Chapter 9
Rigging and Vehicle Recovery

ROPES

Tables 9-1 and 9-2 give characteristics, safety factors, and breaking strength for different diameters of wire, manila, and sisal ropes.

Table 9-1. Wire rope characteristics and safety factors

BREAKING STRENGTH OF 6 x 19 STANDARD WIRE ROPE [2]							
			BREAKING STRENGTH, TONS OF 2,000 LB				
DIAMETER [3] IN	APPROXIMATE WEIGHT LB/FT	IRON	TRACTION STEEL	PLOUGH STEEL	IMPROVED PLOUGH STEEL	EXTRA IMPROVED PLOUGH STEEL
¼	0.10	1.4	2.6	2.39	2.74	
⅜	0.23	2.1	4.0	5.31	6.10	7.55
½	0.40	3.6	6.8	9.35	10.7	13.3
⅝	0.63	5.5	10.4	14.5	16.7	20.6
¾	0.90	7.9	14.8	20.7	23.8	29.4
⅞	1.23	10.6	20.2	28.0	32.2	39.8
1	1.60	13.7	26.0	36.4	41.8	51.7
1 ⅛	2.03	17.2	32.7	45.7	52.6	65.0
1 ¼	2.50	21.0	40.6	56.2	64.6	79.9
1 ½	3.60	29.7	56.6	80.0	92.0	114.0
1 ¾				108.0	124.0	153.0
2				139.0	160.0	198.0

SAFETY FACTORS [1]	
TYPE OF SERVICE	MINIMUM SAFETY FACTOR
Track cables	3.2
Guy lines	3.5
Miscellaneous hoisting equipment	5.0
Haulage ropes	6.0
Derricks	6.0
Small electric and air hoists	7.0
Slings	8.0

NOTES: 1. If age and condition of rope are doubtful and human life or equipment may be endangered, apply a safety factor of at least eight.

2. The 6 x 19 means rope composed of 6 strands of 19 wires each.

3. Breaking strength of 6 x 7 or 6 x 37 wire ropes is 94 percent of the breaking strengh of a 6 x 19 rope of an equal diameter and identical material.

Example:

Find breaking strength of 1 ¼ inch, 6 x 7. Improved Plough Steel wire rope

Breaking strength of 6 x 19. 1 ¼ inch. Improved Plugh Steel wire rope = 64.6 tons

Breaking strength (6 x 7) = .94 x 64.6 = 60.7 tons

[redacted]

Table 9-2. Properties of sisal and manila ropes

NOMINAL DIAMETER, IN	CIRCUM-FERENCE, IN	LB PER FT	NO. 1 MANILA BREAKING STRENGTH, TONS	NO. 1 MANILA SAFE WORKING CAPACITY, TONS (F.S. = 4)	SISAL BREAKING STRENGTH, TONS	SISAL SAFE LOAD, TONS (F.S. = 4)
¼	¾	0.20	0.30	0.07	0.24	0.06
⅜	1 ⅛	.040	0.67	0.16	0.54	0.13
½	1 ½	.075	1.32	0.33	1.06	0.26
⅝	2	.133	2.20	0.60	1.76	0.44
¾	2 ¼	.167	2.70	0.67	2.16	0.54
⅞	2 ¾	.186	3.85	0.96	3.08	0.77
1	3	.270	4.50	1.12	3.60	0.90
1 ⅛	3 ½	.360	6.00	1.50	4.80	1.20
1 ¼	3 ¾	.418	6.75	1.69	5.40	1.35
1 ½	4 ½	.600	9.25	2.31	7.40	1.85
1 ¾	5 ½	.895	13.25	3.31	10.60	2.65
2	6	1.08	15.50	3.87	12.40	3.10
2 ½	7 ½	1.35	23.25	5.81	18.60	4.65
3	9	2.42	32.00	8.00	25.60	6.40

NOTES: 1. Breaking strength and safe loads given are for new rope used under favorable conditions. As rope ages or deteriorates, progressively reduce safe loads to one-half of values given.

