CHAPTER 4

Anchors and Guy Lines

Section I. Anchors

When heavy loads are handled with a tackle, it is necessary to have some means of anchorage. Many expedient rigging installations are supported by combining guy lines and some type of anchorage system. Anchorage systems may be either natural or man-made. The type of anchorage to be used depends on the time and material available and on the holding power required. Whenever possible, natural anchorages should be used so that time, effort, and material can be conserved. The ideal anchorage system must be of sufficient strength to support the breaking strength of the attached line. Lines should always be fastened to anchorages at a point as near to the ground as possible. The principal factor in the strength of most anchorage systems is the area bearing against the ground.

NATURAL ANCHORS

Trees, stumps, or rocks can serve as natural anchorages for rapid work in the field. Always attach lines near the ground level on trees or stumps (see *Figure 4-1.* Avoid dead or rotten trees or stumps as an anchorage because they are likely to snap suddenly when a strain is placed on the line. It is always advisable to lash the first tree or stump to a second one to provide added support. Place a transom between two trees to provide a stronger anchorage than a single tree (see *Figure 4-2, page 4-2).* When using rocks as natural anchorages, examine the rocks carefully to be sure that they are large enough and firmly embedded in the ground (see *Figure 4-3, page 4-2).* An outcropping of rock or a heavy boulder buried partially in the ground will serve as a satisfactory anchor.

Figure 4-1. Natural anchorage (tree)

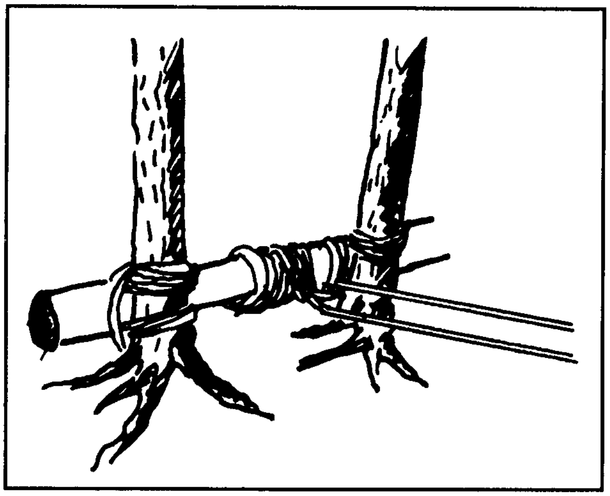

Figure 4-2. Natural anchorage (trees and transom)

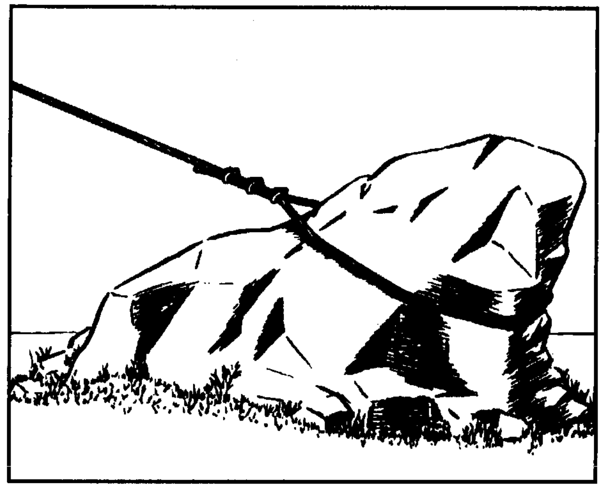

Figure 4-3. Natural anchorage (rock)

MAN-MADE ANCHORS

You must construct man-made anchors when natural anchors are not available. These include—

- Rock anchors.
- Picket holdfasts.
- Combination holdfasts.
- Deadmen.

ROCK ANCHORS

Rock anchors have an eye on one end and a threaded nut, an expanding wedge, and a stop nut on the other end (see *Figure 4-4*). To construct a rock anchor, insert the threaded end of the rock anchor in the hole with the nut's relation to the wedge as shown in *Figure 4-4.* After placing the anchor, insert a crowbar through the eye of the rock anchor and twist it. This causes the threads to draw the nut up against the wedge and force the wedge out against the sides of the hole in the rock. The wedging action is strongest under a direct pull; therefore, always set rock anchors so that the pull is in a direct line with the shaft of the anchor. Drill the holes for rock anchors 5 inches deep. Use a l-inch-diameter drill for hard rock and a 3/4-inch-diameter drill for soft rock. Drill the hole as neatly as possible so that the rock anchor can develop the maximum strength. In case of extremely soft rock, it is better to use some other type of anchor because the wedging action may not provide sufficient holding power.

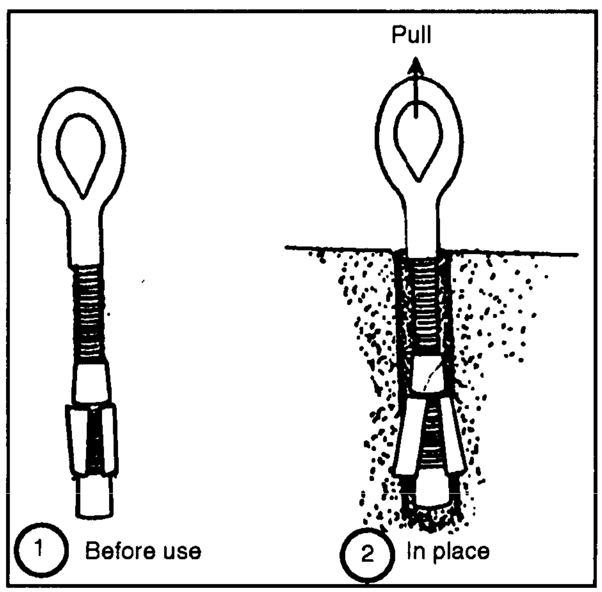

Figure 4-4. Rock anchor

PICKET HOLDFASTS

A single picket, either steel or wood, can be driven into the ground as an anchor. The holding power depends on the—

- Diameter and kind of material used.
- Type of soil.
- Depth and angle in which the picket is driven.
- Angle of the guy line in relation to the ground.

Table 4-1 lists the holding capacities of the various types of wooden picket holdfasts. *Figure 4-5* shows the various picket holdfasts.

Table 4-1. Holding power of picket holdfast in loamy soil

Holdfast	Pounds
Single picket	700
1-1 picket holdfast	1,400
1-1-1 picket holdfast	1,800
2-1 picket holdfast	2,000
3-2-1 picket holdfast	4,000
Note: Wet earth factors: **Clay and gravel mixtures - 0.9** **Riven clay and sand - 0.5**	

