Preface

This manual applies to rigging equipment, materials, procedures and precautions used in the construction industry.

The Construction Safety Association of Ontario believes that proper job training is the answer to improved accident prevention and this manual is an attempt to identify and expand upon the elements of rigging by prescribing minimum safety requirements, guidelines and procedures. It should be used as a guide in conjunction with the applicable safety regulations by contractors, supervisors, riggers, operators and employees who are concerned with or responsible for construction safety.

The text has been endorsed by both labour and management authorities and is fully a document of accord. The Provincial Labour-Management Safety Committee (composed of members of the Provincial Building and Construction Trades Council of Ontario and senior management from the construction industry) worked with the Regional Labour-Management Safety Committees in its review and approval.

In offering this manual to the industry, the Construction Safety Association of Ontario hopes to contribute to a broader understanding of rigging and its importance in the construction field. It is intended that it become a working guide and that the information be used in the training of personnel involved with rigging and be included in standing instructions for the safe use of rigging equipment.

Knowledge of the equipment and materials with which we work is one of the most important factors in accident prevention. Each piece of equipment and material has been designed and developed to serve a specific purpose and knowledge of what it can and cannot do not only improves efficiency but also eliminates hazards.

Owing to the many variations in rigging practices and the different ways in which rigging is used, recommendations must, of necessity, be framed in general terms. The recommendations can only be advisory in nature and are intended to complement relevant regulations and manufacturers' requirements which must be observed.

The Construction Safety Association of Ontario is grateful and wishes to thank all who assisted in the preparation of this handbook. Special thanks go to the following for their input and capable assistance.

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CHAPTER 1

Wire Rope

SELECTION

The responsibility of equipment selection and application involves using material that will not only get the job done as quickly and economically as possible, but that eliminates all possibility of hazard to personnel on the site, the public and the property for as long as it will be used and under all anticipated conditions to which it will be exposed and operated.

Although nothing can take the place of experience in making these decisions, the guidelines set out in this manual are intended to simplify the process by stressing the critical considerations that must not be overlooked.

It is both the equipment supplier's and the contractor's responsibility to ensure that these requirements are met.

Many factors influence the selection of wire rope. The strength of the rope, although of major importance, is only one of these factors. It is advisable, therefore, to use only ropes of the correct size, grade, type and construction as specified by either the equipment manufacturer or the rope manufacturer who must base their recommendations on actual working conditions.

There are six requirements which must be considered when selecting a wire rope:

1. The rope must possess sufficient strength to take the maximum load that may be applied, with a factor of safety of at least 5 to 1, and 10 to 1 when it is used to carry personnel.

   The wire ropes that are supplied as rigging on mobile cranes must possess factors of safety as follows:

   — live or running ropes that wind on drums or pass over sheaves
   = 3.5 to 1 under operating conditions
   = 3.0 to 1 when erecting the boom

   — pendants or standing ropes
   = 3.0 to 1 under operating conditions
   = 2.5 to 1 when erecting the boom.
2. The rope must withstand repeated bending without failure of the wires from fatigue.
3. The rope must resist abrasion.
4. The rope must withstand distortion and crushing.
5. The rope must resist rotation.
6. The rope must resist corrosion.

Table 1.1 illustrates how the design and construction of the rope can be varied to give the best characteristics for specific service demands.

TABLE 1.1

WIRE ROPE SERVICE REQUIREMENTS	WIRE ROPE DESIGN CHARACTERISTICS
Strength: the wire rope must develop sufficient strength to support the load plus the necessary factor of safety.	The strength of a wire rope depends on its size, grade of wire and type of core.
Flexibility or Resistance to Bending Fatigue: the wire rope must have the ability to bend over small sheaves or wind onto relatively small drums without the wires breaking due to bending fatigue.	Strands containing a large number of small wires have greater resistance to bending fatigue than strands containing a few large wires. Lang Lay has greater fatigue resistance than Regular Lay. Preforming increases the wire rope's resistance to bending fatigue.
Resistance to Abrasion: the wire rope is subjected to wear or abrasion as it passes through operating sheaves under high pressure or comes in contact with stationary objects.	Large outer wires are better able to withstand abrasive wear. Lang Lay provides greater resistance to wear than Regular Lay.
Resistance to Crushing: some wire ropes distort or flatten when they are forced to operate under heavy pressure in grooves that do not provide ample support or on drums where multiple lay winding occurs.	An Independent Wire Rope Core (IWRC) provides greater support for strands under heavy bearing pressures. The coarser wire rope constructions provide greater resistance to flattening on drums.
Resistance to Rotation: a wire rope may rotate as the load is applied. This could be undesirable for load control and might lead to rapid deterioration of the wire rope.	Special non-rotating constructions are available for specific applications. Regular Lay provides greater stability than Lang Lay, and wire ropes with an IWRC twist less than those with fibre cores.
Resistance to Corrosion: wire rope may corrode if in contact with corrosive elements or it may rust when exposed to atmospheric conditions over a long period of time.	Galvanized or stainless steel wire offers excellent protection against corrosion. Special lubricants can also inhibit the development of rust.

DESIGN AND CONSTRUCTION:

Wire rope consists of many individual wires laid into a number of strands which are, in turn, laid around a centre core. (Fig. 1.1)

The type and size of wire used, the number of wires in the strands, and the type of core determine the strength of a wire rope of a given size. A typical description of a wire rope would be: 1000 Feet, 1/2" Diameter, 6 x 25 Filler, Preformed, Improved Plow Steel Wire Rope, IWRC, Lang Lay.

The precise meaning of each term is as follows:

(a) 1000 Feet — the length of wire rope is ordered or recorded in feet.

(b) 1/2" Diameter — the nominal diameter of the rope.

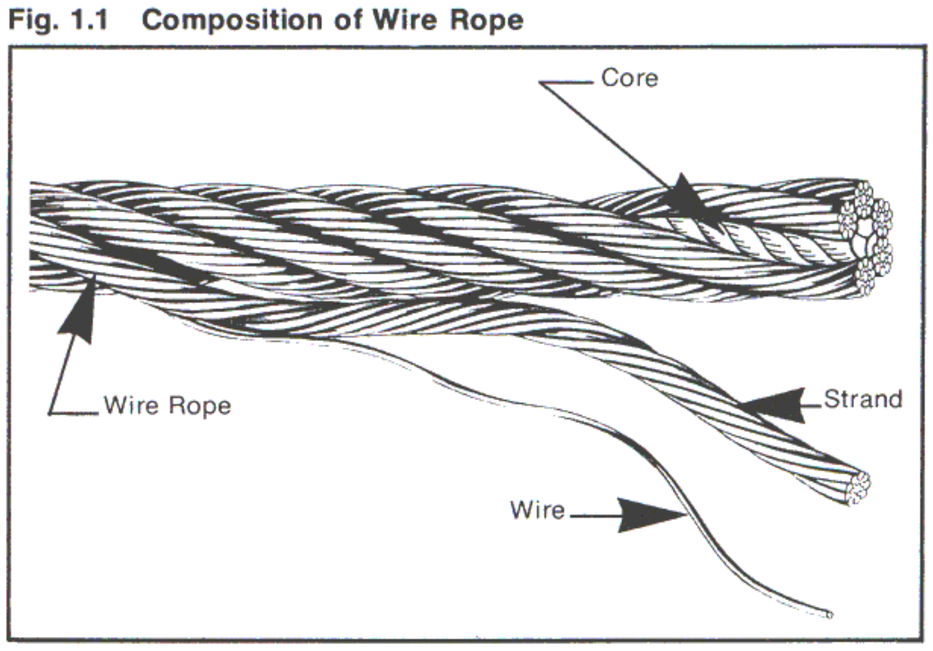
(c) 6 x 25 Filler — the first numeral is the number of strands in the rope (6). The second numeral is the number of wires in each strand (25). The word Filler indicates the pattern of the wires in the strand.

(d) Preformed — a type of process assuring that each strand of the rope is preformed to the helical shape it will assume in the finished rope.

(e) Improved Plow Steel (IPS) — signifies the grade of steel used in the wires.

(f) IWRC (Independent Wire Rope Core) — indicates the type of core.

Fig. 1.1 Composition of Wire Rope



(g) Lang Lay — indicates the direction of the strands and the wires in the strands.

Each distinct design element influences the rope's characteristics. The design objective is to provide a rope with characteristics balanced to withstand the demands of a particular service. There are five basic design elements:

(1) Grade of wire.
(2) Number and pattern of wires in the strand.
(3) Type of lay.
(4) Preforming.
(5) Type of core.

Each of these elements will be explained in more detail since a thorough understanding of wire ropes contributes to hoisting and rigging safety.

GRADES:

To meet the demand for varying degrees of strength, toughness, abrasion resistance, and corrosion resistance, wire rope is manufactured in the following grades for rigging applications:

Grade 120/130 Special Improved Plow Type II — Used for special installations where maximum rope strength is required.

Grade 115/125 Special Improved Plow Type I — Used for special applications where breaking strengths somewhat higher than obtained with Grade 110/120 are desired and where other conditions such as sheave and drum diameters are favourable to its use.

Grade 110/120 Improved Plow — Has a good combination of tensile strength, wearing qualities and excellent fatigue resistant properties. These steels have high strength, are tough, ductile and highly wear resistant and are drawn to 110/120 long tons per square inch or 246,000 to 268,000 psi.

Grade 100/110 Plow — Has lower tensile strength and resistance to wear than Grade 110/120 but retains high fatigue resistant properties. Can be used when strength is secondary to wear resistance.

STRAND CLASSIFICATIONS:

Wire ropes are also characterized by their strand shape as follows. (Fig. 1.2)

— Round Strand Ropes.
— Flattened Strand Ropes.
— Locked Coil Ropes.
— *Concentric Strand Ropes.*

Since almost all rigging and hoisting ropes are of the Round Strand classification the discussion in this manual will be confined to them.

CONSTRUCTIONS:

Round Strand Ropes are grouped into classifications according to the number of wires per strand. As the number increases, the rope develops greater ability to resist bending fatigue — at the expense of resistance to abrasion.

Within the Round Strand classification, the wires may be arranged in certain geometric patterns, called "constructions". The number and pattern of the wires defines the rope's characteristics.

The wires in the strands may be all the same size or a mixture of sizes. There are four common arrangements: (Fig. 1.3)

1. **Ordinary,** where the wires are all the same size.
2. **Seale,** where larger diameter wires are used on the outside of the strand to resist abrasion and smaller wires are inside to provide flexibility.
3. **Warrington,** where alternate wires are large and small to combine great flexibility with resistance to abrasion.
4. **Filler,** where very small wires fill in the valleys between the outer and inner rows of wires to provide good abrasion and fatigue resistance.

As the number of wires per strand increases, combinations of Filler, Seale, and Warrington patterns are used to provide certain characteristics. This combination of rope classifications and strand constructions produces varying degrees of resistance to bending fatigue and abrasion. The effect of varying constructions can be best shown by using, as examples, the most commonly used rigging ropes (A) the 19 Wire Strand and (B) 37 Wire Strand Ropes.

A) Basic 19 Wire Strands: (Fig. 1.4)

— **19 Wire Seale:** Seale patterns always have the same number of outer and inner wires. The outer wires are fairly large and provide good abrasion resistance.

— **19 Wire Warrington:** Outer wires are two sizes and are alternately supported by the crowns and valleys of the inner layer. This type of construction is ideal for small diameter ropes or for intermediate layers when building large diameter strands of many wires.

— **25 Wire Filler:** Filler wires are used to prevent the outer wires from crowding into the

Fig. 1.2 Strand Classifications

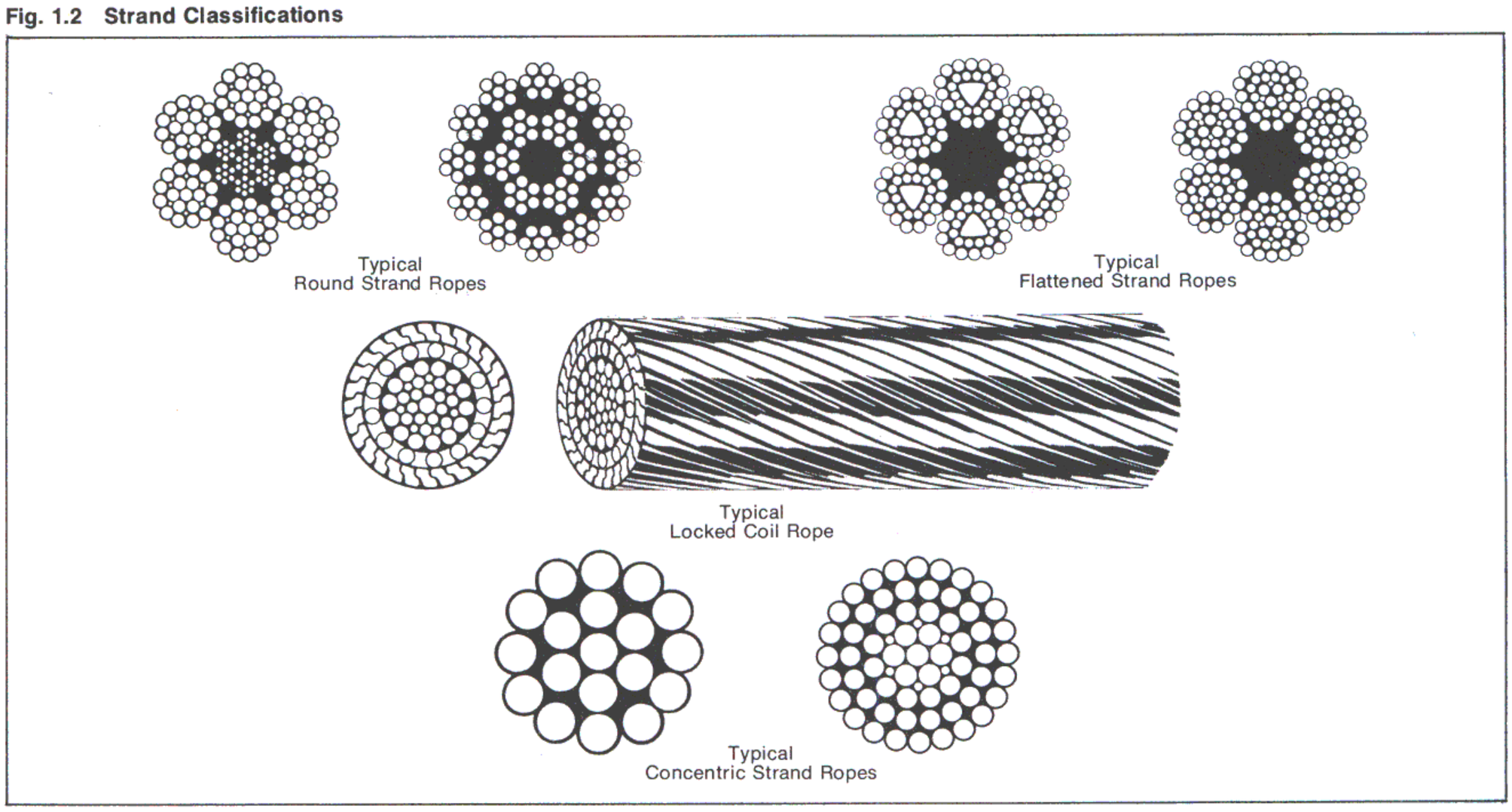


Fig. 1.3 Wire Rope Constructions

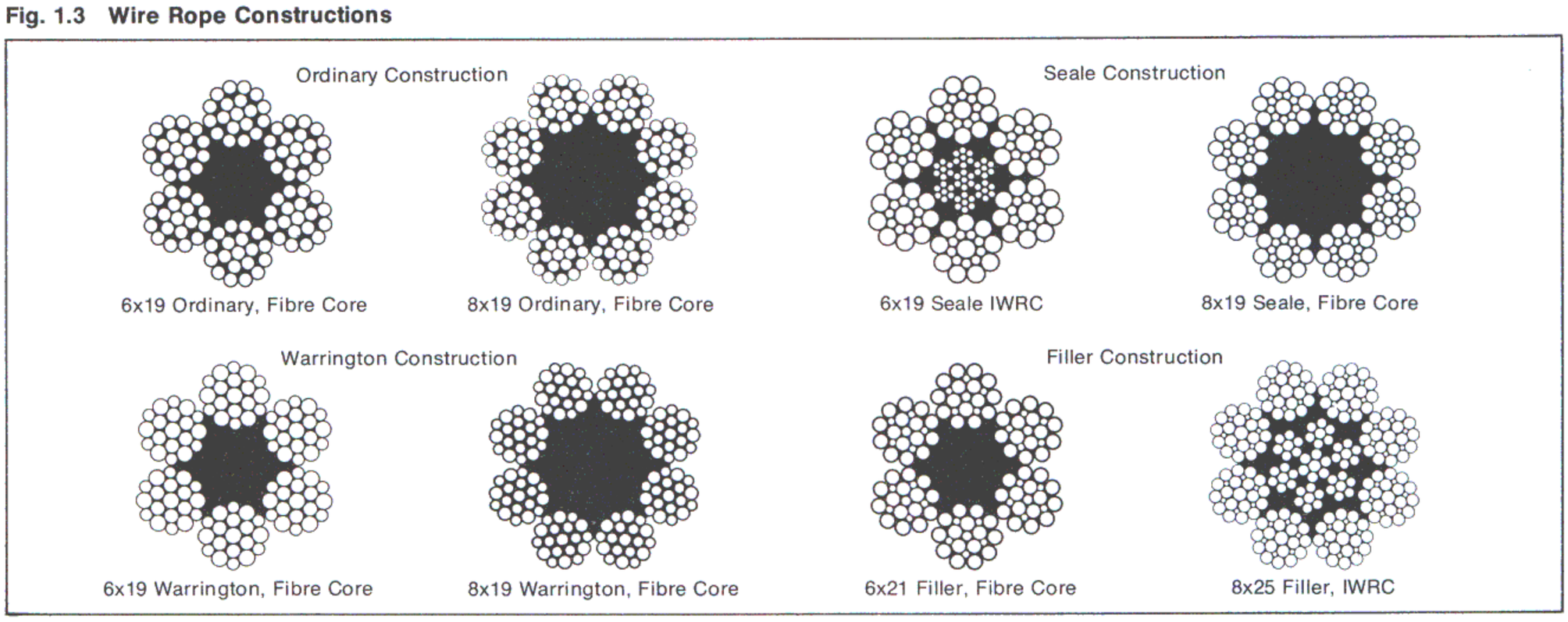
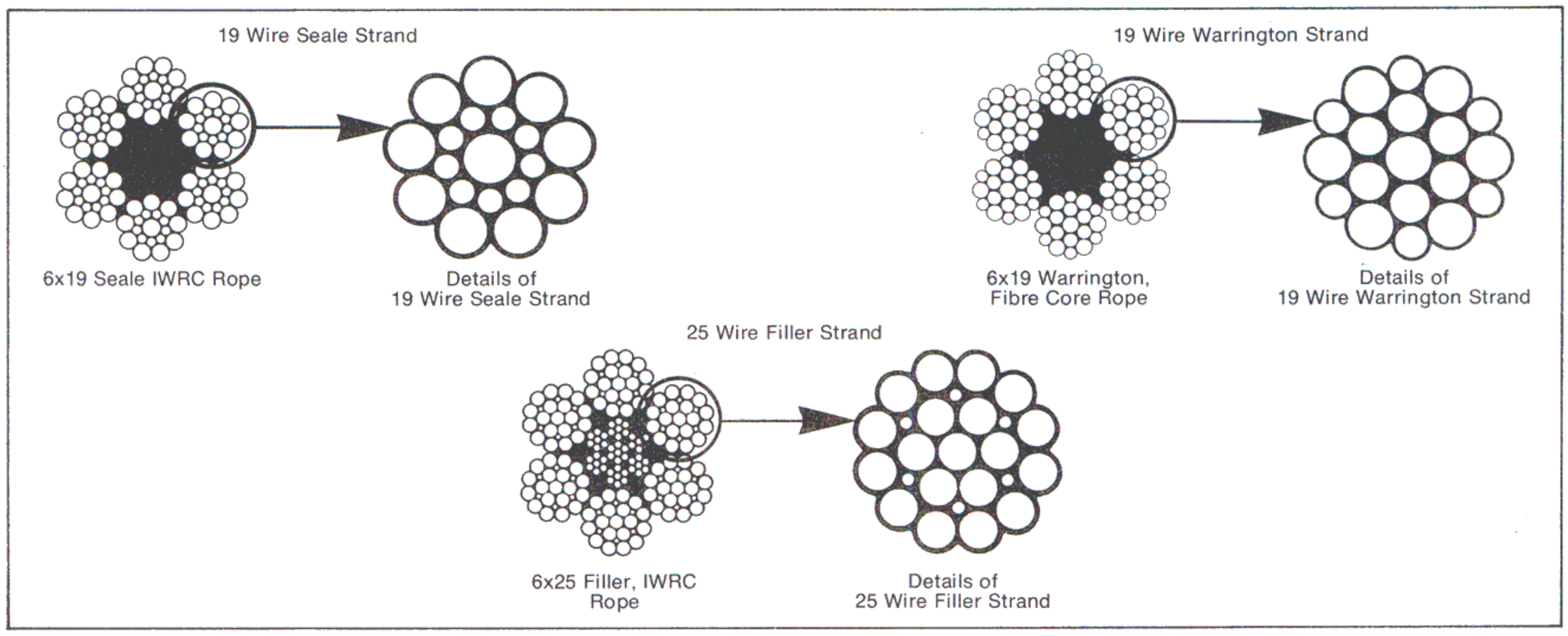


Fig. 1.4 Basic 19 Wire Strand Construction



valleys between the inner wires. The Filler construction has good abrasion and fatigue resistant characteristics.

B) Basic 37 Wire Strands: (Fig. 1.5)

— **31 Wire Warrington Seale:** In this built-up construction, the 19 Wire Warrington strand is enclosed by an outer layer of 12 large diameter wires resting in the valleys between the 12 wires of the inner layer. This construction provides similar abrasion resistance to 25 Wire Filler, but increased flexibility from additional internal wires.

— **41 Wire Filler:** The 41 Wire Filler comprises a 17 wire inner Seale strand, with an outer layer of 16 wires and a layer of 8 Filler wires to prevent crowding of the outer wires. This construction is recommended for larger diameter ropes where more flexibility is required.

— **49 Wire Filler Seale:** The 49 Wire Filler Seale comprises a conventional 33 Wire Filler strand with an outer layer of 16 large diameter wires resting between the 16 wires of the inner layer. This construction is ideal for large diameter ropes where the requirement is maximum flexibility.

ROPE LAY:

The term "rope lay" signifies the direction of rotation of the wires and the strands in the rope. Rotation is either to the right (clockwise) or to the left (counterclockwise).

The lay of the rope affects its flexibility and resistance to wear. The term "lay length" is the distance measured along a rope in which a strand makes one complete revolution around the rope axis. (Fig. 1.6)

In **Regular Lay Ropes** the wires in the strands are laid in one direction (Fig. 1.7) while the strands in the rope are laid in the opposite direction. The result is that the wire crown runs approximately parallel to the longitudinal axis of the rope. These ropes are stable, have good resistance to kinking and twisting and are easy to handle. They are also able to withstand considerable crushing and distortion due to the short length of exposed wires.

In **Lang Lay Ropes** the wires in the strands and the strands in the ropes are laid in the same direction (Fig. 1.8). The outer wires run diagonally across the rope and are exposed for longer lengths than in the Regular Lay Rope. With the outer wires presenting greater wearing surfaces, Lang Lay Ropes have greater resistance to abrasion. They are also more flexible and possess greater resistance to fatigue. They are more liable to kinking and untwisting and are not capable of withstanding the same abuse from distortion and crushing. Lang Lay Ropes should have *both* ends permanently fastened to prevent untwisting and as such they should not be recommended for use on single part hoistlines nor should they be used with swivel end terminals.

Right Lay and Left Lay (Fig. 1.9). A Right Lay Rope is one in which the strands rotate or twist to the right like a conventional screw thread. A Left Lay Rope is just the opposite. No rope should be ordered Left Lay without first considering all features of its proposed end use.

Alternate Lay ropes (Fig. 1.10) have 3 strands made with Right Lay and 3 with Left Lay. The 6 strands are then positioned in the finished rope so that the strands alternate.

Herringbone or Twin Strand (Fig. 1.11) have a combination of right-hand laid and left-hand laid strands. They usually consist of two pairs of the right-hand laid strands (Lang Lay) and two single left laid strands (Regular Lay). The two single left laid strands are separated by the pairs of right-hand strands. This arrangement gives some of the stability of a Regular Lay Rope while retaining a good portion of the bending characteristics of Lang Lay.

The standard rope, unless otherwise stated, is understood to be Right Regular Lay.

PREFORMING:

The wires and strands in preformed rope are shaped in the manufacturing process to fit their position in the finished rope. This removes the tendency of the wires and strands to straighten. (Fig. 1.12)

As a result:

— They can be cut without seizings.

— Broken rope ends do not untwist.

— They are free from liveliness and twisting tendencies which makes installation and handling easier.

— They are less likely to kink or foul.

— They have increased resistance to bending fatigue.

— Each strand carries an equal share of the load.

— They cause less wear on sheaves and drums.

— Individual broken wires do not jut out from the rope when broken. They lie flat with the broken ends only slightly separated. For this reason, preformed rope requires very careful inspection.

Fig. 1.5 Basic 37 Wire Strands

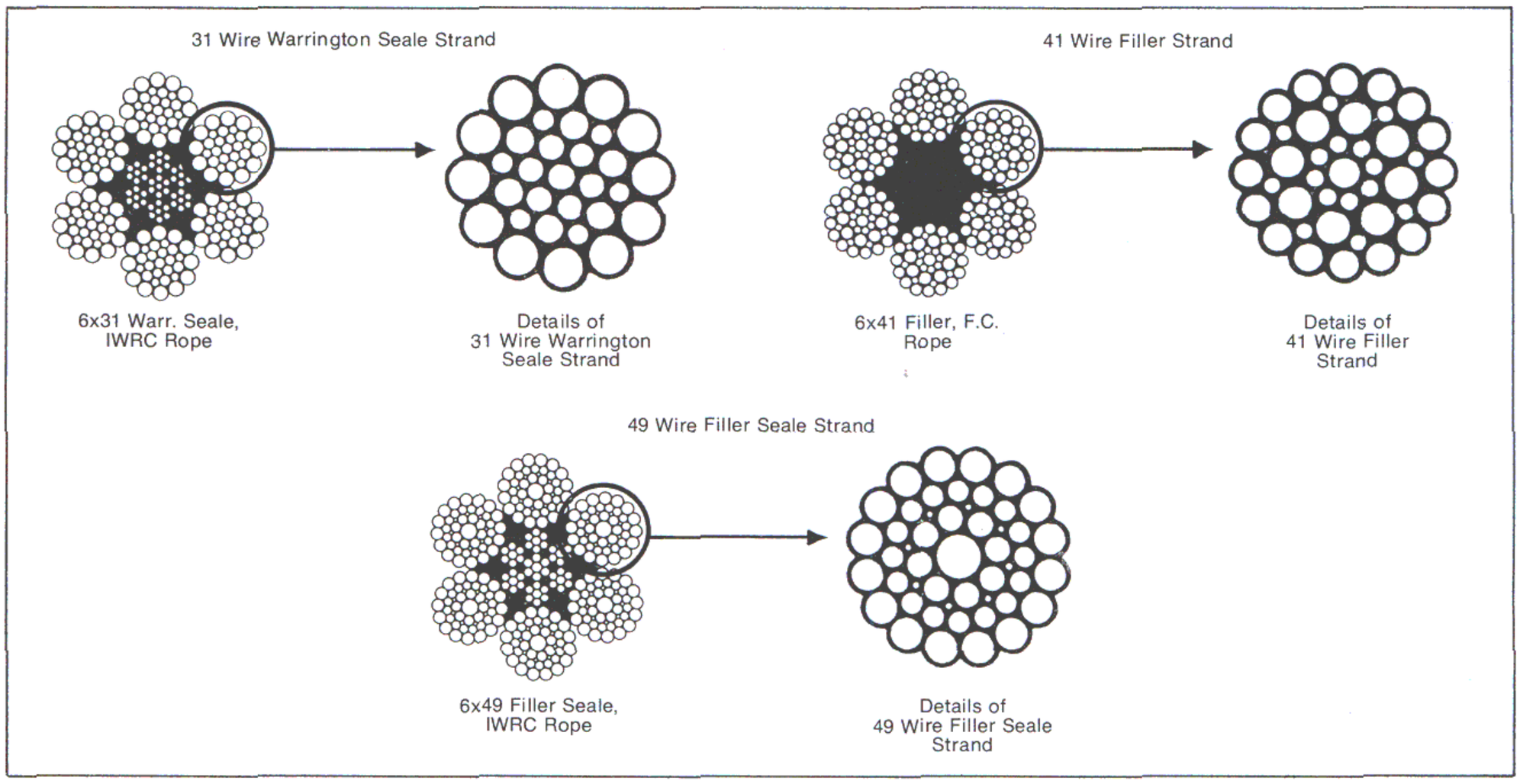


Fig. 1.6 Measurement of Ropes Lay Length

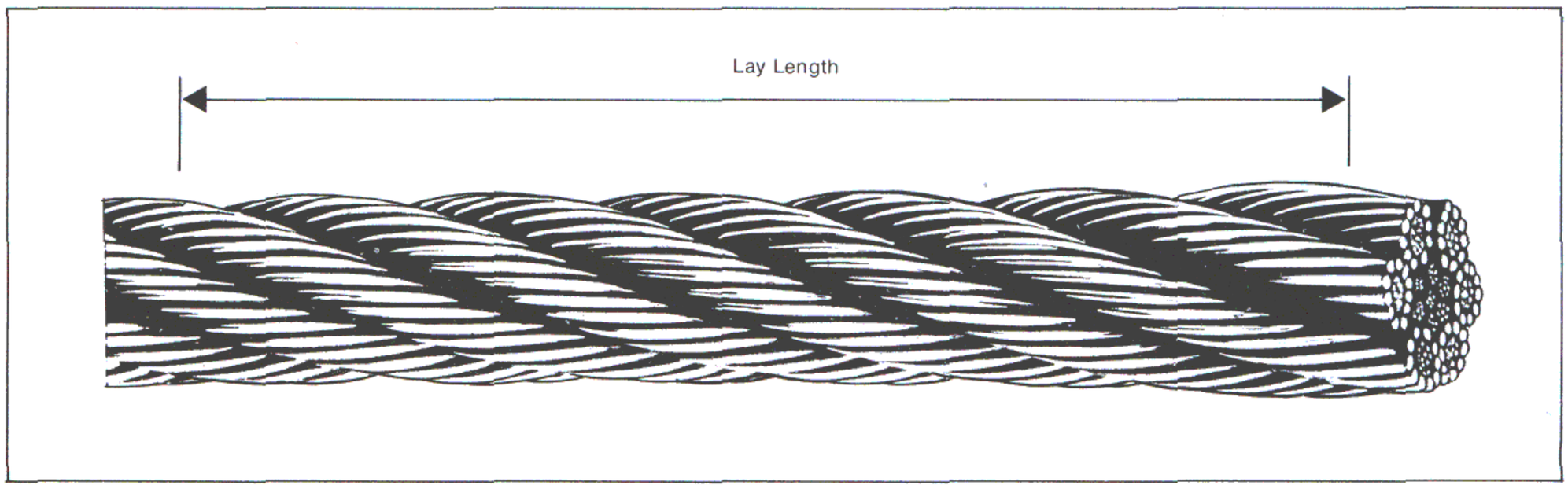


Fig. 1.7 Regular Lay Rope — Wires and Strands Laid in Opposite Directions

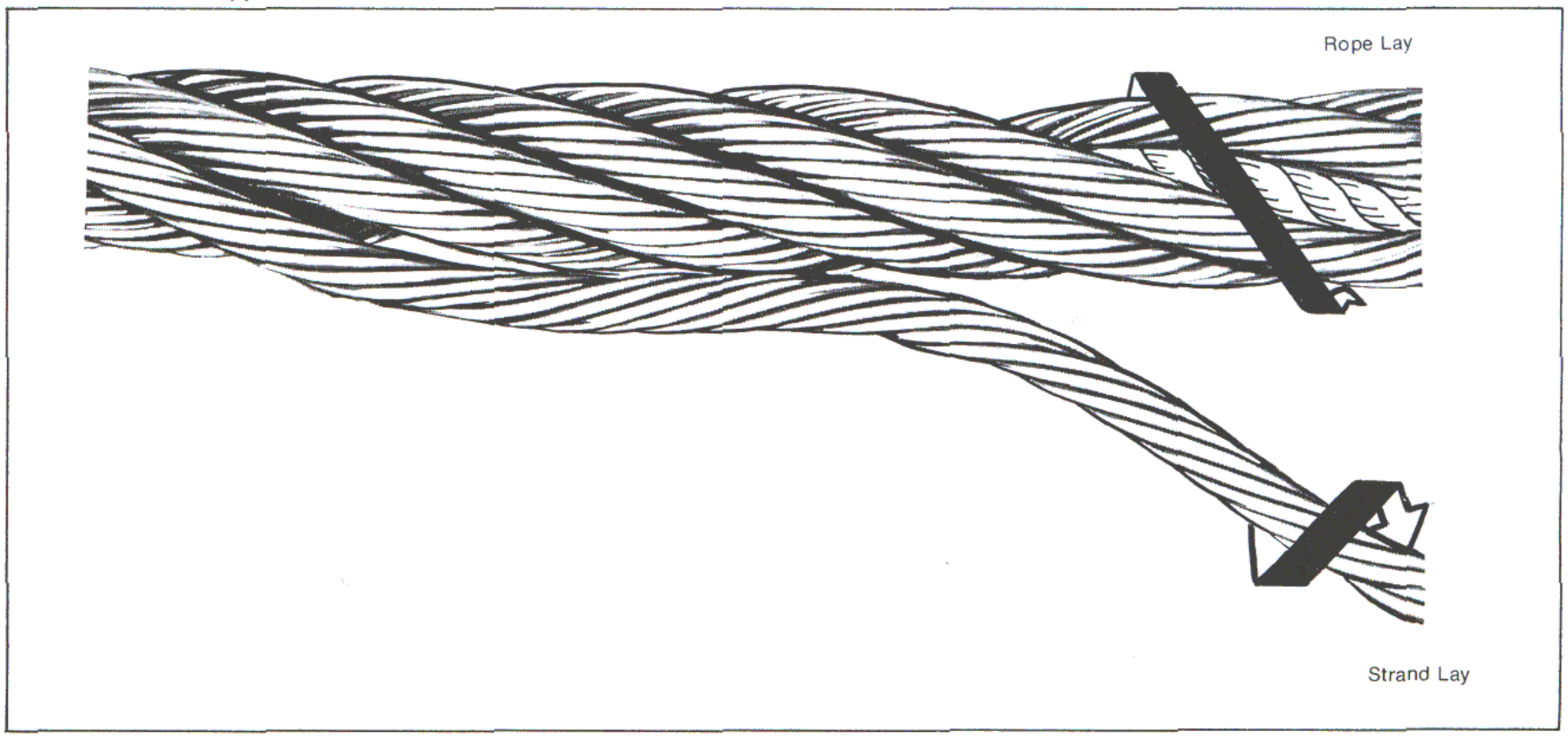


Fig. 1.8 Lang Lay Rope — Wires and Strands Laid in Same Direction

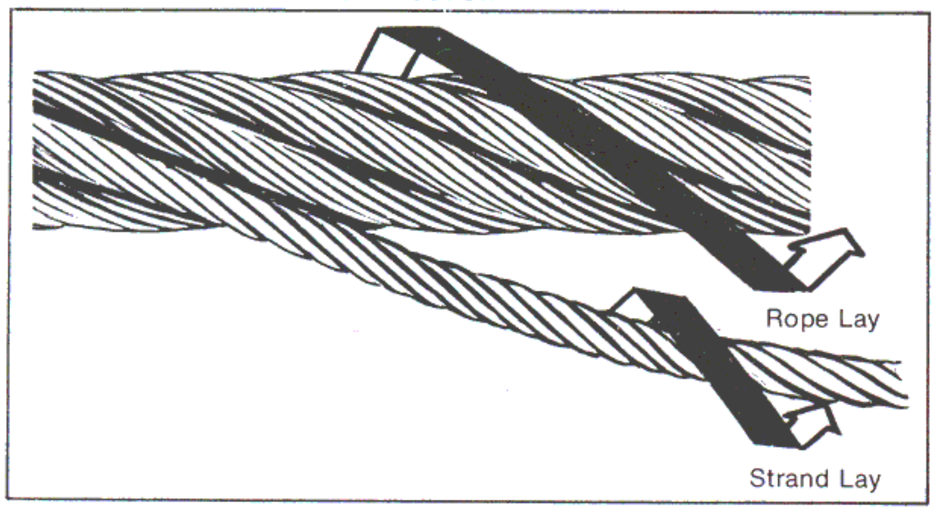


Fig. 1.9 Rope Lay

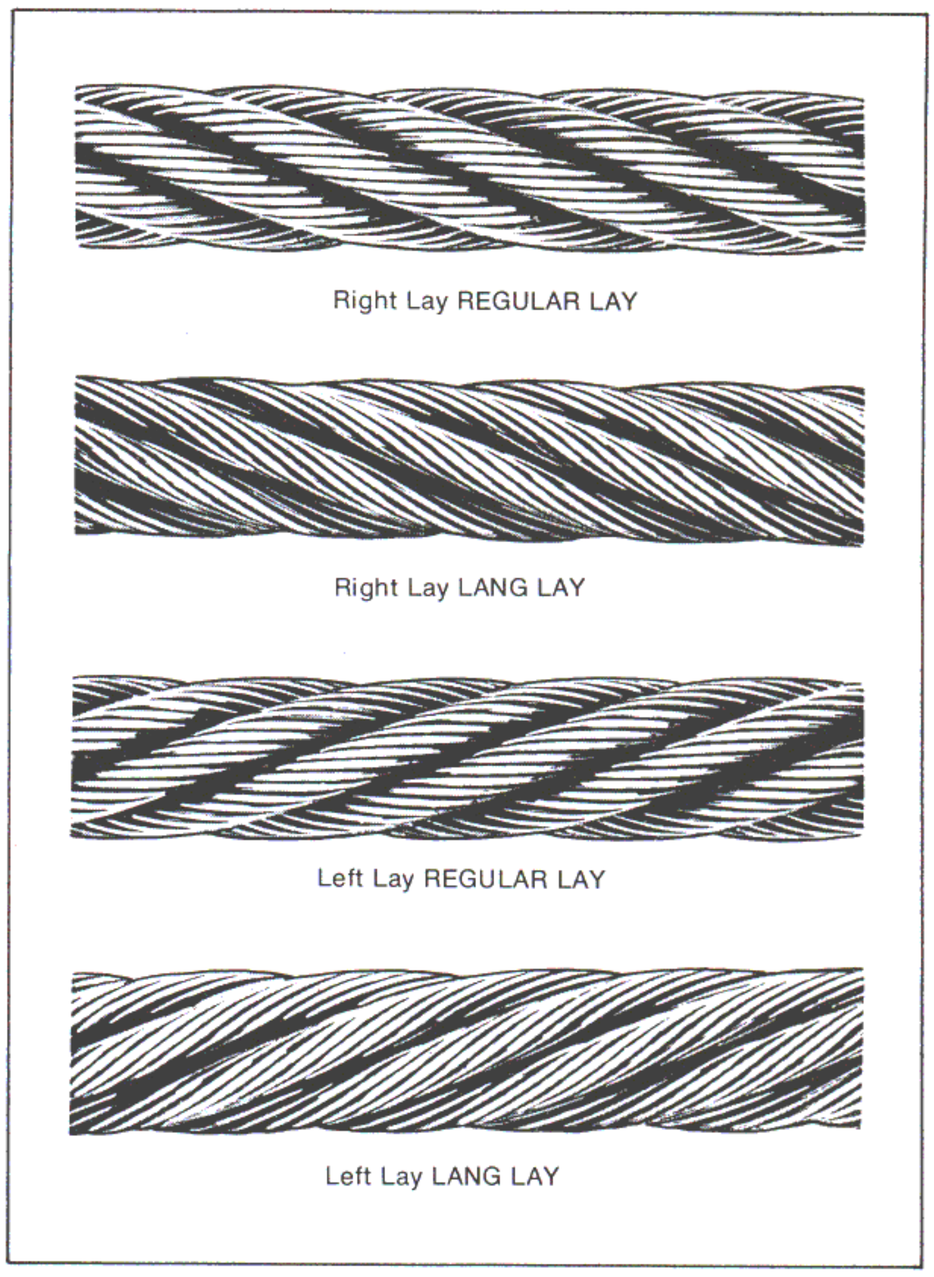


Fig. 1.10 Alternate Lay Rope

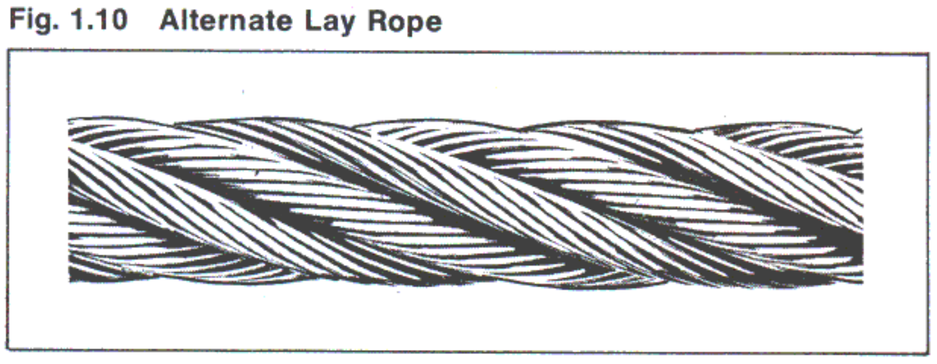


Fig. 1.11 Herringbone or Twin Strand

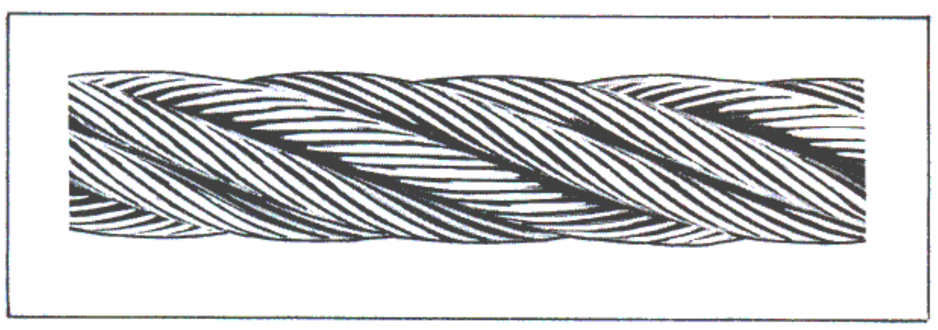
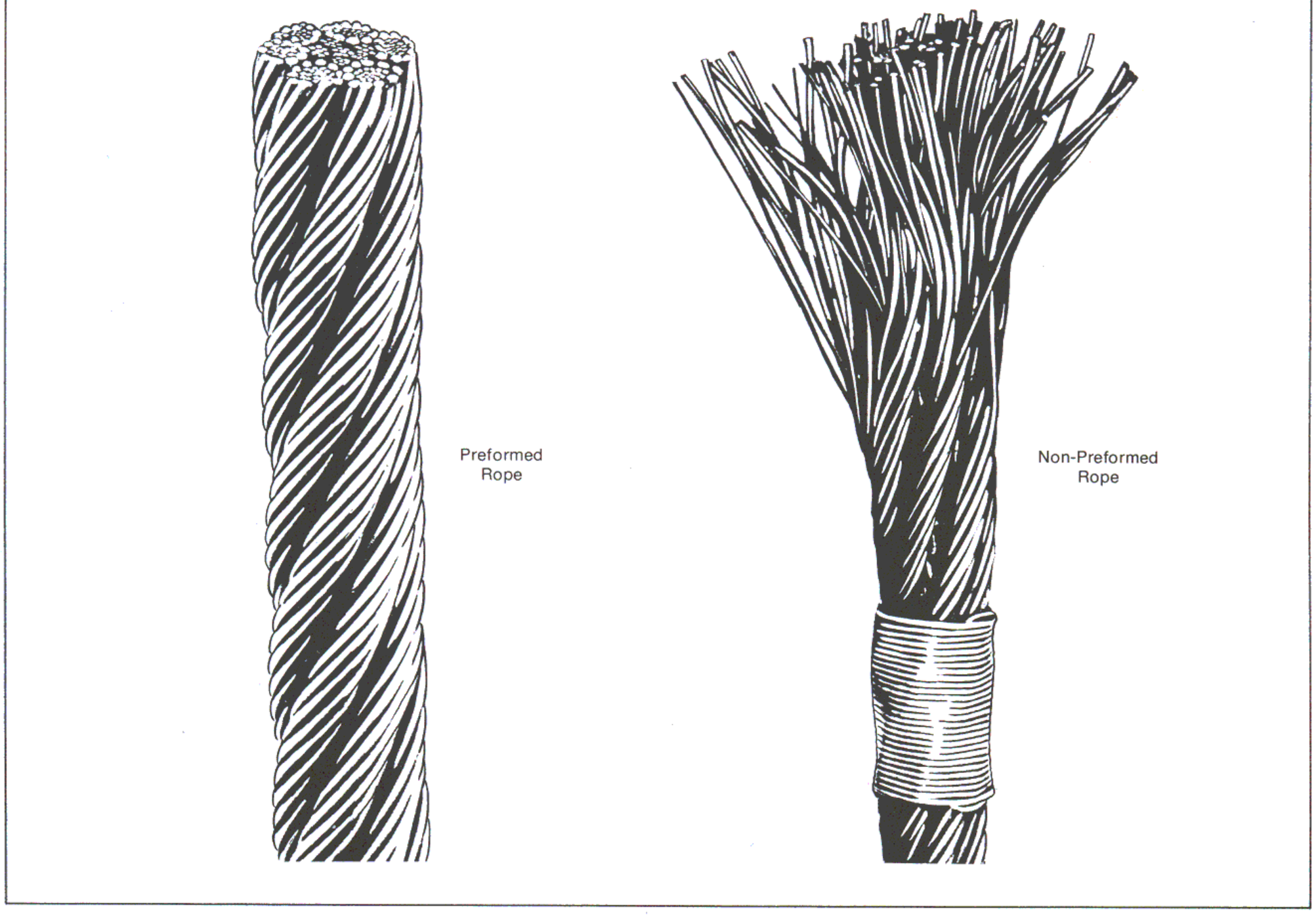


Fig. 1.12 Effect of Preforming on a Wire Rope



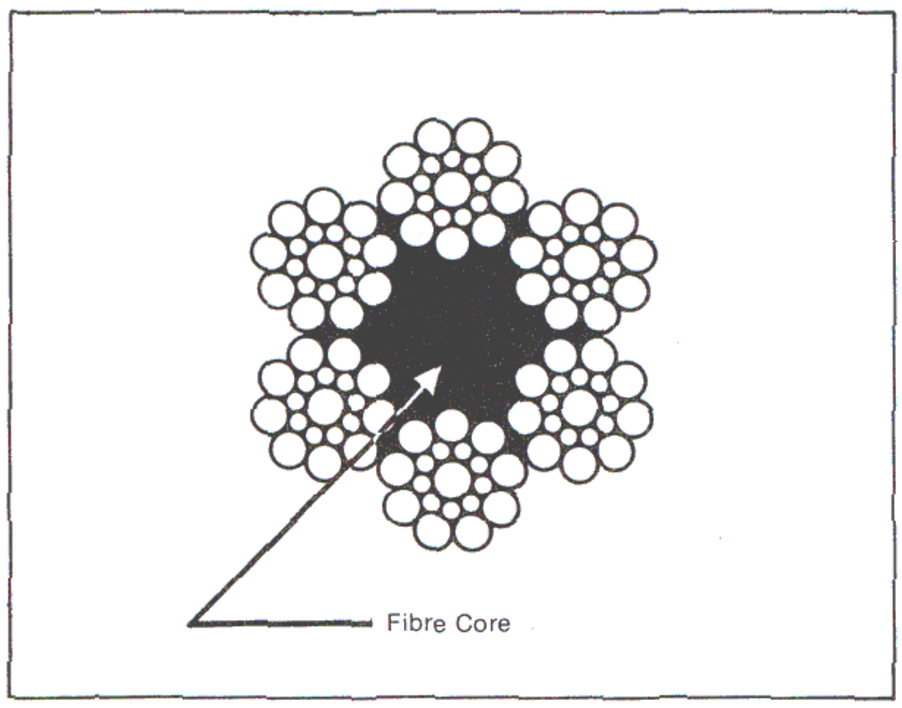
CORES:

The core forms the heart of the rope and is the component around which the main rope strands are laid. The core supports the strands and is intended to keep them from jamming against or contacting each other under normal loads and flexings.

The core may take one of several forms, depending on the conditions under which the rope will be used.

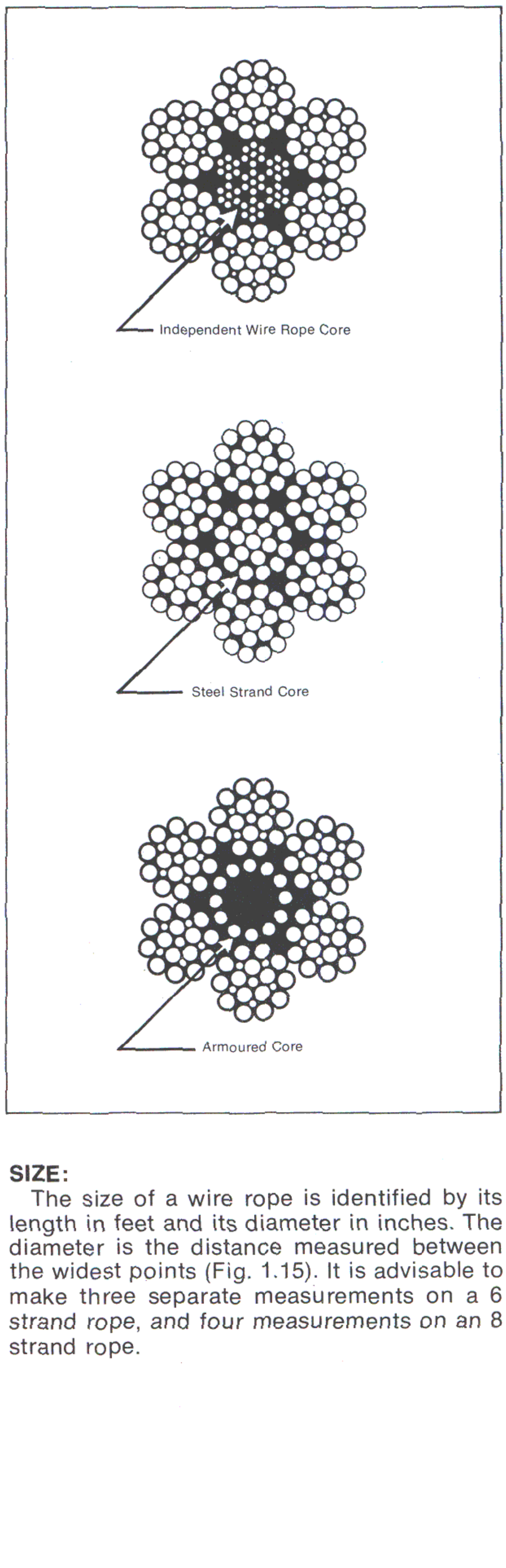
Fibre Cores (Fig. 1.13) are adequate for many types of service by providing maximum flexibility and elasticity to the wire rope. While generally made of hard fibres, usually sisal and occasionally manila, they may also be manufactured from man-made fibres such as polypropylene or nylon. These synthetic cores are less susceptible to compacting, especially under moist conditions and are impervious to many acids. Do not use a fibre core rope where it could be exposed to temperatures at which fibre cores would be damaged. Rope having an independent wire rope or wire strand core, or other temperature damage resistant core must be used. Also, fibre core ropes should not be used when multi-layer winding is used since they are susceptible to crushing.

Fig. 1.13 Fibre Core Ropes



Wire Cores (Independent Wire Rope Core, Steel Strand Core, Armoured Core) (Fig. 1.14) increase the resistance of wire rope to abuse as they do not yield to the compressive action of the outer strands as do fibre cores. This tends to preserve the circular cross-section of the rope when it is crushed by over-winding or when it is bent around small sheaves and drums while heavily loaded. They also prevent the strands from bridging (bearing forcibly against each other) which can result in fatigue failure. Wire cores stretch less and add to the strength of ropes (approximately 7½%) but they are less resilient than fibre core types and are less resistant to shock loads.

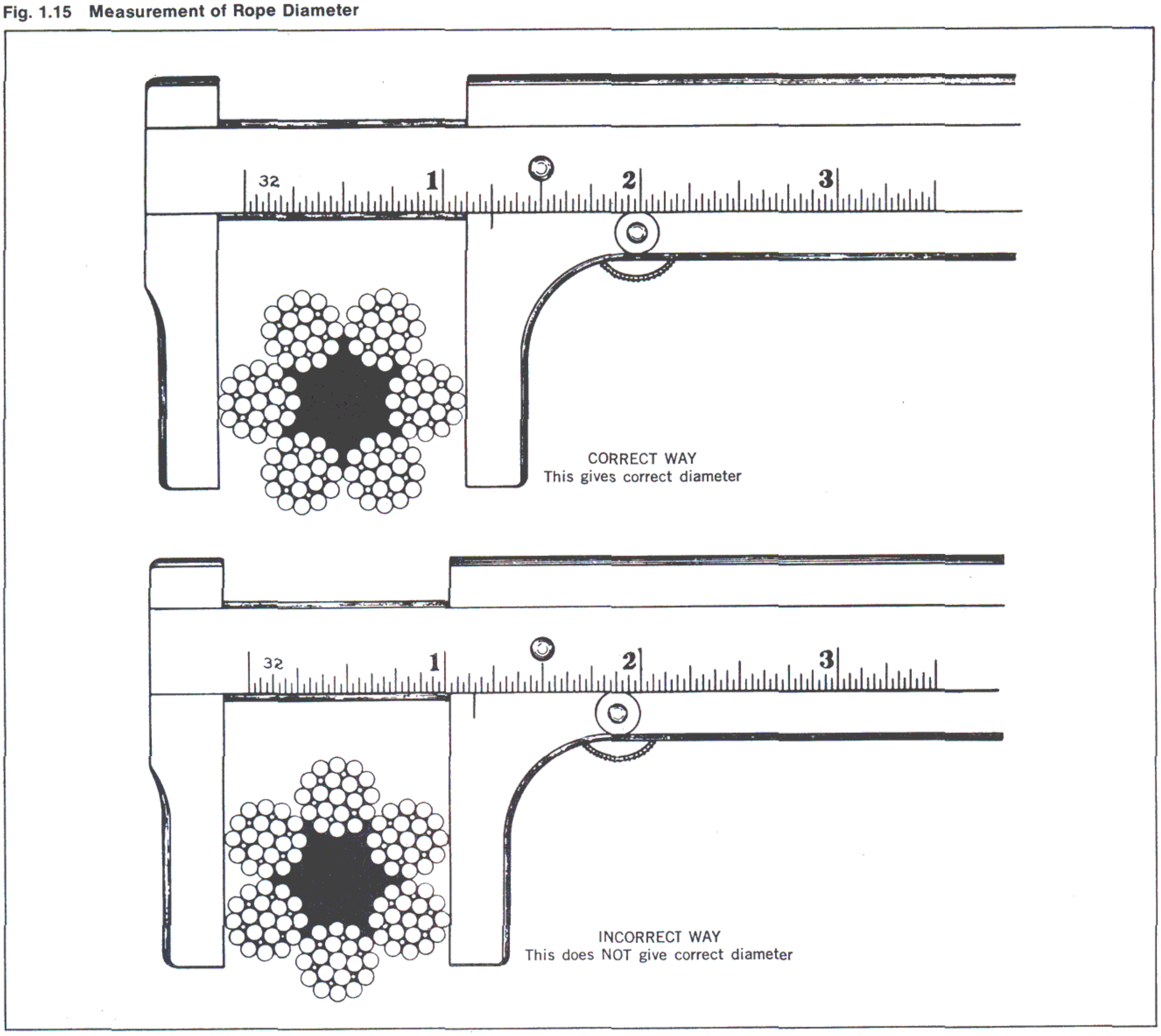
Fig. 1.14 Wire Core Ropes



SIZE:

The size of a wire rope is identified by its length in feet and its diameter in inches. The diameter is the distance measured between the widest points (Fig. 1.15). It is advisable to make three separate measurements on a 6 strand rope, and four measurements on an 8 strand rope.

Fig. 1.15 Measurement of Rope Diameter



Most new wire ropes measure slightly over their nominal diameter, as follows:

TABLE 1.2

DIAMETER TOLERANCES	
Nominal Rope Diameter (Inches)	Oversize (Inches)
0 – 3/4	+1/32
13/16 – 1-1/8	+3/64
1- 3/16 – 1-1/2	+1/16
1- 9/16 – 2-1/4	+3/32
2- 5/16 & Up	+1/8

FATIGUE AND ABRASION RESISTANCE:

The two most important factors to consider when selecting a wire rope are its fatigue and abrasion resistance because every rope in service is being slowly destroyed by fatigue and abrasion.

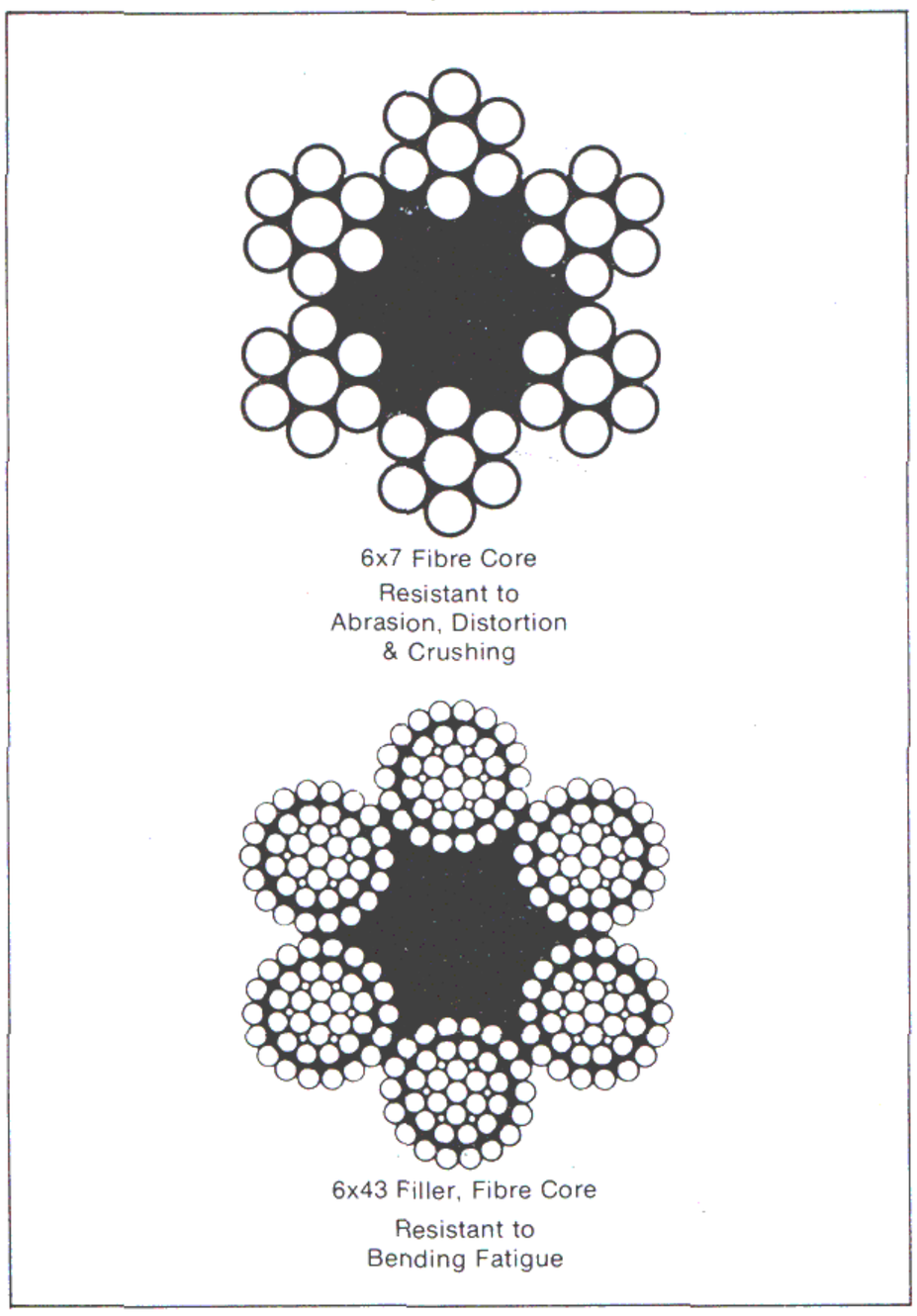
Fatigue is caused by constant bending of the rope over sheaves and around drums. When the load is applied to the rope, each wire is stretched with the result that they are drawn tightly together. As the wire rope is bent around a drum or sheave, there is a complex *movement of the tightly compressed wires.* This movement induces high stresses which may be continually reversing as the rope moves through a system of sheaves, resulting in failure of individual wires due to fatigue. This point can be illustrated by bending a piece of wire back and forth at one spot; the wire will soon break due to fatigue.

This same repeated bending and straightening of the individual wires as they pass over sheaves and drums initiates small cracks in the wires that increase in number and grow larger with continued bending. The process occurs in

all ropes but is accelerated if the drums and sheaves are small or if the rope is relatively inflexible.

In general, the smaller the wires and the more there are, the more flexible the rope. *Adequately sized drums and sheaves will re*duce the severity of the bending stresses and increase the number of bending cycles the rope can tolerate before it is severely fatigue weakened.

Fig. 1.16 Effect of Wire Size on Ability to Resist Abrasion, Distortion, Crushing, and Bending Fatigue



Abrasion occurs primarily on the outer surfaces of wire ropes and is caused by friction on sheaves, etc., and by dust and dirt acting as an abrasive between the rope and the sheaves and drums. Excess abrasion also occurs when the rope comes in contact with rough surfaces or sharp edges. The most difficult form of abrasion to overcome is that caused by the rotation of the wire rope as it runs over sheaves, and on drums with more than one layer of rope.

Abrasion resistance is gained by using rope having:

— Long exposed lengths of outer wires.

— Large diameter outer wires.

— High carbon and manganese content.

— High grade material and heat treatment in the steel.

Where abrasive conditions are severe Lang Lay or specially constructed Regular Lay rope should be used. The wires in the Lang Lay ropes are laid in the same direction as the strands; therefore greater lengths of wires on the surface or crown of the rope are in contact with the sheaves or drum than on Regular Lay ropes thus taking longer to wear through.

Seale rope construction has greater resistance to abrasion because it has larger outer wires which take longer to wear through. It should be noted, however, that the larger wires *tend to crack and break because of their great* stiffness. Because of this, Seale rope should not be used unless it is specifically recommended for the job by a rope manufacturer who knows the conditions.

The ability of the rope to withstand distortion and crushing is governed principally by the use of large outer wires and wire cores to increase the resistance to abuse. (Fig. 1.16)

The ideal rope for hoisting purposes provides a medium combination of these properties. For special conditions, a construction which favours the quality most necessary to the installation must be selected at a sacrifice of other qualities. (Fig. 1.17)

SAFETY FACTORS:

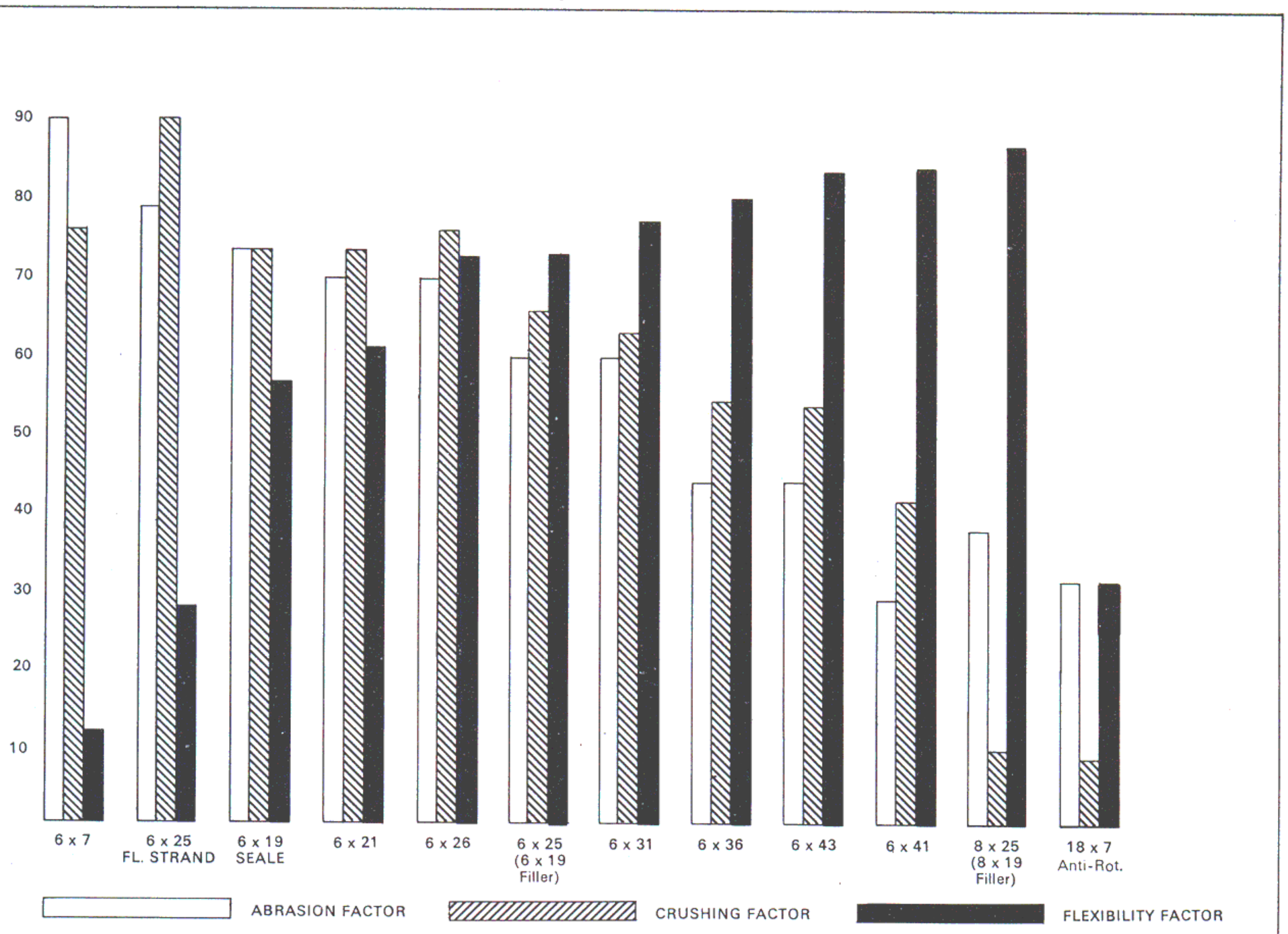
To guard against failure of a wire rope in service, the actual load on the rope should only be a fraction of the breaking load. To account for all the stresses placed on a rope during a hoisting operation and to provide the margin of strength necessary to safely handle loads and guard against accidents, it is necessary for the rope to have a "Factor of Safety".

In its simplest form the Factor of Safety is defined as follows:

$$\text{Factor of Safety} = \frac{\text{Catalogue Breaking Strength of the Rope}}{\text{Maximum Safe Working Load}}$$

For rigging ropes (unlike machine ropes mentioned on page 1), the **minimum acceptable factor of safety is 5**, and when used on equipment that is intended to carry personnel it is 10.

Fig. 1.17 Comparison of Mechanical Properties of Various Ropes



COMPARISON CHART
Abrasion Resistance/Crushing Resistance/Flexibility

The maximum safe working load is calculated as follows:

$$\text{Max. Safe Working Load} = \frac{\text{Catalogue Breaking Strength of the Rope}}{\text{Factor of Safety}}$$

$$= \frac{\text{Catalogue Breaking Strength}}{5}$$

EXAMPLE: If the wire rope catalogue gives the breaking strength of the rope as 10 tons, the maximum safe working load is:

$$\text{Max. S.W.L.} = \frac{10 \text{ tons}}{5} = 2 \text{ tons.}$$

Too often the factor of safety is treated as "reserve strength" and used for additional capacity. **It is not!**

The factor of safety accounts for:

- Reduced capacity of the rope below its stated breaking strength due to wear, fatigue, corrosion, abuse, and variations in size and quality.
- End fittings and splices which are not as strong as the rope itself.
- Extra loads imposed by acceleration and inertia (starting, stopping, swinging and jerking of the load).
- Increases in line pull (load on the rope) due to friction of the rope passing over sheaves.
- Inaccuracies in the weight of the load.
- Inaccuracies in the weight of the rigging.
- Reduced strength of the rope due to bending over sheaves.

This list of variables is not complete. It is intended to show why a factor of safety is required and why it must **never** be lowered.

SAFE WORKING LOADS:

The following tables of safe working loads (Tables 1.3 - 1.8) are based on CSA Standard G4-1967, Steel Wire Rope — General Purpose, and are provided for the most commonly used wire rope classifications. The tables are for reference purposes only. Check your rope manufacturer's ratings before determining the safe working loads as they may differ from the tables. If the manufacturer quotes his rope's capacity in terms of breaking strength, you must divide that figure by the factor of safety to get the safe working load (SWL).

$$\text{Max. S.W.L.} = \frac{\text{Catalogue Breaking Strength}}{\text{Factor of Safety}}$$

Because of the difficulty in remembering the safe working loads of the most common wire ropes, the following rule of thumb should be used to compute the SWL in tons.

SWL = ROPE DIAMETER X ROPE DIAMETER X 8

Examples:

(a) 1/2 inch diameter rope.
SWL = 1/2 x 1/2 x 8 = 2 Tons.

(b) 5/8 inch diameter rope.
SWL = 5/8 x 5/8 x 8 = 3.125 Tons.

(c) 1 inch diameter rope.
SWL = 1 x 1 x 8 = 8 Tons.

TABLE 1.3

6 x 7 Classification Round Strand Group: The ropes included in this group are composed of large wires, have limited flexibility, are resistant to abrasive wear and are not suited to frequent bending.

Rope Diameter (Inches)	Maximum Safe Working Load (Tons) Safety Factor = 5			
	Grade 100/110 Plow		Grade 110/120 Improved Plow	
	Fibre Core	Steel Core	Fibre Core	Steel Core
1/4	.44	.47	.50	.54
5/16	.86	.92	.94	1.00
3/8	1.08	1.16	1.14	1.23
7/16	1.60	1.72	1.70	1.83
1/2	2.08	2.24	2.28	2.45
9/16	2.56	2.75	2.84	3.05
5/8	3.20	3.44	3.50	3.76
3/4	4.60	4.95	5.00	5.38
7/8	6.40	6.88	7.00	7.53
1	8.20	8.82	8.80	9.46
1 1/8	10.20	10.97	11.20	12.00
1 1/4	12.60	13.55	13.80	14.84
1 3/8	15.80	17.00	17.40	18.70
1 1/2	18.80	20.20	20.20	21.72

TABLE 1.4

6 x 19 Classification Round Strand Group: The ropes included in this group have good resistance to abrasion and better flexibility than the 6 x 7 group. This classification covers ropes with 6 strands having 8 to 26 wires per strand.

Rope Diameter (Inches)	Maximum Safe Working Load (Tons) Safety Factor = 5			
	Grade 100/110 Plow		Grade 110/120 Improved Plow	
	Fibre Core	Steel Core	Fibre Core	Steel Core
3/16	.26	.28	.30	.32
1/4	.48	.52	.54	.58
5/16	.76	.82	.82	.88
3/8	1.08	1.16	1.20	1.28
7/16	1.40	1.50	1.60	1.72
1/2	2.00	2.14	2.20	2.36
9/16	2.34	2.50	2.66	2.86
5/8	3.00	3.22	3.30	3.54
3/4	4.30	4.62	4.76	5.10
7/8	5.66	6.08	6.40	6.89
1	7.60	8.17	8.34	8.96
1 1/8	9.70	10.42	10.60	11.38
1 1/4	12.00	12.90	13.10	14.10
1 3/8	14.70	15.80	16.20	17.40
1 1/2	17.70	19.00	19.20	20.64
1 5/8	20.60	22.14	22.60	24.28
1 3/4	23.80	25.58	26.00	27.94
1 7/8	27.60	29.66	30.40	32.68
2	30.80	33.10	33.80	36.32
2 1/4	38.60	41.48	42.00	45.14
2 1/2	47.00	50.52	52.00	55.90
2 3/4	56.00	60.20	61.00	65.56

TABLE 1.5

6 x 25 Classification Flattened Strand Wire Rope: This classification covers ropes with 6 strands closed around a fibre or independent wire rope core and includes ropes having 8 to 12 outer wires per strand, 10 to 12 inner wires per strand with either a solid or built-up triangular center. Following values are for fibre core ropes; add 7 1/2% for wire rope core.

Rope Diameter (Inches)	Maximum Safe Working Load (Tons) Safety Factor = 5		
	Grade 110/120 Improved Plow	Grade 115/125 Special Improved Plow Type I	Grade 120/130 Special Improved Plow Type II
1/2	2.40	—	—
9/16	3.00	—	—
5/8	3.70	—	—
3/4	5.34	5.54	5.74
7/8	7.20	7.46	7.74
1	9.40	9.74	10.10
1 1/8	11.90	12.34	12.80
1 1/4	14.74	15.28	15.84
1 3/8	18.20	18.80	19.40
1 1/2	21.60	22.40	23.20
1 5/8	25.40	26.30	27.20
1 3/4	29.30	30.30	31.40
1 7/8	33.90	35.10	36.40
2	38.00	39.40	40.80

TABLE 1.6

6 x 37 Classification Round Strand Group: The ropes included in this group have excellent flexibility, reasonable resistance to crushing and are well adapted to high speed and multiple reeving applications. This classification covers ropes with 6 strands having 27 to 49 wires per strand.

Rope Diameter (Inches)	Maximum Safe Working Load (Tons) Safety Factor = 5			
	Grade 100/110 Plow		Grade 110/120 Improved Plow	
	Fibre Core	Steel Core	Fibre Core	Steel Core
1/4	.44	.46	.50	.52
5/16	.76	.80	.80	.86
3/8	1.00	1.06	1.10	1.18
7/16	1.38	1.48	1.50	1.60
1/2	1.84	1.96	2.00	2.14
9/16	2.28	2.44	2.50	2.68
5/8	2.90	3.10	3.20	3.44
3/4	4.04	4.34	4.44	4.76
7/8	5.50	5.90	6.04	6.48
1	7.20	7.74	7.90	8.48
1 1/8	8.80	9.46	9.80	10.52
1 1/4	11.00	11.82	12.20	13.10
1 3/8	13.70	14.72	14.90	16.00
1 1/2	16.40	17.62	18.00	19.74
1 5/8	19.30	20.74	21.10	22.68
1 3/4	22.00	23.64	24.20	26.00
1 7/8	25.80	27.72	28.40	30.52
2	28.40	30.52	31.00	33.32
2 1/4	36.40	39.12	40.20	43.20
2 1/2	45.00	48.36	49.00	52.66
2 3/4	53.80	57.82	58.60	63.00

TABLE 1.7

8 x 19 Classification Round Strand Group: This classification covers ropes with 8 strands each having 8 to 26 wires per strand.

Rope Diameter (Inches)	Maximum Safe Working Load (Tons) Safety Factor = 5			
	Grade 100/110 Plow		Grade 110/120 Improved Plow	
	Fibre Core	Steel Core	Fibre Core	Steel Core
1/4	.40	.43	.44	.47
5/16	.62	.67	.68	.73
3/8	.92	.99	1.02	1.10
7/16	1.26	1.35	1.40	1.51
1/2	1.64	1.76	1.80	1.94
9/16	2.06	2.21	2.30	2.47
5/8	2.50	2.69	2.82	3.03
3/4	3.56	3.83	4.00	4.30
7/8	4.80	5.16	5.40	5.81
1	6.24	6.71	7.00	7.53
1 1/8	7.88	8.47	8.86	9.52
1 1/4	9.68	10.40	10.90	11.72
1 3/8	11.66	12.53	13.10	14.08
1 1/2	13.80	14.84	15.60	16.77

TABLE 1.8

18 x 7 Non-Rotating Construction Round Strand Wire Rope: This construction consists of an outer rope of 12 strands laid Right Lay over an inner rope of 6 strands laid Left Lay around a fibre core. All strands have 7 wires.

Rope Diameter (Inches)	Maximum Safe Working Load (Tons) Safety Factor = 5	
	Grade 100/110 Plow	Grade 110/120 Improved Plow
5/16	.69	.77
3/8	1.02	1.12
7/16	1.38	1.52
1/2	1.78	1.95
9/16	2.26	2.48
5/8	2.80	3.06
3/4	3.97	4.35
7/8	5.38	5.89
1	6.99	7.66
1 1/8	8.80	9.60
1 1/4	10.80	11.79
1 3/8	13.01	14.19
1 1/2	15.41	16.80

NON-ROTATING ROPES:

These ropes (Fig. 1.18) warrant special consideration, handling and care since they are much more easily damaged in service than any other type of rope.

The non-rotating characteristic is secured by building into the rope two layers of strands, one having Right Lay and the other Left Lay.The tendency of one layer of strands to rotate in one direction is counteracted by the tendency of the other layer of strands to rotate in the opposite direction. (Fig. 1.19)

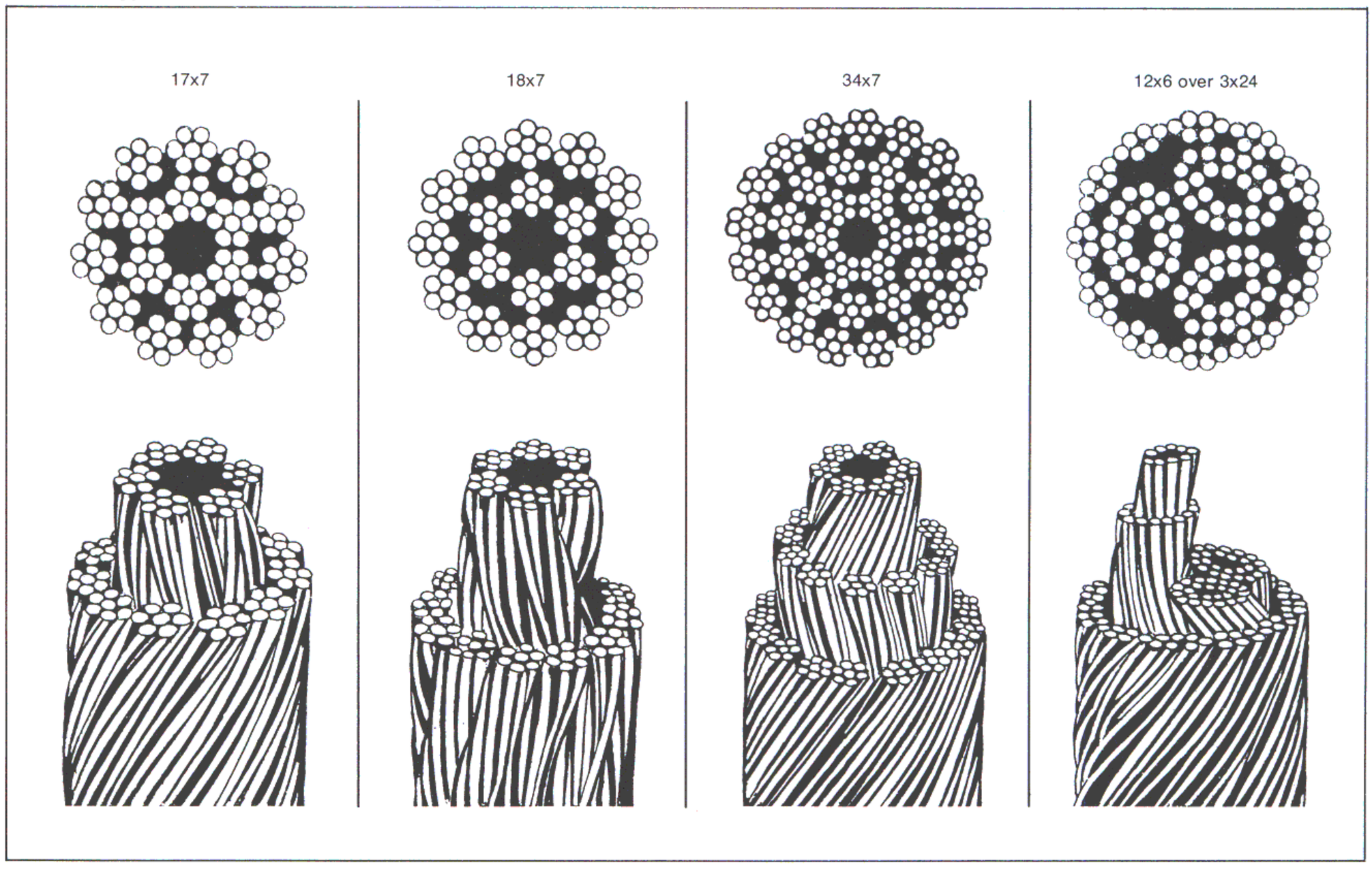
They require very careful handling prior to, during and after installation if good service is to be obtained. The manufacturer's lay length should not be disturbed when installing, by twisting or turning the ropes, otherwise core slippage may occur. As non-rotating ropes are by their design, counter-balanced, they have no tendency to twist or spin either way. However, they are so pliable that "turn", in or out, can easily be imparted. If "turns" are put in to these ropes then the outer strands become shorter in their initial length, the core slips along and may protrude from the rope, the outer strands become overloaded as the core then is not taking its share of the load. When "turns" are taken out of these ropes core slip again occurs, the outer strands bulge out or "Bird Cage" and the inner layers or core will become overloaded by taking all of the load.

Extreme care must be taken, when securing a plain end, to ensure that the entire cross section of the rope is firmly secured. Otherwise core slippage can occur (Fig. 1.20) and the wire core may draw (or pull) inside the rope's end and the surplus core protrude elsewhere through the outer layer. The outer layer of the strands will become overloaded if the core does not take the load.

When a non-rotating rope is to be cut, secure seizings of annealed wire should be placed tightly on both sides of the point where the cut is to be made, otherwise the balance of equal tension in all of the strands placed in the rope by the manufacturer may be disturbed by strand or core slippage. Seizings for these ropes should be put on a short distance apart, and the length should be at least equal to $1^1/_2$ or 2 times the diameter of the rope. There should be three on each side of the cut for ropes up to 1" in diameter, and four on each side when over 1" in diameter.

Core slippage may also occur when bending the rope around a thimble prior to splicing; the outer strands may "Bird Cage" or open

Fig. 1.18 Typical Multi-Strand Non-Rotating Constructions



up. For this reason thimbles of larger size than those specified for similar size ropes should be used. The rope should also be tightly served for the length of the rope around the thimble, plus twice the length for seizing. The seizing should be put on the two parts of rope at the throat of the thimble immediately after securing the thimble into the served eye of rope. The length of the throat seizing should be equal in length to the circumference of the rope. (Fig. 1.21)

Because of the small radius of wedge sockets and the possibility of severe core slippage, wedge socket anchorages should not be used on non-rotating ropes unless extreme care is used in their installation and the rope end is very tightly seized.

Where swaged end fittings are used, because of the possibility of core slippage, it is preferable to press the swaging in the hydraulic press first and after applying the annealed wire seizings previously mentioned, cut off the rope after swaging is completed. This may leave a protrusion of rope beyond the swaged fitting but this is much preferable to core slippage.

To secure optimum non-rotating characteristics the manufacturers of non-rotating rope recommend that they be used with a factor of safety of approximately 8 or 10 to 1. Some limited field experience has shown, however, that these ropes perform satisfactorily and safely on both single and multi-part lines (but not boom hoist reeving) on cranes at factors of safety of 3.5 to 1 providing they are not abused and are given extremely careful inspections.

Fig. 1.19 How the Anti-Rotational Characteristic is Built Into a Non-Rotating Rope

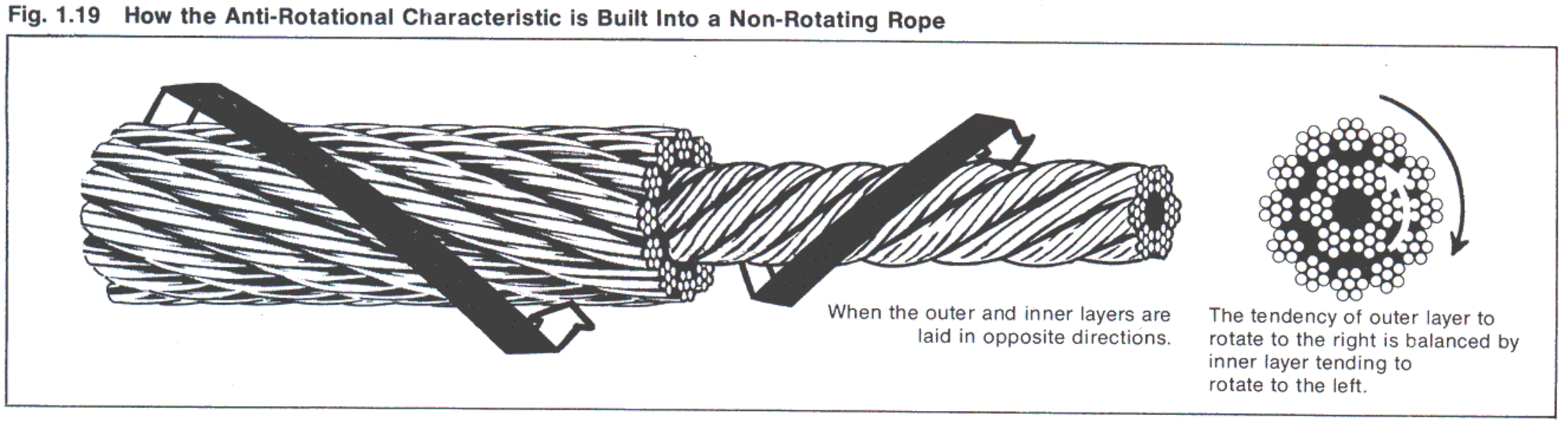


Fig. 1.20 Core Slippage in a Non-Rotating Rope

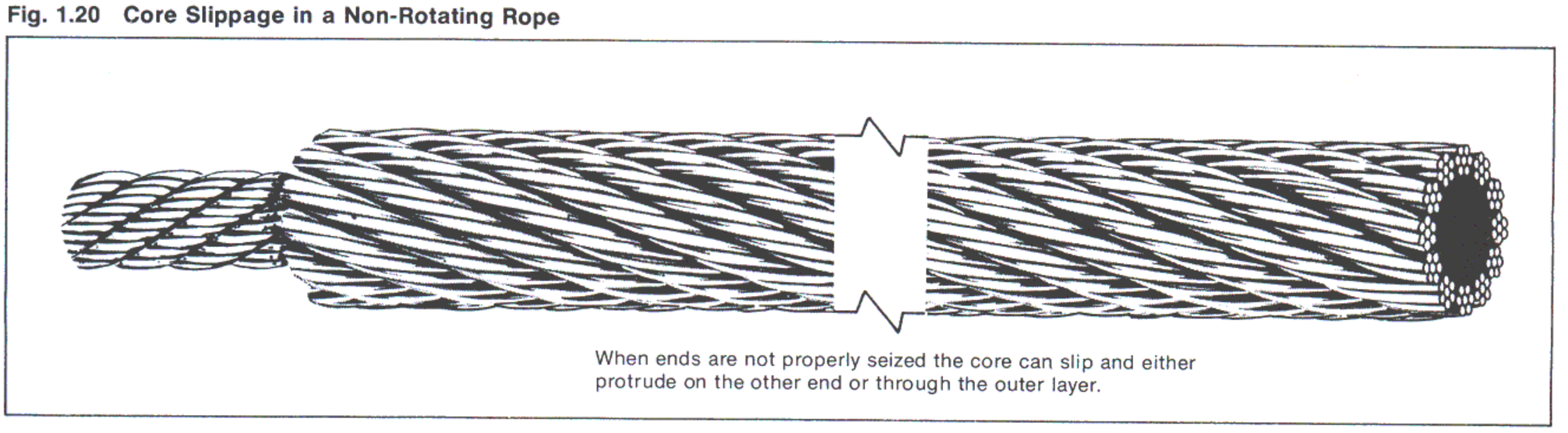
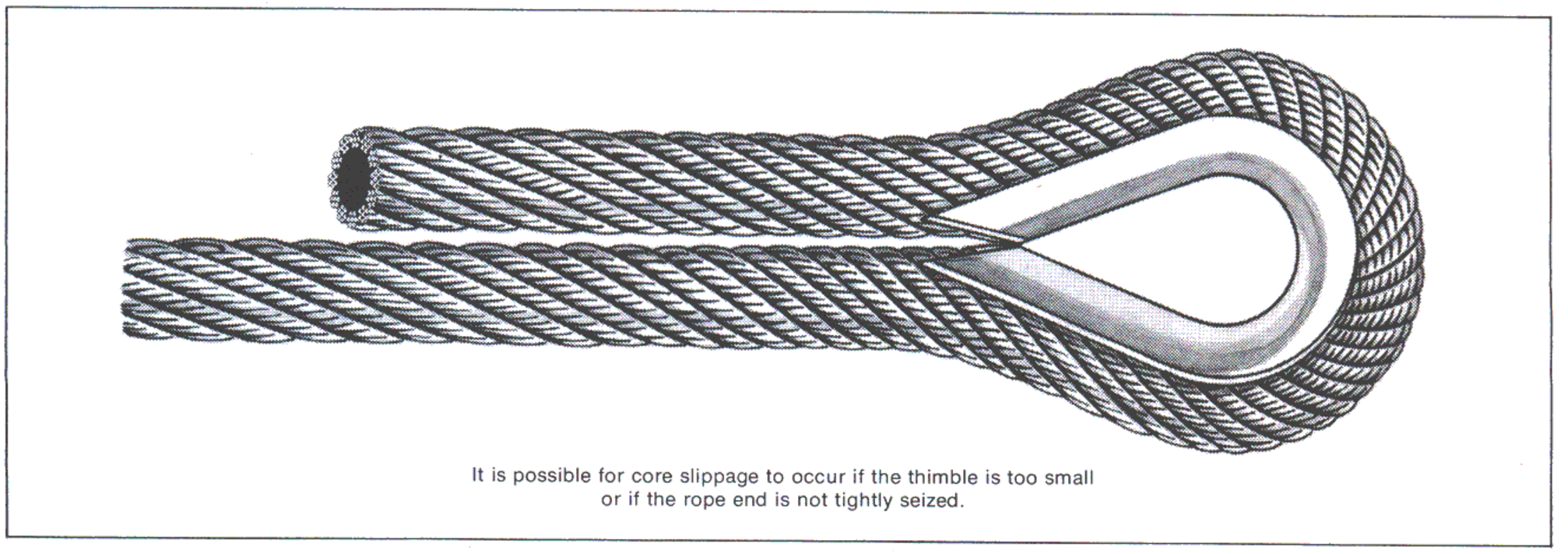


Fig. 1.21 Core Slippage in a Non-Rotating Rope



INSTALLATION

Removing from shipping reel or coil: When removing the rope from the shipping reel or coil, the reel or coil must rotate as the rope unwinds. Any attempt to remove a rope from a stationary reel or coil will almost always result in a kinked rope that is ruined beyond repair at that point.

One of the three following methods should be used: (Fig. 1.22)

— Mount the reel on a shaft supported at each end by jacks or blocks. Grasp the free end of the rope and walk away from the reel which will rotate as the rope unwinds. A piece of planking should be jammed against one of the reel flanges to act as a brake to keep the rope tight and prevent the reel from overwinding.

— Turn the reel onto its flanges, hold one end of the rope and roll the reel away from the end. When it is necessary to lay a rope out on the floor, ensure that the surface is clean.

— The reel may be placed on its side, with one flange on a turntable. As the rope is pulled off, the reel turns on the turntable.

When unwinding a coiled rope use either of the two following methods: (Fig. 1.23)

— Secure or hold the free end of the rope and roll the coil of rope along the ground like a hoop. Ensure that all rope remaining in the coil is held together so that no tight coils or kinks occur. Make certain that the floor is clean.

Fig. 1.22 Proper Methods of Removing Rope From a Reel

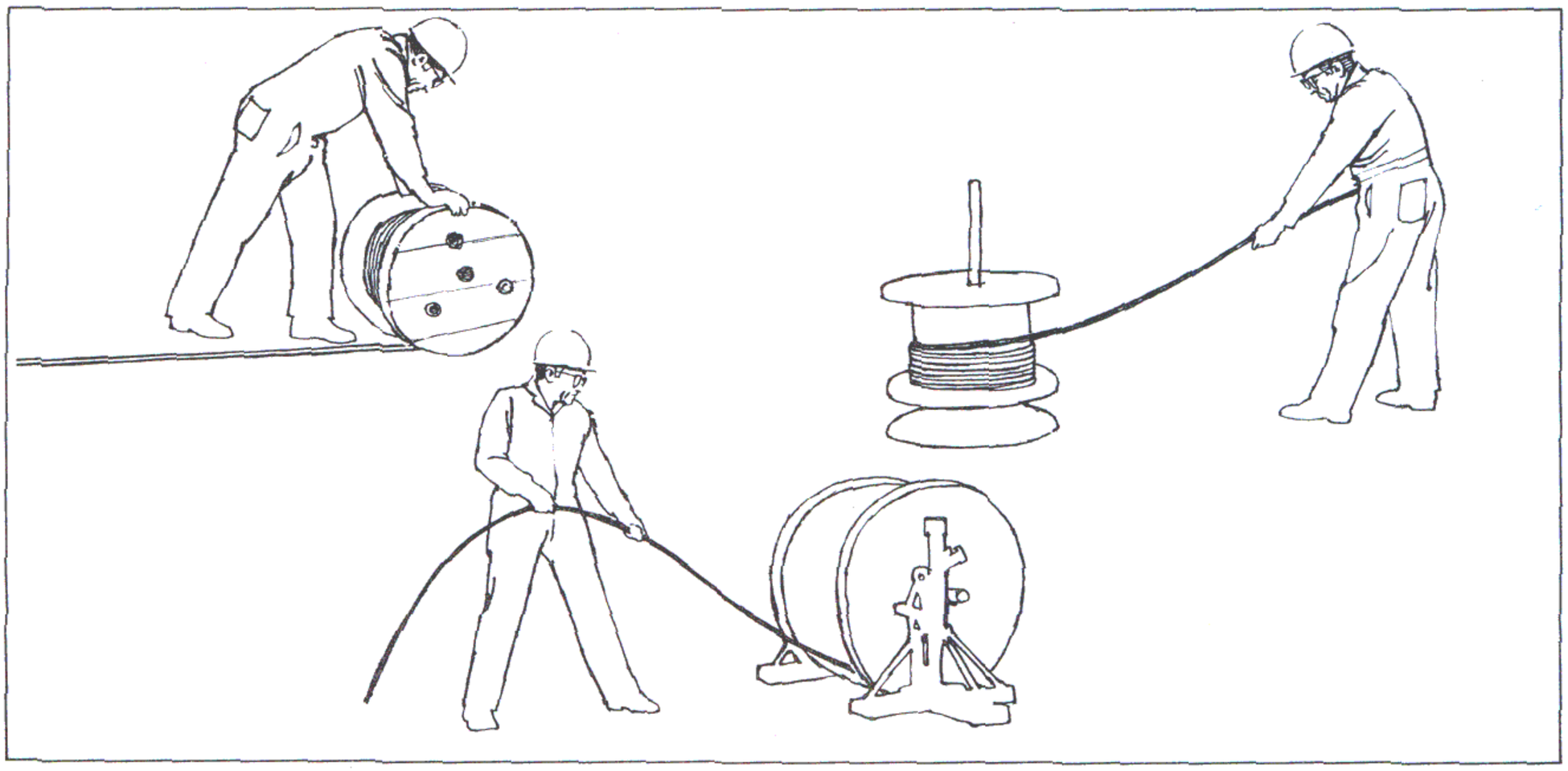
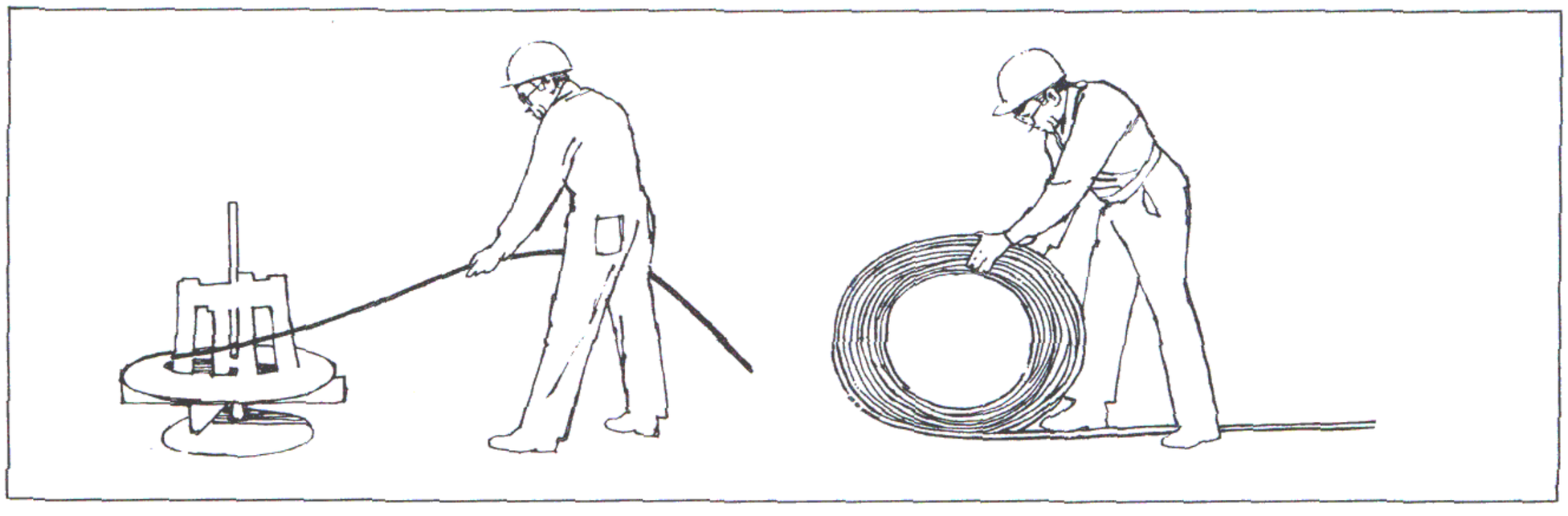


Fig. 1.23 Proper Methods of Removing Rope From a Coil



— Lay the coil on a turntable and pull off the free end as the coil and turntable revolve. The turntable should have a centre core of approximately the same diameter as the eye in the coil. Make certain that the rope turns don't flip up and fall over the center core.