2. Safe working capacity maybe computed, with safety factor of 4. When condition of material is doubtful, divide computation by 2.

$$T = D^2$$

where, T = safe working capacity In tons

D = diameter in inches

3. Cordage rope is issued by circumference sizes.

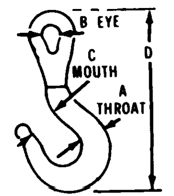
Table 9-3. Safe working load of chains (SF=6)

SIZE	APPROXIMATE WEIGHT PER LINEAR FOOT IN POUNDS	SAFE WORKING LOAD IN POUNDS: COMMON IRON	HIGH GRADE IRON	SOFT STEEL	SPECIAL STEEL
¼	0.8	512	563	619	1.240
⅜	1.7	1.350	1.490	1.650	3.200
½	2.5	2.250	2.480	2.630	5.250
⅝	4.3	3.470	3.810	4.230	7.600
¾	5.8	5.070	5.580	6.000	10.500
⅞	8.0	7.000	7.700	8.250	14.330
1	10.7	9.300	10.230	10.600	18.200
1 ⅛	12.5	9.871	10.858	11.944	21.500
1 ¼	16.0	12.186	13.304	14.634	26.300
1 ⅜	18.3	14.717	16.188	17.807	32.051

NOTE: Size is the diameter in inches of one side of a link.

Table 9-4. Safe load on hooks

DIAMETER OF METAL A, IN	INSIDE DIAMETER OF EYE B, IN	WIDTH OF OPENING C, IN	LENGTH OF HOOK D, IN	SAFE WORKING CAPACITY OF HOOKS, LB
11/16	⅞	1 1/16	4 15/16	1.200
¾	1	1 ⅛	5 13/32	1.400
⅞	1 ⅛	1 ¼	6 ¼	2.400
1	1 ¼	1 ⅜	6 ⅞	3.400
1 ⅛	1 ⅜	1 ½	7 ⅝	4.200
1 ¼	1 ½	1 11/16	8 19/32	5.000
1 ⅜	1 ⅝	1 ⅞	9 ½	6.000
1 ½	1 ¾	2 1/16	10 11/32	8.000
1 ⅝	2	2 ¼	11 27/32	9.400
1 ⅞	2 ⅜	2 ½	13 9/32	11.000
2 ¼	2 ¾	3	14 13/16	13.600
2 ⅝	3 ⅛	3 ⅜	16 ½	17.000
3	3 ½	4	19 ¾	24.000



NOTE: Formula for safe work load for hooks:
$T\ (\text{Tons}) = D^2\ (\text{in}^2)$.

SPRUCE TIMBERS

Approximate weight of timber is 40 pounds per cubic foot. See Table 9-5 for safe capacity

Table 9-5 Safe capacity of spruce timber as gin poles

SIZE OF TIMBER, IN	SAFE CAPACITY FOR GIVEN LENGTH OF TIMBER, LB					
	6M (20 ft)	7.5M (25 ft)	9M (30 ft)	12M (40 ft)	15M (50 ft)	18M (60 ft)
6 dia	5,000	3,000	2,000			
8 dia		11,000	8,000	5,000	3,000	
10 dia	31,000	24,000	16,000	9,000	6,000	
12 dia			31,000	19,000	12,000	9,000
6 x 6	6,000	4,000	3,000			
8 x 8		14,000	10,000	6,000	4,000	
10 x 10	40,000	30,000	20,000	12,000	8,000	
12 x 12			40,000	24,000	16,000	12,000

NOTE: Safe capacity of each leg of shears or tripod is seven-eights of the value given for a gin pole.

KNOTS, LASHINGS, AND FASTENINGS

Knots

The most commonly used knots are shown in Figure 9-1.

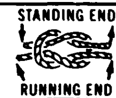
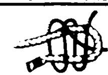
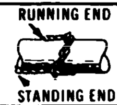
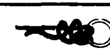
NAME	ILLUSTRATION	USE
SQUARE		Join two ropes of same size. (Will not slip, but will draw tight under strain.) To end block lashing.
DOUBLE SHEET BEND		Join wet ropes, of unequal size, or rope to an eye. (Will not slip or draw tight under strain.)
BOWLINE		Form a loop. (Will not slip under strain and is easily untied.) Must be completed with a half-hitch.
TIMBER HITCH		Lifting or dragging heavy timbers. (Is more easily controlled if supplemented by half-hitches.)
CLOVE HITCH		Fasten rope to pipe, timber, or post. (It is used to start and finish all lashings and may be tied at any point in rope.)
SHEEP SHANK		Shorten rope or take load off wear spot of rope.
FISHERMAN'S BEND		To fasten cable or rope to anchor.