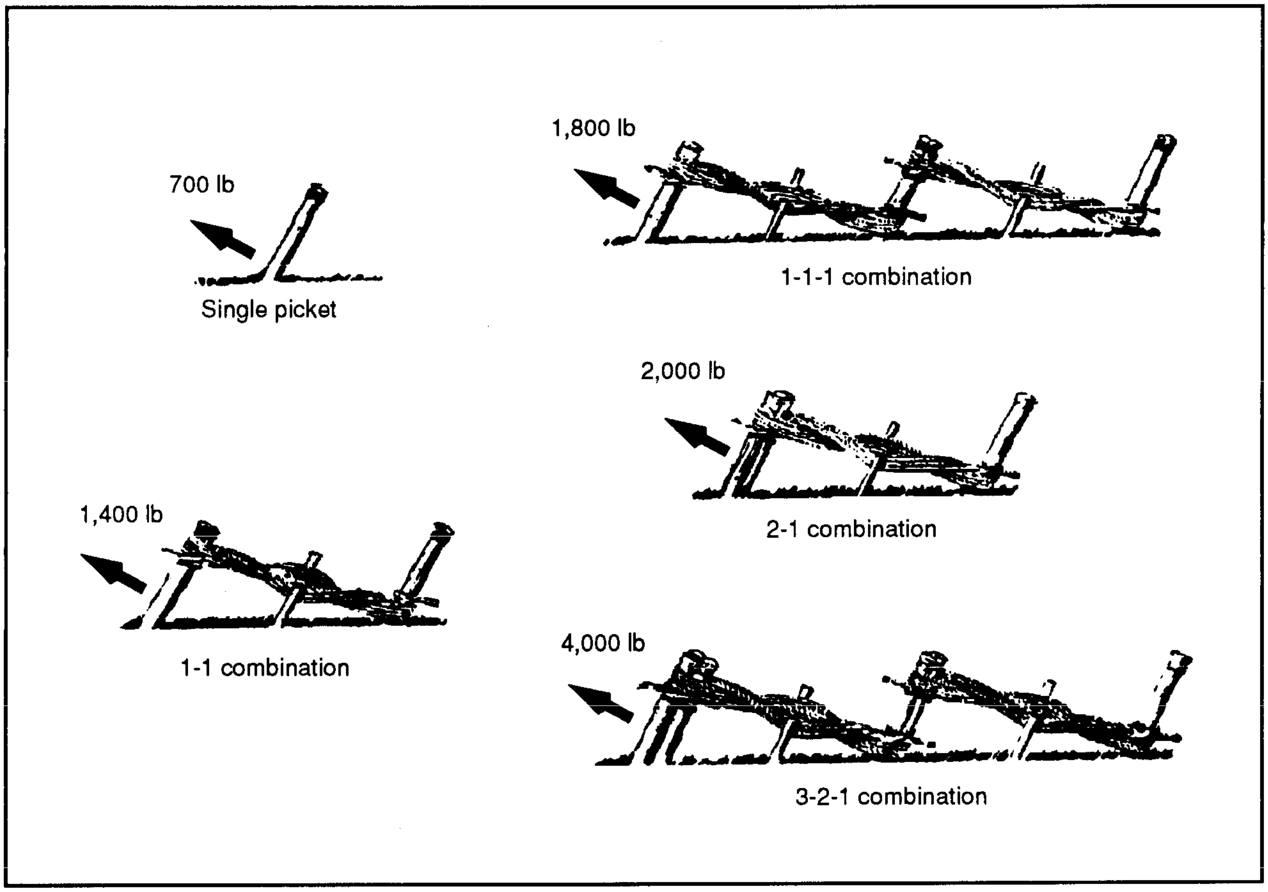

Figure 4-5. Picket holdfasts (loamy soil)

Single Wooden Pickets

Wooden stakes used for pickets should be at least 3 inches in diameter and 5 feet long. Drive the picket 3 feet into the ground at an angle of 15 degrees from the vertical and inclined away from the direction of pull (see *Figure 4-6).*

Multiple Wooden Pickets

You can increase the strength of a holdfast by increasing the area of the picket bearing against the ground. Two or more pickets driven into the ground, spaced 3 to 6 feet apart and lashed together to distribute the load, are much stronger than a single picket (see *Figure 4-6, A).* To construct the lashing, tie a clove hitch to the top of the first picket with four to six turns around the first and second pickets, leading from the top of the first picket to the bottom of the second picket (see *Figure 4-6, B).* Then fasten the rope to the second picket with a clove hitch just above the turns. Put a stake between the rope turns to tighten the rope by twisting the stake and then driving it into the ground (see *Figure 4-6, C).* This distributes the load between the pickets. If you use more than two pickets, make a similar lashing between the second and third pickets (see *Figure 4-6, D).* If you use wire rope for lashing, make only two complete turns around each pair of pickets. If neither fiber rope nor wire rope is available for lashing, place boards from the top of the front picket to the bottom of the second picket and nail them onto each picket (see *Figure 4-7).* As you place pickets farther away from the front picket, the load to the rear pickets is distributed more unevenly. Thus, the prin-

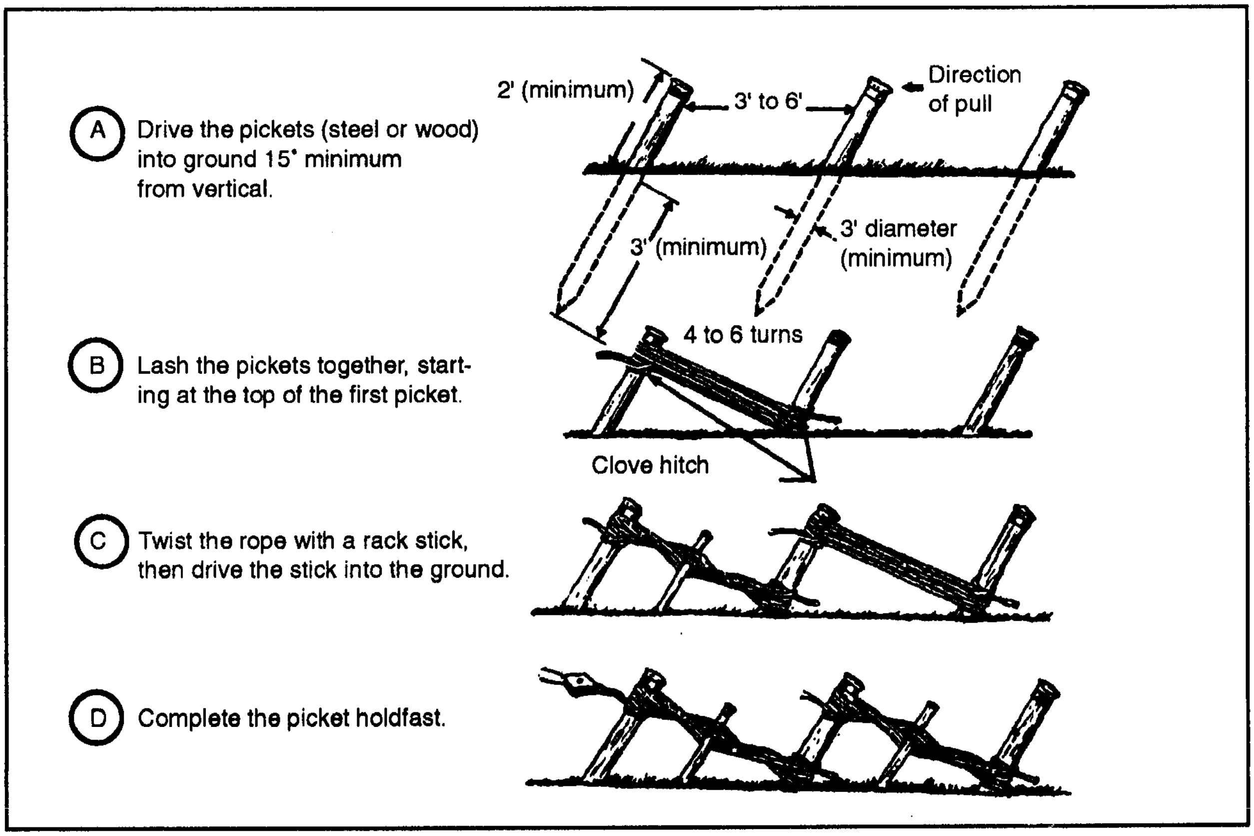

Figure 4-6. Preparing a picket holdfast

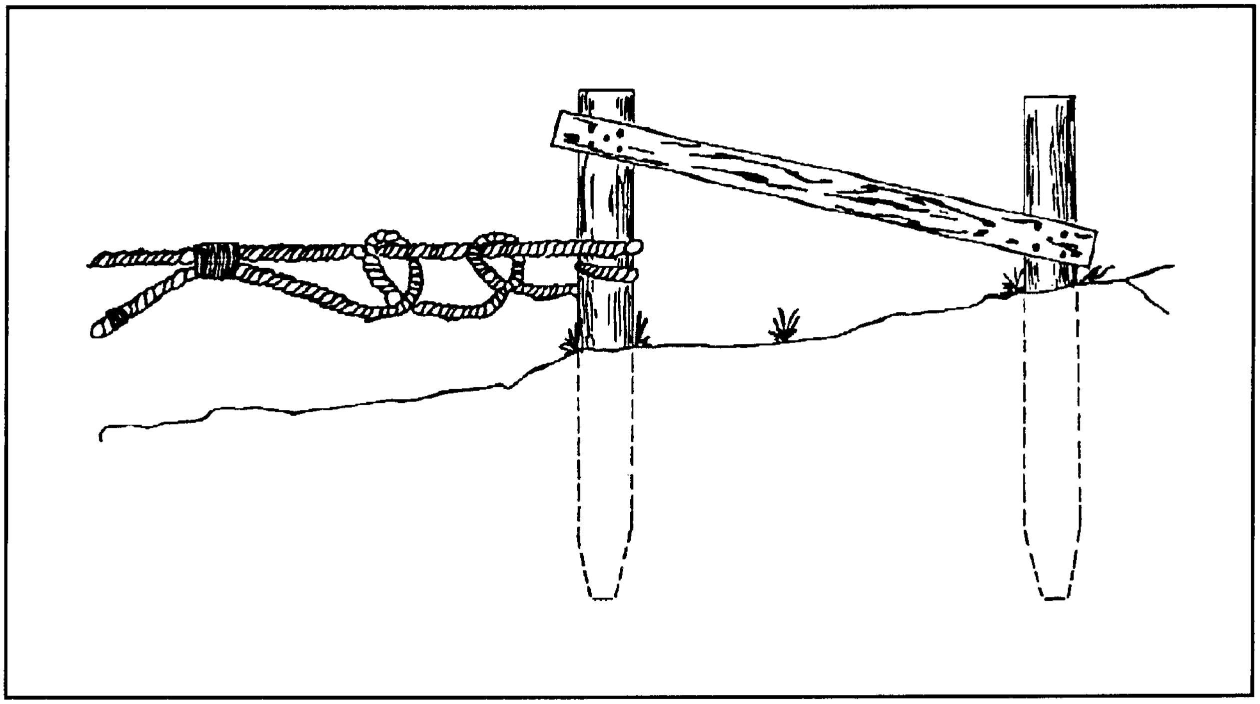

Figure 4-7. Boarded picket holdfast

cipal strength of a multiple-picket holdfast is at the front pickets. Increase the capacity of a holdfast by using two or more pickets to form the front group. This increases both the bearing surface against the soil and the BS.