Winding onto drum or reel: When winding a rope onto a machine drum or onto another reel, make certain that it bends in the same direction. Re-reel from the top of one reel to the top of another, or from the bottom of one reel to the bottom of another. Follow the same procedure when winding onto machine drums. It is also necessary to apply a tensioning load to the rope to achieve good spooling. A simple brake such as a plank, rigged to bear against the reel flanges, will provide ample rope tension throughout the winding. (Fig. 1.24)

Cutting wire rope: Before cutting any wire rope (including preformed rope) apply the correct number of seizings, as per table 1.10, on each side of the proposed cut, then cut the rope.

Locating drum anchorage point: Locate the rope anchorage point on the machine drum in relation to the direction of lay of the rope, as follows:

— Find out if the rope is to be overwound or underwound on the drum. (Fig. 1.25)

If you are installing a **right** lay rope, visualize yourself as being behind the drum; make a fist with your **right** hand to simulate the drum and extend your forefinger to simulate the rope. For overwound rope keep the back of your fist up (see how your extended finger is simulating the rope coming off the top of the drum). For underwound rope turn your palm up and your finger simulates the rope coming off the bottom of the drum. Your extended finger always points to the flange to which the rope must be secured. For **left** lay ropes use exactly the same procedure only use your **left** hand. (Fig. 1.26)

Fig. 1.24 Methods of Winding Rope from Reel to Drum or Reel to Reel

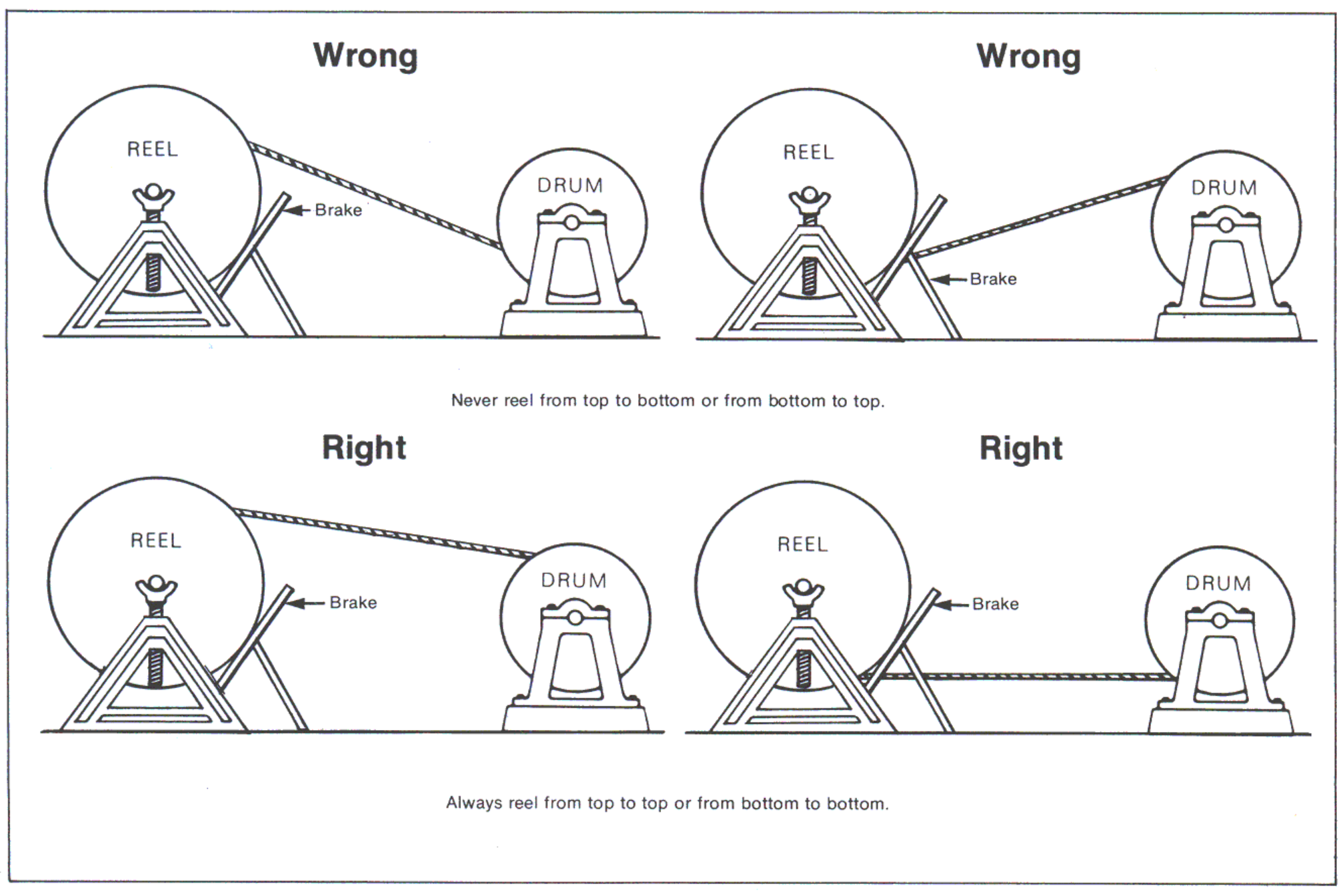


Fig. 1.25 Difference Between Overwound and Underwound Drums

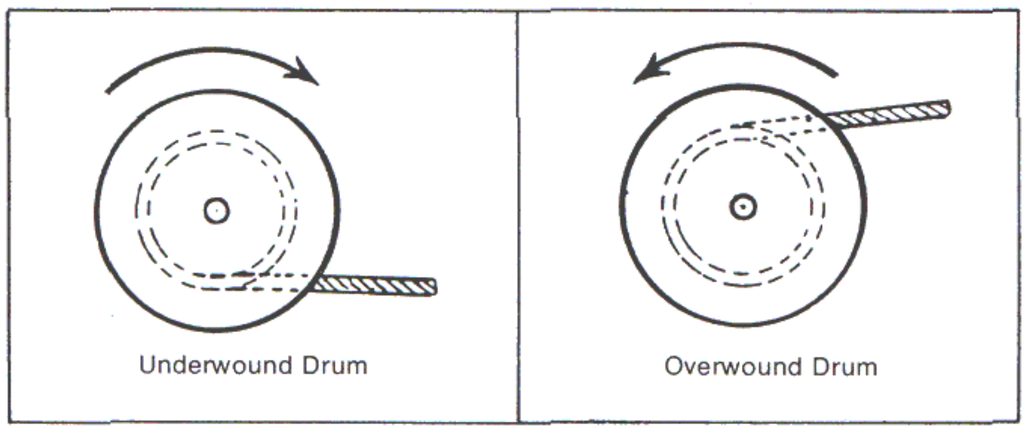


Fig. 1.26 Proper Method of Locating Rope Anchorage Point on a Drum

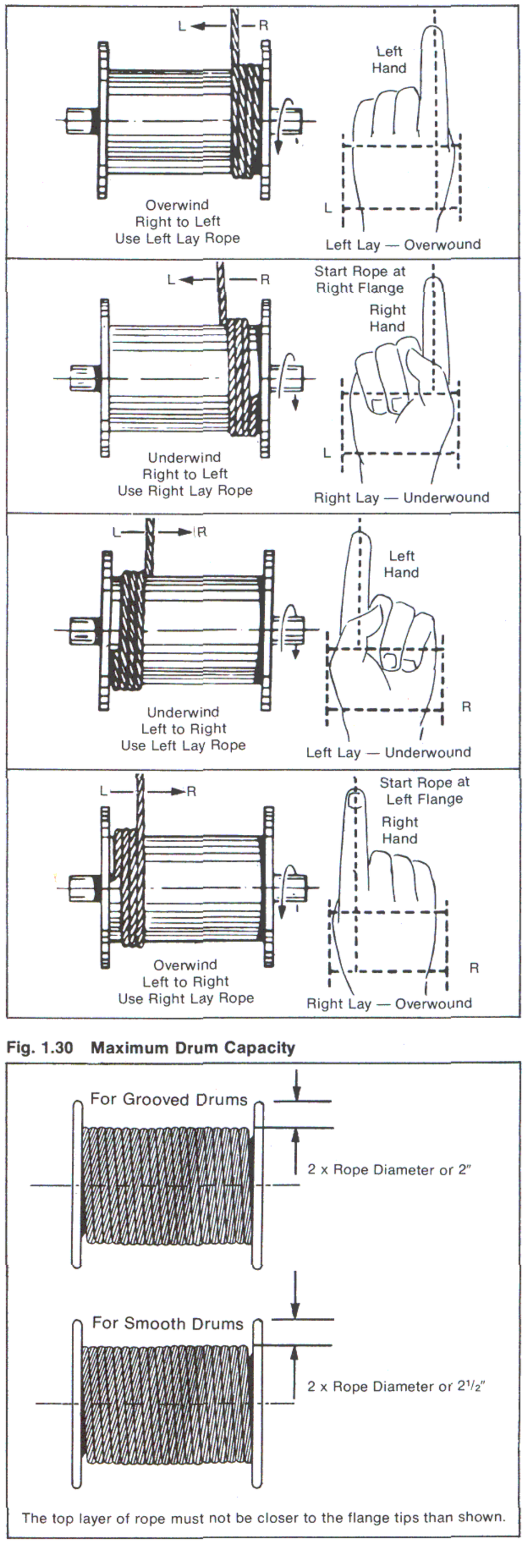


Fig. 1.27 Tapered Starting Piece to Assist Even Winding

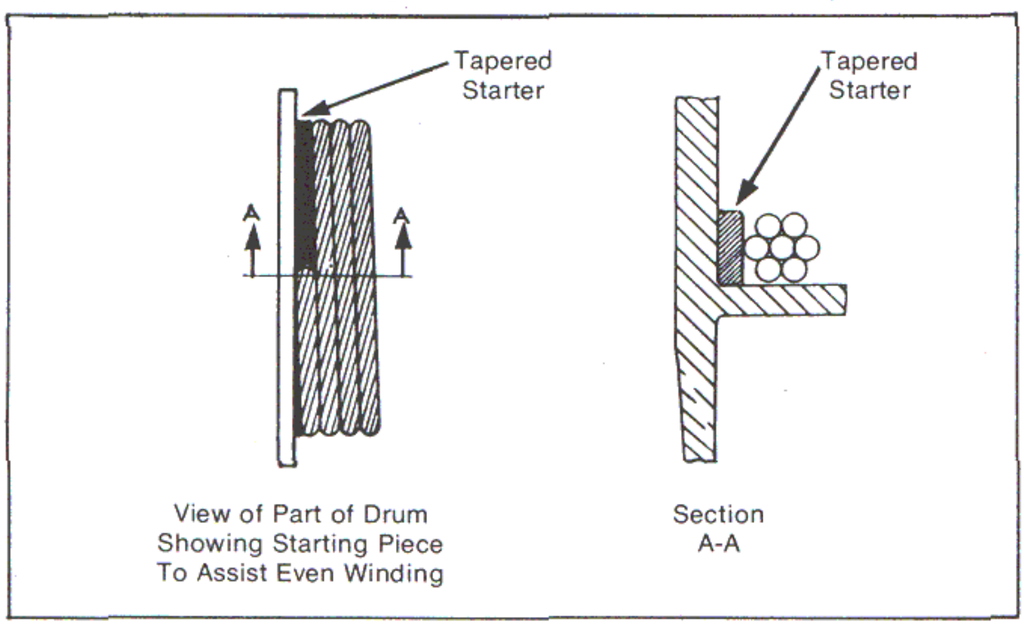


Fig. 1.28 Effect of Improper First Layer Winding on Rope Life

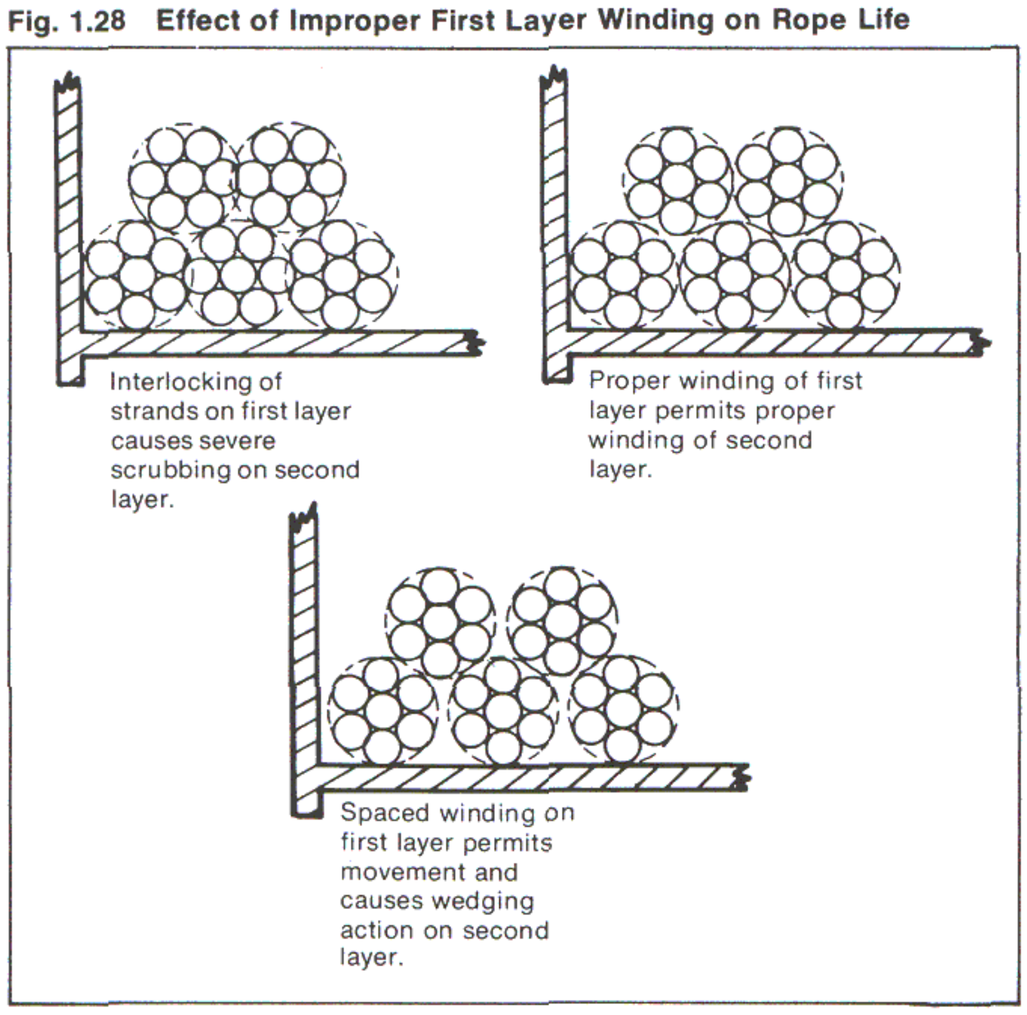


Fig. 1.29 Tapered Steel Lifter to Assist Even Winding

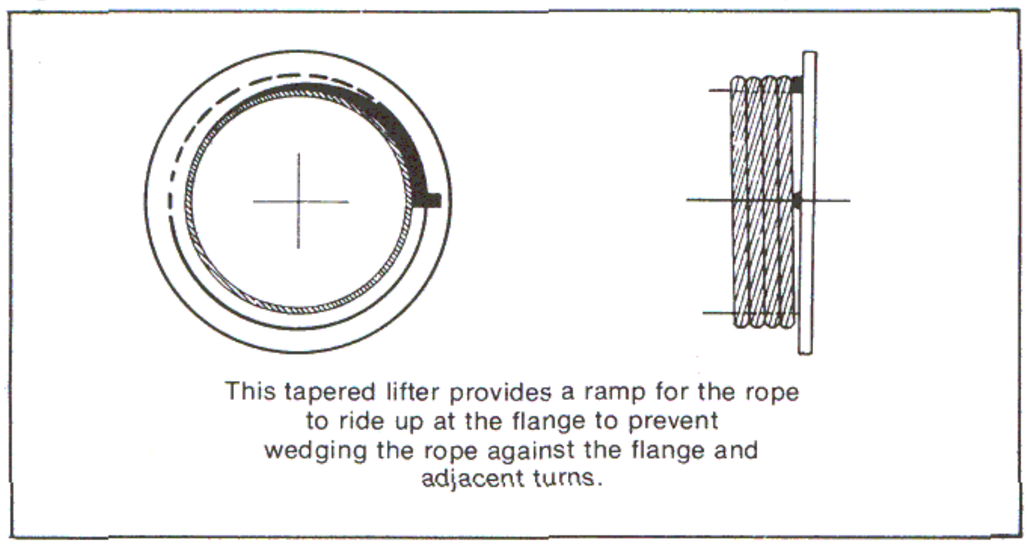


Fig. 1.30 Maximum Drum Capacity

Winding on flat faced drums: On a flat faced drum, it is most important that the rope wind in a straight helix at its proper angle. This can be assisted by means of a steel starting piece cut in a taper to fill the space between the first turn and the flange. (Fig. 1.27)

Precautions should also be taken at the point where the rope enters the face of the drum at the anchorage to avoid a knuckle forming in the rope. This is particularly important for multiple-layer winding where the over-winding turn would cause hammering and rapid fatigue in the knuckle section.

Turn first layers tight and true: When installing new rope it is important that all turns of the first layer on the drum be tight and true. Open or wavy winding will result in serious damage to multiple windings. Adjacent turns should be tapped against each other with a soft metal or wooden mallet, but not so that the strands interlock. The succeeding layers of rope should wind in the groove formed between adjacent turns of the preceding layer of rope. Wire rope must never be allowed to cross-wind. (Fig. 1.28)

Rope length: Ensure that the correct length of rope is fitted. This is particularly important as it may be necessary to fit specific lengths of rope for particular applications and rope reeving combinations. Too short a rope could result in the rope completely paying out and the rope anchorage on the drum having to carry the full load. On the other hand, too long a rope could exceed the drum's spooling capacity, causing it to ride over the flanges with resulting severe damage, crushing or complete failure. It is good practice to check the rope length whenever the structure is changed, rope is changed or reeving altered.

Number of rope layers on drum: As far as is practical, the drum should accommodate all the rope in one smooth layer. More than 3 layers of rope result in reduced rope life and may cause crushing and severe abrasion of the rope on the bottom layer as well as at the end of any layer where pinching occurs.

Multiple-layer winding: On drums with multiple-layer winding, difficulty may be experienced where, as the rope rises from the first to the second layer, wedging action and severe abrasion take place. This can be overcome by the use of a tapered steel lifter to raise the rope from the first to the second layer. (Fig. 1.29)

Tight winding: The whole rope should be wound on the drum tightly and correctly as this will facilitate good winding during its full life. A poor start may mean poor winding and short life and, therefore, the extra care required for proper installation is well justified.

Spooling capacity: With the hook or load at its lowest point there should be at least 2 or 3 full turns of rope on the drum and the spooling capacity must not be exceeded when the hook is at its highest point. The flanges on grooved drums must project either twice the rope diameter or 2 inches beyond the last layer of rope, whichever of the two is the greater. The flanges on ungrooved drums must project either twice the rope diameter, or $2^1/_2$ inches beyond the last layer of rope, whichever of the two is the greater. (Fig. 1.30)

Condition & size of sheaves & drums: Always check the condition and dimensions of the sheave grooves before the new rope is placed in service. Table 4.4 on page 99 provides the sheave groove tolerances for new rope installations where the rope is normally oversized.

When the groove diameter is slightly larger than the nominal rope diameter it provides maximum support for the rope. If the groove is too large it cannot provide adequate support and the rope may become flattened. Alternatively, too small a groove will pinch and bind the rope, causing abrasion and burning. (Fig. 1.31)

The diameter of a rope diminishes in size after lengthy service due to abrasion and loss of core support. An undersized rope may wear an undersized groove in the sheave and if a new rope is installed in the worn groove it may become wedged between the flanges. (Fig. 1.32)

To ensure a long and efficient rope life the grooves should be smoothly contoured, free of surface defects and possess rounded edges. edges.

The tread diameter of the sheave or drum determines the bending stress in the rope and the contact pressure between it and the sheave or drum surface. Too small a sheave or drum subjects the rope to excessive bending stresses with the resulting fatigue of individual wires.

A lightly loaded rope subjected to many small diameter bends may develop fatique in the wires adjacent to the core of the rope — a condition almost impossible to detect.

Fig. 1.31 Matching of Ropes and Sheaves

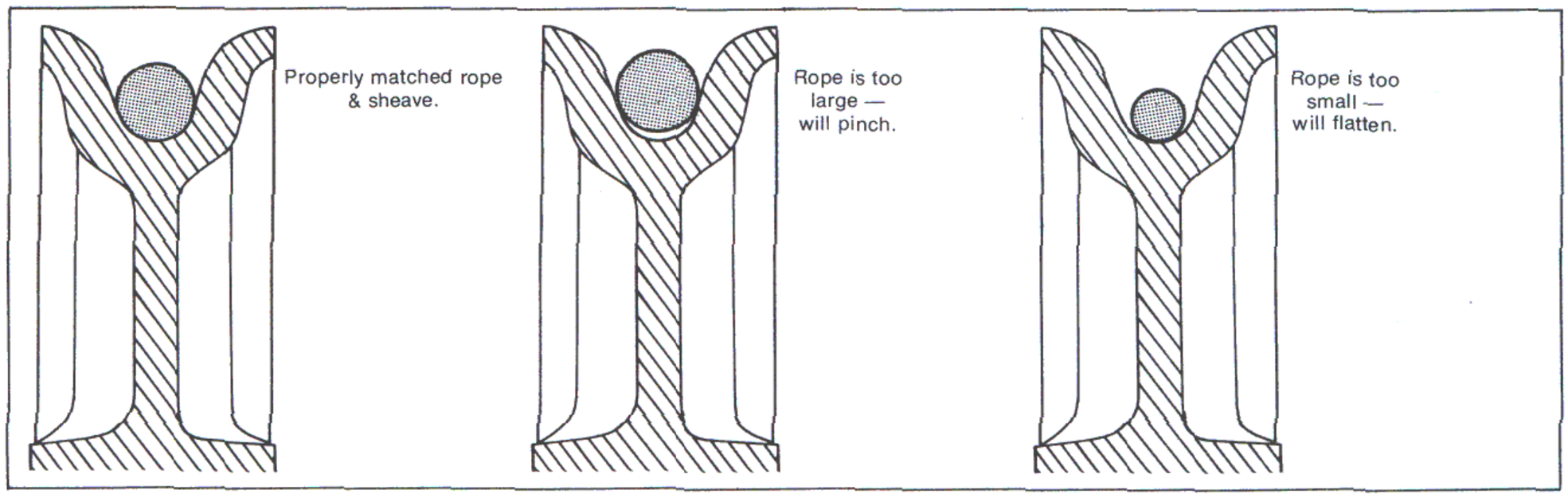
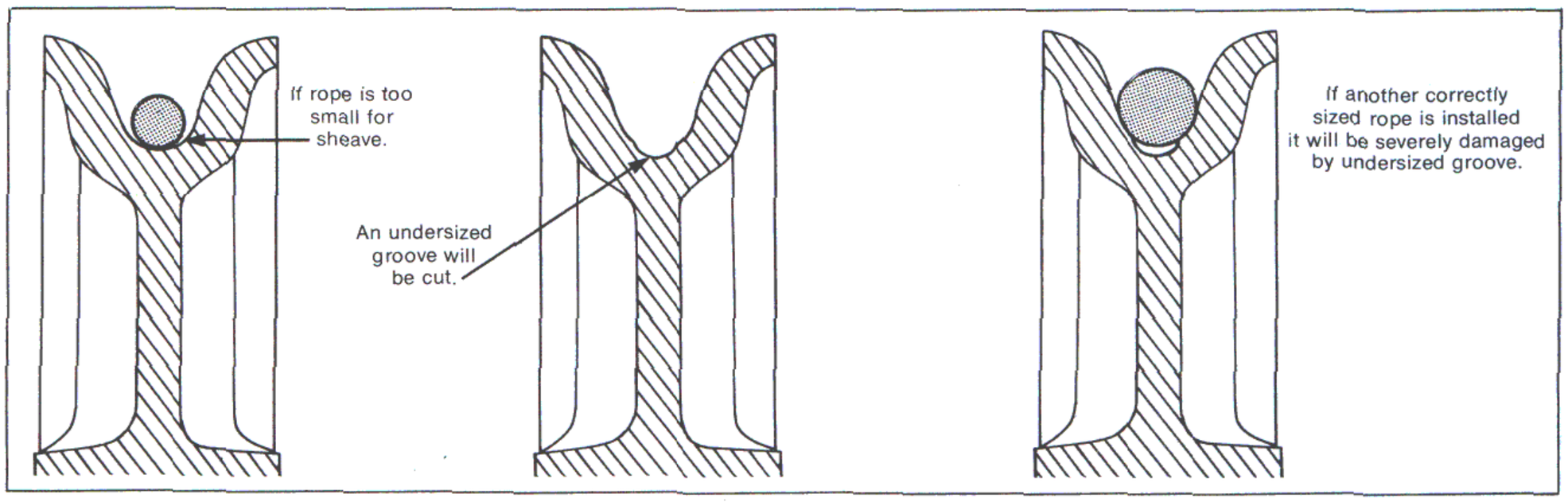


Fig. 1.32 Effect of Improper Match between Rope and Sheave



Heavy bearing pressures introduced by a small sheave may cause wear to both sheave and rope. On applications where the major source of rope deterioration is that caused through bending or bearing pressures, large diameter sheaves or drums should be employed to extend rope life.

Definite sheave and drum diameters cannot be specified to cover all types of operation, *but table 4.3 on page 99 may be used as a* guide.

Sheave alignment: After a rope change check that the sheaves are all properly aligned and running true. If they are not then considerable wear of both rope and sheaves will result with potentially disastrous consequences. A ready indication of poor alignment is rapid wear of one flange of the sheave. Poor alignment of the main sheave may also result in poor winding on the drum.

Fleet angles: When a new installation is designed, the first or main sheave after the drum must be placed so as to give the right fleet angle.

The fleet angle is that angle between the line drawn from the center of the sheave through one flange of the drum and a line through the center of the sheave. Due to offsetting of the drum it is possible, in some installations, that the fleet angle on one side of the drum may be larger than the other; it is the larger of the two which must be considered. (Fig. 1.33)

The generally accepted standards for fleet angles are:

— Grooved Drums — 1/4° - 1 1/4°.

— Smooth Drums — 1° - 2°.

The fleet angle relationships are shown graphically in the following illustration. The shaded areas are the proper range of fleet angles for both grooved and smooth drums. (Fig. 1.34)

If the fleet angle is larger than the recommended limits, the rope may rub badly against the flanges of the groove in the sheave or be subjected to crushing and abrasion on the drum. Too small a fleet angle will cause the rope to pile up against the flange head — damaging both rope and equipment. (Fig. 1.35)

Severe scuffing of grooved drums can result when the rope wears against the groove walls. This action also bruises and crushes the rope.

Fig. 1.33 Fleet Angles

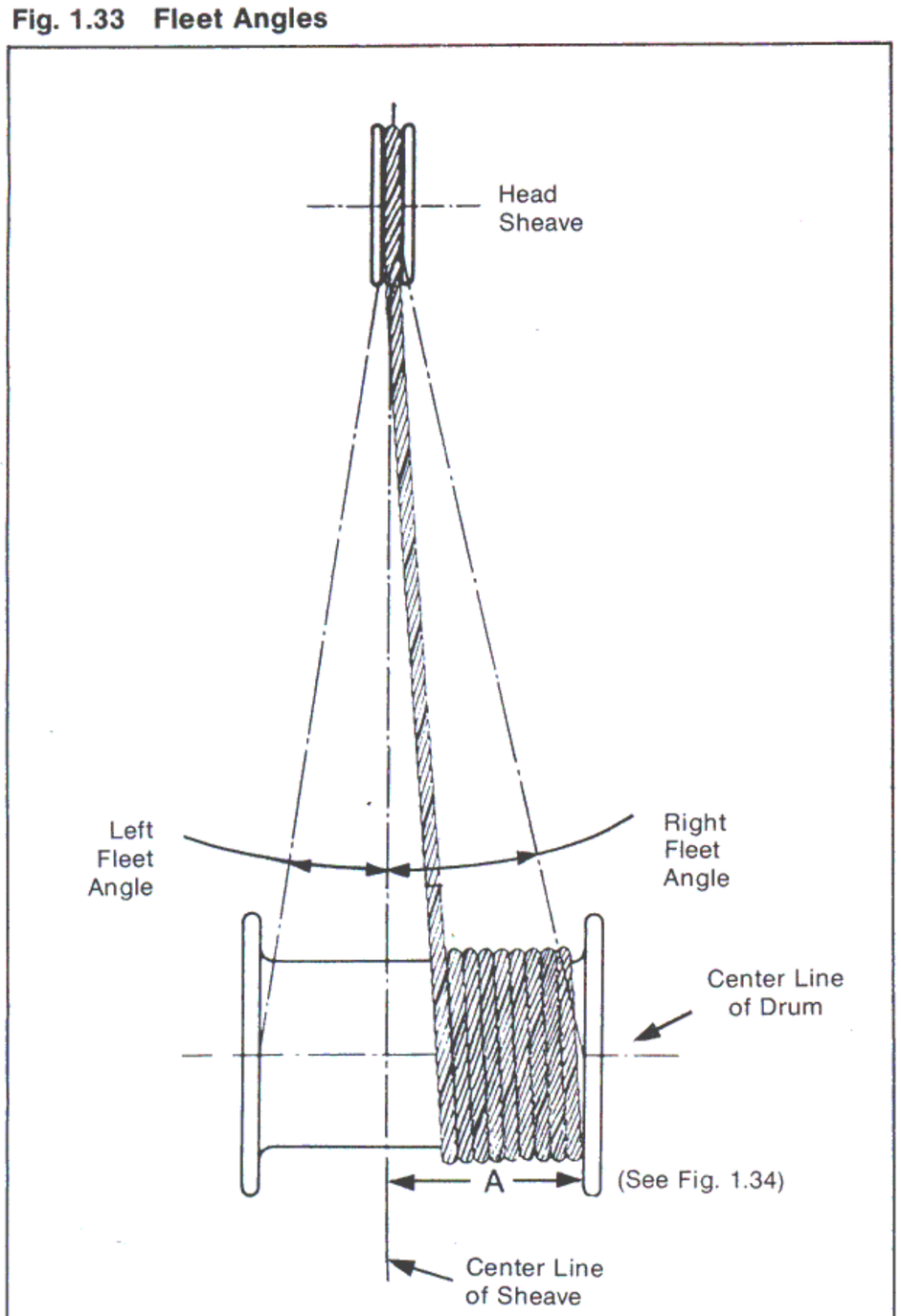


Fig. 1.34 Proper Fleet Angle Ranges for Grooved and Smooth Drums

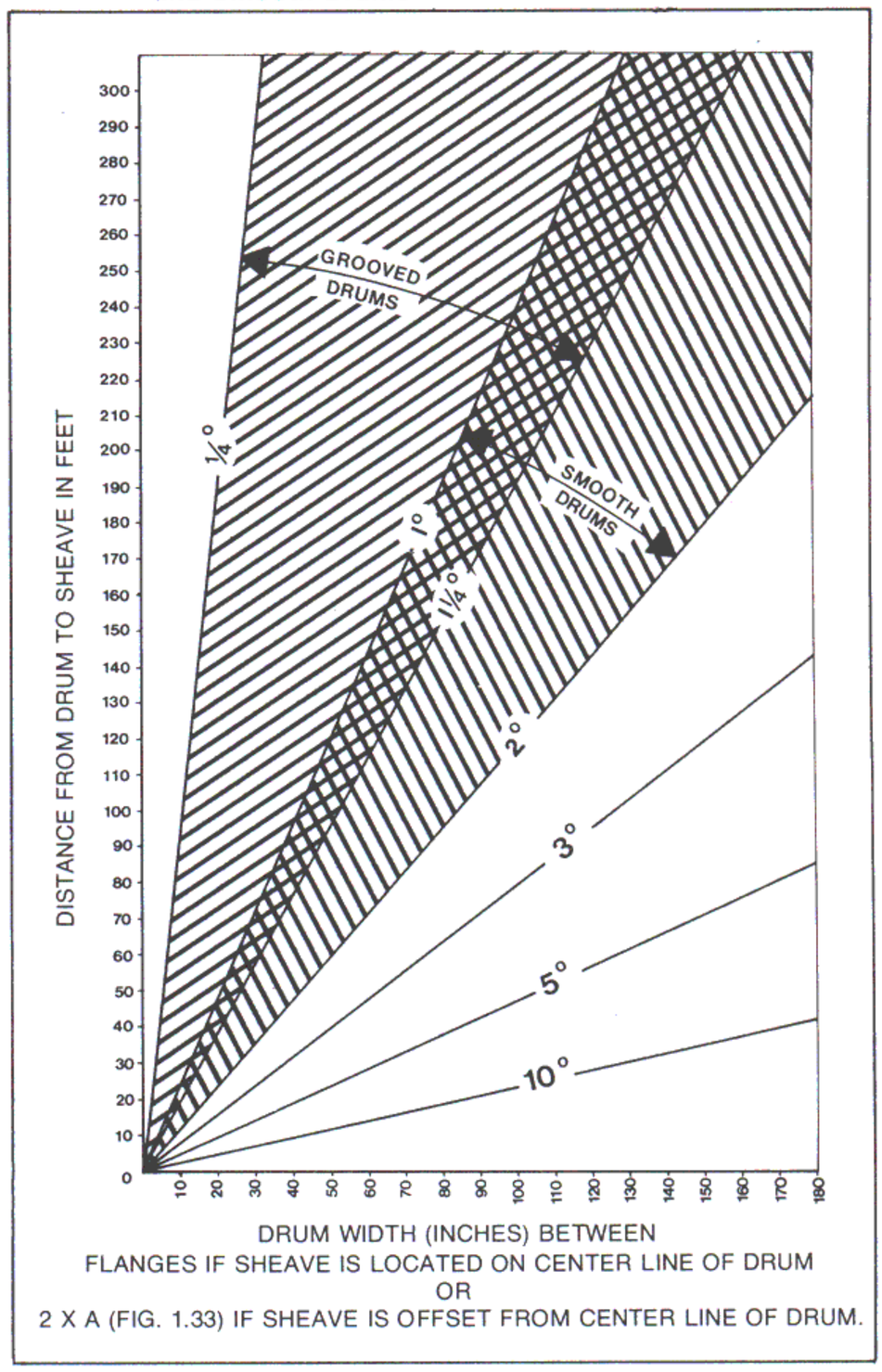
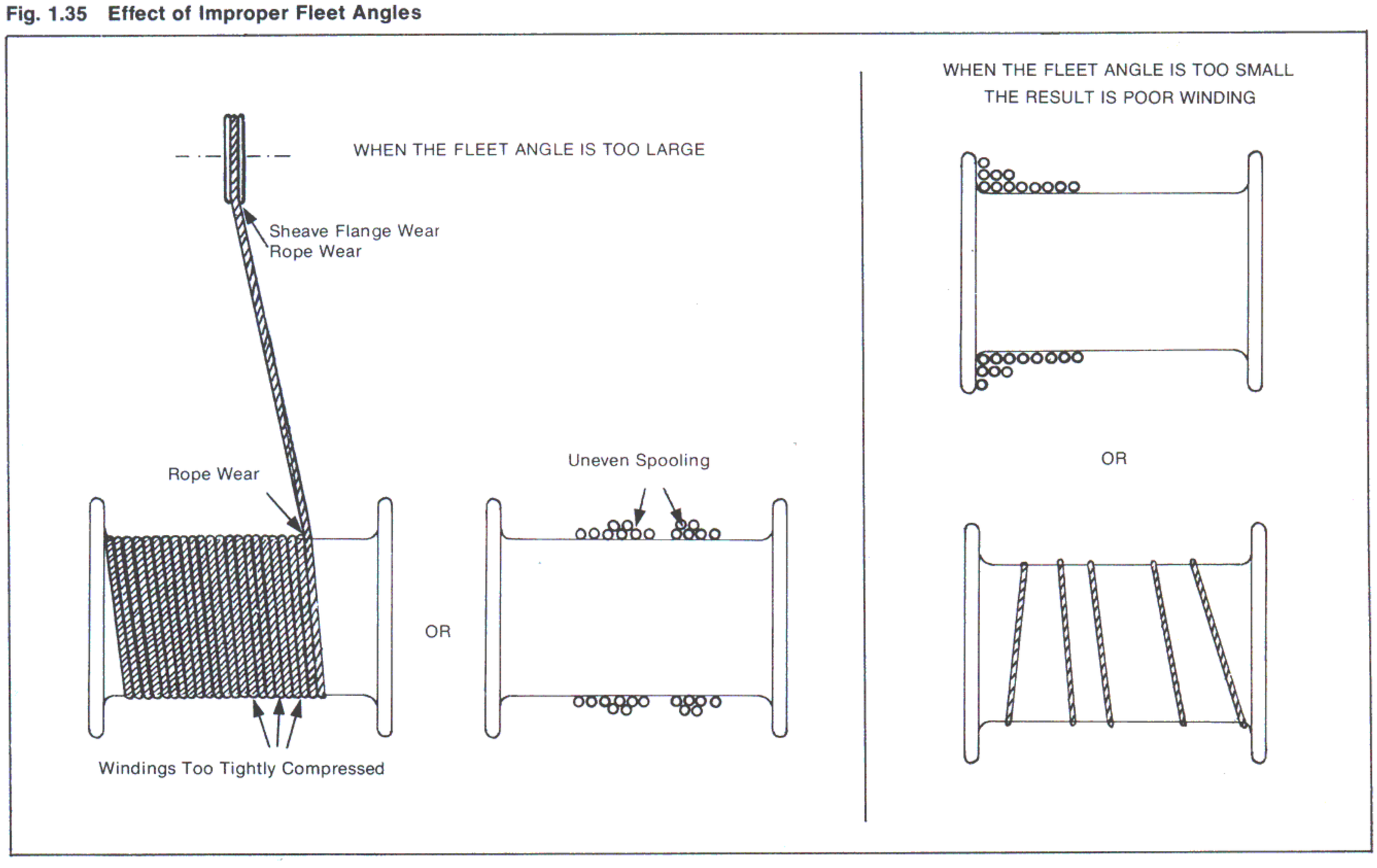


Fig. 1.35 Effect of Improper Fleet Angles



On the other hand the angle should not be too small (e.g. a long distance between the drum and the sheave) as considerable vibration or dancing of the rope results with subsequent deterioration of the rope due to hammering of the rope as it winds on the drum. The installation of intermediate idler sheaves will eliminate this effect. (Fig. 1.36)

Reverse bends: Check that insofar as practical there are no reverse bends in the rope rigging. They accelerate rope deterioration because the rope is first bent in one direction and then the other. This results in accelerated rope fatigue at a rate more than twice what it would be were there no reverse bends.

As the rope passes over a sheave it is bent, and as it leaves the sheave it is straightened. Two distinct actions causing fatigue. This is accentuated if the rope, after being bent in one direction is then straightened and again bent in an entirely opposite direction over another sheave, after which it is again straightened. It must be appreciated that this reverse bending action initiates much greater fatigue than if all bends were made in the one direction. (Fig. 1.37)

Where reverse bends are unavoidable, the sheaves causing the reverse bend should be spaced as far apart as practicable and the most offending sheave should be made about one-third to one-half larger than the others.

Even the equalizing sheave on a hoist block should be kept larger than the critical diameter, for there is enough bending to cause fatigue even though this is not a true operating sheave.

Run in period: After installing a new rope it is advisable to run it through its operating cycle several times under light load and at reduced speed. This allows the new rope to adjust itself gradually to working conditions and enables the strands to become seated, for some stretch to occur, and for the diameter to reduce slightly as the strands and core are compacted.The rope is then less liable to be damaged when full load is applied.

The initial stretching (Constructional Stretch) is a permanent elongation that takes place due to slight lengthening of the rope lay, compression of the core and adjustment of the wires and strands to the load. Constructional Stretch — which varies with the severity of the operation — generally takes place during the first weeks of operation, and increases the length of the rope by approximately $^1/_2$% for fibre core ropes and $^1/_4$% for steel core ropes.

If the new rope is being reeved by being attached to the end of the old one and pulled through the system, the joint between the ropes during the transfer should not only be strong but should also prevent the twisting of the old rope from being transmitted to the new rope.

The rope must also be kept under as much tension as possible when reeving.

Fig. 1.36 Effect of Excessive Distance between Drum and First Sheave

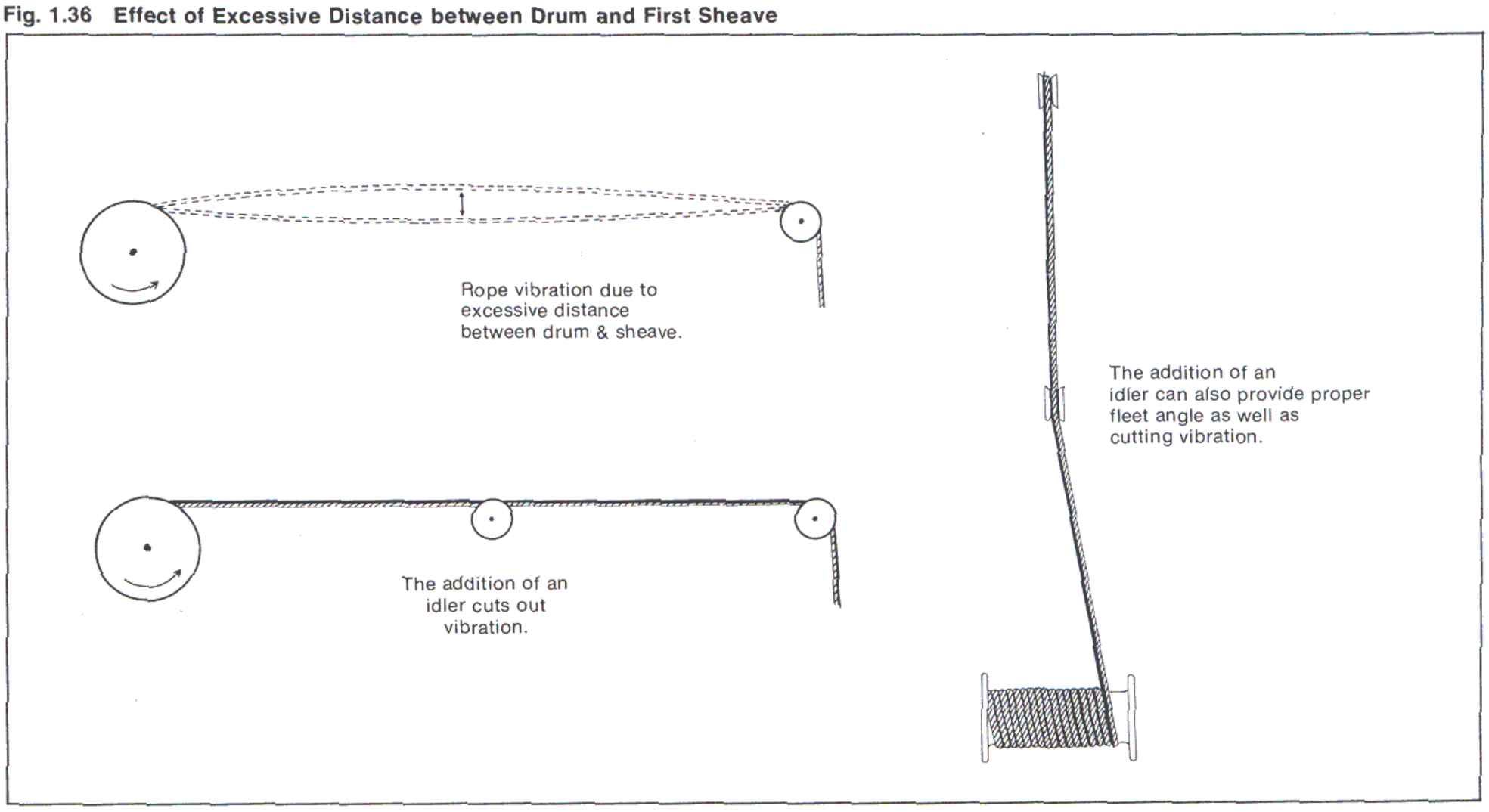
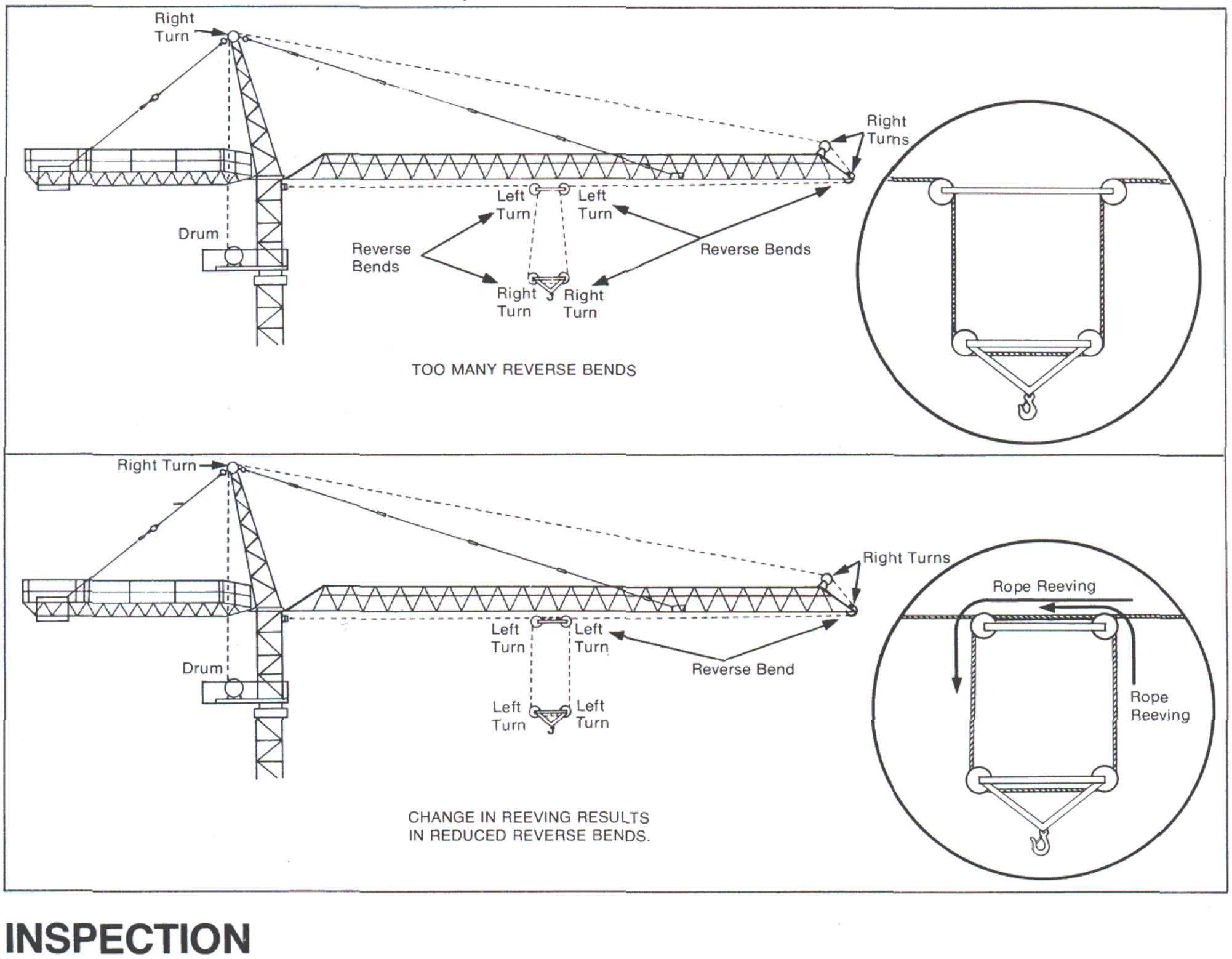


Fig. 1.37 Elimination of Reverse Bends in Wire Rope



INSPECTION

The single, most important operational check to be made on hoisting and rigging equipment is the rope and rigging inspection. Assurance of safety and economy in use of the equipment dictates the requirement for a program of periodic inspections of all load supporting wire rope and fittings. Factors such as abrasion, wear, fatigue, corrosion, improper reeving and kinking are often of greater significance in determining the usable life of wire rope than are strength factors based on new rope conditions.

All wire rope in continuous service should be observed during normal operation and visually inspected on a weekly basis. A complete and thorough inspection of all ropes in use must be made at least once a month and all rope which has been idle for a period of a month or more should be given a thorough inspection before it is put back into service. All inspections should be the responsibility of and be performed by an appointed competent person who makes a complete report of the rope condition. (Fig. 1.38)

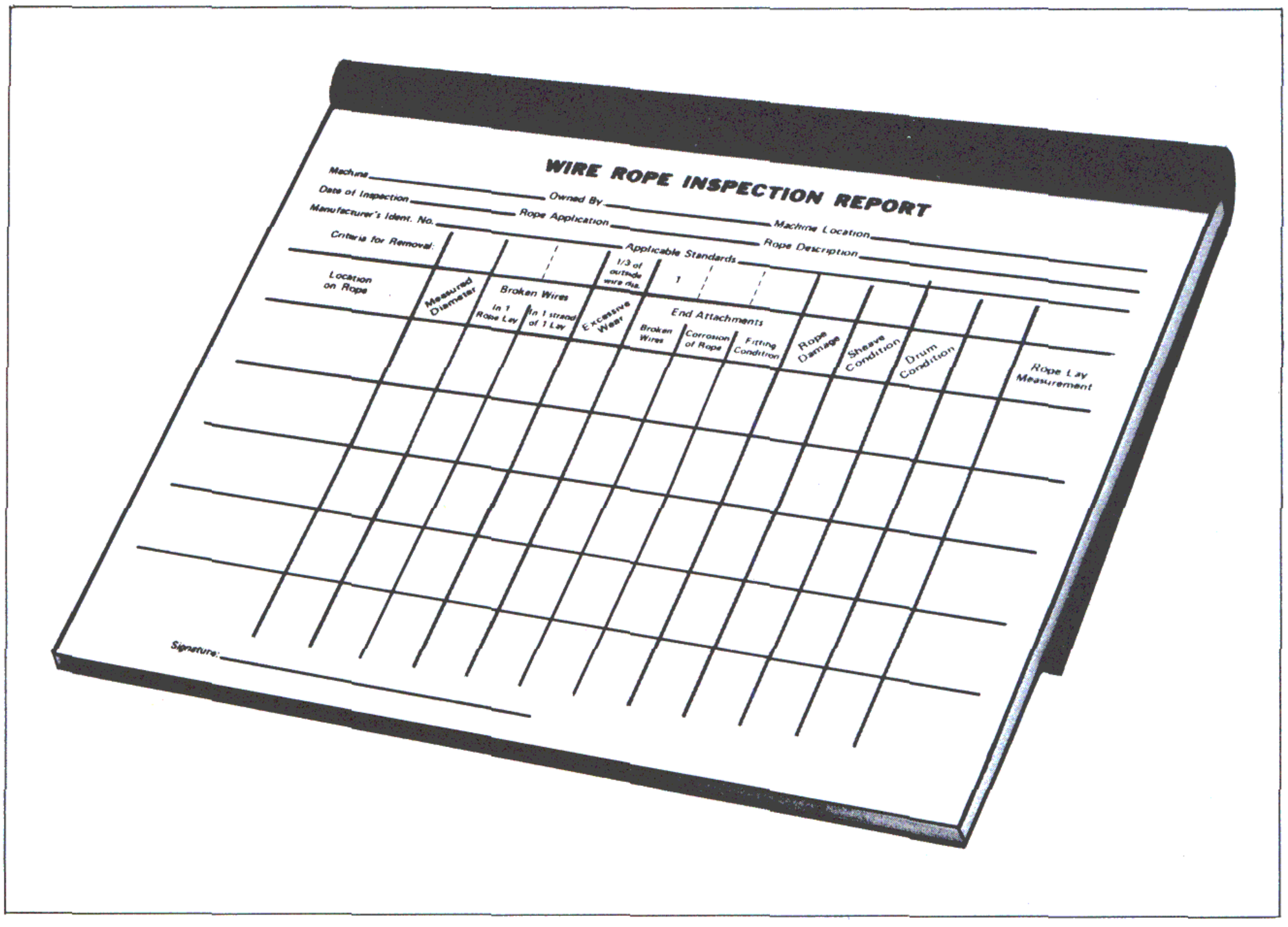
The number of hours per day, week, month or year during which the rope is in use is important. Where the rope is in consistent use, a thorough inspection should be made regularly once a week or more often if required. A record of each rope should be kept (include date of fitting, size, construction, length, defects found during inspections and length of service).

It is good practice, where the equipment is consistently in use, to give the rope a certain length of service, several hundred hours, several weeks or months and then renew the rope regardless of its condition. This method eliminates the risk of fatigue causing rope failure.

Any deterioration, resulting in a suspected loss of original rope strength, should be carefully examined and a determination made as to whether further use of the rope would constitute a safety hazard.

The time to remove a rope from service is related to the conditions of the particular installation. These conditions include the size, na-

Fig. 1.38 Sample Wire Rope Inspection Log



ture and frequency of the lifts, when the next inspection will be, what the operating and maintenance practices are and the extent of possible or probable injury to people, loss of life, material damage, etc., should the rope fail. The user of the rope is the person most familiar with these conditions and as such should have the final responsibility of determining the maximum allowable deterioration before the rope must be removed from service.

Only by inspection can it be determined whether or not the rope should be replaced. (Fig. 1.39) The inspector must decide:

— If the rope's condition presents any possibility of failure, and

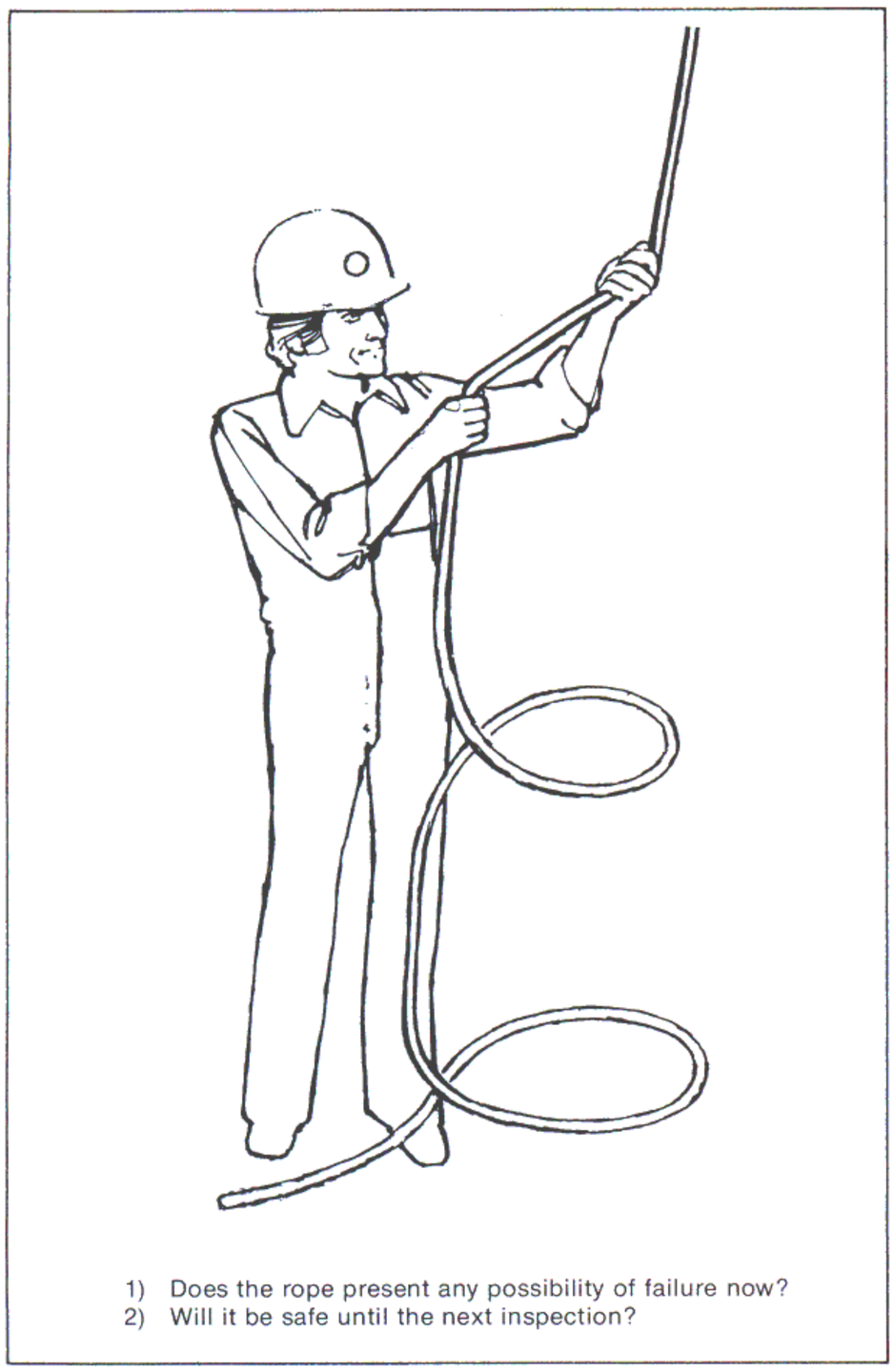
— If the rate of deterioration of the rope is such that it will remain in safe condition until the next scheduled inspection.

When inspecting the rope give every inch of its length equal care as serious deterioration frequently occurs in localized positions. The estimate of the rope's condition must be made at the section showing the **maximum** deterioration.

Conditions such as the following are sufficient to either seriously question the rope safety or immediately remove the rope from service and replace it.

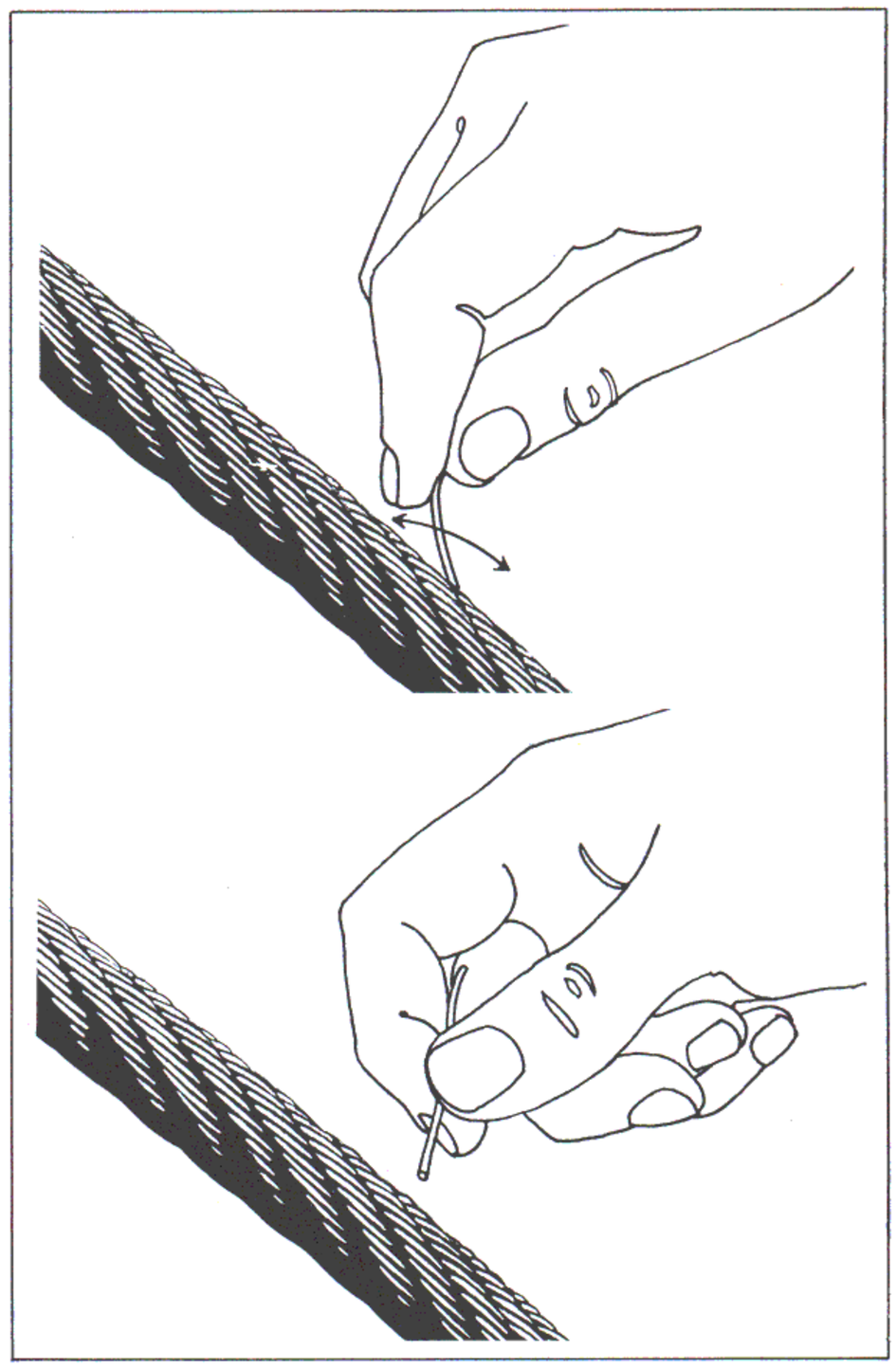
1) **Broken Wires:** The occasional premature wire failure may be found early in the life of almost any rope and in most cases they should not constitute a basis for rope removal provided they are at well spaced intervals. Note the area and watch carefully for any further wire breaks. The broken wire ends should be removed as soon as possible by bending the broken ends backwards and forwards with a pair of pliers or the fingers (if possible). (Fig. 1.40) In this way the wire is more likely to break inside the *rope where the ends are left tucked away* between the strands where they will do no harm. Ripping the broken ends off with pliers is likely to leave jagged ends that can cut and wear unbroken wires.

Fig. 1.39 Criteria for Wire Rope Replacement



1) Does the rope present any possibility of failure now?
2) Will it be safe until the next inspection?

Fig. 1.40 Proper Way to Remove Broken Wires From Rope



The rope must be replaced if: (Fig. 1.41)

(a) In running ropes, there are six or more randomly distributed broken wires in one rope lay, or three or more broken wires in one strand in one rope lay. (A rope lay is the length along the rope in which one strand makes a complete revolution around the rope.)

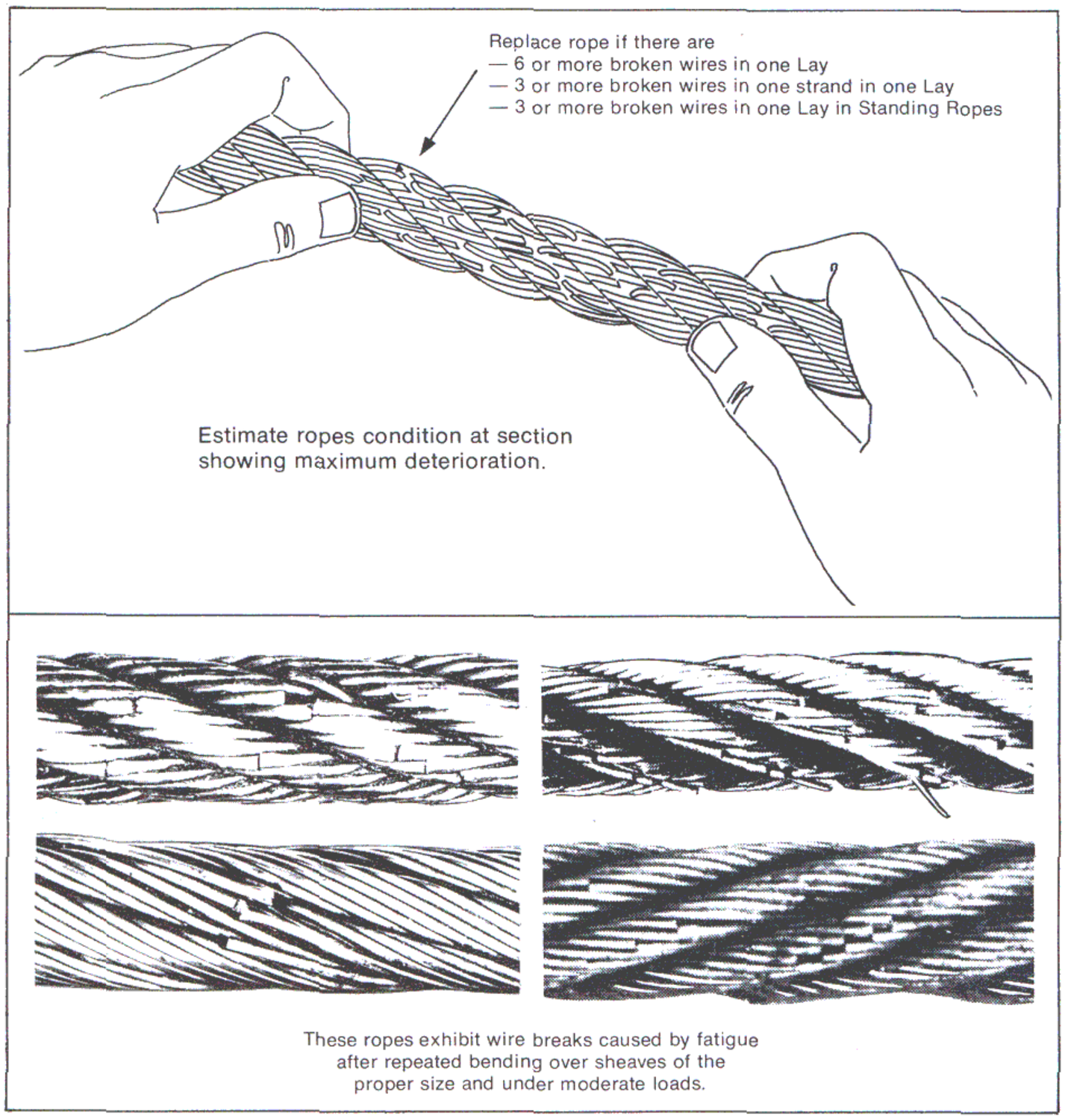
(b) In pendants or standing ropes, there are three or more broken wires in one rope lay.

(c) In any rope there are one or more broken wires near an attached fitting. (Fig. 1.42) Breaks that occur near attached fittings, such as sockets, are usually the result of fatigue stresses concentrated in these localized sections. Wire breaks of this type should be cause for replacement of the rope or renewal of the attachment to eliminate the locally fatigued area. Six to eight feet should be cropped off the rope below the socket.

(d) In running ropes there is any evidence of wire breaks in the **valleys** between strands. (Fig. 1.43) Breaks occurring on crowns of outside wires indicate normal deterioration. Breaks in valleys between strands indicate an abnormal condition, possibly fatigue or breakage of other wires not readily visible. More than one of these valley breaks in one rope lay should be cause for replacement.

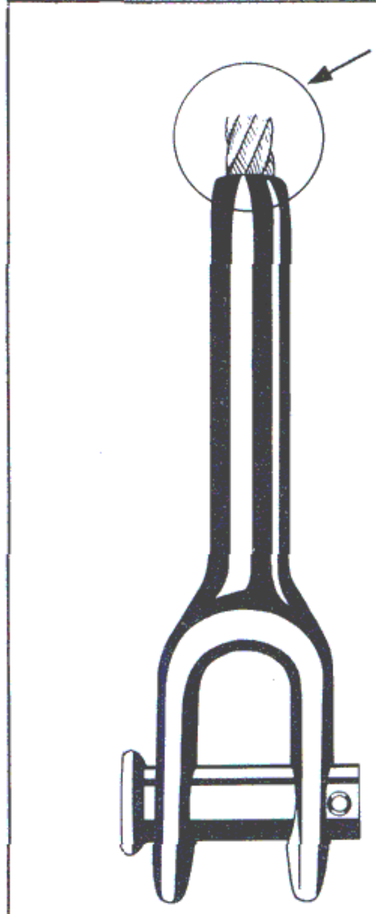
2) **Worn and Abraded Wires:** (Fig. 1.44) Each individual wire in a rope, when new, is a complete circle in cross section. Wear, due to friction on sheaves, rollers, drums, etc., eventually causes the outer wires to become flat on the outside, reducing the circle to a segment which gradually becomes smaller as the "flat" increases. These worn areas become void of lubrication and are characterized by their bright appearance. Close

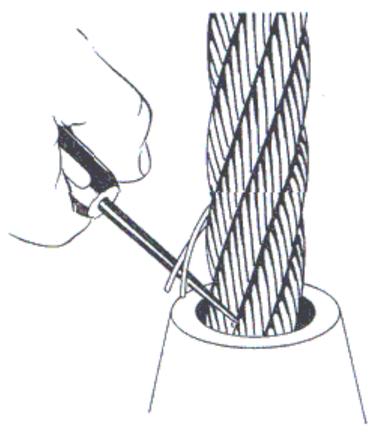
Fig. 1.41 Rope Replacement Criteria Based on the Number of Broken Wires



These ropes exhibit wire breaks caused by fatigue after repeated bending over sheaves of the proper size and under moderate loads.

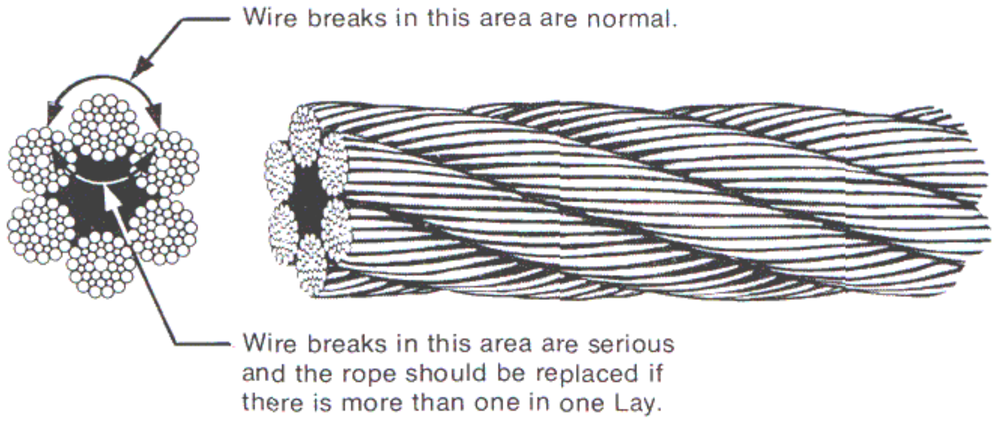
Fig. 1.42 Broken Wires Near Fittings



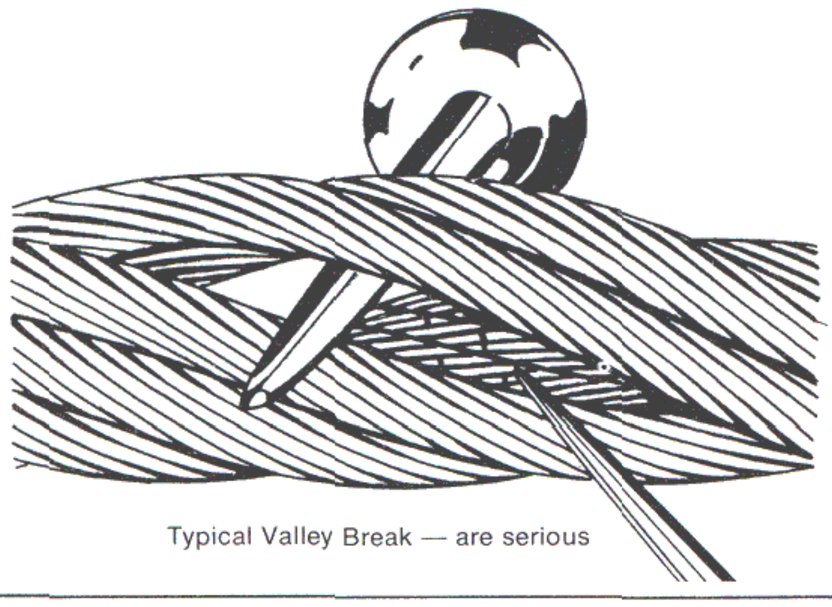


This socket must *be replaced.*

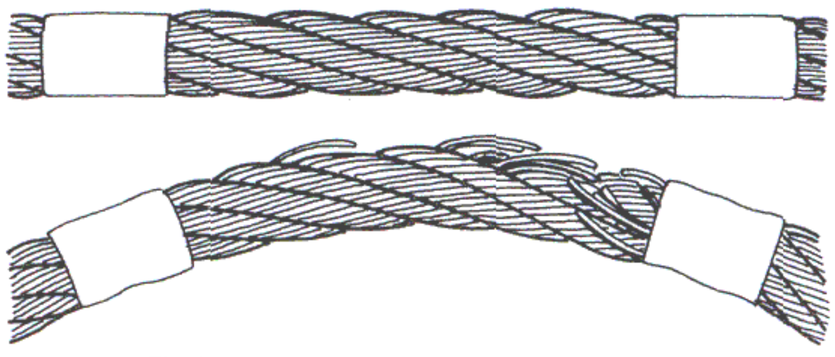
Fig. 1.43 Wire Breaks Inside a Rope



Under ideal and normal conditions, wires should break first on the crowns of strands.



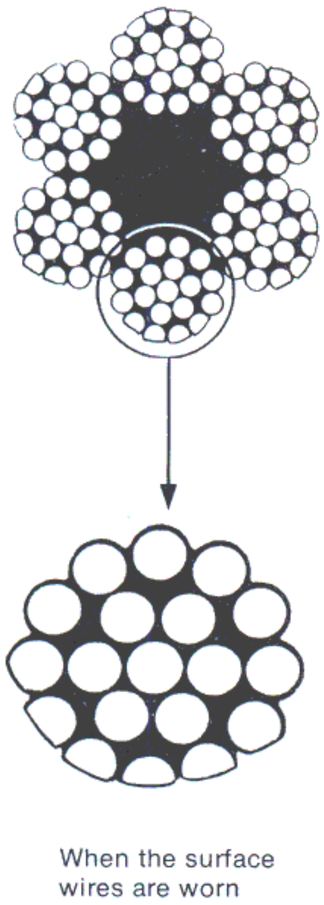
Typical Valley Break — are serious



Flexing a rope can often expose broken wires hidden in valleys between strands.

Fig. 1.44 Worn and Abraded Ropes

Normal Surface Wear



Section Through Worn Section

Enlarged View of Single Strand

When the surface wires are worn by 1/3 or more of their diameter the rope must be replaced.

Severe wear in Langs Lay, caused by abrasion at cross-over points on multi-layer drum windings.

Severe wear and protrusion of core caused by high bearing pressure on drum and sheaves.

Normal surface wear of 1/3 outer wire dia. on Langs Lay rope.

Normal surface wear of 1/3 outer wire dia. on Regular Lay rope.

Rope strand indicating the result of severe surface wear and inter-strand nicking, caused by excessive rope loading.

examination will reveal that the wires are much flatter in appearance than the surrounding wires. This is part of normal service deterioration and in most installations where operating conditions are not particularly severe, relatively even abrasion will occur on the outer wires. **The rope must be replaced, however, if this wear exceeds 1/3 of the diameter of the wire.**

3) **Reduction in Rope Diameter:** (Fig. 1.45) Any marked reduction in rope diameter is a critical deterioration factor. It is often due to excessive abrasion of the outside wires, loss of core support, internal or external corrosion, inner wire failures or a loosening of the rope lay. All new ropes stretch slightly and decrease in diameter after being used. This is normal, however, the rope must be replaced if the diameter is reduced by more than:

   — 3/64 in. for rope diameters of up to and including 3/4 in.

   — 1/16 in. for rope diameters of 7/8 to 1 1/8 in.

   — 3/32 in. for rope diameters of 1 1/4 to 1 1/2 in.

4) **Rope Stretch:** (Fig. 1.46) Severe stretch or elongation of rope is also a deterioration factor. All steel ropes will stretch during their initial periods of use. This is known as Constructional Stretch and is caused by the tightening of the wires and strands into their respective cores. An approximate elongation of 6 inches per 100 feet of rope can be expected in a 6 stranded rope and approximately 9 to 10 inches in an 8 stranded rope. **Excessive stretch beyond this should be cause for replacement.** Watch for a lengthening of rope lay or a reduction in rope diameter. These are the signs of severe stretch, which is generally caused by overloading or a loss of strength as the rope approaches the end of its life cycle.

5) **Corrosion:** (Fig 1.47) This can be infinitely more dangerous than wear. More wires are affected by corrosion and visual field inspections do not give even an approximate idea of the quality of a corroded rope. This is because corrosion frequently develops inside the rope before any evidence is visible on rope surface. If corrosion is detected by the characteristic discoloration of the wires or, in particular, if pitting is observed then consideration must be given to replacing the rope. Noticeable rusting and the development of broken wires in the vicinity of attachments is also cause for replacement. If the corrosion occurs at the base of the socket then it must be cut off.

6) **Insufficient Lubrication:** Check whether the lubrication is sufficient, a rope is usually lubricated internally by the saturated fibre core. However, this either dries out or is heated or squeezed out. Examine the grooves between the strands. Where these are filled with hard packed grease or dirt the lubricant cannot penetrate to prevent internal friction. The rope should be scrubbed and a fairly viscous warm oil applied to allow it to enter the inside of rope, cool, and remain on the rope without being thrown off when revolving around the sheaves.

7) **Damaged or Inadequate Splices:** (Fig. 1.48) All splices must be closely examined for worn and broken wires, pinched or jammed strands, loose strands, cracked fittings, tucks drawing out, corrosion, loose servings, etc. If any of these conditions are evident then that section of the rope must be scrapped and a new splice made.

8) **Corroded, Cracked, Bent, Worn and Improperly Applied End Connections:** (Fig. 1.49) If any of these conditions exist, replace the fitting. Examine all thimbles closely for wear in the crown, for evidence of the throat biting into the rope and for distortion or closure of the thimble (evidence of overloading).

9) **Crushed, Flattened or Jammed Strands:** (Fig. 1.50) Replace the rope as these conditions are dangerous due to severe wire deformation. These conditions can occur when there are multiple layers on drums. Ropes with a large number of wires (i.e. 6 x 37) should never be used on multi-winds. The wires are small for flexibility, but suffer badly from crushing. A larger wired rope (i.e. 6 x 19) should be used but sheave and drum sizes must be increased accordingly to reduce fatigue due to bending. Alternatively, indepen-

Fig. 1.45 Reduction in Rope Diameter

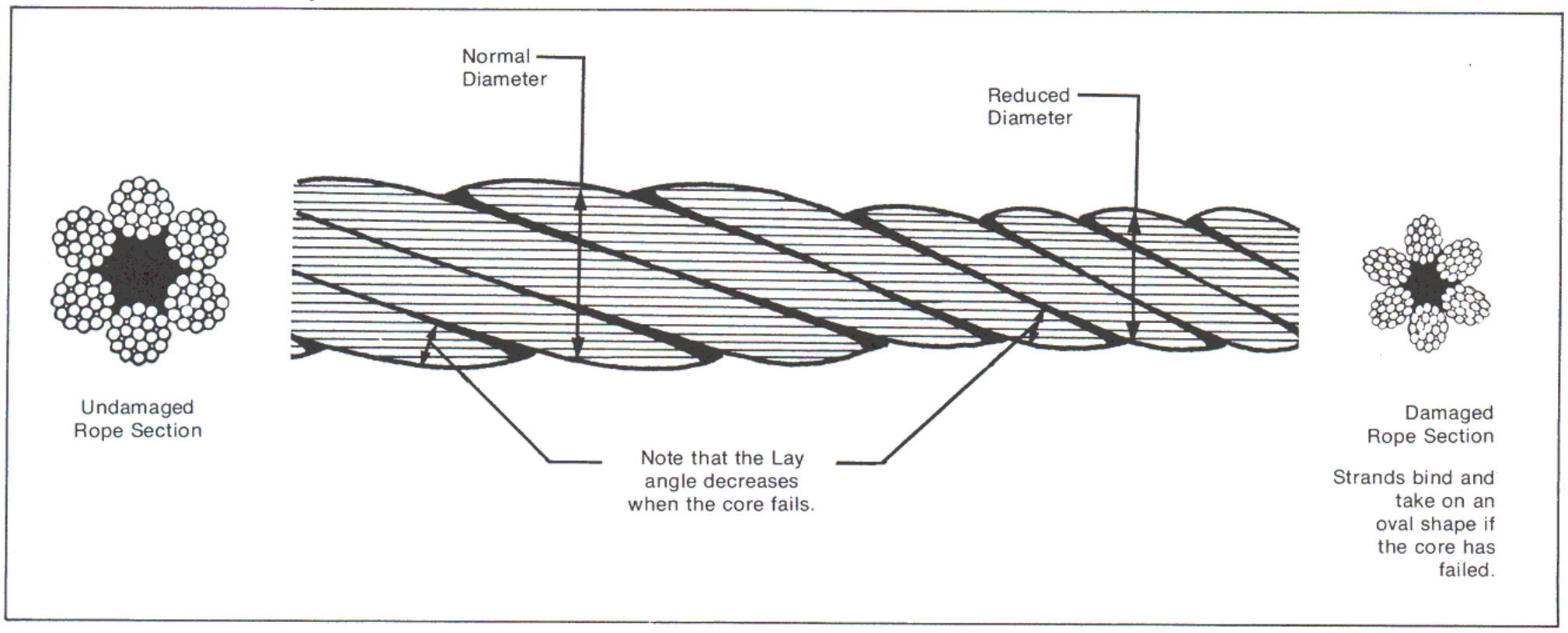


Fig. 1.46 Rope Stretch

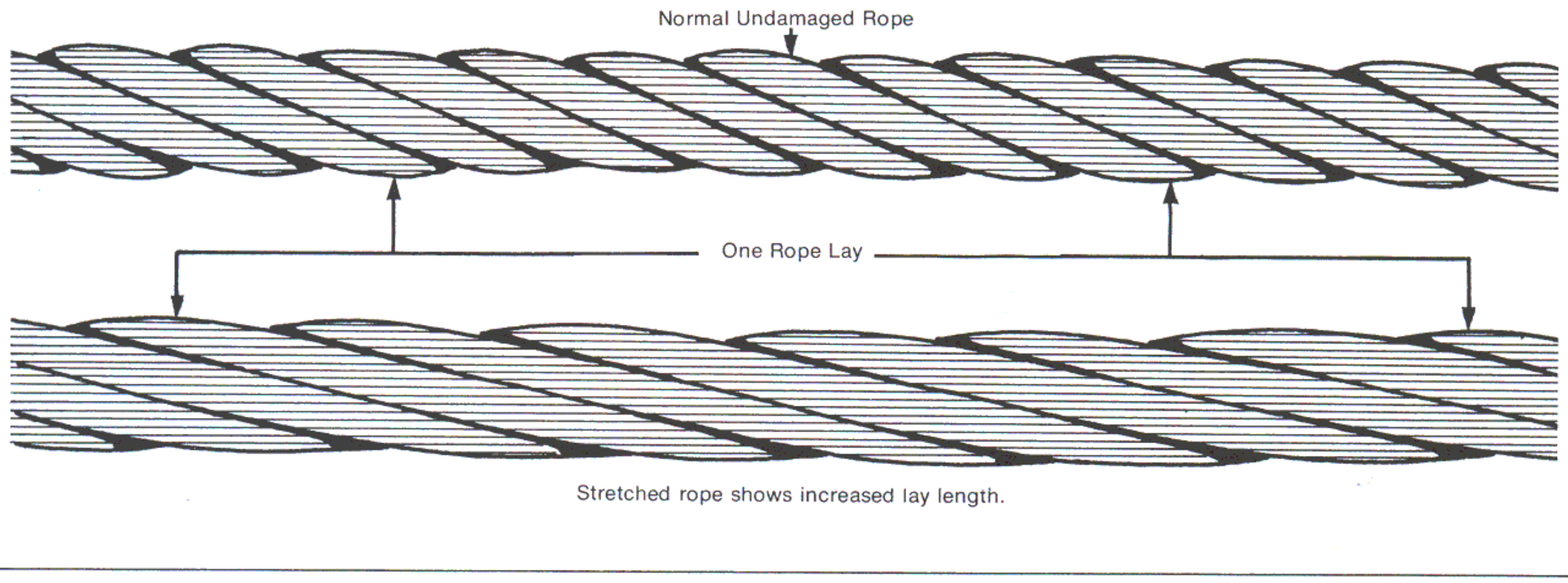


Fig. 1.47 Rope Corrosion

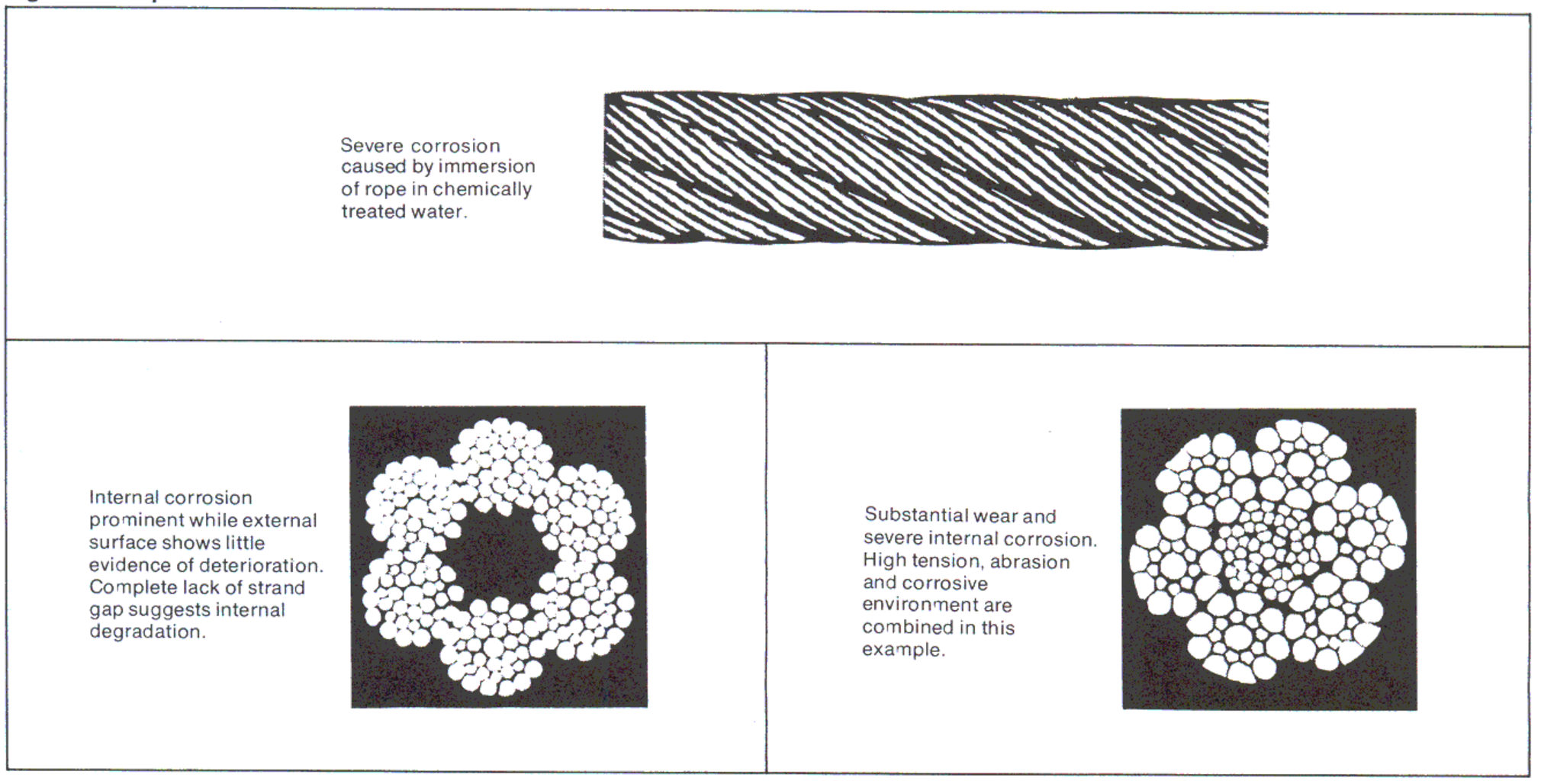
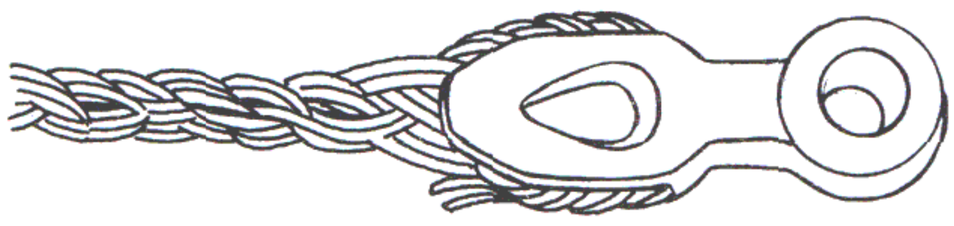
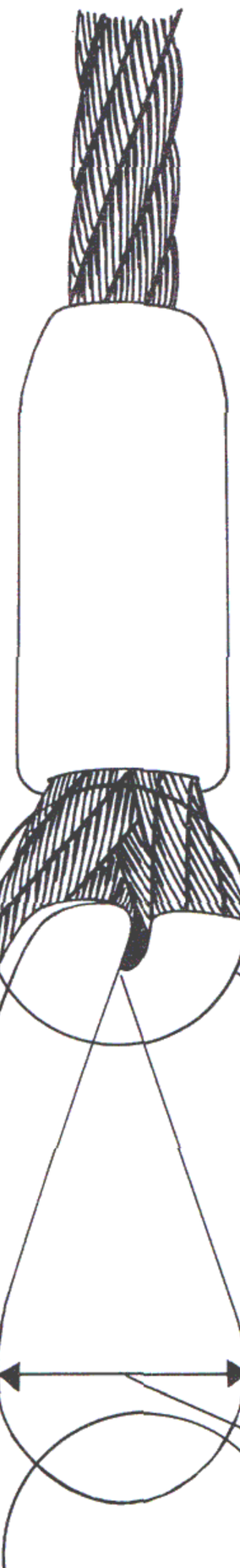


Fig. 1.48 Damaged Splice

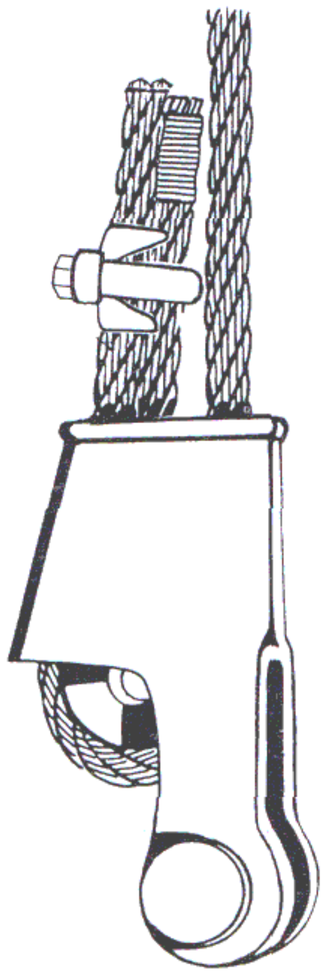


HAND SPLICE
Failure may occur at the first splice tuck.

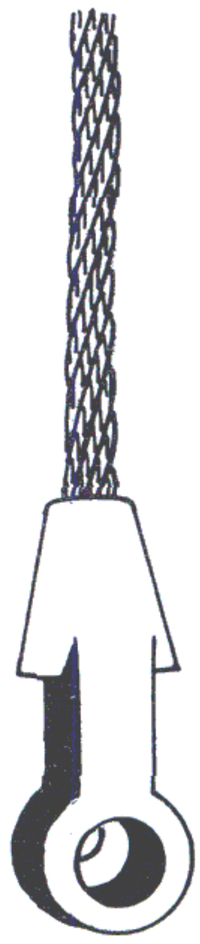
Fig. 1.49 Damaged End Fittings

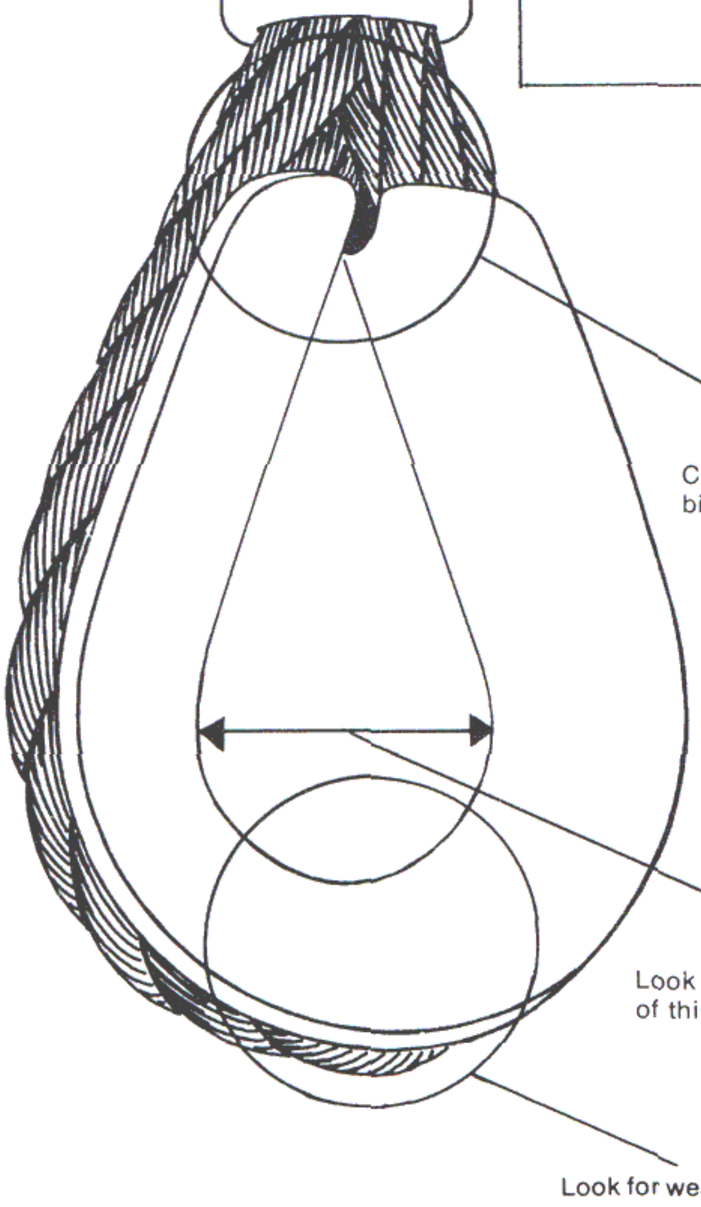


WEDGE SOCKET
This type of fitting will usually fail at the socket bowl.