Figure 9-1. Common knots

Lashings

Figures 9-2 through 9-4 show different types of lashings and splicings.

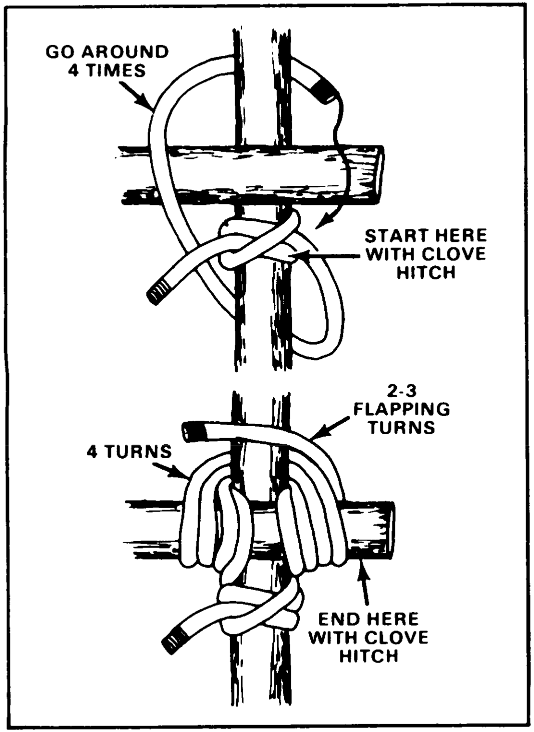


Figure 9-2. Square lashing

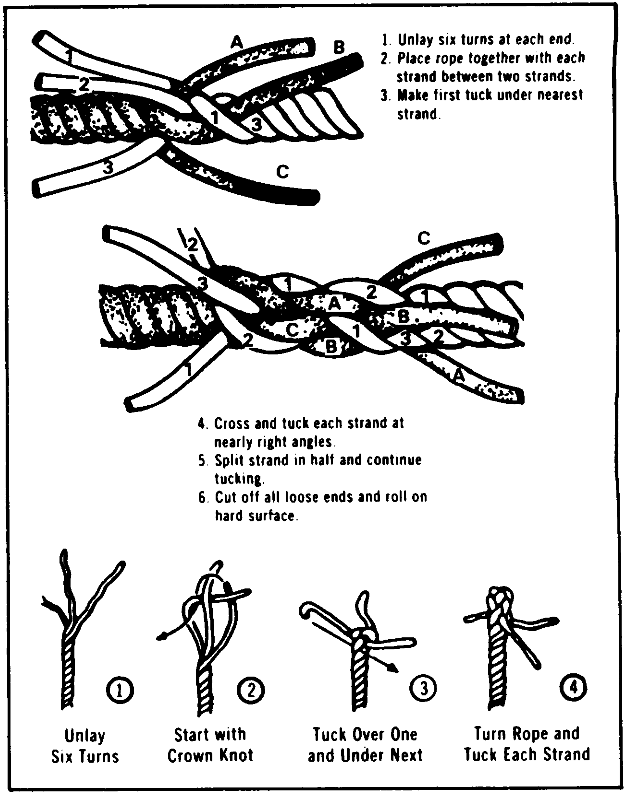


Figure 9-3. Rope splices

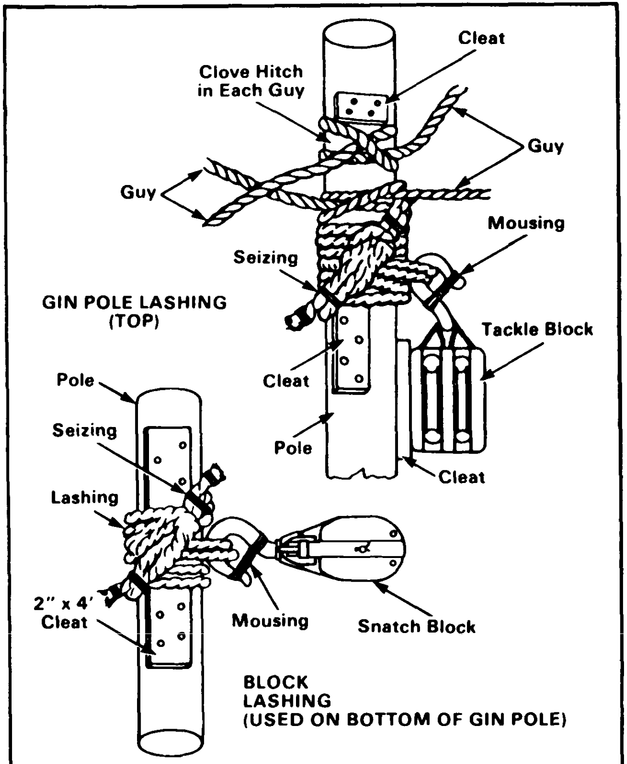


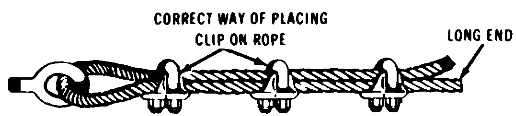
Figure 9-4. Shear, block, and gin pole lashing

Fastenings

See Table 9-6 for characteristics and usage.

Table 9-6. Wire rope clip

WIRE ROPE DIAMETER MM (IN)	NOMINAL SIZE OF CLIPS (IN)	NUMBER OF CLIPS	SPACING OF CLIPS MM (IN)	TORQUE TO BE APPLIED TO NUTS OF CLIPS M-KG x 0.1382 (FT-LB)
7.95 (5/16)	3/8	3	50 (2)	3.5 (25)
9.52 (3/8)	3/8	3	57 (2 1/4)	3.5 (25)
11.11 (7/16)	1/2	4	70 (2 3/4)	5.5 (40)
12.70 (1/2)	1/2	4	76 (3)	5.5 (40)
15.85 (5/8)	5/8	4	95 (3 3/4)	9.0 (65)
19.05 (3/4)	3/4	4	114 (4 1/2)	14 (100)
22.22 (7/8)	1	5	133 (5 1/4)	23 (165)
25.40 (1)	1	5	152 (6)	23 (165)