Steel-Picket Holdfasts

A standard steel-picket holdfast consists of a steel box plate with nine holes drilled through it and a steel eye welded on the end for attaching a guy line (see *Figure 4-8, page 4-6).* The pickets are also steel and are driven through the holes in a way that clinches the pickets in the ground. This holdfast is especially adapted for anchoring horizontal lines, such as the anchor cable on a ponton bridge. Use two or more of these units in combination to provide a stronger anchorage. You can improvise a similar holdfast with a chain by driving steel pickets through the chain links in a crisscross pattern. Drive the rear pickets in first to secure the end of the chain; then, install the successive pickets so that there is no slack in the chain between the pickets. A lashed steel-picket holdfast consists of steel pickets lashed together with wire rope the same as for a wooden-stake picket holdfast (see *Figure 4-9, page 4-6).* As an expedient, any miscellaneous light-steel members can be driven into the ground and lashed together with wire rope to form an anchorage.

Rock Holdfasts

You can place a holdfast in rock by drilling into the rock and driving the pickets into the holes. Lash the pickets together with a chain (see *Figure 4-10, page 4-7).* Drill the holes about 3 feet apart, in line with the guy line. The first, or front, hole should be 2 1/2 to 3 feet deep and the rear hole, 2 feet deep. Drill the holes at a slight angle, inclined away from the direction of the pull.

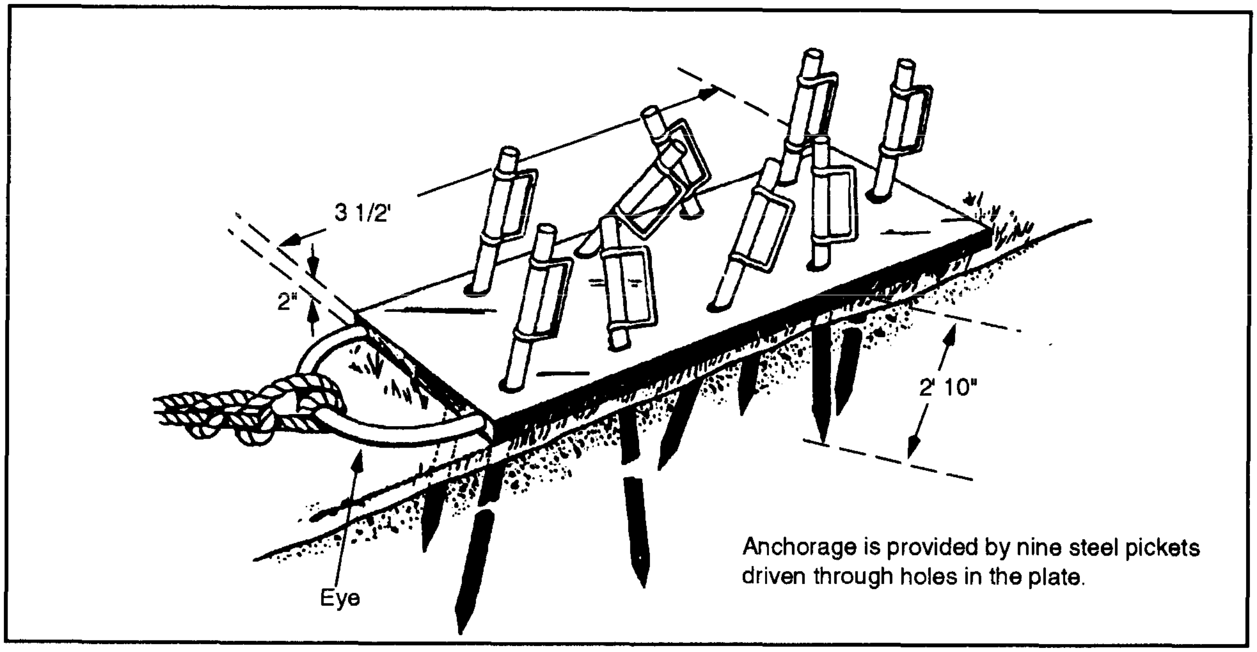

Figure 4-8. Standard steel-picket holdfast

COMBINATION HOLDFASTS

For heavy loading of an anchorage, spread the load over the largest possible area of ground. Do this by increasing the number of pickets used. Place four or five multiple picket holdfasts parallel to each other with a heavy log resting against the front pickets to form a combination log and picket holdfast (see *Figure 4-11).* Fasten the guy line or anchor sling to the log that bears against the pickets. The log should bear evenly against all pickets to obtain maximum strength. Select the timber carefully so it can withstand the maximum pull on the line without appreciable bending. Also, you could use a steel cross member to form a combination steel-picket holdfast (see Figure 4-12, page 4-8).

DEADMEN

A deadman is one of the best types of anchorages for heavy loads or permanent installations because of its great holding power.

Construction

You can construct a deadman from a log, a rectangular timber, a steel beam, or a similar object buried in the ground with a guy line or sling attached to its center. This guy line or sling leads to the surface of the ground along a narrow upward sloping trench. The holding power of a deadman is affected by—

- Its frontal bearing area.
- Its mean (average) depth.

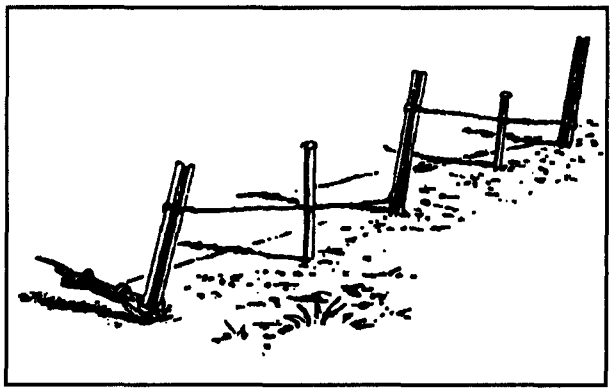

Figure 4-9. Lashed steel-picket holdfast

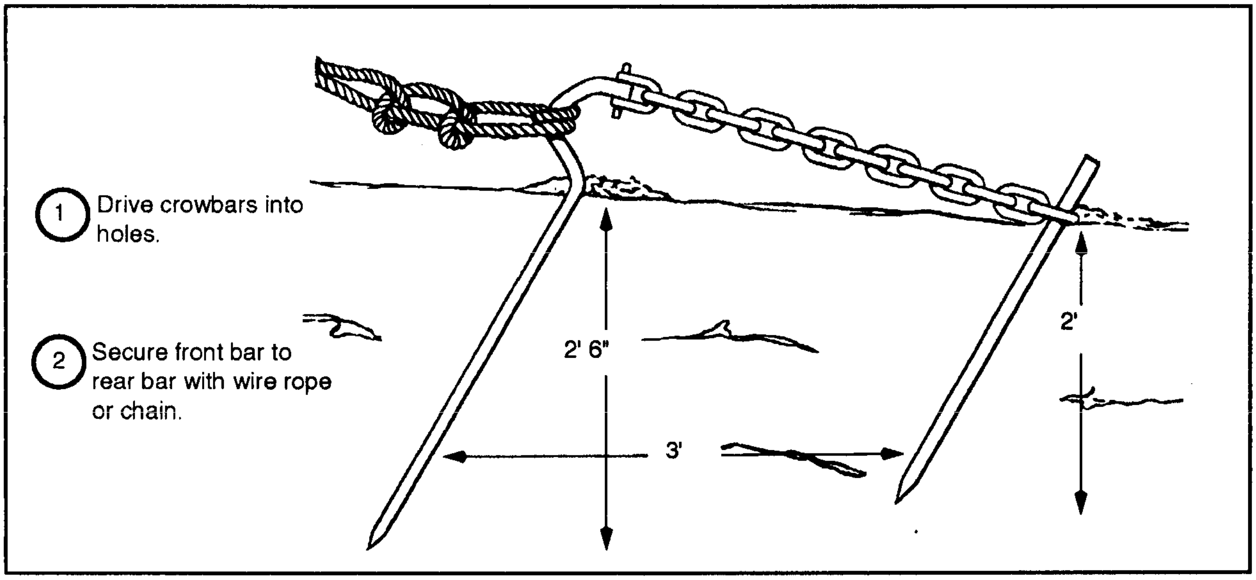

Figure 4-10. Rock holdfast

- The angle of pull.
- The deadman material.
- The soil condition.