POURED ZINC SOCKET
Failure frequently starts at the socket base where the wire enters the fitting.





Check that thimble isn't biting into rope.

Look for deterioration or closure of thimble.

Look for wear in crown

SWAGED SOCKETS
Failure may occur at the base of the swaged fitting in this area.

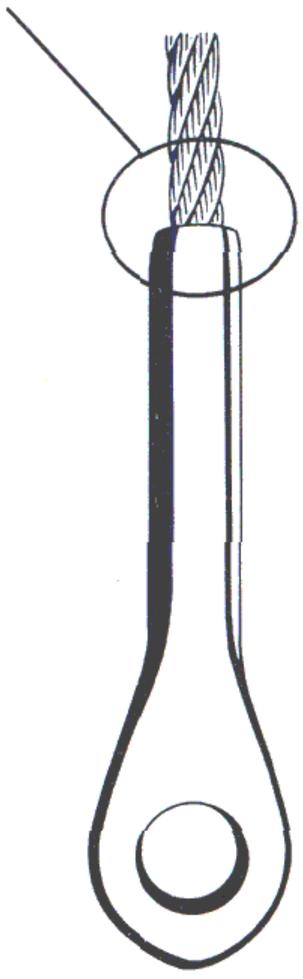


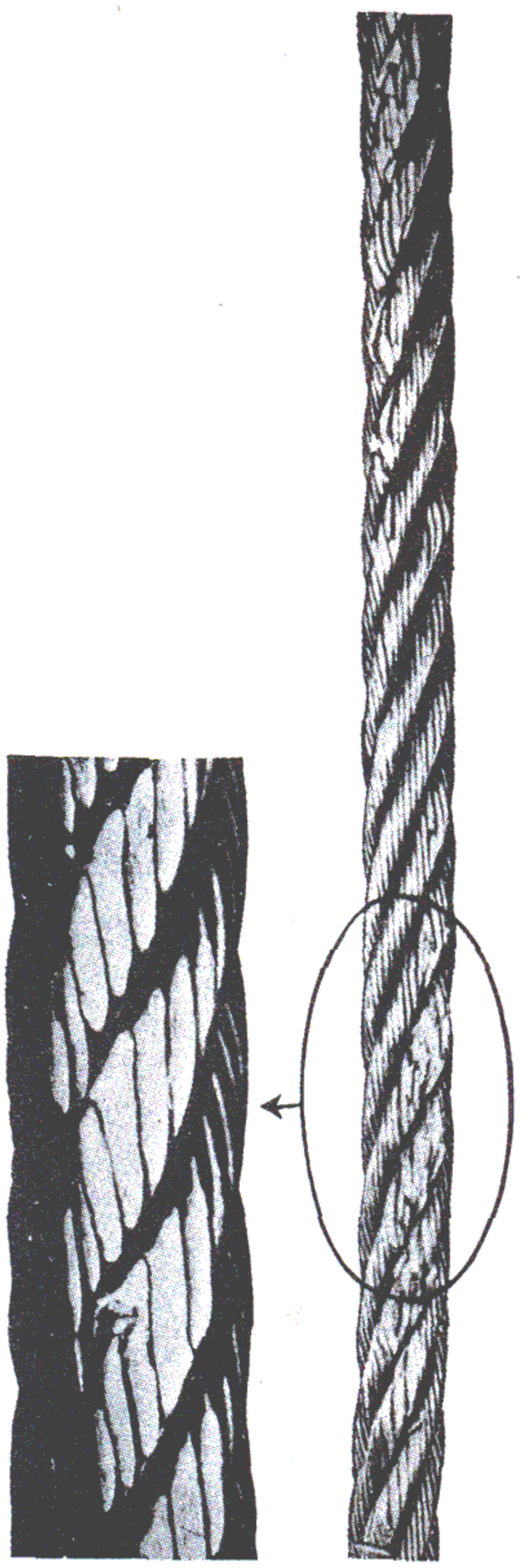
Fig. 1.50 Crushed, Jammed and Flattened Strands

Snagged wires resulting from drum crushing.

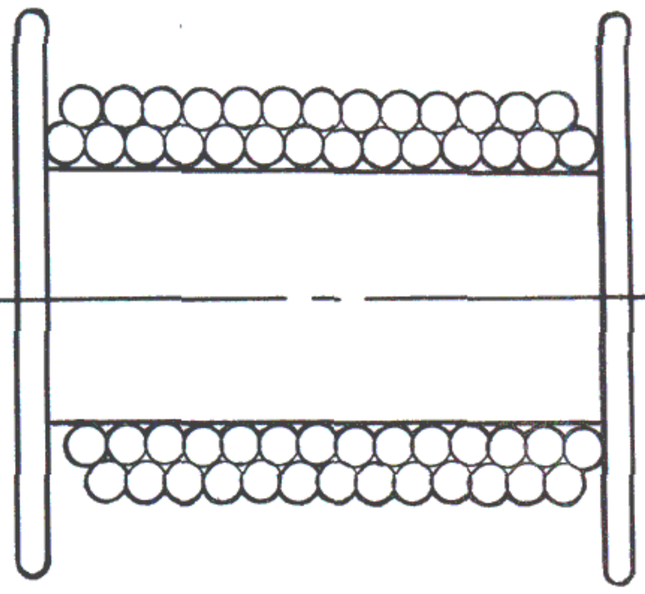
A rope that has been jammed after jumping off a sheave.

Rope subjected to drum crushing. Note the distortion of the individual wires and displacement from their normal position. This is usually caused by the rope scrubbing on itself.

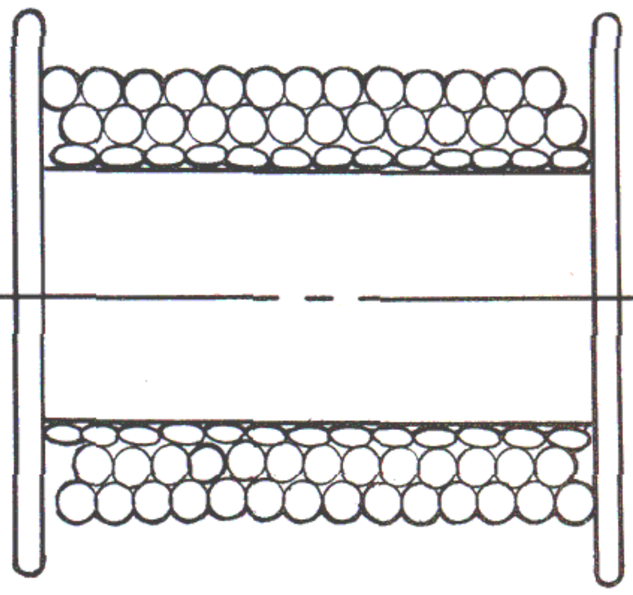
Localized Crushing of Rope



Drum Crushing



With no more than 2 layers on drum use any kind of rope



With more than 2 layers on drum there is danger of crushing — to avoid use larger wired rope or IWRC rope.

dent steel wire cored ropes should be used to prevent crushing. They can also occur if the hoist rope becomes slack and cross-coiled on the drum or trapped in the machinery. No further operations should be carried out until the rope has been payed out, examined for possible damage by a competent person and correctly re-spooled.

10) **High Stranding and Unlaying:** (Fig. 1.51) Replace the rope or renew the end connection to reset the rope lay. In cases such as this, excessive wear and crushing take place and the other strands become overloaded.

11) **Bird Caging:** (Fig. 1.52) Replace the rope or the affected section of the rope.

12) **Kinks:** (Fig. 1.53) Replace the rope or the affected section of the rope. They are usually caused by faulty handling or reeving. The strands become dog-legged and where running on sheaves are subject to excessive wear at the kink.

13) **Bulges in Rope:** Replace the rope, particularly if it is of a non-rotating construction. This is indicative of core slippage or "turns" being put into or taken out of the rope.

14) **Gaps or Excessive Clearance Between Strands:** Replace the rope.

15) **Core Protrusion:** (Fig. 1.54) Replace the rope.

16) **Unbalanced Severely Worn Areas:** (Fig. 1.55) Remove the affected section.

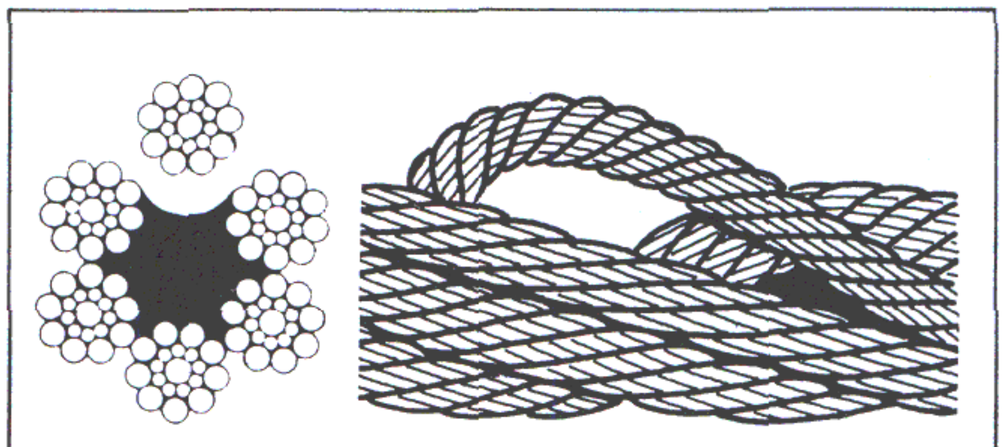
17) **Heat Damage, Torch Burns, Electric Arc Strikes:** Remove either the affected area or the rope.

When inspecting a rope remember that the rope speed has a bearing on the life of a rope. The life expectancy of a high speed rope, due to increased impact effects at sheaves and drums, friction and abrasion, is less than a slow speed rope. Due consideration must be given to this aspect and inspections made accordingly.

If the rope being inspected comprises multi-layers of strands, open it up and examine the inner strands. (Fig. 1.56)

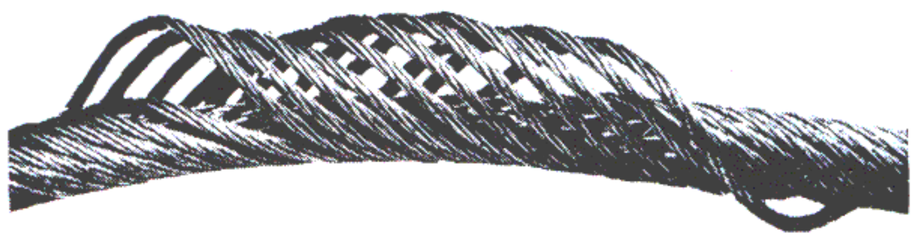
Particular attention should be paid to those areas close to the terminal fittings. Where multi-layer drums are used, examine not only that part of the rope which is in constant use, but also the rope which may remain spooled and inoperative on the drum. Examine all

Fig. 1.51 High Stranding

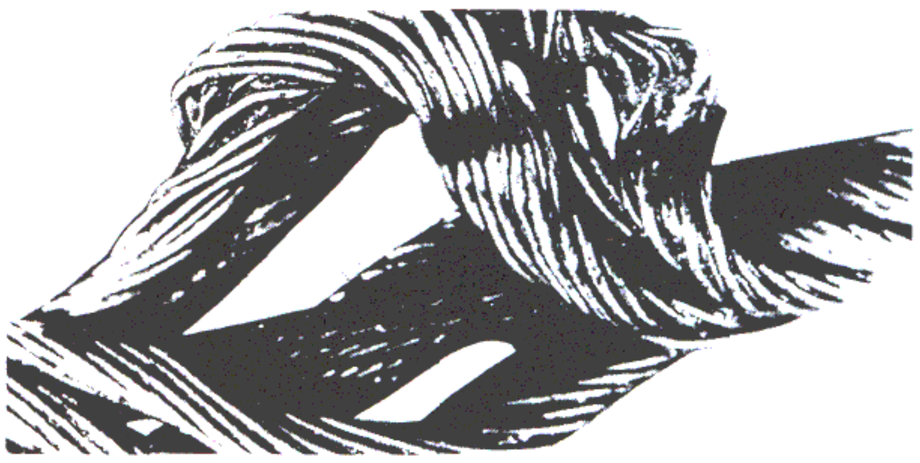


High Stranding

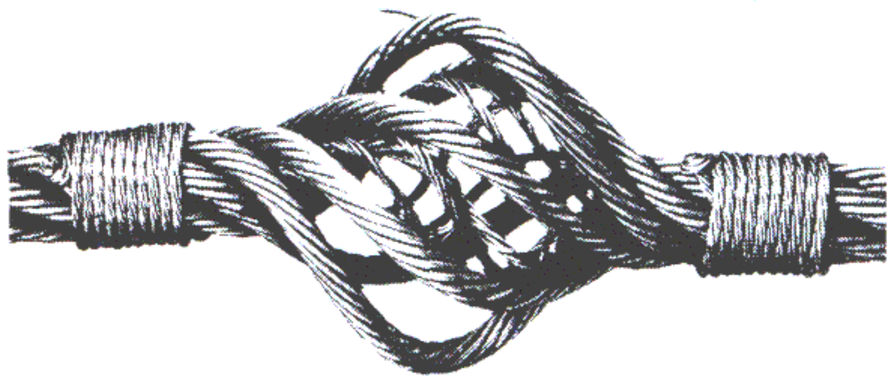
Fig. 1.52 "Bird Cages"



Multi strand rope "bird cages" due to torsional unbalance. Typical of build up seen at anchorage end of multi-fall crane application.



A "bird cage" which has been forced through a tight sheave.



A "bird cage" caused by sudden release of tension and resultant rebound of rope from overloaded condition. These strands and wires will not return to their original positions.

ropes, including standing ropes, for possible defects caused by corrosion, abrasive dust, and erection and dismantling procedures.

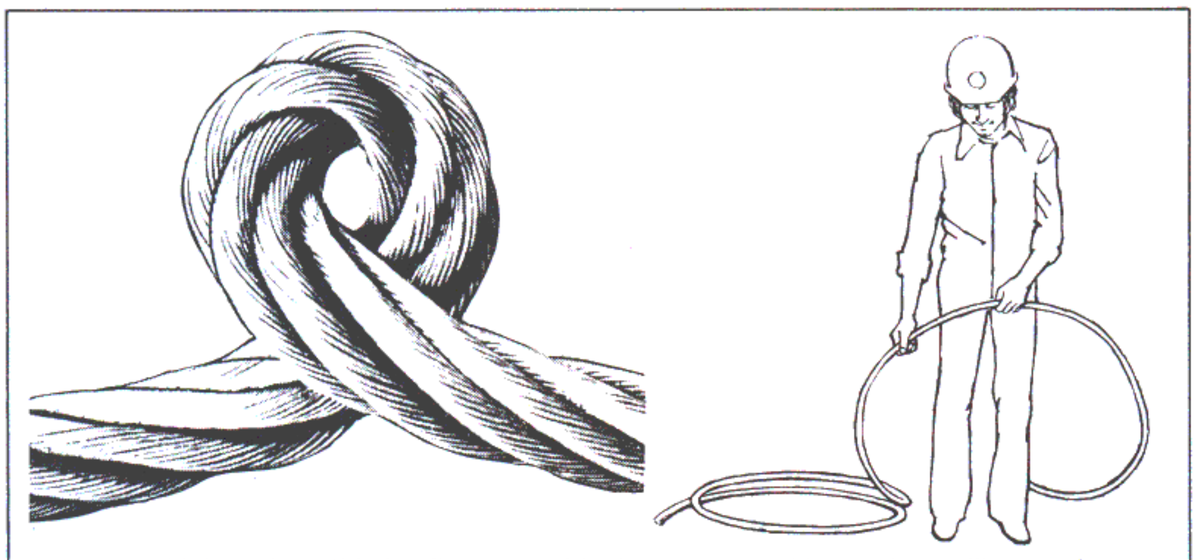
Permanent damage and deformation such as kinks, crushed, flattened, and distorted strands and unbalanced wear locations are the conditions which make a rope extremely susceptible to failure.

When replacing a rope, make certain that the replacement rope is of the correct size and construction. One of the most useful aids in selecting the proper wire rope is to examine the worn ropes that are to be replaced. Knowing what caused the deterioration of the old rope may indicate a direction of change. Table 1.9 and Fig. 1.57 may aid in this determination.

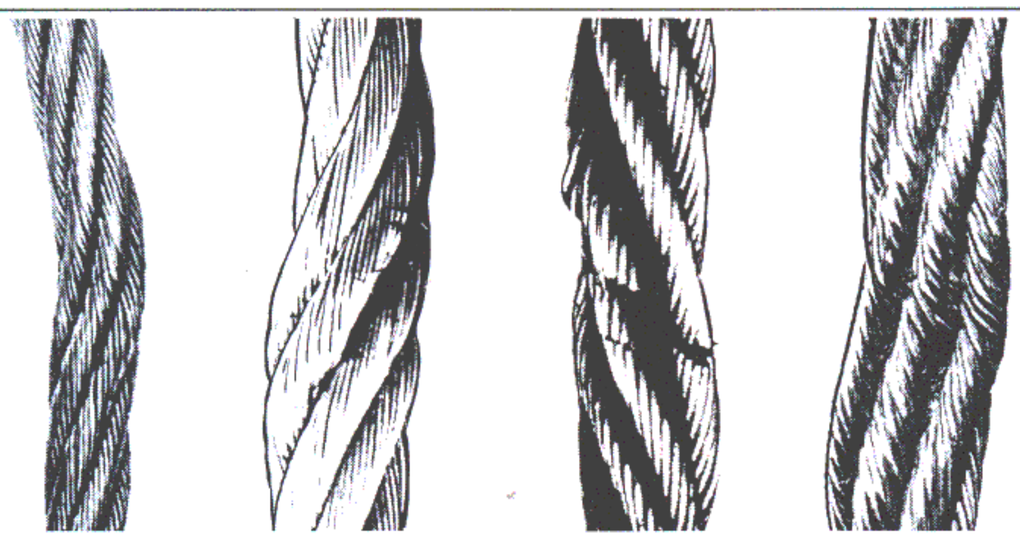
The manner in which the individual wires of a rope break can also give an indication of the probable cause of failure. (Fig. 1.58)

Like a chain, the weakest part of a rope determines the strength of the rope. This weak point may be where the rope is badly worn, where it has a number of broken wires, where the stresses are unequal in the strands, where the local stresses due to bending the rope over a sheave are excessive, or where the rope is attached to the equipment upon which it is used. It is only by inspection that potential hazards can be detected — and accidents avoided.

Fig. 1.53 Rope Kinks

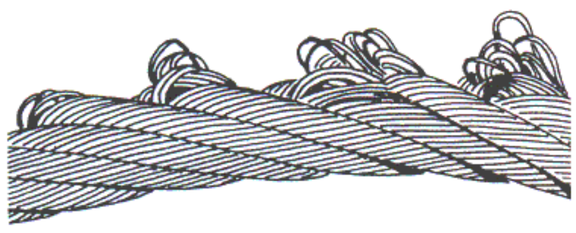


An open kink such as this is often caused by improper handling and uncoiling as shown.

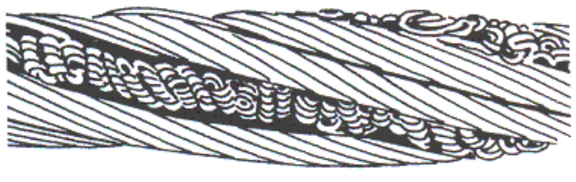


These ropes show the severe damage that results when kinked ropes are used. Local wear, distortion, misplaced wires and early failure are inevitable.

Fig. 1.54 Core Protrusion



Core protrusion as a result of torsional unbalance created by shock loading.



Protrusion of IWRC resulting from shock loading.

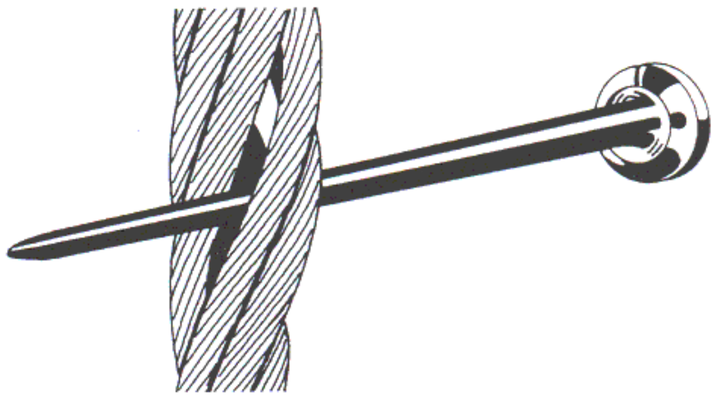
Fig. 1.55 Unbalanced Severely Worn Areas

Fatigued wires in one section of the rope only. Remainder shows relatively good condition.

Localized wear over an equalizing sheave. The danger of this type wear is that it is not visible during operation of the rope. This emphasizes the need of regular inspection of this portion of an operating rope.

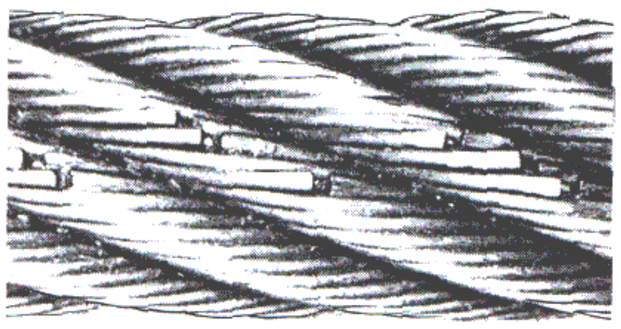
Localized wear due to abrasion on supporting structure. Vibration of rope between drum and jib head sheave.

Fig. 1.56 Proper Method of Opening up a Rope

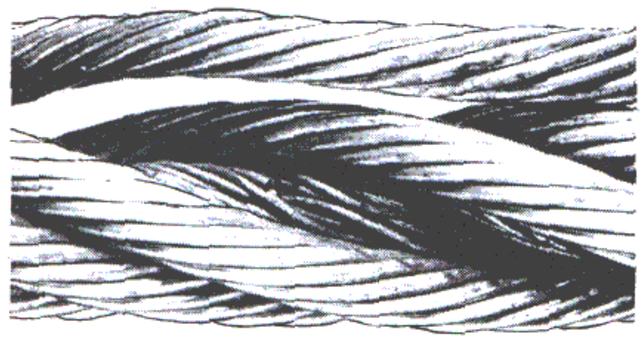


To open a rope, insert marlin spike beneath two strands and rotate to lift strands and provide view of interior.

Fig. 1.57 Typical Rope Damage



Narrow path of wear resulting in fatigue fractures, caused by working in a grossly oversize groove, or over small support rollers.



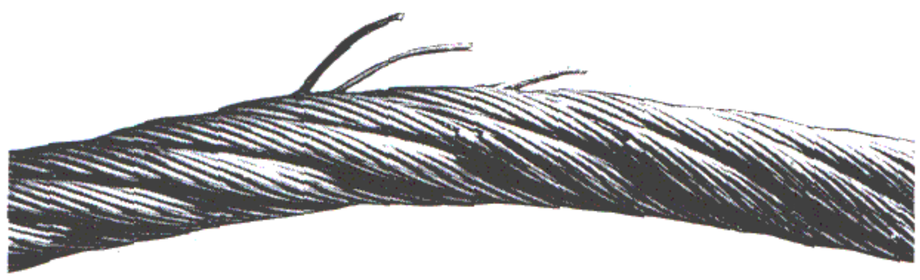
Break up of IWRC resulting from high stress application. Note nicking of wires in outer strands.

Two parallel paths of broken wires indicative of bending through an undersize groove in the sheave.

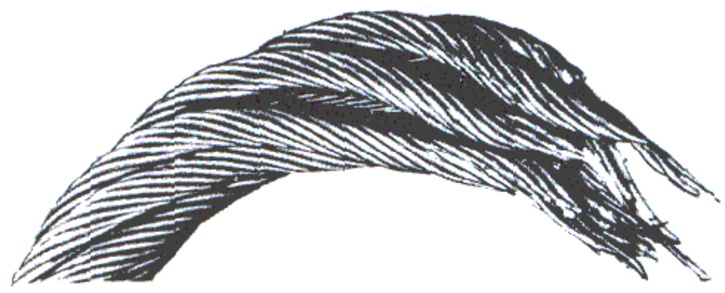
Wire fractures at the strand, or core interface, as distinct from crown fractures, caused by failure of core support.

An example of fatigue failure of a wire rope which has been subjected to heavy loads over small sheaves. The usual crown breaks are accompanied by breaks in the valleys of the strands, these breaks being caused by strand nicking resulting from the heavy loads.

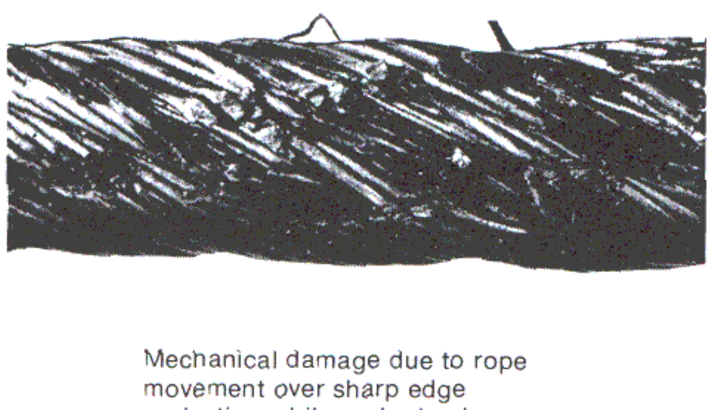
Wire rope that shows severe wear & fatigue from operating over small sheaves with heavy load and severe abrasion



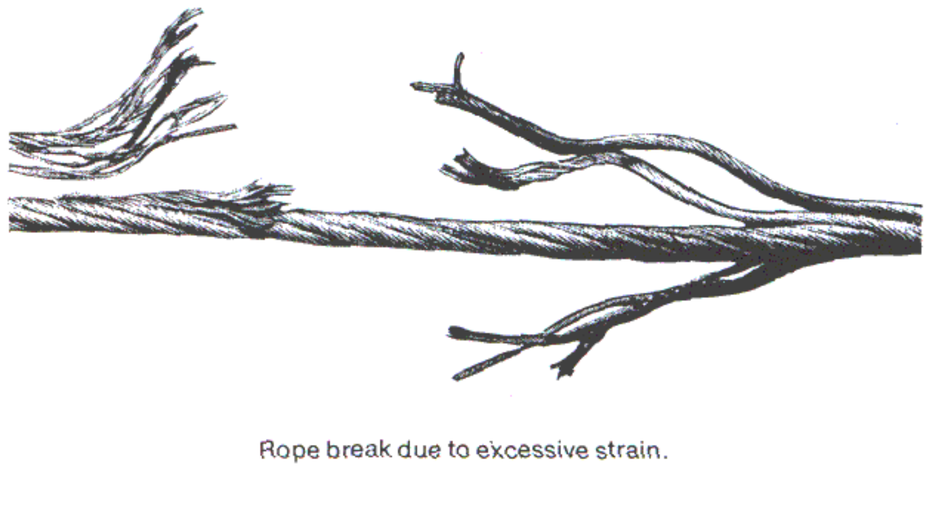
A rope failing from fatigue after bending over small sheaves.



A wire rope which has jumped a sheave. The rope itself is deformed into a "curl" as if bent around a round shaft. Close examination of the wires show two types of breaks — normal tensile "cup and cone" breaks and shear breaks which give the appearance of having been cut on an angle with a cold chisel.



Mechanical damage due to rope movement over sharp edge projection while under load.

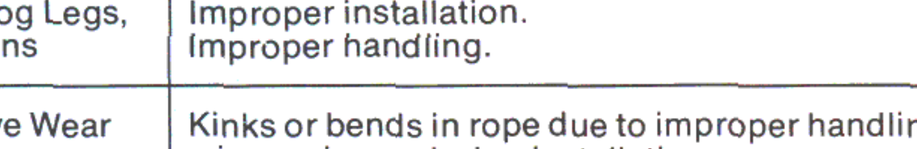


Rope break due to excessive strain.

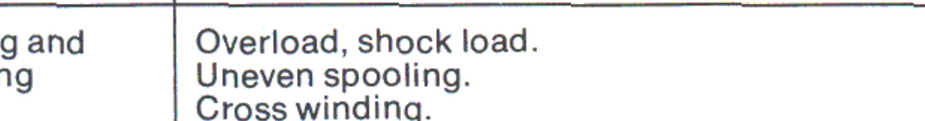
TABLE 1.9

FAULT	POSSIBLE CAUSE	FAULT	POSSIBLE CAUSE
Accelerated Wear	Severe abrasion from being dragged over the ground or obstructions. Rope wires too small for application or wrong construction or grade. Poorly aligned sheaves. Large fleet angle. Worn sheaves with improper groove size or shape. Sheaves, rollers and fairleads having rough wear surfaces. *Stiff or seized sheave bearings.* High bearing and contact pressures.	Broken Wires or Undue Wear on One Side of Rope	Improper alignment. Damaged sheaves and drums.
		Broken Wires Near Fittings	Rope vibration.
		Burns	Sheave groove too small. Sheaves too heavy. Sheave bearings seized. Rope dragged over obstacle.
Rapid Appearance of Broken Wires	Rope is not flexible enough. Sheaves, rollers, drums too small in diameter. Overload and shock load. Excessive rope vibration. Rope speed too high. Kinks that have formed and been straightened out. *Crushing and flattening of the rope.* Reverse bends. Sheave wobble.	Rope Core Charred	Excessive heat.
		Corrugation and Excessive Wear	*Rollers too soft.* Sheave and drum material too soft.
		Distortion of Lay	Rope improperly cut. Core failure. Sheave grooves too big.
		Pinching and Crushing	Sheave grooves too small.
Rope Broken Off Square	Overload, shock load. Kink. Broken or cracked sheave flange.	Rope Chatters	Rollers too small.
		Rope Unlays	Swivel fittings on Lang Lay ropes. Rope dragging against stationary object.
Strand Break	*Overload, shock load.* Local wear. Slack in 1 or more strands.	Crushing and Nicking	Rope struck or hit during handling.
Corrosion	Inadequate lubricant. Improper type of lubricant. Improper storage. Exposure to acids or alkalis.	High Stranding	Fittings improperly attached. Broken strand. Kinks, dog legs. Improper seizing.
Kinks, Dog Legs, Distortions	Improper installation. Improper handling.	Reduction in Diameter	Broken core. Overload. Corrosion. Severe wear.
Excessive Wear in Spots	Kinks or bends in rope due to improper handling in service or during installation. Vibration of rope on drums or sheaves.	Bird Cage	Sudden release of load.
Crushing and Flattening	Overload, shock load. Uneven spooling. Cross winding. *Too much rope on drum.* Loose bearing on drum. Faulty clutches. Rope dragged over obstacle.	Strand Nicking	Core failure due to continued operation under high load.
Stretch	*Overload.* Untwist of Lang Lay ropes.	*Core Protrusion*	*Shock loading.* Disturbed rope lay. Rope unlays. Load spins.

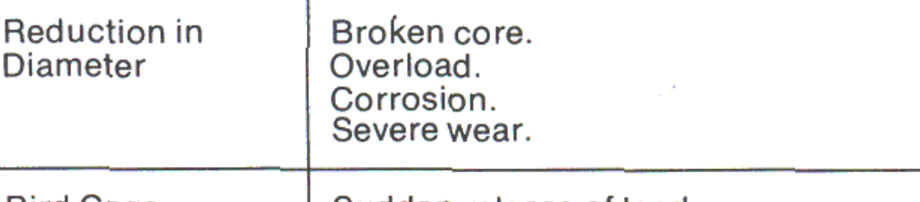
Fig. 1.57 (Continued) Typical Rope Damage



Rapid appearance of many broken wires.

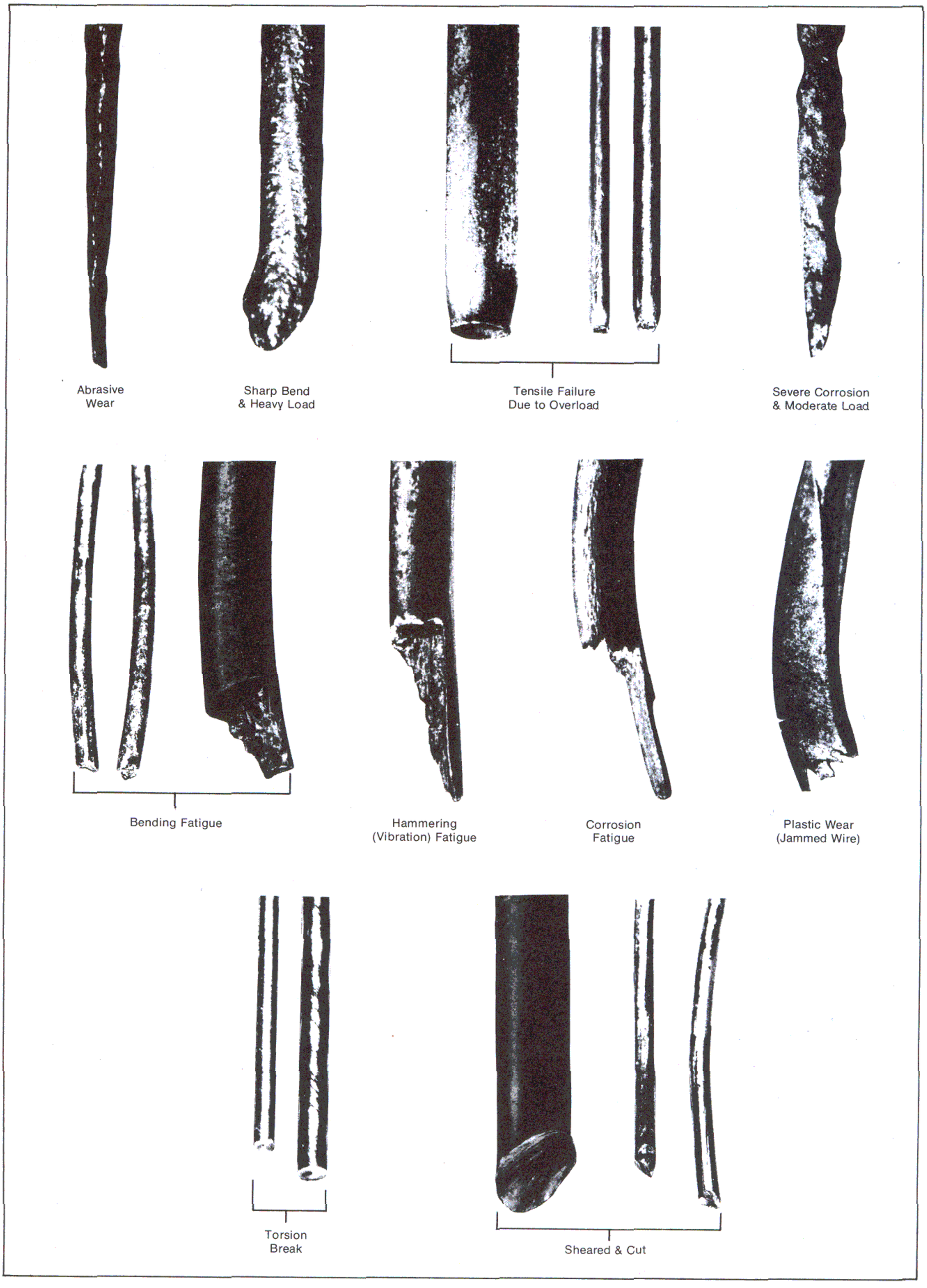


Wear and damage on one side of rope.



A single strand removed from a wire rope subjected to "strand nicking". This condition is the result of adjacent strands rubbing against one another and is usually caused by core failure due to continued operation of a rope under high tensile load. The ultimate result will be individual wire breaks in the valleys of the strands.

Fig. 1.58 Typical Wire Failures



USE, HANDLING & MAINTENANCE

PROCEDURES AND PRECAUTIONS:

Wire ropes, like the machines and hoists on which they are used require careful use, handling and maintenance for satisfactory performance, long life and adequate safety.

The following precautions should be observed to meet these requirements:

— Ensure that the correct rope is used.

— Inspect regularly following the rope manufacturer's guidelines and the recommendations on pages 23-33.

— Never overload.

— Minimize shock loading as overstressing of the rope will occur. In order to ensure that there is no slack in the rope at the start of loading, start the load carefully and apply the power smoothly and steadily.

— Avoid sudden loading in cold weather.

— Never use frozen ropes.

— Take special precautions and/or use a larger sized rope whenever,

(a) the exact load is unknown,

(b) there is a possibility of shock loading,

(c) the conditions are abnormal or severe,

(d) there is a hazard to personnel.

— Protect rope from sharp corners or edges with padding.

— Avoid dragging the rope from under loads or over obstacles.

— Avoid dropping the rope from heights.

— Avoid rolling loads with ropes.

— Store all unused rope in a clean, dry place.

— Never use wire rope which has been cut, badly kinked or crushed.

— Prevent loops in slack lines from being pulled tight and kinking. Once a kink has been made in a wire rope the damage is permanent. A weak spot will always remain no matter how well the kink seems to have been straightened out. If a loop forms don't pull it out, unfold it.

— Ensure that the drums and sheaves are of sufficient diameter.

— Avoid reverse bends.

— Repair or replace faulty guides and rollers.

— Ensure the sheaves are aligned and the fleet angle is correct.

— Replace sheaves having deeply worn or scored grooves, cracked or broken rims, and worn or damaged bearings.

— Repair faulty clutches.

— Check for abnormal line whip and vibration.

— Ensure that the rope spools properly on the drum.

— Never wind more than the proper amount of rope on any drum.

— Never allow the rope to cross-wind.

— Ensure rope ends are properly seized.

— Ensure that the ropes do not bind in sheaves. New wire rope requires a run-in period before operating at full load and full speed.

— Use thimbles in eye fittings at all times.

— Lubricate regularly according to the rope manufacturer's recommendations.

— Watch for local wear. Premature wear at one spot is common and can be prevented if the cause is detected. Uneven wear can be minimized by moving the rope at regular intervals so that different stretches of it are at the critical wear points. Changing layer and crossover points is merely a matter of cutting a few feet of rope from the drum end and refastening it. The cut should be long enough to move the change of layer at least one full coil from its former position and to move the crossover points one-quarter turn around the drum. Move the static section on an equalizer sheave three sheave diameter lengths away by cutting off the section on the drum end of the rope. To distribute wear due to vibration, cut off a section next to the anchorage and refasten the rope.

Even with the utmost care during installation, it is quite common to find that the dead turns on the drum become somewhat slack in operation. This slackness arises from a certain amount of stretch which occurs in a new rope under tension and periodically throughout the life of the rope from release of the load. When this slackness is noted, these turns should be rewound to tighten them. If left uncorrected, a wedging action, causing abrasion from the second layer, will occur and broken wires in the dead turns will appear.

Localized abrasion and fatigue can be dealt with without the necessity of discarding the

whole rope by installing a longer rope than necessary initially and cutting at one end or the other to expose a new section of rope to the place where the deterioration occurs.

In installations where rope deterioration is excessive at one end or the other, the life of the rope may be extended by turning the rope end for end. This must be done before the deterioration becomes too severe.

On equipment having multiple falls of other than non-rotating ropes, a new rope will stretch and unlay slightly, causing turns to appear in the load block. The anchorage, if not fitted to a suitable swivel, should be disconnected, the turns removed and reconnected.

Proper maintenance of the equipment over which the ropes operate has an important bearing on rope life. Worn grooves, poor alignment of sheaves and worn parts resulting in shock loads and excessive vibration will have a deteriorating effect.

Sheaves and grooved rollers should be checked periodically for wear in the grooves which may cause pinching and abrasion of the ropes. If the groove bears the imprint of the rope it should be machined clean or replaced with a sheave of harder material. The same should be done with drums showing similar effect. Sheaves with oversized grooves do not properly support the rope and must be replaced. (Fig. 1.59)

Rollers and fairleads should be checked for worn grooves which may cut the wires. It is economical practice to offset rollers from the center line of the rope so that they may be turned end for end. Rubber faced rollers can be used to advantage in some instances.

Poor alignment of sheaves will result in wear on the rope and wear on the sheave flange. This should be corrected immediately as a distorted groove will also result.

Sheave and roller bearings should be checked for free operation. Sticking will cause unnecessary wear.

Excessive wear in sheave bearings can cause rope fatigue from the vibration.

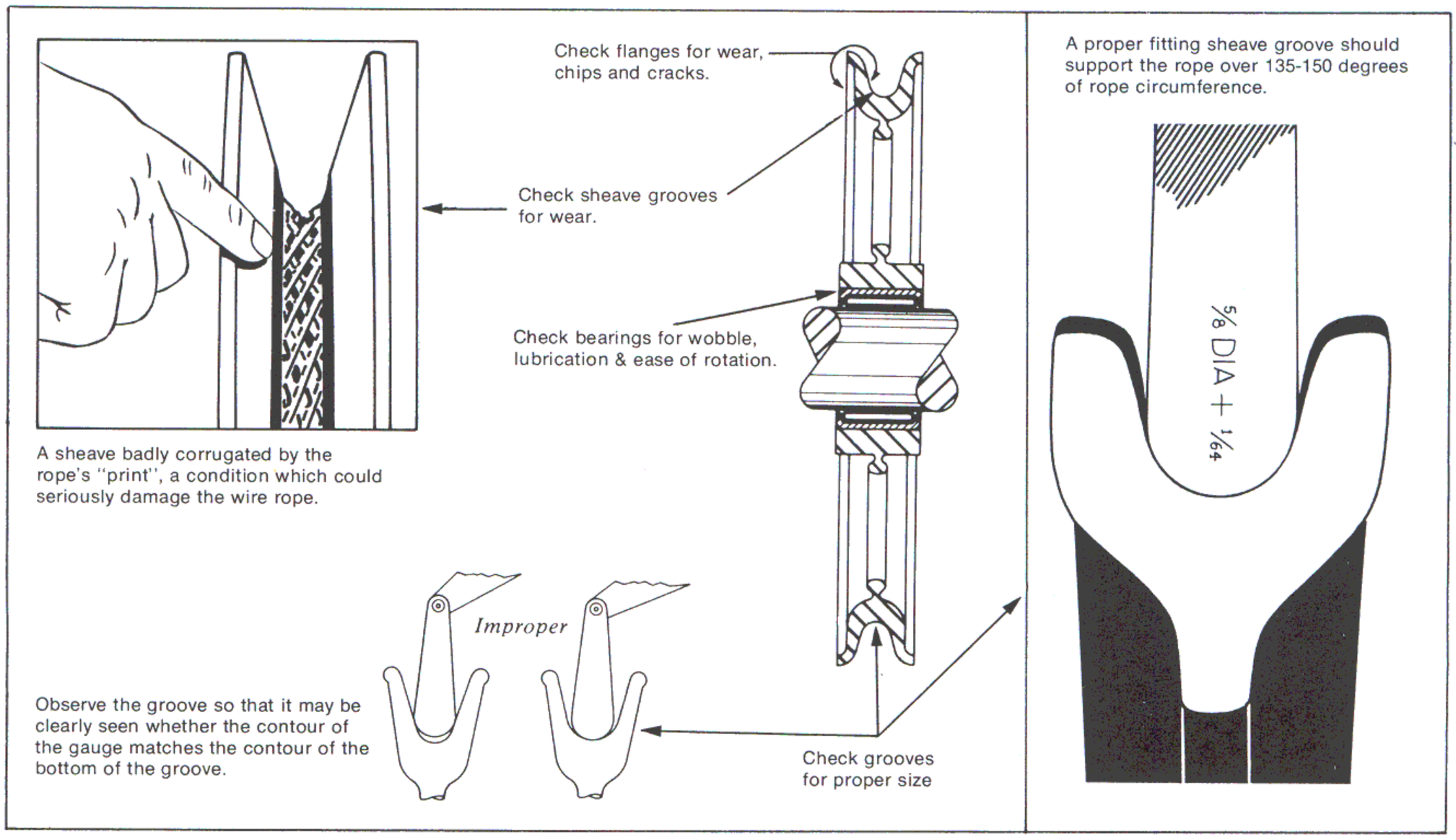
Excessively heavy sheaves should be replaced as they tend to rotate from centrifugal force after the rope stops. This causes wear on the rope.

An excessive fleet angle will cause severe abrasion on the rope as it winds onto the drum. This condition can severely shorten rope life.

LUBRICATION:

The lubrication new ropes receive during manufacture is adequate for initial storage and the early stages of the rope's working life. It must be supplemented, however, at regular intervals in accordance with the rope manufacturer's instructions.

Fig. 1.59



If a planned program of regular lubrication is not carried out then the rope will deteriorate rapidly as follows:

— Corrosion and pitting will occur causing a loss of steel area and, therefore, a loss in strength of the rope.

— The wires will become embrittled from excessive corrosion and will break easily.

— Since each wire in the rope moves relative to the others during operation they are subject to frictional wear. Lack of lubrication will increase the wear rate causing a marked reduction in strength from loss of steel area.

— Pits also cause internal nicking of the wires which results in loss of strength.

— Ropes not in regular service or those not considered as operating ropes are vulnerable to weathering out of the lubrication. Moisture seeps in and both core and wires deteriorate.

Lubricating a rope is as important as greasing any other piece of machinery. Consult your rope manufacturer for lubricants designed especially for the conditions inherent in an operating rope or a standing rope.

Used crankcase oil should never be used to lubricate a rope. It contains tiny metal chips which will abrade the rope, it is acidic and it has few of the characteristics that a good rope lubricant should have.

Good lubricants have the following characteristics:

— Corrosion resistance.

— Water repellant.

— Penetrating ability.

— Chemically neutral.

— High pressure flow characteristics.

— Adhesiveness and an affinity for steel.

— Plastic coating.

— Temperature stability.

The rope must be clean and dry before the lubricant is applied because effective lubrication occurs only when the dressing comes in contact with bare metal.

If this is not done, the lubricant will fall off allowing moisture to work into the rope to cause corrosion. Excessive moisture gradually leaches out the internal lubricant.

The old lubricant can be removed by stationary or power-driven wire brushes or by compressed air jets. (Fig. 1.60) It is advisable to use a light penetrating cleaner to soften the built up material before removing it. The lubricant supplier should be contacted regarding the proper cleaning oil to use. Do not, if at all possible, use gasoline or kerosene since too much of it will remove the internal lubricant.

In view of the small space existing between wires in the strand and strands in the rope, do not expect an externally applied lubricant to completely penetrate the rope.

The main object in external lubrication is to fill the gaps between the strands and rope so that a complete seal is provided. The lubrication should be carried out periodically to maintain this seal. The frequency required will depend on the particular installation.

Application of the lubricant may be accomplished by several methods. These should be considered with due regard to the viscosity of the compound in its state for application, length of rope involved and limitation of facilities.

Light oils may be applied by brushing or running the rope through an oil bath, by spraying, drip method and mechanical force feed. (Fig. 1.61)

For maximum penetration, the lubricant should be applied to the rope where it "opens up" as it travels around a sheave or winds on a drum. It is also advisable to apply the lubricant in a warm area. If the lubricant must be applied manually in an extremely cold area, however, rope lubricants are available with pour points as low as -50°F to -60°F.

Medium weight lubricant or heavy lubricant applied hot can be brushed on, applied by hand or running the rope through a funnel containing the lubricant. The air blast may also be used provided that dry air only is used as any moisture would promote corrosion.

Where long lengths of rope are involved brushing or hand application is tedious. However,a thorough examination can be carried on at the same time so that two important jobs can be accomplished in one operation.

It is impossible to make general recommendations regarding the time interval that should elapse between lubrications except to reiterate that the rope should be properly lubricated at all times, and thorough periodic inspections will indicate when it must be done.

If a wire rope is taken out of service for an appreciable length of time it should be cleaned, lubricated and stored in a dry place where it will be protected from the elements.

Fig. 1.60 Method of Cleaning a Rope

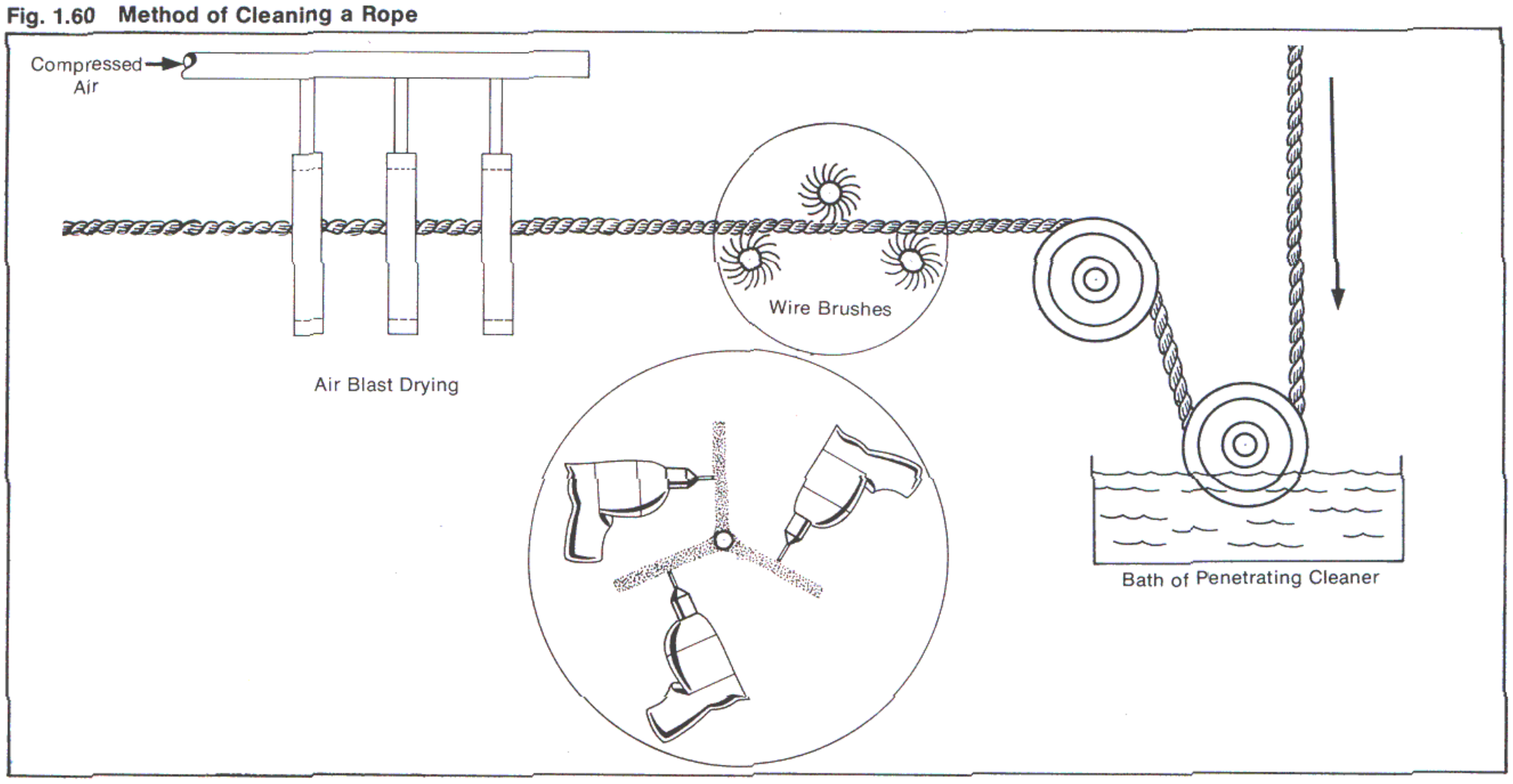
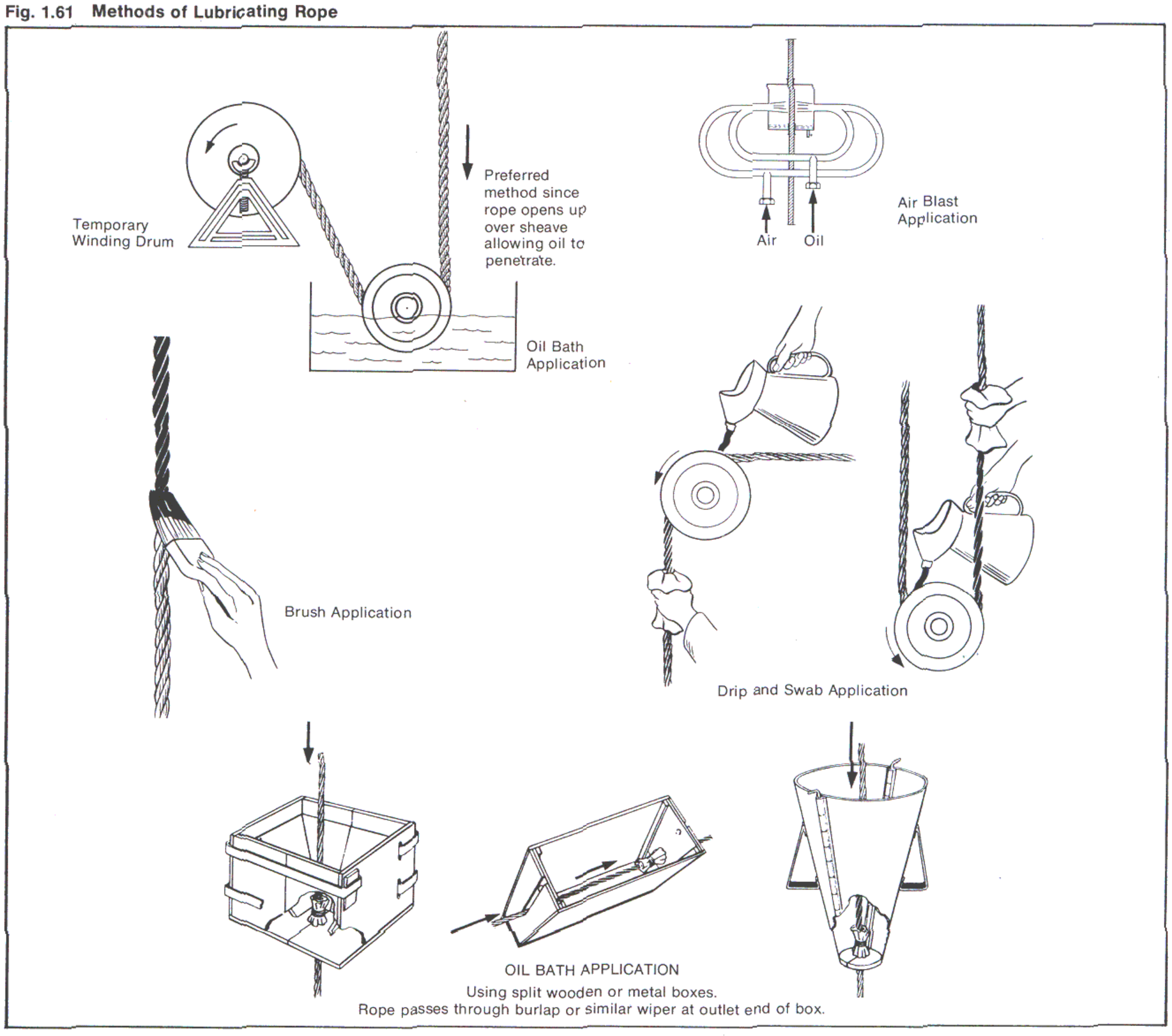


Fig. 1.61 Methods of Lubricating Rope



STORAGE:

Ropes should be stored in coils or on reels in a clean, dry place indoors. If outdoor storage is necessary then their surfaces must be covered to prevent the ingress of moisture or matter injurious to the rope. If lengthy storage is required it is good practice to periodically examine the ropes and lubricate them as necessary. (Fig. 1.62)

The rope must be kept away from heat and steam and must never be allowed to rest for lengthy periods of time on concrete or ash floors. The lime sulfur and ash can cause corrosion pits which act as stress raisers and eventually to broken wires, sometimes before the rope is put into service.

SEIZING AND CUTTING:

It is most important that tight seizings of annealed wire or strand be maintained on the ends of all ropes. If this is not done the wires and strands are apt to become slack with consequent upsetting of uniformity of tensions in the rope. This results in overloading of some strands, underloading of others, "Bird Caging" and breakage.

For stranded ropes there are 2 preferred methods of seizing:

— **For ropes larger than 1-inch diameter,** use a soft annealed seizing wire and place one end in the valley between two strands. The long end of the wire should then be turned at right angles to the rope and wound closely and tightly back over the end of the wire and around the rope several times. Finally, the two ends of the wire should be twisted together and pulled until the seizing is tight. (Fig. 1.63)

— **For ropes smaller than 1-inch diameter,** after winding the seizing wire on the rope, the two ends should be twisted together at approximately the centre of the seizing by alternately twisting and pulling until the seizing is tight. (Fig. 1.64)

If the rope is to be cut, seizings must be placed on both sides of the point where the cut is to be made. It can then be cut with a torch, mechanical shears, guillotines, or abrasive wheels.

For the recommended size and number of seizings see Table 1.10.

SPLICING:

The splicing of wire rope has an important bearing on the safety of the rope as insecure splices will fail if the ropes are subjected to shock loads. Also, improperly made splices that disturb the construction of the rope will damage the sheaves and drums which will, in turn, damage other rope sections.

Rope splicing is a skill that requires training and proper tools to be done safely and effectively. Refer to the wire rope manufacturer's handbooks and manuals for the proper splicing types, methods and procedures to use.

Fig. 1.62 Proper Way to Store Wire Rope Reels

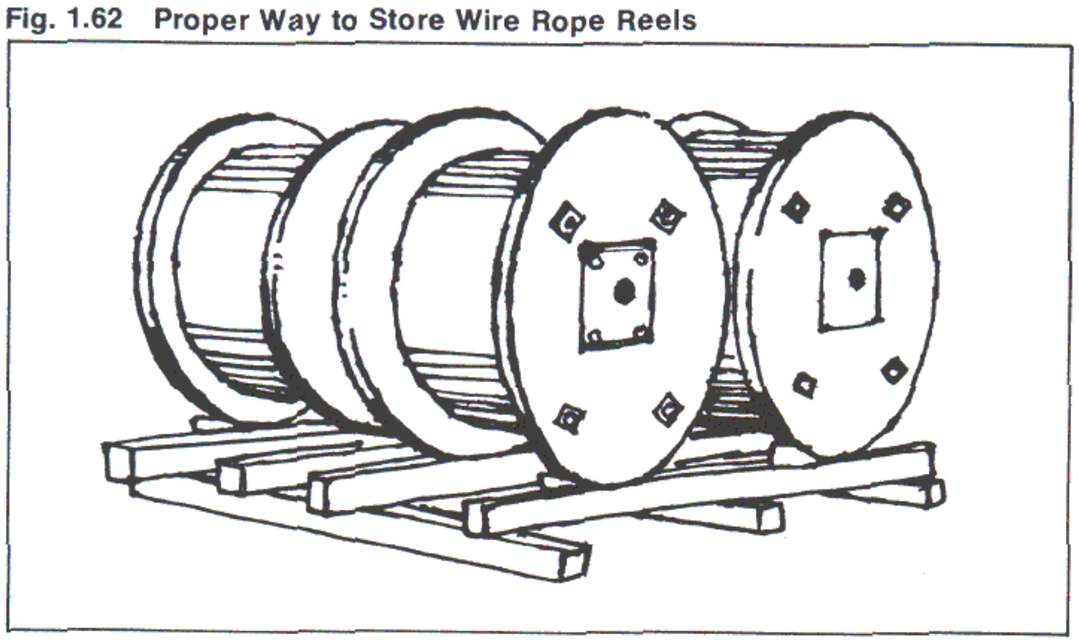


Fig. 1.63 Proper Method of Seizing a Rope Larger than 1″ in Diameter

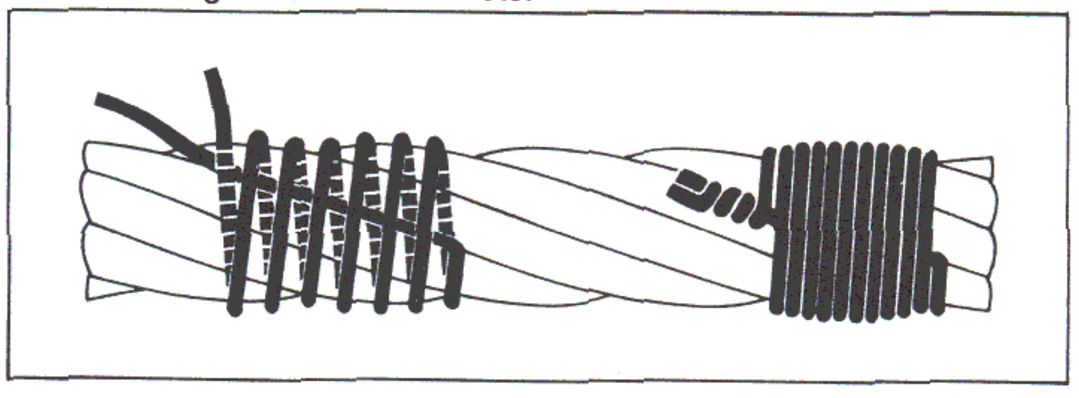


Fig. 1.64 Proper Method of Seizing a Rope Smaller than 1″ in Diameter

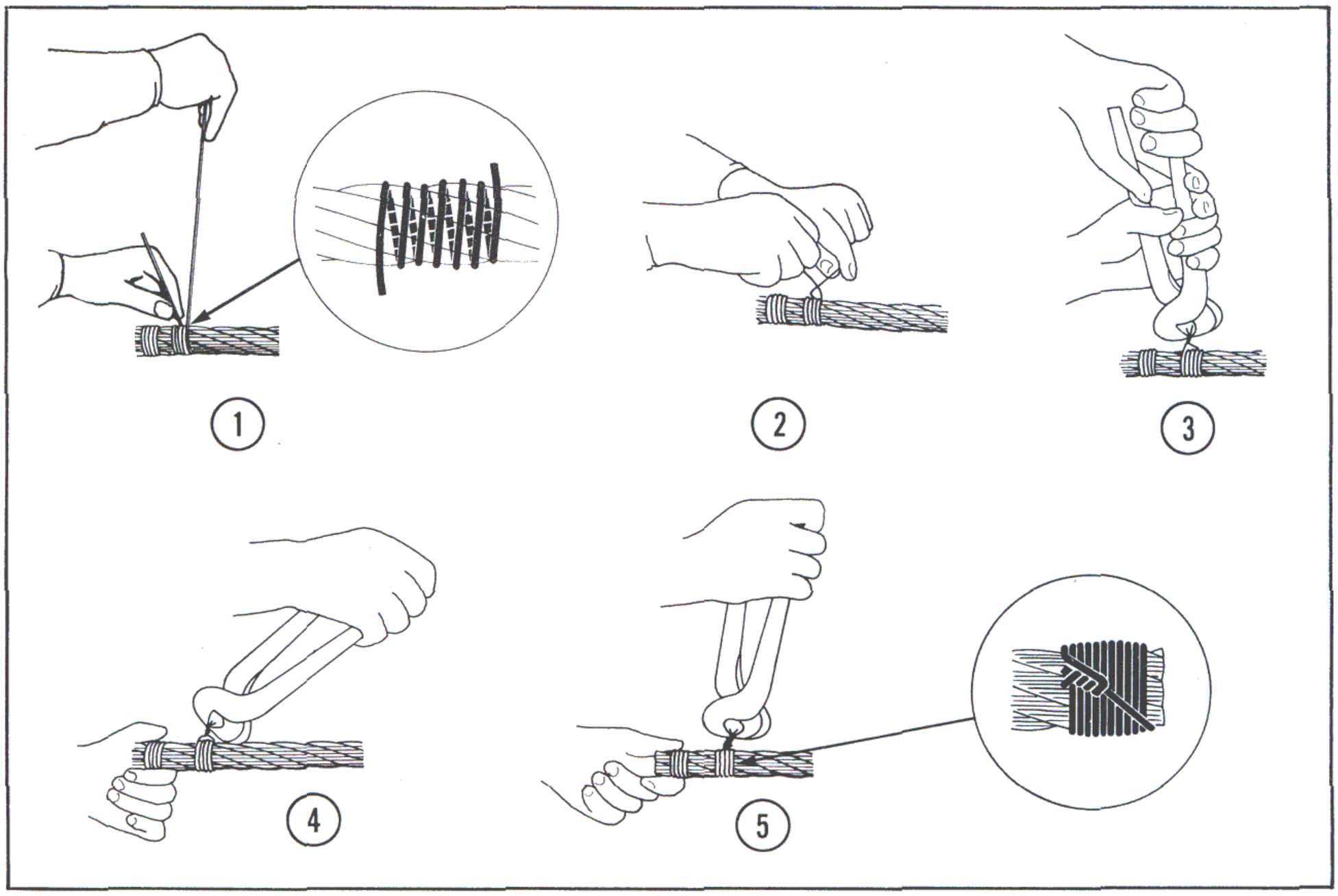


TABLE 1.10

RECOMMENDED NUMBER OF SEIZINGS AND SIZE OF SEIZING WIRE OR STRAND						
Rope Diameter (Inches)	MINIMUM NUMBER OF SEIZINGS				Approx. Diam. of Seizing (Inches)	
	6 and 8 Strand Ropes Round and Flattened Strand		Non-Rotating Ropes Round & Flattened Strand		Stranded Ropes	
	Reg. Lay, F.C.	Lang Lay, F.C. Reg. Lay, Steel Core Lang Lay, Steel Core	Groups	Seizings Per Group	Wire	Strand
3/32 & smaller	2	2	2	3	.020	
1/8 — 1/4	2	3	2	3	.024	
5/16 — 1/2	3	4	2	3	.032	
9/16 — 7/8	3	4	2	3	.040	1/16
15/16 — 1 1/2	3	4	3	3	.080	3/32
1 9/16 — 2	4	5	3	3	.106	1/8
Larger than 2	4	5	3	3	.128	5/32

END FITTINGS & CONNECTIONS

End attachments of wire rope installations are of the greatest importance to safety and it is important to know that many wire rope attachments even when properly made and installed, develop less than the full strength of the rope. Not only must you know what type to use and how to properly install them, but you must know their safe working loads as compared to that of the rope. Safety requires knowing how to:

— Select the correct fittings and connections.

— Properly install them.

— Evaluate their safe load capacity.

It is extremely important that all fittings be of adequate strength for the application. Whenever possible, "load rated" (safe working load stamped on the fitting) fittings should be used. For overhead lifting, **forged fittings** of weldless construction are the **only** type recommended.

Many types are available and the choice depends on various factors of the installation.

Zinc and Swaged Socket attachments are used on the more permanent type of installation such as pendants. They are suitable only for standing ropes subject to little or no movement, as rope movements tend to crack the ropes at entry to sockets. Rapid hoisting, road travelling and impact loads, acceleration or braking loads always set up severe vibration in the rope directly above the point of the load attachment. There is no way to prevent rope fatigue and eventual wire breaks from occurring at the point where the rope enters the sockets. Fig. 1.65 shows the relative fatigue life of various end fittings.

Zinc (Spelter) Sockets (Fig. 1.66) are efficient and permanent terminal attachments for wire rope. They are the most reliable of all terminal fittings and when properly attached, these standard drop forged sockets are 100% efficient. They are recommended for all standing ropes and whenever service conditions are severe. Only trained and properly qualified personnel should be permitted to make these connections since it is a skill that requires good facilities and a thorough understanding of the manufacturer's instructions.

Swaged Sockets (Fig. 1.67) also make efficient and permanent terminal attachments for wire rope. They are made by compressing a steel sleeve over the rope with a hydraulic press. Properly made they provide an efficiency of 100%.

Careful inspection of the wires leading into these socketed terminals is most important because the strength of this section (from 5 to 10 feet above the load attachment) is bound to be greatly reduced because of fatigue within the wires. On visual inspection, one broken wire is sufficient to cause it to be condemned. It is, therefore, advisable to cut this damaged section off periodically even though it may look sound. About one-third of the estimated life of the rope is a good interval.

When inspecting any existing socketted connection, examine the rope closely for corrosion at the socket base. This corroded wire is very susceptible to fatigue.

Fig. 1.65 Relative Fatigue Life of End Fittings

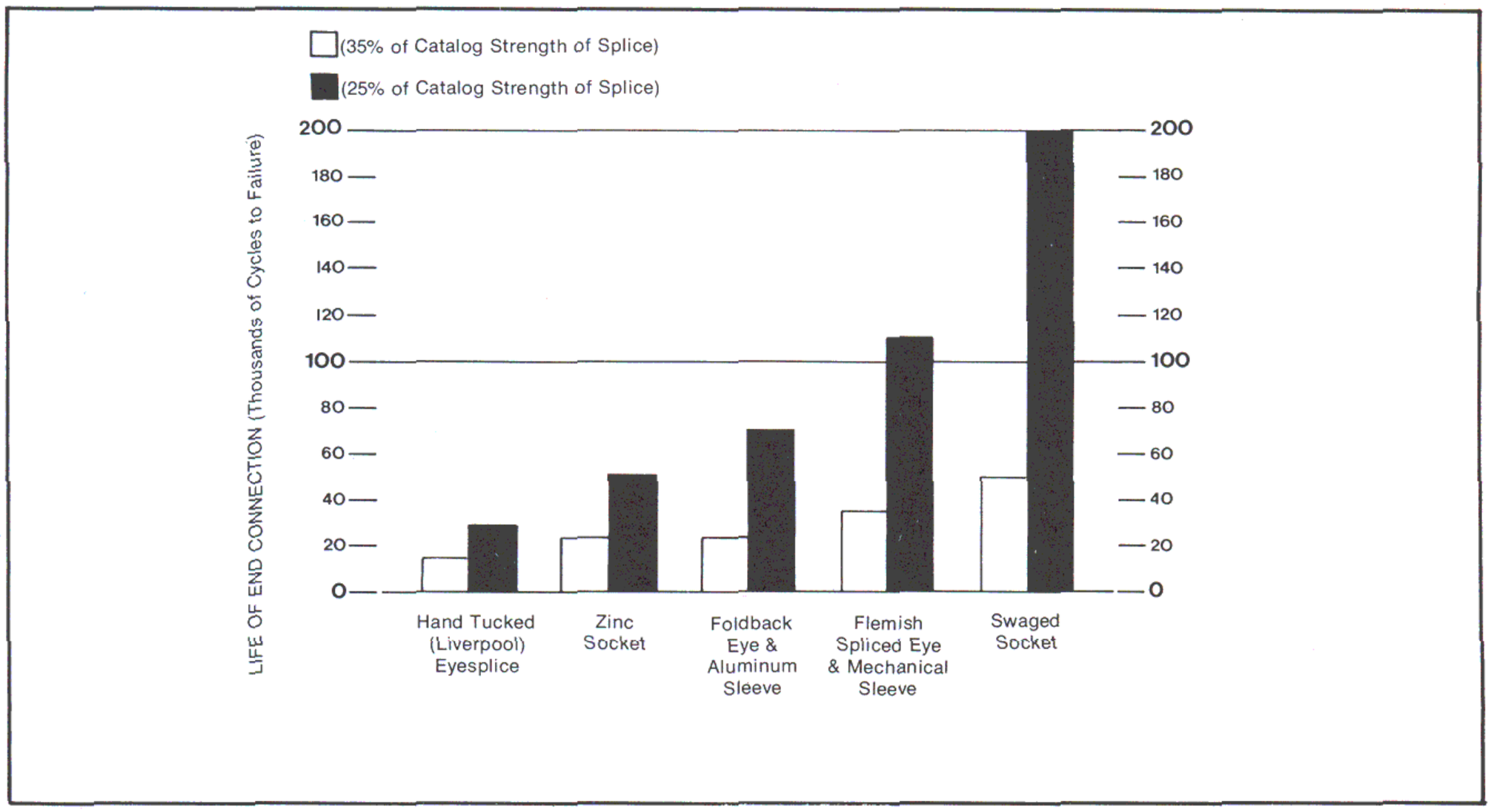
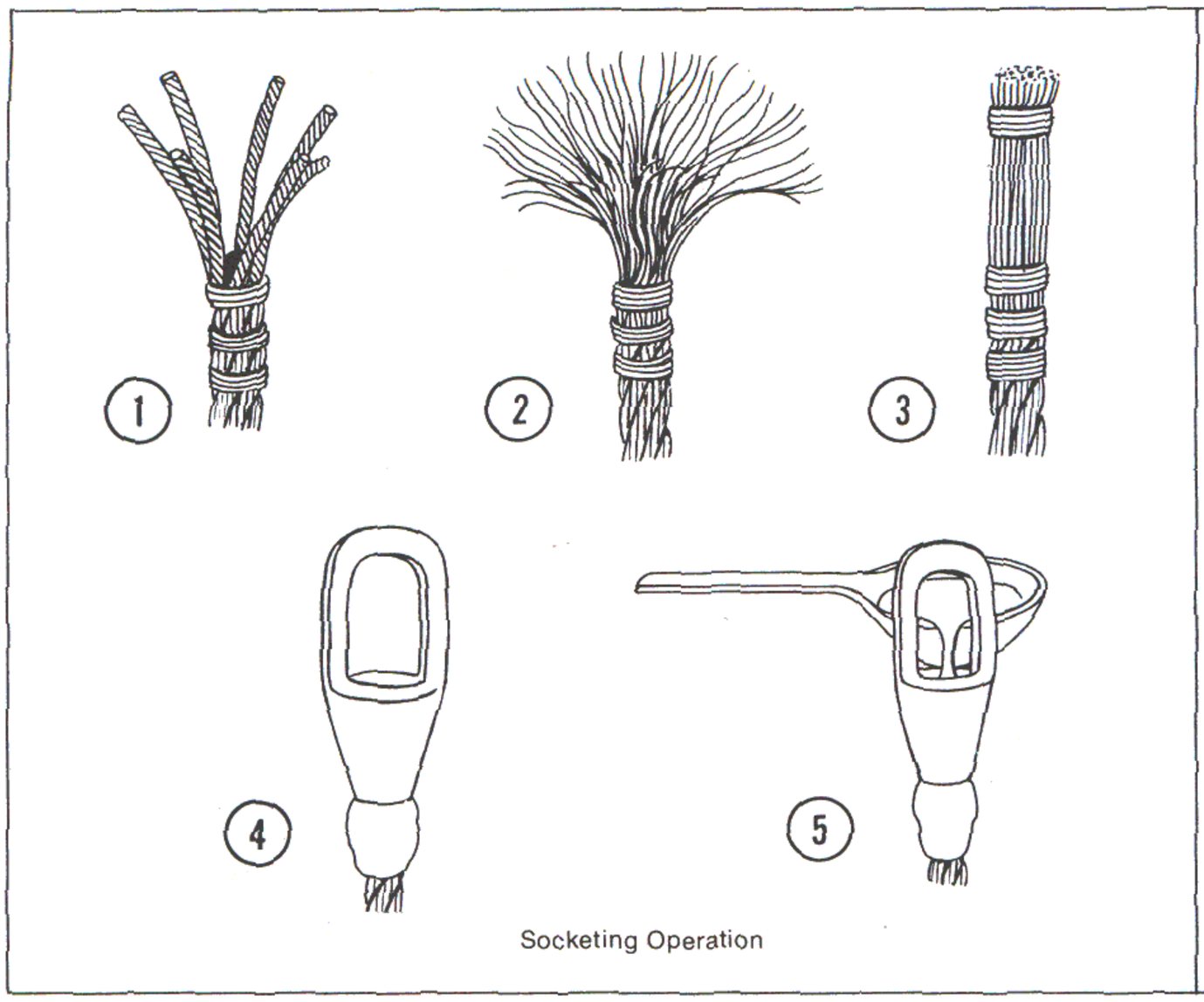


Fig. 1.66 Zinc (Spelter) Sockets



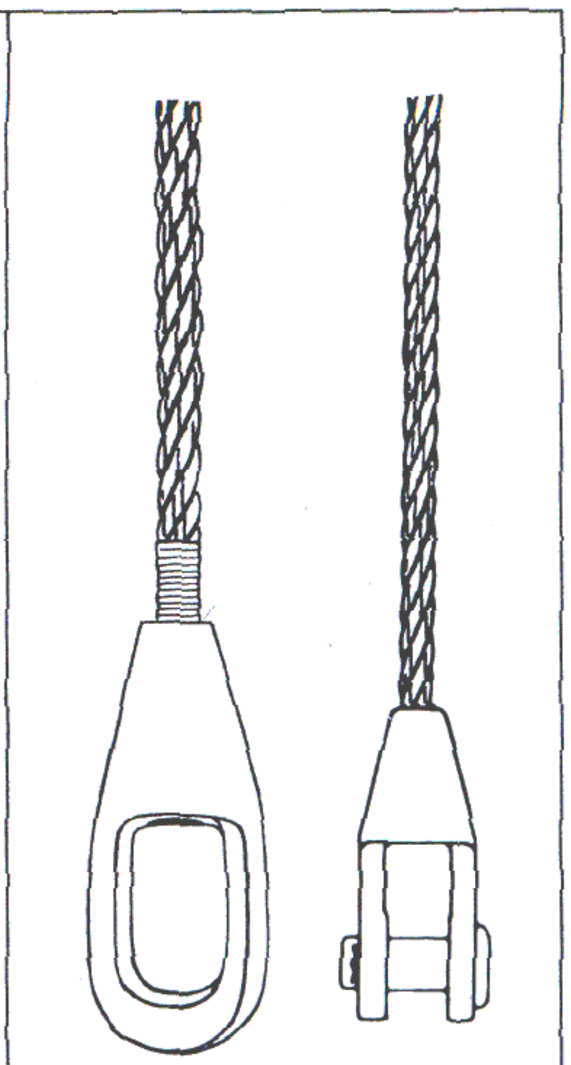


Fig. 1.67 Swaged Sockets

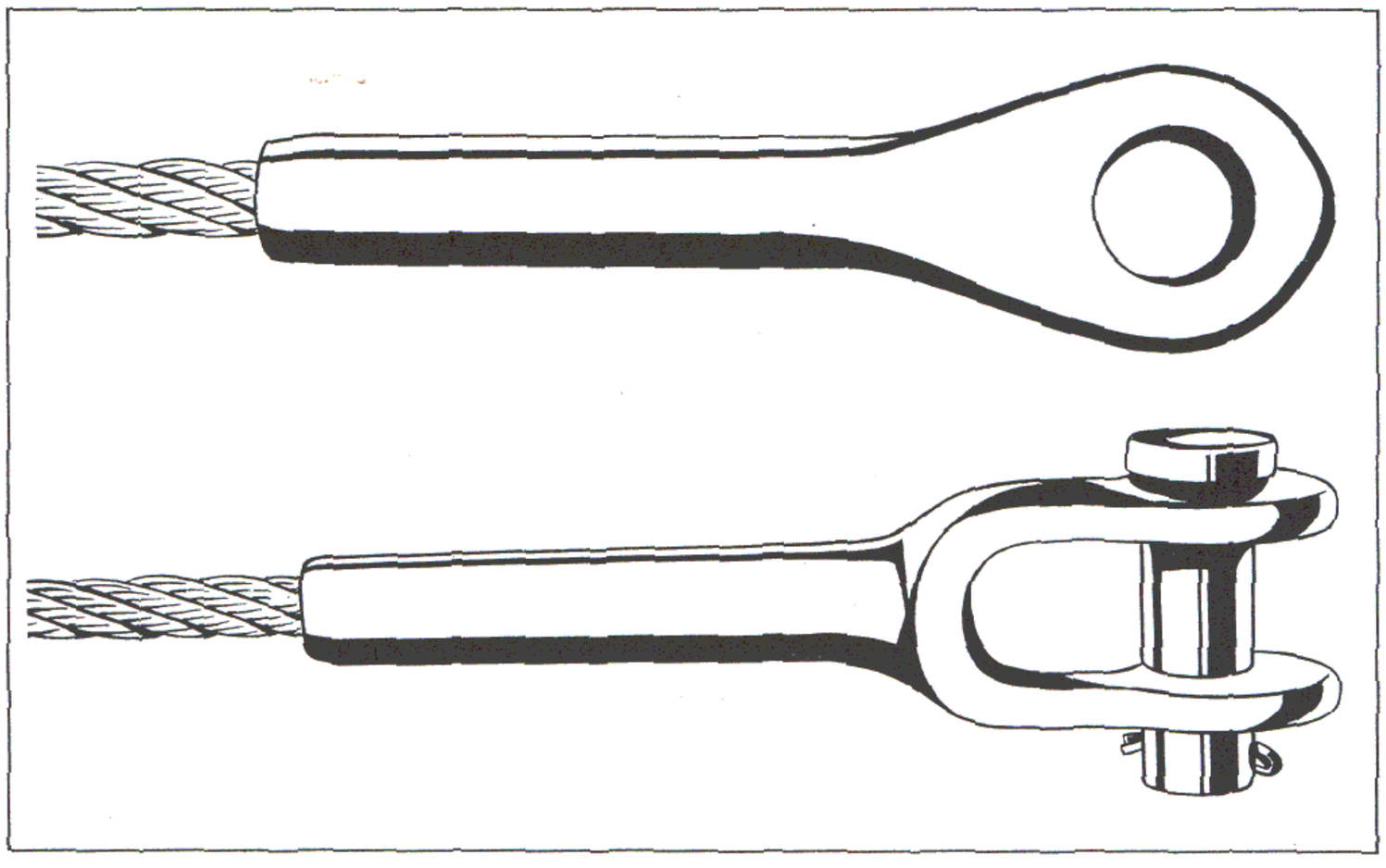
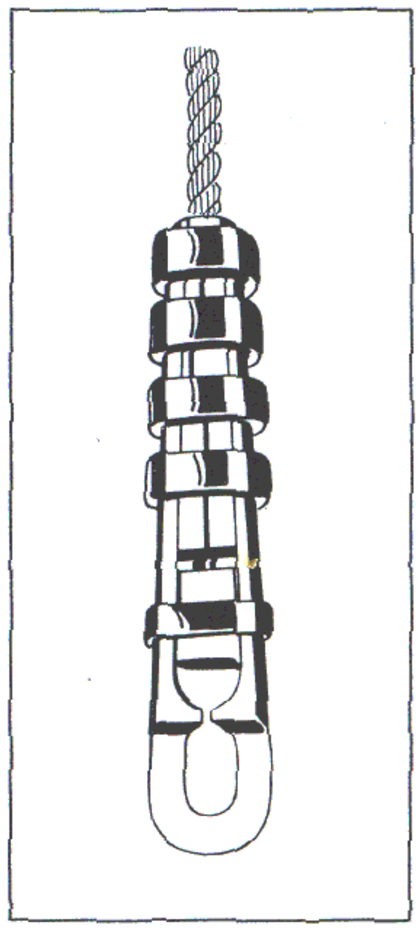


Fig. 1.68 Cappel Socket



Cappel Sockets (Fig. 1.68), when properly installed and frequently inspected, provide 100% efficiency. But their efficiency depends entirely upon the wedges being kept tight. Since the wedges are interlocked and cannot move independently of each other, the unit affords a holding power equal to the strength of any type of wire rope. The sockets also allow frequent inspection of the whole section of rope on which the grip is exerted.

Wedge Sockets are one of the simplest devices for anchoring a wire rope. They are intended for on-the-job attachment and for quick rope replacement. For overhead lifting, their advantages include ease and speed of applying and detaching. They are also used where spliced eyes cannot be reeved and would have to be made after the rope is in place.

The efficiency of wedge sockets is among the lowest of all end terminations and varies depending on model and manufacturer. Care must be taken that jarring and vibration do not force the wedges out and that accidental slackening of the rope does not release the socket. To prevent this, wedge sockets should be secured. Figure 1.69 shows three methods of securing the connnection.

Unless you use a special "piggyback" clip (Fig. 1.69), don't clip the dead end of rope to the live side. This seriously weakens the attachment. The clip takes the load and can deform and break the rope (Fig. 1.70).

When clipping to non-rotating or rotation-resistant rope, follow the rope manufacturer's guidelines on end terminations since procedures vary from rope to rope. Typically, these ropes have a slightly smaller radius than conventional ropes because they are tightly wound. Take care to avoid core slippage.

When using wedge sockets it is good practice to start out with a longer rope than is required so that the socket can be renewed periodically without having to splice the rope. The wedge can be punched out of the socket, the bad wire cut off and the new end re-fitted in the socket. The rope end should always protrude at least 6 to 9 inches, or one rope lay, beyond the socket.

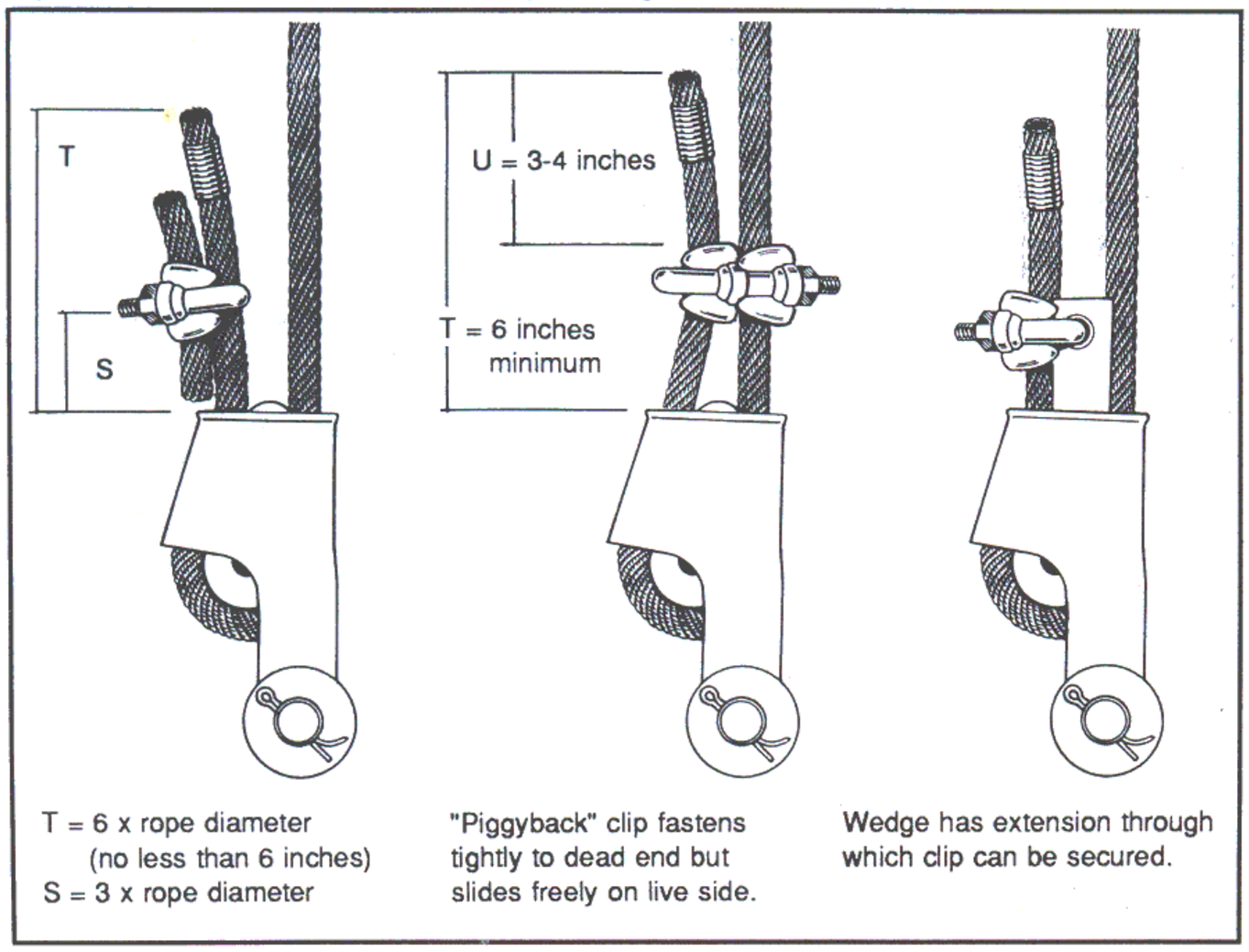
It is very important to ensure that the loaded part of the rope is not kinked where it leaves the wedge. The sockets must be installed so that the load line is in a straight line pull with the eye of the socket (Fig. 1.71).

Spliced Eyes in various forms are frequently used as wire rope end attachments.

With the exception of some slings, all spliced eyes must incorporate rope thimbles to maintain rope strength and reduce wear. If a thimble is not used on a spliced eye, the efficiency of the connection can be reduced by as much as 10% because the rope flattens under load (Fig. 1.72).

The danger with eye splices is that they differ widely in efficiency but differ very little in appearance. There are many forms of eye splices that look similar. Moreover, the type can be difficult to identify exactly when covered by serving wire or pressed metal sleeves. Caution is the word with eye splices.

Fig. 1.69 Proper Methods of Securing a Wedge Socket



T = 6 x rope diameter (no less than 6 inches)
S = 3 x rope diameter

"Piggyback" clip fastens tightly to dead end but slides freely on live side.

Wedge has extension through which clip can be secured.