31.75 (1 1/4)	1 1/4	5	190 (7 1/2)	35 (250)
34.92 (1 3/8)	1 1/2	6	210 (8 1/4)	52 (375)
38.10 (1 1/2)	1 1/2	6	230 (9)	52 (375)
44.45 (1 3/4)	1 3/4	6	267 (10 1/2)	78 (560)



NOTE. The spacing of clips should be SIX times the diameter of the wire rope. To assemble end-to-end connectlon, the number of clips indicated above should be increased by two. The proper torque indicated above should be used on all clips: U-bolts are reversed at the center of connection so that the U-bolts are on the dead (reduced load) end of each wire rope.

Slings

For different types of slings, see Figure 9-5.

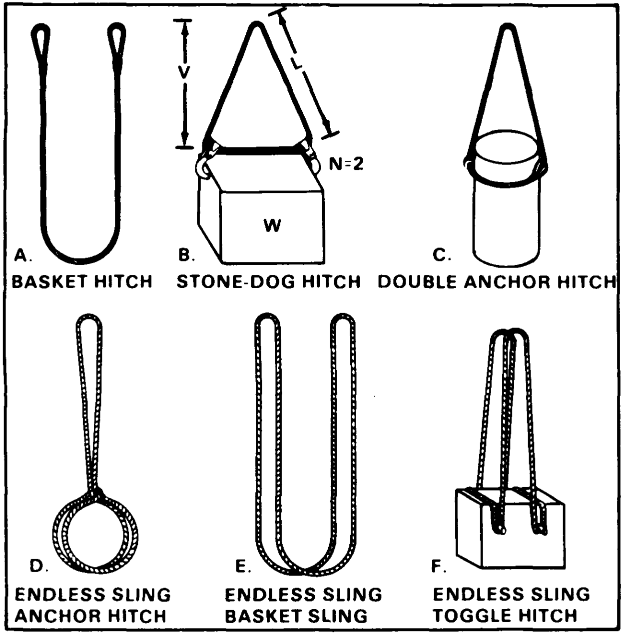


Figure 9-5. Single, combination, and endless slings

To determine the sling capacity, use the formula:

$$T = \frac{W}{N} \times \frac{L}{V}$$

Where: T = tension, in pounds
N = number of legs
W = weight of load in pounds
V = vertical distance, in feet
L = length of leg, in feet

} See Figure 9-5.