The holding power increases progressively as you place the deadman deeper and as the angle of pull approaches a horizontal position (see *Table 4-2, page 4-8)*. The holding power of a deadman must be designed to withstand the BS of the line attached to it. In constructing a deadman, dig a hole at right angles to the guy line and undercut 15 degrees from the vertical at the front of the hole facing the load (see *Figure 4-13, page 4-8)*. Make the guy line as horizontal as possible, and ensure that the sloping trench matches the slope of the guy line. The main or standing part of the line leads from the bottom of the deadman. This reduces the

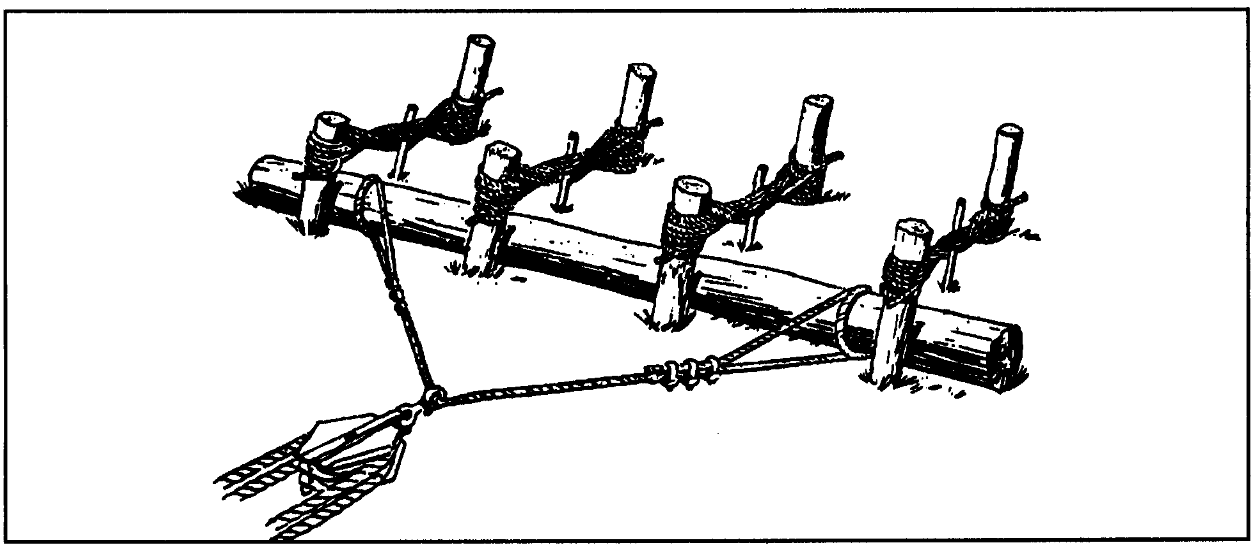

Figure 4-11. Combination log and picket holdfast

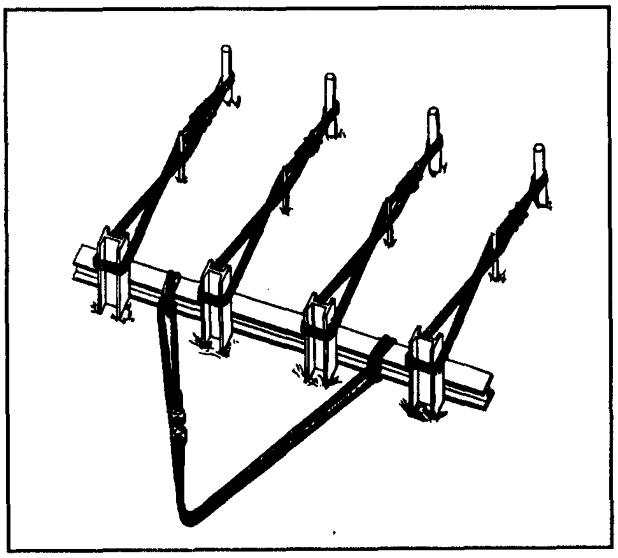

Figure 4-12. Combination steel picket holdfast

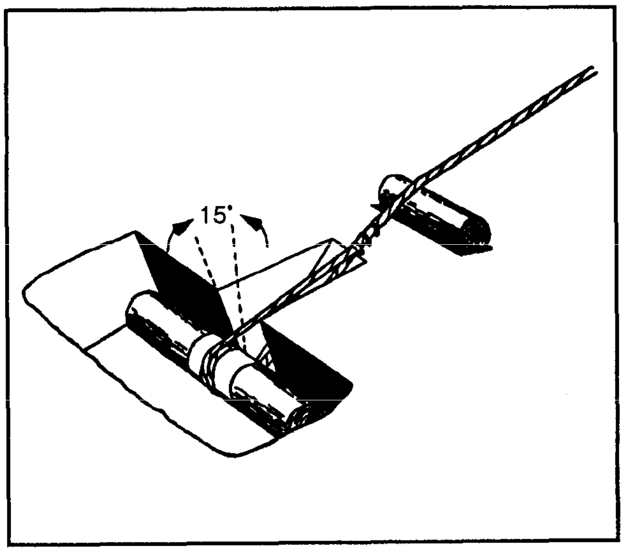

Figure 4-13. Log deadman

tendency to rotate the deadman upward out of the hole. If the line cuts into the ground, place a log or board under the line at the outlet of the sloping trench. When using wire-rope guy lines with a wooden deadman, place a steel bearing plate on the deadman where the wire rope is attached to avoid cutting into the wood. Always place the wire-rope clips above the ground for retightening and maintenance.

Terms

Table 4-3 lists the terms used in designing a deadman.

Table 4-2. Holding power of deadmen in ordinary soil

Mean Depth of Anchorage (feet)	Inclination of Pull (Vertical to Horizontal) and Safe Resistance of the Projected Area of the Deadman (pounds per square foot [psf])				
	Vertical	1:1 (45°)	1:2 (26.5°)	1:3 (18:5°)	1:4 (14°)
3	600	950	1,300	1,450	1,500
4	1,050	1,750	2,200	2,600	2,700
5	1,700	2,800	3,600	4,000	4,100
6	2,400	3,800	5,100	5,800	6,000
7	3,200	5,100	7,000	8,000	8,400

Table 4-3. Deadman design terminology

Term	Acronym	Definition
Mean depth	MD	The distance from the ground level to the center of the deadman
Horizontal distance	HD	The distance measured horizontally from the front of the hole to the point where the sloping trench comes out of the ground
Vertical depth	VD	The distance from the ground level to the bottom of the hole
Width of sloping trench	WST	
Diameter of timber	D	
Effective length	EL	The length of log that must be bearing against solid or undisturbed soil
Timber length	TL	The total length required
Holding power	HP	The holding power of a deadman in ordinary earth (see *Table 4-2*)
Breaking strength	BS	The breaking strength of rope attached to the deadman
Slope ratio	SR	The slope ratio of the guy line and the sloping trench
Bearing area	BA	The bearing area of the deadman required to hold the BS of the attached rope

Formulas

The following formulas are used in designing a deadman:

- $BA_r = \frac{BS}{HP}$
- $EL = \frac{BA_r}{D}$
- $TL = EL + WST$
- $VD = MD + \frac{D}{2}$
- $HD = \frac{VD}{SR}$

A sample problem for designing a deadman is as follows:

Given: l-inch-diameter 6-by-19 IPS rope

$MD = 7$ *feet*

$SR = 1.3$

$WST = 2$ *feet*

- Requirement I: Determine the length and thickness of a rectangular timber deadman if the height of the face available is 18 inches (1 1/2 feet).