Fig. 1.70

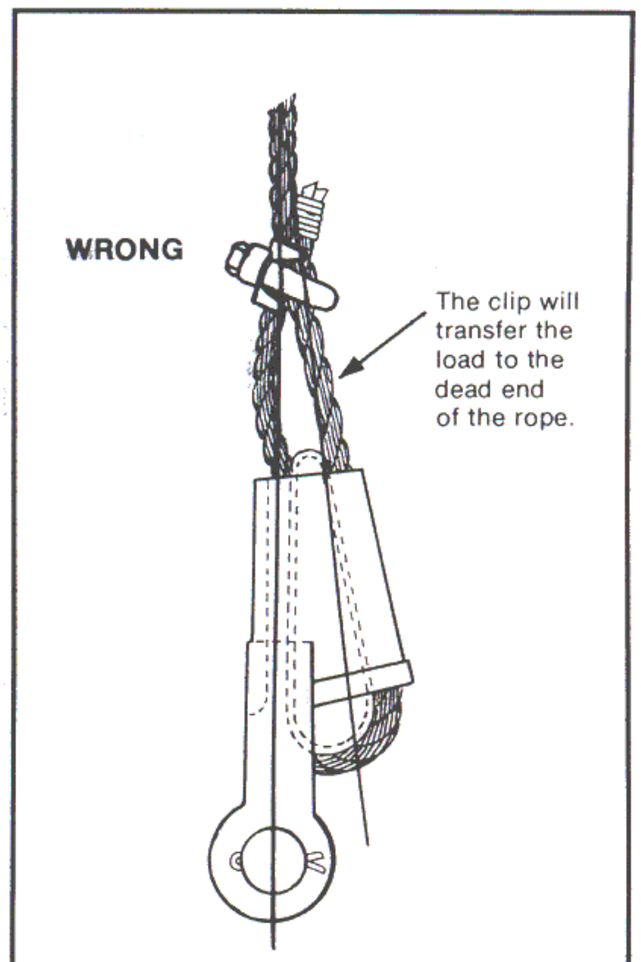


Fig. 1.71 Installing a Wedge Socket on a Rope

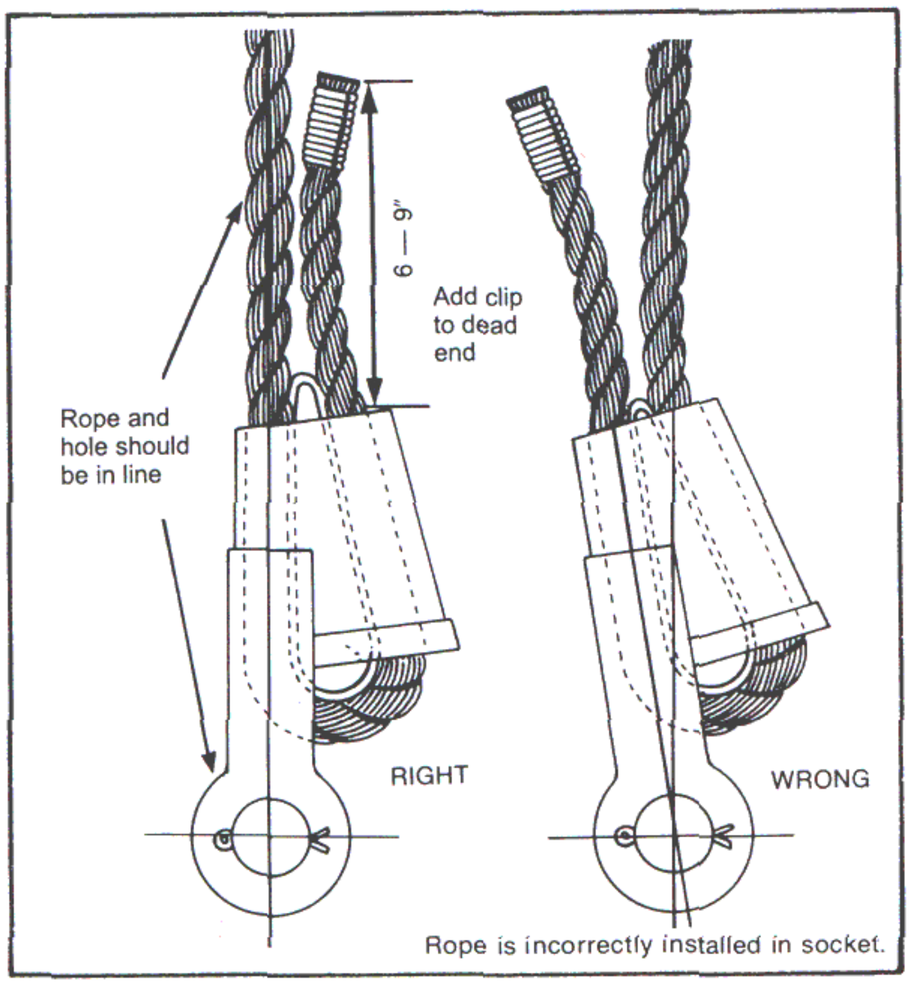


Fig. 1.72 Reason Why a Thimble Should Be Used in All Eyes

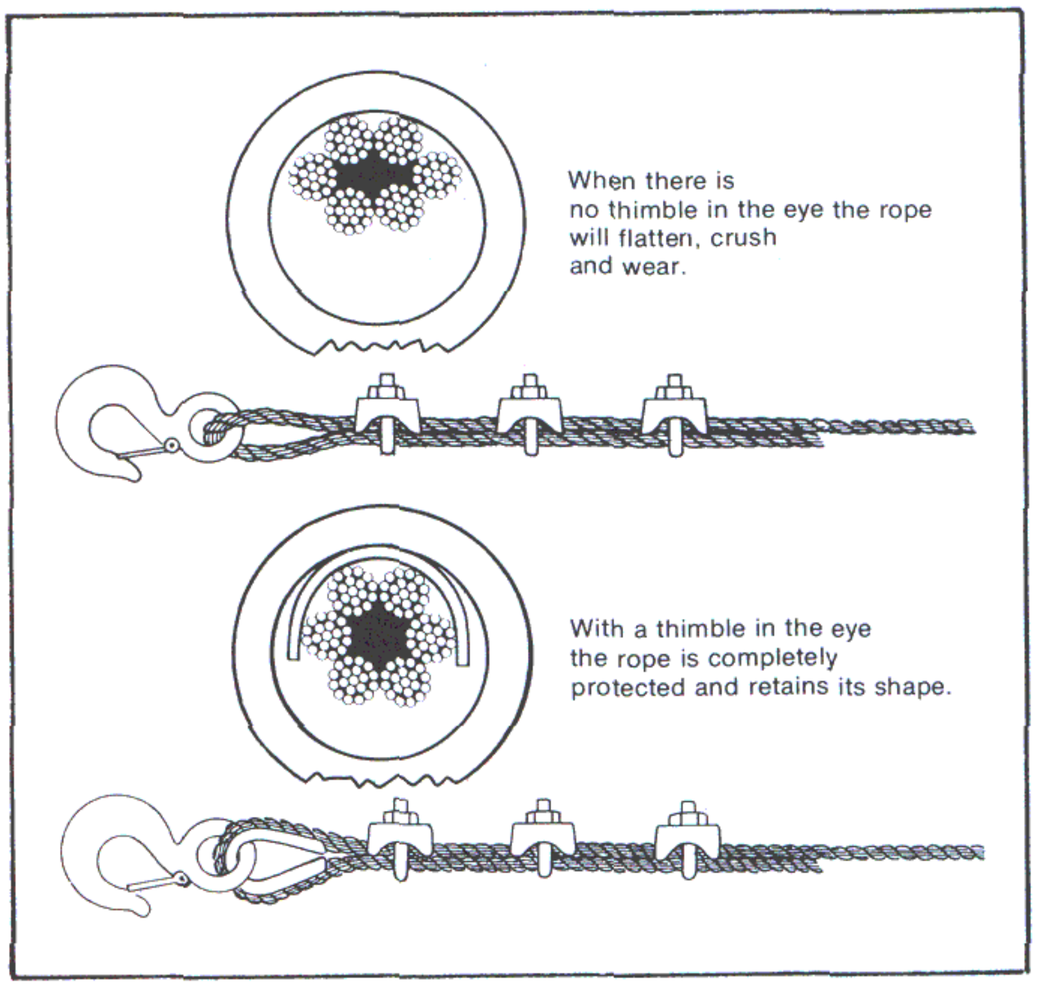


Fig.1.73 Flemish Eye and Serving

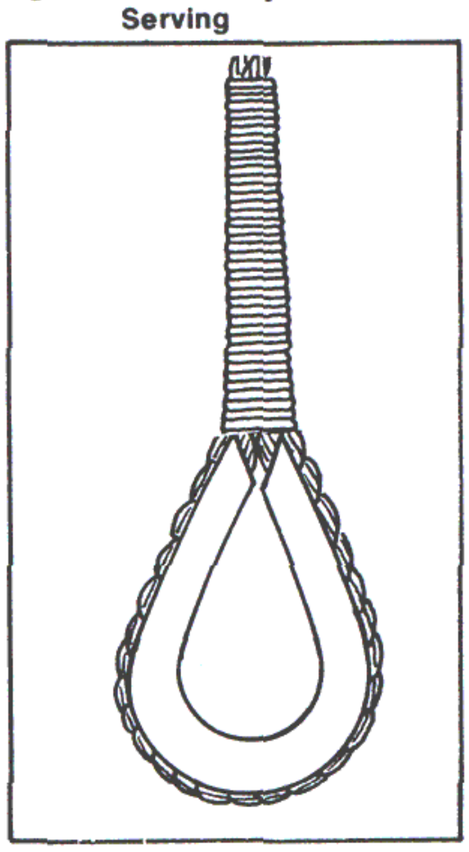


Fig. 1.74 Flemish Eye and Pressed Metal Sleeve

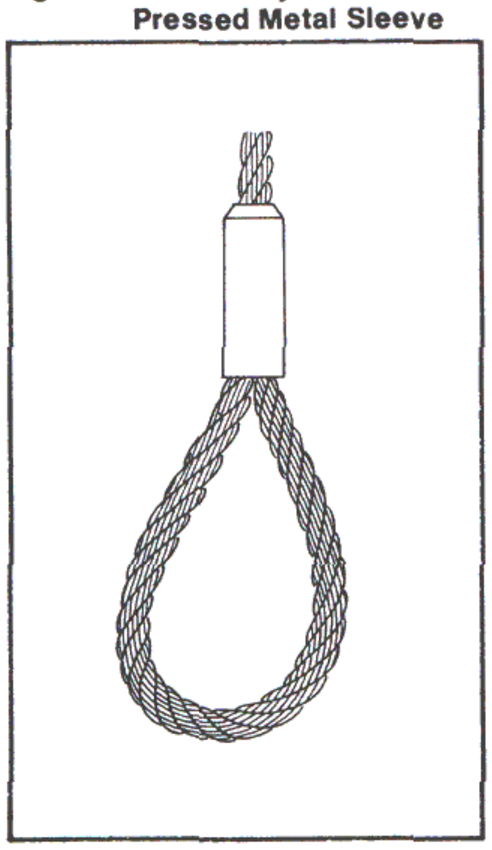


Fig. 1.75 Tucked Eye and Serving

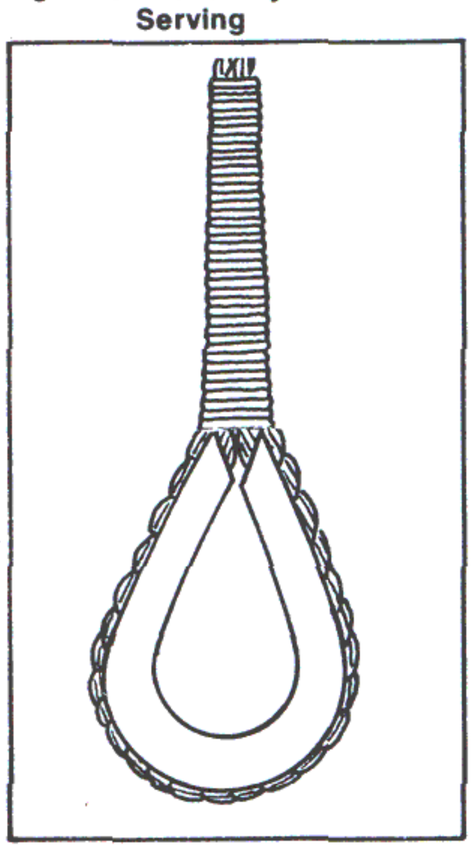


Fig. 1.76 Tucked Eye and Pressed Metal Sleeve

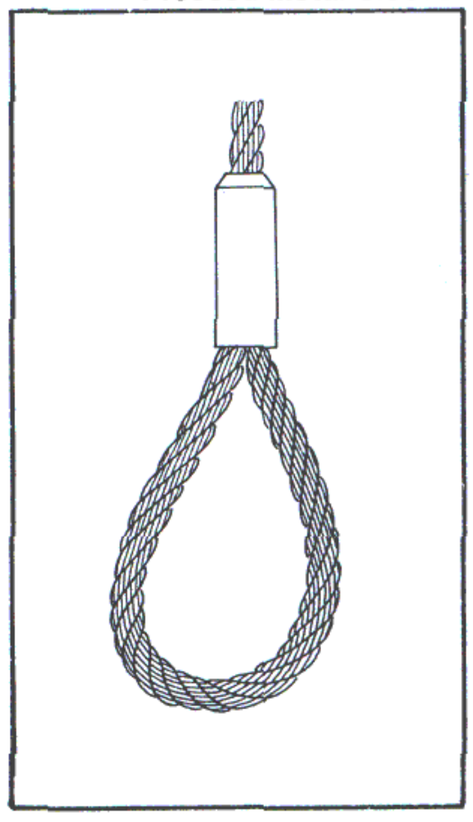
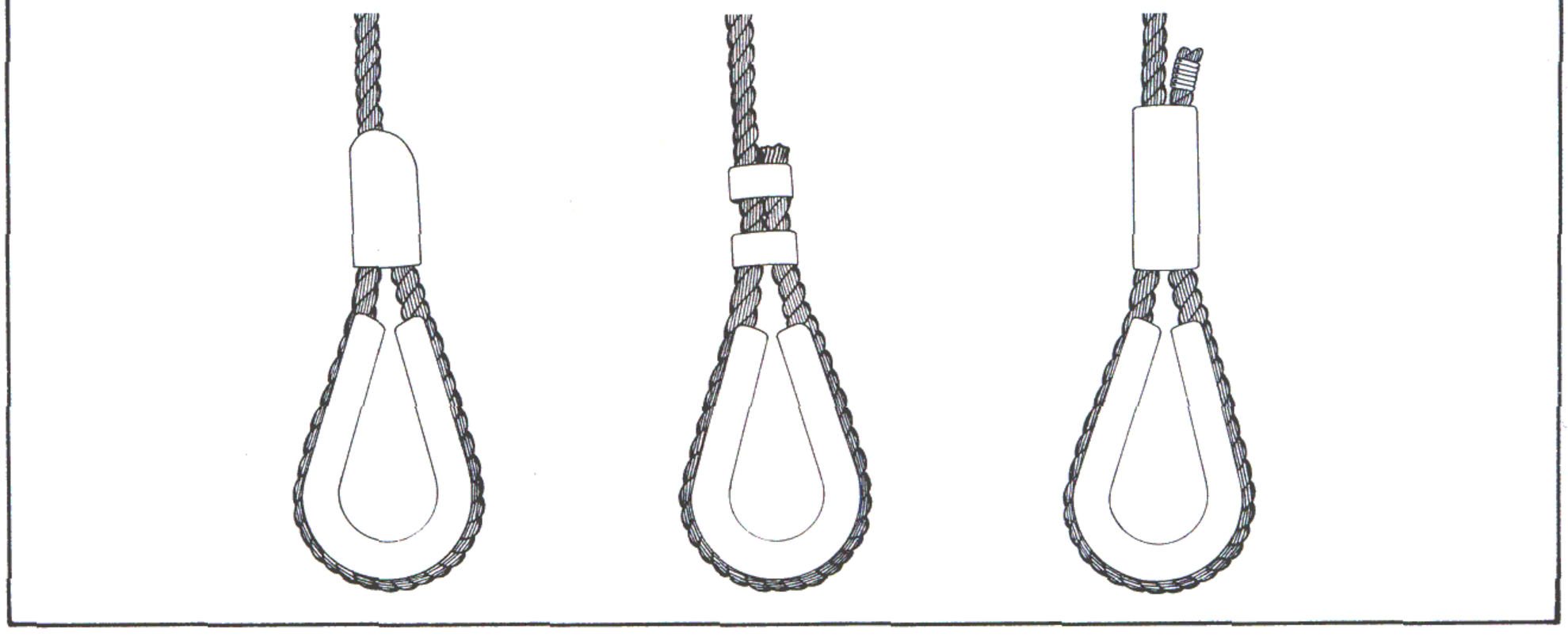


Fig. 1.77 Fold Back Eye and Pressed Metal Sleeve



Every wire rope manufacturer attaches a different name to his particular type of eye splice but they are usually variations of the three basic types:

Group I: —**Flemish Eye (Rolled Eye)**
—**Flemish Eye + Serving (Fig. 1.73)**
—**Flemish Eye + Pressed Metal Sleeve (Fig. 1.74)**

Group II: —**Tucked Eye (Hand Spliced Eye or Liverpool Splice)**
—**Tucked Eye + Serving (Fig. 1.75)**
—**Tucked Eye + Pressed Metal Sleeve (Fig. 1.76)**

Group III: —**Fold Back Eye + Pressed Metal Sleeve (Fig. 1.77)**

A comparison of figures 1.73-1.76 shows that it is almost impossible to determine what kind of splice you are working with when it is covered by serving wire or pressed metal sleeves. All personnel must be told exactly what type the company uses and all splices must be identical on all slings.

The best and most secure splices are those from Group I and the best of all and the one recommended for all rigging and hoisting use is the Flemish Eye + Pressed Metal Sleeve. It is an excellent attachment. When properly made it develops almost 100% of the catalogue breaking strength. The strand ends of the spliced eye are secured against the live portion of the rope by means of a steel or aluminum sleeve set in place under pressure. Of the various types of mechanical splices this is the most dependable. The strength of the splice is not wholly dependent on the sleeve since it has the hand splicing to fall back on should the sleeve fail and the tapered end of the sleeve allows the splice to pass over obstructions without snagging.

The splices from **Group II** (with the exception of the Tucked Eye + Pressed Metal Sleeve which is almost 100% efficient) are less secure than those from Group I. The Tucked Eye unlike the Flemish Eye can develop only 70% of the strength of the rope and tends to come free as the rope unwinds. As the ropes untwist, the tucks in the eye begin to pop free and on short lengths of cable or sling one or two turns will seriously weaken the eye and consequently they should not be used for hoisting loads. This, of course, refers to the splice connection only. The addition of wire seizings protects the splice and the rigger's hands, but adds no strength.

All Group II eye splices should have at least 5 tucks and the completed splice should be carefully and tightly wrapped with a wire serving to cover the whole of the splice. The efficiencies of the Tucked or Hand Spliced Eyes (without pressed metal sleeves) are as given in Table 1.11.

TABLE 1.11

Rope Diameter	Efficiency
1/4" and Smaller	95%
5/16" — 3/4"	90%
7/8" — 1"	85%
1 1/8" — 1 1/2"	80%
1 5/8" — 2"	75%
2 1/8" and Larger	70%

The **Group III** Eye Splices, the Fold Back Eyes + Pressed Metal Sleeves are made by bending the rope to the eye dimension required and securing the free or dead end of the rope against the live portion of the rope by means of a steel or aluminum sleeve set in place under pressure. Some manufacturers unlay or separate the dead end strands and relay them into the grooves between the strands around the body of the live side of the rope. To hold these strands in place, steel ferrules are pressed onto the splice by a hydraulic press.

It is strongly recommended that these splices never be used for overhead hoisting since improper swaging or split sleeves will result in complete failure without warning. (Fig. 1.78)

It is very easy to confuse the excellent mechanically spliced eye with this fold back eye so be certain that all spliced eyes on the job are of one type or the other, preferably of the mechanically spliced type.

Collet Connections (Fig. 1.79) are similar to the Fold Back Eye except that instead of the sleeve being swaged on, it takes the form of a split collet, sleeve and nut arrangement. The nut is placed on the rope, a loop of the eye size required is made. The collets are placed on the rope and the dead end of the rope is extended at least one-half of the rope diameter beyond them. The collets are held together by hand and the nut turned on as far as possible by hand. The loop is closed around the thimble by holding the live end of the rope and pulling on the clamp. The thimble is kept 1/2 to 1-rope diameter from the clamp. The assembly is then placed in a vise and the nut is torqued.

Fig. 1.78 Failure of Fold Back Eye Splice

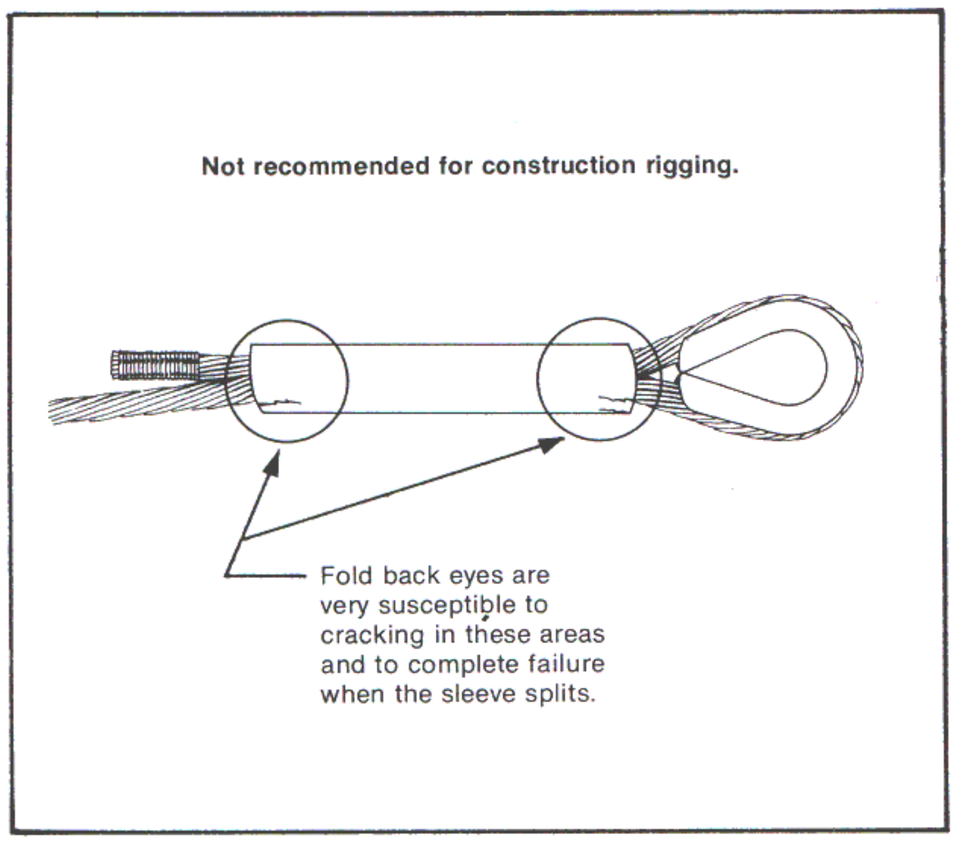


Fig. 1.80 Clamp and Thimble Connection

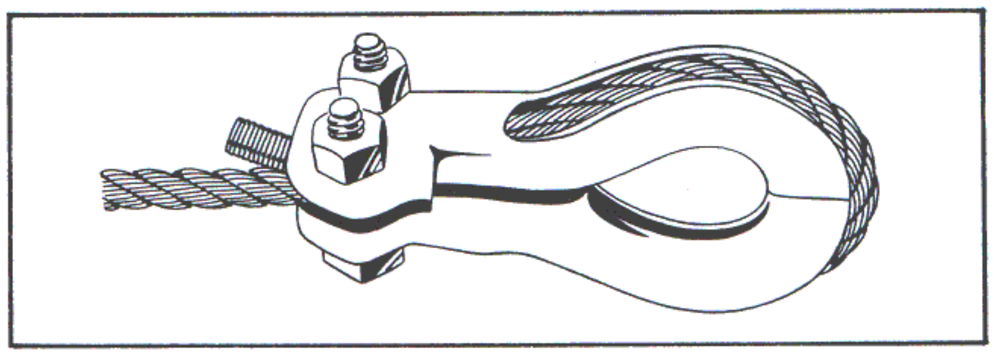


Fig. 1.81 Cable Clip Connection

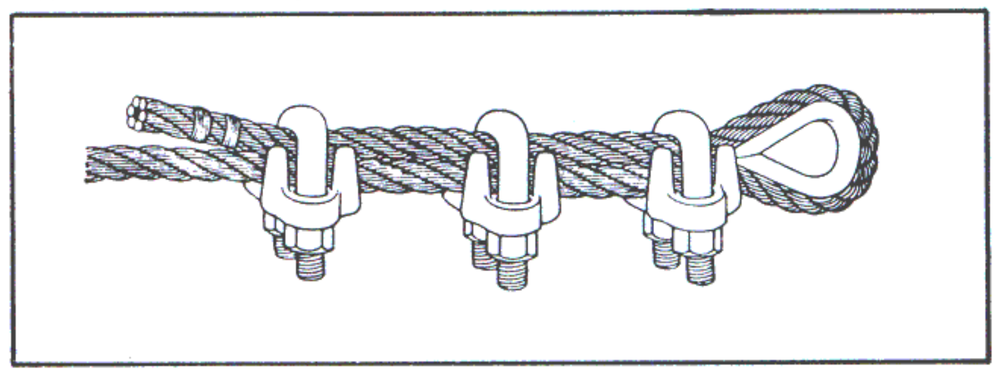
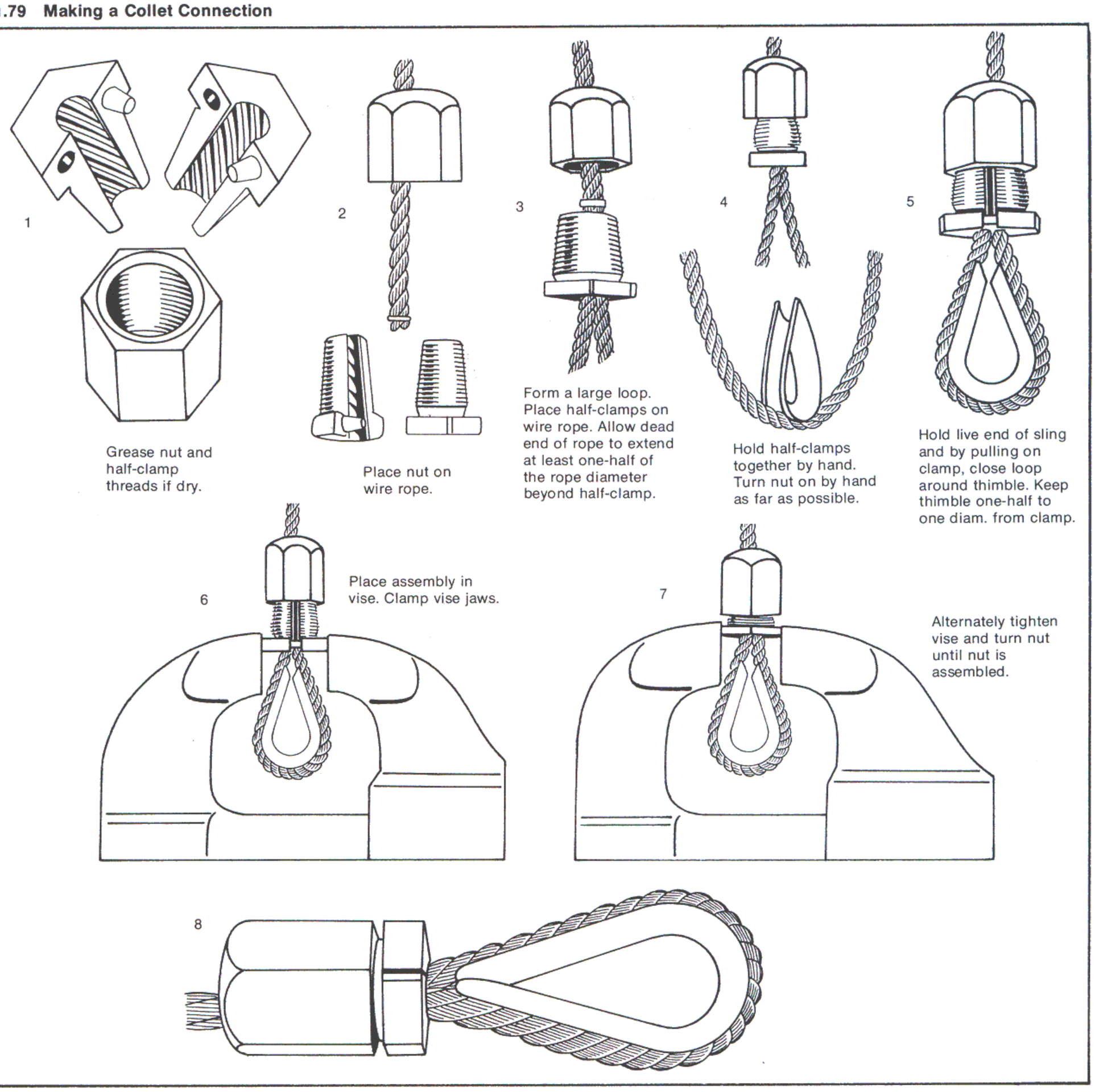


Fig. 1.79 Making a Collet Connection



Clamp and Thimble Connections (Fig. 1.80) combine both the clamp and the thimble in one unit, and are capable of developing approximately 80% of the wire rope strength.

Cable Clips (Fig. 1.81) The most common method used to make an eye or attach a wire rope to a piece of equipment is with cable or Crosby clips of the U-Bolt and saddle type or of the double integral saddle and bolt type (known as Safety or Fist Grip).

These terminations have the advantage of allowing thorough examination and ease of field installation. When applied with proper care, thimbles, and according to the following tables, clipped eye terminations will develop approximately 80% of the rope strength. All clips must be of drop-forged steel; malleable iron clips must never be used.

U-Bolt clips must have the U-Bolt section on the dead or short end of the rope and the saddle on the live or long end of the rope. The wrong application (U-Bolt on live instead of dead end) of even one clip can reduce the efficiency of the connection to 40%. (Fig. 1.82)

Never use fewer than the number of clips recommended in Table 1.12. Turn back the correct amount of rope for dead ending to permit proper spacing of the clips. Always use **new** clips; re-used clips will not develop the proper efficiency. It is equally important to always use a thimble to prevent the rope from wearing in the eye and to provide a safer connection.

Apply the first clip one base width from the dead end of the wire rope. (Fig. 1.83) Tighten the nuts. Apply the second clip adjacent to the thimble, but don't tighten the nuts. Apply all the other clips, leaving equal space between each. For maximum holding power they should be installed 6-7 diameters apart. Take up the rope slack by applying tension to the eye and cable and tighten all the nuts evenly on all the clips to the recommended torque.

After the rope has been in operation for an hour or so, all nuts on the clip bolts will have to be retightened, and they should be checked for tightness at frequent intervals thereafter. This is necessary because the rope will stretch slightly, causing a reduction in diameter which will slacken the clips.

Double saddle clips or **Fist Grip clips** (Fig. 1.84) are preferable to the U-Bolt clips. It is impossible to install them incorrectly and they cause less damage to the rope. Less turn back is required and fewer double saddle clips than U-Bolt clips are required in some rope sizes as indicated in Table 1.13.

TABLE 1.12

INSTALLATION OF WIRE ROPE CLIPS

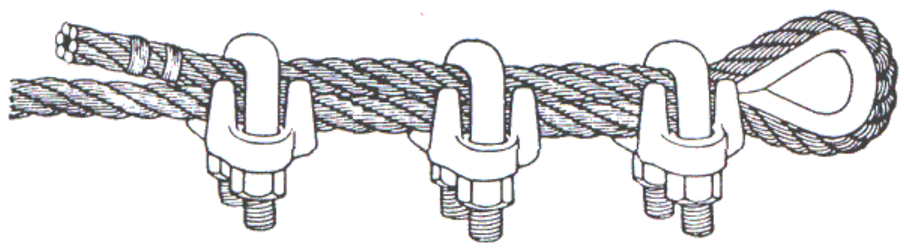
Rope Diameter (Inches)	Minimum No. of Clips	Amount of Rope Turn Back From Thimble (Inches)	Torque in Foot-Pounds Unlubricated Bolts
1/8	2	3 1/4	—
3/16	2	3 3/4	—
1/4	2	4 3/4	15
5/16	2	5 1/2	30
3/8	2	6 1/2	45
7/16	2	7	65
1/2	3	11 1/2	65
9/16	3	12	95
5/8	3	12	95
3/4	4	18	130
7/8	4	19	225
1	5	26	225
1 1/8	6	34	225
1 1/4	6	37	360
1 3/8	7	44	360
1 1/2	7	48	360
1 5/8	7	51	430
1 3/4	7	53	590
2	8	71	750
2 1/4	8	73	750
2 1/2	9	84	750
2 3/4	10	100	750
3	10	106	1200

TABLE 1.13

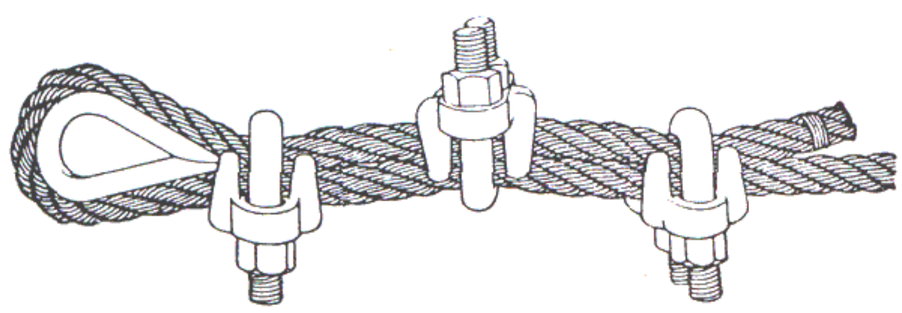
INSTALLATION OF DOUBLE SADDLE CLIPS

Rope Diameter (Inches)	Minimum No. of Clips	Amount of Rope to Turn Back (Inches)	Torque in Foot-Pounds Unlubricated Bolts
3/16	2	4	30
1/4	2	4	30
5/16	2	5	30
3/8	2	5 1/2	45
7/16	2	6 1/2	65
1/2	3	11	65
9/16	3	12 3/4	130
5/8	3	13 1/2	130
3/4	3	16	225
7/8	4	26	225
1	5	37	225
1 1/8	5	41	360
1 1/4	6	55	360
1 3/8	6	62	500
1 1/2	6	66	500

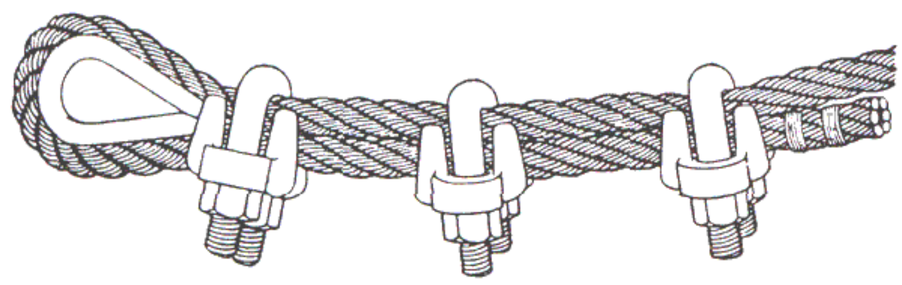
Fig. 1.82 Right and Wrong Ways of Using Cable Clips



Correct
U-Bolt of all clips on dead end of rope



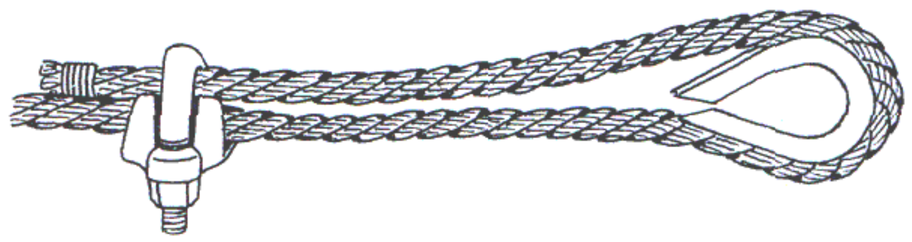
Incorrect
Do not stagger clips



Incorrect
U-Bolt of all clips on live end of rope

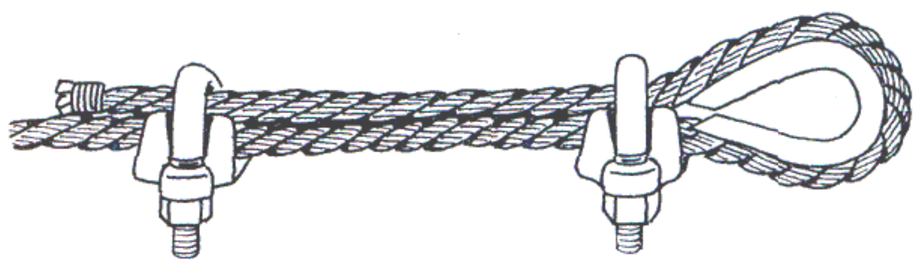
Fig. 1.83 Proper Method of Installing Cable Clips

STEP 1



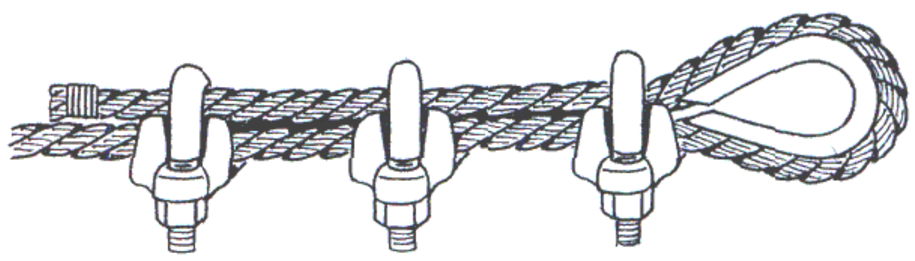
APPLY FIRST CLIP — one base width from dead end of wire rope — U-Bolt over dead end — live end rests in clip saddle. Tighten nuts evenly to recommended torque.

STEP 2



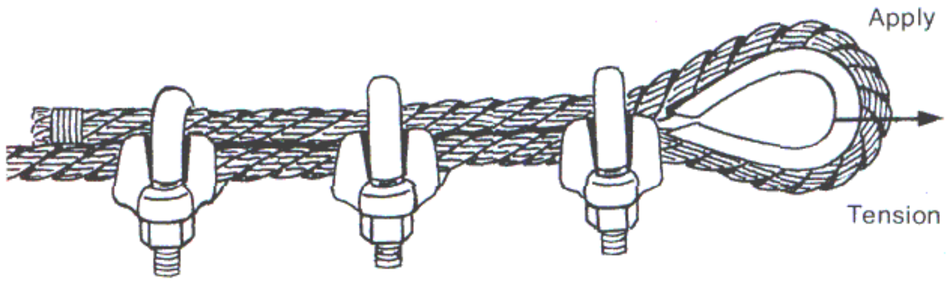
APPLY SECOND CLIP — nearest loop as possible — U-Bolt over dead end — turn on nuts firm but DO NOT TIGHTEN.

STEP 3



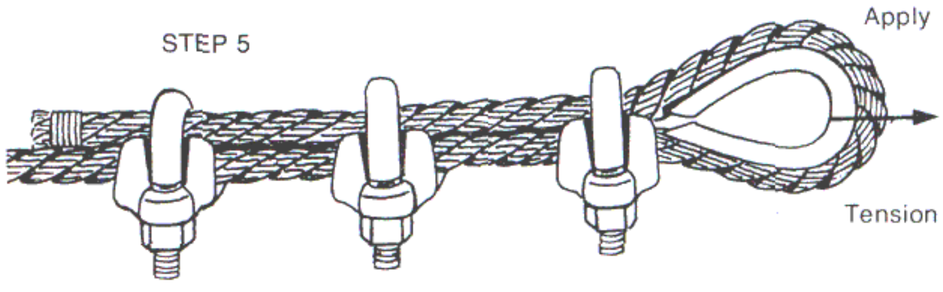
ALL OTHER CLIPS — Space equally between first two.

STEP 4



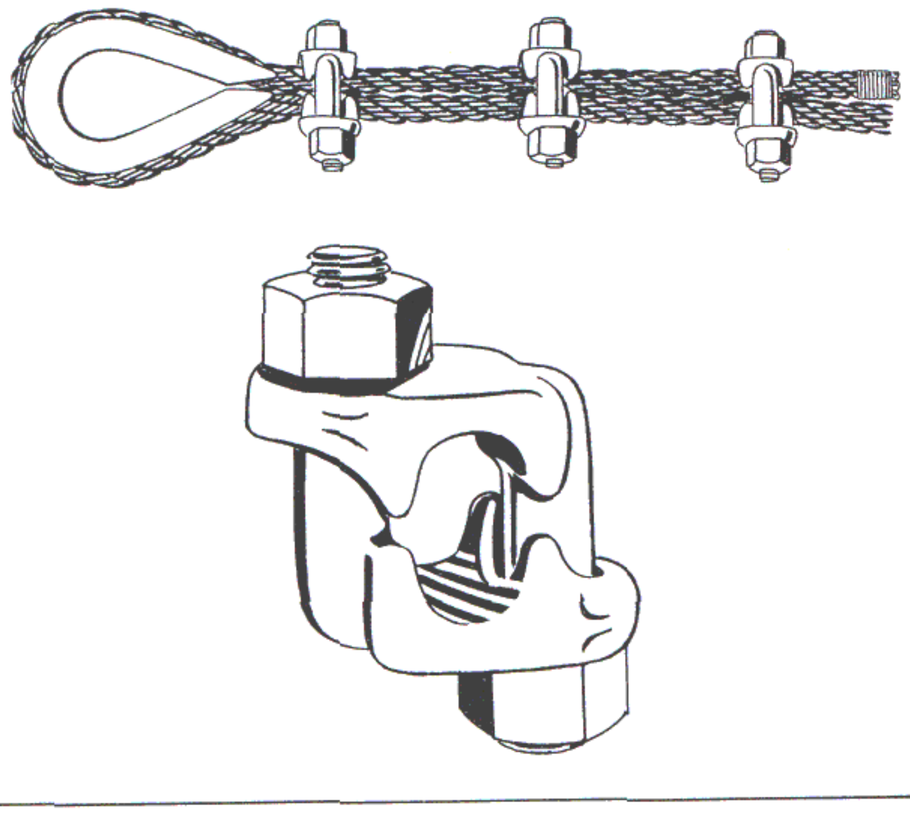
Apply tension and tighten all nuts to recommended torque.

STEP 5



Recheck nut torque after rope has been in operation.

Fig. 1.84 Double Saddle Clips (Fist Grip Clips)



Still greater efficiency can be obtained by the use of long, double base clamps extending at least 6 rope diameters in length; these obtain a greater clamping force on the rope without damaging it, and rope life and safety increase accordingly. (Fig. 1.85)

Never use any kind of clip to directly connect two straight lengths of rope. If this is necessary, use the clips to form an eye (with thimble) in each length and connect the eyes together. (Fig. 1.86)

Fig. 1.85 Double Base Clamp

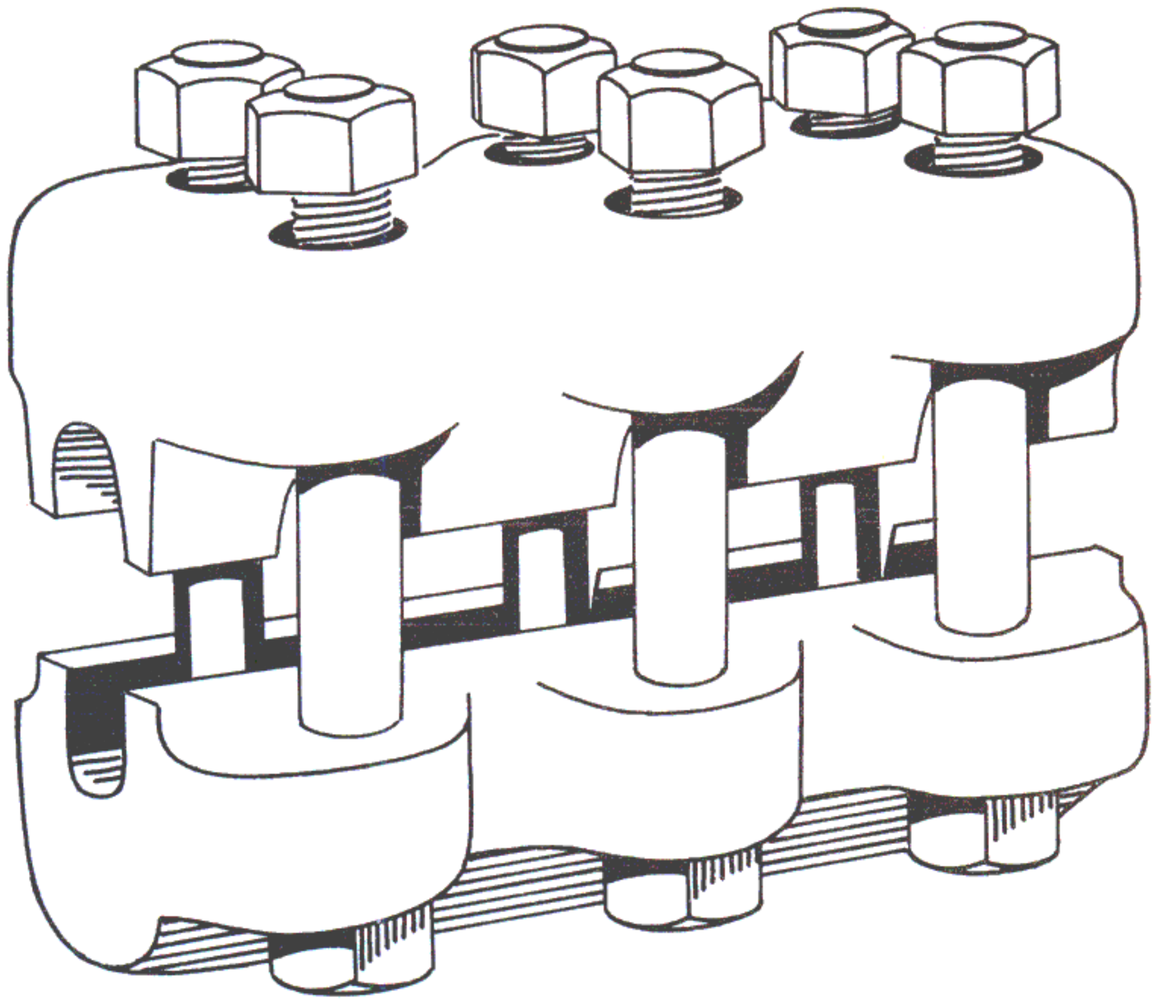
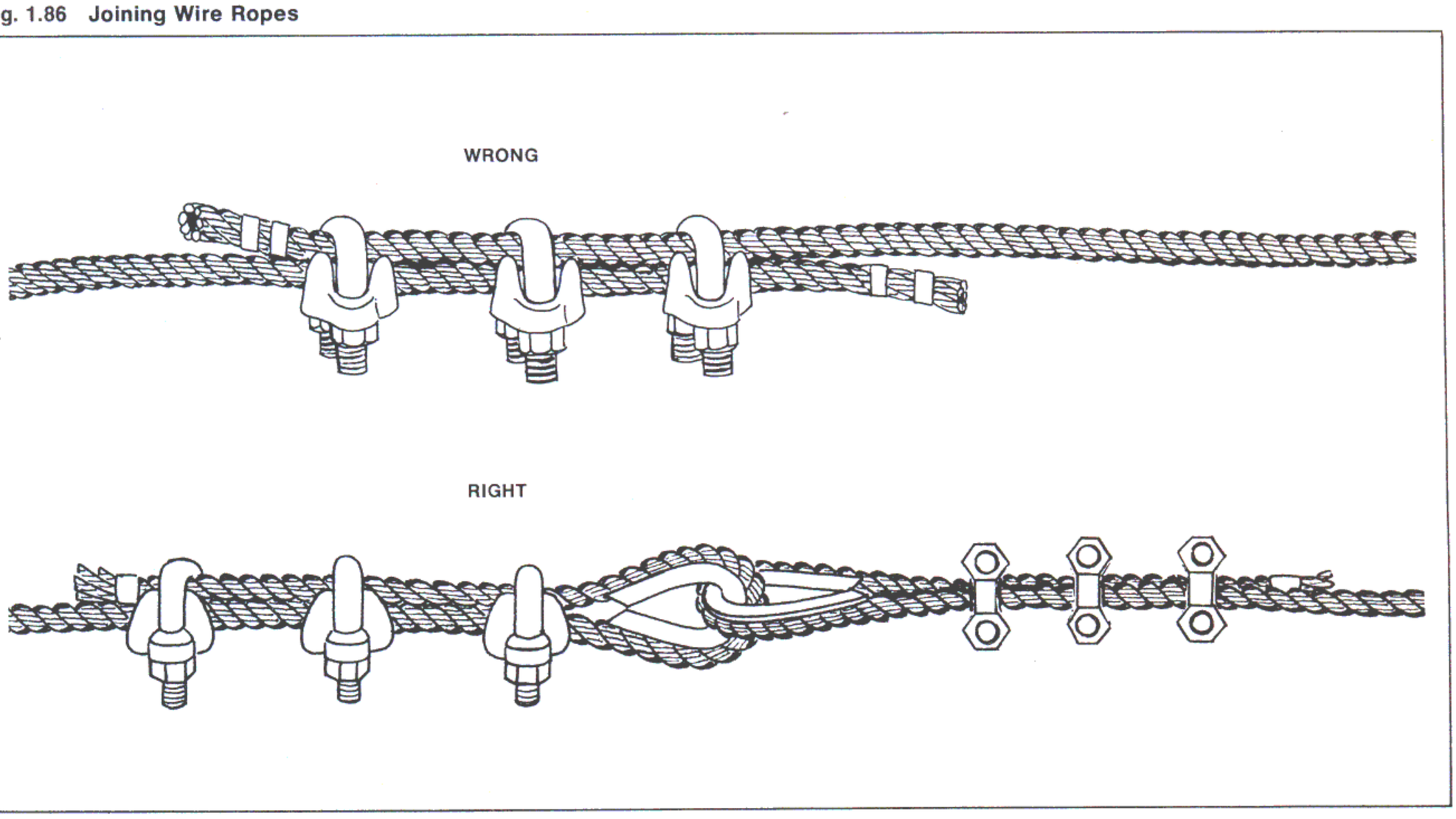


Fig. 1.86 Joining Wire Ropes



CHAPTER 2

Fibre Rope

TYPES AND CHARACTERISTICS:

Fibre ropes are made from either natural or synthetic fibres. The natural fibres come from plants and include manila, sisal and hemp, and the synthetic fibres include nylon, polypropylene, and the polyesters. The strength of these ropes depends on their size, the fibre used, and the type of stranding.

NATURAL FIBRE ROPES:

The two most commonly used natural fibre ropes are manila and sisal, but the only type suitable for construction rigging is Number 1 Grade manila. It is strong and durable and must be used where dependability, ability to stand up under severe use, and weathering resistance is required. Sisal fibres are less durable and lower in strength and are generally made up into ropes used where the requirements are less demanding and cost is a major factor. Sisal rope is whitish, rather coarse and feels harsh to the touch.

The grades of manila ropes most commonly used are:

— **Yacht-rope:** The highest quality manila of very fine appearance. Costly, but used on special jobs where appearance is an important factor.

— **Bolt-rope:** High grade manila, about 10-15% stronger than Number 1 grade manila.

— **Number 1 Grade:** The standard high-grade hoisting rope used for important rigging jobs. Usually identified by a trade marker.

— **Number 2 Grade:** Has about the same initial strength as Number 1 Grade, but loses its strength **more rapidly** in service.

— **Number 3 Grade:** Has about the same initial strength as Number 1 Grade, but loses its strength **very rapidly** in service.

— **Hardware Store Rope:** A very poor grade of manila, of low strength and short life.

In purchasing manila rope for hoisting purposes, the specifications should require that it be made of first-grade manila fibres, and the order should be placed with a reputable manufacturer. Most rope manufacturers place a marker of some kind in their first-grade rope for identification. Some have one or more yarns coloured, or they may have a coloured string in one strand, or they may have a tightly twisted paper ribbon with their trade mark on it in one of the strands. Rope without such a marker should not be used for hoisting purposes.

In ordering new rope the purchaser should specify the type of construction best suited to his requirements. Manila rope is usually made up with three strands, each containing a number of threads. The rope itself is twisted in a right-hand direction, each strand in a left-hand direction, and the individual threads in a right-hand direction. This reversal of twist in the strand gives the rope a balance or set and eliminates the tendency towards unwinding. (Fig. 2.1 shows a typical rope construction.)

Fig. 2.1 3-Strand Fibre Rope Construction

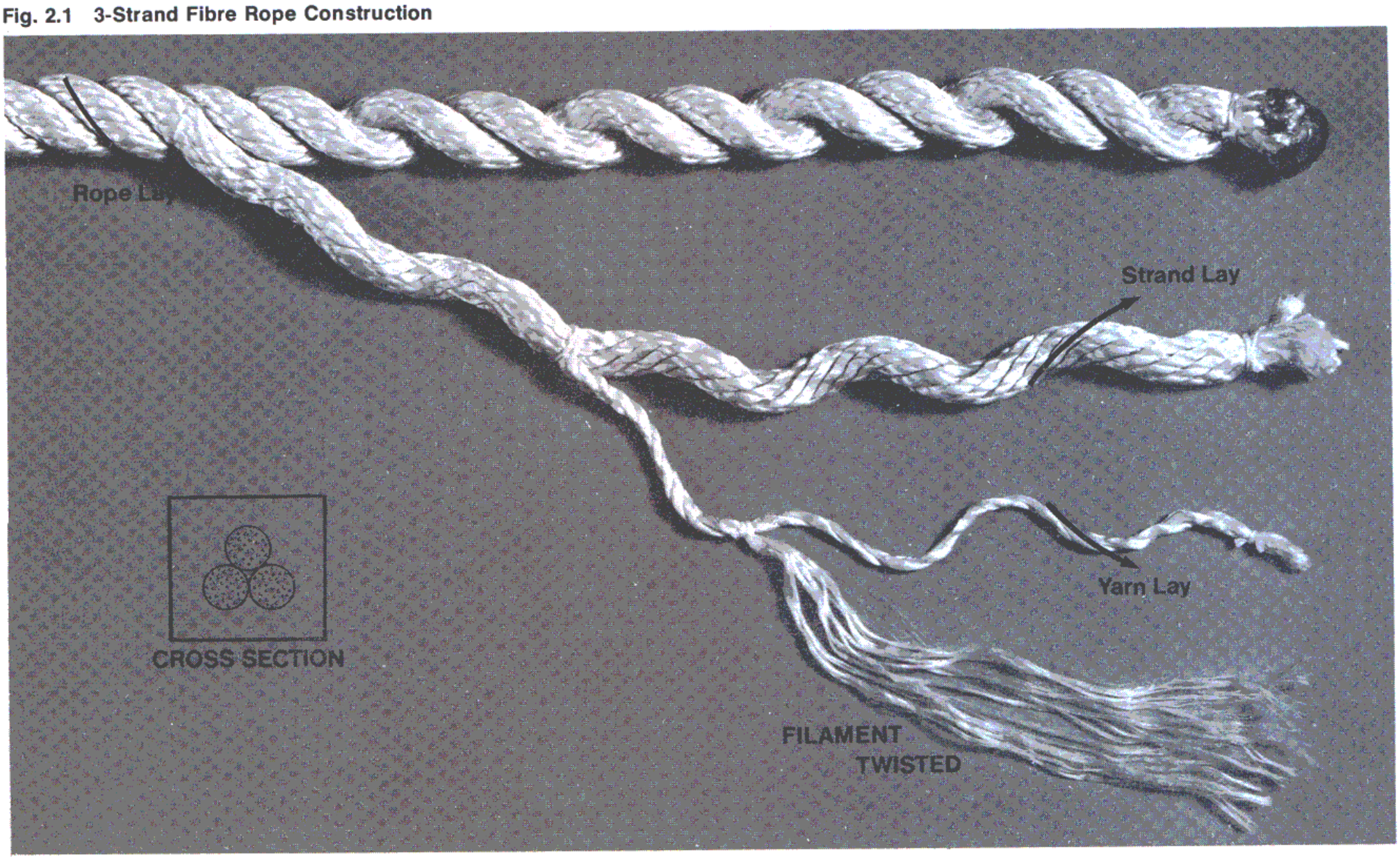


Fig. 2.3 Difference Between Natural Fibre & Synthetic Fibre Ropes

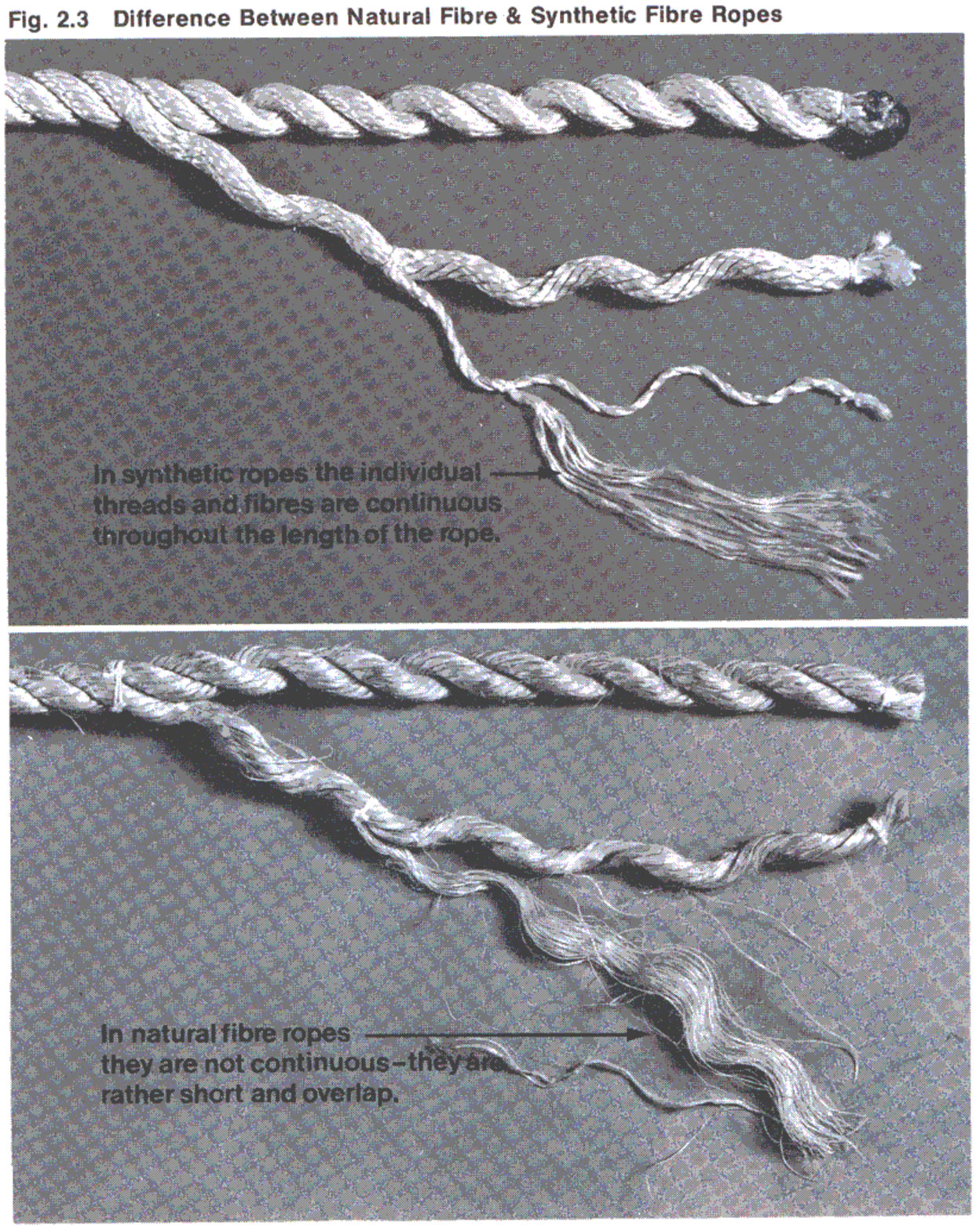
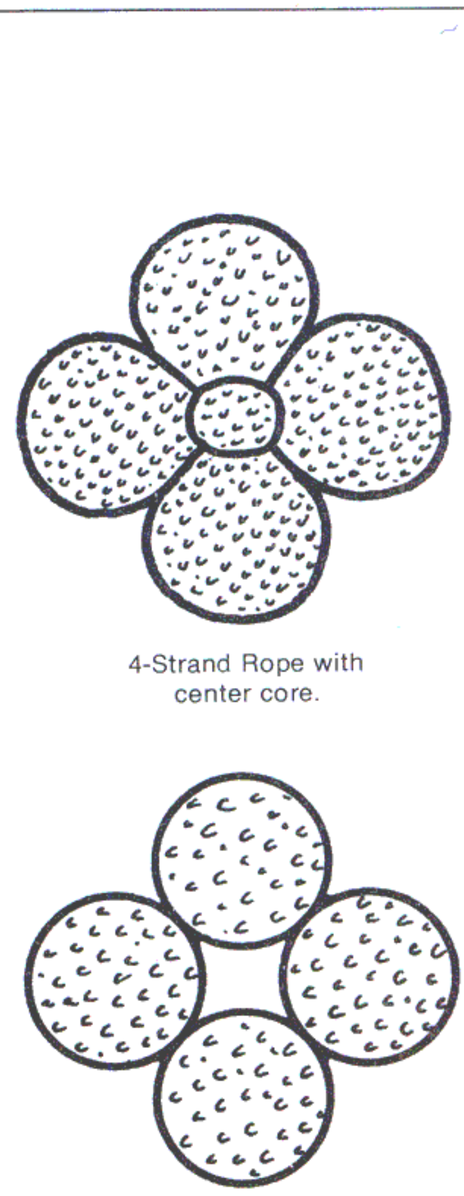


Fig. 2.2 4-Strand Rope



4-Strand Rope with center core.

4-Strand Rope without center core.

For work where abrasion is a factor, a rope having four strands laid around a small rope core is recommended. This rope is more nearly round in cross section and is used quite extensively for power hoisting. Its strength, however, is slightly less than three-strand rope. (Fig. 2.2)

In making a rope, the yarns can be formed into the strands and the strands can be laid into the rope either tightly or loosely making what is known respectively as,"hard-laid" or "soft-laid" rope. "Hard-laid" rope is stiffer and more resistant to abrasion, whereas "soft-laid" rope is limp but stronger. A medium lay is generally recommended.

Manila rope should be light yellow in colour, with a silvery lustre, and should have a smooth waxy surface. The grades have the following colours:

—Number 1 Grade is very light in colour.

—Number 2 Grade slightly darker.

—Number 3 Grade is considerably darker.

—Hardware Store Rope is still darker, and the short fibres cause many ends to protrude from the strands.

—Yacht and bolt-rope are very light in colour.

All manila ropes are subject to rot, even though they are chemically treated to repel moisture and resist mildew and dry rot. The best way to slow down the rotting process is to maintain the rope properly. They will withstand long periods of use under wet, dirty and rot producing conditions, provided they are cleaned and dried at frequent intervals and stored so that the air can circulate around them. It is important to understand that manila ropes shrink when wet and often are of lower strength in the wet condition due to uneven distortion of the rope structure. The best cleaning method involves washing the rope in cold water and hanging it in loose folds or coils over pegs so that the air can dry it. Since mildew and rot are the most common causes of natural fibre rope deterioration, it is good economic sense to maintain the ropes in a clean and dry state. Slings and safety lines should receive special attention in this regard.

Prolonged exposure to sunlight will also cause manila rope to deteriorate; where possible they should either be covered or shaded.

General purpose manila rope, if dried out after use and properly stored, needs no added lubricant. If the rope becomes stiff, however, a thin coat of warm lubricating oil applied with a paint brush will make the rope pliable again.

SYNTHETIC FIBRE ROPES:

Synthetic fibre ropes, particularly nylon and polypropylene have rapidly gained acceptance and, to a great degree, are replacing manila rope. These ropes have individual fibres running their entire length, rather than short, overlapped fibres as in natural fibre ropes. Consequently, they have greater strength. (Fig. 2.3)

Synthetic fibre ropes are generally impervious to rot, mildew and fungus and have good resistance to chemicals. Nylon absorbs very little moisture and polypropylene none; consequently the ropes do not stiffen when wet, do not freeze and have good dielectric properties when clean and dry.

Synthetic ropes are stronger than natural fibre ropes, nylon being about $2^1/_2$ times the strength of manila. They are also lighter, are easier to handle and have excellent impact, fatigue and abrasion resistance. They will also outwear manila ropes by 4 or 5:1.

They are liable to melt at high temperatures, however, and should not be used where they are likely to encounter excessive heat or where friction is sufficiently high and concentrated enough to melt the fibres. Avoid using them near welding operations.

Synthetic fibres, in general, have relatively poor resistance to abrasion and particular care must be taken to protect them from chafing.

The synthetic ropes are not generally affected by mildew or dry rot, and can withstand long periods of wetting without any noticeable loss of strength or change in appearance.

The important features of the most commonly used synthetic fibre ropes for rigging purposes are as follows.

1) Nylon:

Nylon is the best known and has gained the widest acceptance of the synthetic fibre ropes. It is strong, roughly $2^1/_2$ times stronger than manila, has good abrasion resistance qualities and good resistance to weathering. It is usually chalky white in colour, with a smooth surface, is soft and pliant and has a feeling of elasticity to it.

Some properties of nylon ropes are:

—High breaking strength (wet or dry).

—Light weight per unit of strength.

—Excellent elasticity and tensile recovery.

—Superior absorption of impact and shock loads.

—Excellent flex and abrasion resistance.

Fig. 2.4 Stretch Characteristics of Nylon Rope

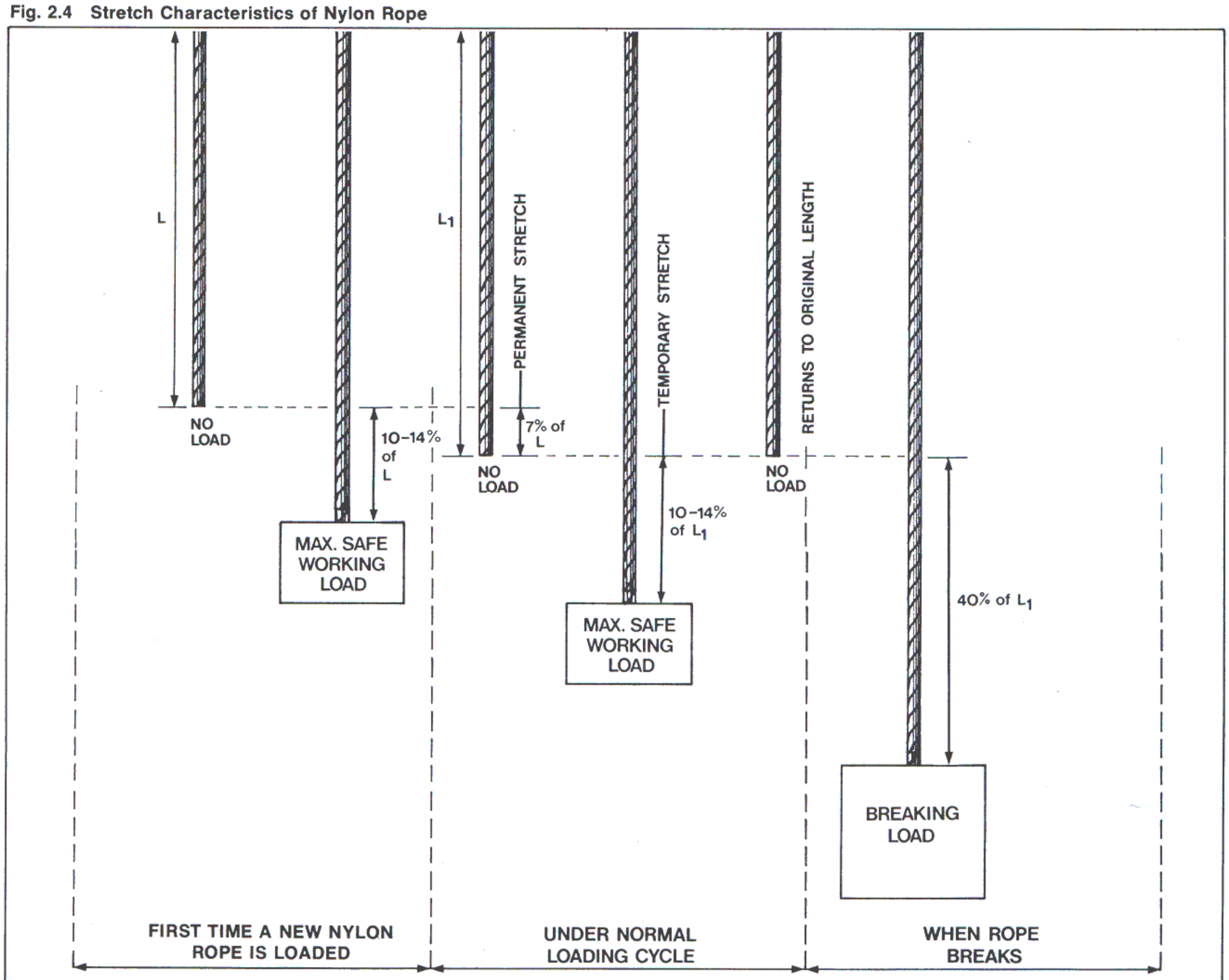


Fig. 2.5 2 in 1 Braided Rope

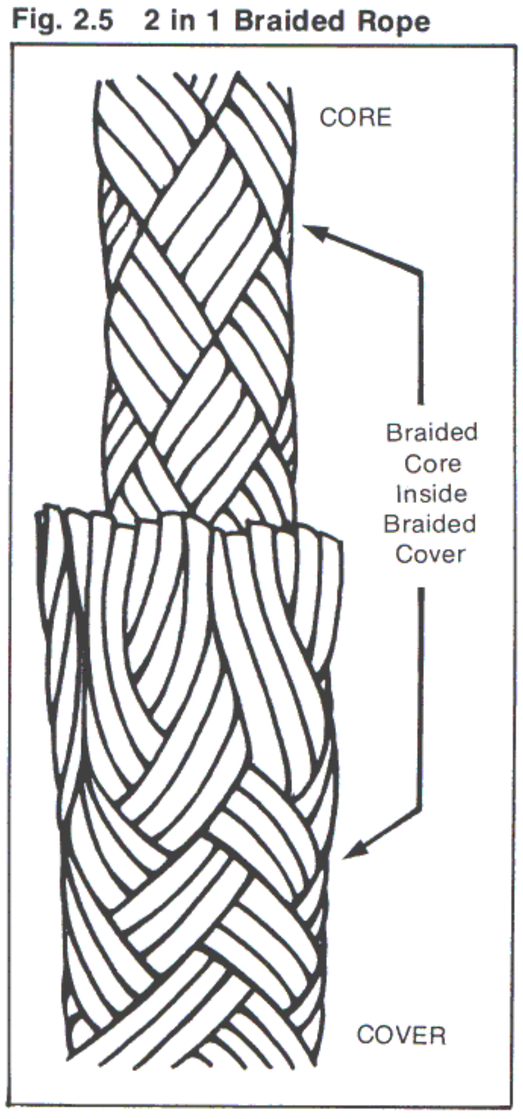
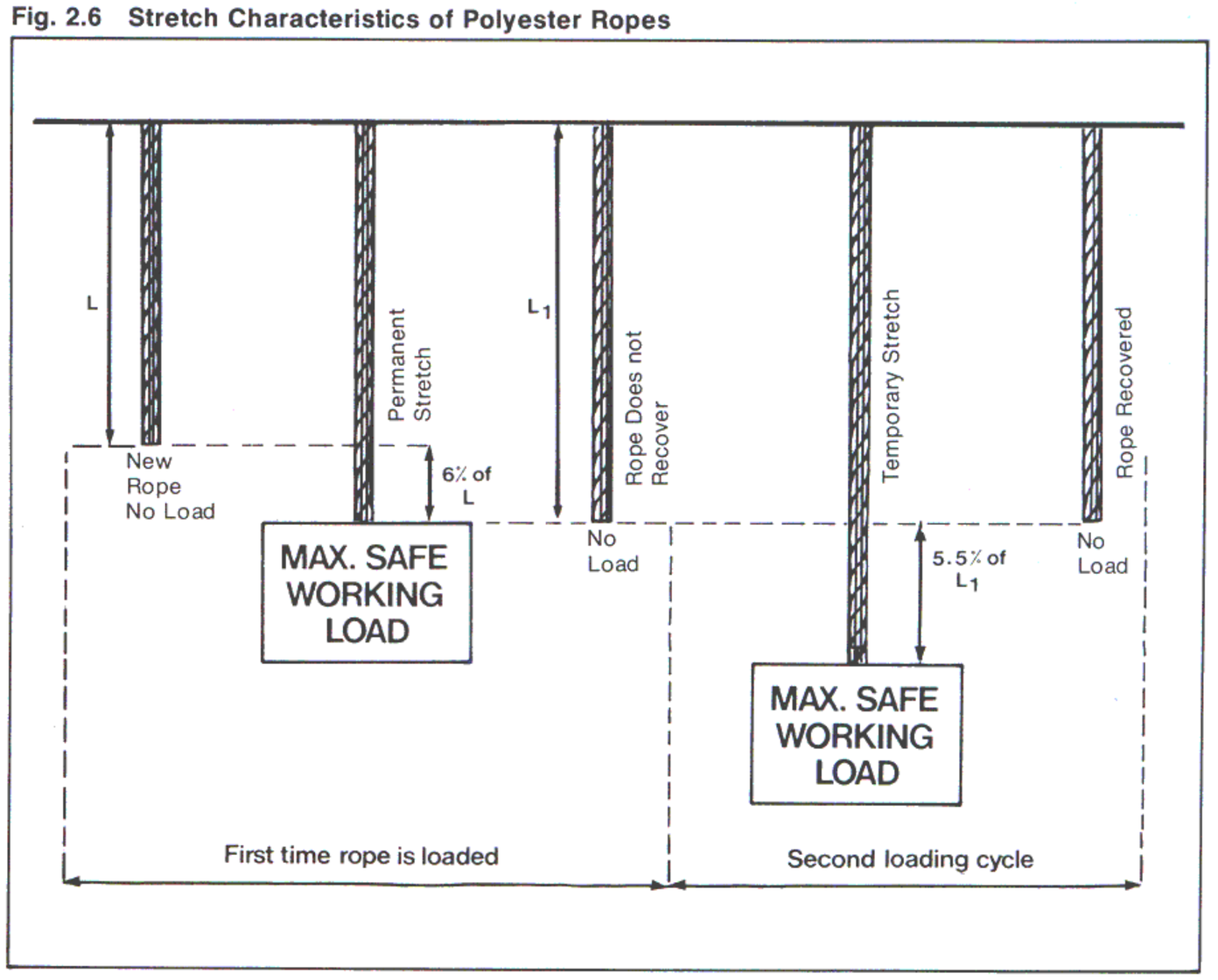


Fig. 2.6 Stretch Characteristics of Polyester Ropes



—Good flexibility.

—Excellent resistance to rotting.

—Good sunlight and weather resistance.

—High melting point.

Nylon ropes are the strongest available because the filaments from which the ropes are made run continuously through the length of the rope. This also means that resistance to creep under sustained loads is very high.

Nylon rope has good resistance to abrasion because the outer fibres, if abraded, form a protective fuzz which slows down the abrasion of the rope's inner fibres.

Nylon is highly elastic and ropes are capable of withstanding severe shock loads. Because of this feature it should be used where high energy absorption is needed or where shock loading is a factor to contend with. The high degree of stretch (10 to 40%) is an excellent feature in some respects but a serious disadvantage in others since it can produce problems where headroom for lifting is restricted and slings have to be as short as possible.

The elongation of nylon rope under actual service conditions is considerably less than its ultimate breaking elongation, 10-14% under working loads and over 40% at its breaking loads. The first time a nylon rope is loaded, the rope fibres compact and the rope is permanently stretched when the load is released. The increase in length is approximately 7%. However, once this permanent stretch is in the rope it recovers completely from subsequent stretching under load. (Fig. 2.4) Nylon ropes should be broken in prior to field use to allow them to stretch.

Nylon does not become progressively softer with rise in temperature but retains its physical properties almost to its melting point. Ropes can be used at temperatures up to 300°F for long periods without serious loss of strength and at slightly higher temperatures for limited periods of time.

Nylon ropes absorb moisture and lose approximately 10% of their strength when wet. They also become very slippery. The full strength is regained when the rope dries out.

Nylon ropes can be stored wet or dry without fear of attack by rot and mildew but good storage conditions away from heat and protected from exposure to sunlight are recommended. rope is stiffer and be avoided whenever possible by covering the rope.

Nylon is highly resistant to alkalis, but is rapidly attacked by most acids, paints and linseed oil, and it is recommended that all contact with chemicals be avoided. If contamination is suspected, wash the rope thoroughly in cold water and then examine the fibres carefully for evidence of weakening.

2) Braided Nylon:

Where the highest possible strength is required it is recommended that braided nylon ropes providing a braided sheath over a braided core be used. The load is divided equally between the sheath and the core and regardless of the outside sheath damage, 50% of the rope's initial strength remains in the core. The construction provides a soft flexible rope that does not twist or kink. (Fig. 2.5)

Twisted 3-strand ropes transmit a turning, twisting motion under load but braided rope with inner core and outer sheath does not have this built-in tendency to twist. They also present approximately 50% more surface area for wear and grip, are stronger size for size, are more stable, exhibit much less stretch when working, have less permanent stretch, and greater flexibility than 3-strand nylon ropes.

These 2 in 1 braided ropes are available with nylon core/nylon cover to provide high strength, more elongation and excellent wearing qualities; polypropylene core/nylon cover for lower strength and lower stretch; and polypropylene core/polyester cover for very low stretch, high strength and good abrasion qualities.

3) Polyester (Trade Names: Dacron and Terylene):

Polyester rope is nearly identical to nylon in appearance but has little or no elastic feeling. Size for size, they are heavier and not as strong as nylon, but are very similar in construction. Continuous filaments throughout the rope length ensure high resistance to creep under sustained loads and the low stretch properties of this material offer advantages when lifting with limited headroom. At working loads the stretch is approximately the same as manila rope. Ability to absorb shock loads is about two-thirds that of nylon, but is much greater than manila.

The first time a polyester rope is loaded it will be permanently stretched approximately 6% but future stretching under load (approximately 5.5%) is always recovered when the load is removed. (Fig. 2.6) Thus, all polyester

ropes should be given a "breaking in" time to allow them to stretch.

These ropes have similar abrasion resistance qualities as nylon rope.

Polyester, like nylon, does not soften progressively with rise in temperature and it can be used in similar hot conditions. The fibre is somewhat tougher than nylon, does not lose strength when wet and has a very high resistance to the degrading effects of sunlight and weather. It is immune from attack by rot and mildew, although the same general advice on good storage conditions is relevant.

Unlike nylon, polyester is resistant to acids and attack by alkalis. All chemicals should be avoided where possible. The slings should be washed frequently in cold water.

4) Polypropylene:

Polypropylene and polyethylene ropes are nearly identical in appearance. They are available in various colours and are smooth and pliant and somewhat slippery, particularly polyethylene.

Although polypropylene is light in weight (it floats on water), this advantage has to be considered in relation to its lower strength than either nylon or polyester and accordingly it is intermediary in use between the natural fibre ropes and the more sophisticated nylon and polyester.

Stretch properties of polypropylene ropes vary with the type of construction but, generally, they stretch somewhat more than polyester. The energy absorption properties are approximately half that of nylon.

Polypropylene ropes soften progressively with rise of temperature and this plastic behaviour, combined with a relatively low melting point, make it unsuitable for use in hot conditions.

It is not as tough as either nylon or polyester, but it does not lose strength when wet. It degrades in sunlight, but it is immune to attack by rot and mildew and is highly resistant to attack by acids and alkalis, although industrial solvents have a softening effect. It is also an excellent non-conductor of electricity.

5) Polyethylene:

Polyethylene ropes are low in strength compared with the other synthetic fibre ropes, and soften progressively with rise in temperature. They are resistant to strong and weak acids and alkalis (excepting nitric acid) and are also resistant to alcohol and bleaching solutions.

COMPARISON OF ROPES:

Strength: The relative strength of fibre ropes is an important factor when selecting ropes to perform a particular task. (Table 2.1)

TABLE 2.1

RELATIVE STRENGTH OF FIBRE ROPES (DRY)	
Type of Rope	Relative Capacity (Related to Nylon)
Nylon	100%
Polyester	87%
Polypropylene	60%
Polyethylene	52%
Manila	37%

The strength of most ropes changes when they are wet. (Table 2.2)

TABLE 2.2

% CHANGE IN ROPE STRENGTH WHEN WET	
Type of Rope	% Change in Strength
Nylon	−10%
Polyester	No Change
Polypropylene	+ 5%
Polyethylene	+ 5%
Manila	− 5% Approx.

Synthetic fibres generally absorb very little water and, accordingly, do not swell or distort the rope body. Nylon has the greatest absorption factor. This results in a loss of strength in the nylon filaments of approximately 10%. It is important to note that the full strength is recovered on drying out, and the initial strength superiority of nylon over ropes made from the other man-made fibres gives a very adequate margin to compensate for this loss.

With natural fibre rope a loss of strength will occur due to swelling of the fibres by water absorption, with a consequent distortion of the rope body. This distortion will vary within wide limits dependent upon the construction of the rope and the type of fibre. Losses up to 25-30% of the dry rope strength are possible. Waterproofing of natural fibre ropes can retard the absorption of water, but any process, short of completely sealing the fibres, can only delay the absorption which will take place ultimately on prolonged immersion. Natural fibre ropes (unlike nylon) do not always come back to full strength on drying.

Ability to take shock loads: One of the more important properties of fibre ropes is their ability to absorb repeated shock loads. This capacity is a function of the extensibility and elasticity of the ropes and the materials from which they are made. The ability of a rope to absorb energy is related to the following physical properties:

(a) Breaking load, weight and breaking length.
(b) Load/extension characteristics.
(c) Recovery after repeated loadings.
(d) Limiting velocity (rate of transmission of stress).

Table 2.3 gives the energy absorption capacities of various ropes. The table is based on all ropes being of equal diameter and length.

TABLE 2.3

ENERGY ABSORPTION CAPACITY	
Type of Rope	Relative Capacity (Related to Nylon)
Nylon	100%
Polyester	62%
Polypropylene	40%
Steel Wire Rope	22%
Polyethylene	21%
Sisal	15%
Manila	13%

Note that polyethylene rope has a very low energy absorption capacity. This is because it transmits stress at a slow rate. The shock is not absorbed uniformly throughout the length of the rope, but is concentrated at a local spot where reactive heat is generated. Accordingly, ropes made from polyethylene mono filaments are not recommended for applications where shock loads are anticipated.

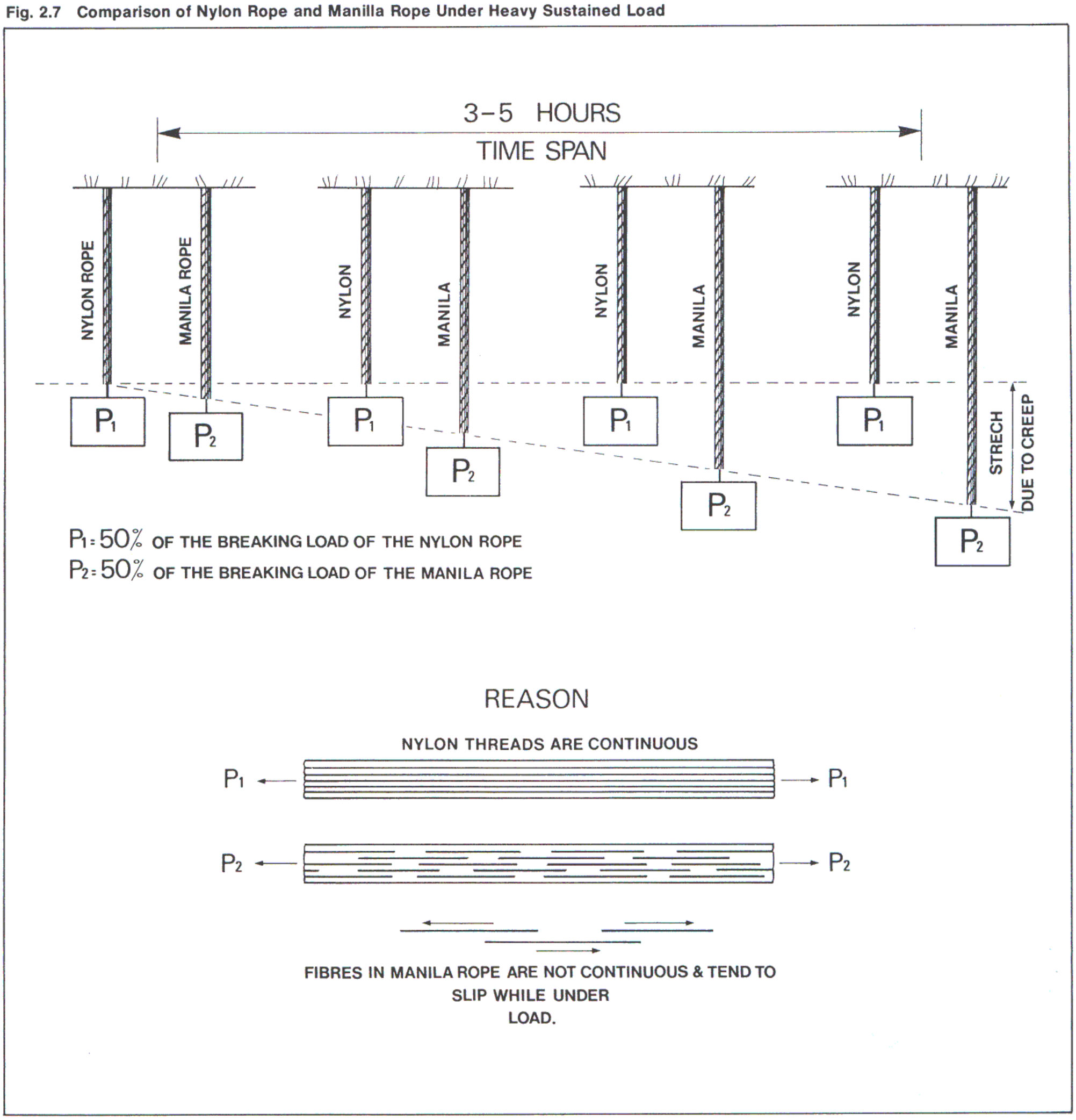
Ability to take sustained loads: When a load or stress is first applied to any fibre rope, it will stretch in a proportionate degree to the magnitude of the load applied. Normally this stretch is referred to as the strain. It is a characteristic of fibre ropes that, should heavy loads be sustained over periods of time, further and progressive extension takes place until the ultimate extension is reached and the rope fractures. This phenomenon of creep can have an important bearing on selecting the right rope for an application where dead loads are involved.

Table 2.4 compares the performance of various ropes while loaded to 75%, 50% and 25% of their breaking strengths. The table shows the marked superiority of ropes made from materials in which the fibres are continuous throughout the length of the yarns in the ropes. Natural fibres are held together in the yarns by surface contact and twist and, when placed under load, tend to slip. As the slip progresses the rope eventually fractures. (Fig. 2.7)

TABLE 2.4

INFLUENCE OF SUSTAINED LOADING			
Type of Rope	Length of Time At		
	75% Load	50% Load	25% Load
Nylon	Indefinitely	Indefinitely	Indefinitely
Polyester	Indefinitely	Indefinitely	Indefinitely
Polypropylene	Indefinitely	Indefinitely	Indefinitely
Polyethylene	3-6 Days (Varies With Temperature)	2-4 Weeks (Varies With Temperature)	Indefinitely
Manila	5 Minutes	3-5 Hours	Indefinitely
Sisal	4 Minutes	45-60 Minutes	Indefinitely

Fig. 2.7 Comparison of Nylon Rope and Manilla Rope Under Heavy Sustained Load



Ability to take repeated loads: In normal usage, ropes are often subjected to repeated loadings. The ability of a rope to withstand heavy loadings at frequent intervals without failure, creep or loss of energy absorption capacity is a valuable asset to the user. No fibre rope is capable of satisfying all requirements completely but knowledge of the relative responses of ropes to repeated loading is of considerable value in determining the best rope for any application.

Table 2.5 rates performance under conditions of repeated loading and unloading.

TABLE 2.5

ROPE PERFORMANCE UNDER REPEATED LOADING & UNLOADING	
Type of Rope	Relative Performance
Nylon Polyester Polypropylene Polyethylene Manila Sisal	Best Decreasing Performance Worst

Flexing endurance: The ability of a rope to take repeated bending under load is an important property. This is called flexing endurance and its effect on rope performance and strength is an important factor on the length of rope life.

Table 2.6 lists the relative flexing endurance of a number of ropes in both the dry and wet states. The percentage values relate to the ratio of the number of bending cycles to failure of the rope as compared to dry nylon rope.

TABLE 2.6

RELATIVE FLEXING AND BENDING ENDURANCE		
Type of Rope	Relative Resistance To Failure (Related to Dry Nylon Rope)	
	Dry Ropes	Wet Ropes
Nylon	100.0%	55.0%
Polyester	66.0%	68.0%
Polypropylene (Monofil)	5.1%	5.4%
Polypropylene (Multifilament)	2.7%	2.6%
Sisal	1.9%	4.1%
Manila	1.4%	3.8%
Polyethylene	0.5%	2.5%

Effects of heat: (Tables 2.7, 2.8, 2.9) Of all the hazards to which ropes are subjected during their working lives perhaps the worst is the effect of heat since the damage done may not be apparent on normal examination.

The principal sources of heat (with the exception of welding and cutting operations) liable to damage ropes are:

(a) Contact with hot surfaces.

(b) Radiated heat from hot gases, fires, heaters, boilers, etc.

(c) Frictional heat.

Table 2.7 shows the effect of rope contact with a hot surface (steam pipe at 287°F) while under load for a period of $5^1/_2$ hours.

If a rapidly moving loaded rope passes over a stationary rope of the same type, considerable heat develops on the stationary rope at the point of contact. This heat rapidly builds up to a temperature sufficiently high to cause melting and failure of the stationary rope. Nylon in particular is prone to breakdown of this type. This is due to its rather high co-efficient of friction and its slow rate of thermal conductivity.

Natural fibre ropes are more resistant to these conditions; they do not burn readily and breakdown is slower.

TABLE 2.7

EFFECT OF HOT SURFACES (287°F)	
Type of Rope	% Loss of Original Strength
Polyester	13.2%
Nylon	16.5%
Sisal	17.0%
Manila	24.6%
Polypropylene	100.0% (Distorted)
Polyethylene	100.0% (Melted)

TABLE 2.8

EFFECT OF RADIATED HEAT AND HOT GASES	
Type of Rope	Effect
Nylon Polyester	No effect. Do not soften progressively but melt sharply at their respective melting points.
Polypropylene	Softens slowly and loses strength.
Polyethylene	Softens rapidly.
Manila Sisal	Lose strength slowly by loss of moisture, oils and lubricants and fibre embrittlement.

TABLE 2.9

STRENGTH LOSS VS. TEMPERATURE					
Type of Rope	Temperature (°F)				
	68	105	140	175	212
Manila	0	−3%	− 8%	−20%	−30%
Nylon	0	−2%	− 7%	−14%	−20%
Polypropylene	0	−7%	−18%	−30%	−40%

Effects of low temperatures: (Table 2.10) Ropes are often used in extremely low temperatures and it is important to know what the effects of low temperature are on the ropes.

Provided the rope is dry (i.e. containing only its normal amount of moisture) low temperatures do not reduce its tensile strength, although polypropylene does get somewhat brittle.

If a natural fibre rope is wet before cooling in cold dry air it loses considerable tensile strength. Under the same conditions, synthetic ropes lose very little strength.

In freezing conditions, synthetic fibre ropes stay more flexible than natural-fibre ropes and because of their low water absorption properties they handle well in sub-zero conditions.

Insulating characteristics: It is occasionally necessary to use ropes when working close to electrical power lines and a knowledge of insulating characteristics of ropes is important. (Fig. 2.8)

All ropes will conduct electricity when they are wet. However, polyester, polyethylene and polypropylene ropes all have good and consistent insulating properties under conditions of low or high humidity. Nylon is **not** recommended where insulation against high voltages is required. It absorbs moisture from the atmosphere so that, unless dried and varnished, its insulating properties vary widely.

Fig. 2.8 Ropes to use around Power Lines

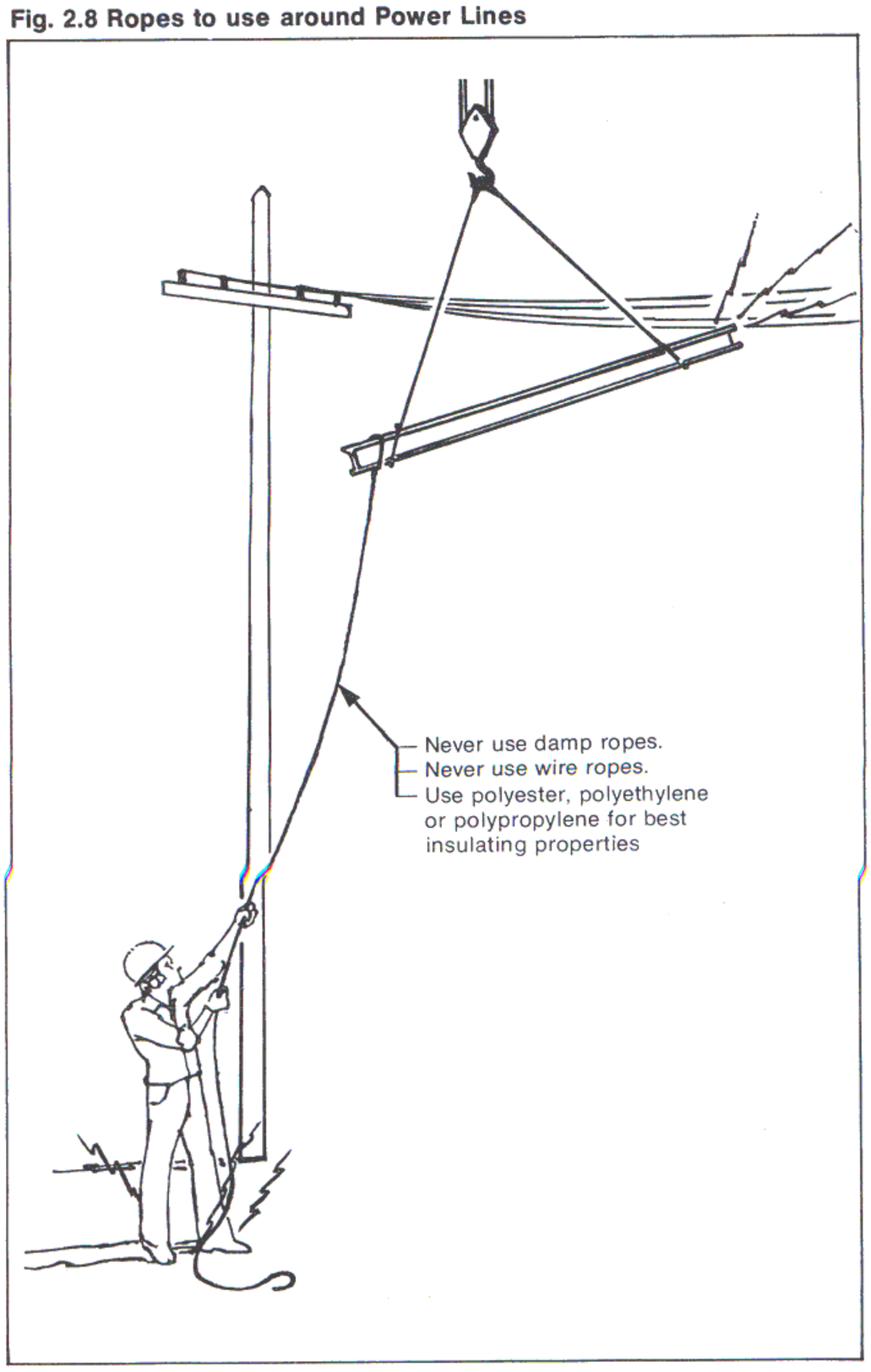


TABLE 2.10

EFFECT OF LOW TEMPERATURE ON ROPE STRENGTH
Percentage Change in Strength Over Original Strength (At 70°F)

Type of Rope	Cooled (Dry) In Air To −50°F	Cooled (Dry) In Air To −50°F and Warmed To 70°F	Cooled in Air To −50°F After Soaking In Water	Cooled in Air To −50°F After Soaking In Water and Warmed to 70°F	Frozen In Ice
Nylon	+ 8%	No Change	+ 4%	+10%	− 9%
Polyester	+ 2%		+ 4%	+ 6%	− 2%
Polyethylene	− 4%		+ 2%	+ 2%	− 4%
Polypropylene	−15%		−12%	No Change	−17%
Manila	+ 7%		−34%	−15%	−33%
Sisal	+ 9%		−35%	− 5%	−36%

SAFETY FACTORS:

Fibre rope, like wire rope, must have a factor of safety to account for loadings over and above the weight being hoisted and for reductions in capacity due to:

— The reduced capacity of the rope below its rated strength due to ordinary usage, wear, broken fibres, broken yarns, age, variations in size and quality.

— Extra loads imposed by acceleration and inertia (starting, stopping, swinging and jerking of the load).

— Increases in line pull due to friction of the rope passing over sheaves.

— Inaccuracies in the weight of the load.

— Reduced strength due to bending over sheaves.

— Reduced strength because of drying out, mildew and rot.

— Severe strength reductions caused by knots in the rope.

— Weakened yarns due to ground in dirt and abrasives.

This list is not complete. It illustrates why the factor of safety is required and why the safe working loads must never be exceeded. The factor of safety does **not** give you extra usable capacity.

The factor of safety for all fibre ropes is 5 and when used to hoist or support personnel it is 10.

Calculate the safe working load as follows:

$$SWL = \frac{\text{Breaking Strength}}{\text{Factor of Safety}}$$

$$= \frac{\text{Breaking Strength}}{5}$$

For example, a rope rated at 1500 lbs. breaking strength has a safe working load of 300 lbs.

$$\frac{1500 \text{ lbs.}}{5} = 300 \text{ lbs.}$$

SAFE WORKING LOADS

Tables 2.11 and 2.12 of safe working loads for fibre ropes are for reference purposes only. Check your rope manufacturer's ratings before determining the safe working loads as they may differ from the tables.

If the manufacturer quotes his rope's capacity in terms of its breaking strength, you must apply the appropriate factor of safety; 10 when hoisting or holding personnel and 5 at all other times.

Table 2.11 lists the maximum safe working loads for common 3-strand fibre ropes generally used for rigging. The figures are based on ropes without knots or hitches. Safe working loads for fibre rope slings are listed in the section on "Slings".

TABLE 2.11

APPROXIMATE SAFE WORKING LOADS OF NEW FIBRE ROPES — POUNDS
3-Strand Ropes
Safety Factor = 5

Nominal Rope Diameter (Inches)	Manila	Nylon	Polypropylene	Polyester	Polyethylene
3/16	100	200	150	200	150
1/4	120	300	250	300	250
5/16	200	500	400	500	350
3/8	270	700	500	700	500
1/2	530	1,250	830	1,200	800
5/8	880	2,000	1,300	1,900	1,050
3/4	1,080	2,800	1,700	2,400	1,500
7/8	1,540	3,800	2,200	3,400	2,100
1	1,800	4,800	2,900	4,200	2,500
1 1/8	2,400	6,300	3,750	5,600	3,300
1 1/4	2,700	7,200	4,200	6,300	3,700
1 1/2	3,700	10,200	6,000	8,900	5,300
1 5/8	4,500	12,400	7,300	10,800	6,500
1 3/4	5,300	15,000	8,700	12,900	7,900
2	6,200	17,900	10,400	15,200	9,500

The following rules of thumb work well for new ropes when load tables are not available.

MANILA ROPE

— Change the rope diameter into eighths of an inch.
— Square the numerator and multiply by 20.

Example:

(a) 1/2 inch manila rope = 4/8 inch diameter.
SWL = 4 x 4 x 20 = 320 lb.

(b) 5/8 inch manila rope
SWL = 5 x 5 x 20 = 500 lb.

(c) 1 inch manila rope = 8/8 inch diameter.
SWL = 8 x 8 x 20 = 1280 lb.

NYLON ROPE

— Change the rope diameter into eighths of an inch.
— Square the numerator and multiply by 60.

Example:
1/2 inch nylon rope = 4/8 inch diameter.
SWL = 4 x 4 x 60 = 960 lb.

POLYPROPYLENE ROPE

— Change the rope diameter into eighths of an inch.
— Square the numerator and multiply by 40.

Example:
1/2 inch polypropylene rope = 4/8 inch diameter.
SWL = 4 x 4 x 40 = 640 lb.

POLYESTER ROPE

— Change the rope diameter into eighths of an inch.
— Square the numerator and multiply by 60.

Example:
1/2 inch polyester rope = 4/8 inch diameter.
SWL = 4 x 4 x 60 = 960 lb.

POLYETHYLENE ROPE

— Change the rope diameter into eighths of an inch.
— Square the numerator and multiply by 35.

Example:
1 inch polyethylene rope = 8/8 inch diameter.
SWL = 8 x 8 x 35 = 2240 lb.

Since rope on a job is rarely new, the rigger will have to use judgment as to what value to use. If there is any doubt as to the type or condition of the rope it should not be used at all. There can be no substitute for safety.

Table 2.12 provides the approximate safe working loads of 2 in 1 braided ropes i.e., braided core and braided cover.

TABLE 2.12

APPROXIMATE SAFE WORKING LOADS OF NEW BRAIDED SYNTHETIC FIBRE ROPES (LBS.) SAFETY FACTOR = 5

Nominal Rope Diameter (Inches)	Nylon Cover Nylon Core	Nylon Cover Polypropylene Core	Polyester Cover Polypropylene Core
1/4	420	—	380
5/16	640	—	540
3/8	880	680	740
7/16	1,200	1,000	1,060
1/2	1,500	1,480	1,380
9/16	2,100	1,720	—
5/8	2,400	2,100	2,400
3/4	3,500	3,200	2,860
7/8	4,800	4,150	3,800
1	5,700	4,800	5,600
1 1/8	8,000	7,000	—
1 1/4	8,800	8,000	—
1 1/2	12,800	12,400	—
1 5/8	16,000	14,000	—
1 3/4	19,400	18,000	—
2	23,600	20,000	—

CARE AND USE OF FIBRE ROPE:

COILING AND UNCOILING:

Fibre rope, like wire rope, can be damaged as it is removed from the shipping coil. If you are handling a new coil of rope, lay it flat on the floor with the inside rope end at the base closest to the floor. Reach down inside the coil and pull the inside rope end up through the coil and unwind it in a counter-clockwise direction. (Fig. 2.9) Even though the rope is unwound properly, loops and kinks may form in it and must be carefully removed otherwise when pulled tight they will cause severe damage to the rope.

After use, the rope should be recoiled in a clockwise direction as shown in Fig. 2.10.