Example problem. You have a ¾-inch-diameter manila rope. Is it safe to use the rope to lift a 2,000-pound load wiht a 4-leg sling which has a vertical distance of 6 feet and length of leg of 12 feet?

$$T = \frac{W}{N} \times \frac{L}{V}$$

$$T = \frac{2{,}000}{4} \times \frac{12}{6} = 1{,}000 \text{ pounds}$$

The tension on each leg will be 1,000 pounds. The safe working capacity of ¾ - inch-diameter manila rope from Table 9-2 is 0.67 tons or 1.340 pounds. Since the safe working capacity is greater than the tension, the rope is safe to use.

Hoisting

Figures 9-6 through 9-8 show expedient lifting devices and their design.

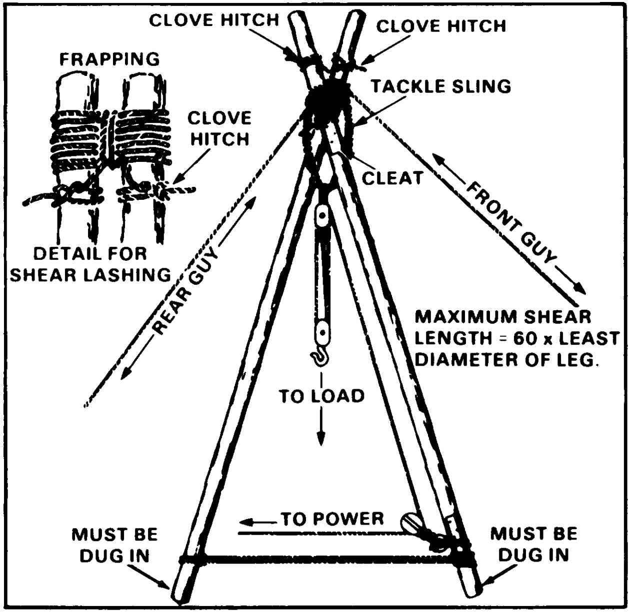


Figure 9-6. Lashing for shears

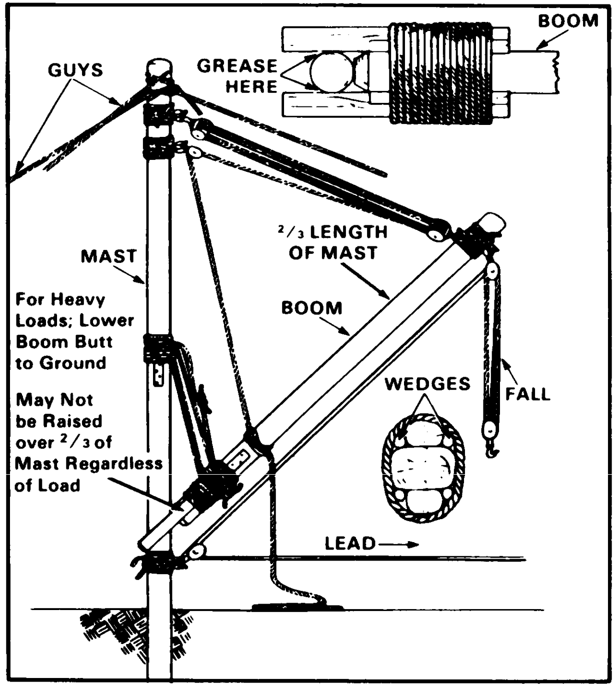


Figure 9-7. Boom derrick

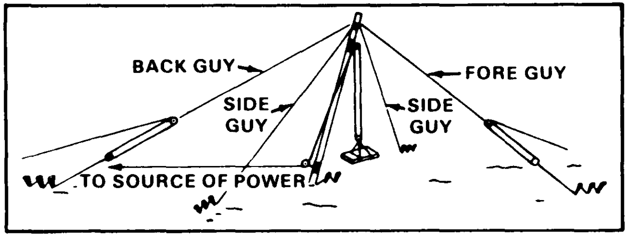


Figure 9-8 Gin pole ready for operation

NOTE: 1. A gin pole 30 to 40 feet may be raised by hand.
2. Maximum length of pole is 60 times minimum diameter.
3. Guys are three to four times the pole length.
4. Refer to Figure 9-4 (page 9-5) for lashing details.

Tackle Systems

Figure 9-9 shows examples of different tackle systems in a simple tackle system, the mechanical advantage is equal to the number of lines leaving the load. To determine the advantage of a multiple system. see Figure 9-9.