  BS of wire rope = 83,600 psf (see Table 1-2)

  HP= 8,000 psf (see Table 4-2)

Note: Design the deadman so it can withstand a tension equal to the BS of the wire rope

$$BA_r = \frac{BS = 83{,}600 \text{ pounds}}{HP\ 8{,}000 \text{ psf}} = 10.5 \text{ feet}^2$$

$$EL = \frac{BA_r}{\text{face height}} = \frac{10.5 \text{ feet}^2}{1.5 \text{ feet}} = 7 \text{ feet}$$

$$TL = EL + WST = 7 \text{ feet} + 2 \text{ feet} = 7 \text{ feet}$$

Conduct a final check to ensure that the rectangular timber will not fail by bending by doing a length-to-thickness ratio (L/t), which should be equal to or less than 9. Determine the minimum thickness by $L/_t$= 9 and solve for (t):

$$\frac{L}{1t} = 9$$

$$\frac{9}{t} = 9$$

$$= \frac{9}{9} = l \text{ feet}$$

Thus, an 18-inch by 12-inch by 9-foot timber is suitable.

- Requirement II: Determine the length of a log deadman with a diameter of 2 1/2 feet.

$$EL = \frac{BA_r}{D} = \frac{10.5 \text{feet}^2}{2.5 \text{ feet}} = 4.2 \text{ feet}$$

$$TL = EL + WST = 4.2 \text{ feet} + 2 \text{ feet} = 6.2 \text{ feet}$$

Conduct a final check to ensure that the log will not fail by bending by doing a length-to-diameter ratio (L/d), which should be equal to or less than 5. The ratio for Requirement II would be equal to L/d = 6.2/2.5 = 2.5. Since this is less than 5, the log will not fail by bending.

Length-to-Diameter Ratio

If the length-to-diameter ratios for a log or a rectangular timber are exceeded, you must decrease the length requirements. Use one of the following methods to accomplish this:

- Increase the mean depth.
- Increase the slope ration (the guy line becomes more horizontal).
- Increase the thickness of the deadman.
- Decrease the width of the sloping trench, if possible.

NOMOGRAPH-DESIGNED DEADMEN

Nomography and charts have been prepared to facilitate the design of deadmen in the field. The deadmen are designed to resist the BS of the cable. The required length and thickness are based on allowable soil bearing with 1-foot lengths added to compensate for the width of the cable trench. The required thickness is based on a L/d ratio of s for logs and a L/d ratio of 9 for cut timber.

Log Deadman

A sample problem for designing a log deadman is as follows:

- Given: 3/4-inch IPS cable. You must bury the required deadman 5 feet at a slope of 1:4.
- Solution: With this information, use the nomograph to determine the diameter and length of the deadman required (see *Figure 4-14*). *Figure 4-15, page 4-12,* shows the steps, graphically, on an incomplete nomograph. Lay a straightedge across section A-A

(left-hand scale) on the 5-foot depth at deadman and 1:4 slope and on 3/4-inch IPS on B-B. Read across the straightedge and locate a point on section C-C. Then go horizontally across the graph and intersect the diameter of the log deadmen available. Assume that a 30-inch diameter log is available. Go vertically up from the intersection on the log and read the length of deadman required. In this case, the deadman must be over 5 1/2 feet long. Be careful not to select a log deadman in the darkened area of the nomograph because a log from this area will fail by bending.