Loop the rope over the left arm a number of times until about 15 ft. of rope remains. When coiling the rope remove kinks as they form. Then, starting about a foot from the top of the coil, the rope should be wrapped about six times around the loops by rolling them in the left hand.

Then the left hand is extended through the coil and the bight pulled back through the loops. Two half-hitches are tied around the bight, leaving a short end for carrying or for tying to a peg or supporting bar.

WHIPPING:

Whenever a fibre rope is cut, the rope ends must be bound or whipped to prevent the rope from untwisting, fraying and the strands from slipping in relation to each other causing one of them to assume more or less than its share of the load. Each of these conditions result in shortened rope life. (Fig. 2.11)

Ordinary whippings are made with fine twine as follows: (Fig. 2.12)

Make a loop in the end of the twine and place the loop at the end of the rope, as shown in the illustration. Wind the standing part around the rope covering the loop of the whipping, but leave a small loop uncovered, as shown. Pass the remainder of the standing end up through the small loop and pull the dead end of the twine, thus pulling the standing end and the small loop (through which it is threaded) back. towards the end of the rope underneath the whipping. Pull the dead end of the twine until the small loop with the standing end through it reaches a point midway underneath the whipping. Trim both ends of the yarn close up against the loops of the whipping.

STORAGE:

Poor storage conditions can cause fibre rope to deteriorate as rapidly as harsh usage does. In order to keep ropes in good condition for as long as possible:

— Store them in a dry cool room that has good air circulation. A temperature of 50-70°F and a humidity of 40-60% are recommended.

— Do not store them on the floor, in boxes, or in cupboards where the air circulation is restricted. They should be hung up in loose coils on large diameter wooden pegs well above the floor in an area where there is good air circulation. (Fig. 2.13)

— Protect them from the weather, dampness and sunlight. They should be kept away from boilers, radiators, steam pipes and other sources of heat plus all exhaust gases.

— Dry and clean wet ropes before storing them. Moisture not only hastens decay but also causes the rope to kink very easily. If a wet rope becomes frozen, it must not be disturbed until it is completely thawed, otherwise the frozen fibres will break when handled. Allow wet and frozen rope to dry naturally. Too much heat will cause the fibres to become brittle in a few hours and the rope will be unfit for further service. If a sour odour is detected on natural fibre ropes, the rope should be aired until the odour disappears.

USE:

If fibre ropes are abused then you are not only wasting money but also introducing unnecessary hazards to the operation since they will not retain their full capacity.

Remember, the rope that takes your abuse today, may have to take your weight tomorrow. Play it safe. Follow these guidelines to safe rope usage:

— Keep ropes clean and dry. When they become dirty wash them in clean cool water and hang them up to dry. Dirt on the surface or imbedded in the rope acts as an abrasive on the strands and fibres. (Fig. 2.14)

— Keep ropes away from chemicals, excessive heat, acids, acid fumes, strong alkali, drying oils, paint, fumes and exhaust gases. They can cause serious damage and strength reductions. Most of the synthetic ropes withstand corrosive chemicals better than

Fig. 2.9 Proper Method of Removing Rope From a Shipping Coil

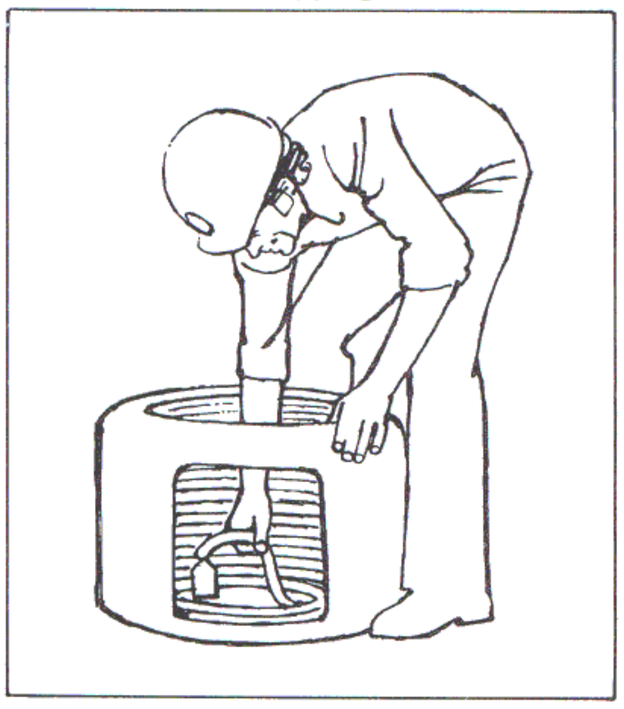


Fig. 2.10 Proper Way to Coil a Rope

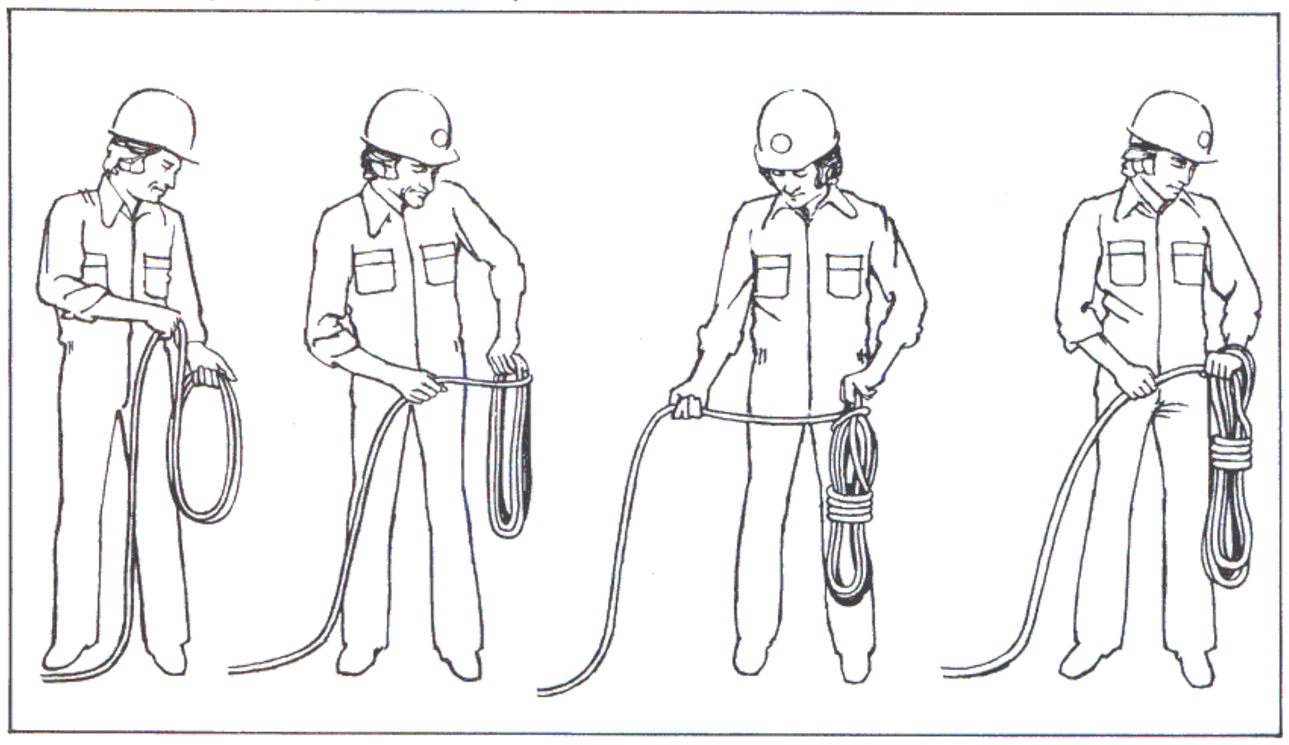


Fig. 2.11 Reason Why All Rope Ends Should Be Whipped

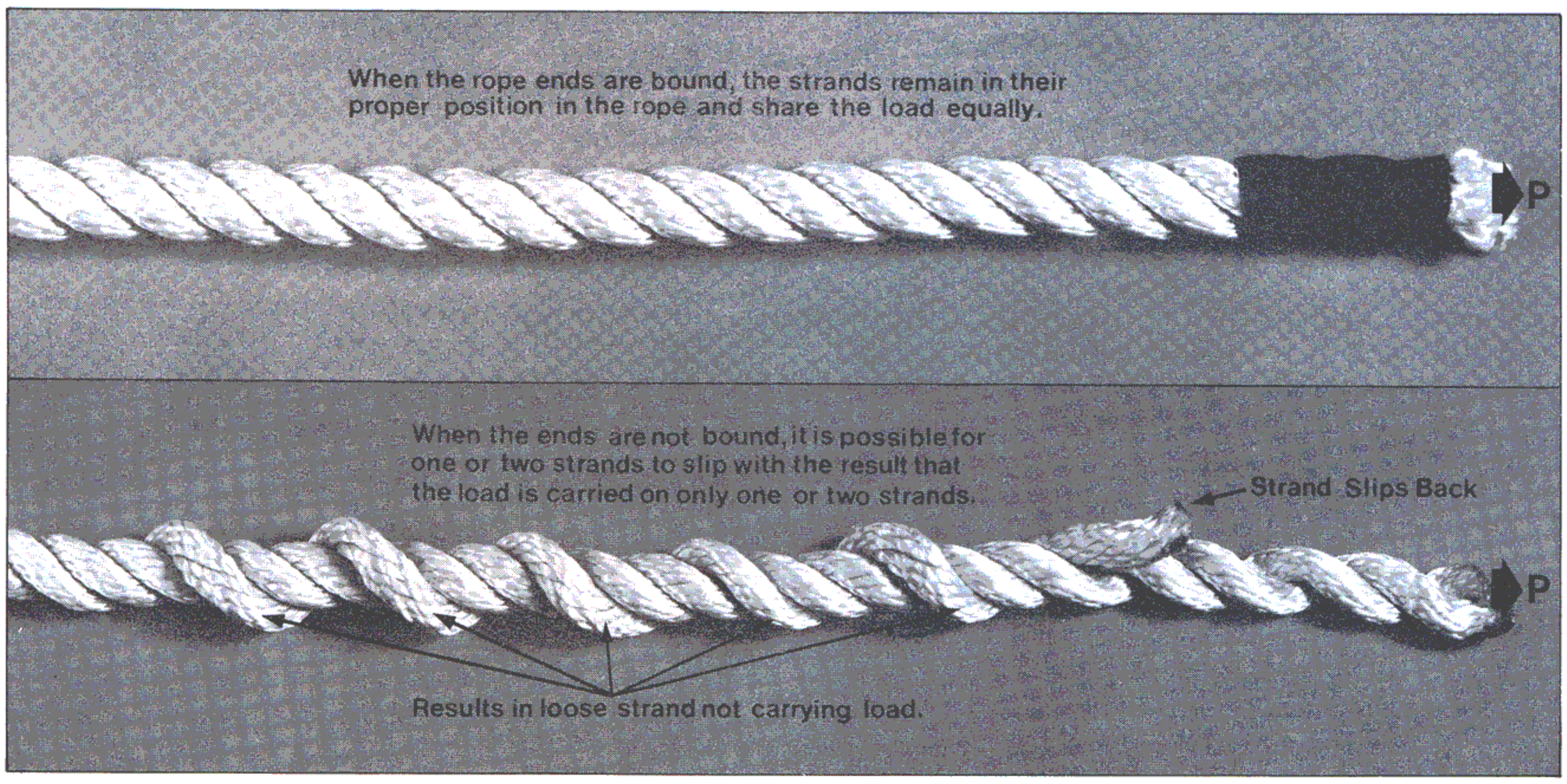


Fig. 2.12 Proper Way to Apply a Rope Whipping

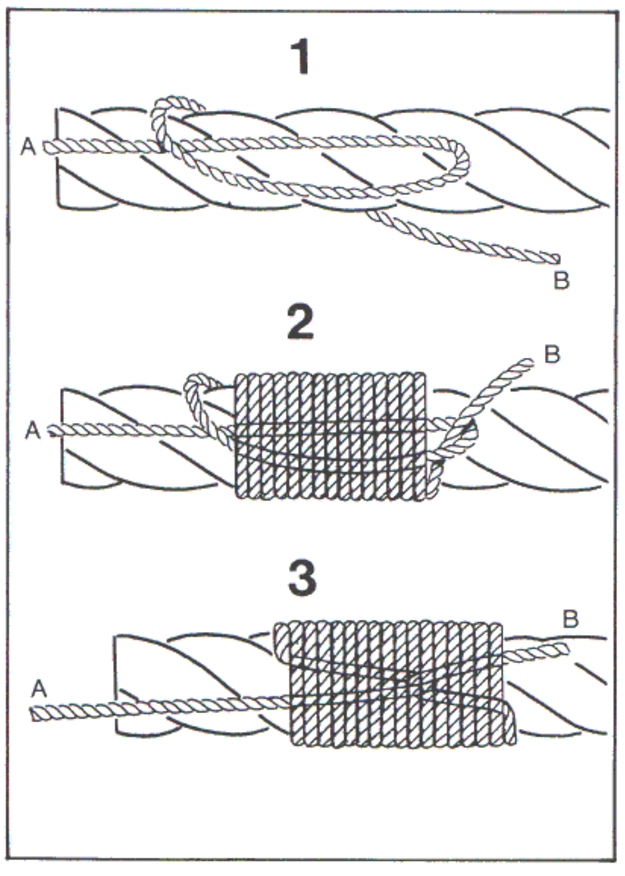


Fig. 2.13 All Ropes Should Be Hung Up To Allow Them To Dry

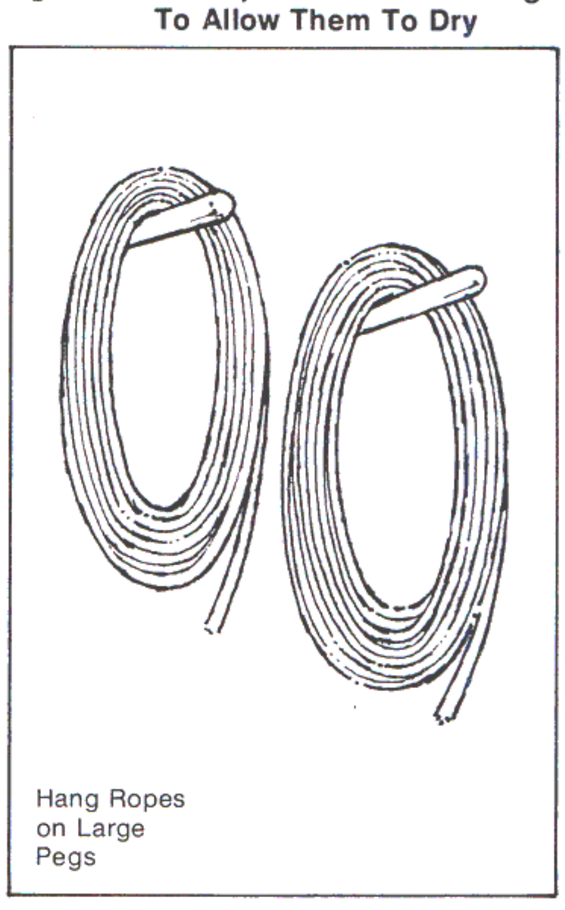
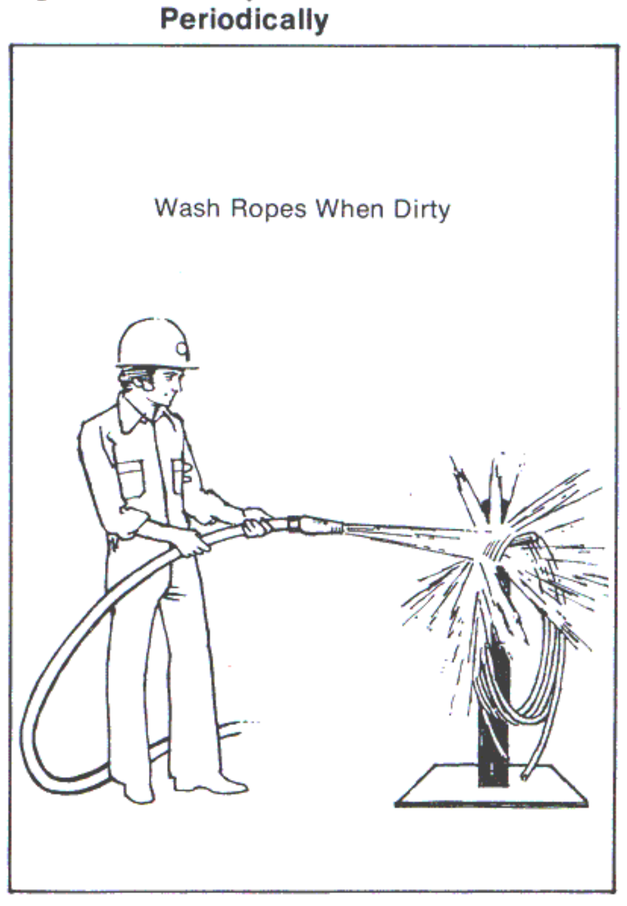


Fig. 2.14 All Ropes Should Be Cleaned Periodically



natural fibre ropes, however, to be certain keep acids, etc. away from **all** ropes. If contamination is suspected wash synthetic ropes in cold water but take natural fibre ropes out of service.

— Never overload a rope. Apply the factor of safety of at least 5:1 or 10:1 and make even further allowances for the age and condition of the rope.

— Never use a frozen rope. It must be carefully handled to avoid breaking the fibres. Allow it to thaw and dry.

— Never drag a rope along the ground. The outside surfaces will become worn and cut by the abrasive action and grit will work into them, become embedded and destroy the internal fibres.

— Never drag a rope over sharp or rough edges and never drag one part of a rope over another part.

— Avoid all but straight line pulls with rope. Abrupt bends interfere with the stress distribution of the fibres that make up the strands. With a straight pull, a rope will give 100% efficiency; tie a knot in the same rope or bend it severely and it is weakened approximately 50%. (Fig. 2.15)

— Pack all sharp corners when lifting materials with rope. (Fig. 2.16)

— Use thimbles in the eyes of all ropes. When a rope is attached to a hook, ring or pulley block, a thimble should be placed in the loop or eye to reduce the wear on the rope, and to decrease the stresses developed in the rope when it is bent around a very small diameter. (Fig. 2.17)

— Observe proper sling angles. Severe load increases occur as the sling angle is decreased. (Fig. 2.18)

— Never use fibre rope near welding or flame cutting operations. The sparks and molten metal can cut through the rope or set it on fire.

— Avoid unnecessary exposure to strong sunlight. Prolonged exposure will degrade and weaken the rope.

— Avoid exposure to all forms of heat.

— Never couple a left-hand laid rope to a right-hand laid rope.

— When coupling wire and fibre ropes, use metal thimbles in both eyes to prevent the eye of the fibre rope from being cut by the wire rope. (Fig. 2.19)

When tackle is used, the rope must be the correct size for the sheaves. The sheave grooves must be smooth and properly radiused to provide good rope seating. There should be no projections and rough or sharp edges on the blocks which might cut or chafe the rope. The sheaves must have diameters at least 6 times and preferably 10 times greater than the rope diameter.

When using synthetic ropes, extra caution must be taken because:

— Synthetics stretch more than manila.

— Synthetics have a low melting point and are not suitable for use where high temperatures prevail or where friction may cause the rope to melt or fuse.

— Synthetics can be slippery, particularly when new and especially when wet and as such extra care may be required when tying knots and when handling them.

INSPECTION

The only way to determine the safety of a rope, its life expectancy and its load carrying ability is by regularly inspecting every foot of its length. Base your estimate on the section showing the most deterioration.

Care should be taken during the inspection to avoid distorting the lay. The main points to be watched for are external wear and cutting, internal wear between the strands and deterioration of the fibres.

First examine the outside of the rope. Check for broken fibres and yarns, cuts, nicks, signs of abrasion, burns, unlaying and reductions in diameter. Each represents a loss of strength so their size, number and distribution must be considered when determining if the rope is suitable for its intended use. Acid contact with a manila rope results in dark brown spots, and in synthetic rope, it either eats away the rope or makes the fibres very brittle. (Fig. 2.20)

Open up the rope by untwisting the strands but take care not to kink them. The interior of the rope should be as bright and clean as when it was new. Check for broken yarns, excessively loose strands and yarns, or an accumulation of a powder-like dust, which indicates excessive internal wear between the strands as the rope is flexed back and forth in use. (Fig. 2.21)

If the rope is large enough, open up a strand and try to pull out one of the inside yarns, keeping in mind that if a rope has been over-

Fig. 2.15 Effect of Knots and Severe Bends on Rope Strength

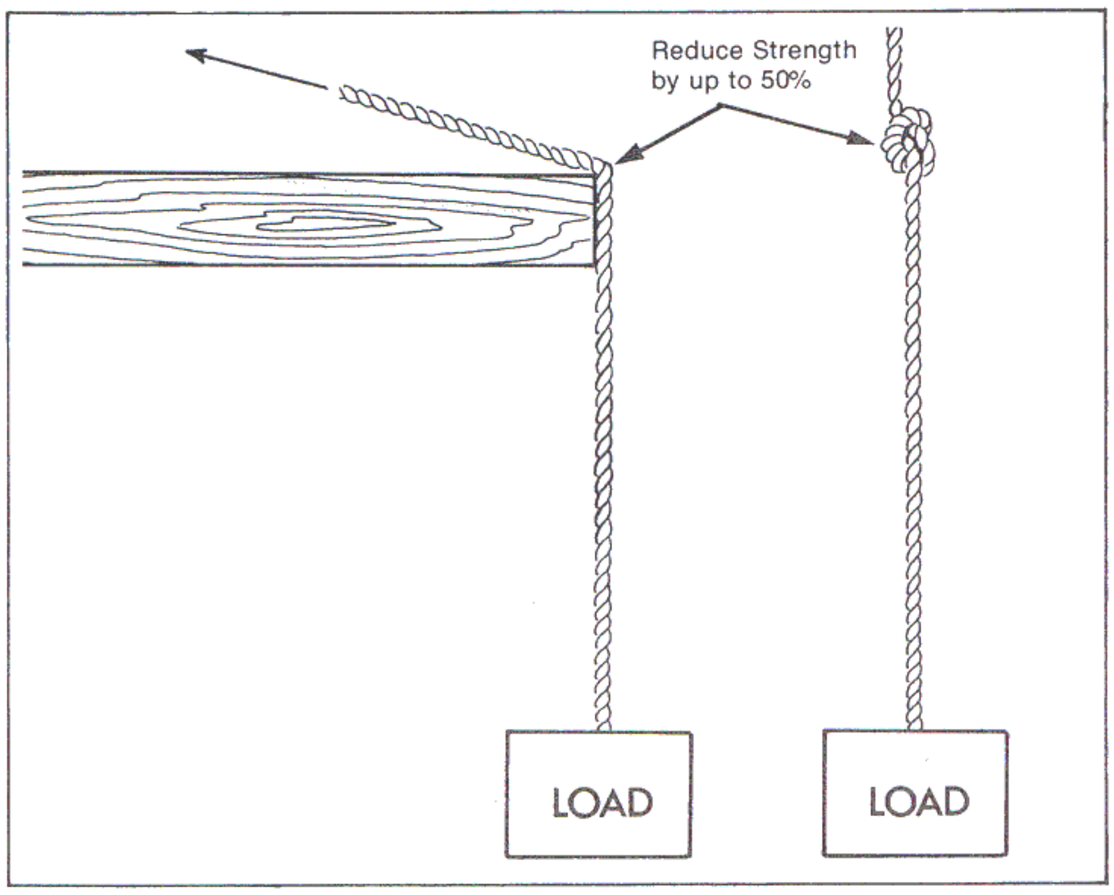


Fig. 2.16 Effective Use of Corner Pads

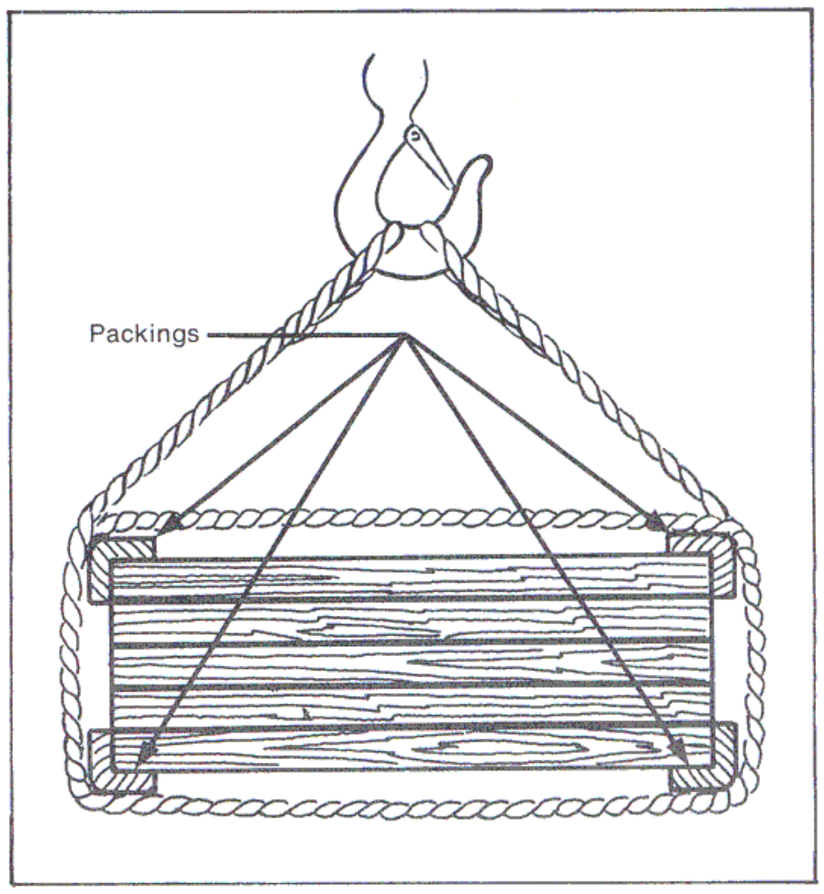


Fig. 2.17 Use Thimbles in the Eyes of all Hoisting Ropes

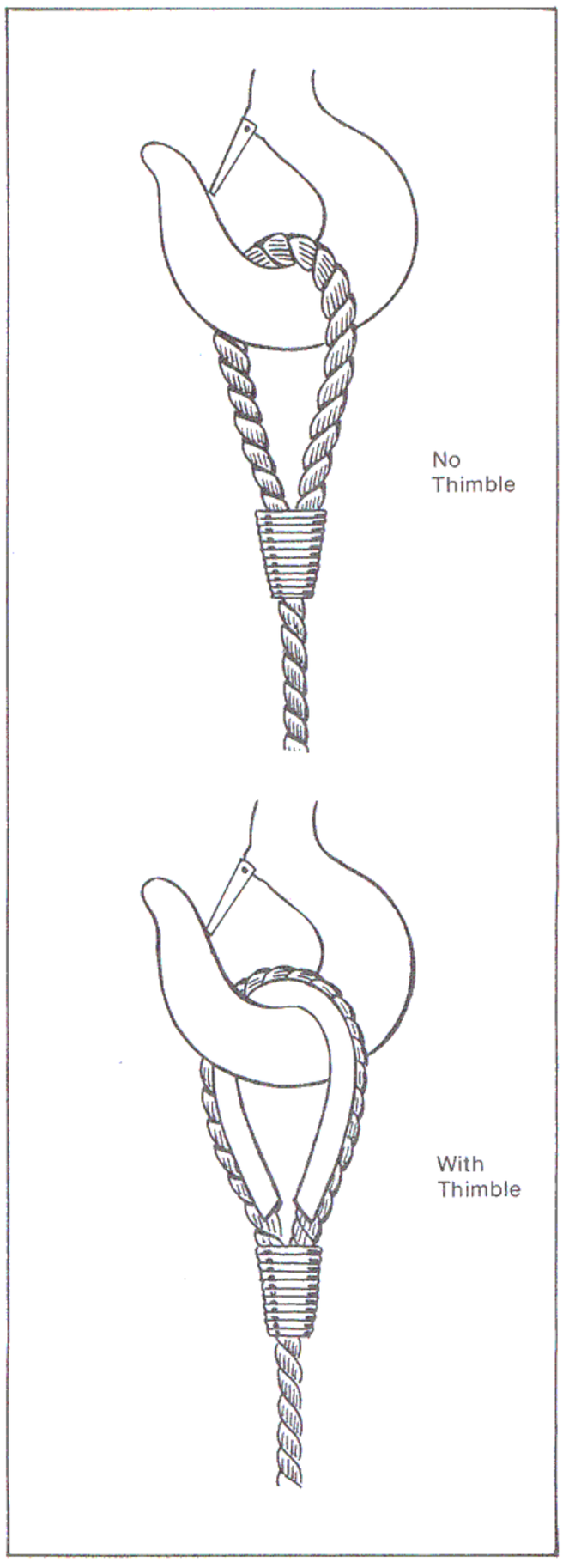


Fig. 2.18 Effect of Sling Angle on Sling Load

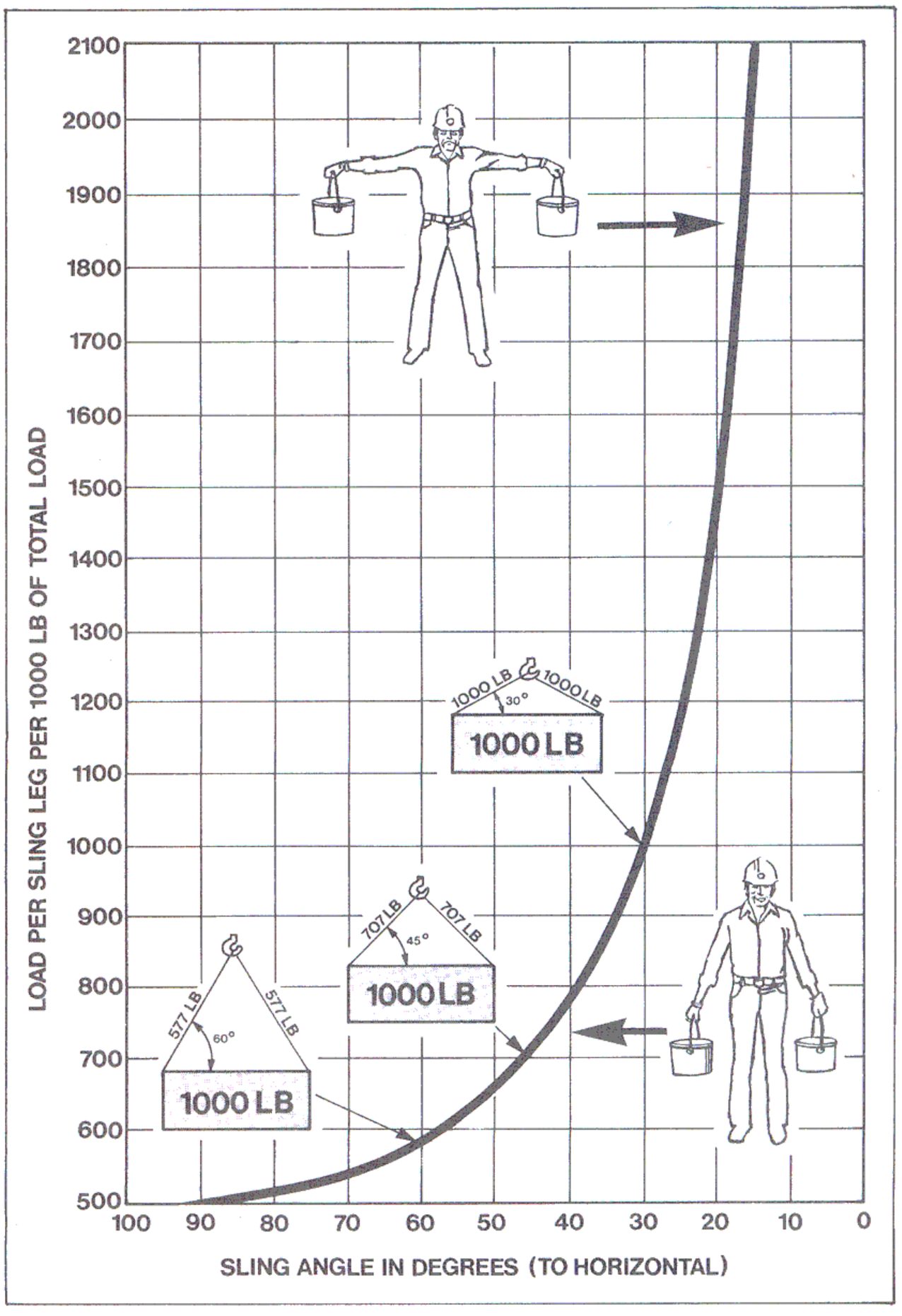


Fig. 2.19 When Connecting Fibre & Wire Ropes Use Thimbles in Both Eyes

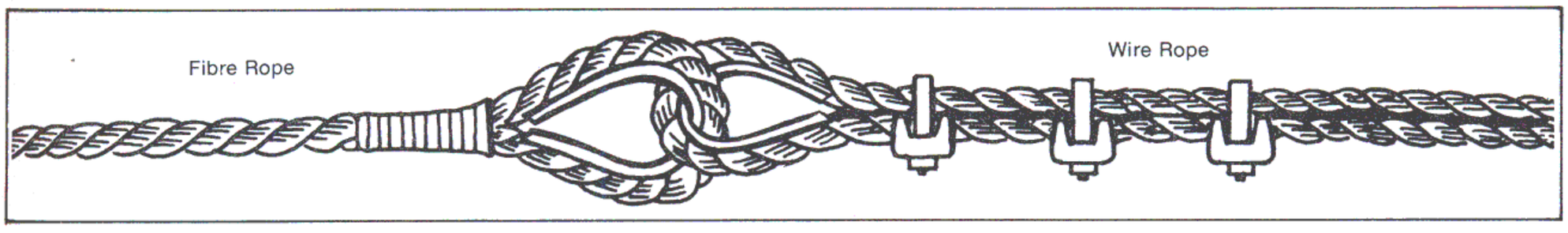


Fig. 2.20 Typical Rope Damage to Watch for During Inspections

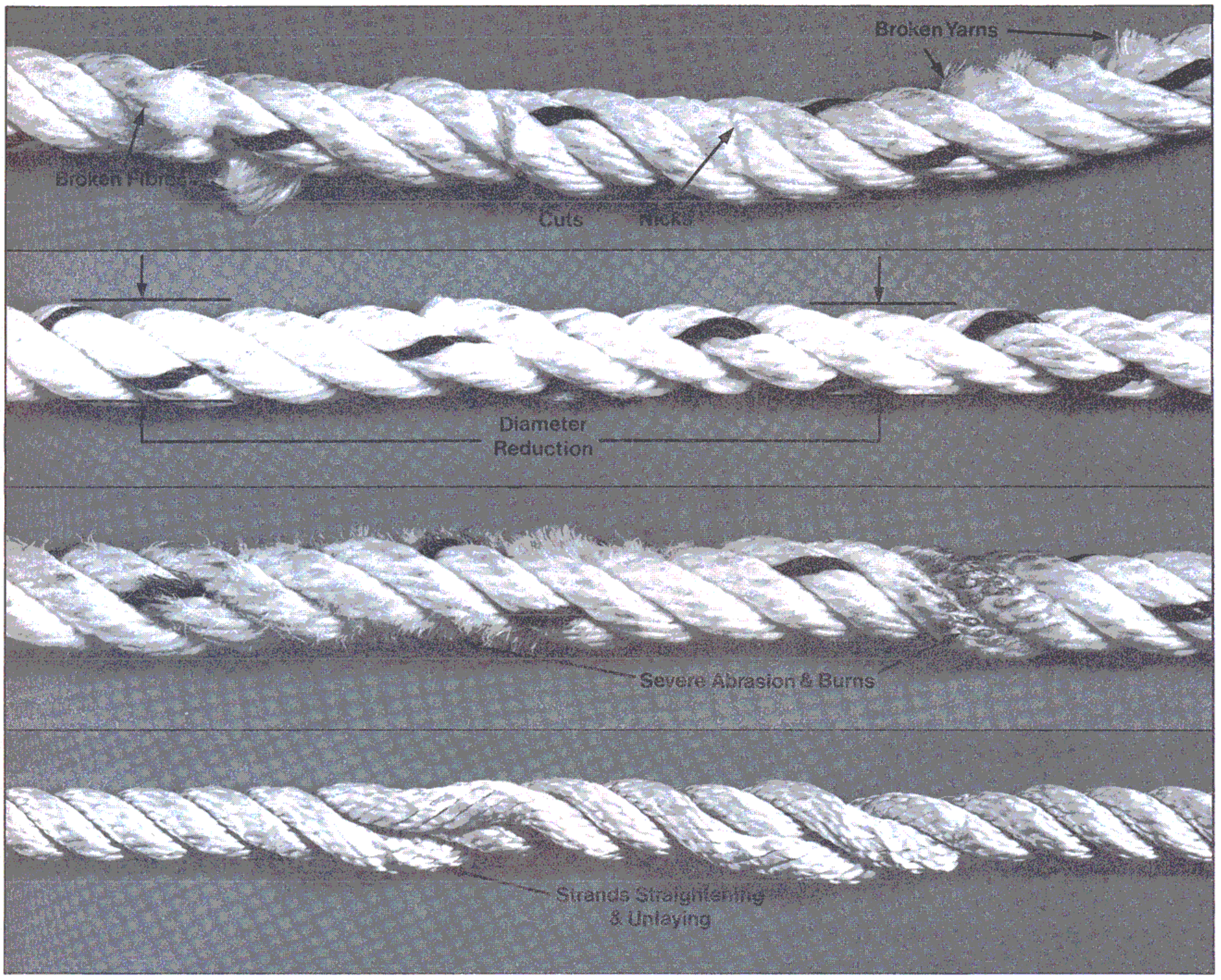
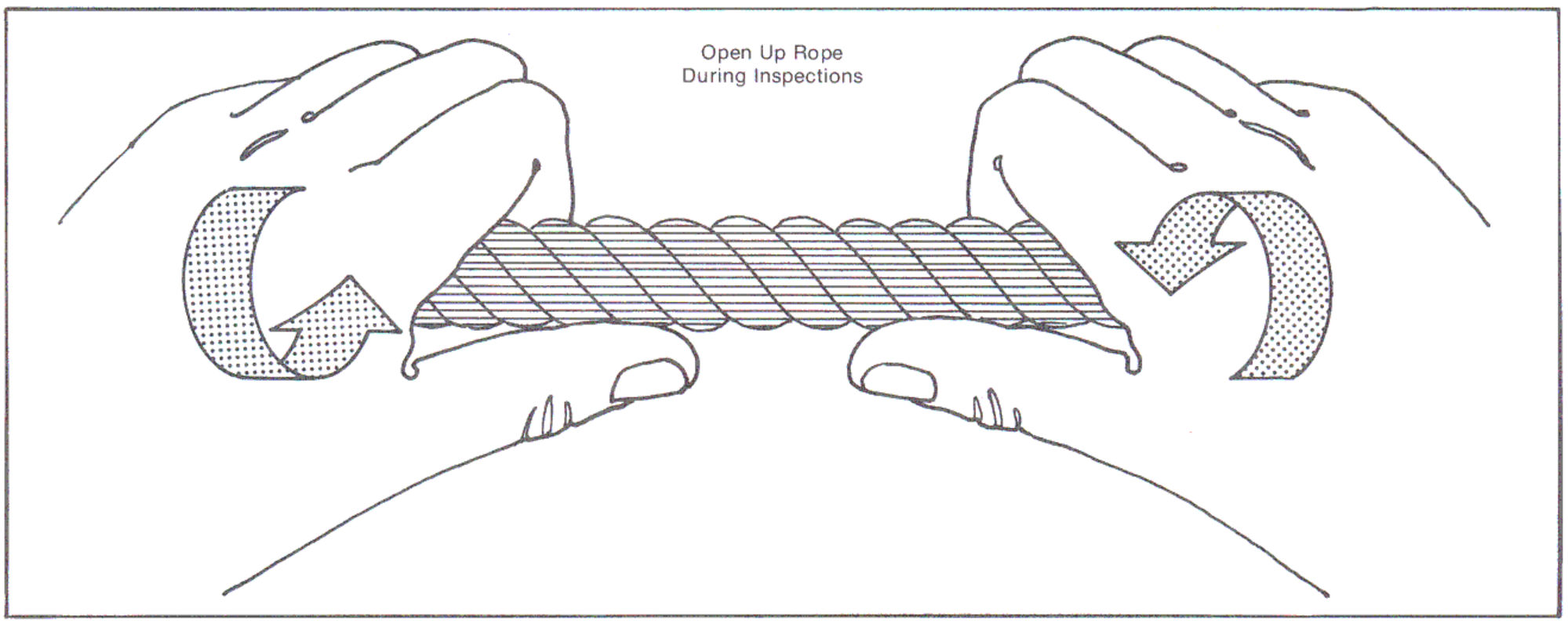


Fig. 2.21 Proper Method of Opening Up the Rope



loaded, it is the interior yarns that will have failed first. Excessive oil on the outside of a new manila rope is also an indication that it has been overloaded.

If it is 4-strand rope with a core, try to pull out the heart. If it comes out in short pieces, the rope has been overloaded and should not be used for hoisting.

If possible, pull out a couple of long fibres from the end of the rope and try to break them. If they break easily then the rope should be replaced.

If the inside of the rope is dirty, if the strands have begun to unlay, or if the rope has lost its life and elasticity, it should not be used for hoisting purposes. If the rope is high-stranded and presents a spiral appearance, or if the heart protrudes, the load will not be equally distributed on the strands and a very short life may be expected. (Fig. 2.22)

Often the surface of a rope feels dry and brittle, or it may show evidence of having been in contact with a hot pipe or other source of heat (glazing, fused sections), or it may be discoloured as the result of exposure to acid fumes. In all cases it should be discarded.

If thimbles are loose in eyes due to rope stretch they can be retightened in the eye by seizing the eye. Never allow a thimble to become so loose that it can rock in the eye. (Fig. 2.23)

Ensure that all splices are properly served or taped. Do not allow any tuck to become undone. Every tuck is necessary for optimum splice efficiency. (Fig. 2.24)

If a rope is weak in just one spot, that portion can be cut out and the rope spliced. A Short Splice should be used wherever possible, but use a Long Splice if the rope is to be run through a pulley.

Should there be any doubt as to whether or not a rope is fit for use, it should be replaced at once. Never risk danger to life or damage to property by taking a chance.

When a rope has been condemned, it should be destroyed at once or cut up into short lengths so that it cannot be used for hoisting purposes.

ROPE SPLICING

A rope splice is the joining of the ends of two ropes or the end of the rope with the body of the rope by weaving the strands over and under the strands of the other part.

Remember that even with a new rope, a splice, regardless of the type, reduces the load carrying ability of that rope by 10 to 15%.

If synthetic rope is to be spliced, take extra precautions owing to the large number of filaments in each yarn and the smooth surface of the strands. It is also advisable to insert extra tucks to maintain full efficiency and prevent slippage.

Care must be taken during the splicing operation to avoid loss of twist and to maintain the form and lay of yarns and strands. Owing to the smooth cylindrical form of the synthetic fibres, yarns do not "cling" to each other in the manner of natural fibre yarns and, accordingly, care must be exercised to prevent the part of the strands used for tucking from separating into what can only be described as a bundle of yarns.

The normal Long, Short, and Eye Splices can be made on synthetic ropes, but owing to the smooth surfaces of the yarns, it is necessary to insert extra tucks to maintain full efficiency and prevent slippage.

With Short and Eye Splices, four full tucks, tapered to finish with one-half and one-quarter tucks will give full efficiency. Where very heavy and rapidly fluctuating loads are involved the number of full tucks can be increased as a safety measure, but with medium sized and large ropes it is, at all times, advisable to taper the splice in order to obtain maximum strength. Well made tapered splices on synthetic fibre ropes will yield a strength of approximately 90% of the initial breaking load of the rope.

Here is a general guide to the making of secure splices:

— Care should be taken when unlaying the rope that the formation of the individual strands is not disturbed.

— After the rope has been unlayed, maintain the strand form by applying a series of half-hitches to each strand at intervals of about 1 inch with a twine.

— Seize the rope at the throat of an eye splice to prevent any unlaying during the splicing operation.

— Apply a greater number of tucks in synthetic fibre ropes than you would apply to natural fibre ropes.

— The minimum number of tucks recommended is five. These can be made up of five tucks for small ropes and four full tucks and two tapered tucks for medium-sized or large ropes.

Fig. 2.22 High Stranded Rope

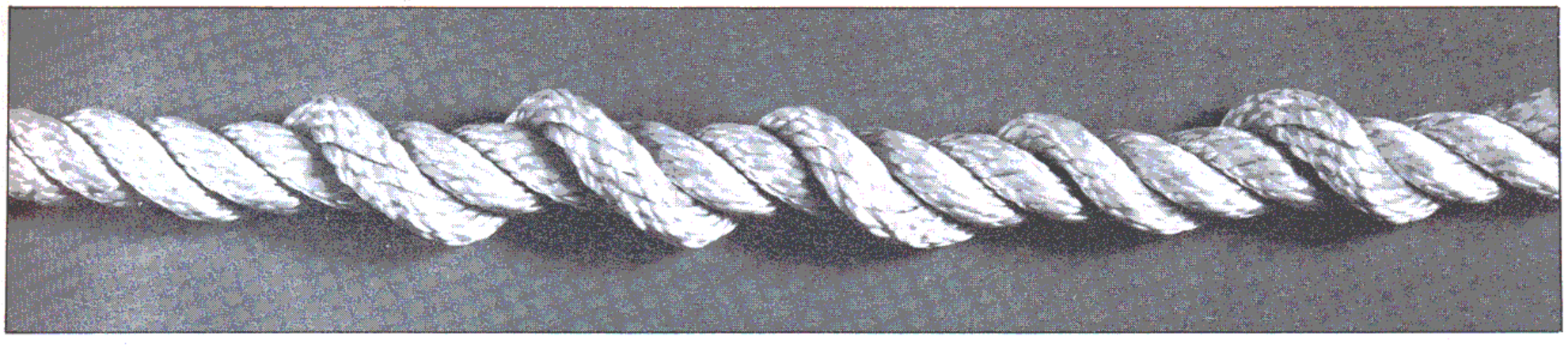


Fig. 2.23 Thimbles Must Fit Tightly In Eye

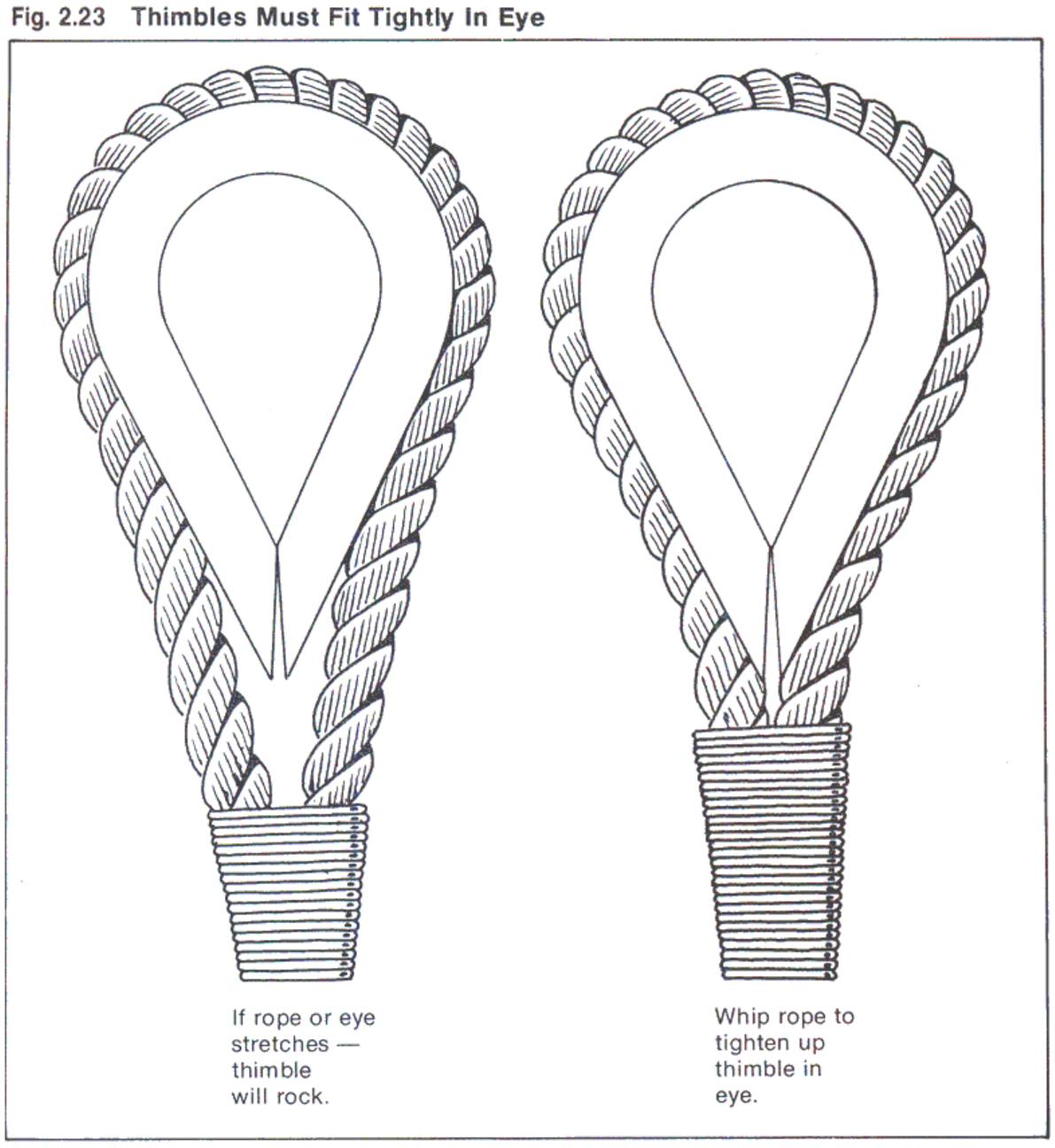


Fig. 2.24 All Splice Tucks Must Be Secure

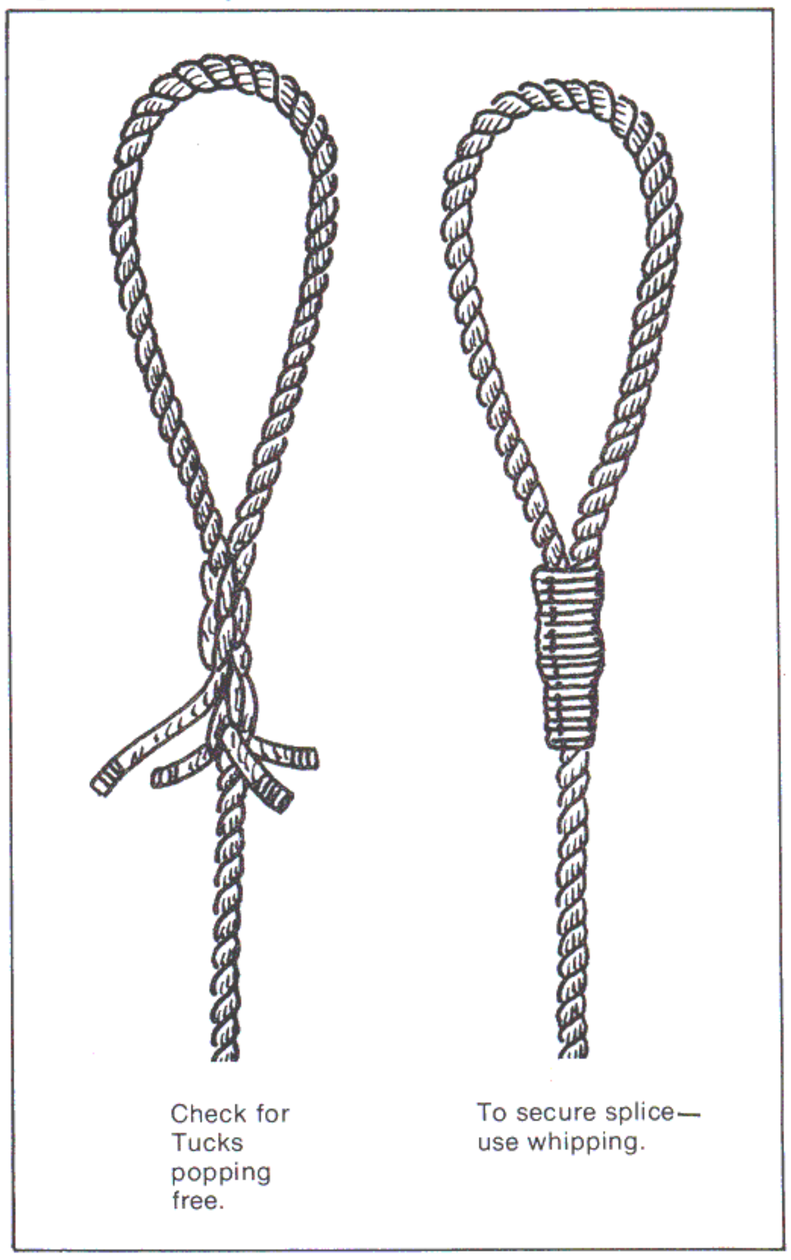
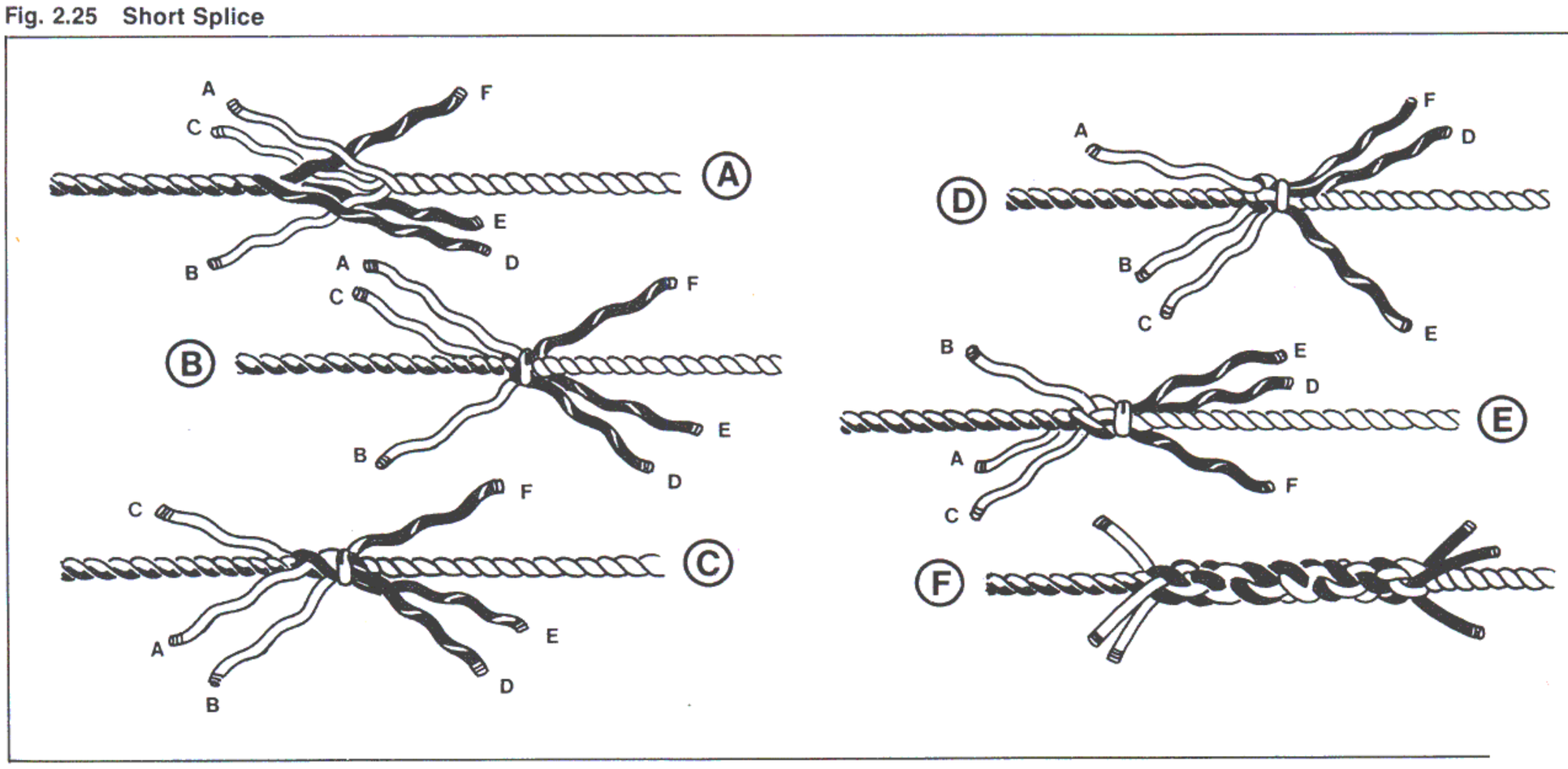


Fig. 2.25 Short Splice



— The yarn ends of the strands should be left with long tails, preferably not less than 1 or 2 inches and simply seized to the finished rope.

When using spliced rope, never subject the splice to a severe bend such as would occur if one were placed in a hook throat. The severe bending and flexing tends to spring the splice.

SHORT SPLICE:

The Short Splice, while the strongest of all splices, is not suitable if the rope runs over sheaves or through blocks because the diameter of the rope is almost doubled at the point of joining. They are most suitable for making endless slings, etc.

Here's a step-by-step guide to making a Short Splice: (Fig. 2.25)

— **One:** Unlay the strands at one end of each rope for 6 or 8 turns. The ends of the strands should be whipped to prevent their untwisting and brought together so that each strand of one rope alternates with a strand of the other rope. (Sketch A, Fig. 2.25)

— **Two:** Bring the ends tightly together and apply a temporary seizing where they join. (Sketch B, Fig. 2.25)

— **Three:** Take any one strand and begin tucking, the sequence being over one and under one. Strand A is passed over the strand nearest to it, which is Strand D, and then under the next strand, Strand E. (Sketch C, Fig. 2.25)

— **Four:** Rotate the splice away from you one-third of a turn and make the second tuck. Strand B is passed over Strand E and then under Strand F. (Sketch D, Fig. 2.25)

— **Five:** Before making the third tuck, rotate the splice again one-third of a turn away from you. Strand C is then passed over Strand F and under the next one, Strand D. (Sketch E, Fig. 2.25)

— **Six:** This completes the first round of tucks in the left-hand half of the splice. Each strand should now be tucked at least twice more, always over one and under one as before, making sure that each strand lies snug and with no kinks.

— **Seven:** To finish the splice, reverse the rope end for end so that Strands D, E and F are now at the left instead of the right and repeat the operation on their side of the rope. Each of the six strands will now have had at least three tucks. A tapered splice is made by taking two more tucks with each strand, cutting away some of the threads from each strand before each extra tuck.

— ***Eight:*** When tucking is finished, remove the centre seizing and cut off the ends of all strands, leaving at least 3/4" on each end. To give a smooth appearance roll the splice back and forth, either under your foot or between two boards. (Sketch F, Fig. 2.25)

LONG SPLICE:

The Long Splice is slightly weaker than the short splice but it increases the rope diameter only slightly and thus allows the rope to run through a sheave or block without obstruction and lessens wear and chafing of the rope fibres at the point of splicing. A long splice should be made only with two ropes of the same size. They are not suitable for endless slings because of their lower strength.

Here is a step-by-step procedure for making a Long Splice: (Fig. 2.26)

— **One:** Begin by unlaying one strand of each rope for 10 or 15 turns. Whip the ends of each strand to prevent untwisting. Then lock the two ropes together by alternating the strands from each end. (Sketch A, Fig. 2.26)

— **Two:** Starting at one end, take an opposite pair of strands, A and B, and unlay Strand A. Follow it with Strand B, turn by turn, continuing until only a foot or less of Strand B remains. Keep Strand B tight during this step and pull it down firmly into Strand A's former place. Repeat this operation with Strands C and D. Strand D is unlaid and Strand C is laid in its place. (Sketch B, Fig. 2.26)

— **Three:** Now each pair of strands is tied loosely together with a simple overhand knot, as indicated by Strands A and B. Each knot is then pulled down into the rope like Strands C and D. (Sketch C, Fig. 2.26)

— **Four:** Each strand is now tucked twice, over and under, as in the Short Splice. The illustration shows Strands C and D after tucking. If a smaller diameter splice is desired, taper by tucking each strand twice more, cutting away some of the threads for each additional tuck. (Sketch D, Fig. 2.26)

— **Five:** When tucking is finished, cut all strands off close to the rope and roll the splice on the floor under your foot to smooth it out. (Sketch E, Fig. 2.26)

EYE OR SIDE SPLICE:

These splices are normally used to form an eye in the end of a fibre rope. The Side Splice is also called the Eye Splice because it is used to

Fig. 2.26 Long Splice

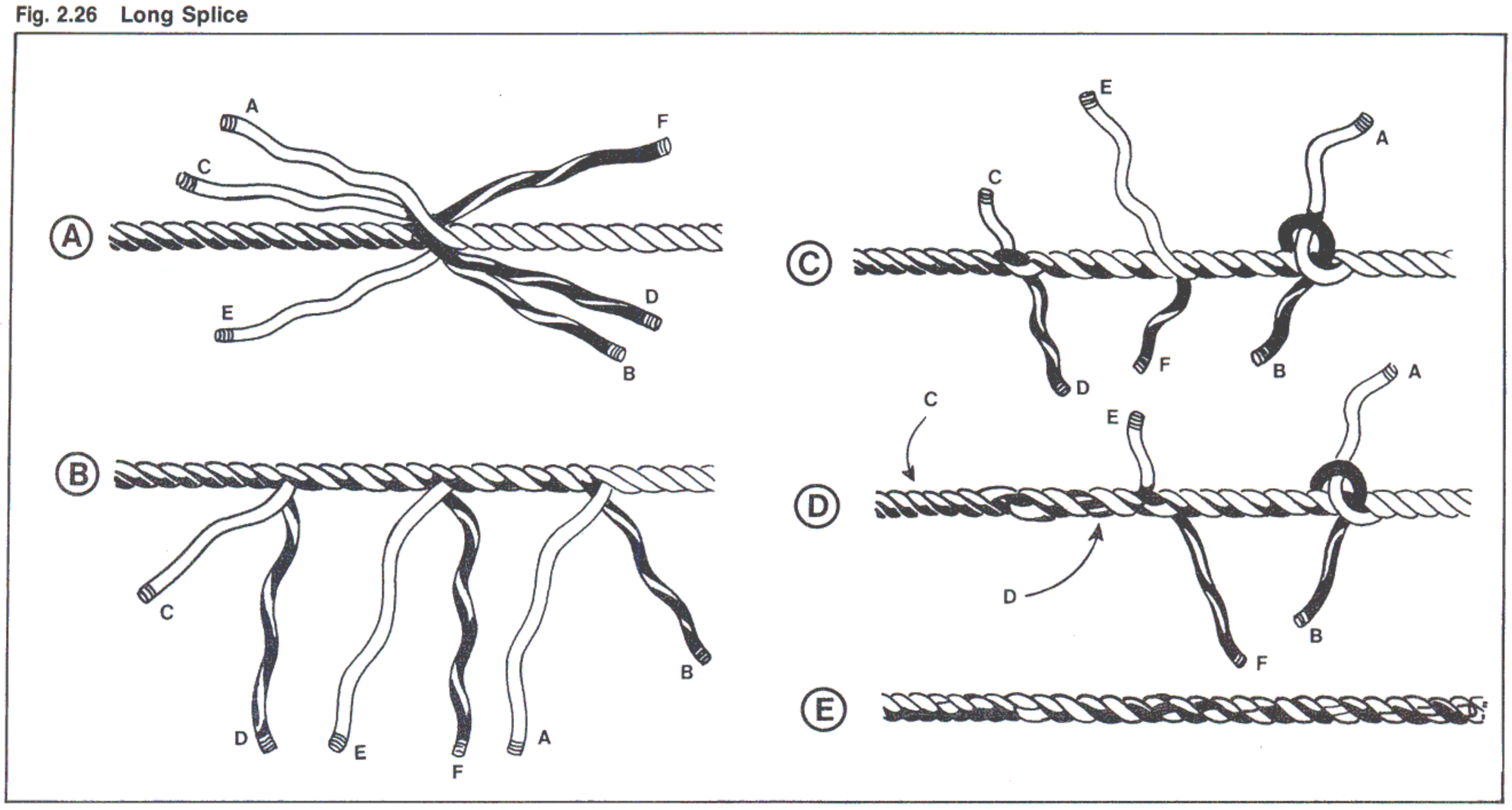
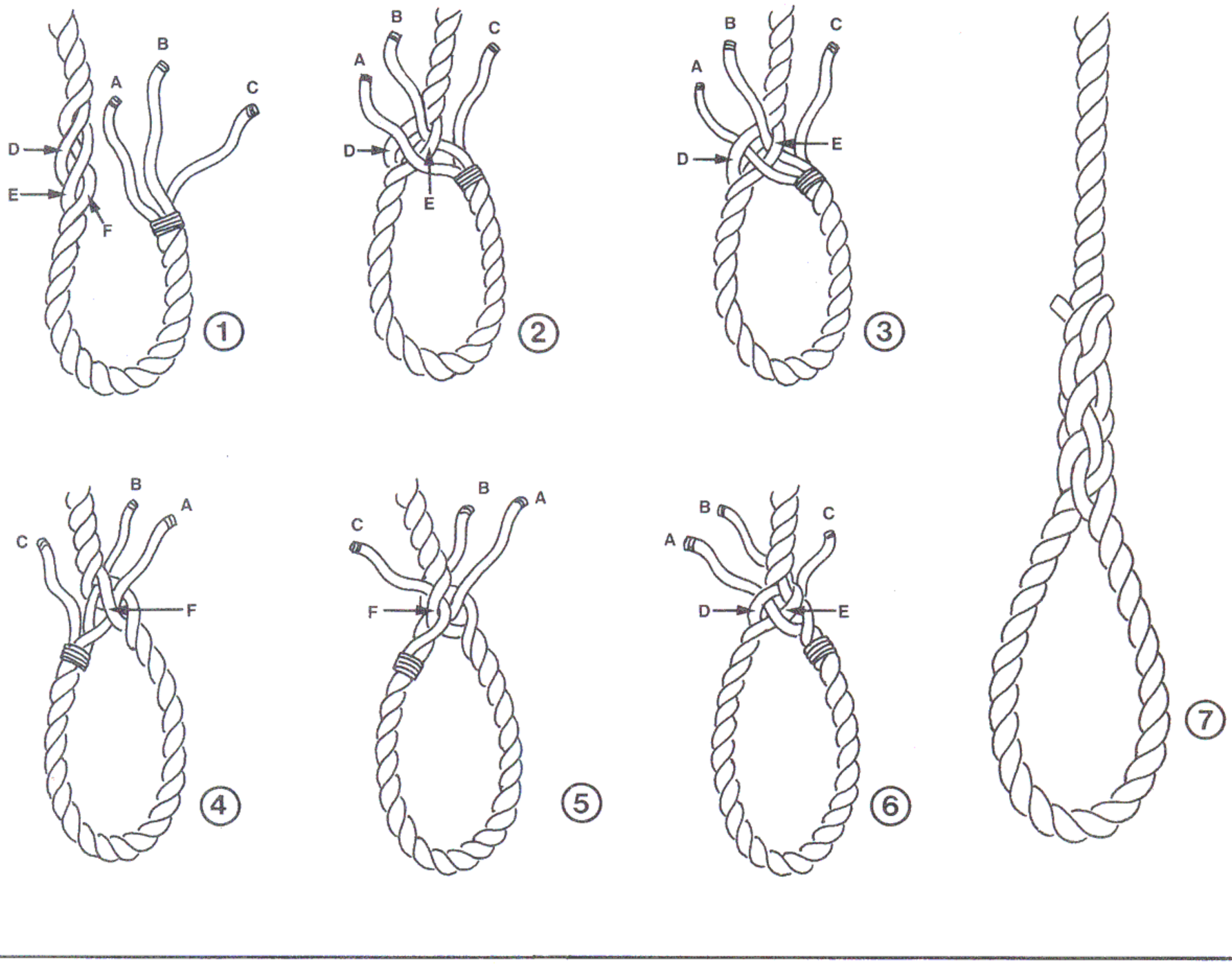


Fig. 2.27 Eye Splice



form an eye or loop in the end of a rope by splicing the end back into its own side. This splice is made like the Short Splice except that only one rope is used. Metal or nylon thimbles should be fitted to all eye splices for lifting.

Here is a step-by-step guide: (Fig. 2.27)

— **One:** Start by seizing the working end of the rope. Unlay the three Strands A, B and C, to the seizing and whip the end of each strand. Then twist the rope slightly to open up Strands D, E and F of the standing part of the rope as indicated. (Sketch 1, Fig. 2.27)

— **Two:** The first tuck is as shown in the illustration. The middle strand is always tucked first, so Strand B is tucked under Strand E, the middle strand of the standing part. (Sketch 2, Fig. 2.27)

— **Three:** The second tuck is now made. Left Strand A of the working end is tucked under Strand D, passing over Strand E. (Sketch 3, Fig. 2.27)

— **Four:** This figure shows how the third tuck is made. In order to make Strand F easy to get at the rope is turned over. Strand C now appears on the left side. (Sketch 4, Fig. 2.27)

— **Five:** Strand C is then passed to the right of and tucked under Strand F, as shown. This completes the first round of tucks. (Sketch 5, Fig. 2.27)

— **Six:** This illustration shows the second round of tucks started, with the rope reversed again for ease in handling. Strand B is passed over Strand D and tucked under the next strand to the left. Continue with Strands A and C, tucking over one strand and then under one to the left. To complete the splice, tuck each strand once more. (Sketch 6, Fig. 2.27)

— **Seven:** The finished Eye Splice is as shown. Remove the temporary seizing and cut off the strand ends, leaving at least $^1/_2$" on each end. Roll the splice back and forth under your foot to even up and smooth out the strands. (Sketch 7, Fig. 2.27)

Where metal thimbles are used in the eyes it is important to have a correct design. Synthetic fibre ropes are more extensible under load than natural fibre ropes, and under load the eye splice pulls a greater distance from the thimble end. This can result in the angular sides of the thimble losing contact with the rope at the eye. Accordingly the only bearing of rope to thimble is around the thimble radius and rocking of the thimble can occur, leading to chafing of the rope inside the eye, with ultimate breakdown.

FLEMISH EYE SPLICE:

The Flemish Eye Splice, while taking longer to make, affords greater resistance to splice failure or slippage than does the Eye or Side Splice.

Here's how this splice is made: (Fig. 2.28)

— **One:** Unlay one strand of the rope a distance sufficient to account for the eye and splicing. (Sketch 1, Fig. 2.28)

— **Two:** Form a loop with the two unlaid strands. (Sketch 2, Fig. 2.28)

— **Three:** Lay the first strand back in its former place in the rope but work around the other side of the eye. (Sketch 3, Fig. 2.28)

— **Four:** Terminate the splice by making an ordinary Side or Eye Splice as previously described. (Sketch 4, Fig. 2.28)

CROWN KNOT AND BACK SPLICE:

The Crown Knot and Back Splice are used to prevent the strands at the end of a rope from unlaying. These are developed as follows: (Fig. 2.29)

— **One:** The illustration shows the crowning begun. Open the strands of the rope as shown, lay the Strand A down over the centre of the rope, and then bring B down over A and Strand C over B and through the bight of A. (Sketch 1, Fig. 2.29)

— **Two:** The illustration shows how the strands tie when they are nearly taut. Pull the crown tight then pass one end over the next strand in the standing part and under the following one. (Sketch 2, Fig. 2.29)

— **Three:** Do the same to each of the other strands in succession, three times, then cut the ends off. This completes the Back Splice. (Sketch 3, Fig. 2.29)

KNOTS, BENDS AND HITCHES:

The distinction between knots, bends and hitches is generally accepted as being as follows. A knot is the intertwining of the end of a rope within a portion of the rope; a bend is the intertwining of the ends of two ropes or of the same rope to make one continuous rope or endless rope; a hitch is the attachment of a rope to a post, pole, ring, hook or other object.

Hundreds of different knots, bends and hitches have been devised to suit varying purposes, but of this number some have been

Fig. 2.28 Flemish Eye Splice

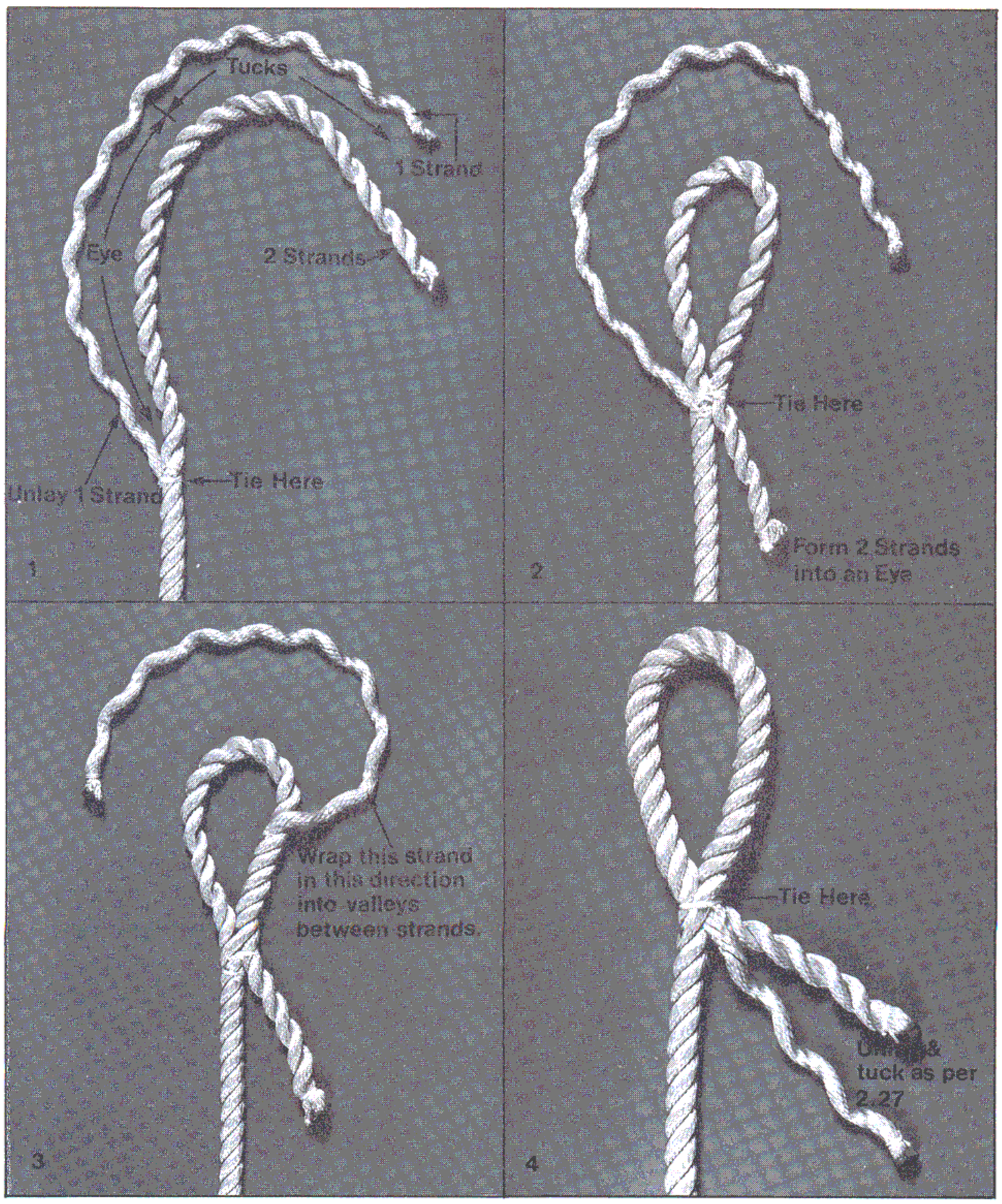
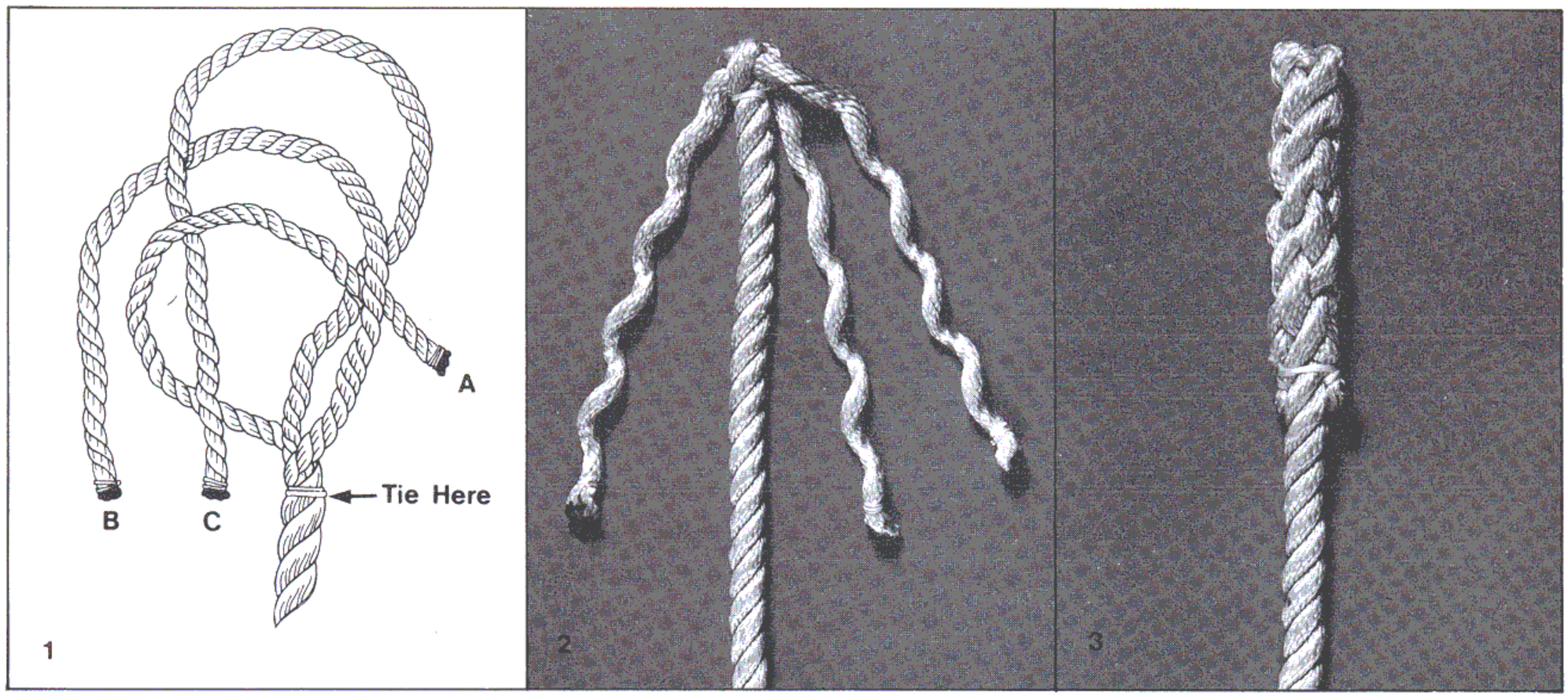


Fig. 2.29 Crown Knot and Back Splice



found to be superior for construction rigging and these are the only ones considered in this manual.

A good knot, bend or hitch is one that can be tied with speed and ease and which, when tied, will hold. Their prime requirements are security against slippage, suitability and strength.

The proper fastening (knot, bend or hitch) must be selected for the job to be done and tied correctly to obtain the maximum strength.

Remember that a rope fastening is never as strong as the original rope; knots, bends and hitches reduce the strength of the rope. The bending of the rope in the making of a knot or hitch causes the outside fibres to carry more than their share of the load and the resultant stretching of the fibres weakens the rope. When a failure occurs, the outside fibres are the first to break followed by the inside fibres.

Knots and bends cut the rope strength in half. Hitches reduce the strength by 25%. These figures relate to the ultimate strength of the rope at the knot and must not be accepted as representative of the holding power of the knot against slip in certain applications. (Fig. 2.30)

Loops formed by one rope passing over another of the same size will yield the full strength of the single rope, provided the pull is exerted by and applied to the double ropes forming the loops. (Fig. 2.31)

It is important to note that the strength losses due to splices and knots are not cumulative in an assembly. For example, if a load is being carried by two ropes of equal size, joined by a Carrick Bend and anchored to one end with an Eye Splice and the other with a Bowline, the strength of the assembly is, in fact, the strength of the Bowline, i.e. 50% of the tensile strength of the ropes. (Fig. 2.32)

Unless absolutely necessary, do not use knotted ropes for overhead hoisting and when using synthetic fibre ropes it is advisable to double knot because of the rope's smooth exterior.

All the common knots can be tied successfully in synthetic fibre ropes, but in regard to polyethylene and, to a certain extent, polypropylene monofilament ropes most knots tend to slip and it is necessary to "double up" on the knot in order to hold. This is due to the waxy nature of the monofilament surfaces.

Blackwall Hitch: (Fig. 2.33) Satisfactory for temporarily attaching light loads to a hook and only if the tension is never allowed to slacken and the rope is dry. It consists of a loop passed under the standing part and across the hook. Under load, the live end jams and holds the dead end against the hook. Synthetic ropes are too slippery for this hitch.

Double Blackwall Hitch: (Fig. 2.34) Provides better security than the single Blackwall and can be used with wet or slippery ropes.

Bowline: (Fig. 2.35) Never jams or slips if properly tied. It is a universal knot that is easily tied and untied. Two interlocking Bowlines can be used to join two ropes together, single Bowlines can be used for hoisting or hitching directly around a ring or post. Make an overhand loop with the end of the rope held toward you. Pass the end of the rope up through the loop, then up behind the standing part and back down through the loop. Draw up tight.

Double Bowline: (Fig. 2.36) Forms a good non-slipping eye or set of spreaders for a sling. Make an overhand loop with the end of the rope held toward you, exactly as for the ordinary Bowline. Pass the end through the loop twice — making two lower loops. The end is then passed behind the standing part and down through the first loop again as in the ordinary Bowline. Pull tight.

Bowline on the Bight: (Fig. 2.37) The knot is used to tie a Bowline in the middle of a line or for making up a set of double leg spreaders. It can also be used as a sling to sit in by sitting in one loop and putting the other loop around the back and under the arms. To tie, double the rope, make an overhand loop and pass the loop end up through it. Bring the loop end toward you, down and over the other loop section. Bring the loop up back until it lies behind the standing part. Draw it tight by a slow even pull on the upper right side as shown.

Triple (Rescue) Bowline: (Fig. 2.38) Is effective for lifting injured persons since a third loop is available to support the back and shoulders as well as individual loops for each leg. Double the rope, make an overhand loop and pass the loop end up through it then up and in behind the standing part and back down through the loop, thus making the third loop. Draw up tight.