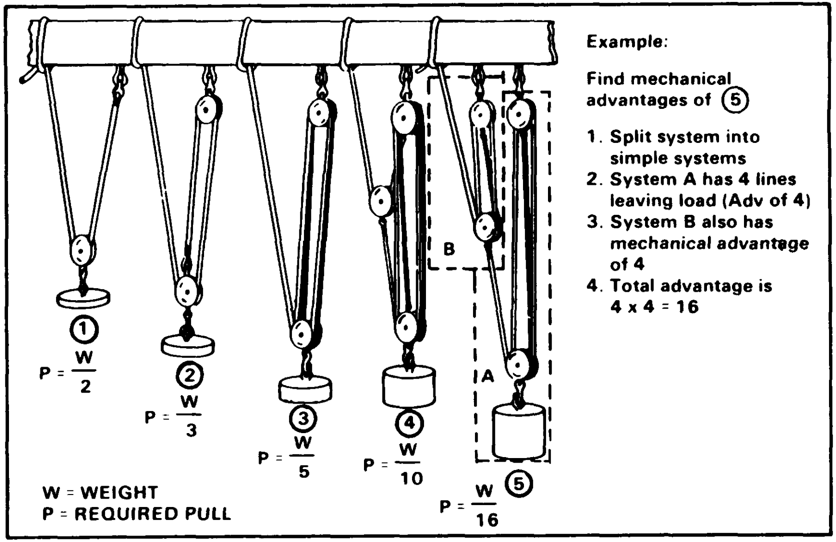
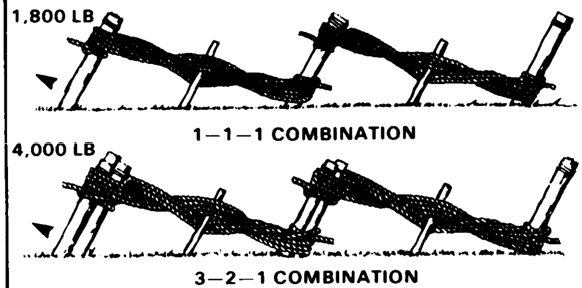


Figure 9-9. Block and tackle systems and mechanical advantages

ANCHORAGES AND GUY LINES

Anchorages

Use natural anchorage whenever possible (trees, boulders, and so forth). Figure 9-10 shows the design and characteristics of several picket holdfasts. For deadman design and characteristics, see Chapter 7 (page 7-14).



TYPE OF HOLDFAST	UNDIS-TURBED EARTH	WET CLAY AND GRAVEL	WET RIVER CLAY AND SAND
Single picket	700	630	350
1—1 Picket holdfast	1.400	1.260	700
1—1—1 Picket holdfast	1.800	1.620	900
2—1 Picket holdfast	2.000	1.800	1.000
3—2—1 Picket holdfast	4.000	3.600	2.000

Figure 9-10. Picket holdfast characteristics

Guy Lines

Use a minimum of four guy lines for gin poles and boom derrick and two guy lines for shears. To determine what tension will be on a guy line, use the formula.

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

Where: T = tension in guy line
W_L = weight of load
W_S = weight of spar
D = drift distance
Y = perpendicular distance

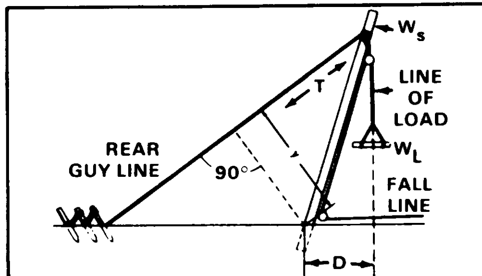


Figure 9-11. Guy line

HIGHLINE

The highline is a trolley line passing through a snatch block at each support (Figure **9-12).**

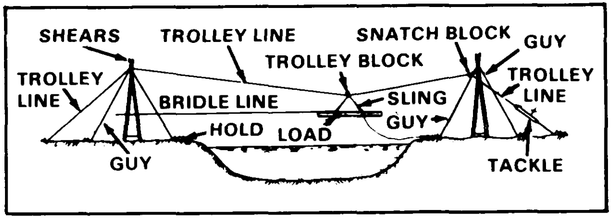


Figure 9-12. Highline

Sag

The sag in the track cable when loaded should be not less than 5 percent of the span.