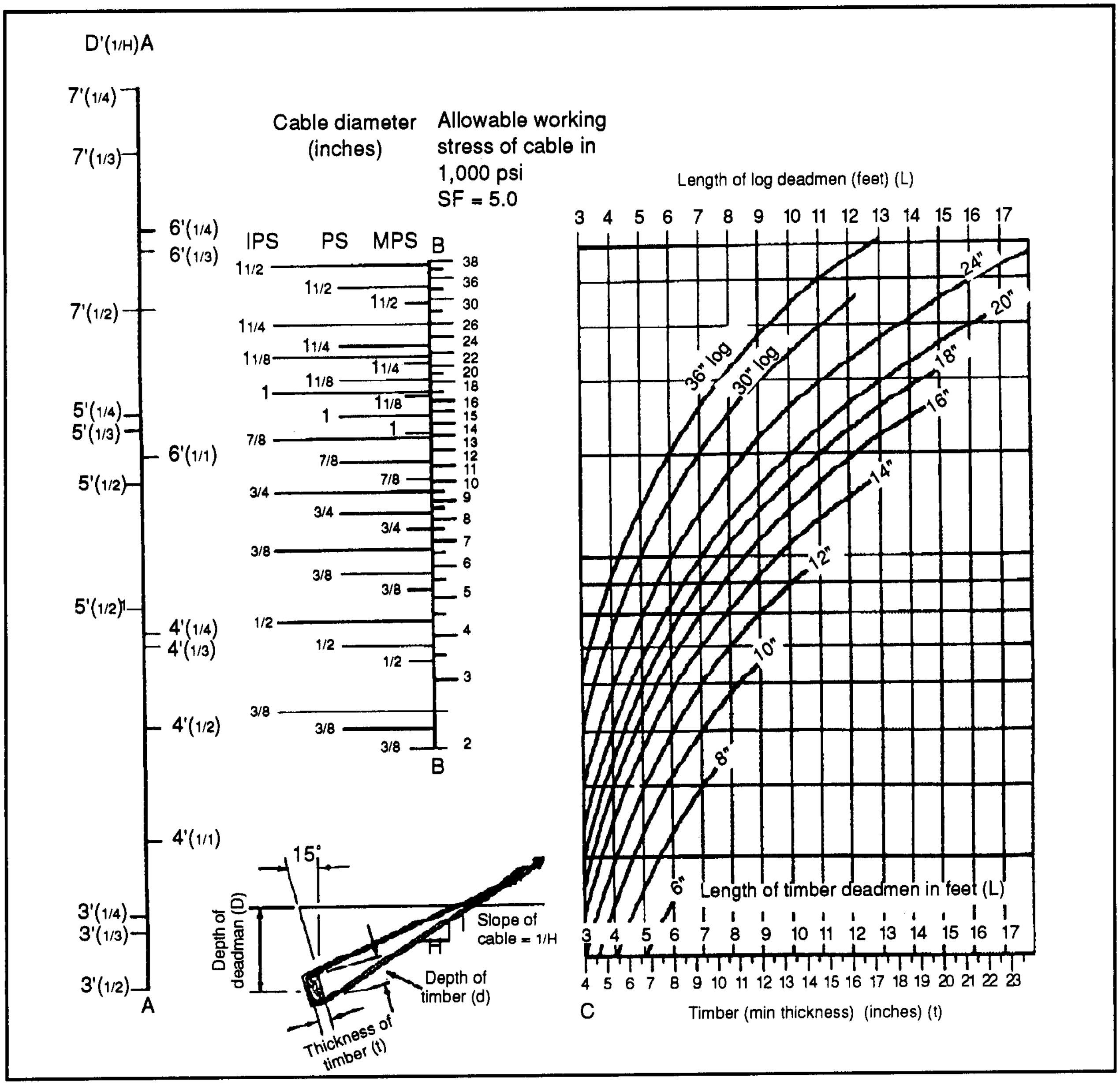

Figure 4-14. Designing a deadman

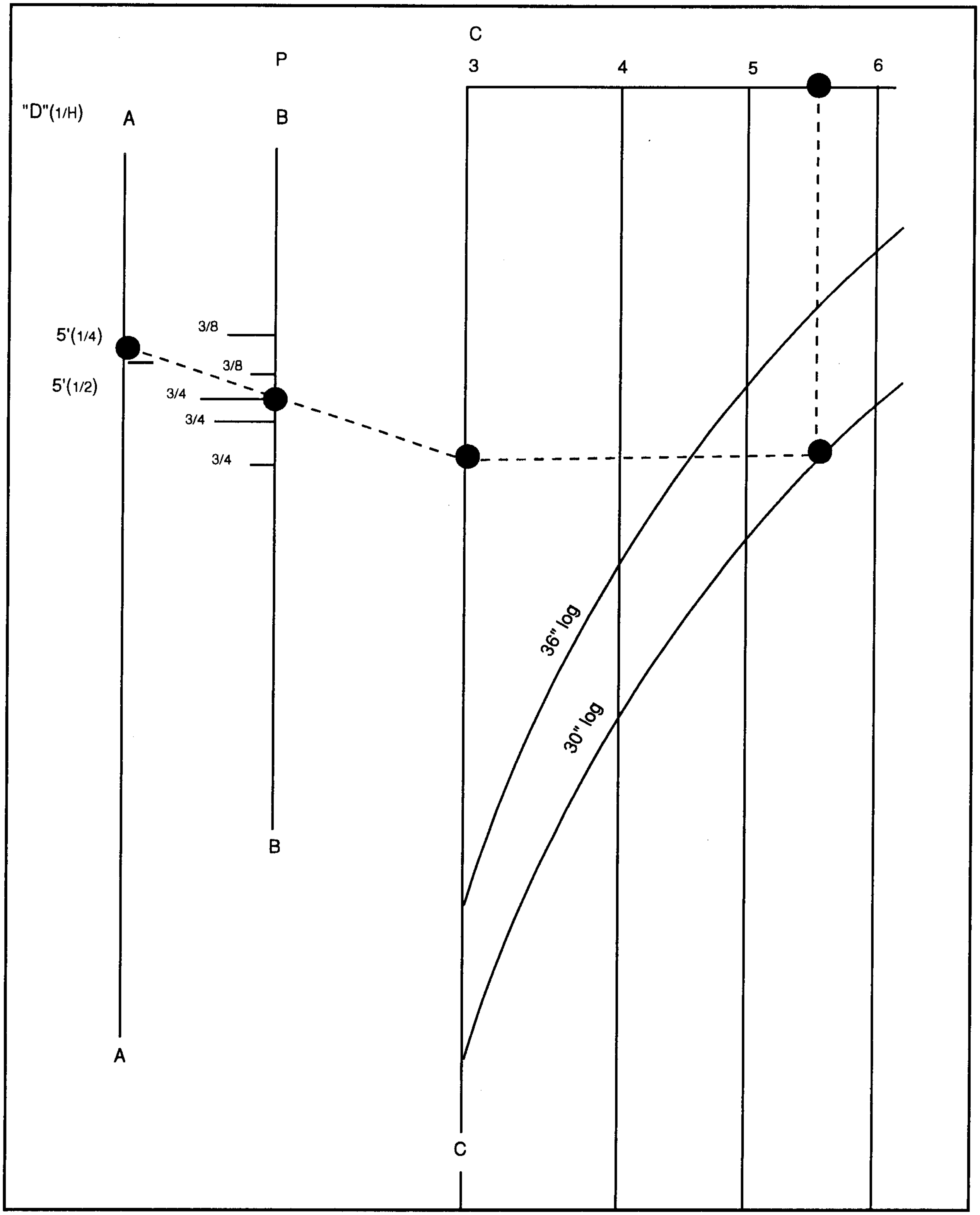

Figure 4-15. Using a nomograph

Rectangular Timber Deadman

A sample problem for designing a rectangular timber deadman is as follows:

- Given: 3/4-inch IPS cable. You are to bury the deadman 5 feet at a slope of 1:4.
- Solution: Use the same 1:4 slope and 5-foot depth, along with the procedure to the left of the graph, as in the previous problem (see Figure 4-14, page 4-11). At C-C, go horizontally across the graph to the timber with an 18-inch face. Reading down (working with cut timber), you can see that the length is 8 feet 6 inches and that the minimum thickness is 11 1/2 inches. None of the timber sizes shown on the nomograph will fail due to bending.

Horizontal Distance

Use the following formula to determine the distance behind the tower in which deadmen are placed:

$$\text{Horizontal distance} = \frac{\text{tower height + deadman depth}}{\text{slope ratio}}$$

A sample problem for determining the horizontal distance behind a tower is as follows:

- Given: The tower height is 25 feet 4 1/4 inches, and the deadman depth is 7 feet with a 1:4 slope.
- Solution:

$$\frac{25\text{ ft } 4\ 1/4\text{ in} + 7\text{ ft}}{1:4} = \frac{32\text{ft } 4\ 1/4\text{ in}}{1:4} = 129\text{ ft } 5\text{ in}$$

Place the deadman 129 feet behind the tower.

Note: The horizontal distance without a tower is as follows:

$$\frac{\text{deadman depth}}{\text{slope ratio}} = \frac{7\text{ft}}{1:4} = 28\text{ft}$$

BEARING PLATES

To prevent the cable from cutting into the wood, place a metal bearing plate on the deadman. The two types of bearing plates are the flat bearing plate and the formed bearing plate, each with its particular advantages. The flat bearing plate is easily fabricated, while the formed or shaped plate can be made of much thinner steel.

Flat Bearing Plate

A sample problem in the design of flat bearing plates is as follows:

- Given: 12-inch by 12-inch timber
  3/4-inch IPS cable
- Solution: Enter the graph (see *Figure 4-16, page 4-14)* from the left of the 3/4-inch cable and go horizontally across the graph to intersect the line marked 12-inch timber, which shows that the plate will be 10 inches wide. (The bearing plate is made 2 inches narrower than the timber to prevent cutting into the anchor cable.) Drop vertically and determine the length of the plate, which is 9 1/2 inches. Go to the top, vertically along the line to where it intersects with 3/4-inch cable, and determine the minimum required thickness, which is 1 1/16 inches. Thus, the necessary bearing plate must be 1 1/16 inches by 9 1/2 inches by 10 inches.

Formed Bearing Plate

The formed bearing plates are either curved to fit logs or formed to fit rectangular timber. In the case of a log, the bearing plate must go half way (180 degrees) around the log. For a shaped timber, the bearing plate

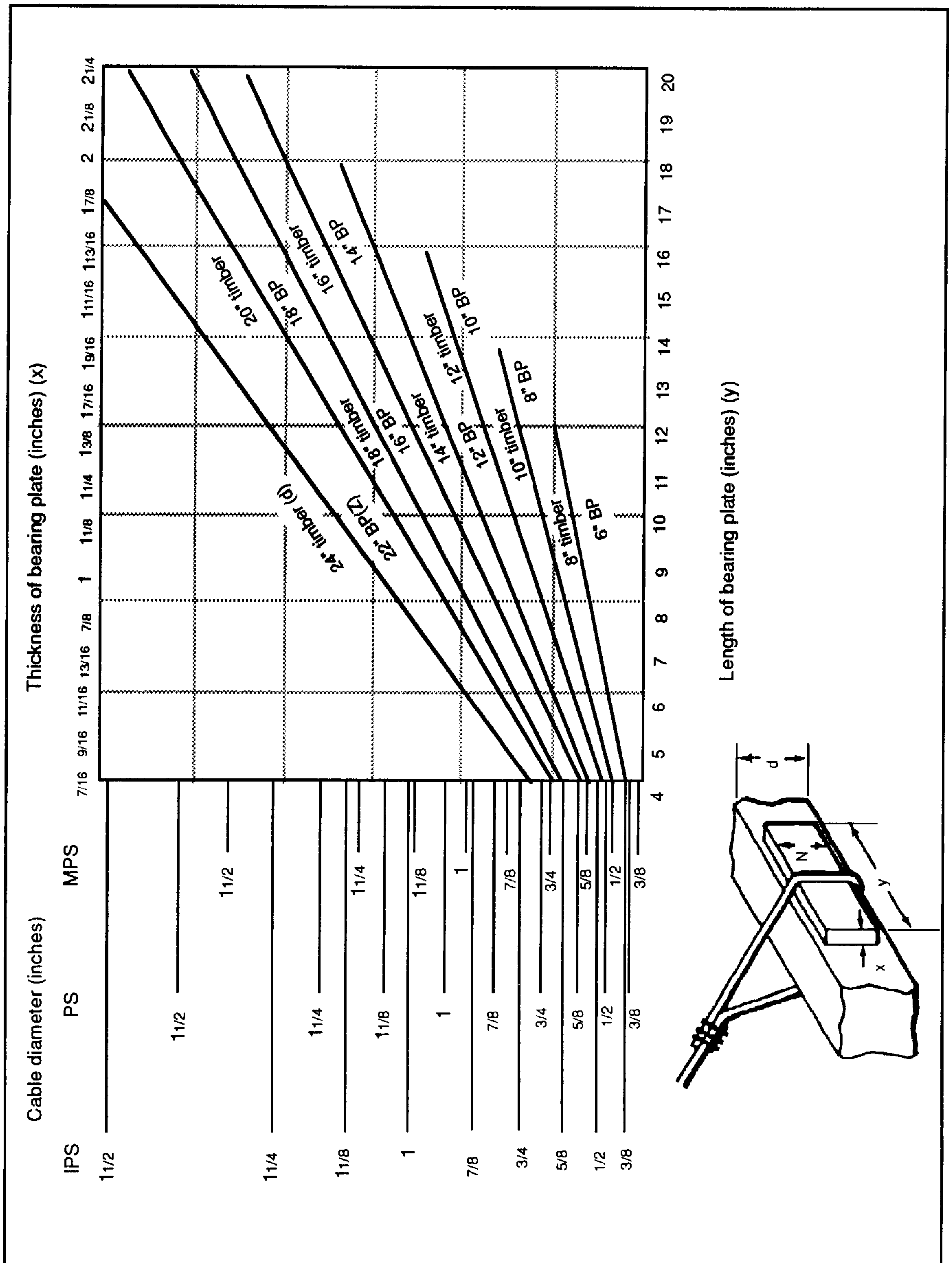

Figure 4-16. Designing a flat bearing plate for a regular deadman

extends the depth of the timber with an extended portion at the top and the bottom (see *Figure 4-17).* Each extended portion should be half the depth of the timber.