Running Bowline: (Fig. 2.39) Makes an excellent slip knot or noose. It runs freely on the standing part, is easily untied and is very strong and efficient. To tie, make an overhand

Fig. 2.30 Effect of Knots, Bends and Hitches on Rope Strength

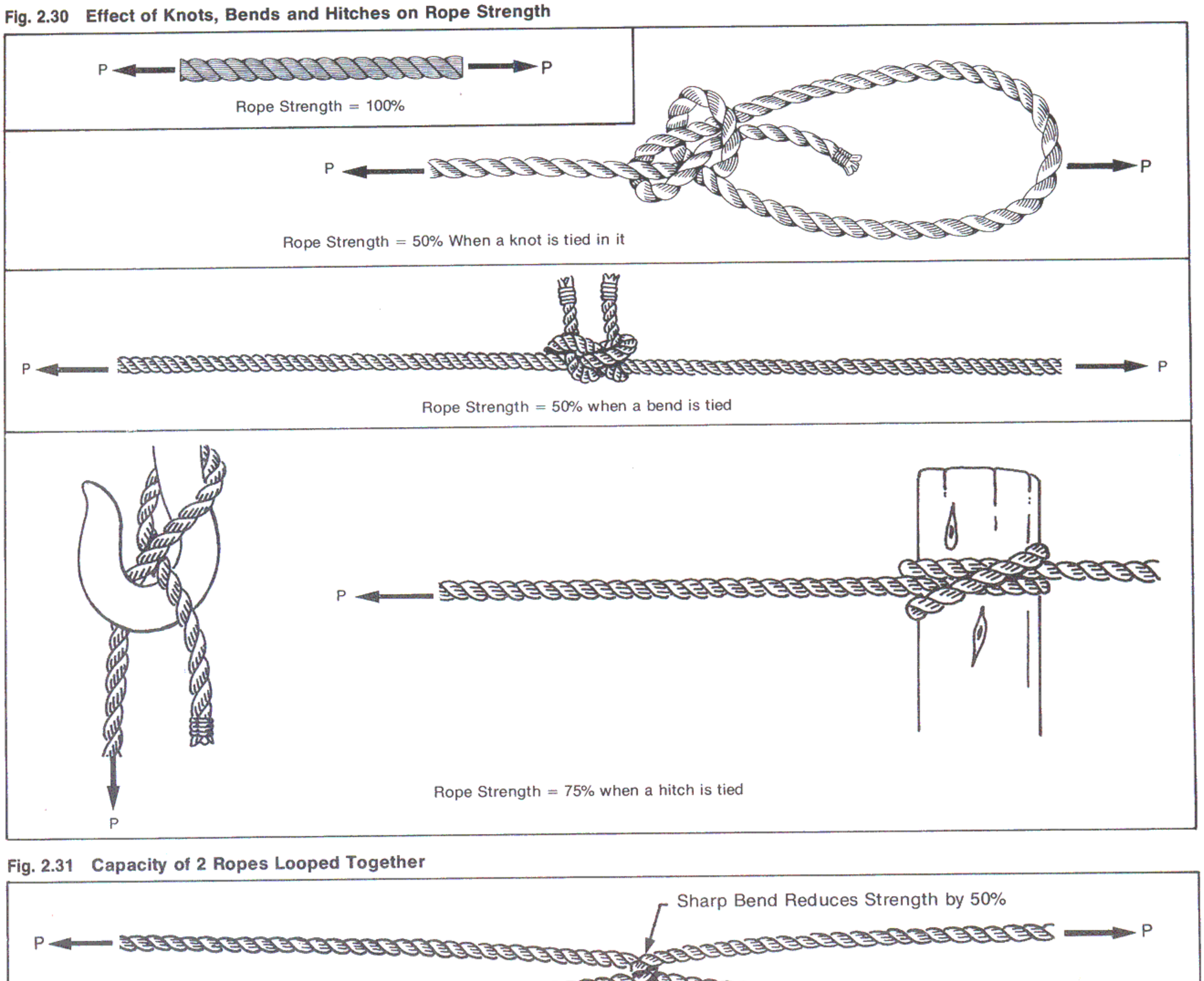


Fig. 2.31 Capacity of 2 Ropes Looped Together

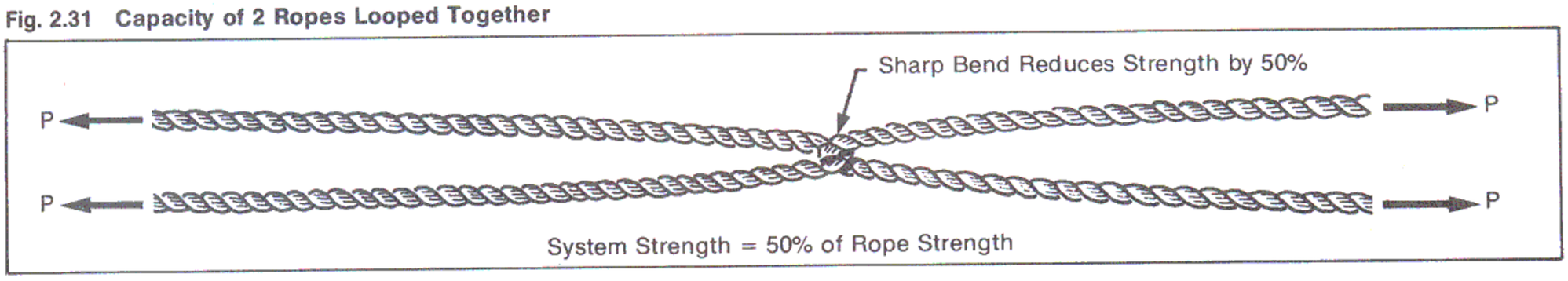


Fig. 2.32 System Strength When a Series of Knots and Splices are Tied

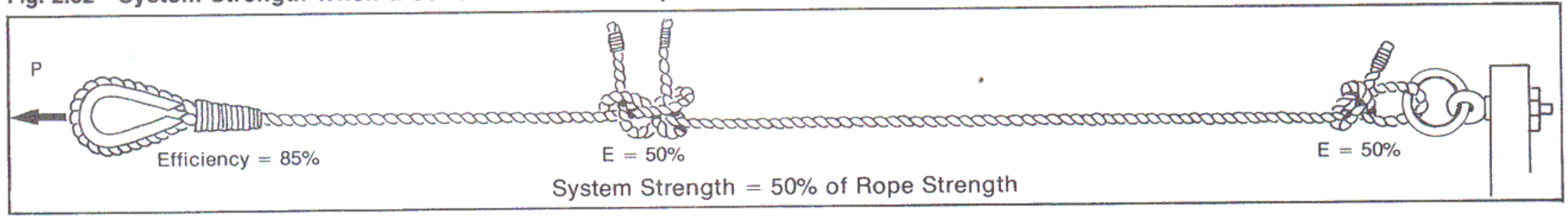


Fig. 2.33 Blackwall Hitch

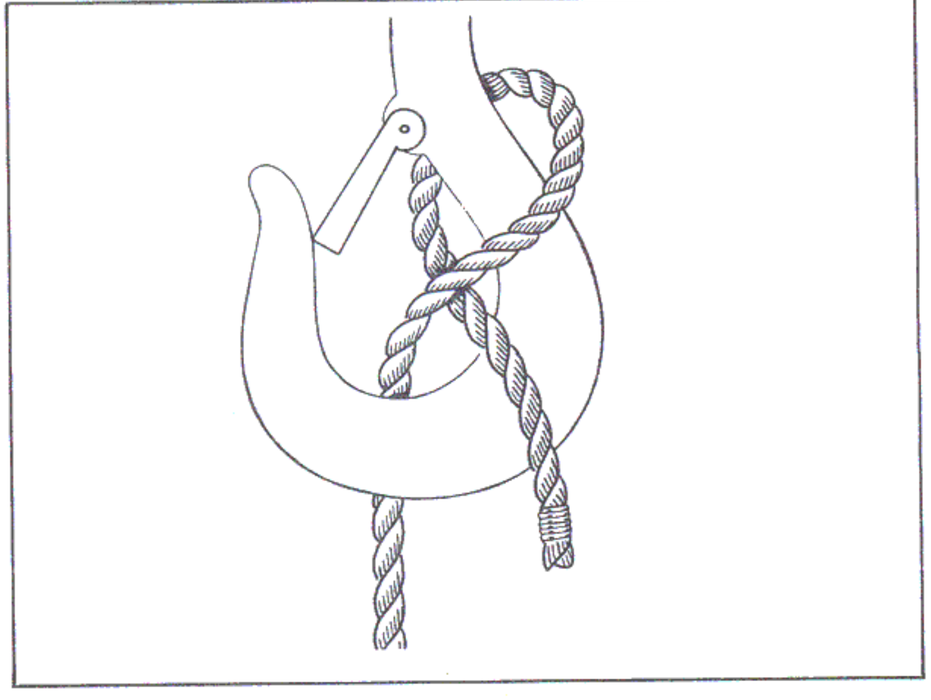


Fig. 2.34 Double Blackwall Hitch

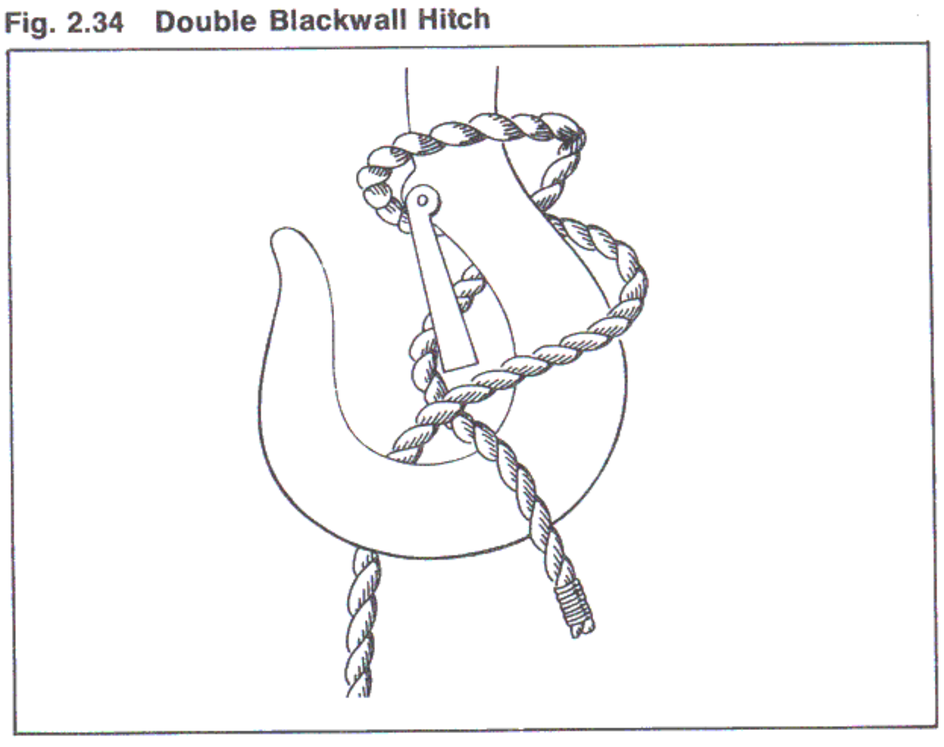


Fig. 2.35 Bowline

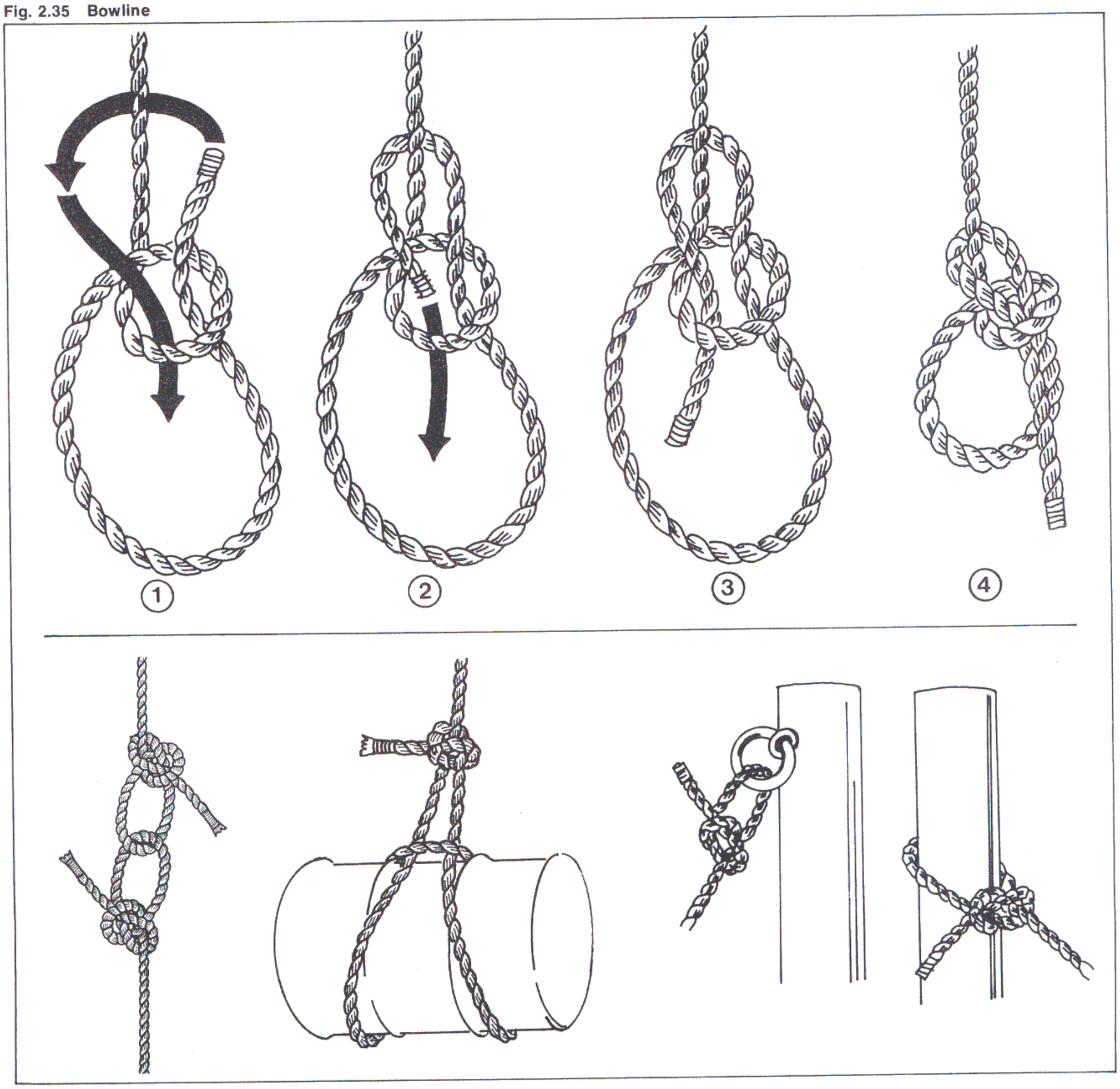


Fig. 2.36 Double Bowline

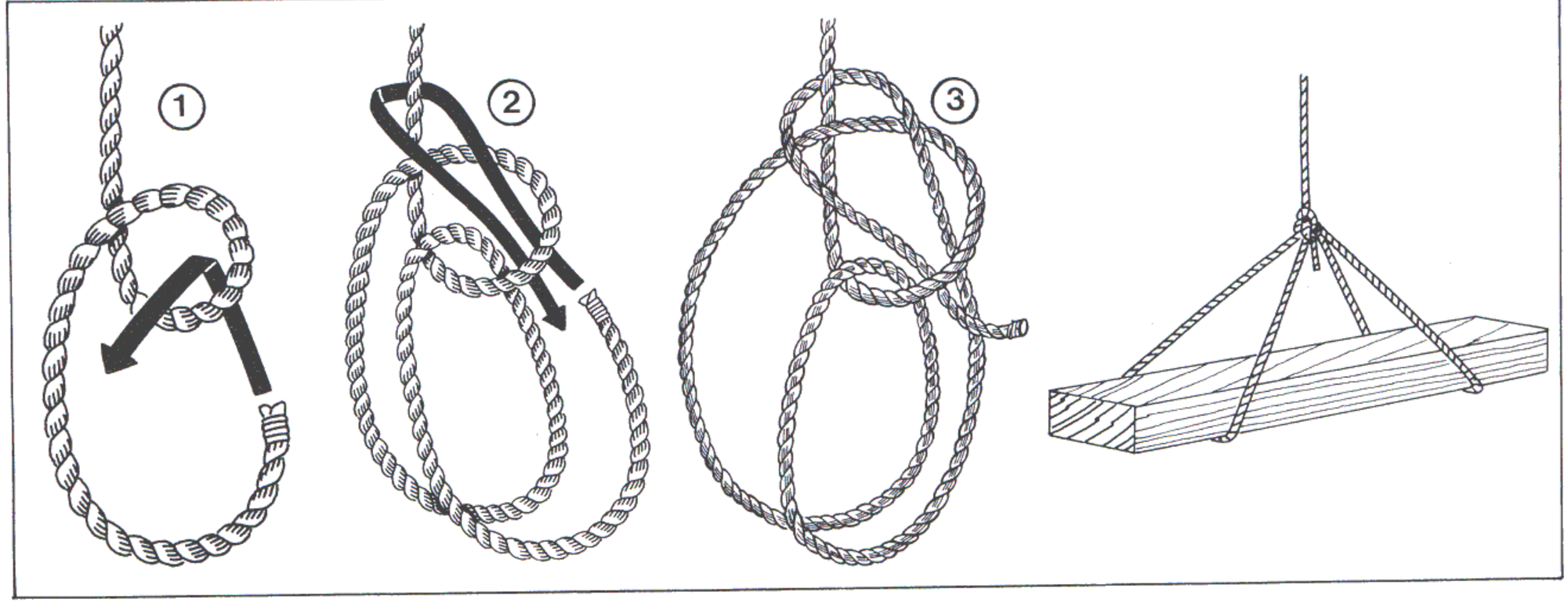


Fig. 2.37 **Bowline on the Bight**

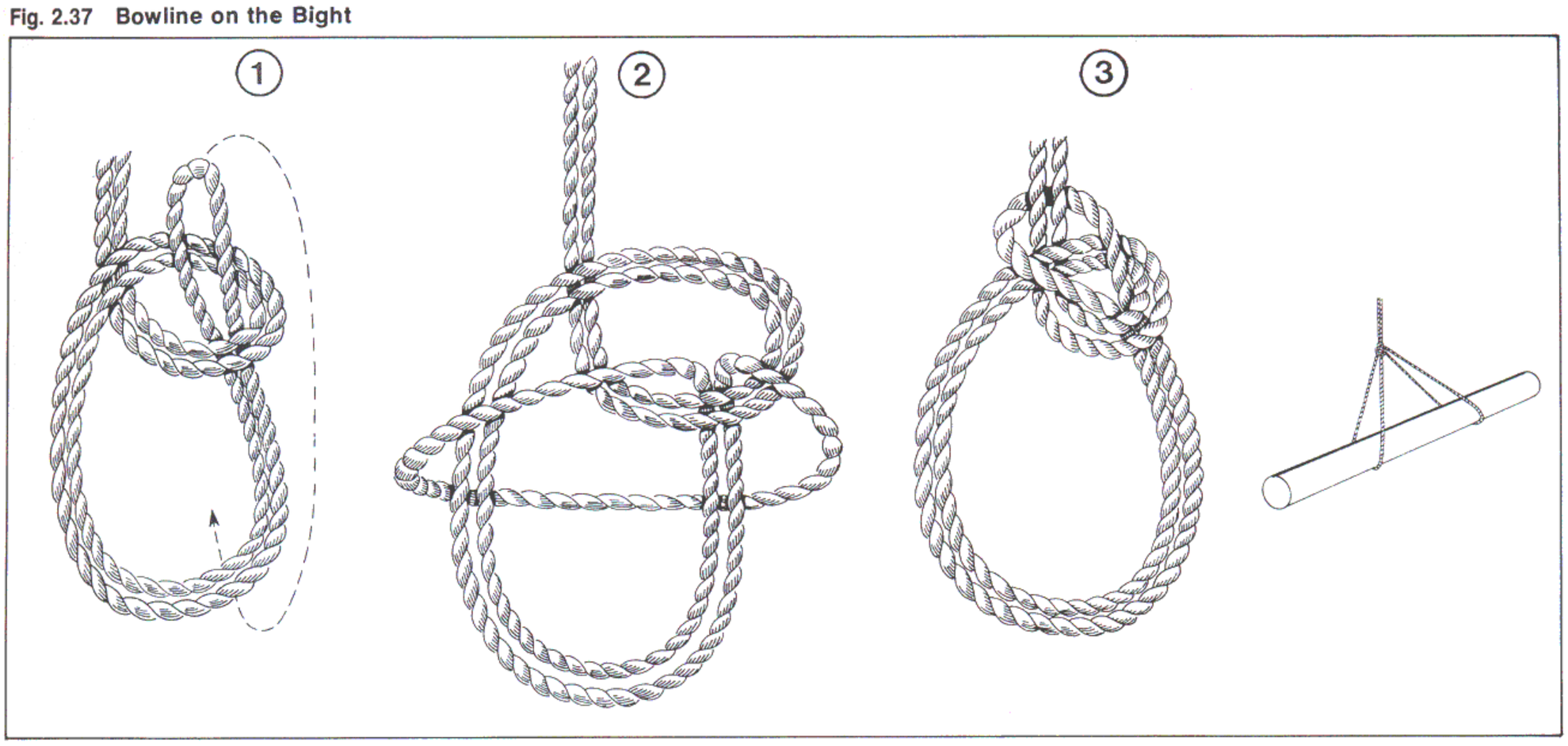


Fig. 2.38 **Triple Bowline**

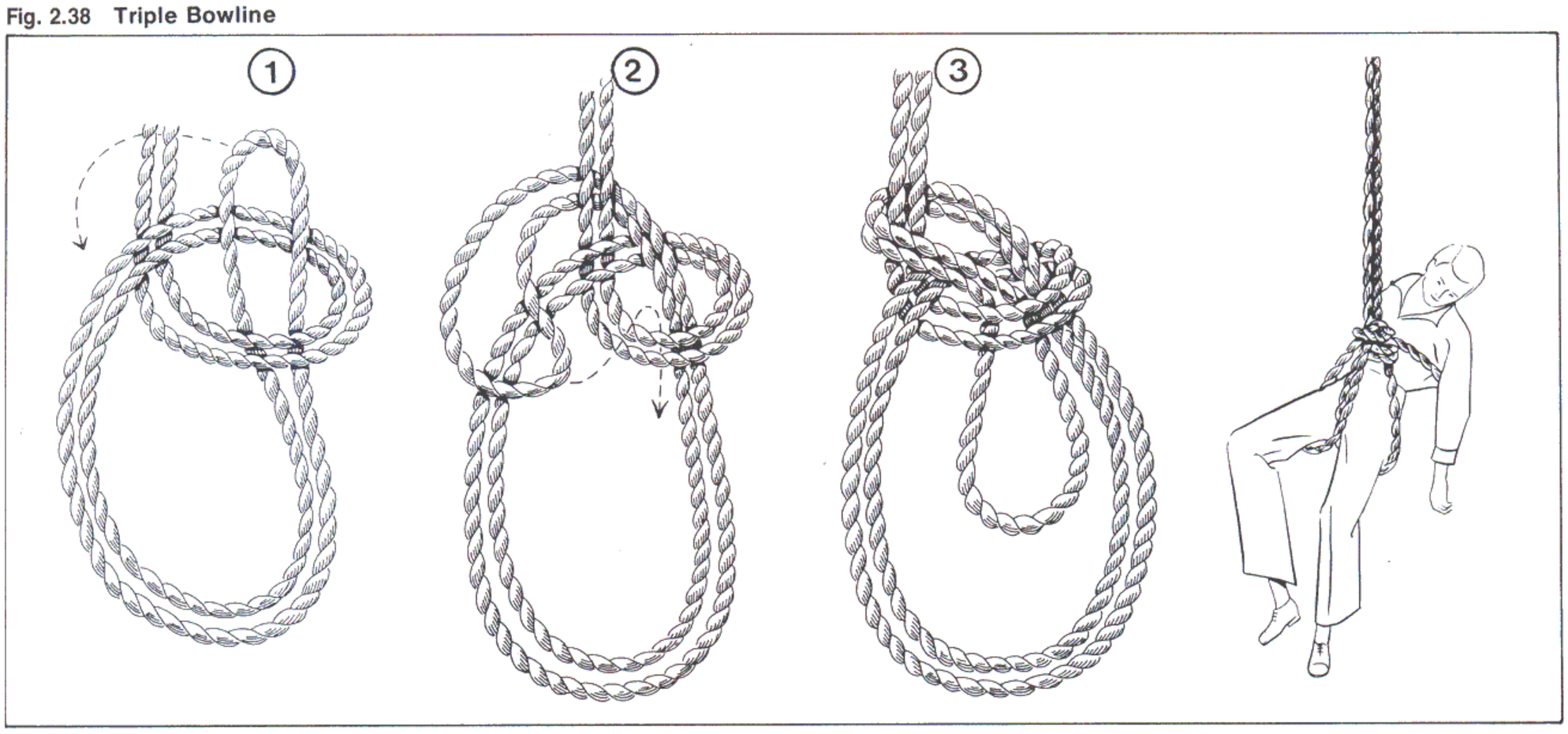


Fig. 2.39 **Running Bowline**

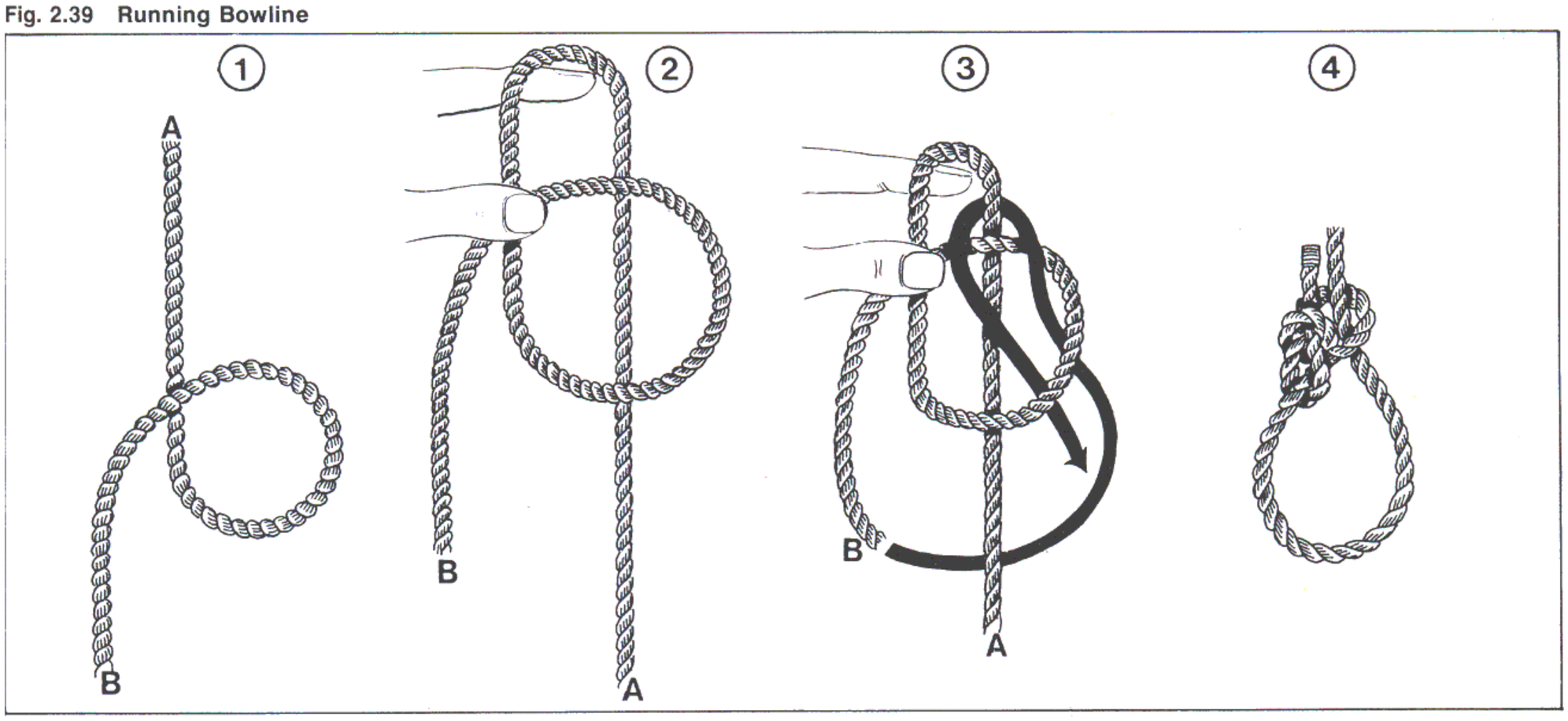


Fig. 2.40 Carrick Bend

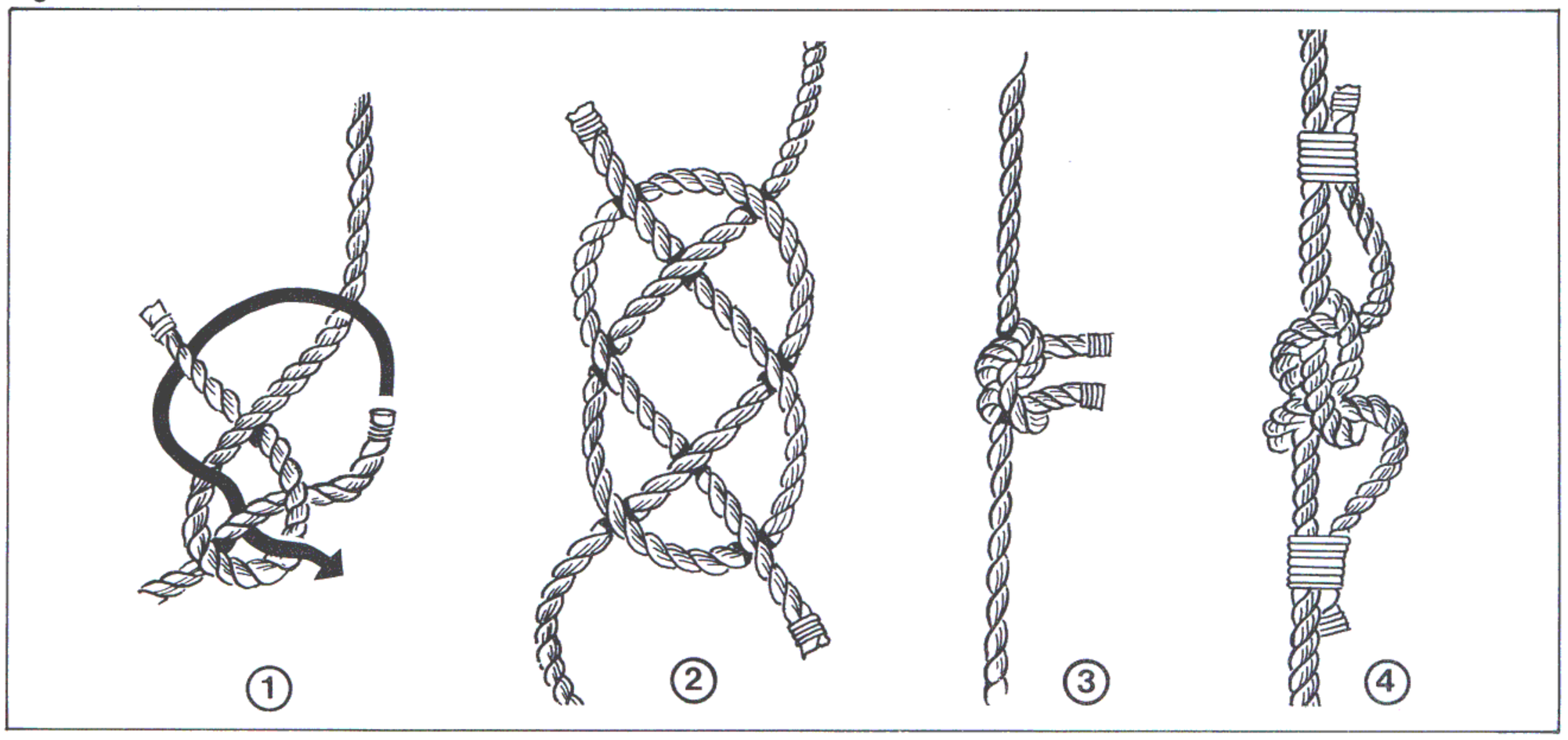


Fig. 2.41 Catspaw

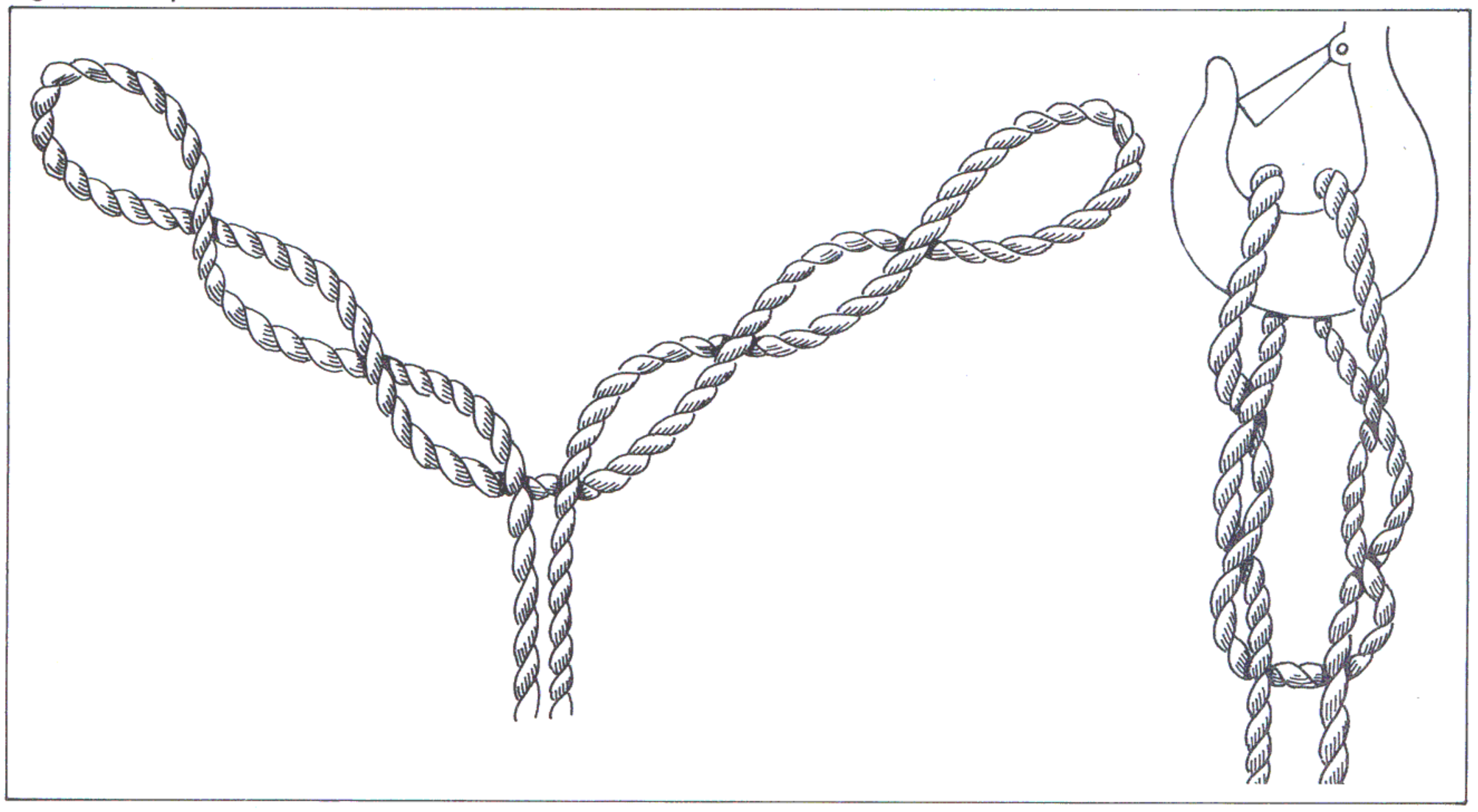
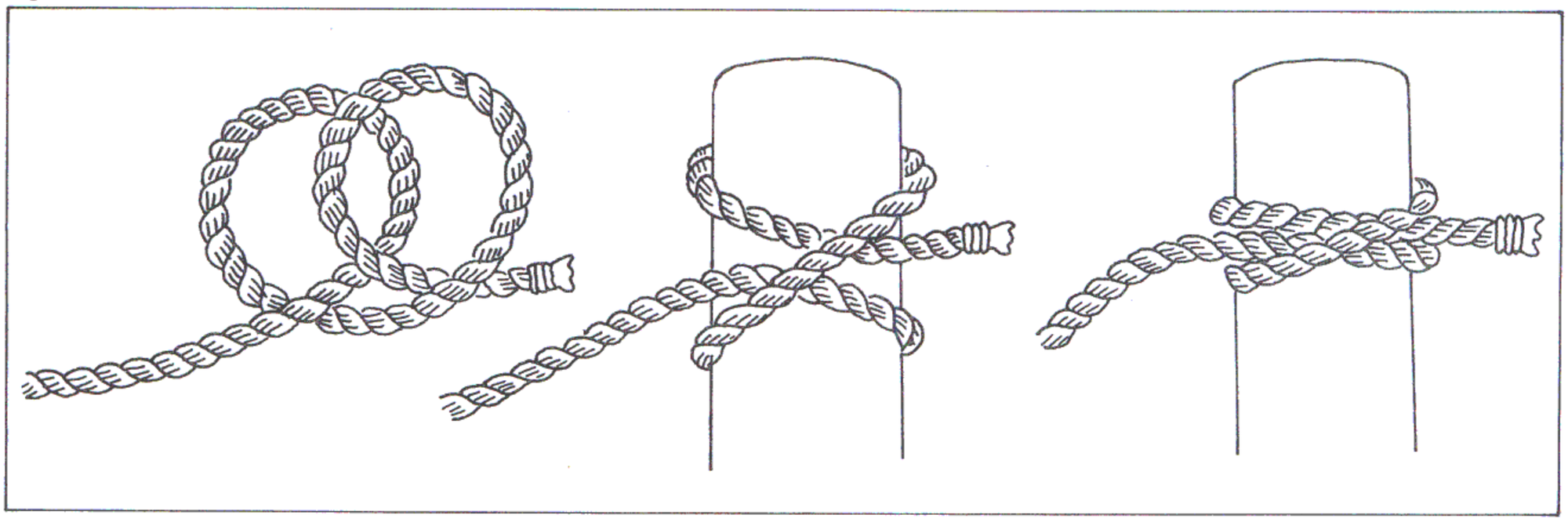


Fig. 2.42 Clove Hitch



loop with the end of the rope held toward you, hold the loop with your thumb and fingers and bring the standing part of the rope back so that it lies behind the loop. Take the end of the rope in behind the standing part, bring it up and feed it through the loop. Pass it behind the standing part at the top of the loop and bring it back down through the loop.

Carrick Bend: (Fig. 2.40) This knot can be used for joining ropes together and is easier to untie than most knots after being subjected to load. It is one of the strongest of knots, cannot jam and under load it always draws up tight which is important because very heavy ropes usually cannot be fully tightened by hand. With one rope end form an underhand loop with both the free end and standing part pointing away from you. Start the second rope end beneath both sides of the loop. Cross it over the standing part of the first rope. Then under the free end of the first rope. Then over the left side of the loop. Cross it under itself and let the second free end lie over the right side of the loop. Finish by seizing each end to the standing part.

Catspaw: (Fig. 2.41) Is used to attach a rope to a hook and is particularly useful when securing the middle of a rope to a hook. It does not jam and unties by itself when removed from the hook. It is tied by forming two loops in the rope and twisting them away from you (at least 3 twists). The two twisted loops are then brought together and placed over the hook.

Clove Hitch: (Fig. 2.42) The Clove Hitch is a quick, simple method of fastening a rope around a post or pipe. It can be tied in the middle or end of a rope. But since it has a tendency to slip when used at the end of a rope, the end should be half-hitched to the standing part for greater security. The hitch is tied by forming an underhand loop around the post followed by another underhand loop, as shown.

Figure Eight Knot: (Fig. 2.43) Generally tied at the end of a rope to temporarily prevent the strands from unlaying. They can be tied simply and quickly, and do not jam as easily as the overhand knot. They are also larger, stronger and do not injure the rope fibres. They are useful in preventing the end of a rope from slipping through a block or an eye. To tie, make an underhand loop. Bring the end around and over the standing part. Pass the end under and then through the loop. Draw up tight.

Half-Hitch: (Fig. 2.44) The Half-Hitch is generally used for fastening to an object for a right-angle pull. To tie, pass the end of the rope around the object and tie an Overhand Knot to the standing part. The illustration shows the Half-Hitch tied with the end nipped under the turn of the rope some distance away from the standing part; this method is fairly reliable for temporary use if the pull is steady and the arrangement is not disturbed.

Two Half-Hitches: (Fig. 2.45) Just as its name states, Two-Half-Hitches is simply a Half-Hitch tied twice. It is quickly tied, reliable, can be put to almost any general use.

Noose or Halter Hitch: (Fig. 2.46) Can be used to tighten a rope around an object. Tie as shown in diagram, making sure that final tuck is made with bight near end. Then after drawing up, drop end through this bight so knot cannot fail.

Overhead Knot: (Fig. 2.47) Can be used for joining two ropes, it will not slip but tends to jam and has a low efficiency.

Reef or Square Knot: (Fig. 2.48) Can be used for tying two ropes of the same diameter together. It is unsuitable for wet or slippery ropes and should be used with caution since it unties easily when either free end is jerked. The knot is easy to tie but the finished knot should be checked to make certain it is correct, both the live and dead ends of the ropes must come out of the loops on the same side.

Rolling Hitch: (Fig. 2.49) This knot can be effectively used for lifting round objects such as pipe or bar steel and for fastening a rope to another rope or a pole parallel to it. It grips tightly if the pull is constant but slackens when the load is relieved.

Round Turn and Two Half Hitches: (Fig. 2.50) Can be used to secure a rope to a column or post. It is easily tied, does not jam, and will stand heavy strains without slipping.

Sheet Bend: (Fig. 2.51) Can be used for joining ropes of different sizes provided they are of light or medium size. On large ropes the Carrick Bend is preferable. To tie, make an overhand loop with the end of one rope. Pass the end of the other rope through the loop thus formed, then up behind its standing part, then down through the loop again. Draw up tight.

Sheepshank: (Fig. 2.52) The Sheepshank is intended to shorten a rope for temporary use only. Carefully tied and drawn up tight, it is

Fig. 2.43 Figure Eight Knot

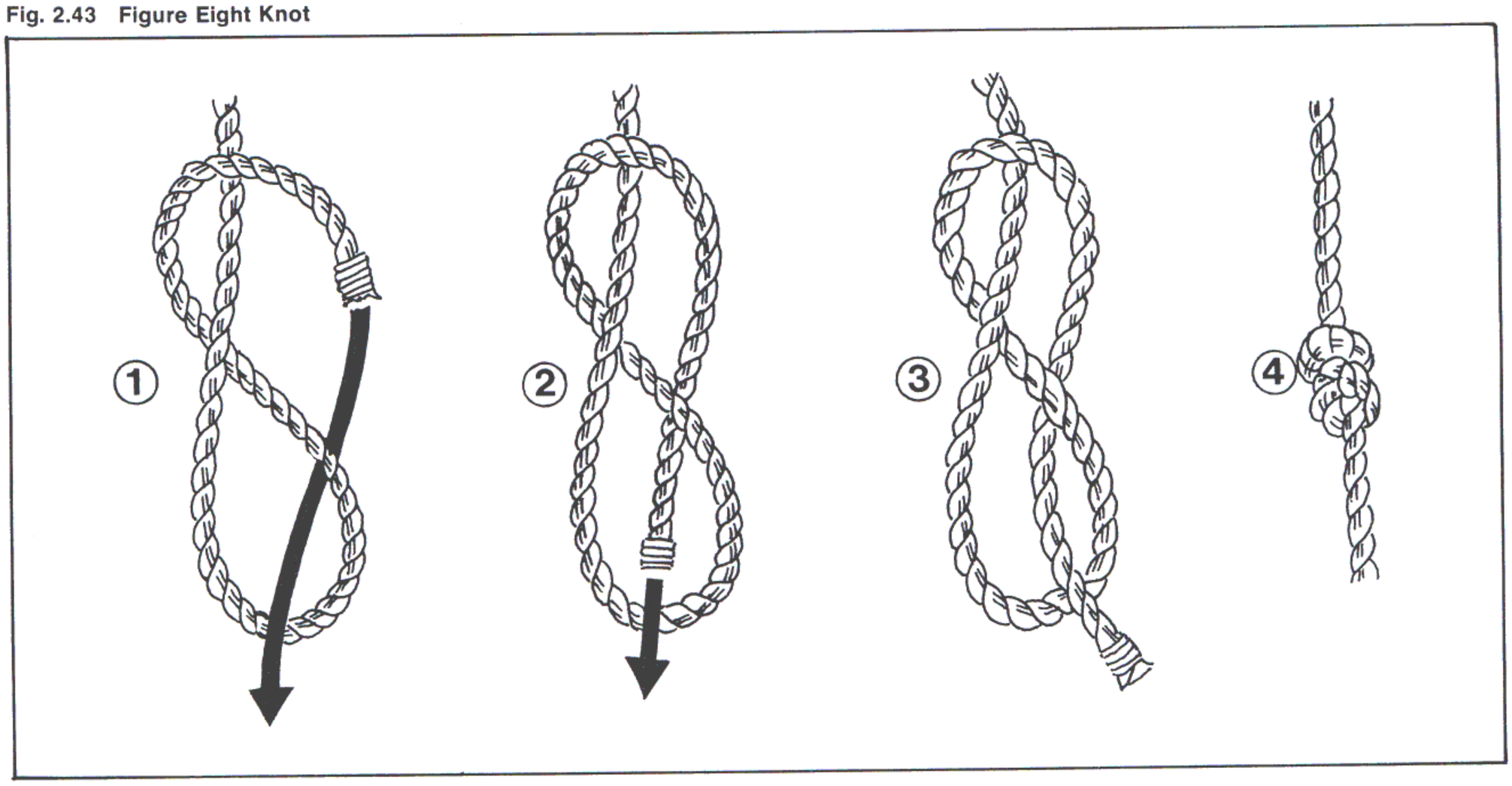


Fig. 2.44 Half-Hitch

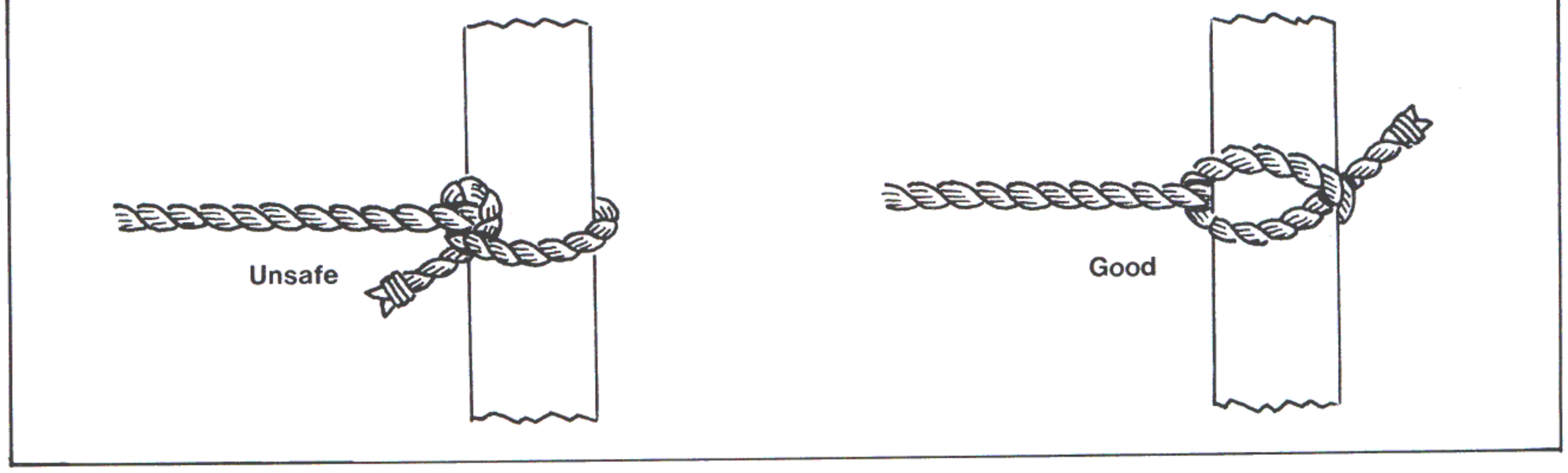
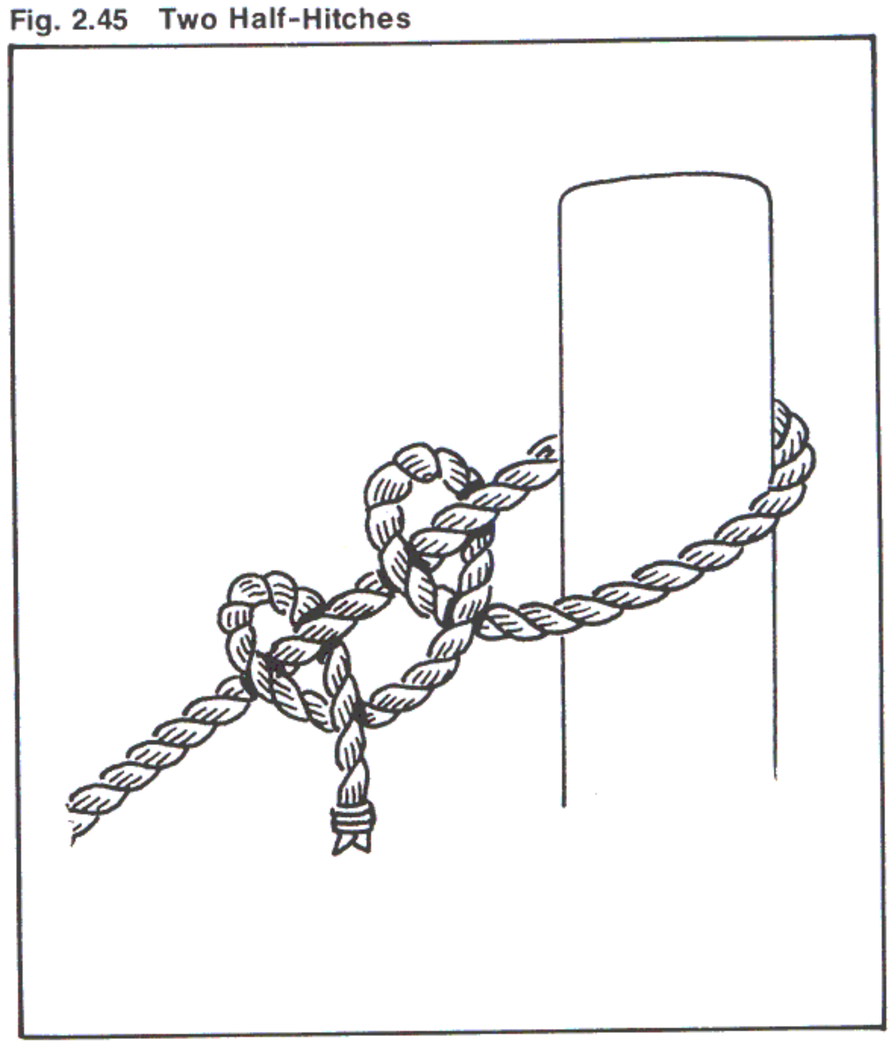


Fig. 2.45 Two Half-Hitches



fairly reliable under a steady pull. It is especially useful if the ends of the rope are not free as it can be tied anywhere in the length of an already tied rope. It can also be used to take the strain off a damaged piece of rope when there is not time to replace it. The knot can be made more secure if it is seized. To tie, form an "S" loop as shown in the diagram. Then with one free end of the rope make a Half-Hitch and slip it over one of the loops. Tighten. Repeat procedure with the other loop.

Slippery Hitch: (Fig. 2.53) Provides a quickly tied and easily released hitch for securing a rope to rings, posts or light loads.

Snubber: (Fig. 2.54) For holding or slowly lowering a heavy load. The load on the hand line is only a fraction of the load on the live line. Three or four turns should be taken.

Timber Hitch: (Fig. 2.55) Generally used for fastening rope to posts and for hoisting planks, timbers, pipe, etc. but use it only when the load is steady. The Timber Hitch holds without slipping and does not jam but loosens when strain is relieved. One or two Half-Hitches should be added to keep a plank or length of pipe on end while it is being lifted. To tie, pass a rope around the object and take a turn with the end around the standing part. Then, as shown in the diagram, twist or turn the end back on itself. Three turns back are sufficient and they should follow the lay of the rope.

Triple Sliding Hitch: (Fig. 2.56) Is generally used to secure a safety belt lanyard to a life line. Manila rope must not be used as the lanyard material because if the person wearing it were to fall, the knot grabs the life line creating shock loads and severe bending of the rope such that manila rope will fail. Use nylon for all lanyards.

Scaffold Hitch: (Fig. 2.57) The Scaffold Hitch is used for fastening single scaffold planks and needle beams so that they hang level and are prevented from tilting.

Fig. 2.46 Noose or Halter Hitch

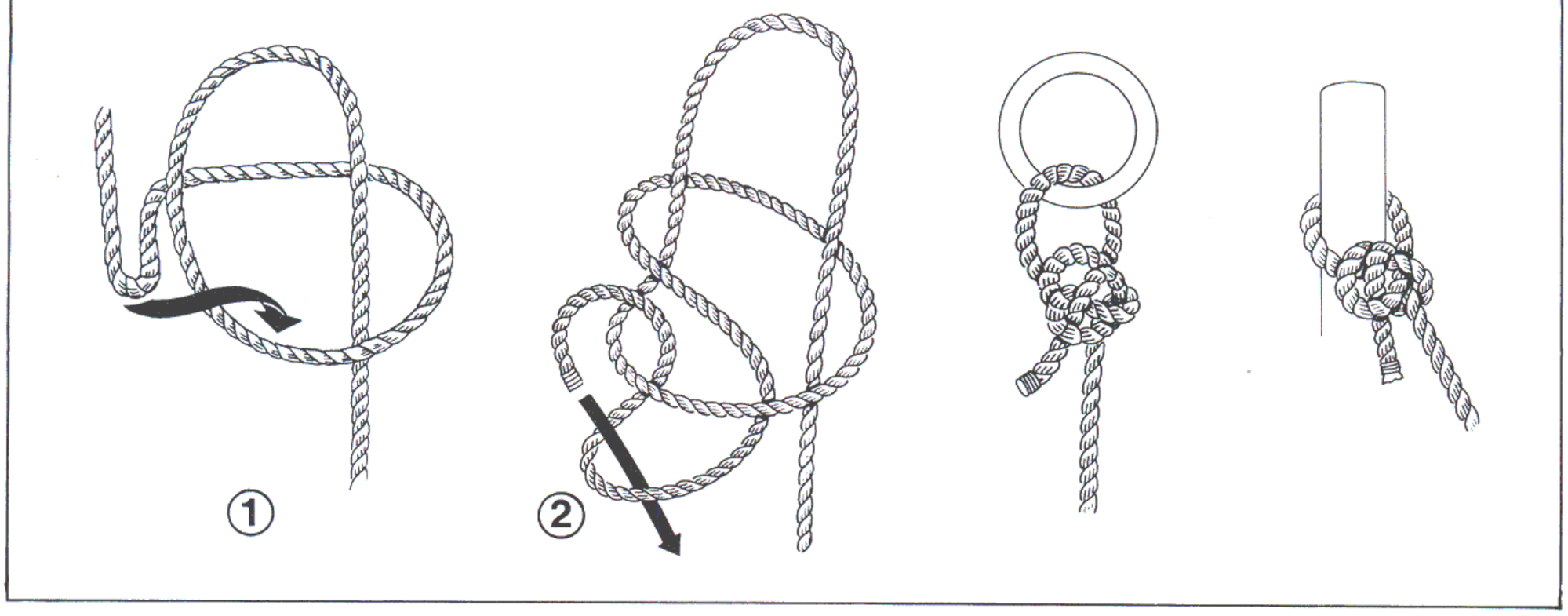


Fig. 2.47 Overhead Knot

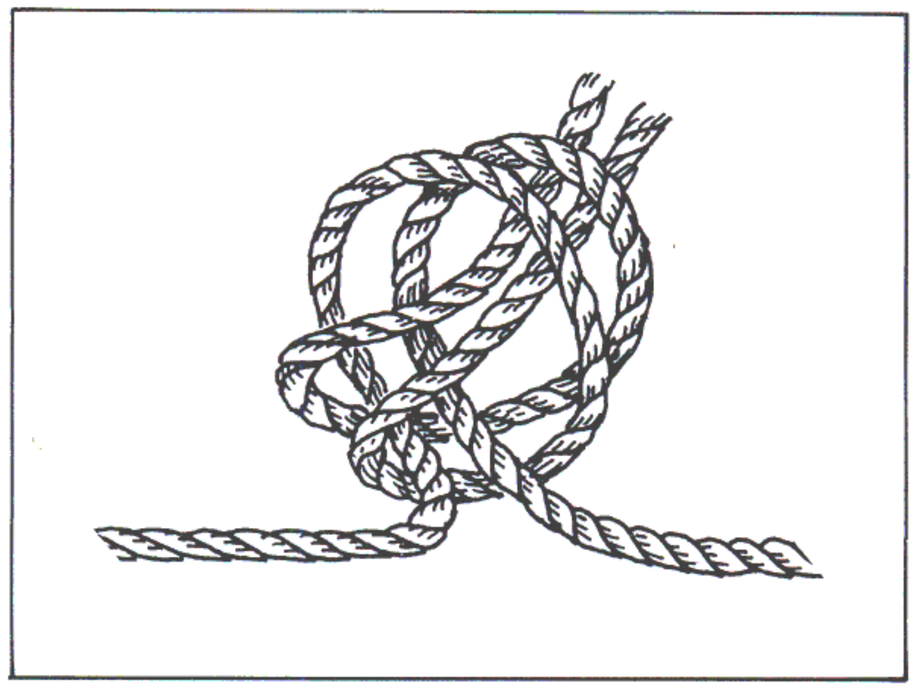


Fig. 2.48 Reef or Square Knot

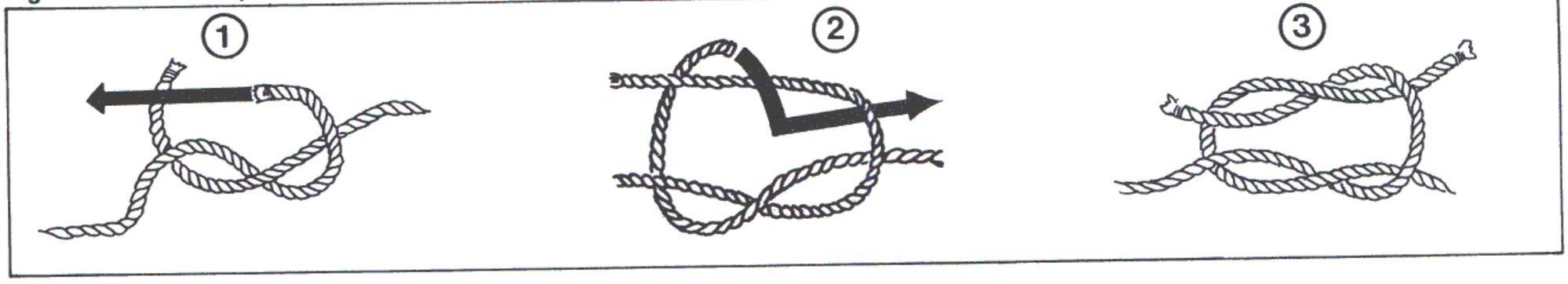


Fig. 2.49 Rolling Hitch

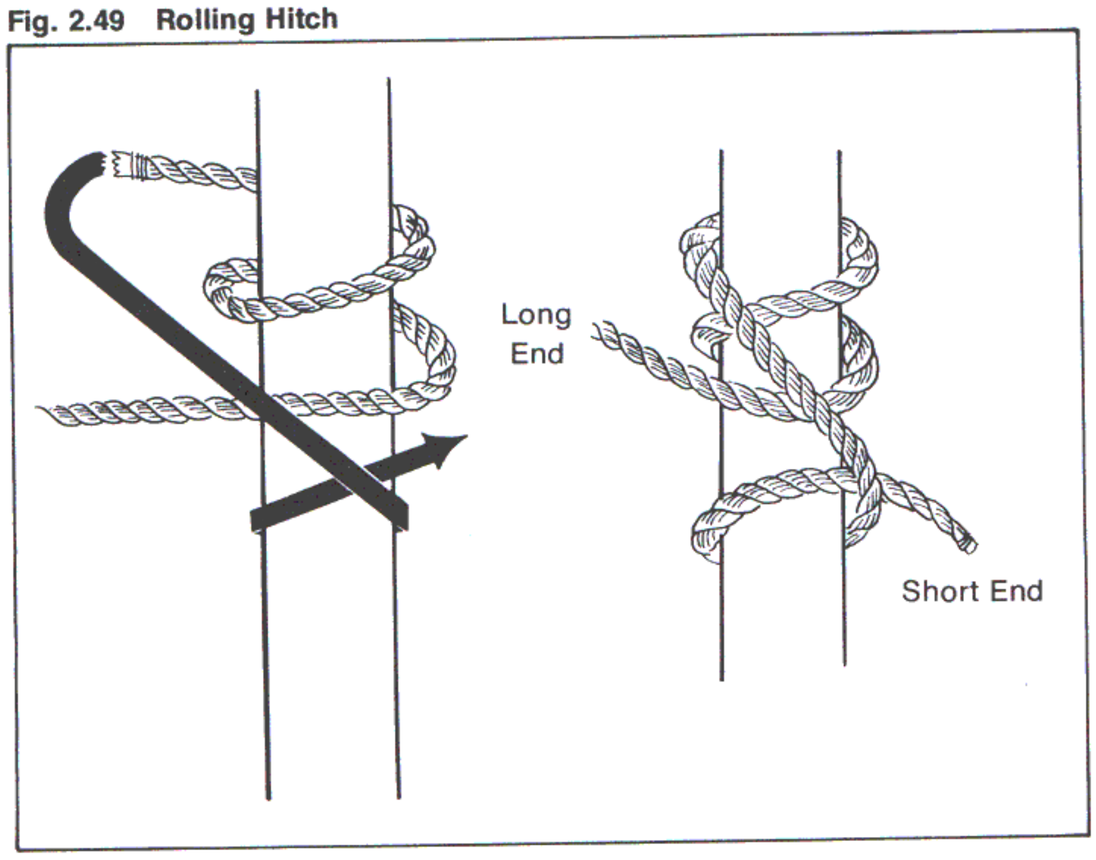


Fig. 2.50 Round Turn & Two Half-Hitches

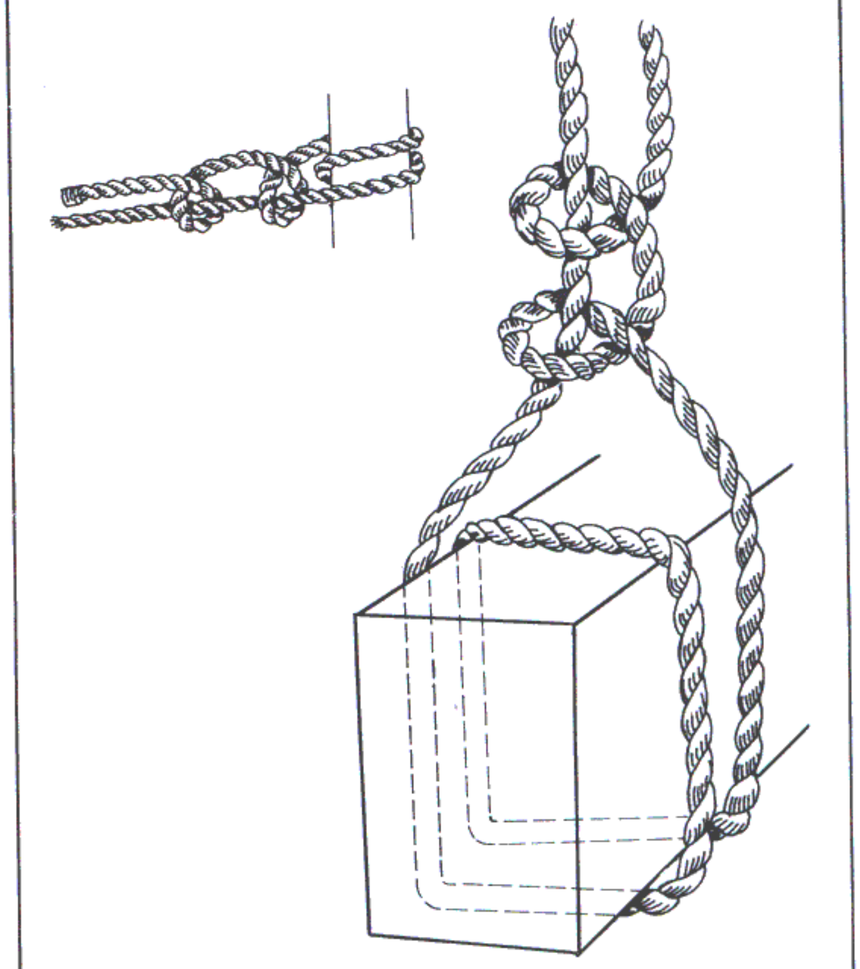


Fig. 2.51 Sheet Bend

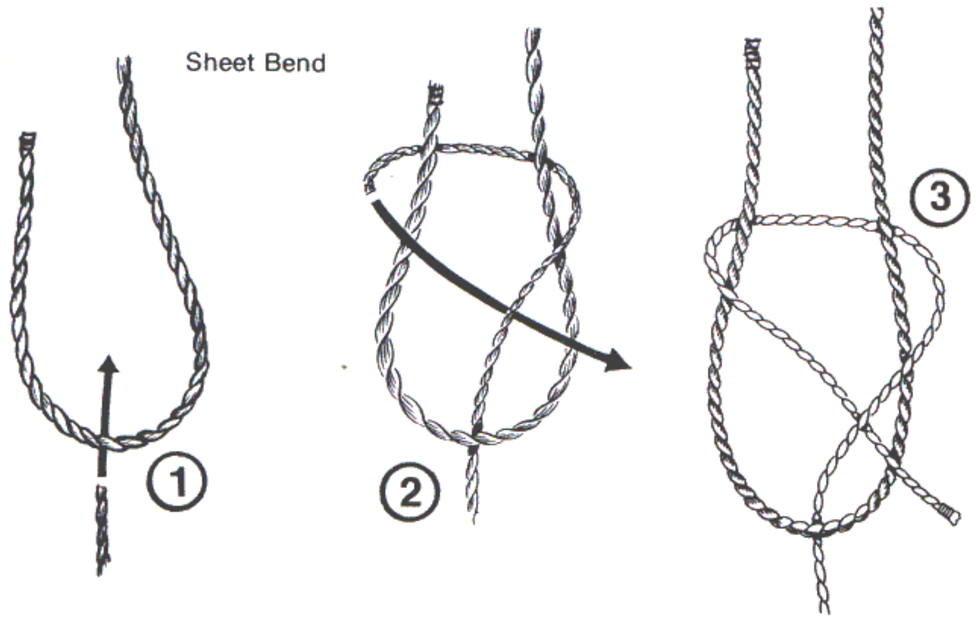
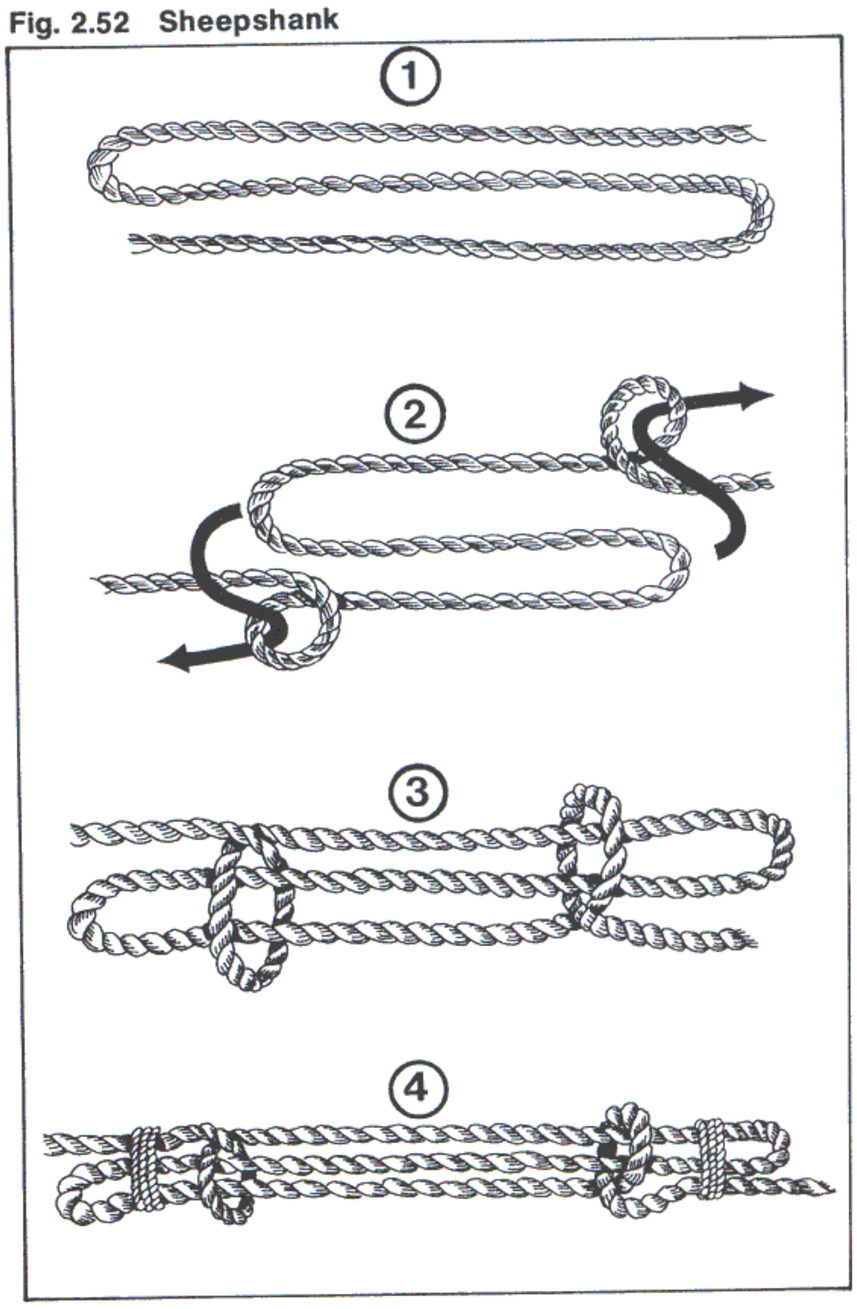


Fig. 2.52 Sheepshank



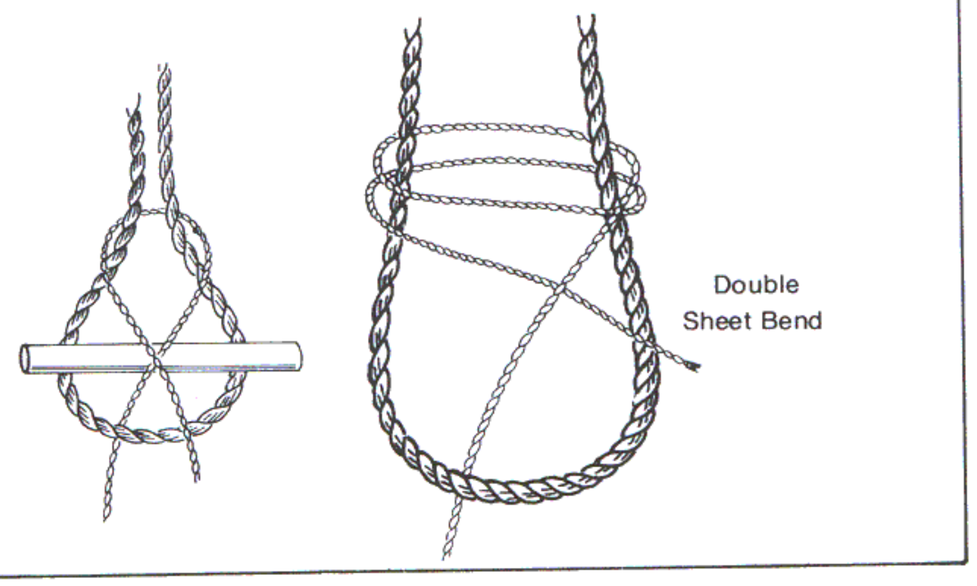


Fig. 2.53 Slippery Hitch

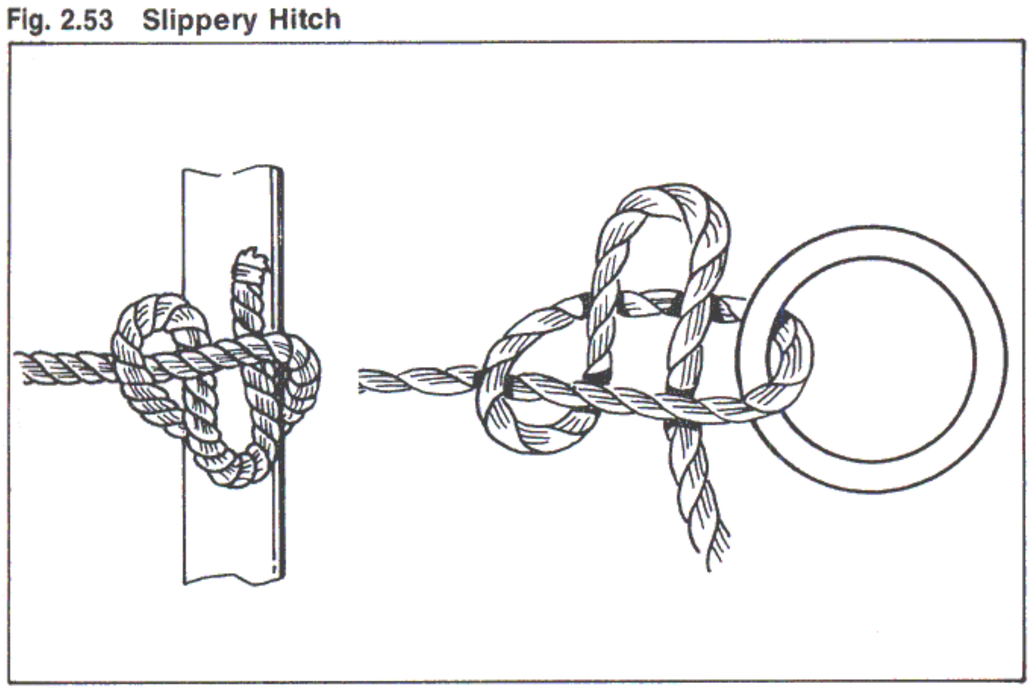


Fig. 2.54 Snubber

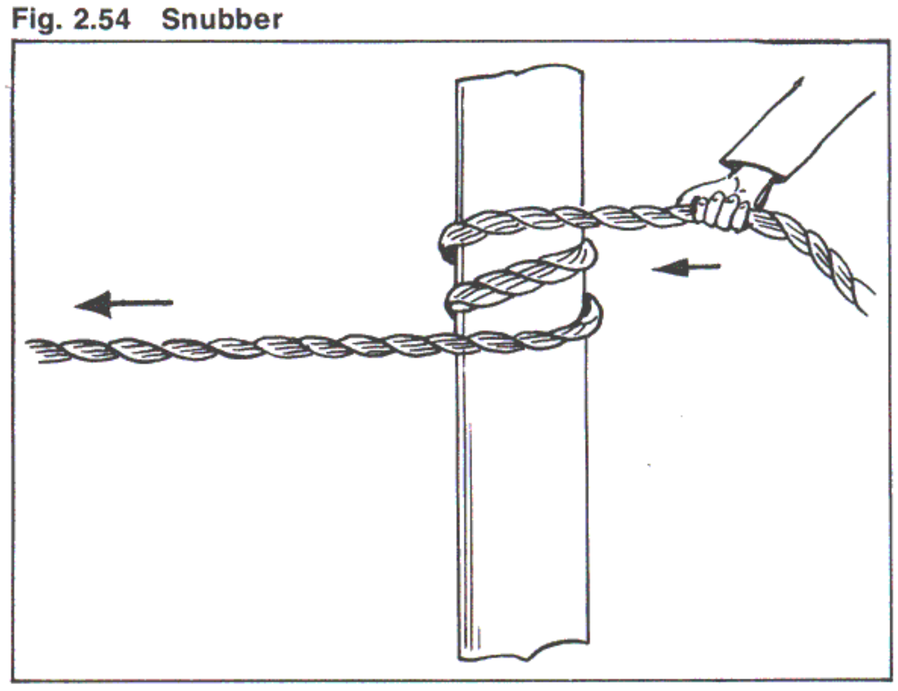


Fig. 2.55 Timber Hitch

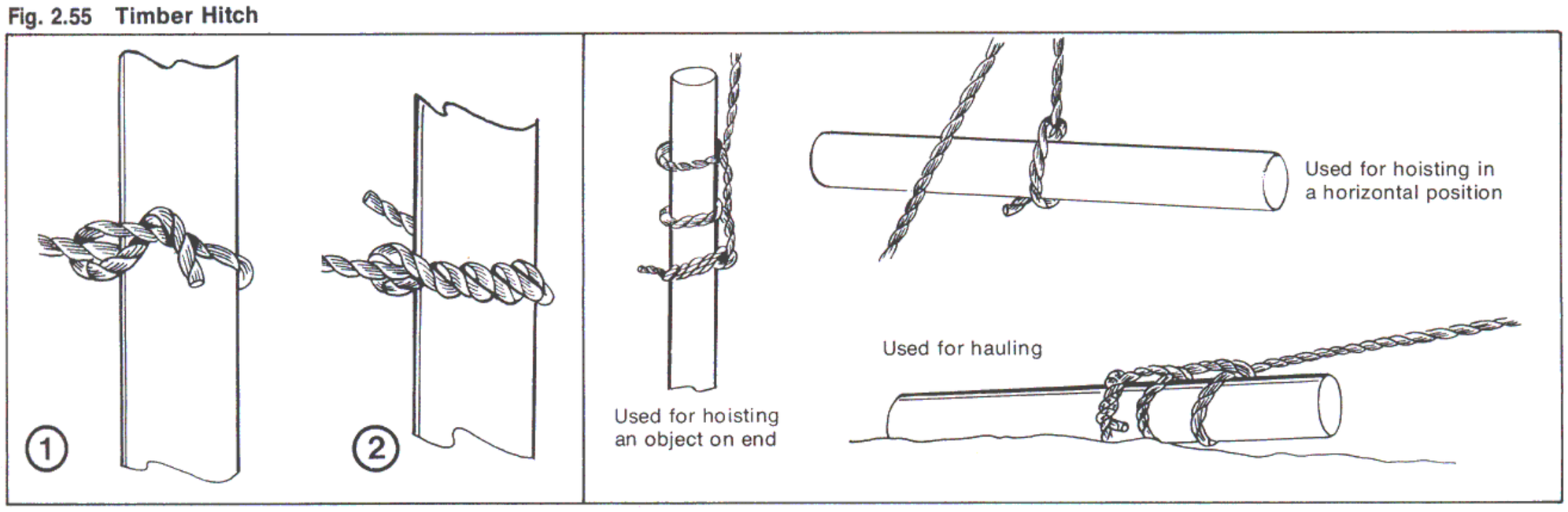


Fig. 2.56 Triple Sliding Hitch

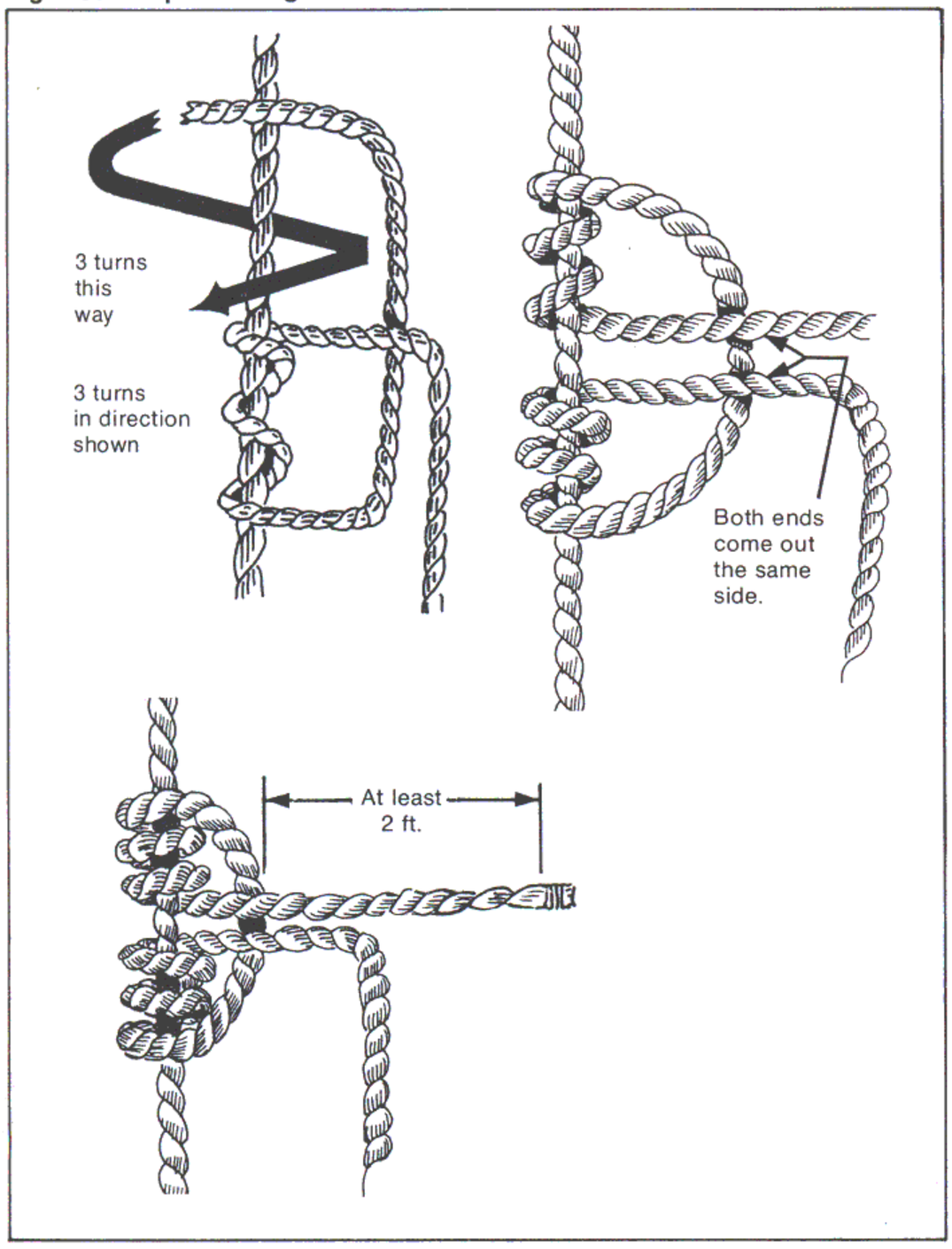
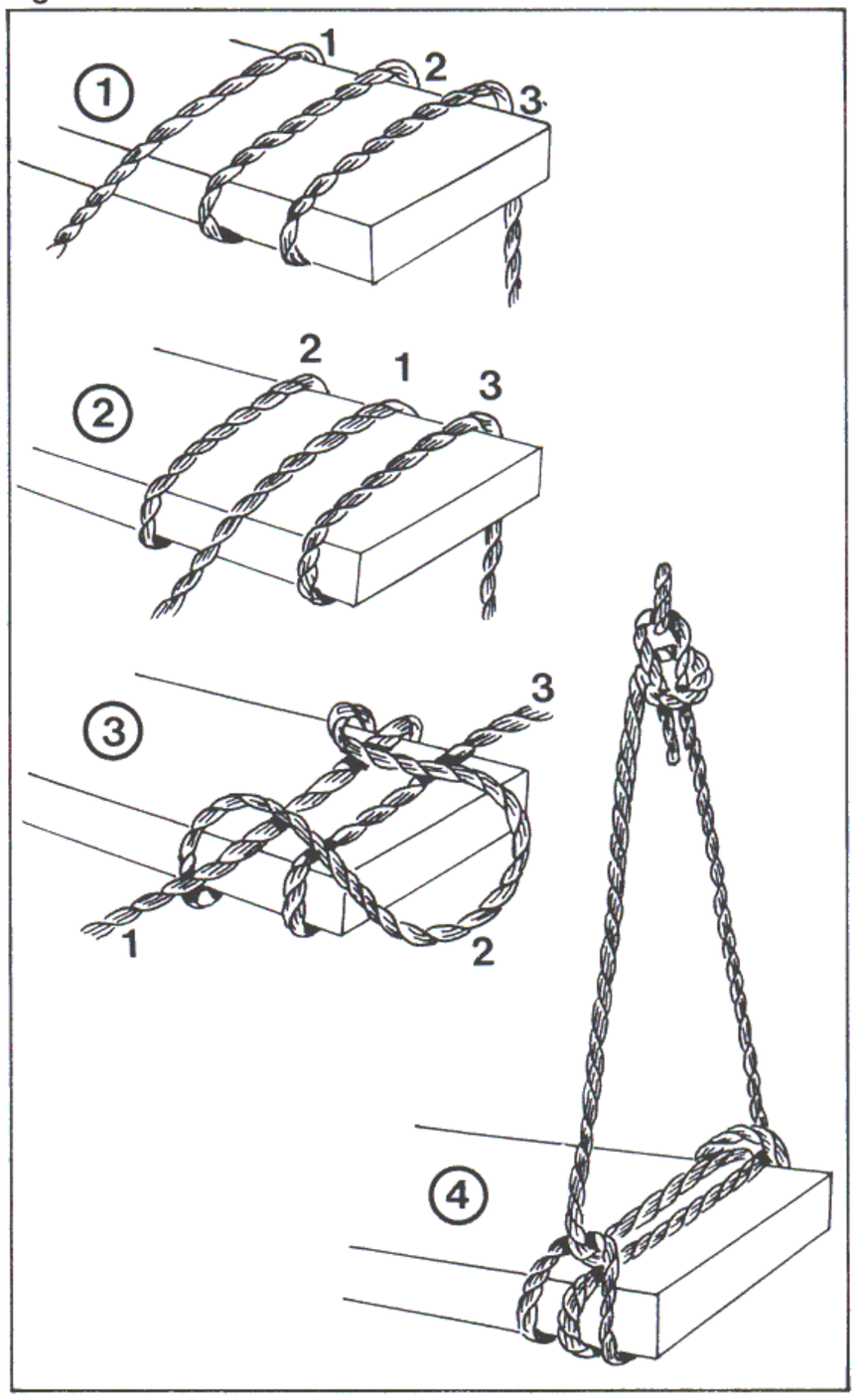


Fig. 2.57 Scaffold Hitch



CHAPTER 3

Chain

For general construction rigging never use a chain when it is possible to use wire rope. The failure of a single link of a chain can result in a serious accident but wire rope on the other hand is frequently composed of 114 wires all of which must fail before the rope breaks. Wire rope gives you reserve strength and a chance to notice a hazard, chains do not.

When a wire rope is fatigued from severe service, the wires break one after the other over a relatively long period of time and thus afford the inspector an opportunity to discover the condition. If severely overloaded, the wires and strands will break progressively over a period of perhaps several seconds and with considerable noise, before complete failure occurs. This may afford the man handling the load a brief time in which to either lower it or jump to safety before it falls.

Chains, on the other hand, will usually stretch a bit under excessive loading, the links elongating and narrowing down until they bind on each other, thus giving some visible warning. However, if the overloading is great enough, the chain will ultimately fail with less warning than wire rope. Should a weld be defective they break with no warning.

Chains are also much less resistant to sudden or shock loads than wire rope and can break with no warning under such conditions.

There are certain jobs, however, for which chain is better suited than wire rope. Chains withstand rough handling, do not knit, are easily stored, have dead flexibility and when used as slings, grip the load well. They are much more resistant to abrasion and corrosion than wire rope and are particularly well suited as slings for lifting rough loads such as heavy castings, which would quickly weaken or destroy wire rope slings due to the sharp bends over the edges of the castings.

GRADES:

It is very difficult to determine the grade of a chain by examination. However, all chain suitable for construction use and in particular for hoisting is marked by an identifying letter stamped on the links. For the highest degree of safety ensure that only chain stamped with the letter ''A'' is used on hoisting operations. The letter''A''designates heat treated alloy steel which is the strongest chain commonly made. (Fig. 3.1)

These alloy steel chains must never be welded or exposed to excessive temperatures as the heat treatment will be affected and the chain will lose its strength.

STRENGTH:

Table 3.1 gives the maximum safe working loads of new alloy steel chain when used as a single vertical sling. Maximum safe working loads of inclined slings, etc., are presented in the section on Slings.

Any change in the above factors, such as twisting of the chain, deterioration of the chain or its fittings by overload, use, rust, shock loading or inclined (offset) loading will lessen the load that the chain will safely carry.

Fig. 3.1 Identification of Alloy Steel Chain

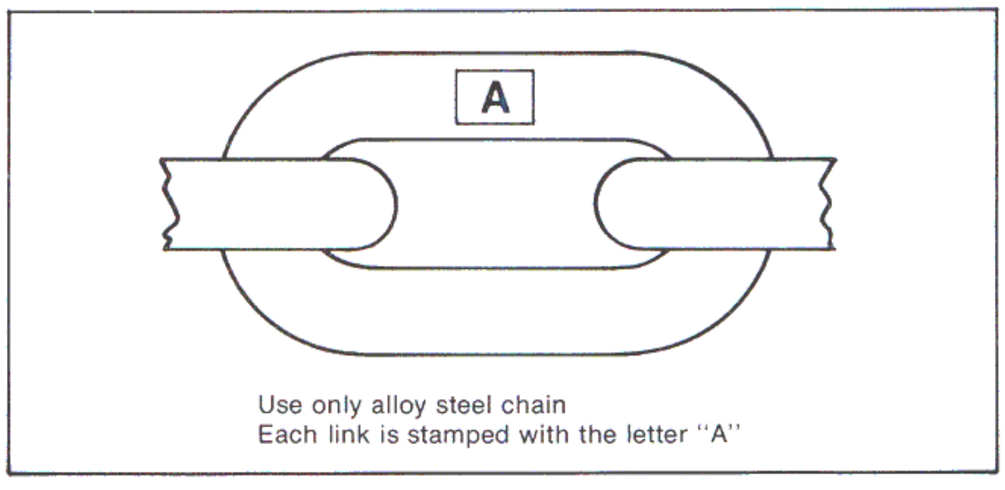


Fig. 3.2 Every Chain Should Have an Identification Tag

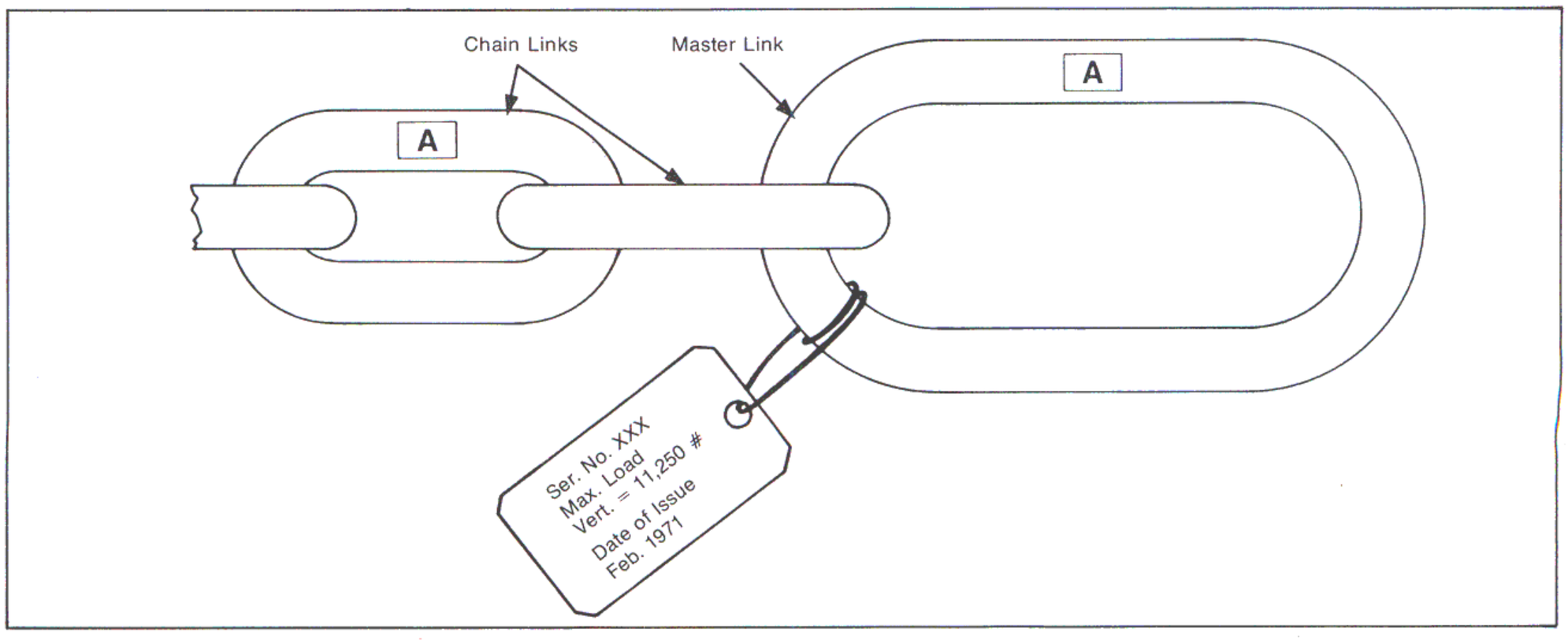


Fig. 3.3 Look for Chain Stretch During Inspections

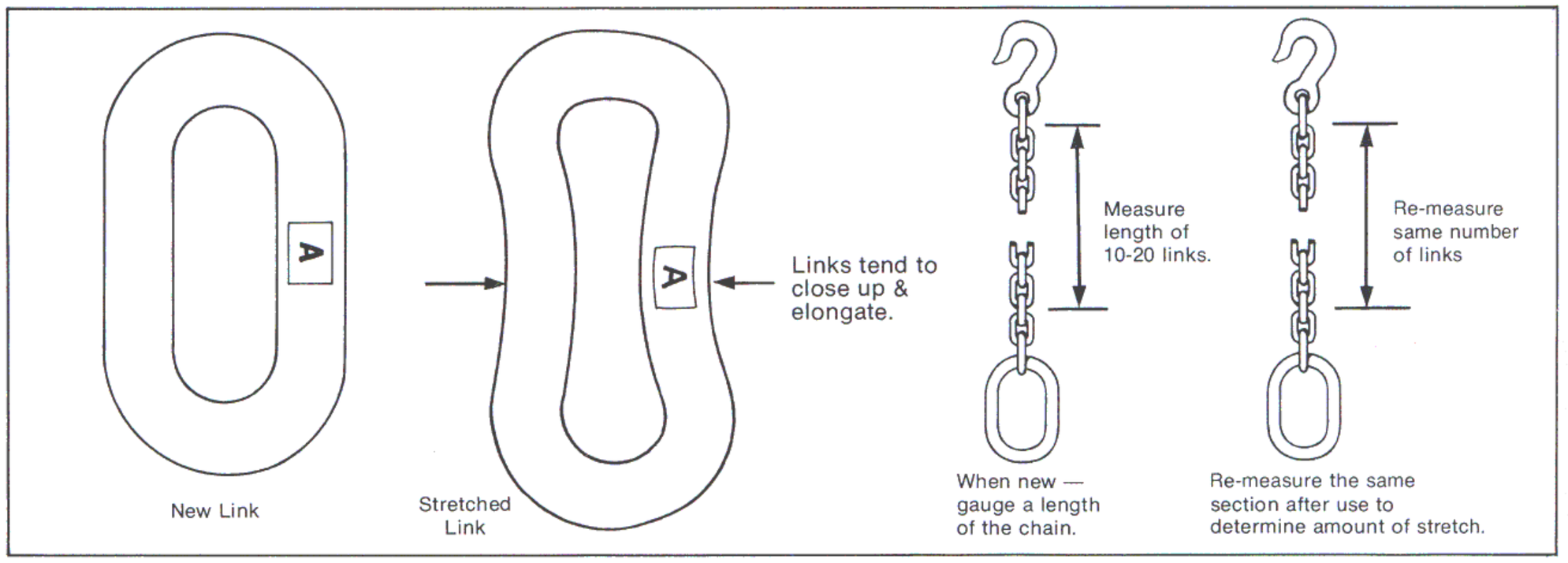
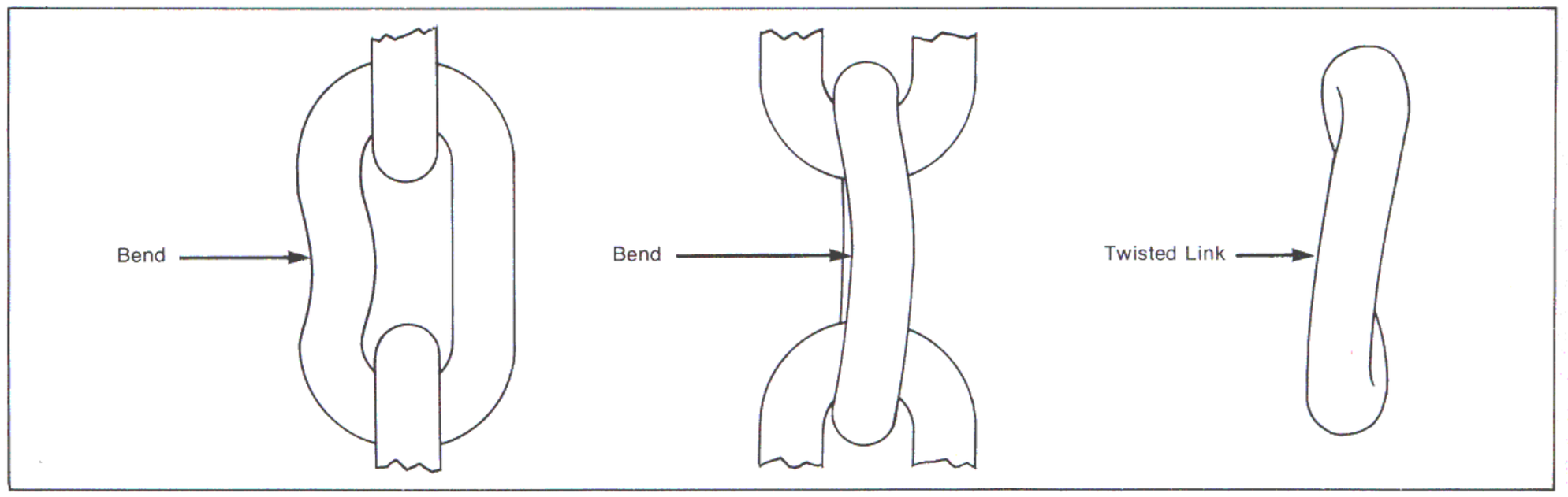


Fig. 3.4 Inspect All Links for Bends, Twists and Damage



Alloy steel chain can be used in environments up to 500°F without reducing the safe working load but at temperatures above this level the load limit decreases as per Table 3.2.

INSPECTION:

All chains used regularly should be thoroughly inspected on a link-by-link basis at least once a month by a competent inspector and under no circumstances should a chain be used for hoisting purposes unless it has been closely examined for defects or wear.

Whenever a chain is subjected to shock or impact loads it must be immediately inspected before being put back into service.

It is recommended that every chain carry a small metal identification tag bearing a serial number and its safe working load. (Fig. 3.2) A log book should also be kept for the chain identifying its characteristics and setting up an inspection schedule.

TABLE 3.1

MAXIMUM SAFE WORKING LOAD "A" TYPE ALLOY STEEL CHAIN SINGLE VERTICAL SLING	
Chain Size (Inches)	Capacity (Pounds)
1/4	3,250
3/8	6,600
1/2	11,250
5/8	16,500
3/4	23,000
7/8	28,750
1	38,750
1 1/8	44,500
1 1/4	57,500
1 3/8	67,000
1 1/2	80,000
1 3/4	100,000

TABLE 3.2

EFFECT OF HEAT ON SAFE WORKING LOAD		
CHAIN TEMPERATURE	REDUCTION OF SAFE WORKING LOAD LIMIT WHILE HEATED*	PERMANENT REDUCTION IN SAFE WORKING LOAD LIMIT**
500°F	None	None
600°F	10%	None
700°F	20%	None
800°F	30%	None
900°F	40%	10%
1000°F	50%	15%

* While chain is at temperature in first column.
** When chain is used at room temperature after being used at temperature shown in first column.

When inspecting chain remember to give every link a close examination, one bad link is all it needs to fail. The following guidelines may be of assistance in carrying out the inspection:

— Clean the chain thoroughly in a solvent solution.

— Lay it out on a clean surface or hang it up in a well lit area. Use a magnifying glass to aid in the inspection.

— Look for elongated or stretched links. When the links are severely stretched they tend to close up so that in some cases stretch may be indicated by links that bind or a chain that won't hang perfectly straight. Elongation should be determined by measuring all new chains in sections of one to three feet with a caliper and re-measuring them during the inspection. If the inspection reveals a stretch of more than 3%, take the chain out of service. (Fig. 3.3)

— Look for bent, twisted or damaged links that often occur when the sling is used to lift a load having unprotected sharp edges. (Fig. 3.4)

— Look for cracked links. The presence of any crack, regardless of its size, means the chain

is unsafe and must be removed from service. Where a crack is suspected, the link may be soaked in thin oil and then wiped dry. A coating of powdered chalk or other white material is applied to the surface and allowed to remain there for several hours. If a crack exists, the oil pocketed in it will be drawn out and discolour the white coating.

— Look for gouges, chips, scores or cuts in each link. If they are deep or large in area then the chain should be removed from service. If the depth of these defects is such that the link size is reduced below that listed in the table for wear, then the chain is unsafe. In addition, watch all sharp nicks and cuts because cracks usually initiate at or near them. (Fig. 3.5)

— Look for small dents, peen marks and bright polished surfaces on the links. These usually indicate that the chain has been work-hardened or fatigued.

— Look for lifted fins at welds. They are evi-

Fig. 3.5 Inspect All Links for Gouges, Chips and Cuts

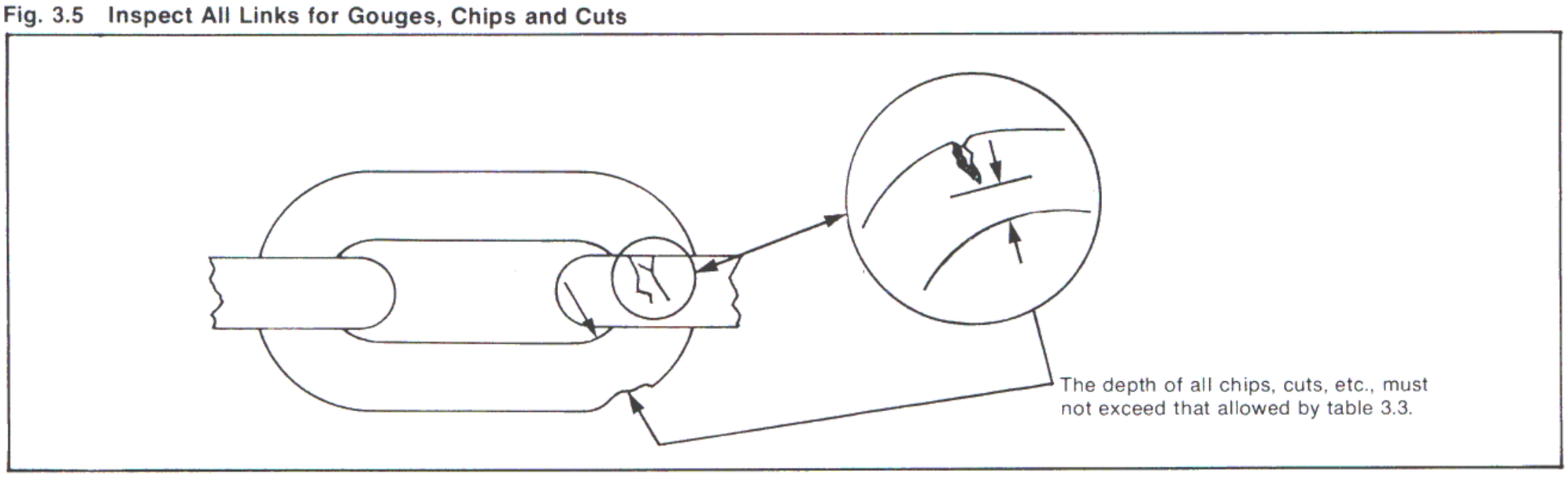


Fig. 3.6 Inspect All Links for Wear at the Bearing Surfaces

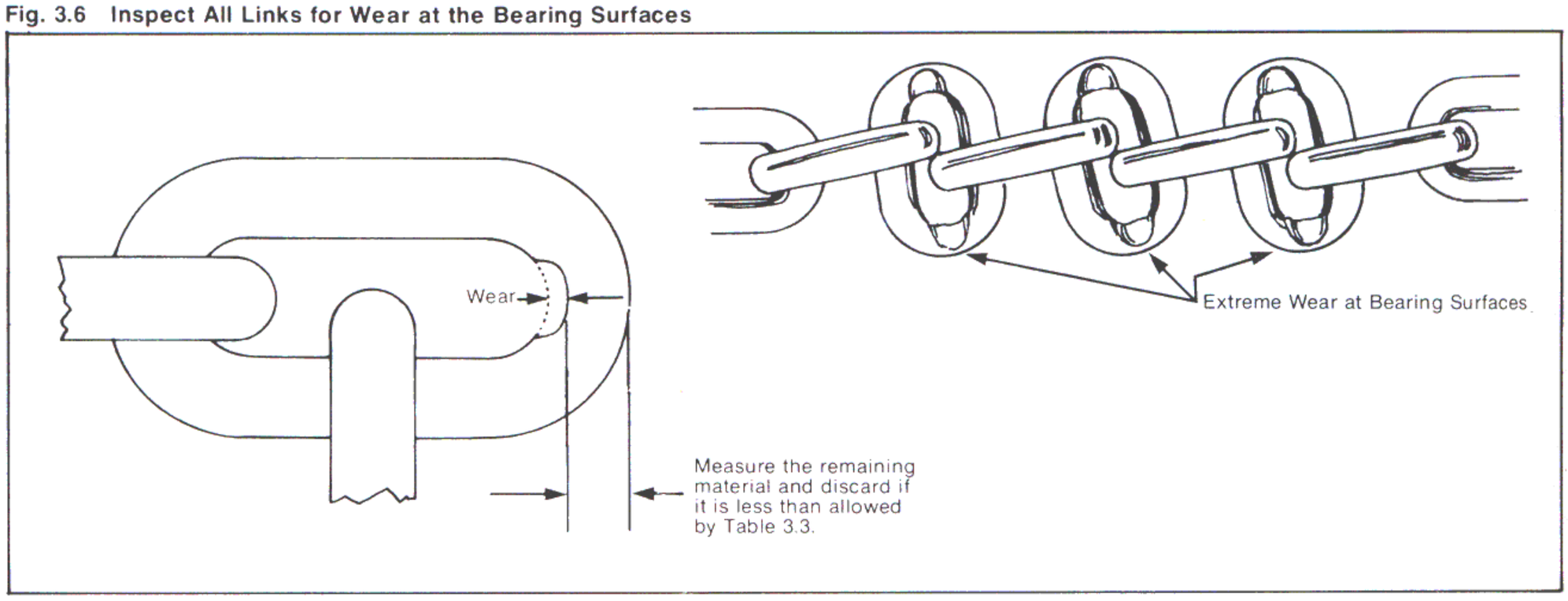
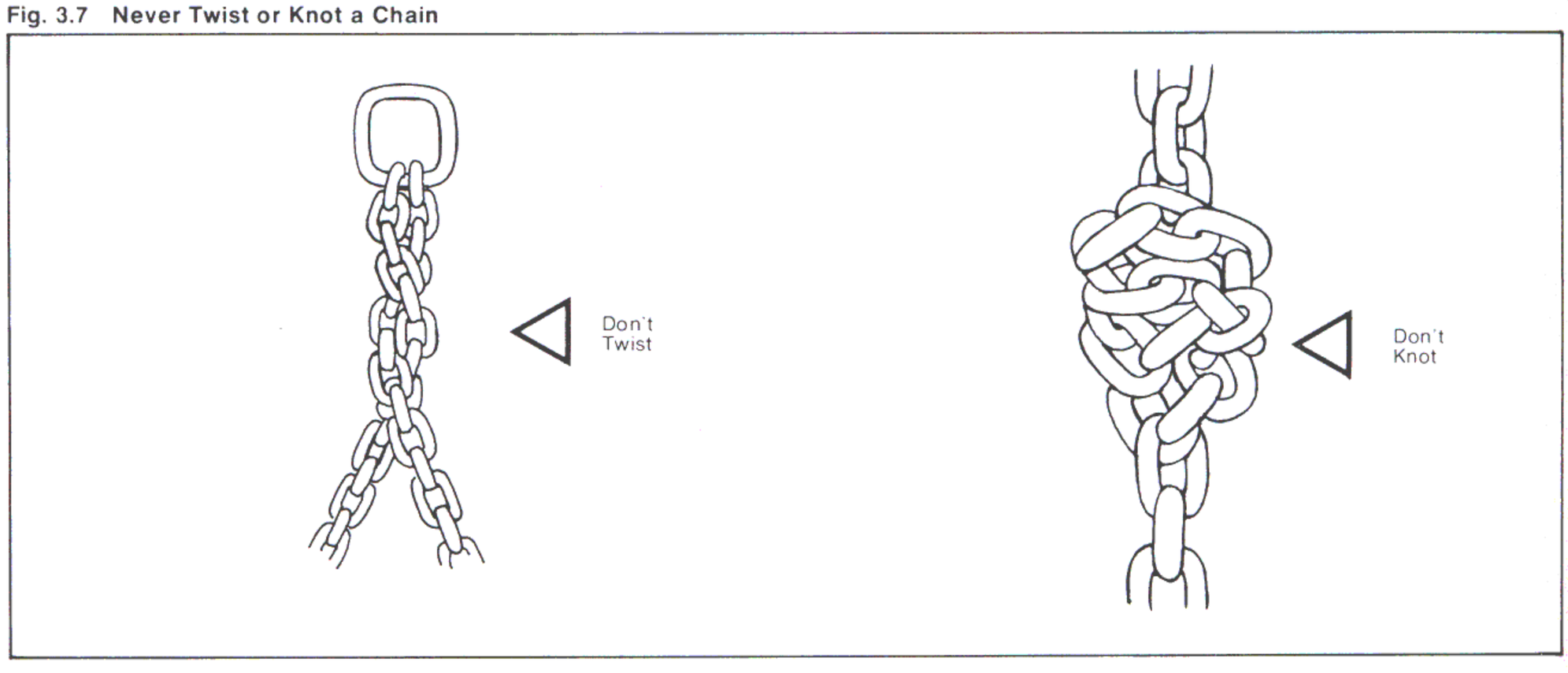


Fig. 3.7 Never Twist or Knot a Chain



dence of severe overloading and indicate that the whole chain should be destroyed.
— Look for severe corrosion resulting in measurable material loss or severe pitting.
— Be particularly careful in determining link wear at the point where they bear on each other. A caliper should be used for the measurement and the degree of wear at the worst section or the most badly worn link must be determined during the inspection. Table 3.3 gives the percentages by which the rated loads must be reduced to compensate for wear and the point at which the chain must be removed from service. (Fig. 3.6)

TABLE 3.3

CORRECTION TABLE TO COMPENSATE FOR WEAR

Original Nominal Chain Stock Diameter (Inches)	Reduce Rated Capacity by Following % When Diameter at Worn Section is as Follows (Inches)		Remove From Service When Diameter is (Inches)
	5%	10%	
1/4 = 0.250	0.244	0.237	0.233
3/8 = 0.375	0.366	0.356	0.335
1/2 = 0.500	0.487	0.474	0.448
5/8 = 0.625	0.609	0.593	0.559
3/4 = 0.750	0.731	0.711	0.671
7/8 = 0.875	0.853	0.830	0.783
1 = 1.000	0.975	0.949	0.895
1 1/8 = 1.125	1.100	1.070	1.010
1 1/4 = 1.250	1.220	1.190	1.120
1 3/8 = 1.375	1.340	1.310	1.230
1 1/2 = 1.500	1.460	1.430	1.340
1 5/8 = 1.625	1.590	1.540	1.450
1 3/4 = 1.750	1.710	1.660	1.570
1 7/8 = 1.875	1.830	1.780	1.680
2 = 2.000	1.950	1.900	1.790

CARE AND USE:

— Use only alloy steel chain and never exceed their rated safe working loads.
— Inspect them regularly and take them out of service and destroy them when they are defective. Damaged or worn sections can sometimes be returned to the manufacturer for repair and reconditioning. Only specialists can repair alloy steel chain — don't attempt it yourself.
— Know the weight of all loads to avoid accidental overload.
— Avoid impact loading.
— Store chains where they will not be damaged or corroded.
— Never shorten a chain by twisting or knotting it or with nuts and bolts. (Fig. 3.7)
— When wrapping chain around sharp corners use pads to prevent damage to the links.
— Never use homemade links or makeshift fasteners formed from bolts, rods, etc.
— Never use repair links, mechanical coupling links or low carbon steel repair links to splice broken lengths of alloy steel chain. They are much weaker than the chain links.
— Never use a chain when the links are locked, stretched or without free movement. Stretching can be distinguished by small checks or cracks in the links, elongation of the links or a tendency for the links to bind on each other.
— Never hammer a chain to straighten the links or to force the links into position.
— Avoid crossing, twisting, kinking or knotting a chain.
— Never use the tip of chain hooks to carry a load.
— Never re-weld alloy steel chain links. They must be replaced by the manufacturer.
— Inspect each link regularly for wear, nicks, gouges, stretch, localized bending and shearing.
— Make sure the chain is of the correct size and grade for the load.
— Make sure all attachments and fittings are of a type, grade and size suitable for service with the chain used.
— Make sure that alloy steel chains are never annealed or heat treated. Their capacity will be completely destroyed if they are.

