigging before the lift is made. Whenever signs of deterioration are found, defective components should be replaced or renewed as soon as possible. If the inspection indicates a dangerous condition or weakness of any component, this should be reported without delay, and the boom in question should not be operated until it is repaired or replaced. Refer to FM 55-17 for more information on cargo rigging.

GROUNDING MASTS

20-39. Unless otherwise directed, mast shrouds should be grounded at the deck to prevent accumulation of static charges. One method of grounding shrouds is shown in Figure 20-11. Most electrical insulation and grounds on metallic standing rigging should be inspected periodically for deterioration at points of contact between dissimilar metals. When deterioration is evidenced, the connections should be thoroughly cleaned and replaced as required.

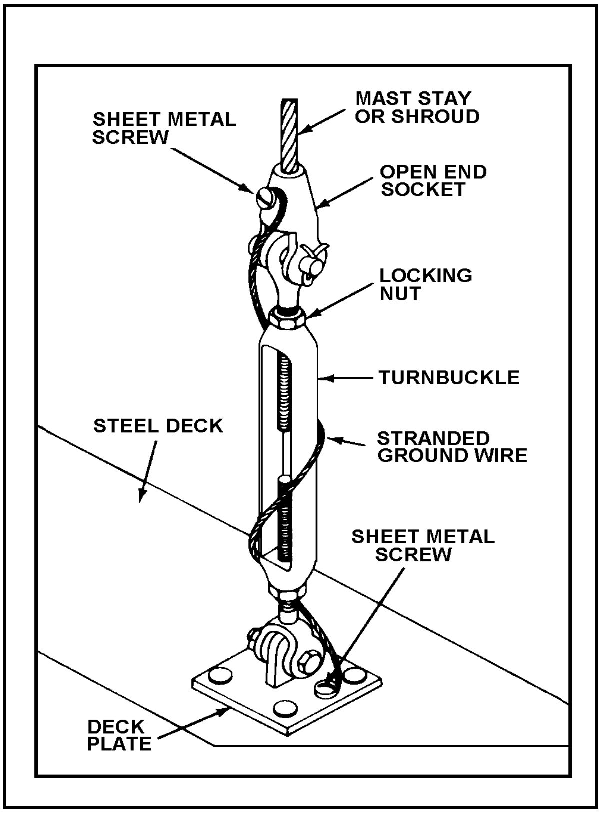

Figure 20-11. Grounding a Shroud