A sample problem for designing a formed bearing plate is as follows:

- Given: 14-inch log or timber with 14-inch face and 1 1/8 MPS cable.
- Solution: Design a formed bearing plate. Enter the graph on the left at 1 1/8 MPS and go horizontally across to intersect the 14-inch line (see *figure 4-17).* Note that the lines intersect in an area requiring a l/4-inch plate. Drop vertically to the bottom of the graph to determine the length of the plate, which in this instance is 12 inches. If you use a log, the width of the bearing plate is equal to half the circumference of the log.

$$\frac{d}{2} \quad \textit{in this case, 22 inches}$$

$$\frac{d}{2} = \frac{3.14 \times 14}{2} = 21.98 \text{ (use 22 inches)}$$

The bearing plate would therefore be 1/4 inch by 12 inches by 22 inches. For a rectangular timber, the width of the plate would be 14 inches for the face and 7 inches for the width of each leg, or a total width of 28 inches (see *Figure 4-17).* The bearing plate would therefore be 1/4 inch by 12 inches by 28 inches.

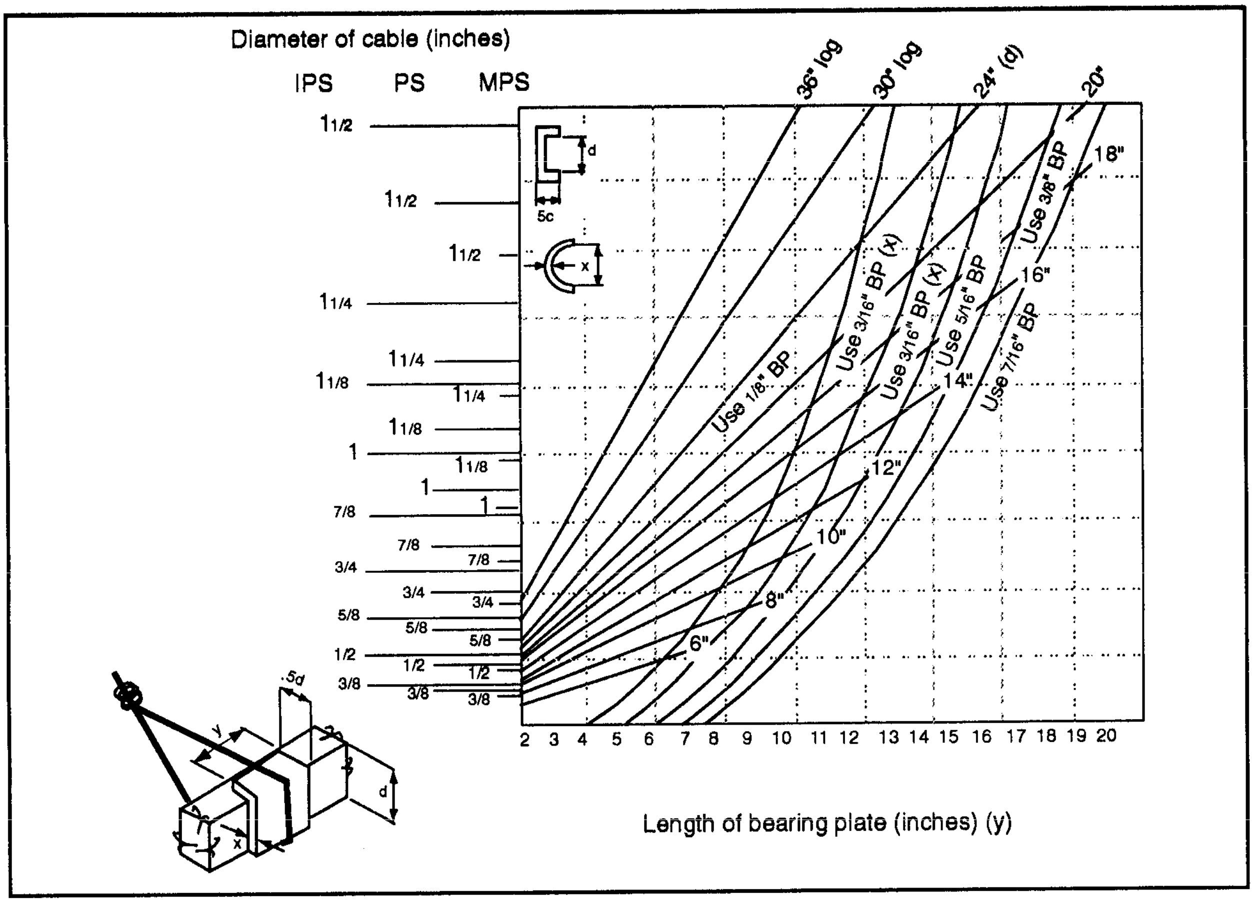

Figure 4-17. Designing a formed bearing plate

Section II. Guy Lines

Guy lines are ropes or chains attached to an object to steady, guide, or secure it. The lines leading from the object or structure are attached to an anchor system (see *Figure 4-18)*. When a load is applied to the structure supported by the guy lines, a portion of the load is passed through each supporting guy line to its anchor. The amount of tension on a guy line depends on the—

- Main load.
- Position and weight of the structure.
- Alignment of the guy line with the structure and the main load.
- Angle of the guy line.

For example, if the supported structure is vertical, the stress on each guy line is very small; but if the angle of the structure is 45 degrees, the stress on the guy lines supporting the structure will increase considerably. Wire rope is preferred for guy lines because of its strength and resistance to corrosion. Fiber is also used for guy lines, particularly on temporary structures. The number and size of guy lines required depends on the type of structure to be supported and the tension or pull exerted on the guy lines while the structure is being used.