CHAPTER 4

Rigging Hardware

The hardware used in and with rigging installations and applications is just as important as the ropes, chains, etc.,that are used with them. Not only must you know what hardware to use and how to use it, but you must know how the safe working loads compare with the rope or chain, etc.

It is extremely important that all fittings be of adequate strength for the application and it is strongly recommended that only forged "load rated" (Safe Working Load stamped on the fitting) hardware be used for overhead lifting.

DRUMS:

With regard to drum assemblies, be certain that:

— They have adequate power and operational characteristics to perform all hoisting, holding and lowering functions when operated under all conditions and configurations as recommended and approved by the manufacturer.

— They are provided with suitable clutching or power engaging devices that facilitate immediate starting and stopping of the drum motion.

— They are provided with self-setting brakes that are capable of supporting all rated loads with recommended reeving.

— Their brakes and clutches are provided with adjustments to compensate for wear and maintain adequate force in springs where used.

— The drums have sufficient rope capacity with recommended rope size and reeving to perform all hoisting and lowering functions under recommended and actual service conditions. In addition, all hoist drums should be provided with adequate means to ensure even spooling of the rope on the drum.

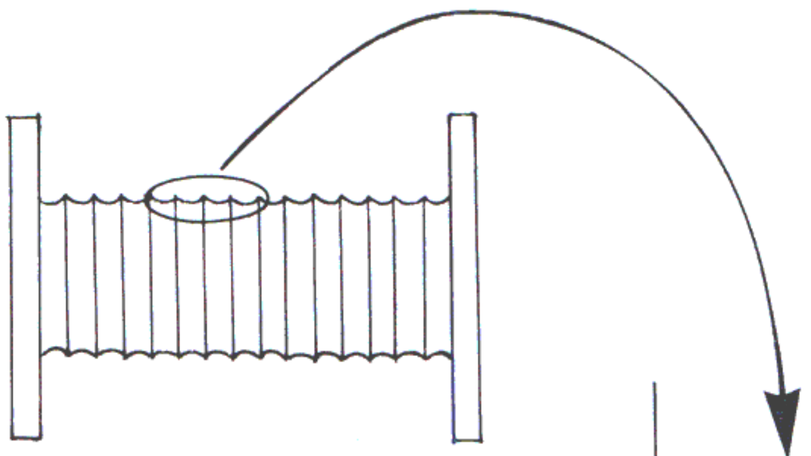
— At least two or three full wraps of rope remain on the drum in all service conditions.

— The drum end of the rope is anchored by a clamp, securely attached to the drums with an arrangement approved by the manufacturer.

— The drums are provided with rims and flange guards of size sufficient to prevent the rope from jumping off the drum.

— Grooved drums have the correct groove pitch for the diameter of the rope. The depth of the groove must also be correct for the diameter of the rope. (Fig. 4.1)

Fig. 4.1 Check Drum Grooves During Inspections



Even though both these gauges properly follow groove contours, when used side-by-side they indicate grooves are too close. Two gauges which overlap in this manner reveal that wraps of rope will scrub when spooling on to or off the drum.

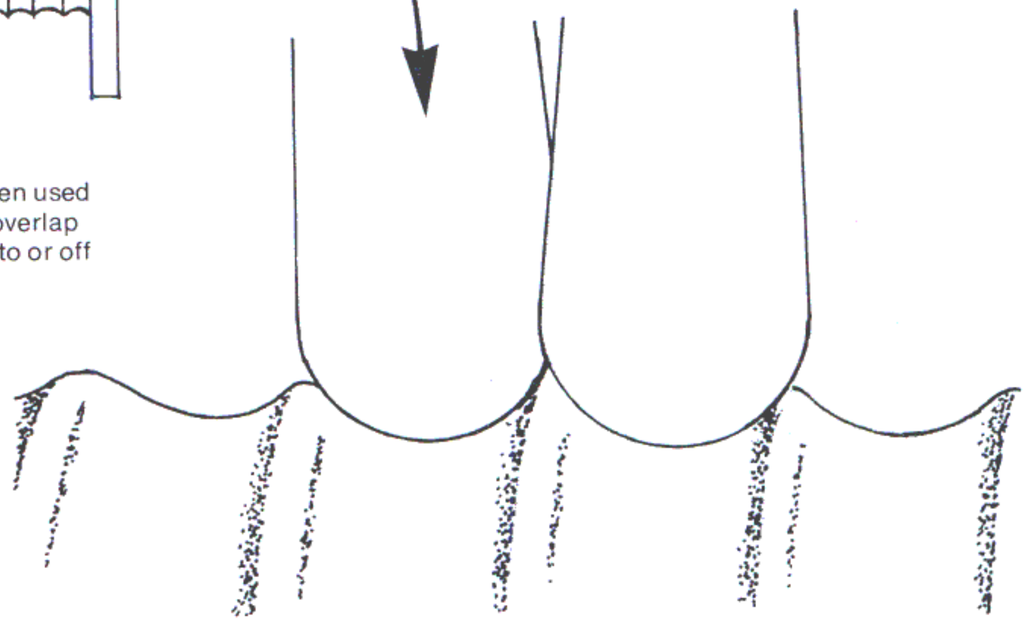
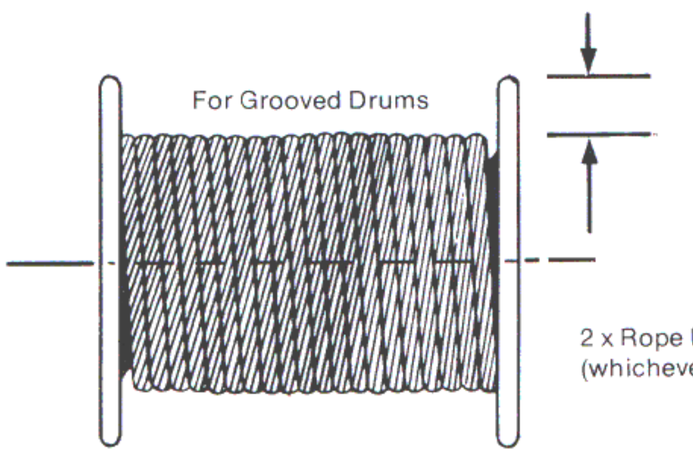


Fig. 4.2 Maximum Drum Capacity

The top layer of rope must not be closer to the flange tips than shown.



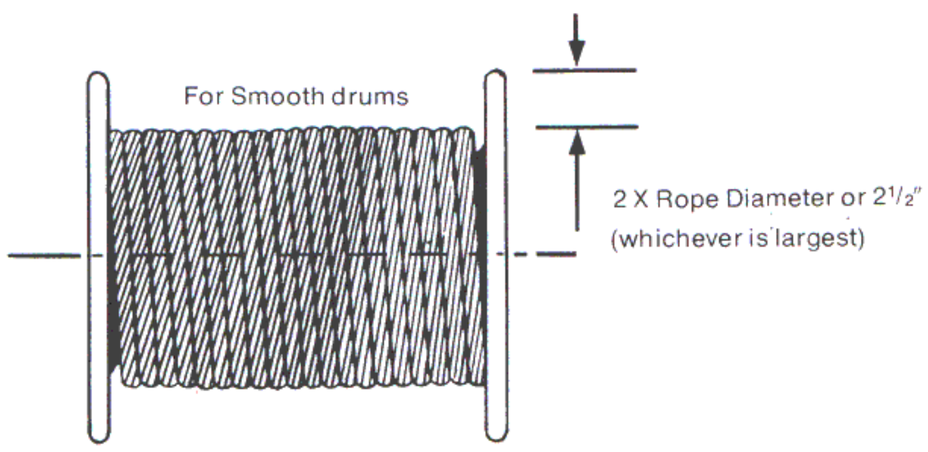


Fig. 4.3 Fleet Angles

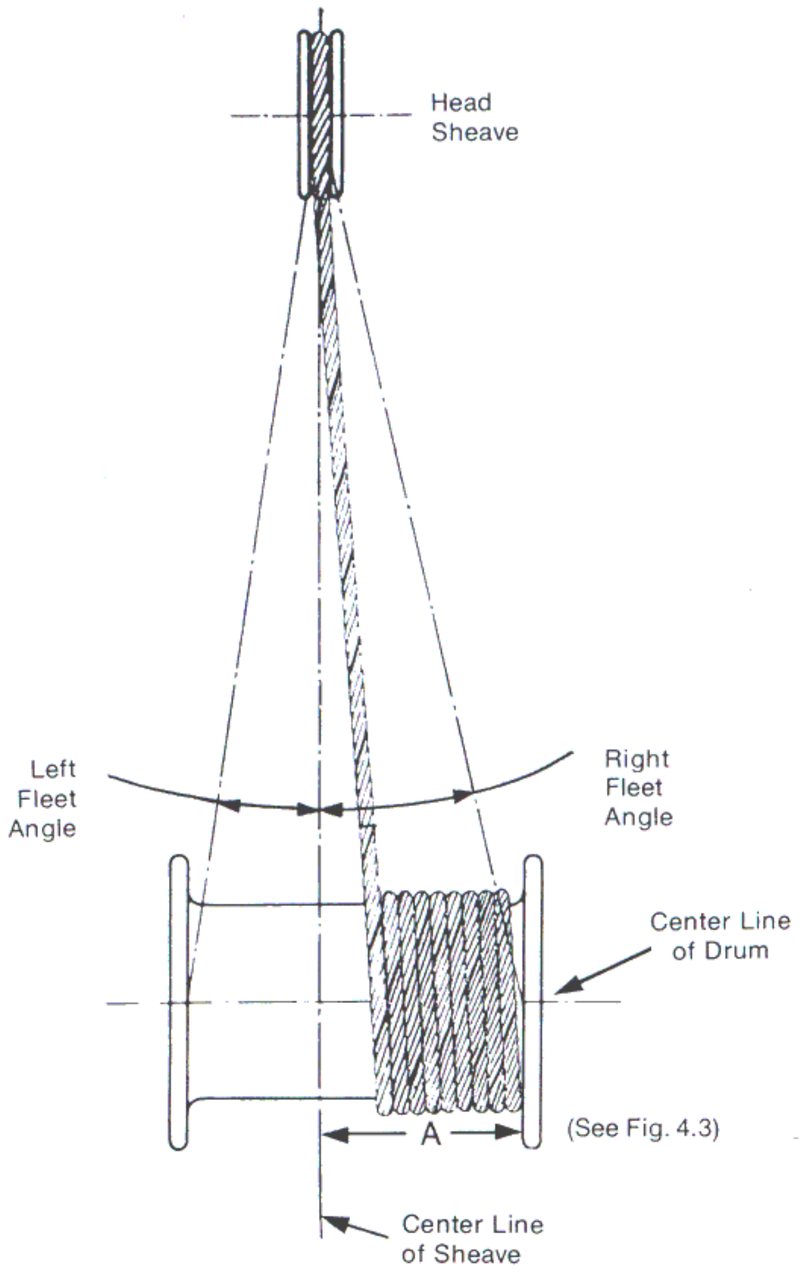


Fig. 4.4 Proper Fleet Angle Ranges for Grooved and Smooth Drums

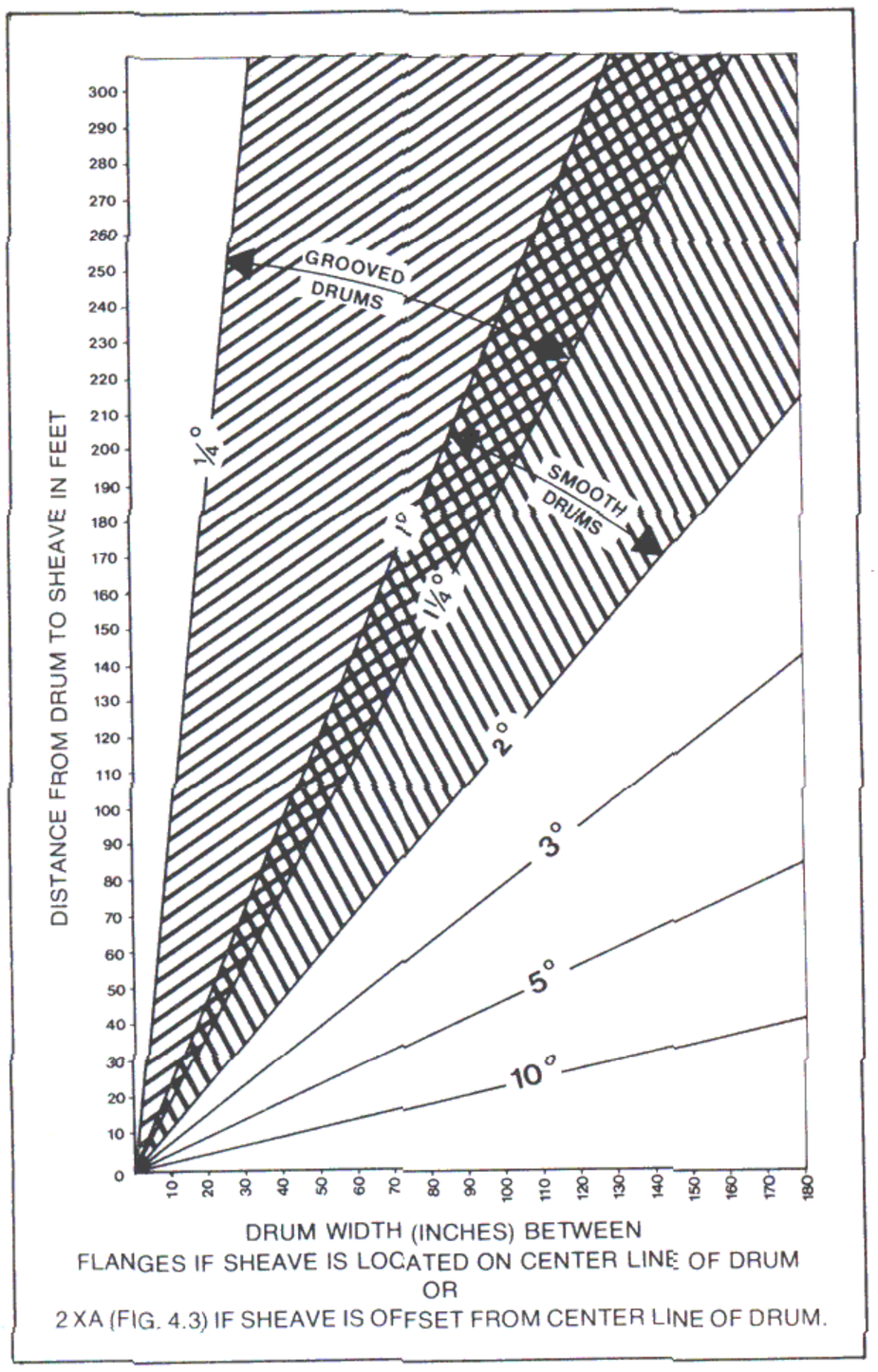
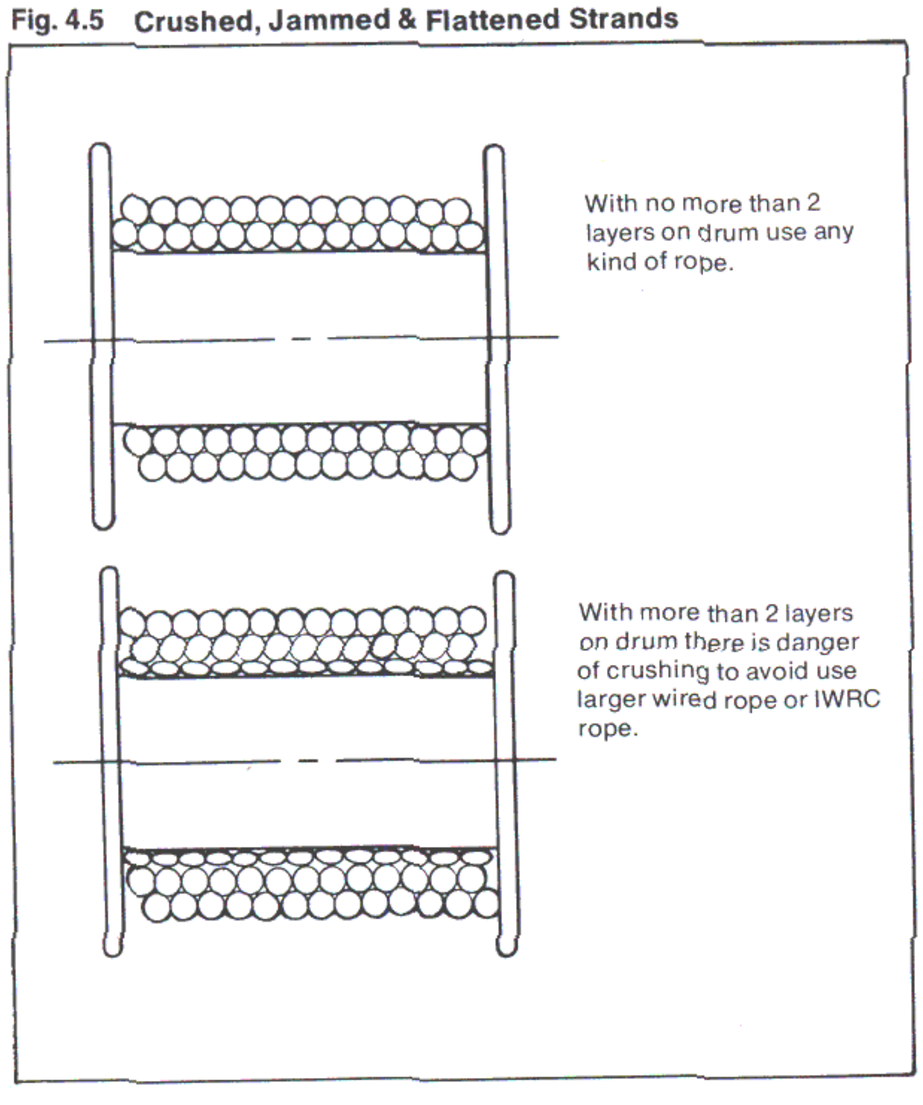


Fig. 4.5 Crushed, Jammed & Flattened Strands



— The flanges on grooved drums must project either twice the rope diameter, or 2 inches beyond the last layer of rope, whichever of the two is greater. (Fig. 4.2)

— The flanges on ungrooved drums must project either twice the rope diameter, or $2^1/_2$ *inches beyond the last layer of rope,* whichever of the two is the greater. (Fig. 4.2)

— The fleet angle for grooved drums should lie between $^1/_4°$ and $1^1/_4°$ and for smooth drums it should lie between 1° and 2°. (Fig. 4.3, Fig. 4.4)

— Where the operator cannot see the drum or rope, drum rotation indicators should be provided and located to afford easy sensing by the operator.

Whenever possible, a drum should be de*signed to hold all the rope on one smooth, even* layer. Two and sometimes three layers are permitted, but more than three layers may cause crushing of the rope on the bottom layer as well as at the end of any layer where pinching occurs. (Fig. 4.5)

Make sure the rope is property installed on the drum. The method to be followed is described on page 17 in Chapter 1.

The manner in which rope spools on a drum depends upon:

— *The rope size and construction.*

— The drum size and ratio of drum diameter to rope diameter.

— The rope speed.

— The amount of rope to be spooled.

— The type of hoisting equipment.

— The load on the rope.

To be certain that the rope spools evenly on the drum, either use a spooling device or keep the fleet angle to within the correct limits and keep tension on the rope at all times. Approximately 10% of the working load is recommended.

It is often necessary to know the approximate capacity of a given drum or reel for a particular rope diameter. The following method can be used to make this calculation: (Fig. 4.6)

Add the diameter of the drum (B) to the depth of the flange (A). Multiply this sum by the depth of flange (A). Multiply the result by the distance between the drum flanges (C). Then multiply this result by the factor (F) listed in table 4.1 opposite the size of rope to be installed.

Fig. 4.6 Determination of Drum Capacity

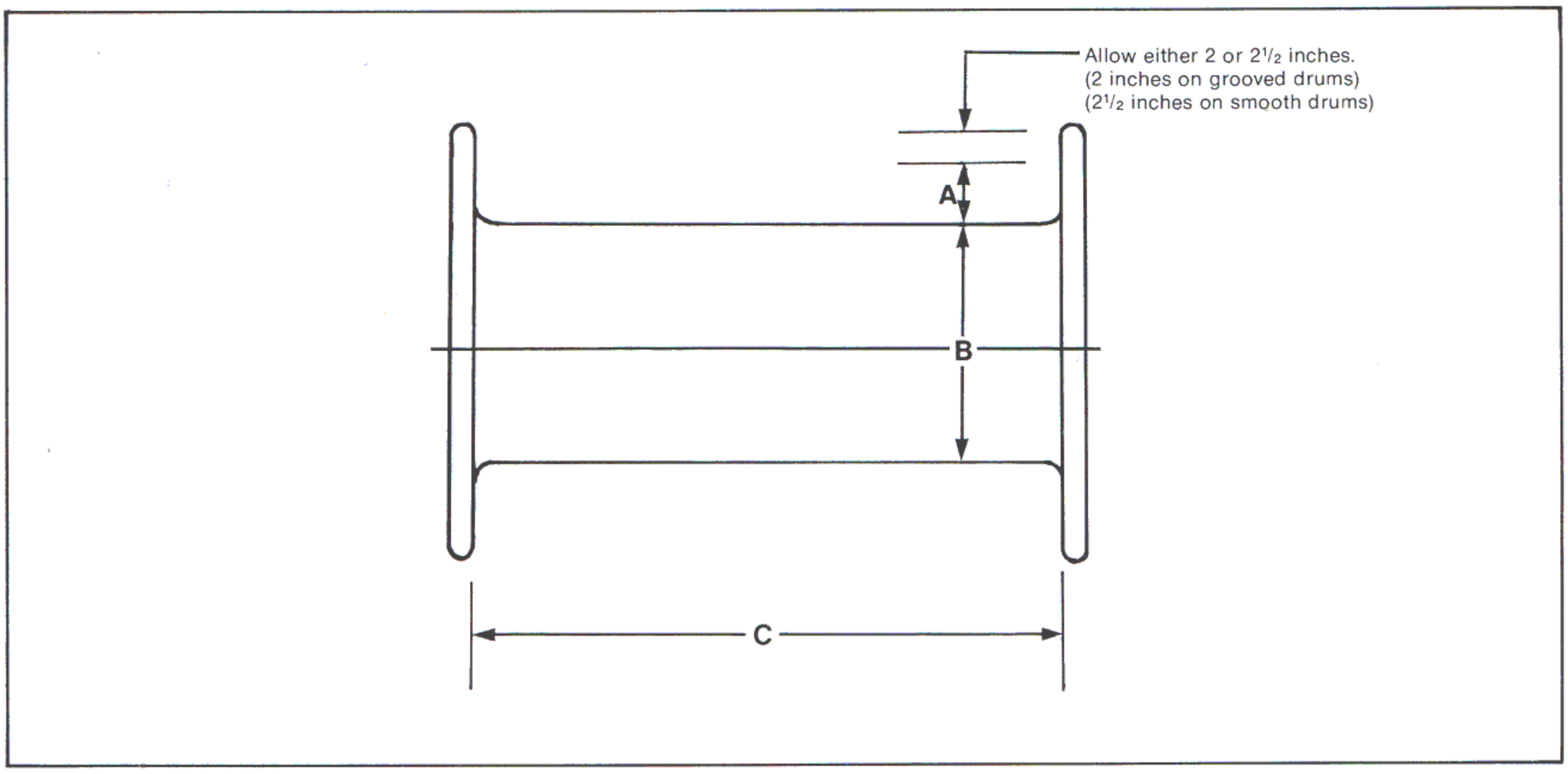


Fig. 4.7 Check For Drum Scoring During Inspections

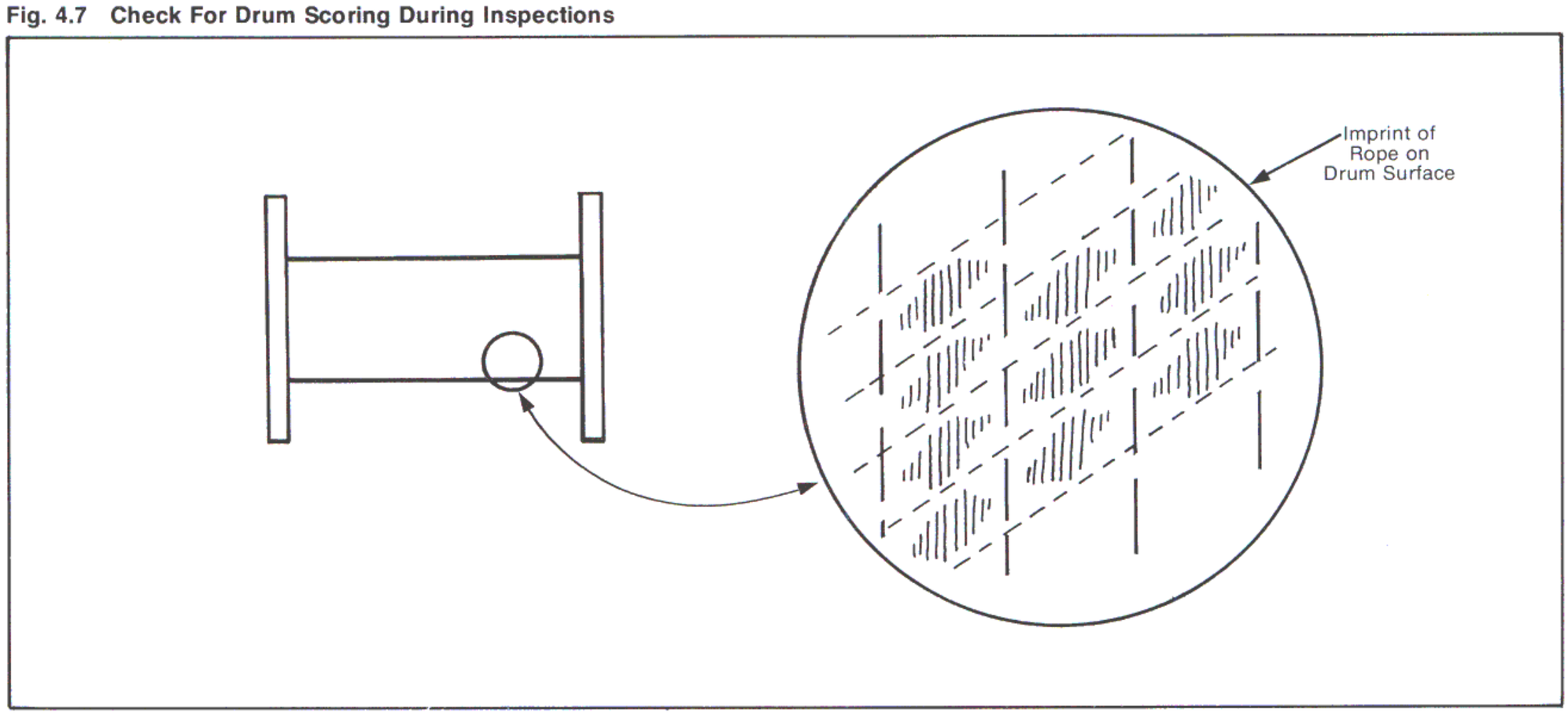
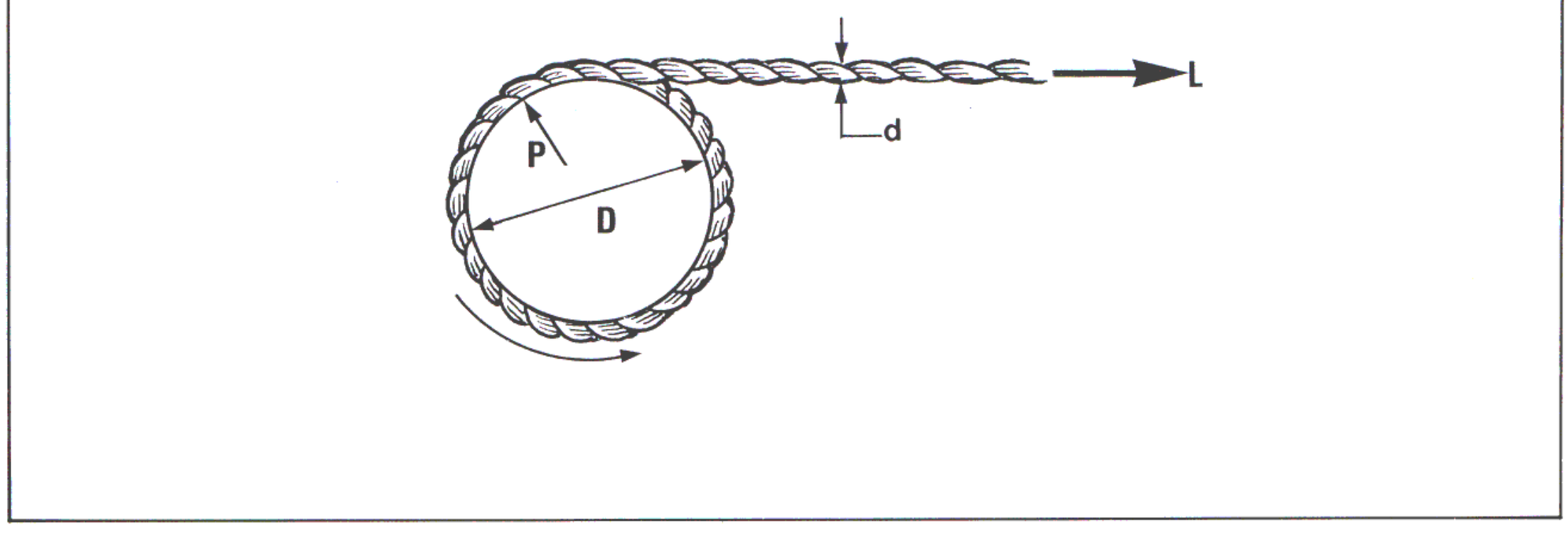


Fig. 4.8 Determination of Drum Contact Pressures



Drum Capacity (Feet of rope) =
(B +A) x A x C x F
where A, B and C are in inches.

For example, if the diameter of the drum is 18 inches, the depth of the flange is 2 inches and the distance between drum flanges is 24 inches, the drum's capacity for a 3/4 inch rope is:

Capacity = (18 + 2) 2 x 24 x .465 = 446 feet.

TABLE 4.1

DRUM OR REEL CAPACITY FACTOR	
Nominal Rope Diameter (Inches)	F
1/4	4.160
5/16	2.670
3/8	1.860
7/16	1.370
1/2	1.050
9/16	0.828
5/8	0.672
3/4	0.465
7/8	0.342
1	0.262
1 1/8	0.207
1 1/4	0.167
1 3/8	0.138
1 1/2	0.116
1 5/8	0.099
1 3/4	0.085
1 7/8	0.074
2	0.066
2 1/8	0.058
2 1/4	0.052
2 3/8	0.046
2 1/2	0.042

The factor (F) applies to nominal rope size and level winding. Since new ropes are usually oversized by 1/32" per 1" of rope diameter, the result obtained by the formula must be decreased to account for oversized rope and/or random or uneven winding, as follows:

For oversized ropes decrease the calculated length by from 0 — 6%.

For random wound ropes decrease the calculated length by from 0 — 8%.

Whenever possible use grooved drums rather than smooth drums as the grooves furnish better support for the rope than do flat surfaces, and more uniform winding results in less abrasive wear on the rope. The groove surfaces on grooved drums and the complete surface on smooth drums should be perfectly smooth, those which have taken the imprint of the outer wires of previous ropes will exert a grinding action on new ropes. (Fig. 4.7)

This imprinting and scoring is caused by high contact pressures between the rope and drum surface. If this condition is evident then the drum must be resurfaced and the contact pressure reduced by:

(a) decreasing the load on the rope, or

(b) increasing the drum diameter, or

(c) replacing the drum with one having harder metal.

The radial contact pressure can be calculated as follows:

$$P = \frac{2L}{Dd}$$

where P = radial pressure in psi (Fig. 4.8)
L = rope load in pounds
D = tread diameter of drum or sheaves (inches)
d = rope diameter (inches).

Example: 7/8" 8 x 19 Round Strand rope
maximum working load = 11,800 lbs.
drum diameter = 18"

$$P = \frac{2L}{Dd} = \frac{2\ (11{,}800)}{18 \times 7/8} = 1498 \text{ psi}$$

This contact pressure means, from the table, that the drum must be manganese steel.

It is suggested the limits given in table 4.2 be observed for all drums and sheaves.

TABLE 4.2

Rope Construction	Contact Pressure (PSI) Limits For Sheave & Drum Materials		
	Cast Iron	Cast Steel	Manganese Steel
6 x 7 Reg. Lay	300	550	1,500
6 x 7 Lang Lay	350	625	1,700
6 x 19 Reg. Lay	500	900	2,500
6 x 19 Lang Lay	575	1,025	2,850
6 x 37 Reg. Lay	600	1,075	3,000
6 x 37 Lang Lay	700	1,250	3,500
8 x 19 Reg. Lay	600	1,075	3,000
6 x 8 Flat Strand	500	900	2,500
6 x 25 Flat Strand	800	1,450	4,000
6 x 33 Flat Strand	975	1,800	4,900

In order to minimize the rope bending stresses the drum diameter should be at least as large as indicated in table 4.3.

Fig. 4.9 Proper Arc of Support Provided the Rope by a Sheave

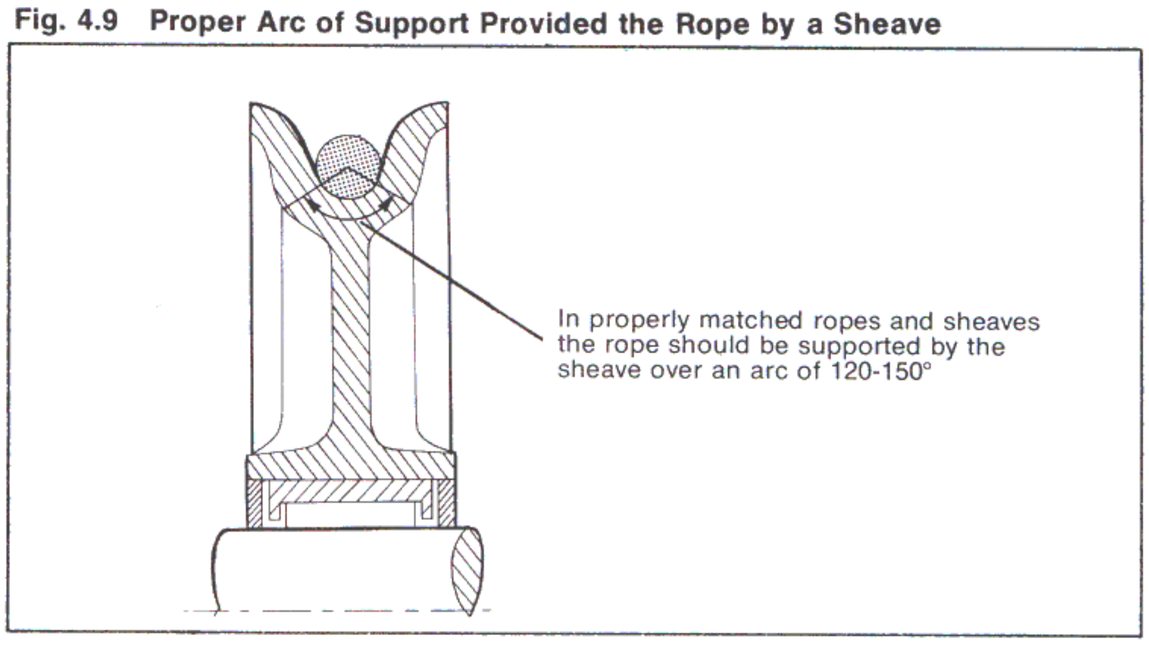


Fig. 4.10 Matching of Ropes and Sheaves

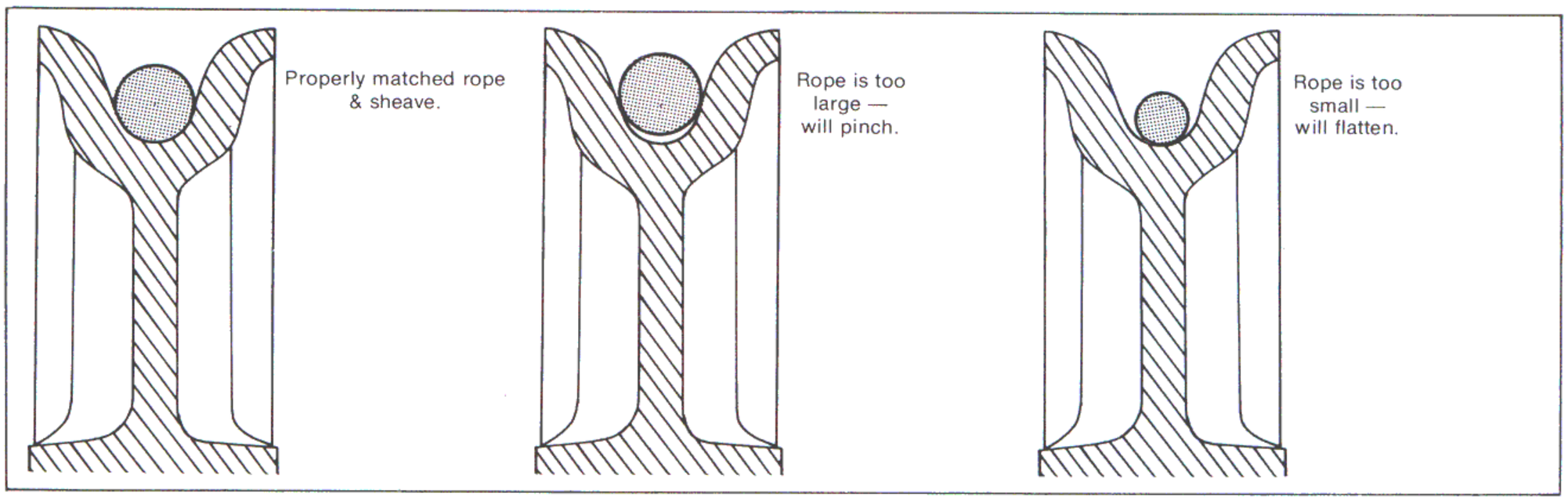


Fig. 4.11 Effect of Improper Match between Rope and Sheave

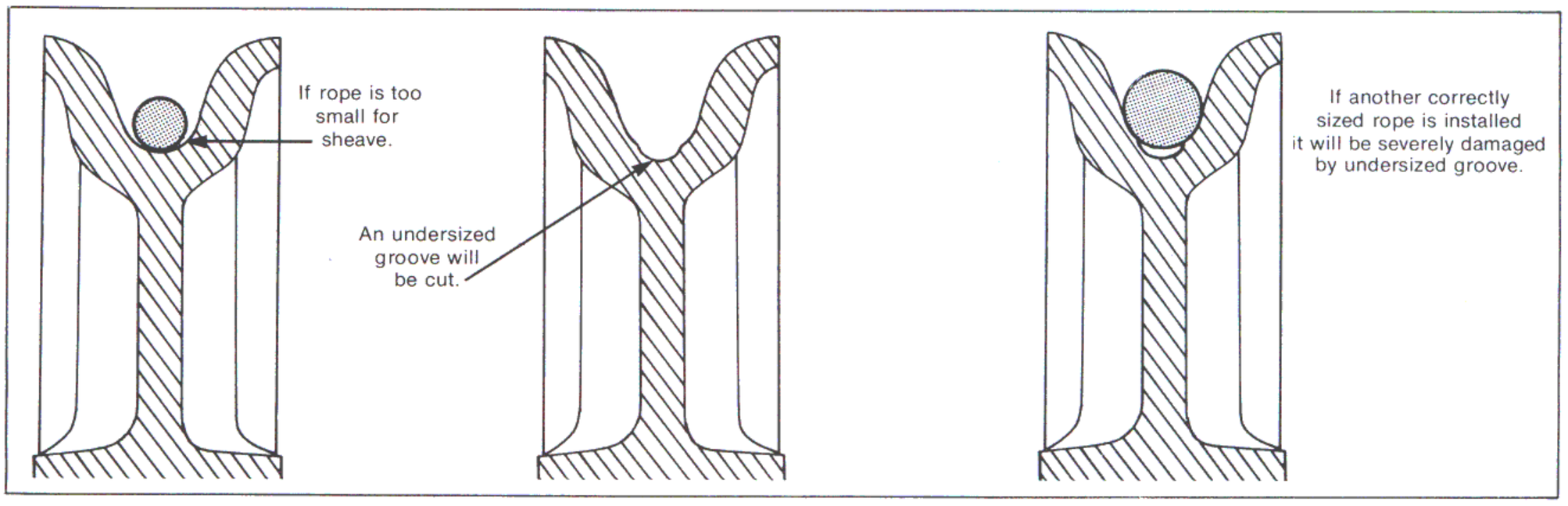


Fig. 4.12 Effect of Sheave Misalignment

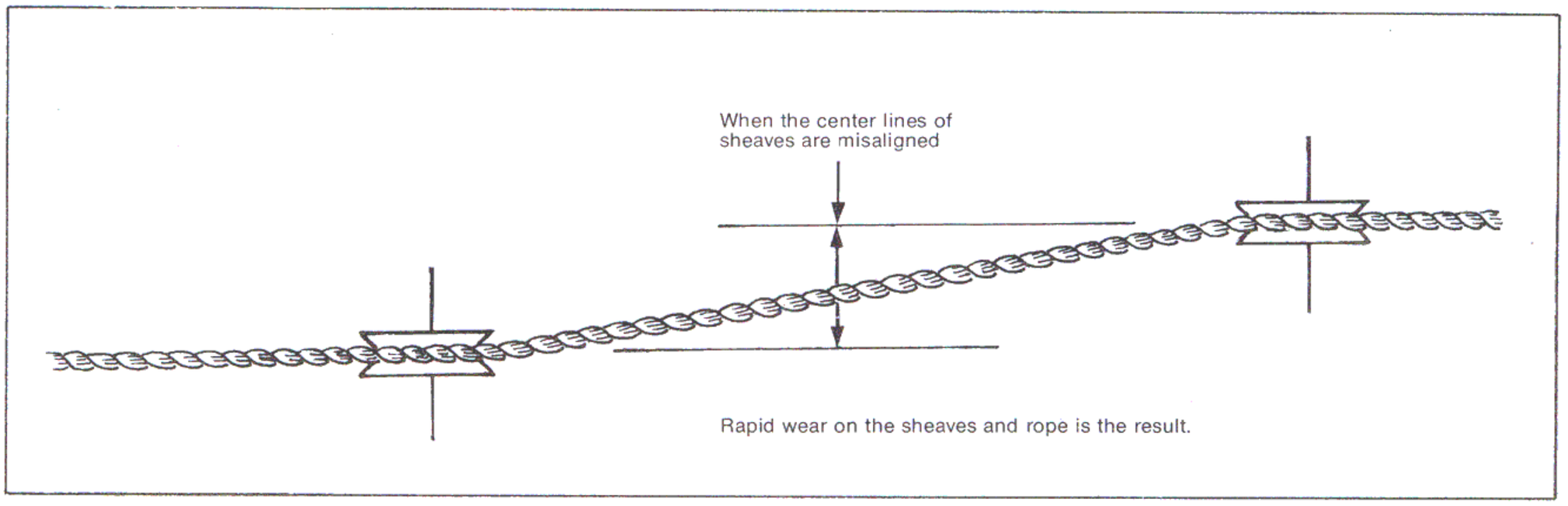


TABLE 4.3

Rope Diameter (Inches)	DRUM DIAMETER (INCHES) FOR VARIOUS TYPES OF ROPES				
	6 x 7	6 x 19 18 x 7 N.R.	6 x 19 Warr. 6 x 16 F 6 x 27 F.S.	6 x 19 F 8 x 19 Seale	6 x 37
1/4	10	8	7	6	5
5/16	13	11	9	8	6
3/8	16	13	11	10	7
7/16	18	15	13	11	8
1/2	21	17	15	13	9
9/16	23	19	17	15	10
5/8	26	21	19	16	11
3/4	31	25	22	19	13
7/8	37	30	26	23	16
1	42	34	30	26	18
1 1/8	47	38	34	29	20
1 1/4	52	42	37	32	22
1 3/8	58	47	41	36	25
1 1/2	63	51	45	39	27
1 5/8	—	55	49	42	29
1 3/4	—	59	52	45	31
1 7/8	—	64	56	49	34
2	—	68	60	52	36
2 1/4	—	—	67	58	40
2 1/2	—	—	75	65	45

SHEAVES:

The condition and contour of sheave grooves have a major influence on rope life. The grooves must be smooth and slightly larger than the rope to prevent it from being pinched or jammed in the groove. Since most ropes are made slightly larger than their nominal size, the sheave grooves for new rope should just accommodate the full oversize of the rope, as given in table 4.4.

TABLE 4.4

SHEAVE GROOVE TOLERANCES		
Nominal Rope Diameter (Inches)	Groove Oversize (Inches)	
	Min.	Max.
1/4 — 5/16	1/64	1/32
3/8 — 3/4	1/32	1/16
13/16 — 1 1/8	3/64	3/32
1 3/16 — 1 1/2	1/16	1/8
1 9/16 — 2 1/4	3/32	3/16
2 5/16 up	1/8	1/4

The bottom of the groove should have an arc of support of at least 120° to 150°, and the sides of the groove should be tangent to the arc. (Fig. 4.9)

The more closely the contour of the groove approaches that of the wire rope the greater becomes the area of contact between the two. This minimizes rope distortion, bending fatigue and eases sheave rotation. If the groove diameter is too large, the rope will not be properly supported and will tend to flatten and become distorted. This accelerates bending fatigue in individual wires and can cause premature failures. (Fig. 4.10, 4.11)

If the sheave groove is too narrow for the rope the operating tension will draw the rope deeply into the groove, causing it to be pinched and subjecting both the rope and sheave to severe abrasive wear. This condition can arise if new ropes are installed over old sheaves.

If the sheaves are not perfectly aligned both the rope and sheave flanges will be subjected to severe wear and rapid deterioration will occur. A ready indication of poor alignment is rapid wear of only one of the flanges on any given sheave. (Fig. 4.12)

One of the fastest ways to ruin a rope is to operate it over small sheaves. The excessive and repeated bending and straightening of the wires leads to premature failure from fatigue. Use the maximum possible diameter of sheave that the equipment will carry.

The sheaves should never be of smaller diameter than indicated in table 4.3.

Fig. 4.13 Sheave Requirements

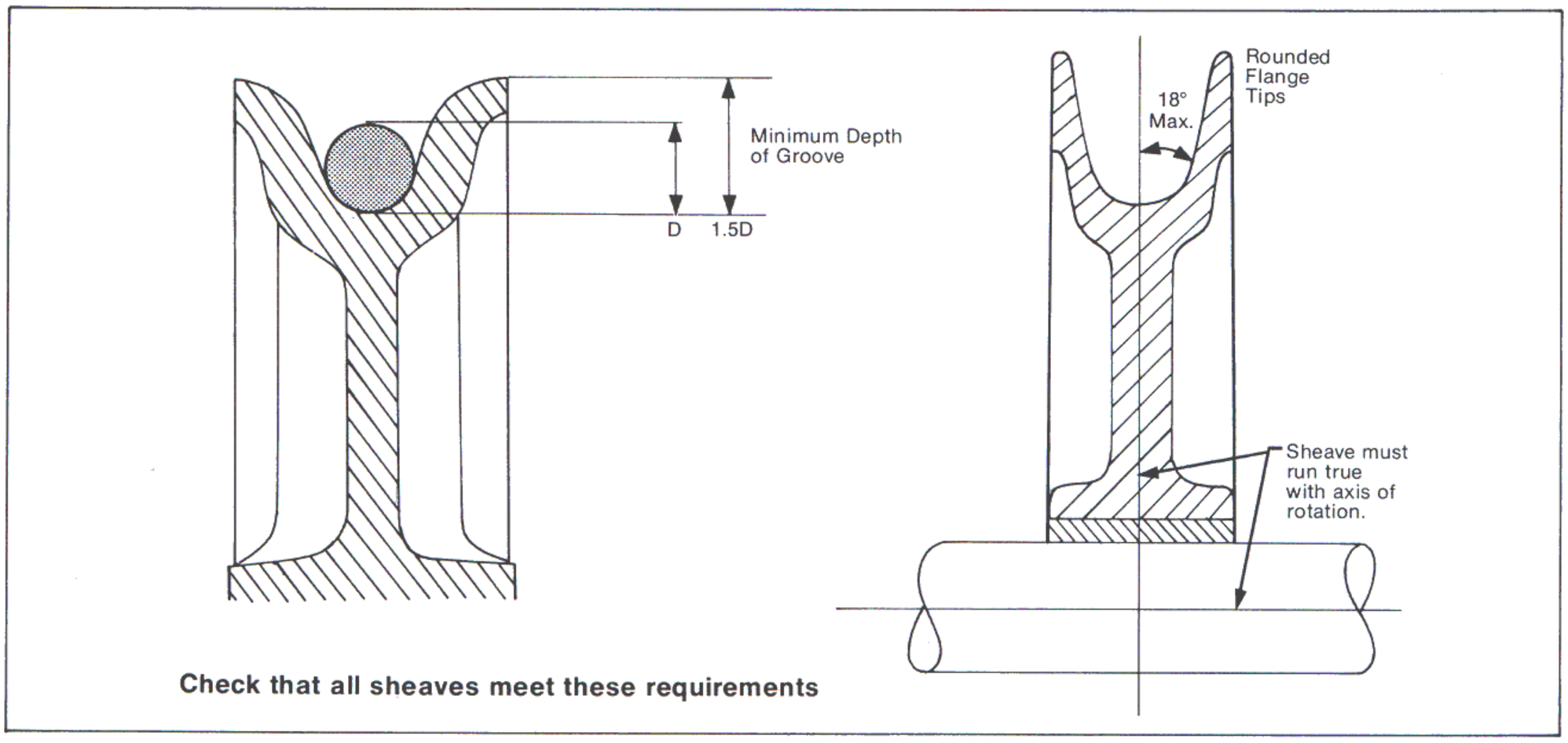


Fig. 4.14 Effect of Improper Sheaves or Poor Sheave Maintenance on Rope Life

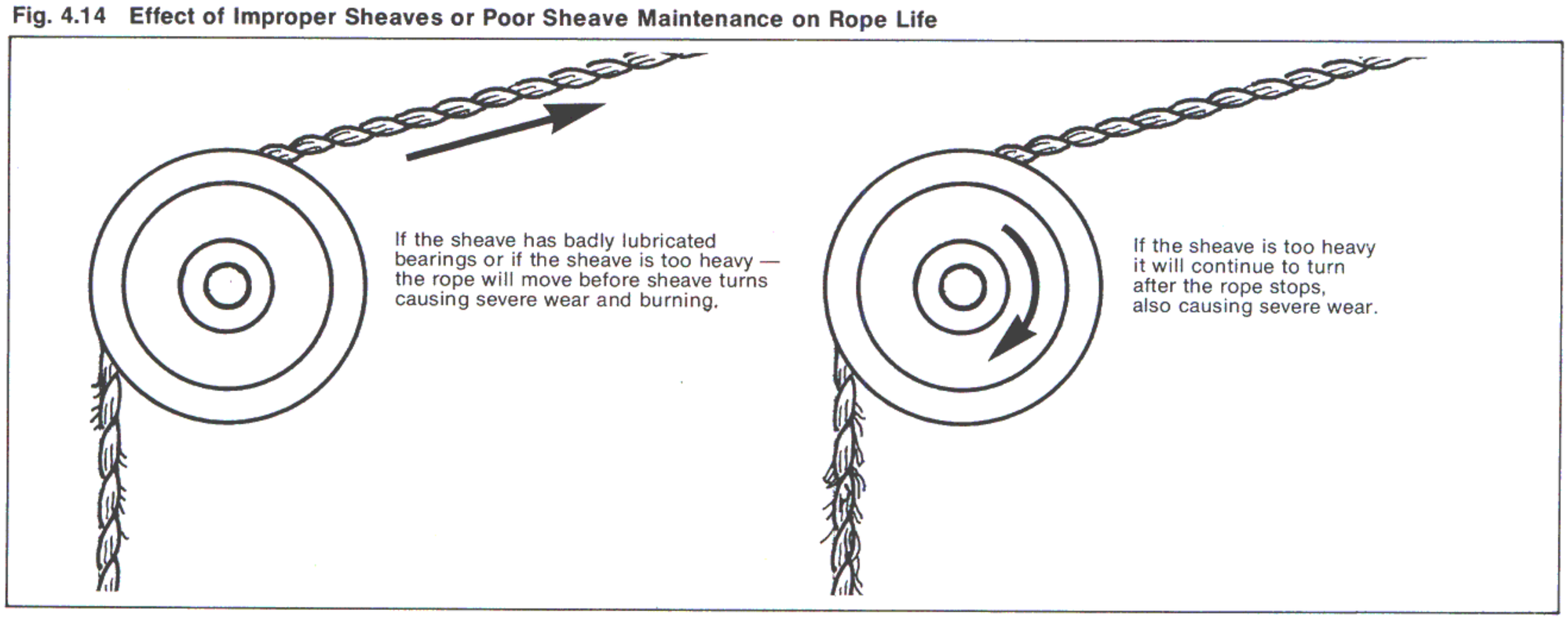
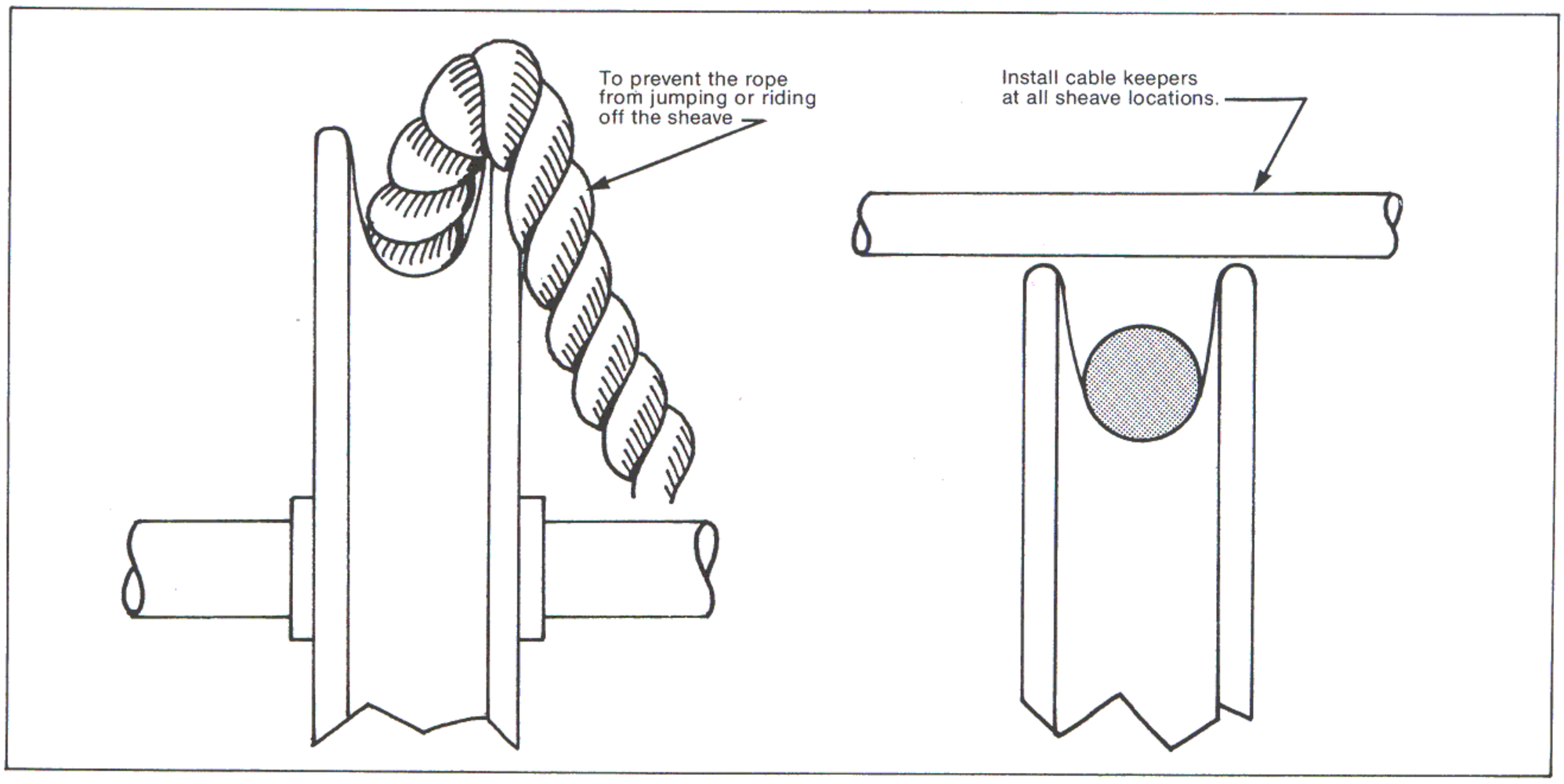


Fig. 4.15 Sheave Cable Keepers



The depth of the sheave grooves should be at least $1^1/_2$ times the rope diameter and the tapered side walls of the grooves should not make an angle of more than 18° with respect to the center line. The flange corners should be rounded and the rims should run true about the axis of rotation. (Fig. 4.13)

The bearings should either be permanently lubricated or be equipped with means for lubrication. Inadequate lubrication or a sheave that is too heavy for the load will cause the rope to slip in the sheave whenever the rope velocity changes. The momentum of the heavy sheave will cause it to continue turning after the rope has stopped. This grinding wheel action causes severe rope abrasion and will wear flat spots in the sheave that further damages the rope. (Fig. 4.14)

If the sheaves are carrying ropes that can be momentarily unloaded, as in the case of a hoist line, then the sheave must be equipped with cable-keepers that prevent the unloaded rope from leaving the groove. The sheaves in lower load blocks should also be equipped with either cable-keepers or with close-fitting guards that prevent the ropes from becoming fouled when the block is lying on the ground with the ropes loose. When these guards are fitted it is important that they be removed only for the purposes of maintenance, inspection or adjustment. Failure to observe this procedure may allow a rope to jump clear and become trapped. (Fig. 4.15)

Badly worn sheaves have an adverse effect on rope life and must be examined at regular intervals. When replacement becomes necessary only equipment supplied or approved by the equipment manufacturer should be fitted. Some designs may allow for re-machining the grooves but this operation should only be undertaken in accordance with the manufacturer's instructions as there is a limit to the amount of metal which can be removed before the strength of the component will be affected.

Inspect the sheaves carefully for any sign of cracks in the flanges. If the flange breaks off it will allow the rope to jump free with disastrous results. Even if only a small portion of the flange is broken, the rope is liable to be cut completely through by the rough edge of the break.

Never use fibre ropes on sheaves that have seen wire rope service. And wire rope must never be used on equipment designed for fibre rope.

The groove surfaces on sheaves should be perfectly smooth. Those which have taken the imprint of the outer wires will exert a grinding action on the ropes. (Fig. 4.16)

This imprinting and scoring is caused by high contact pressures between the rope and sheave surface. If this condition is evident then the sheave must be resurfaced and the contact pressure reduced by:

(a) decreasing the load on the rope, or

(b) increasing the sheave diameter, or

(c) replacing the sheave with one having harder metal.

The calculations for radial pressures of drums in the previous section apply equally well to sheaves.

Fig. 4.16 Scored Sheave Groove

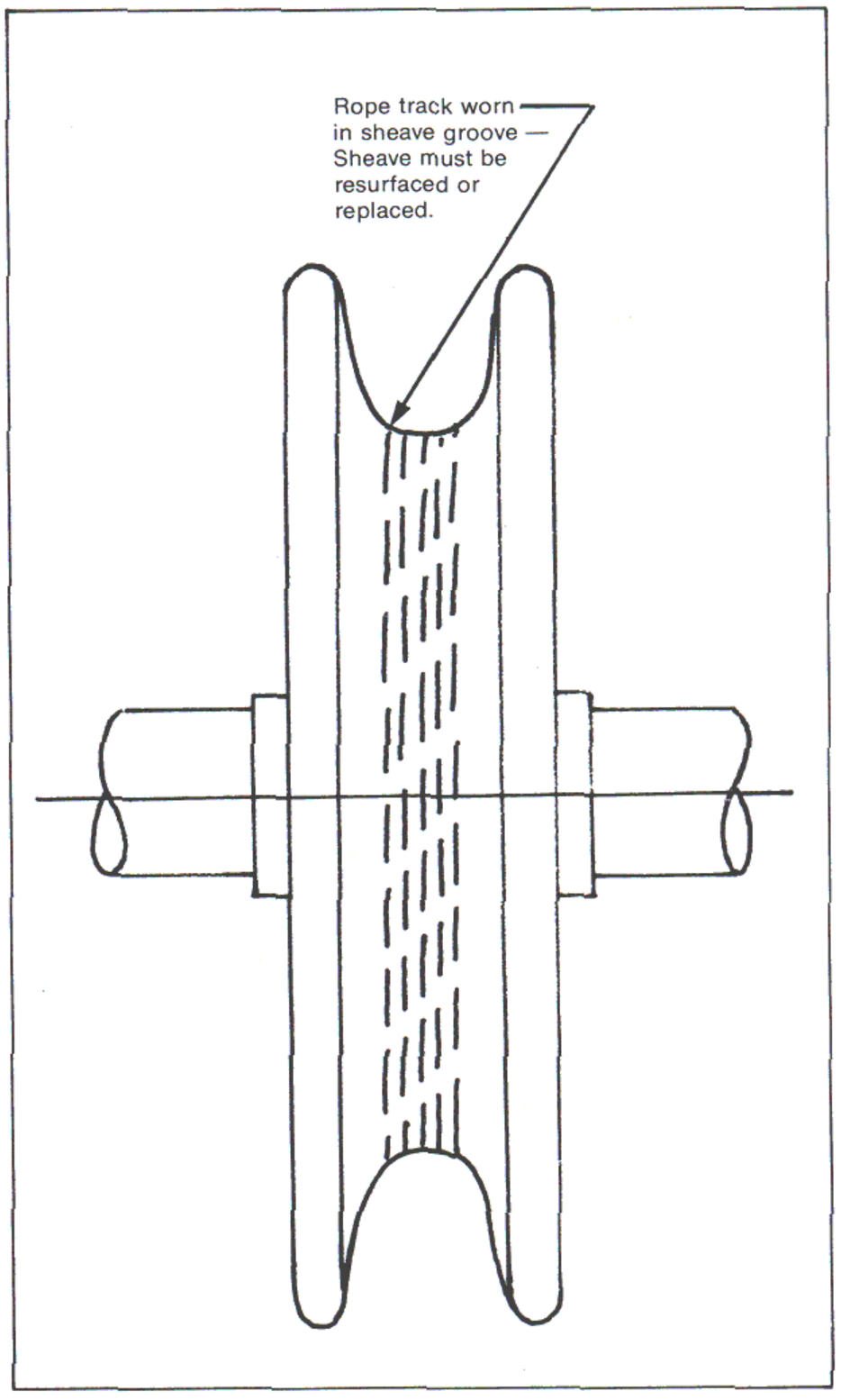


Fig. 4.17 Hook Inspection Areas

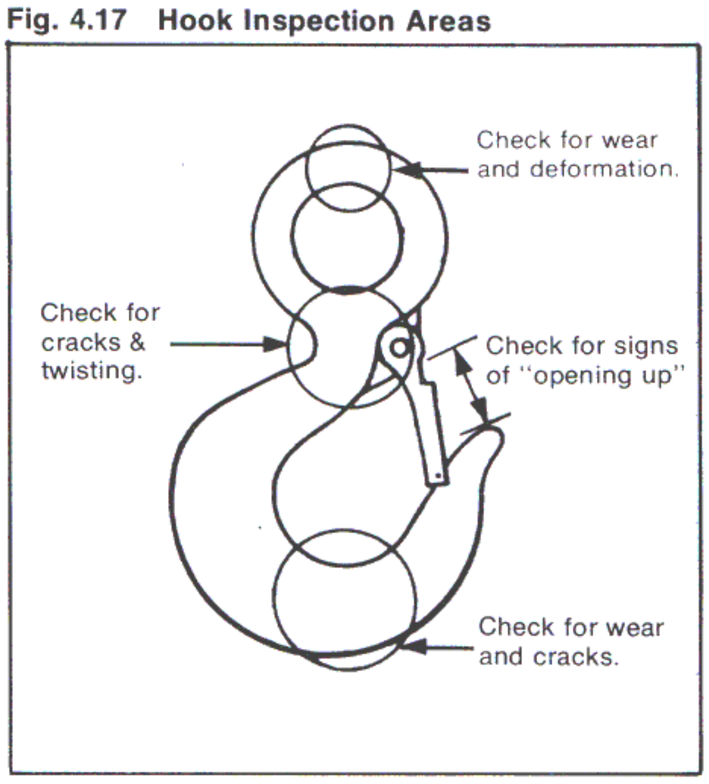


Fig. 4.18 Effect of Eccentric Loads on Hook Capacity

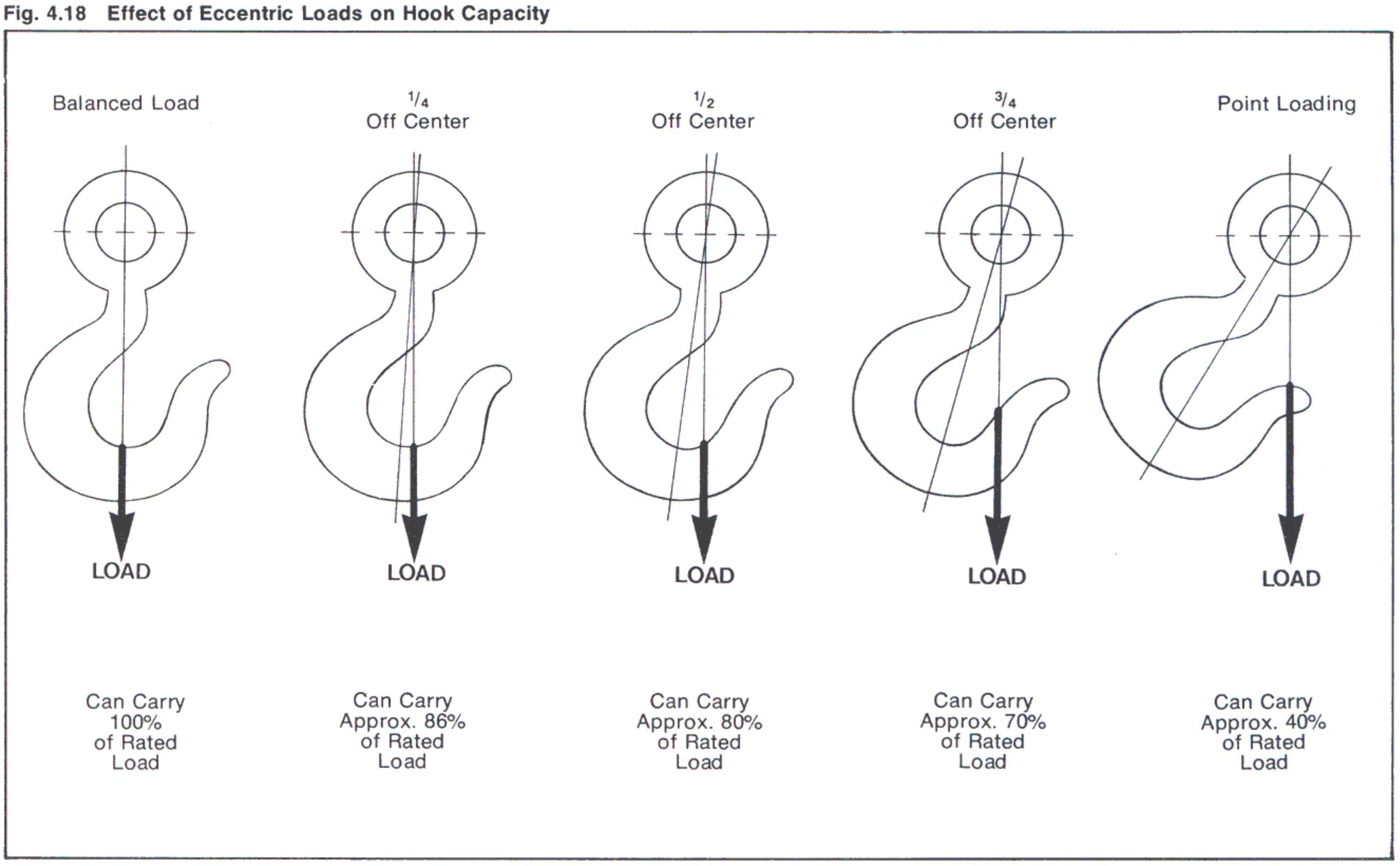


Fig. 4.19 Standard Choker Hook

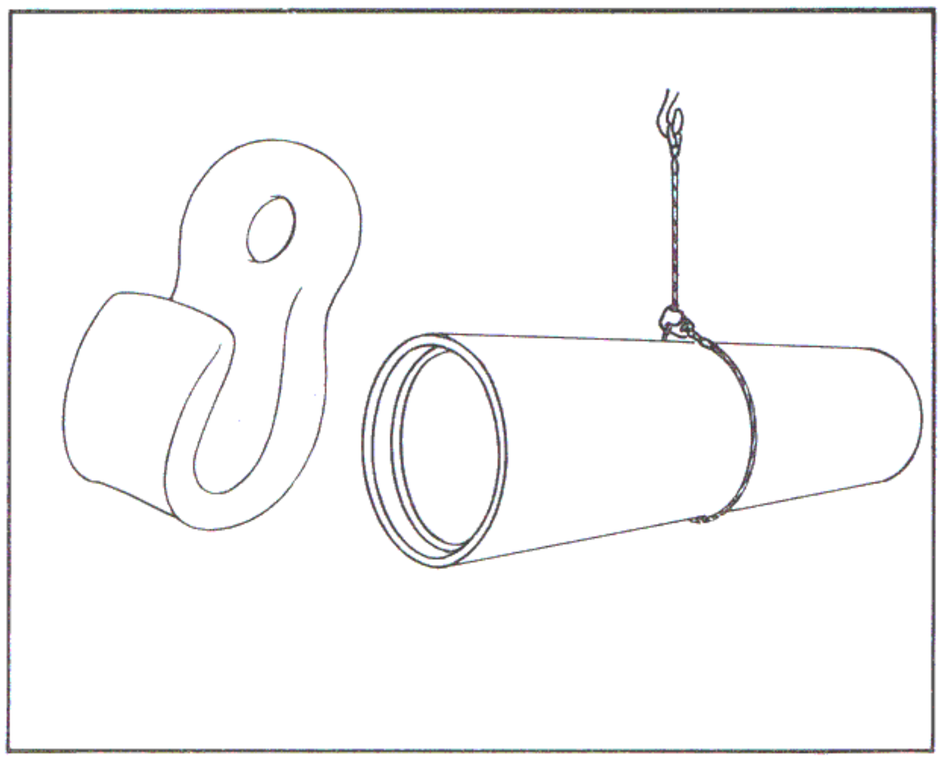


Fig. 4.20 Adjustable Sliding Choker Hook

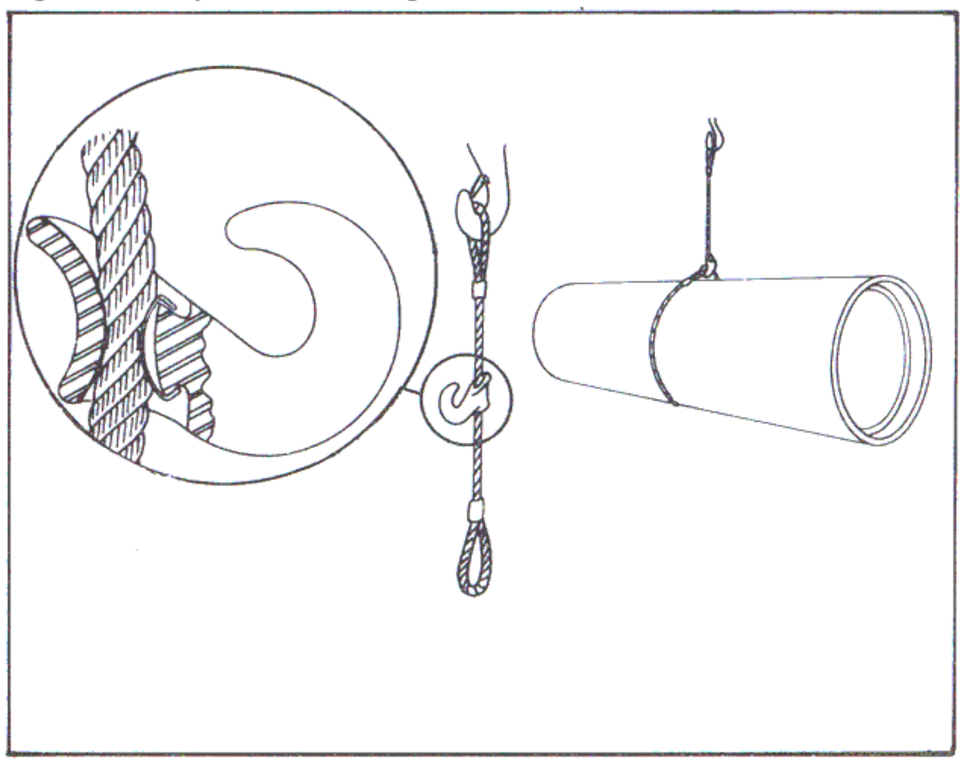
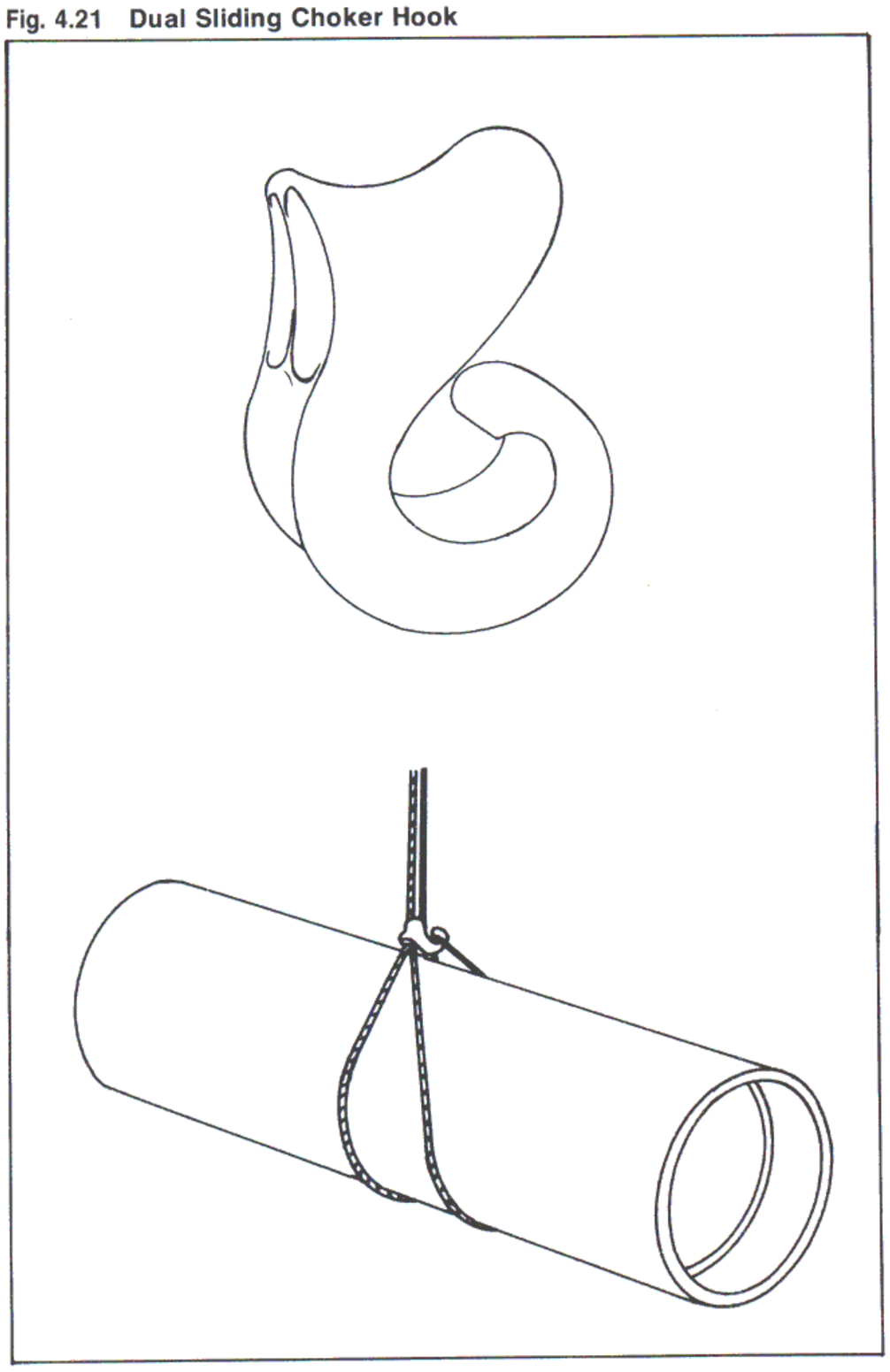


Fig. 4.21 Dual Sliding Choker Hook



HOOKS:

There is such a variety of hooks available for hoisting and rigging operations that it is impossible to deal with all of them in detail. There are, however, several considerations that apply to all hooks and observance of them will improve the safety standard.

Make sure that all hoisting hooks, excepting grab and sorting hooks are equipped with safety catches.

Inspect all hooks frequently. (Fig. 4.17) Look for wear in the saddle of the hook. Look for cracks, severe corrosion and twisting of the hook body. Be especially careful to measure the throat opening. If a hook has been overloaded or if it is beginning to weaken the throat will open. If there is any evidence of opening or distortion, destroy the hook. If you discard it without destroying it someone else may attempt to use it.

Be especially careful during the inspection to look for cracks in the saddle section and at the neck of the hook.

Buy and use only the best hooks available. These are usually forged alloy steel and generally are stamped with their rated safe working loads.

The safe working loads apply only when the load is applied in the saddle of the hook. If the hook is eccentrically loaded or if the load is applied anywhere between the saddle and the tip, the safe working load is very much reduced. (Fig. 4.18)

Commonly used choker hooks include:

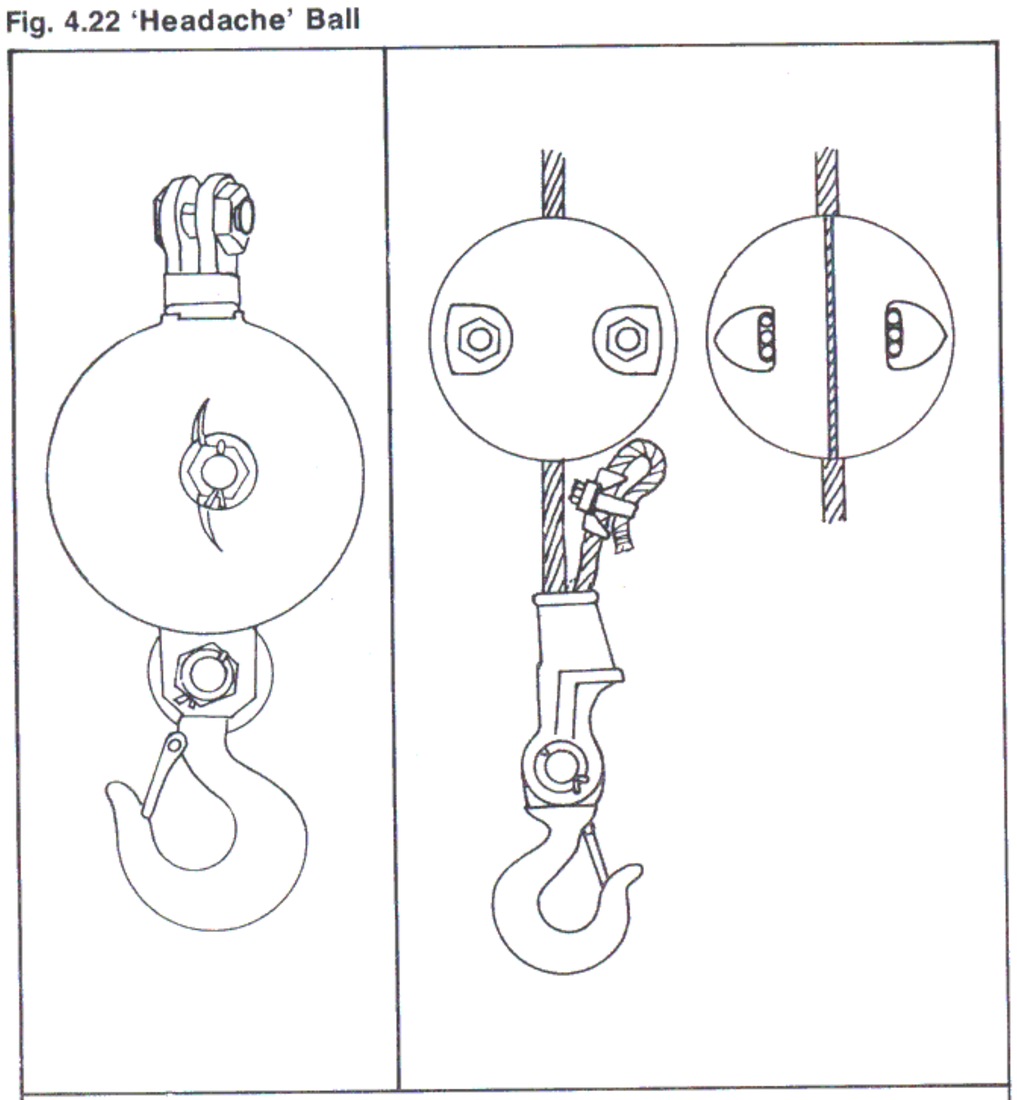
— **Standard choker hook** designed for attachment to the end of a sling. It frees the main part of the sling of fittings. (Fig. 4.19)

— **Adjustable sliding choker hook** which prevents the hook from sliding on the sling when not loaded. A spring insert has just enough tension to hold the hook in any position on the body of the sling. The hook is easily moved by hand and will choke under load. (Fig. 4.20)

— **Dual sliding choker hook** for endless slings and conventional slings when two eyes are over main hook. (Fig. 4.21)

It is recommended that all hoisting hooks, as opposed to sling hooks, be equipped with swivels and headache balls. Ensure that the headache ball is securely attached to either the hook or the rope so that there is no possibility of it sliding up and down on the load line. (Fig. 4.22)

Fig. 4.22 'Headache' Ball

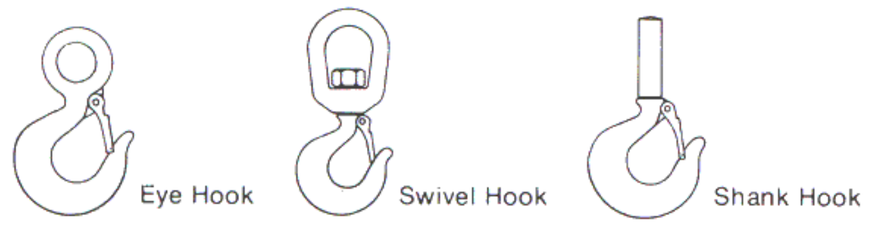


Headache Ball Must Be Securely Attached to the Hook or the Rope

The following tables of loads (Tables 4.5, 4.6, 4.7, 4.8 and 4.9) are included to provide an indication of what can be expected from a hook based on its throat opening. Refer to the manufacturers' ratings for specific values of specific hooks.

TABLE 4.5

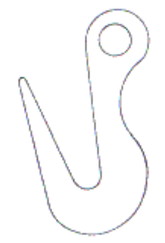
EYE HOOKS, SHANK HOOKS, SWIVEL HOOKS
FORGED ALLOY STEEL
(SAFETY FACTOR = 5)



Throat Opening (Inches)	Maximum Safe Working Load (Pounds)
5/8	600
11/16	800
1	1,500
1 1/16	2,000
1 1/8	2,500
1 1/4	4,000
1 3/8	4,500
1 13/32	5,000
1 1/2	5,500
1 17/32	6,000
1 11/16	6,800
1 25/32	8,000
1 7/8	8,400
1 15/16	10,000
2 1/16	10,400
2 1/8	11,000
2 1/4	12,500
2 5/16	13,000
2 1/2	16,000
2 9/16	18,000
3	19,200
3 1/16	20,000
3 3/8	24,000
3 7/16	26,000
4	33,400

TABLE 4.6

TYPICAL SORTING HOOK
FORGED ALLOY STEEL



I.D. of Eye	1 1/4"
Opening at Top of Hook	2 13/16"
Safe Working Load 2 1/2" From Tip	2 Tons
Safe Working Load at Bottom of Hook	7 1/2 Tons

TABLE 4.7

Clevis Type

CHAIN GRAB HOOKS
(CLEVIS TYPE AND EYE TYPE)
FORGED ALLOY STEEL

Eye Type

Throat Opening (Inches)	For Size of Chain (Inches)	Maximum Safe Working Load (Pounds)
11/32	1/4	2,750
7/16	5/16	4,300
1/2	3/8	5,250
9/16	7/16	7,000
21/32	1/2	9,000
25/32	5/8	13,500
15/16	3/4	19,250
1 1/16	7/8	26,000
1 3/16	1	34,000

TABLE 4.8

Clevis Type

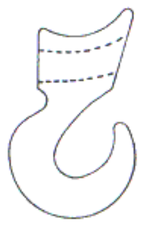
CHAIN SLIP HOOKS
(CLEVIS TYPE AND EYE TYPE)
FORGED ALLOY STEEL
(SAFETY FACTOR = 4)

Eye Type

Throat Opening (Inches)	For Size of Chain (Inches)	Maximum Safe Working Load (Pounds)
15/16	1/4	2,750
1 1/16	5/16	4,300
1 5/16	3/8	5,250
1 9/16	7/16	7,000
1 11/16	1/2	9,000
2	5/8	13,500
2 1/8	3/4	19,250
2 3/4	7/8	26,000
3	1	34,000

TABLE 4.9

SLIDING CHOKER HOOKS
FORGED ALLOY STEEL
(SAFETY FACTOR = 5)



Throat Opening (Inches)	For Rope Size (Inches)	Maximum Safe Working Load (Pounds)
1/2	1/4 - 5/16	1,500
5/8	3/8	2,600
7/8	1/2	3,400
1 1/8	5/8	5,100
1 1/8	3/4	8,000
1 7/16	7/8 - 1	15,000
1 3/4	1 1/8 - 1 1/4	23,000
2 3/16	1 3/8 - 1 1/2	30,000

RINGS, LINKS, SWIVELS:

These hardware items, like all other hoisting and rigging fittings, must be forged alloy steel to provide the highest degree of safety.

In the absence of manufacturers' safe working loads, the following tables (Tables 4.10, 4.11, 4.12, 4.13, 4.14, 4.15) can be used to get an approximate idea of the capacities of the items.