Safe Load Highline Formula

$$SL = \frac{BS}{5 \times SF} - \frac{DL}{2}$$

Where: SL = safe load in pounds
BS = breaking strength of line in
DL = dead load in pounds
SF = safety factor

Problem: Span is 400 feet
Track line is ¾ - inch-diameter manila rope
Haul line is ½ - inch-diameter manila rope
Track cable sag is 5 percent

Solution: BS for ¾ - inch diameter manila rope (Table 9-2. page 9.2)= 5,400 pounds (2.70 tons)
SF for ¾ - inch rope (Table 9-2) = 4.0
DL for ¾ - inch rope (Table 9-2) = 66.8 pounds/400 feet
DL for ½ - inch rope (Table 9-2) = 60 pounds/800 feet

Therefore:
$$SL = \frac{5,400}{5 \times 4.0} - \frac{66.8}{2}$$

$$SL = 270 - 33.4$$
$$SL = 236.6 \text{ pounds}$$

For the payload, use the formula
PL = SL - (½ W of haul rope + W of traveler + W of carrier)

For this problem, this would mean
PL = 236.6 - (30 plus the weight of the traveler and carrier)

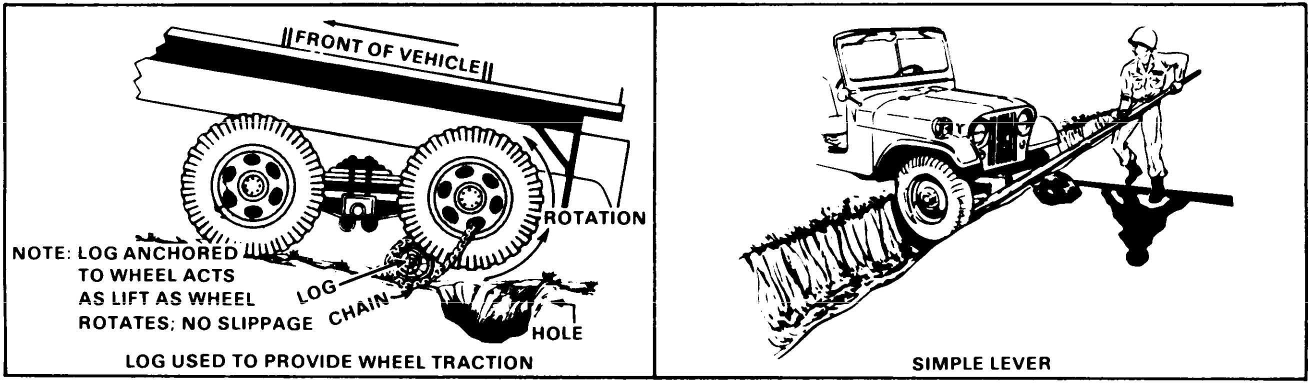


Figure 9-13. Simple lifting techniques

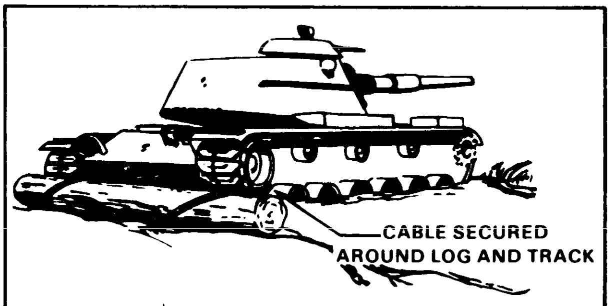


Figure 9-14. Log used to provide truck traction

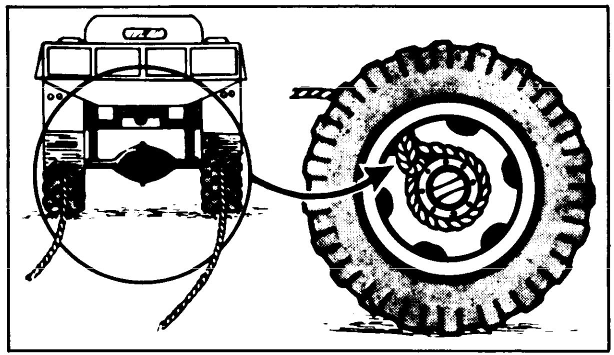


Figure 9-15. Use of dual wheels for a winch