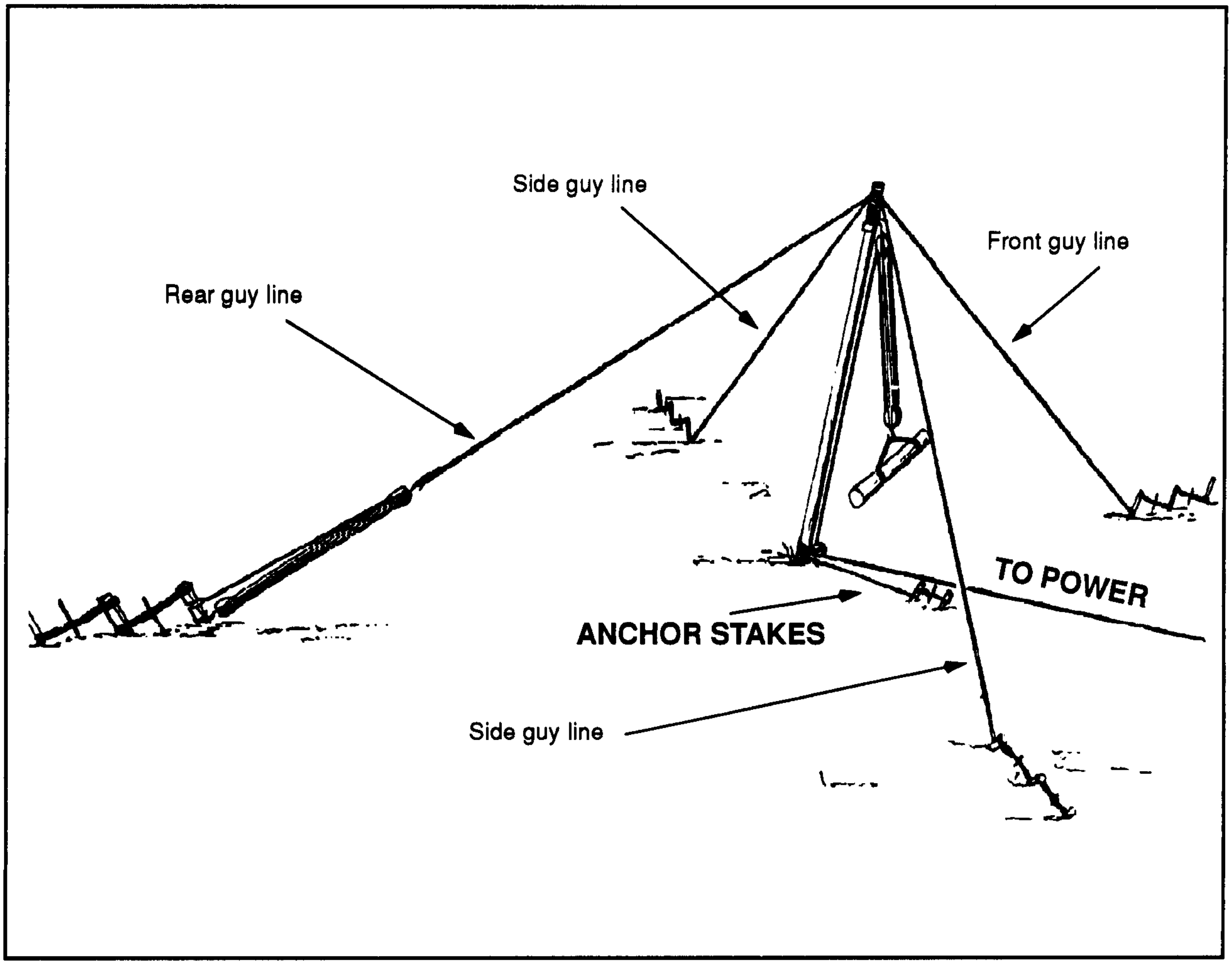

Figure 4-18. Typical guy-line installations

NUMBER OF GUY LINES

Usually a minimum of four guy lines are used for gin poles and boom derricks and two for shears. The guy lines should be evenly spaced around the structure. In a long, slender structure, it is sometimes necessary to provide support at several points in a tiered effect. In such cases, there might be four guy lines from the center of a long pole to anchorage on the ground and four additional guy lines from the top of the pole to anchorage on the ground.

TENSION ON GUY LINES

You must determine the tension that will be exerted on the guy lines beforehand to select the proper size and material you will use. The maximum load or tension on a guy line will result when a guy line is in direct line with the load and the structure. Consider this tension in all strength calculations of guy lines. You can use the following formula to determine the tension for gin poles and shears (see *Figure 4-19, page 4-18):*

$$T = \frac{(W_L + 1/2W_3)\ D}{Y}$$

T = Tension in guy line

W_L = *Weight of the load*

W_3 = *Weight of spar(s)*

D = *Drift distance, measured from the base of the gin pole or shears to the center of the suspended load along the ground.*

Y= *Perpendicular distance from the rear guy line to the base of the gin pole or, for a shears, to a point on the ground midway between the shear legs.*

A sample problem for determining the tension for gin poles and shears follows:

- Requirement I: gin pole.

  Given: $W_L = 2{,}400$ lb
  $W_3 = 800$ lb
  D = 20

  Solution:

  $$T = \frac{(W_L + 1/2W_3)D}{Y} = \frac{(2{,}400 + 1/2\ (800))\ 20}{28}$$

  = 2,000 pounds of tension in the rear or supporting guy line

- Requirement II: shears.

  Given: The same conditions exist as in Requirement I except that there are two spars, each one weighing 800 pounds.

  Solution:

  $$T = \frac{(W_L + 1/2W_3)D)}{Y} = \frac{(2,\ 400 + 1/2\ (800))\ 20}{Y}$$

  = *2,285 pounds*

NOTE: The shears produced a greater tension in the rear guy line due to the weight of an additional spar.

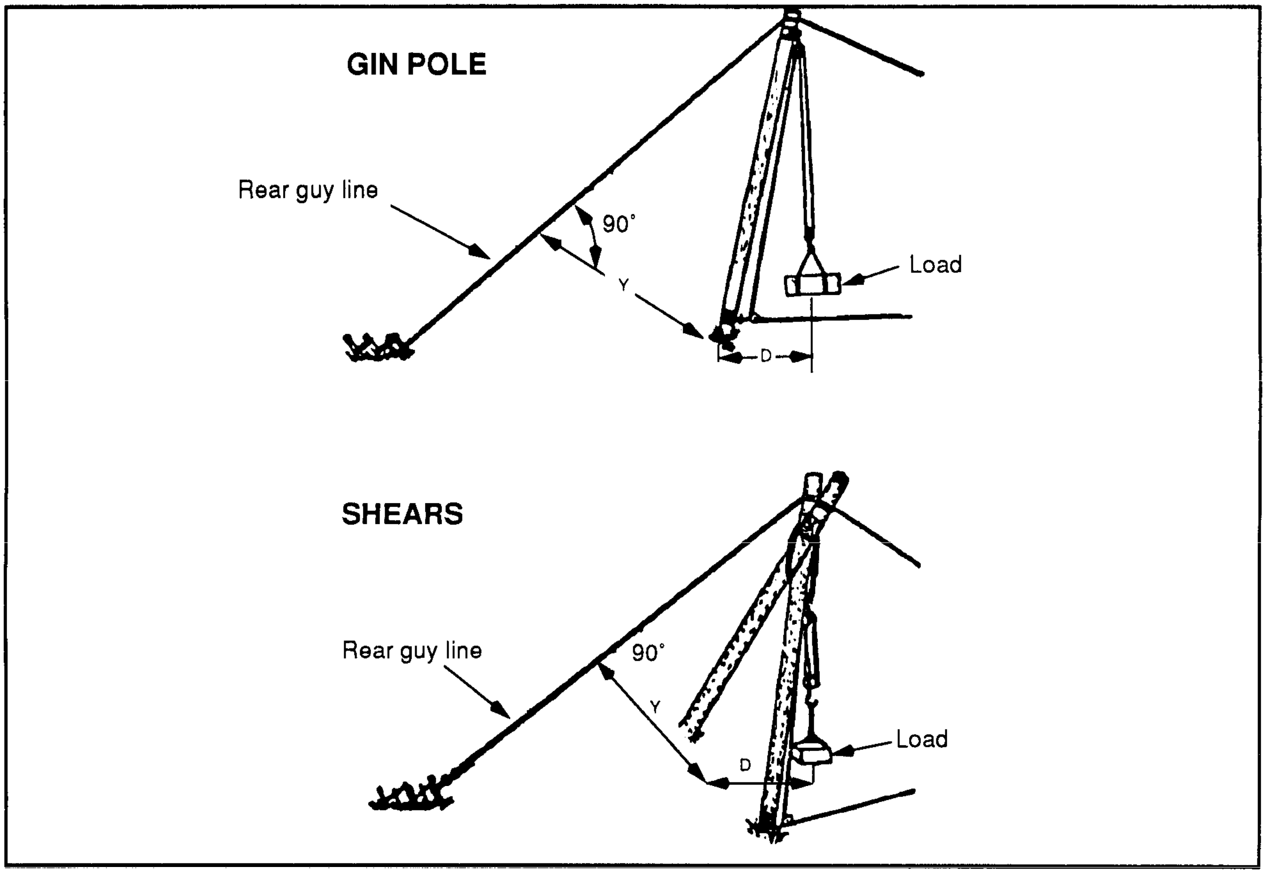

Figure 4-19. Gin pole and shears

SIZE OF GUY LINES

The size of the guy line to use will depend on the amount of tension placed on it. Since the tension on a guy line may be affected by shock loading (and its strength affected by knots, sharp bends, age, and condition), you must incorporate the appropriate FSs. Therefore, choose a rope for the guy line that has a SWC equal to or greater than the tension placed on the guy line.

ANCHORAGE REQUIREMENTS

An ideal anchorage system should be designed to withstand a tension equal to the BS of the guy line attached to it. If you use a 3/8-inch-diameter manila rope as a guy line, the anchorage must be capable of withstanding a tension of 1,350 pounds, which is the BS of the 3/8-inch diameter manila rope. If you use picket holdfasts, you will need at least a 1-1 combination (1,400-pound capacit y in ordinary soil). Anchor the guy line as far as possible from the base of the installation to obtain a greater holding power from the anchorage system. The recommended minimum distance from the base of the installation to the anchorage for the guy line is twice the height of the installation.