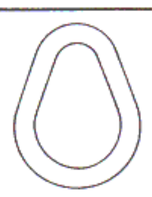
TABLE 4.10

RINGS
— Weldless Construction
— Forged Alloy Steel

Stock Diameter (Inches)	Inside Diameter (Inches)	Maximum Safe Working Load (Pounds)
7/8	4	7,200
7/8	5 1/2	5,600
1	4	10,800
1 1/8	6	10,400
1 1/4	5	17,000
1 3/8	6	19,000

TABLE 4.11

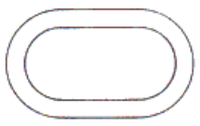
PEAR SHAPED LINKS
(Sling Links)
— Weldless Construction
— Forged Alloy Steel



Stock Diameter (Inches)	Inside Length (Inches)	Maximum Safe Working Load (Pounds)
3/8	2 1/4	1,800
1/2	3	2,900
5/8	3 3/4	4,200
3/4	4 1/2	6,000
7/8	5 1/4	8,300
1	6	10,800
1 1/4	7 3/4	16,750
1 3/8	8 1/4	20,500

TABLE 4.12

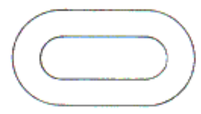
MASTER LINKS
— Weldless Construction
— Forged Alloy Steel



Stock Diameter (Inches)	Inside Width (Inches)	Maximum Safe Working Load (Pounds)
1/2	2 1/2	3,250
5/8	3	4,400
3/4	2 3/4	7,000
1	3 1/2	16,500
1 1/4	4 3/8	25,000
1 1/2	5 1/4	35,500
1 3/4	6	44,500
2	7	57,500

TABLE 4.13

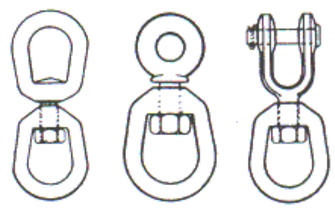
END LINKS
— Weldless Construction
— Forged Alloy Steel



Stock Diameter (Inches)	Inside Width (Inches)	Maximum Safe Working Load (Pounds)
5/16	1/2	2,500
3/8	9/16	3,800
1/2	3/4	6,500
5/8	1	9,300
3/4	1 1/8	14,000
7/8	2	12,000
1	2 1/4	15,200
1 1/4	2 1/2	26,400
1 3/8	2 3/4	30,000

TABLE 4.14

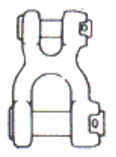
SWIVELS (ALL TYPES)
— Weldless Construction
— Forged Alloy Steel



Stock Diameter (Inches)	Max. Safe Working Load (Pounds)
1/4	850
5/16	1,250
3/8	2,250
1/2	3,600
5/8	5,200
3/4	7,200
7/8	10,000
1	12,500
1 1/8	15,200
1 1/4	18,000
1 1/2	45,200

TABLE 4.15

DOUBLE CLEVIS LINKS
— Weldless Construction
— Forged Alloy Steel



Small Pin Diameter (Inches)	Large Pin Diameter (Inches)	Maximum Safe Working Load (Pounds)
5/16	1/2	3,250
7/16	5/8	6,600
9/16	11/16	8,750
5/8	3/4	11,250

Fig. 4.23 Typical Shackles

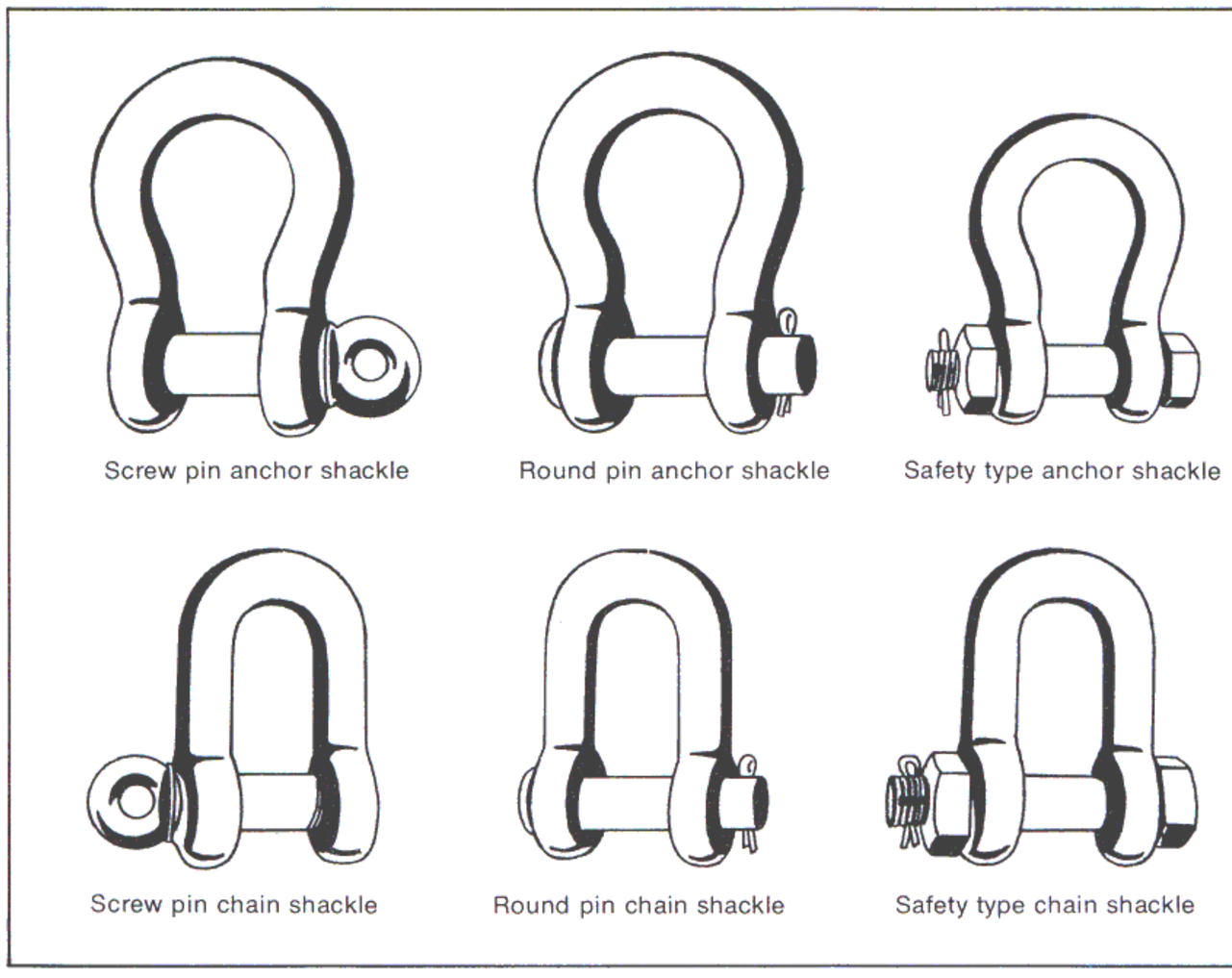


Fig. 4.24 Replacing Shackle Pins

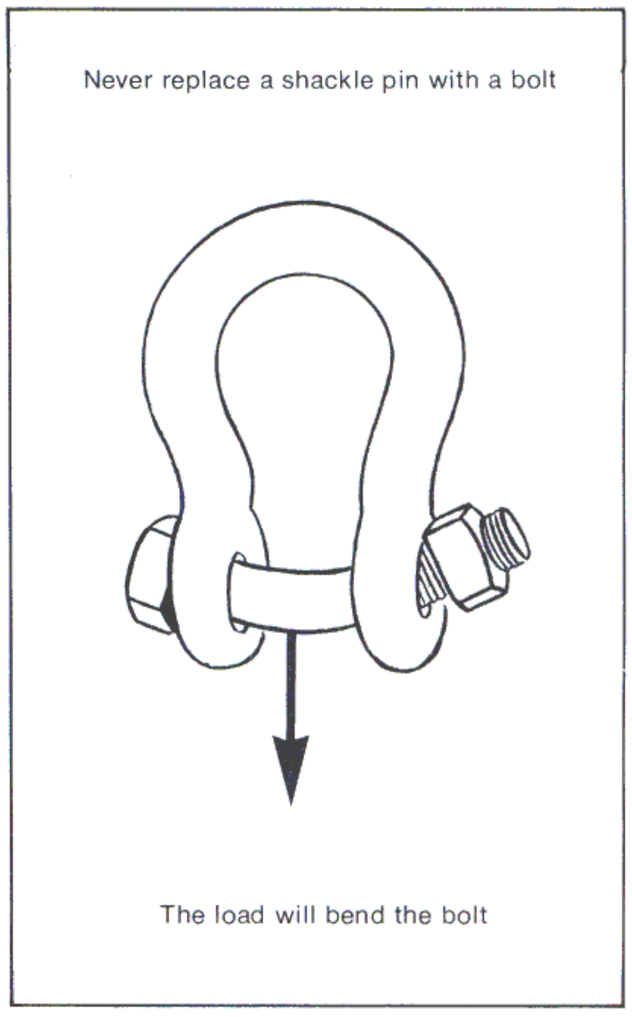


Fig. 4.25 Shackle Inspection Areas

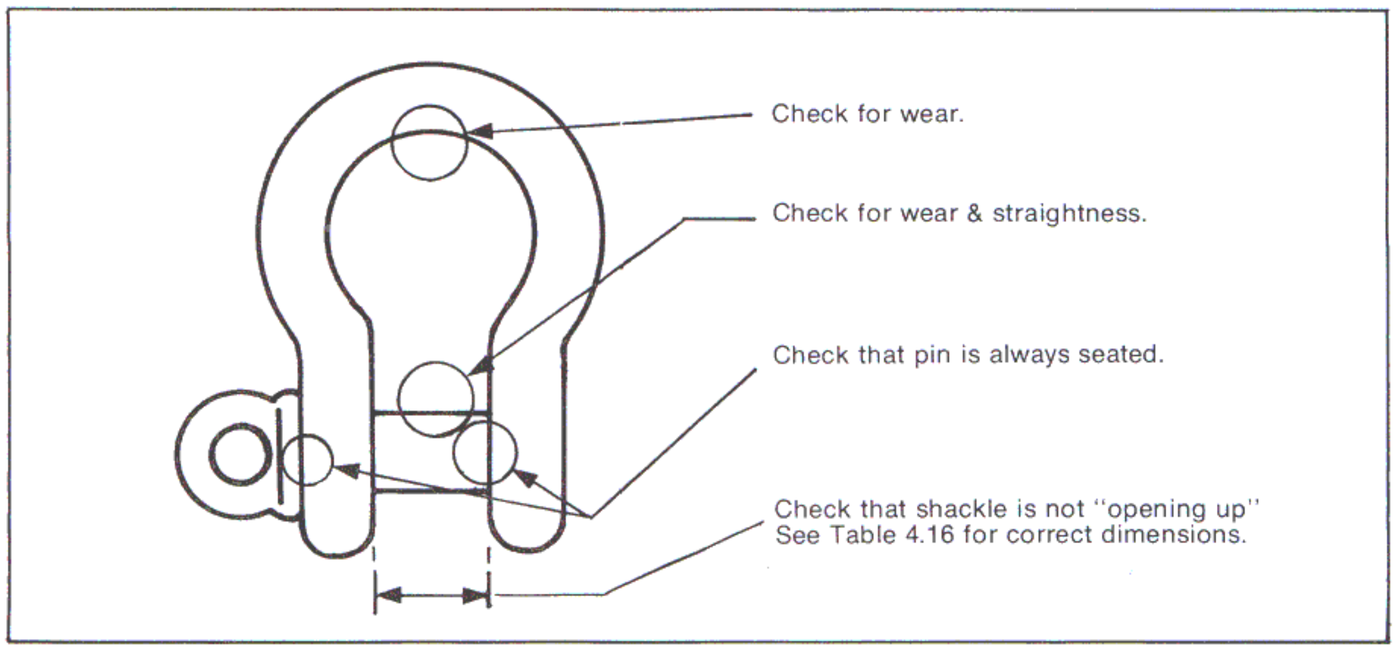


Fig. 4.26 Eccentric Shackle Loads

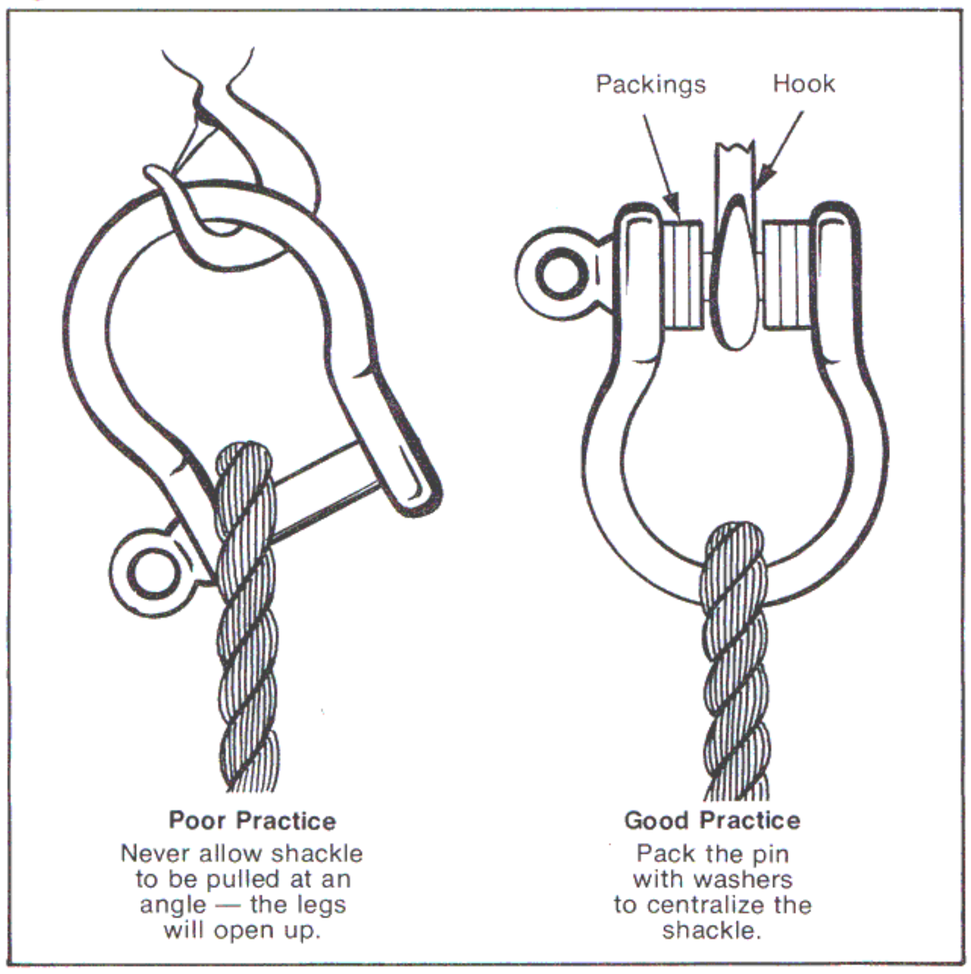
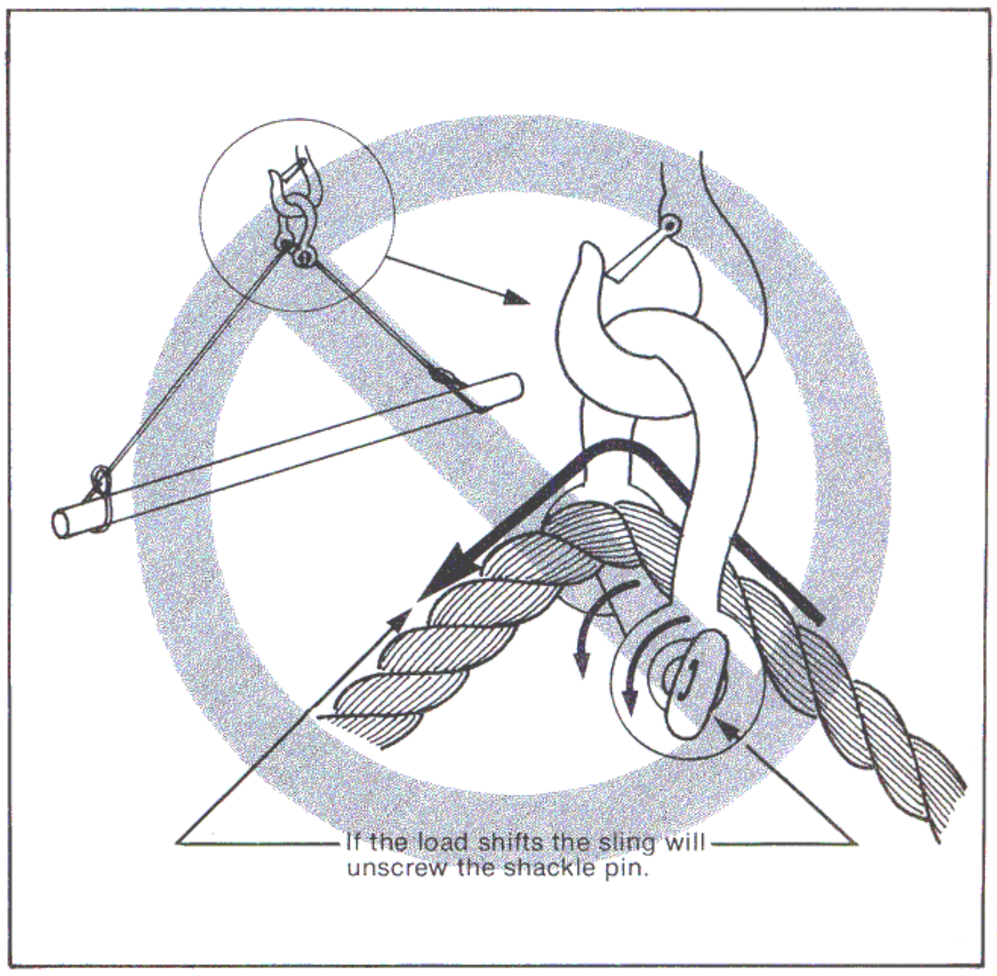


Fig. 4.27 Do Not Use Screw Pin Shackles if the Pin can Roll Under Load and Unscrew



SHACKLES:

There are two types of shackles commonly used in rigging. They are the anchor (bow type) shackle and chain (''D'' type) shackle both of which are available with screw pins or round pins. (Fig. 4.23)

Shackles, like most other rigging hardware are sized by the diameter of the steel in the bow section rather than the pin size. They should only be of forged alloy steel.

Never replace the shackle pin with a bolt, only the proper fitted pin should be used. Bolts are not intended to take the bending that is normally applied to the pin. (Fig. 4.24)

Never use a shackle if the distance between the eyes is greater than listed in the following table. All pins must be straight and all screw pins must be completely seated. Cotter pins must be used with all round pin shackles.

Shackles worn in the crown or the pin by more than 10% of the original diameter should be destroyed. (Fig. 4.25)

Never allow a shackle to be pulled at an angle because the capacity will be tremendously reduced. Centralize whatever is being hoisted on the pin by suitable washers or spacers. (Fig. 4.26)

Do not use screw pin shackles if the pin can roll under load and unscrew. (Fig. 4.27)

Refer to Table 4.16 for the rated safe working loads of shackles.

TABLE 4.16

SHACKLES (ALL TYPES) — Weldless Construction — Forged Alloy Steel		
Stock Diameter (Inches)	Inside Width At Pin (Inches)	Max. Safe Working Load Single Vertical Pull (Pounds)
3/16	3/8	665
1/4	15/32	1,000
5/16	17/32	1,500
3/8	21/32	2,000
7/16	23/32	3,000
1/2	13/16	4,000
5/8	1 1/16	6,500
3/4	1 1/4	9,500
7/8	1 7/16	13,000
1	1 11/16	17,000
1 1/8	1 13/16	19,000
1 1/4	2 1/32	24,000
1 3/8	2 1/4	27,000
1 1/2	2 3/8	34,000
1 3/4	2 7/8	50,000
2	3 1/4	70,000
2 1/2	4 1/8	100,000
3	5	150,000
3 1/2	5 3/4	200,000
4	6 1/2	260,000

EYE BOLTS:

It is recommended that all eye bolts and ring bolts used for hoisting be of forged alloy steel and equipped with shoulders or collars. The plain or shoulderless eye bolt is fine for vertical loading but as soon as it is loaded at an angle it is subjected to bending and the load it can safely carry is severely reduced. (Fig. 4.28)

Even when equipped with shoulders, the safe working loads of eye bolts and ring bolts are reduced with angular loading. When installed the shoulder must be at right angles to the axis of the hole and must contact the working surface and the nuts must be properly torqued. Washers may have to be used to ensure that the shoulders are firmly in contact with the working surface. The tapped hole for screwed eye bolts (body bolts) should have a minimum depth of one and one-half times the bolt diameter and must be a good fit for the screwed shank of the eye bolt. (Fig. 4.29)

To keep the bending to a minimum, the loads should always be applied to the plane of the eye, never in the other direction. This is particularly important when bridle slings are used because an angular pull is always developed in the eye bolts, unless a spreader bar is used as part of the sling. (Fig. 4.30)

Never insert the point of a hook in an eye bolt, always use a shackle. (Fig. 4.31)

Do not use a sling reeved through an eye bolt or reeved through a pair of eye bolts. One single leg only should be attached to each eye bolt. (Fig. 4.32)

Where eye bolts cannot be kept in line with each other and at the same time tightened, thin washers or shims may be inserted under the collars to permit the eye bolt being tightened and turned in line with each other. (Fig. 4.33)

The same precautions apply to ring bolts and the working loads are generally the same as for the eye bolts.

Refer to Table 4.17 for the rated safe working loads of eye bolts.

Fig. 4.28 Use of Eye Bolts

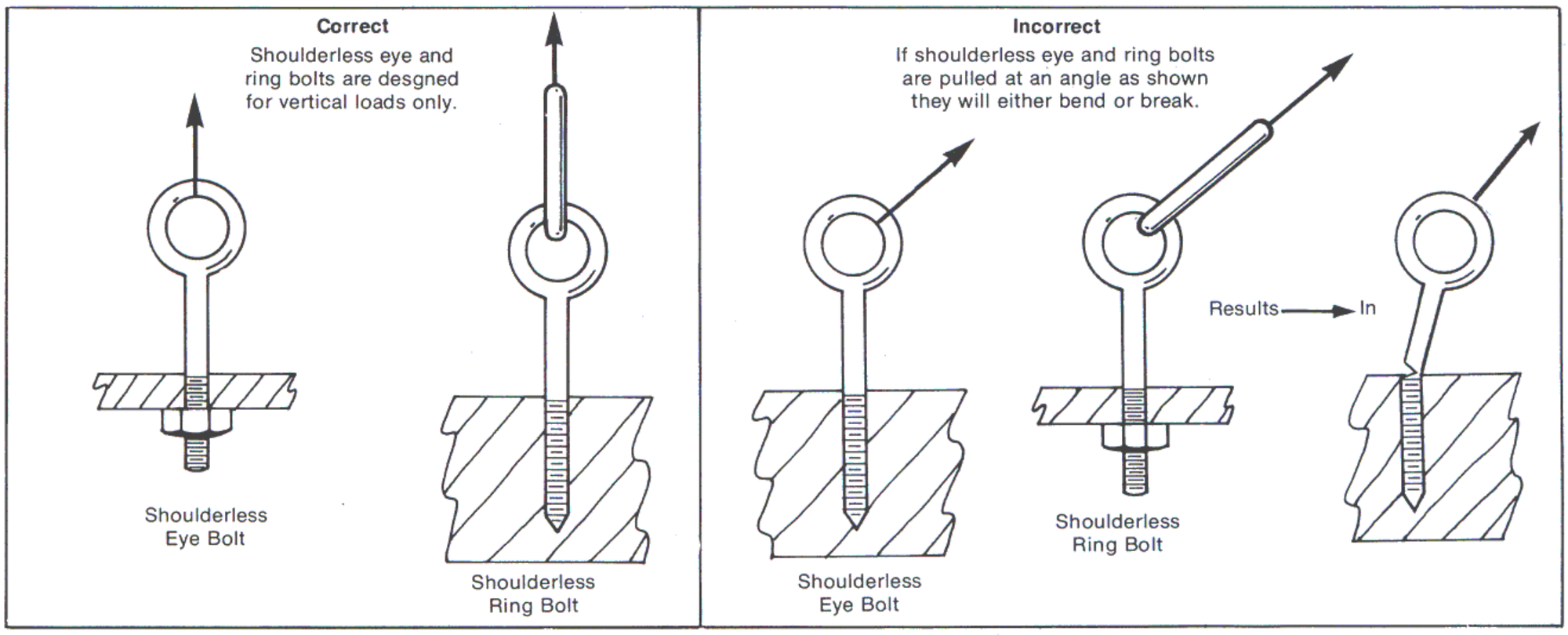


Fig. 4.29 Use of Shoulder Type Eye and Ring Bolts

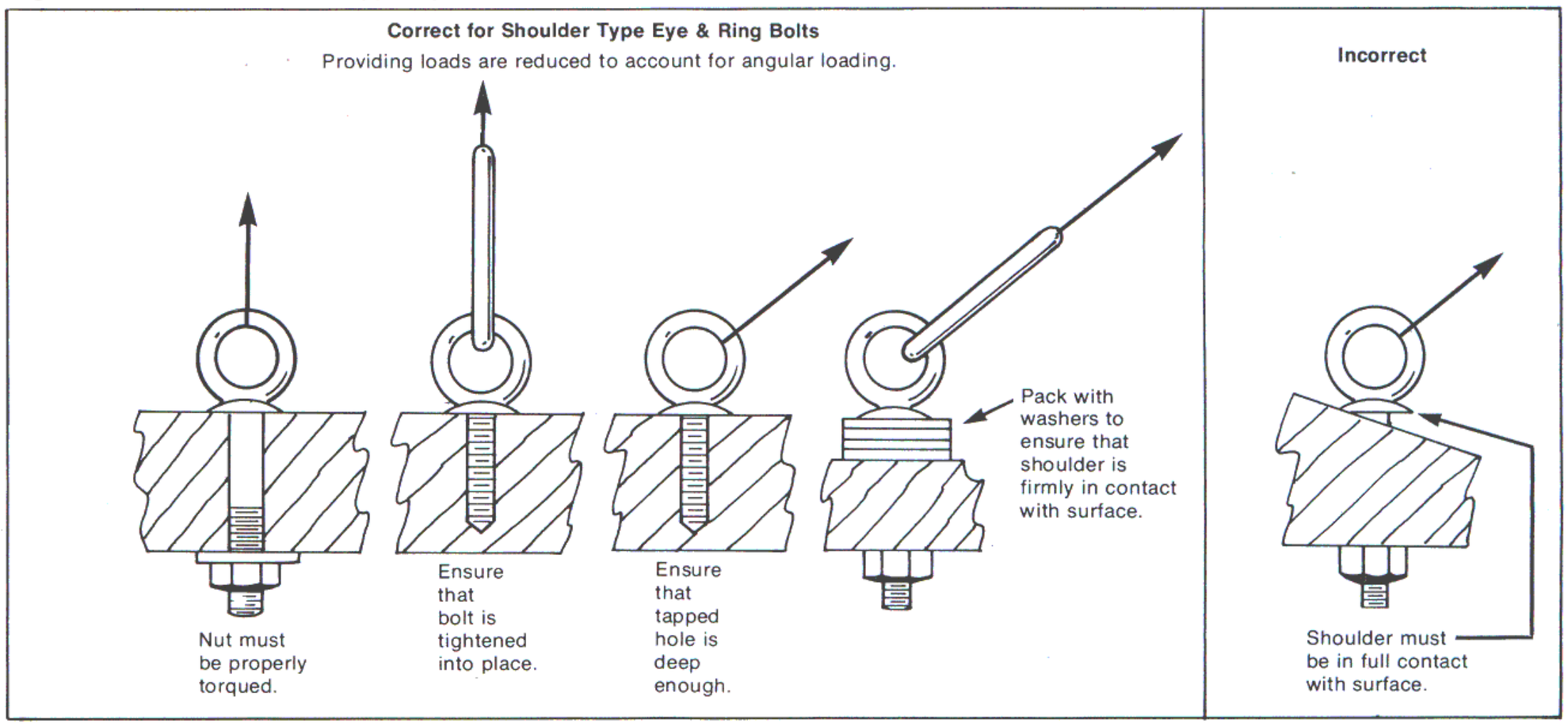


Fig. 4.30 Orientation of Eye Bolts

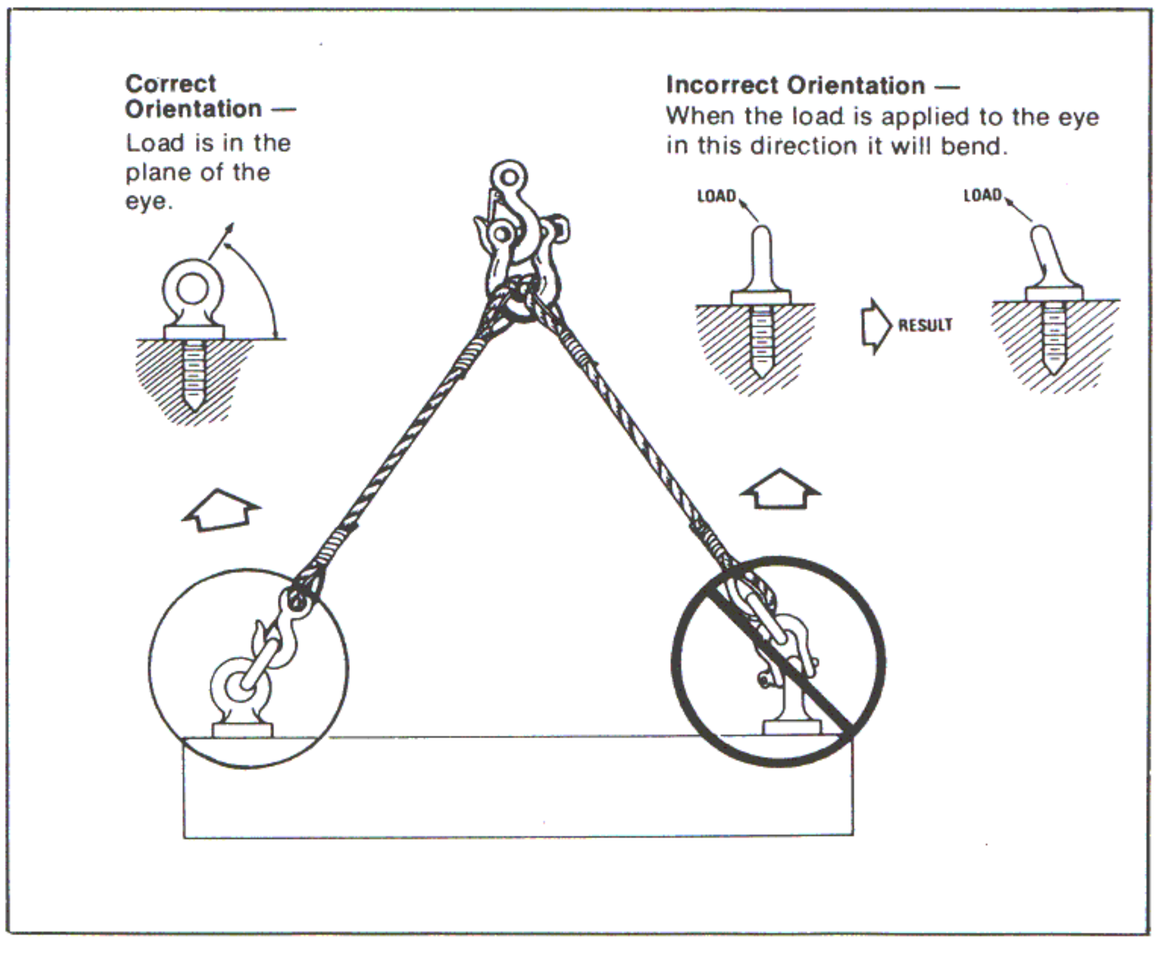


Fig. 4.31 Never Insert the Point of a Hook in an Eye Bolt

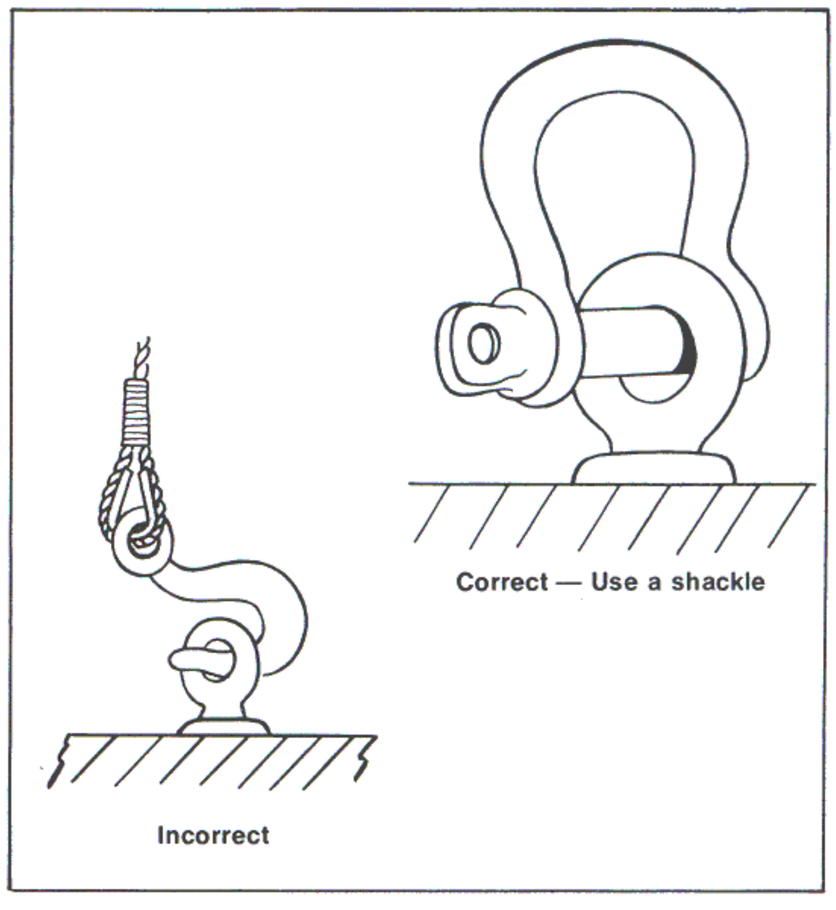


Fig. 4.32 Lifting With Eye Bolts

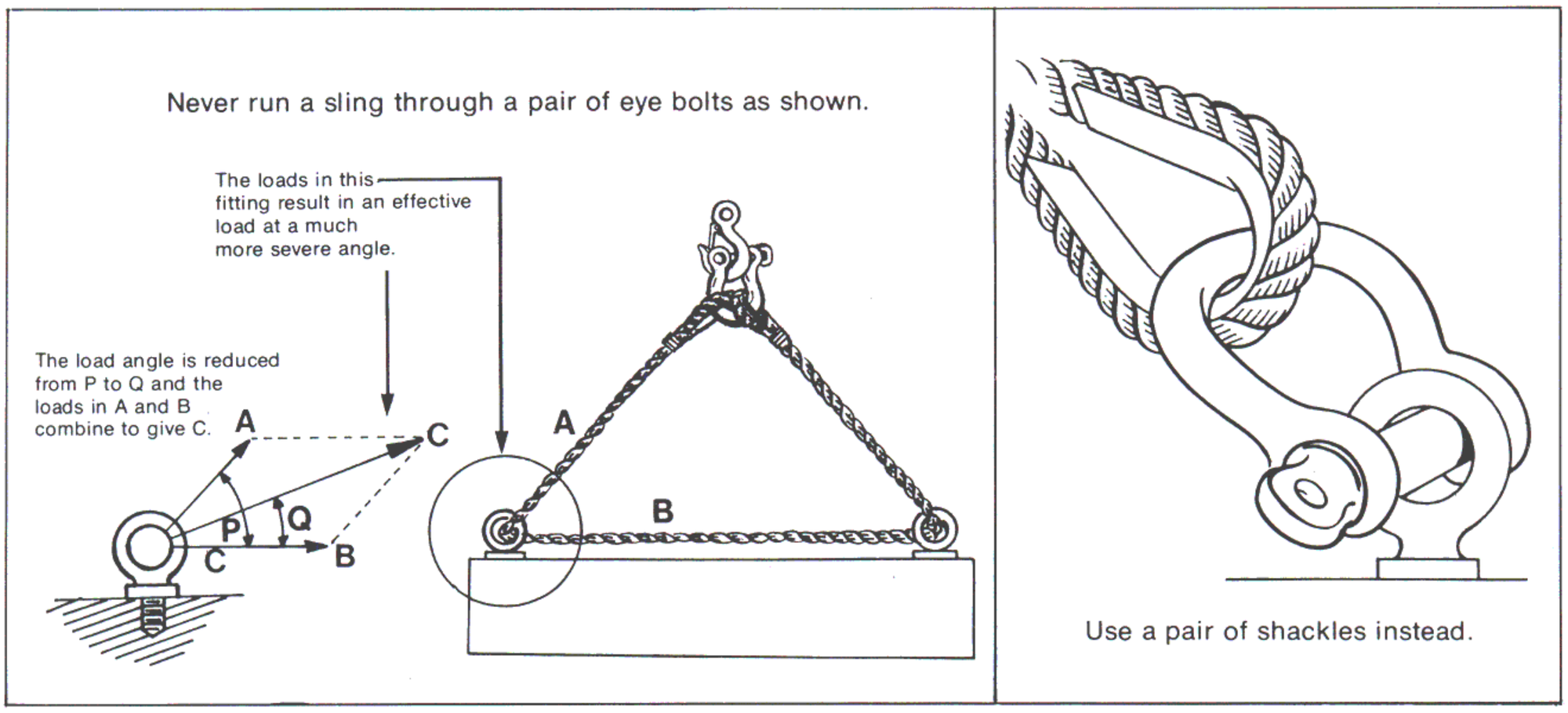


Fig. 4.33 Alignment of Eye Bolts

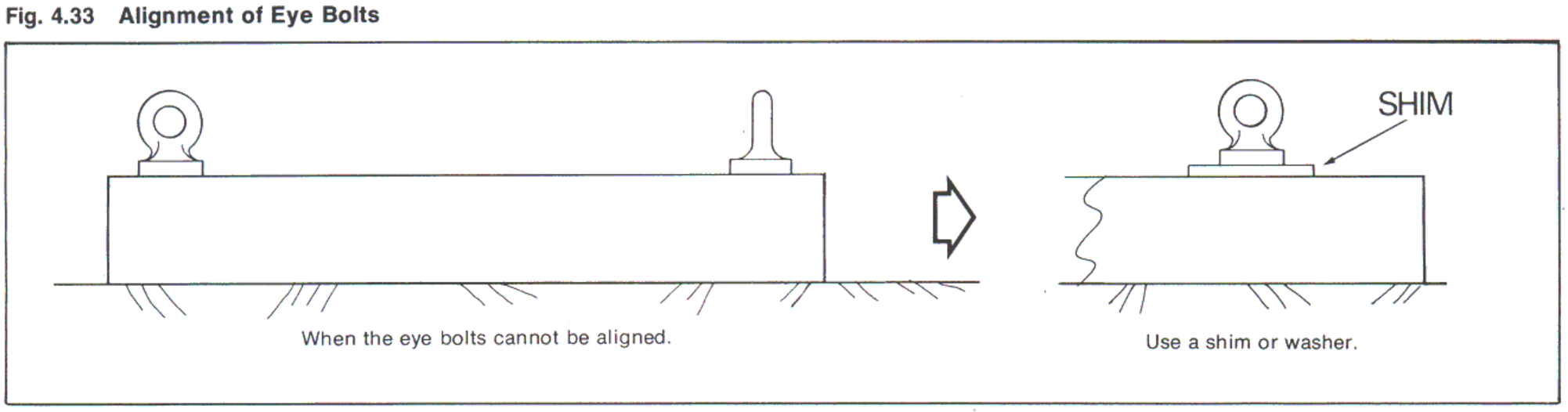
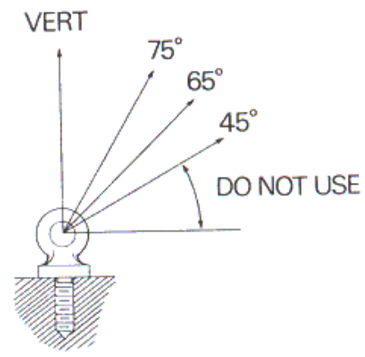


TABLE 4.17

EYE BOLTS
— Shoulder Type Only
— Forged Carbon Steel



Stock Diameter (Inches)	SAFE WORKING LOADS (LBS) CORRESPONDING TO ANGLE OF PULL				
	Vertical	75°	60°	45°	Less than 45°
1/4 5/16 3/8 1/2 5/8 3/4 7/8 1 1 1/4 1 1/2	500 800 1,200 2,200 3,500 5,200 7,200 10,000 15,200 21,400	Reduce Vertical Loads By 45%.	Reduce Vertical Loads By 65%.	Reduce Vertical Loads By 75%.	NOT RECOMMENDED

Note: S.W.L. for plain (shoulderless) eye bolts are same as for shoulder bolts under vertical load. Angular loading is not recommended.

Fig. 4.34 Turnbuckles

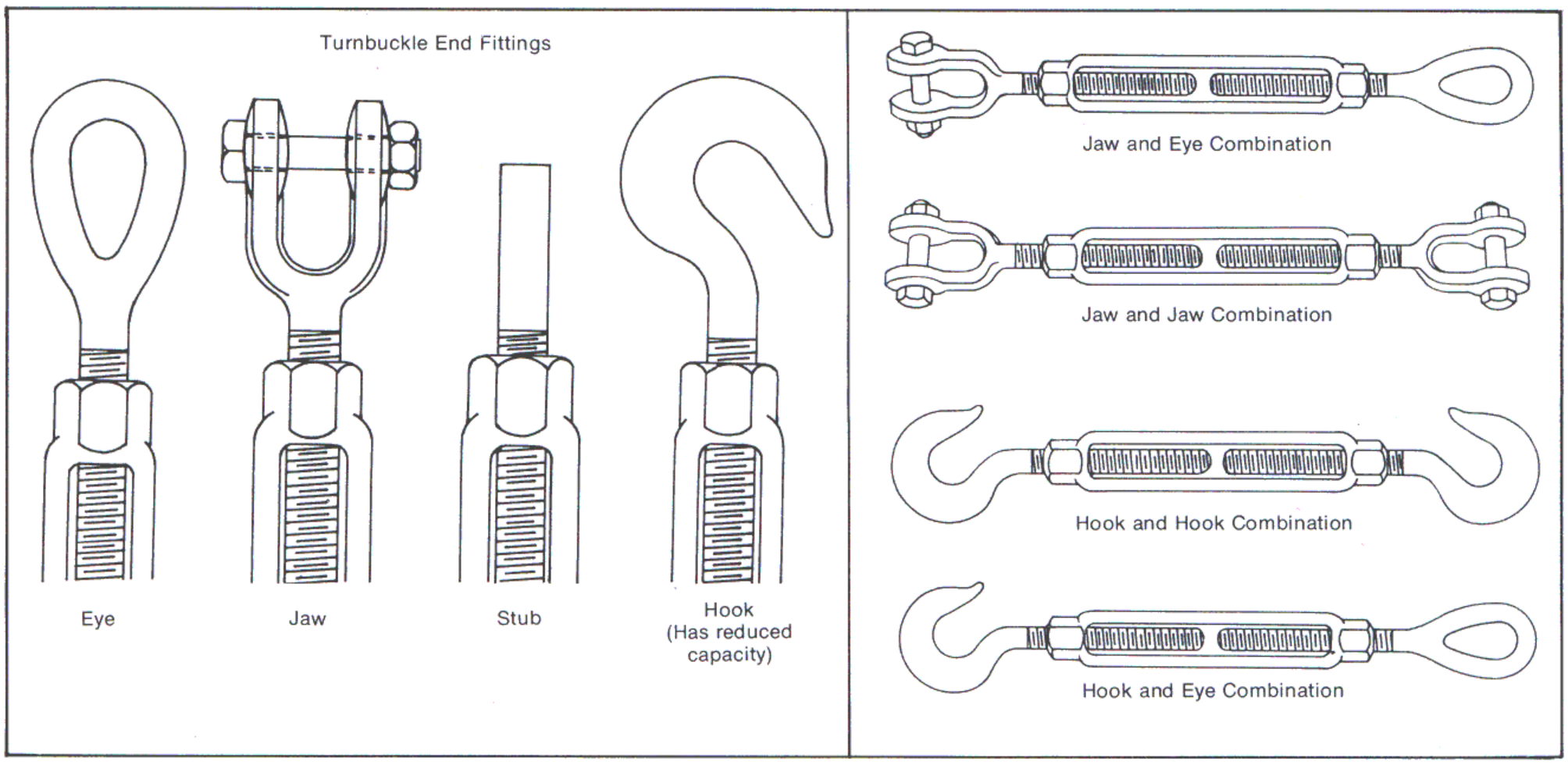


Fig. 4.35 Securing of Turnbuckle End Fittings

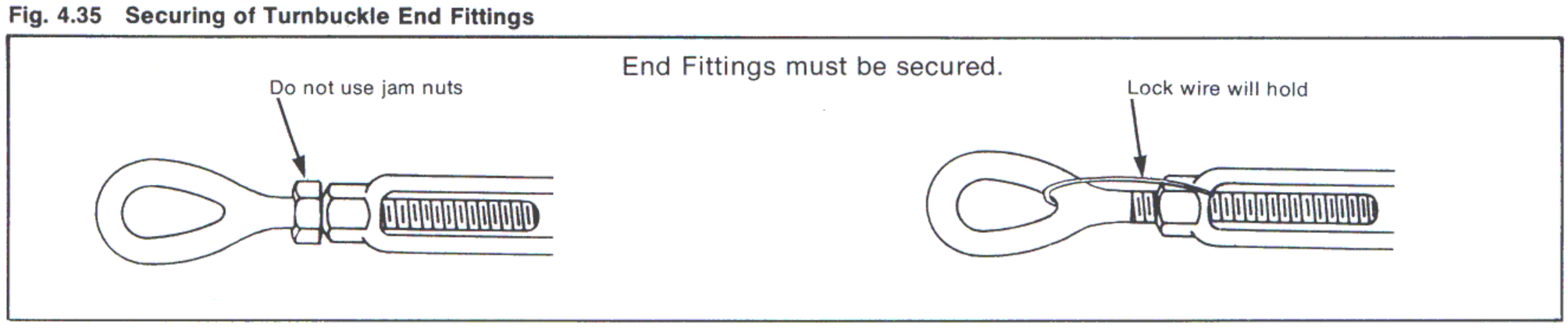


Fig. 4.36 Turnbuckle Inspection Areas

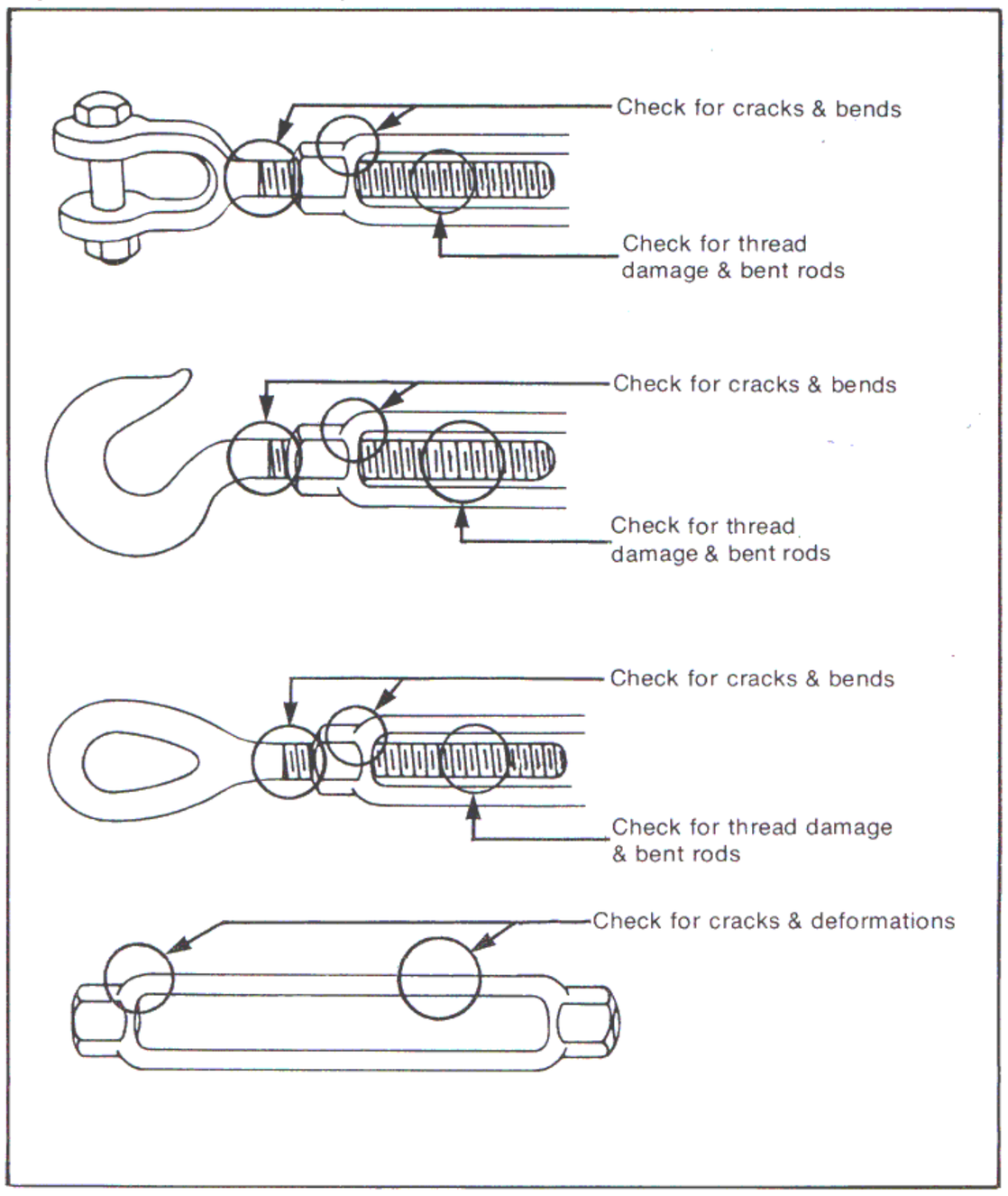


TABLE 4.18

TURNBUCKLES — Weldless Construction — Forged Alloy Steel		
End Fitting, Stock Diameter (Inches)	SWL of Any Combination of Jaw End Fittings, Eye End Fittings and Stub End Fittings (Lbs)	SWL of Any Turnbuckle Having a Hook End Fitting (Lbs)
1/4	500	400
5/16	800	700
3/8	1,200	1,000
1/2	2,200	1,500
5/8	3,500	2,250
3/4	5,200	3,000
7/8	7,200	4,000
1	10,000	5,000
1 1/4	15,200	5,000
1 1/2	21,400	7,500
1 3/4	28,000	—
2	37,000	—
2 1/2	60,000	—
2 3/4	75,000	—

TURNBUCKLES:

Turnbuckles can be supplied with eye end fittings, hook end fittings, jaw end fittings, stub end fittings, and any combination of these. Their rated loads depend upon the outside diameter of the threaded portion of the end fitting and on the type of end fitting. The jaw, eye and stub types are rated equally and the hook types have reduced ratings. (Fig. 4.34)

All turnbuckles used in hoisting or rigging operations should be of weldless construction and fabricated from alloy steel. When they are supplied with hook end fittings ensure that the hooks are fitted with safety catches.

If the turnbuckle is to be used in an application where vibration is present it is extremely important to lock the frame to the end fittings to prevent it from turning and loosening. Lock nuts or jam nuts are not effective and add greatly to the load in the screw thread. (Fig. 4.35)

When tightening up a turnbuckle, do not apply any more torque to it than you would to a bolt of equal size.

Turnbuckles should be inspected frequently for cracks in the end fittings, especially at the neck of the shank, deformed end fittings, deformed and bent rods and bodies, cracks and bends around the internally threaded portion and signs of thread damage. (Fig. 4.36)

Refer to Table 4.18 for the rated safe working loads of turnbuckles.

SPREADER AND EQUALIZER BEAMS:

Spreader beams are usually used to support long loads during lifts. They eliminate the hazard of the load tipping, sliding or bending as well as the possibility of low sling angles and the tendency of the slings to crush the load. Equalizer beams are used to equalize the load in sling legs and to keep equal loads on dual hoist lines when making tandem lifts. (Fig. 4.37)

Both types of beams are normally fabricated to suit a specific application. If a beam is to be used which has not been designed for the application, make sure it has adequate width, depth, length, and material.

The capacity of beams with multiple attachment points depends upon the distance between the points. For example, if the distance between the attachment points is doubled, the capacity of the beam is halved.

BLOCKS:

The hoisting and moving of heavy objects or objects weighing more than the safe working load of the rope being used calls for multiplication of the pulling force or changing the direction of pull, or both. Blocks make this possible.

The blocks used in construction rigging can run from the custom designed 400 ton capacity unit weighing 20 tons through all types of crane and hook blocks, wire rope blocks, snatch blocks down to the simplest of tackle blocks.

The essential parts of any block are the shell, the sheaves, the center pin, the straps and the connections. (Fig. 4.38) They can be equipped with a number of end fittings including hooks, wedge sockets, clevis', shackles of all types and swivels of all types as well as combinations of these items. The blocks may also be equipped with a becket which is the term used for a rope end anchorage point on a block.

The shell provides protection for the sheave or sheaves and acts as a guide to keep the rope in place in the sheave groove. Wood shells add no strength to the block but merely serve as an enclosure for the sheaves. They are used for fibre ropes only. Steel shells are used on all blocks with wire rope. They add strength, rigidity and protection for the block.

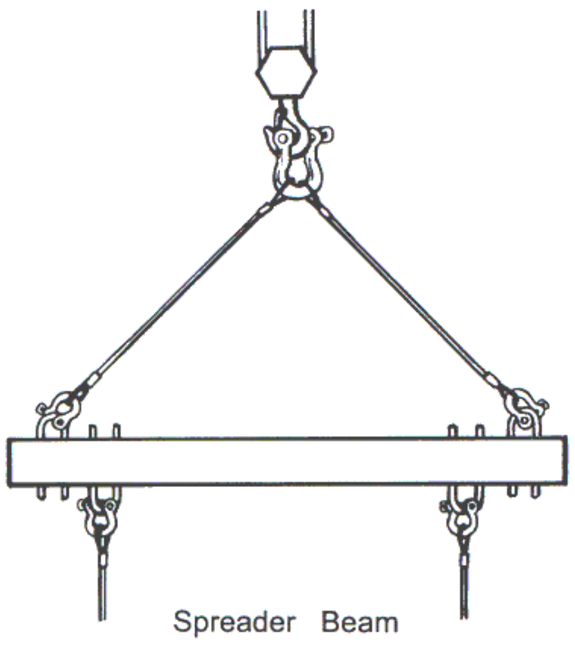
The straps and side or cheek plates perform the important structural function of transmitting the sheave load to the connections and add rigidity to the block.

The sheaves transmit the load imposed by the rope to the center pin, straps and connections. On fibre rope blocks the sheaves are normally fabricated from cast iron but on wire rope blocks they should be cast steel because of its greater strength, hardness and abrasion resistance. Never run fibre ropes over sheaves that have been used with wire ropes — rapid rope damage will result. Fibre rope sheaves must not be used with wire rope because their diameters are too small.

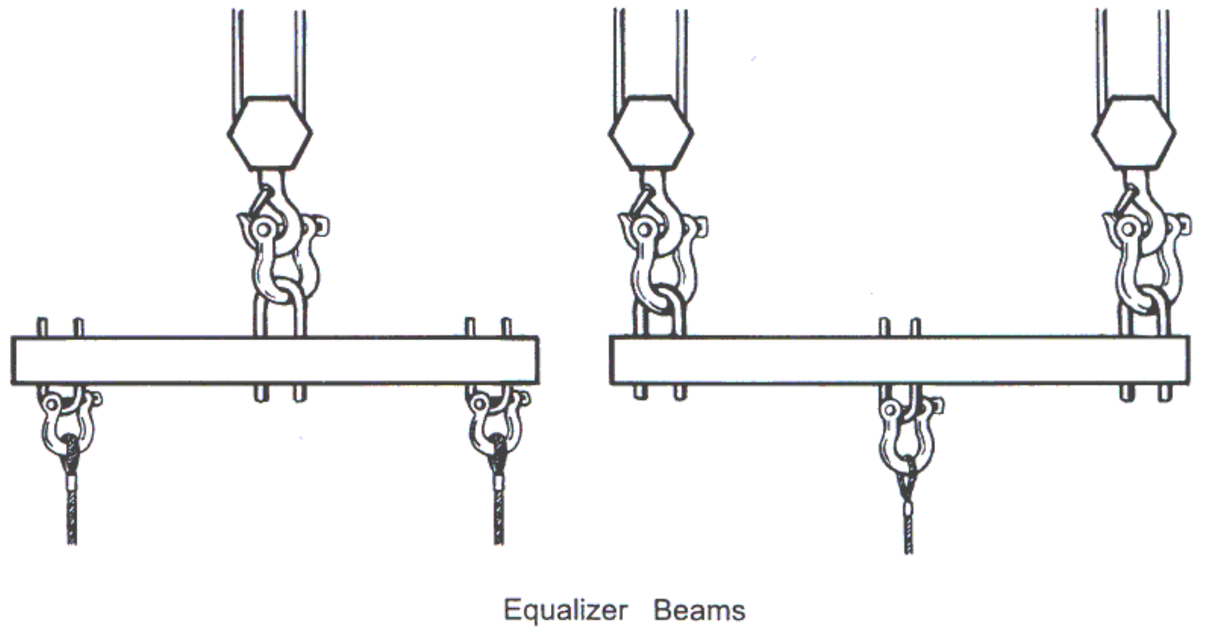
In **plain bore sheaves** the cast iron of the sheave provides its own bearing. They are recommended for light, intermittent service only and they must be frequently oiled to reduce friction and avoid excessive wear. (Sketch A Fig. 4.39)

Roller bushed sheaves are made with unground rollers and without races are recommended for light, intermittent service only. They must be lubricated periodically with a heavy grease. (Sketch B Fig. 4.39)

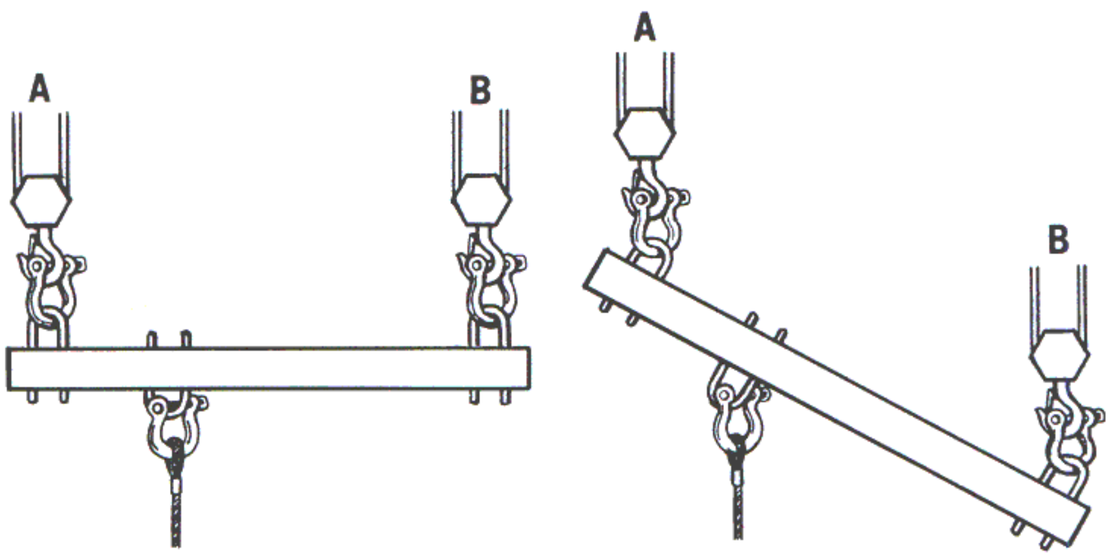
Fig. 4.37 Spreader and Equalizer Beams



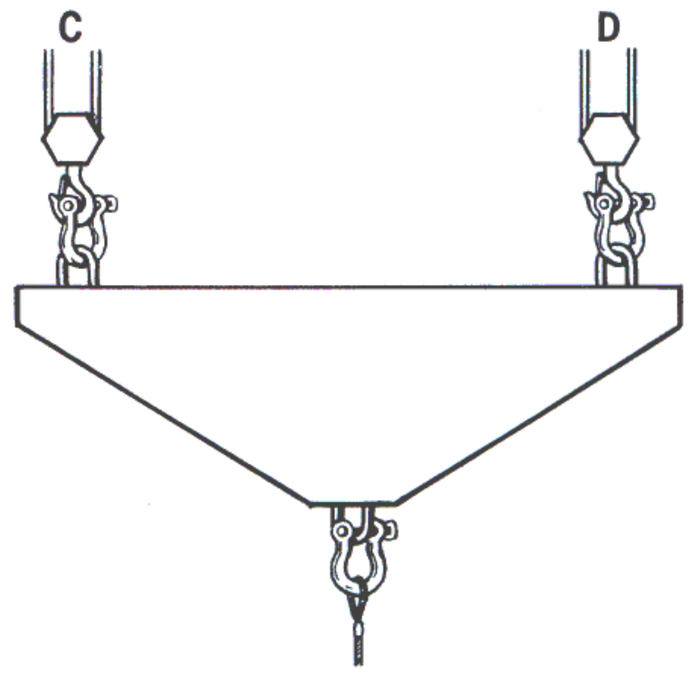
Spreader Beam



Equalizer Beams



Loads in A & B do not change when beam angle changes



Loads in C & D will change if beam angle changes

Combination of spreader and equalizer beams

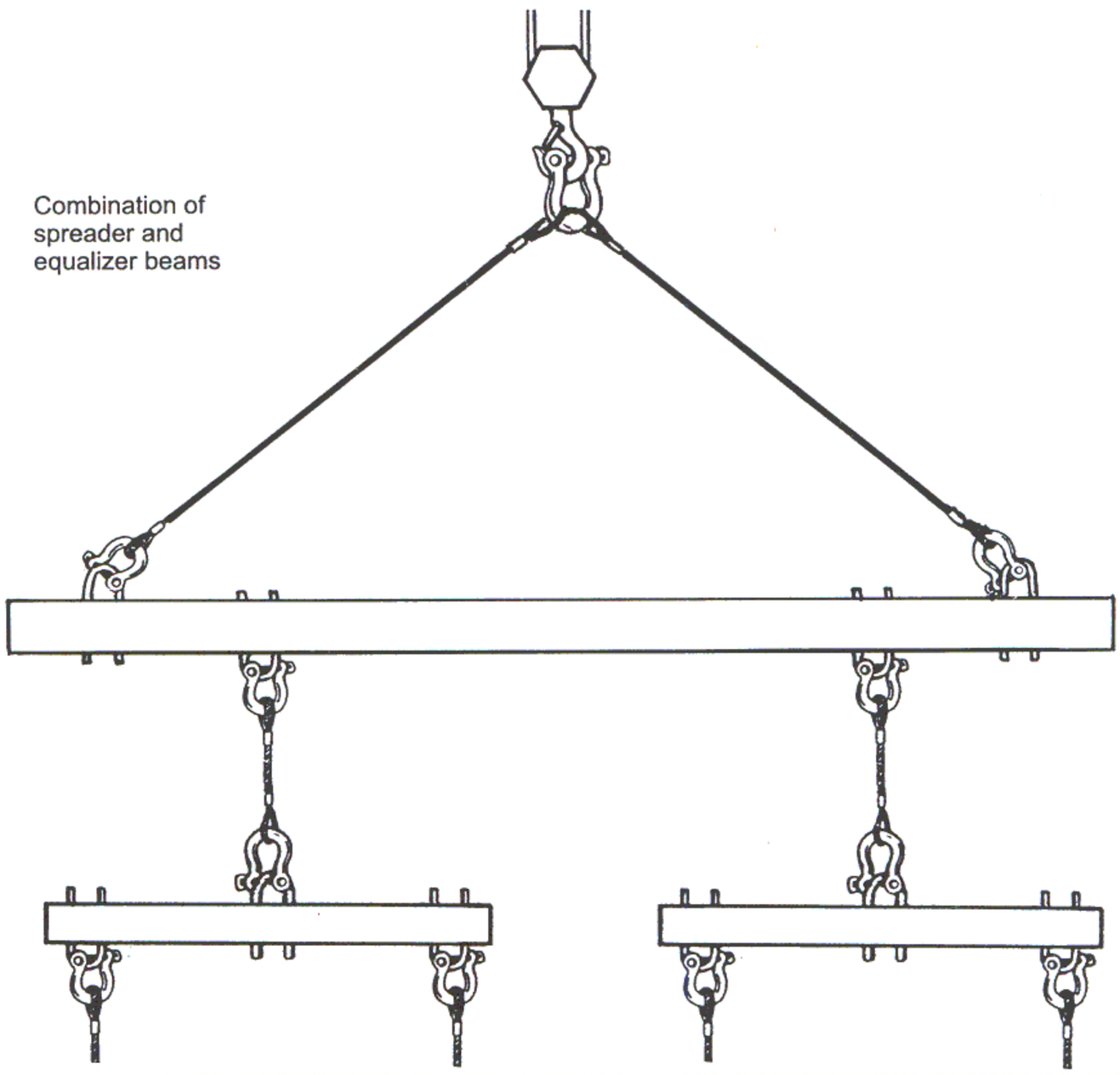
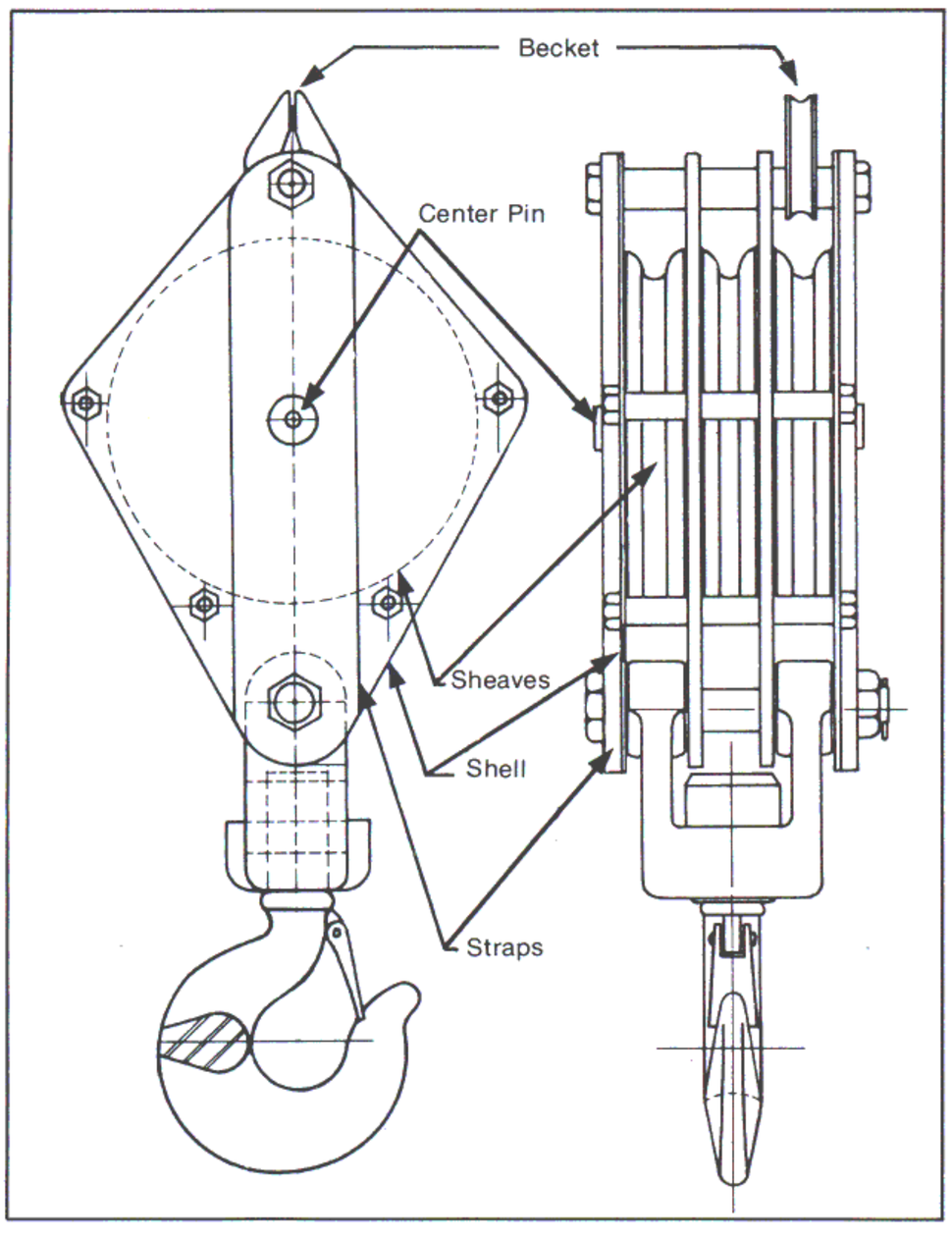


Fig. 4.38 Typical Wire Rope Block



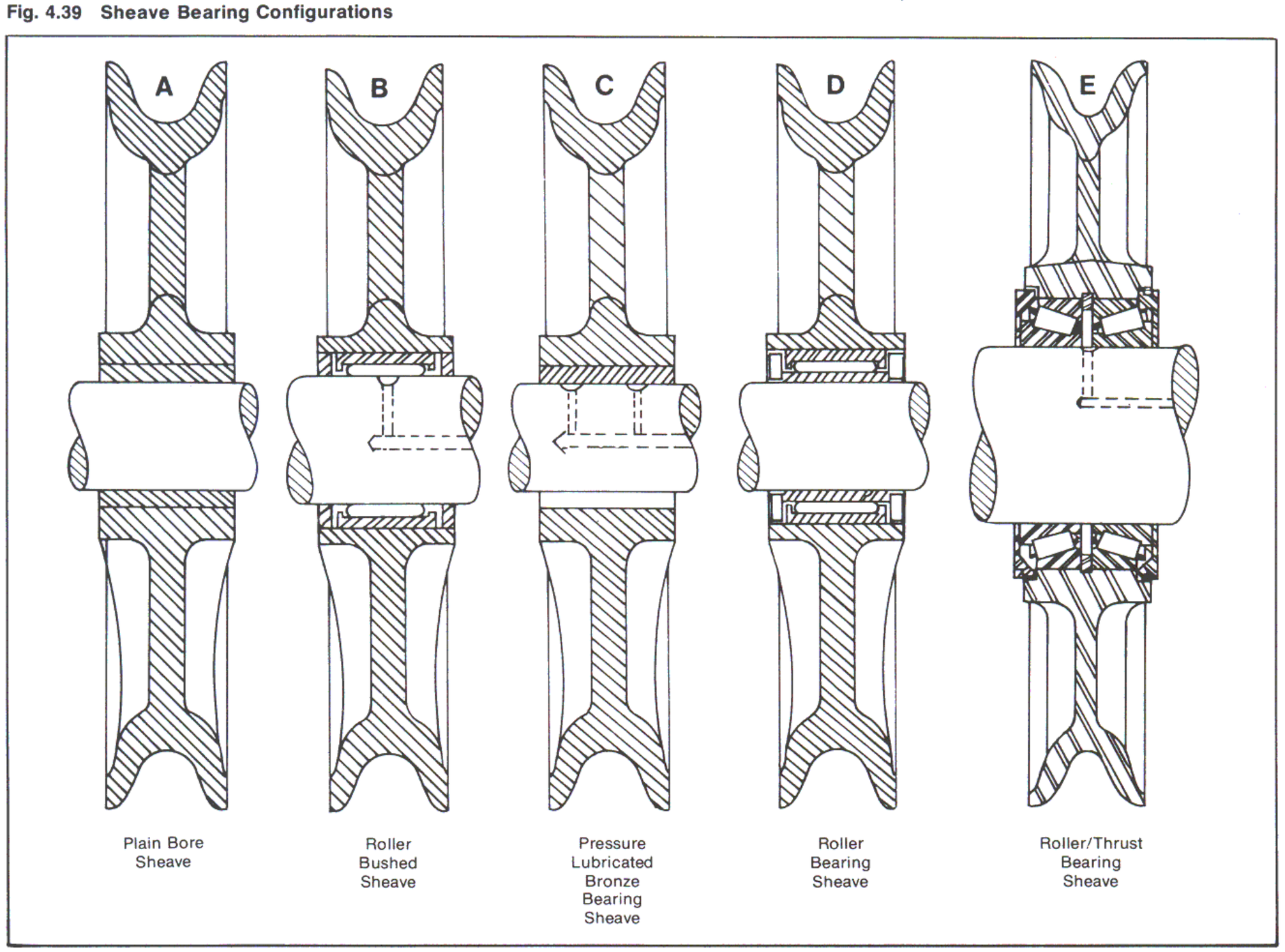
Self-lubricating bronze bearings are recommended where service requirements are severe or where the block cannot be frequently lubricated. They should not be subjected to high speed or continuous operation. The plug type of bearing should not be lubricated or oiled. Oil dissolves and washes away the graphite-wax mixture, destroying the bearings' self-lubricating characteristics. Oil is not harmful to the graphite impregnated type of bearing.

Pressure lubricated bronze bearings are recommended where loads are extra heavy and continuous. Frequent, periodic lubrication is required. (Sketch C Fig. 4.39)

Roller bearing sheaves are made with ground rollers and full races and are recommended for medium duty and high speed operation. (Sketch D Fig. 4.39)

Precision Anti-friction bearings capable of sustaining both radial and thrust loads are particularly suited to continuous high operating speeds and heavy loads. They combine long life with minimum maintenance. (Sketch E Fig. 4.39)

Fig. 4.39 Sheave Bearing Configurations



The center pin, sometimes called the sheave pin, transmits the sheave load to the strap. It should be prevented or restrained from turning. (Fig. 4.40)

All fittings on the blocks should be forged alloy steel. Shackles and eyes are inherently stronger than hooks; blocks equipped with them are rated at higher working loads. They are recommended for block connections where the block is to be mounted permanently, where accidental disengagement of the hook connection would be dangerous or where higher strength ratings are needed. Shackle connections are particularly recommended for standing blocks which must support not only the load, but also the hoisting strain of the lead line.

Blocks usually take their name from the purpose for which they are used, the position they occupy or from a particular shape or type of construction. They can be designated according to the number of sheaves they have as single, double, triple, etc. or in accordance with the shell shape as diamond pattern, oval pattern, etc.

For the purposes of this manual, however, the most commonly used types of blocks are designated as:

(a) **Crane and Hook Blocks.** (Fig. 4.41)
(b) **Wire Rope Blocks.** (Fig. 4.42)
(c) **Snatch Blocks.** (Fig. 4.43)
(d) **Tackle Blocks.** (Fig. 4.44)

Fig. 4.40 Block Center Pins

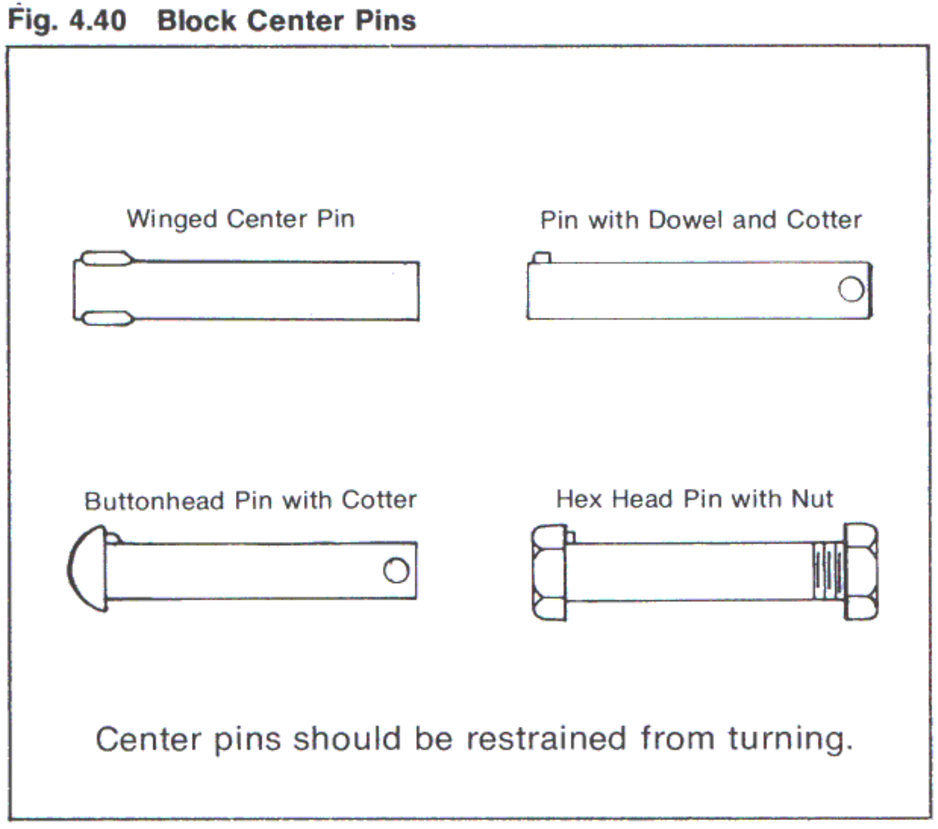


Fig. 4.41 Typical Crane & Hook Block

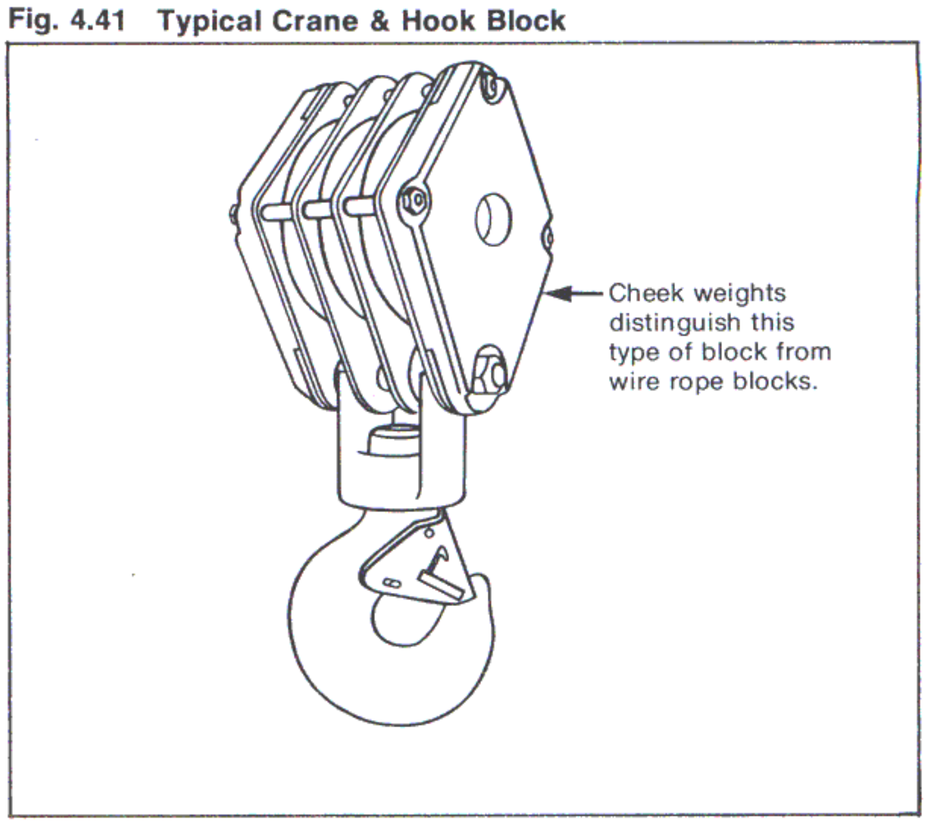
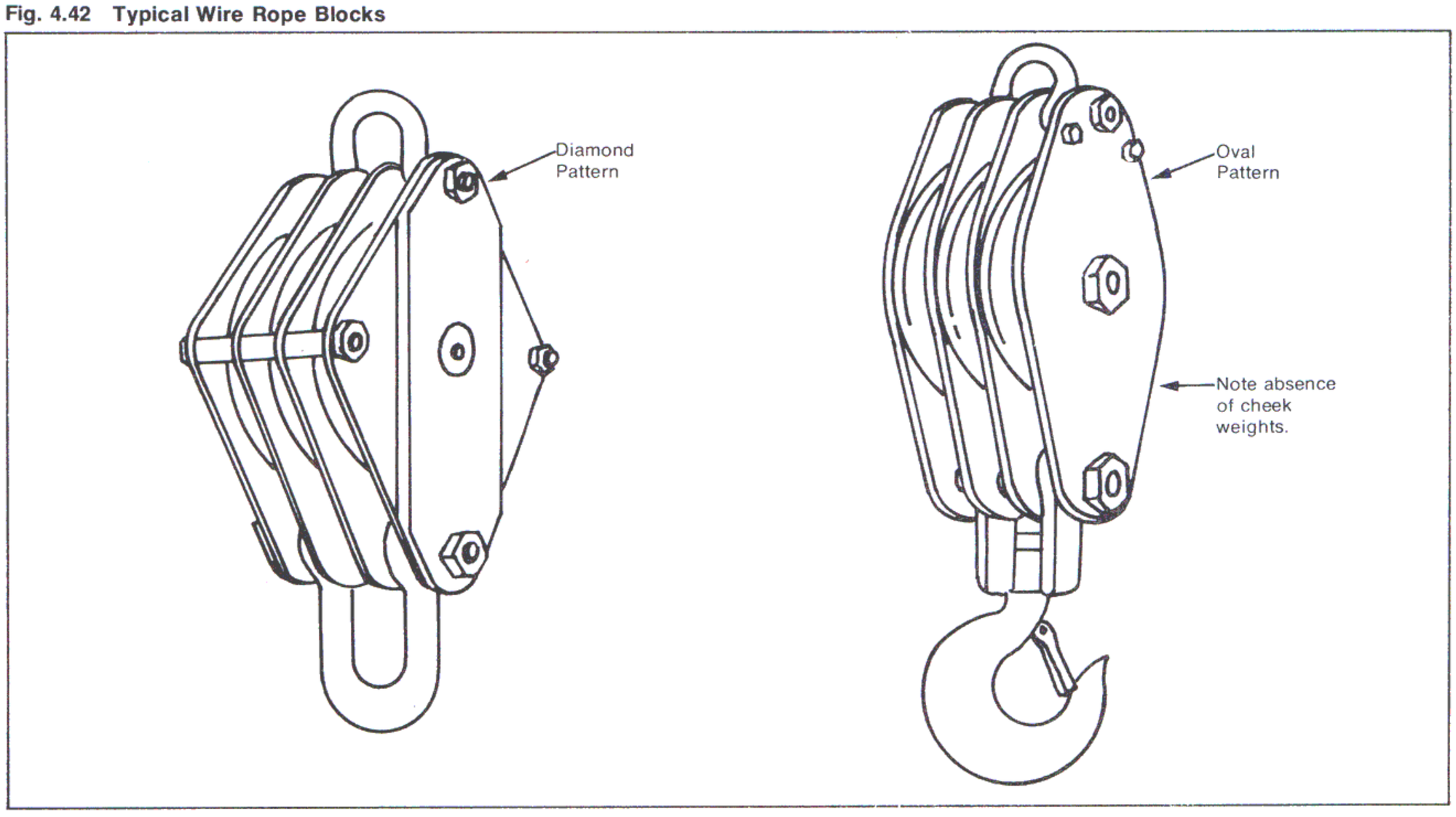


Fig. 4.42 Typical Wire Rope Blocks



The basic differences between them relate to their construction and are evident from the illustrations. **Crane and Hook Blocks** are equipped with heavy iron cheek weights whereas the **Wire Rope Blocks** are normally much lighter and are equipped with cheek straps that provide strength between the end attachments and sheave center pins. Both types are well suited to high speed applications and heavy loads, however, the wire rope blocks are not intended to withstand the heavy service and abuse expected of the Crane and Hook Blocks.

A **Snatch Block** can be a single or multi-sheave block that opens on one side to permit a rope to be slipped over the sheave thus eliminating the need for it to be threaded through the block. They are available in many configurations for wire rope, manila rope and synthetic ropes, and can be purchased with hook, shackle, eye and swivel end fittings.

Snatch blocks are normally used when it is necessary to change the direction of the pull on a line. In cases such as this, the stress on the snatch block varies tremendously with the angle between the lead and load lines. When the two lines are parallel, 1000 pounds on the lead line results in a load of 2000 pounds on the block, hook and whatever it is hooked onto. As the angle between the lines increases, the stress on the block and hook is reduced as illustrated in Fig. 4.45.

Fig. 4.43 Typical Snatch Blocks

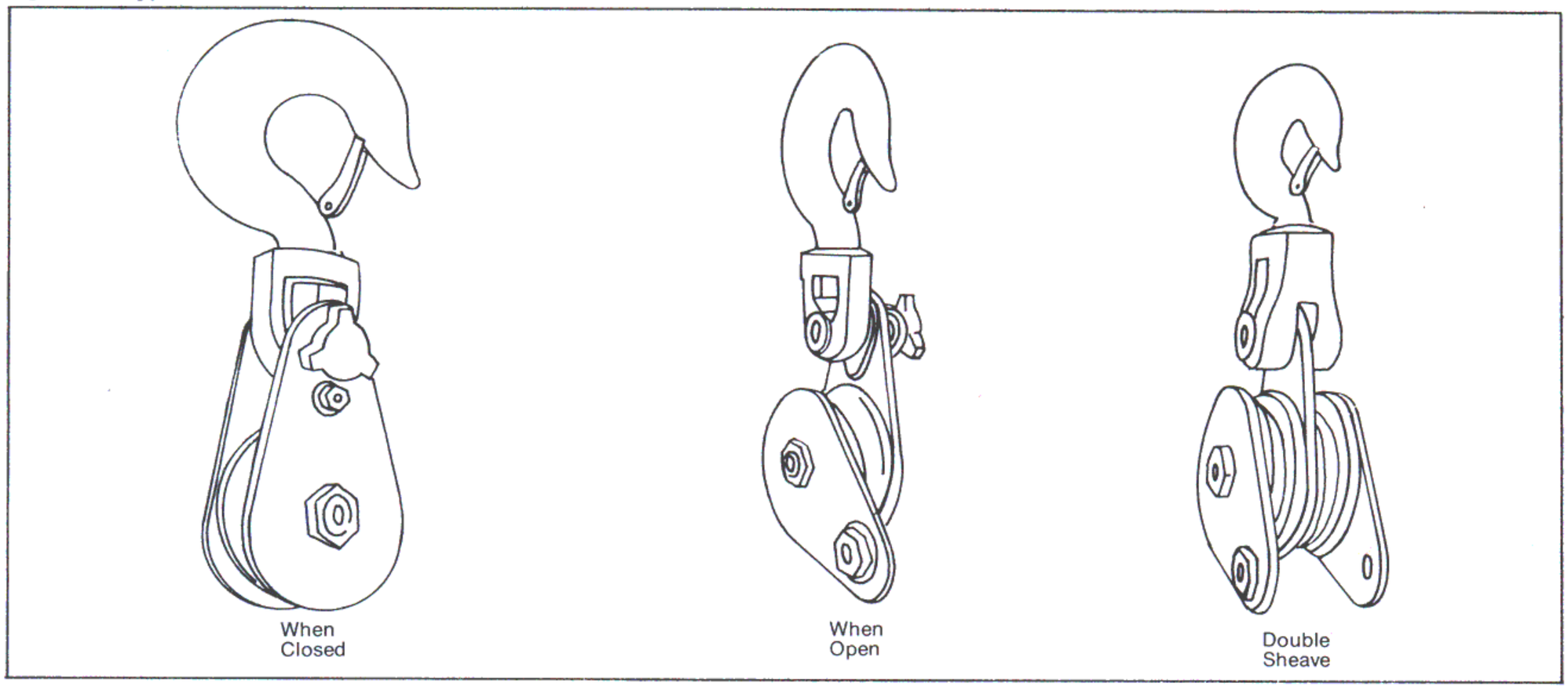


Fig. 4.44 Tackle Block Fittings

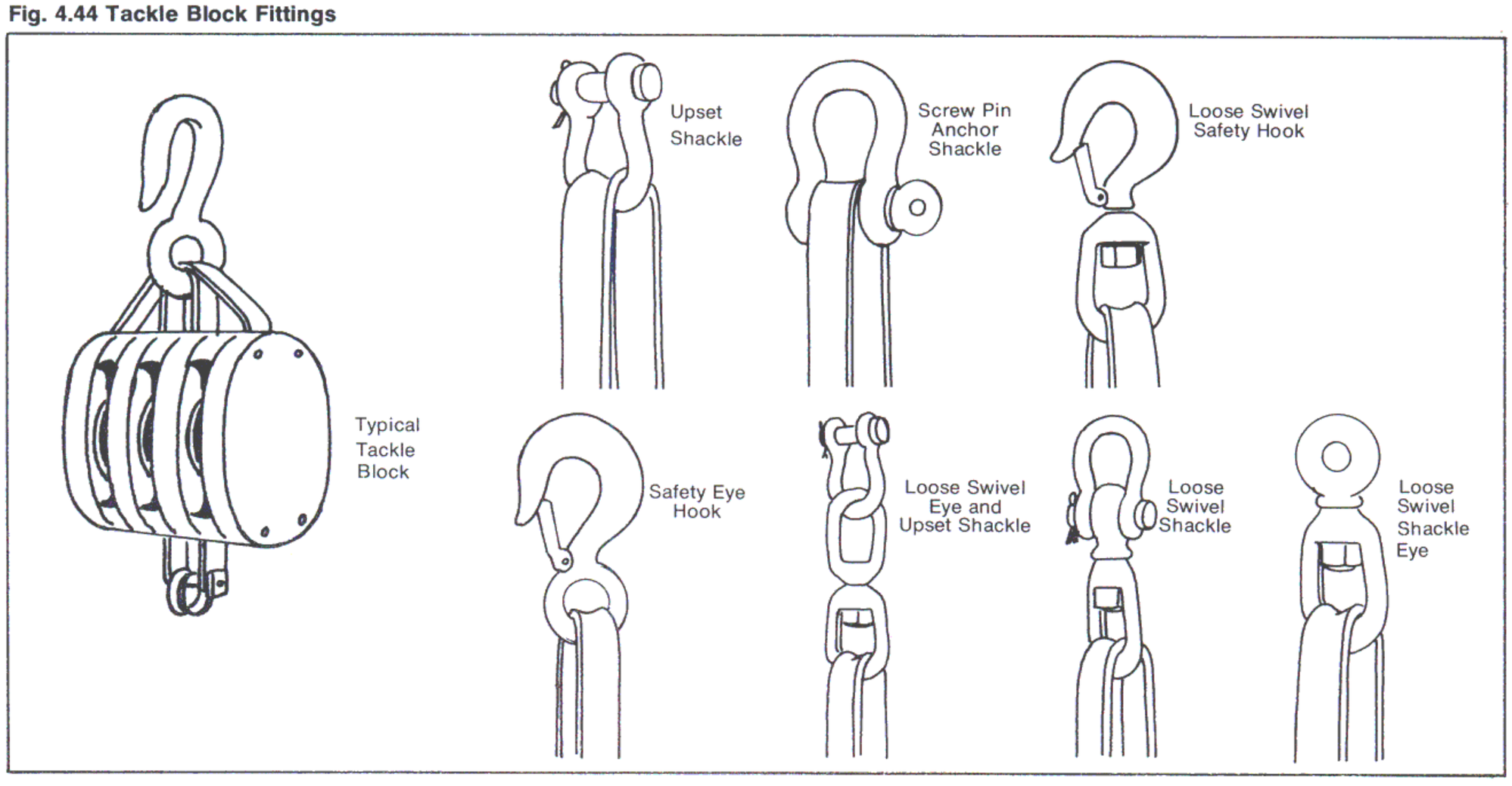


Fig. 4.45 Variation of Snatch Block Loads with Rope Angle

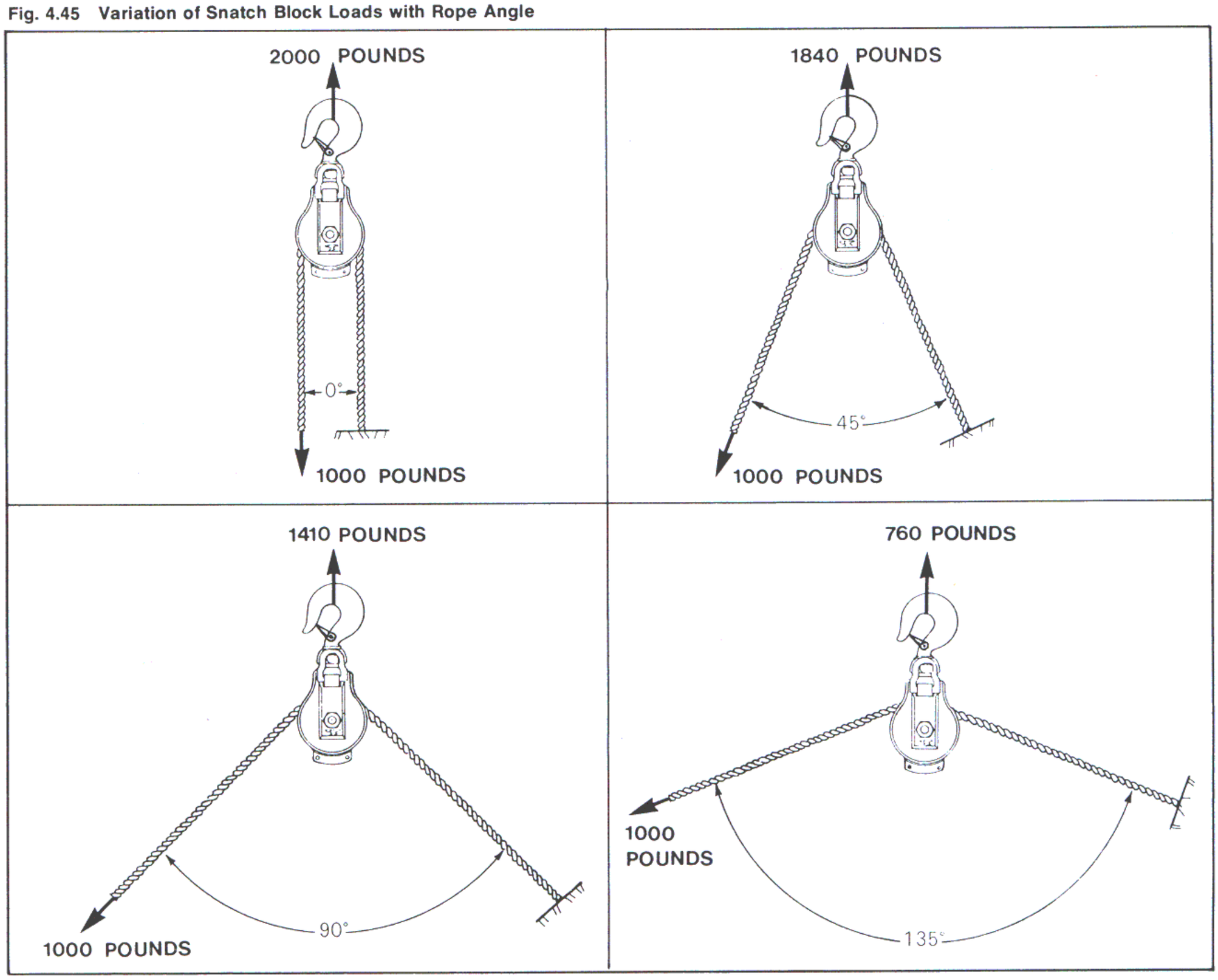


Fig. 4.46 Tackle Block Nomenclature

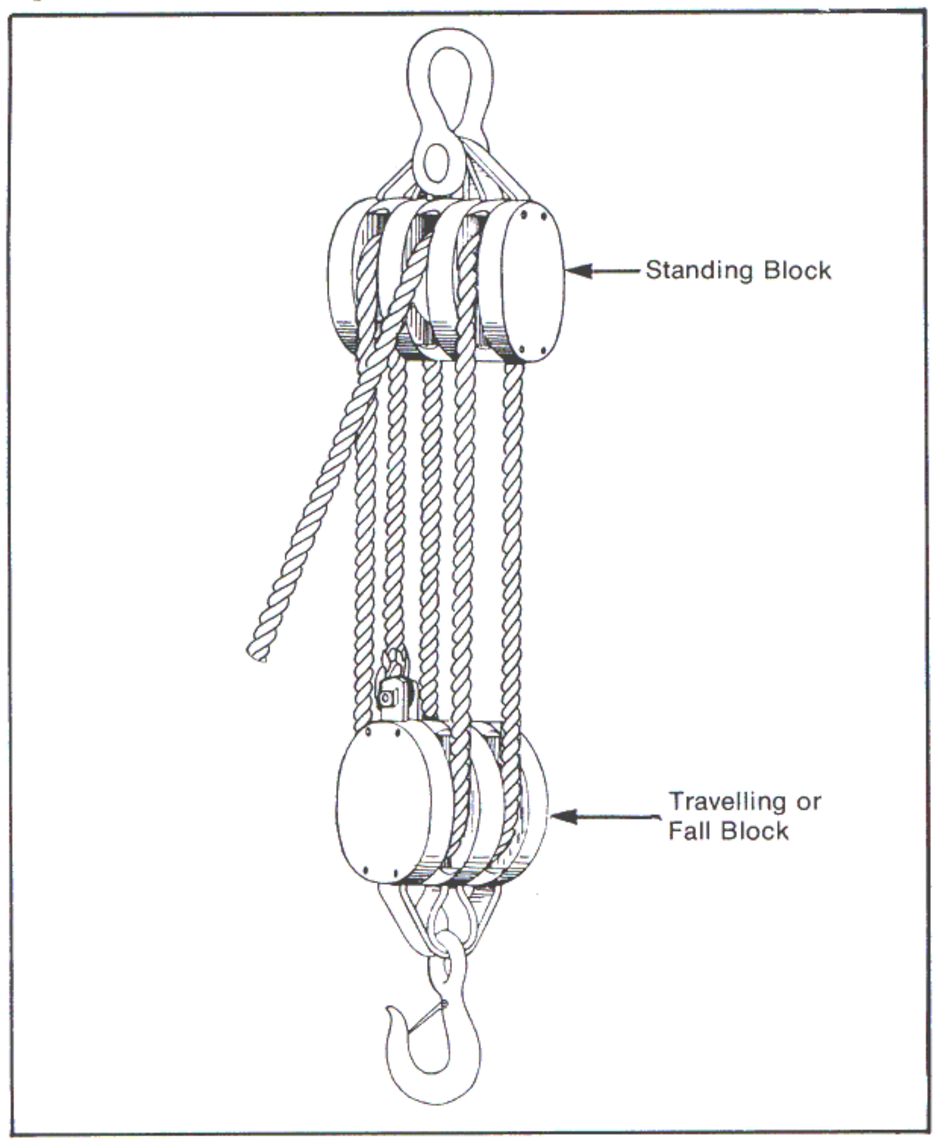


TABLE 4.19

MULTIPLICATION FACTORS FOR SNATCH BLOCK LOADS

Angle Between Lead and Load Lines	Multiplication Factor
10°	1.99
20°	1.97
30°	1.93
40°	1.87
50°	1.81
60°	1.73
70°	1.64
80°	1.53
90°	1.41
100°	1.29
110°	1.15
120°	1.00
130°	.84
140°	.68
150°	.52
160°	.35
170°	.17
180°	.00

To determine the load on the block, hook and anchorage point, multiply the pull on the lead line or the weight of the load being lifted by a suitable factor from table 4.19 and add 10% for sheave friction.

Tackle Blocks are used in conjunction with fibre ropes, both natural and synthetic fibre, and are similar to Wire Rope Blocks except for their much lighter weight and capacity. They are available with either wood or metal shells and either with or without cheek straps, depending on their capacity.

The sheaves in the blocks should be of the proper size for the rope being used and must be free and well lubricated.

With the exception of snatch blocks, the other types of blocks (i.e. Crane and Hook, Wire Rope, Tackle) can be classified according to their position in a reeved system. A travelling or fall block is a block that is attached to the load being lifted or moved and moves with the load. A standing block is a block that is fixed to a stationary object acting as the reaction point of the loading. (Fig. 4.46)

Many factors govern the selection and use of Tackle Blocks. Trouble will result from overloading, excess friction, angle of pull, condition of rope, sudden application of load, or lack of lubricant. The actual weight of the load to be moved does not necessarily determine the stress on the blocks. Obstruction to the free movement of the load, twisted ropes due to improper reeving or rigging, or improper angle of the tackle in relation to the load should be avoided. Moving heavy loads over rough ground, on an incline, without rollers or with too small rollers, can introduce severe stresses. A load suspended on two sets of blocks should be evenly distributed or one set will be subjected to more than its calculated share of the load. It is possible through careless preparation to have any or all of these conditions present to such a degree that the load on a set of blocks will greatly exceed the actual weight of the load itself.

In selecting blocks the governing consideration should be the load to be handled, rather than diameter or strength of the rope they will carry. In multiple-sheave blocks the load is distributed among several parts of the rope, whereas the hooks or shackles on the blocks have to carry the entire load. It is not practical to make double blocks twice as strong and triple blocks three times as strong as single blocks, since they would be too heavy and needlessly expensive for general use.

A suitable working load is not the greatest load that blocks can lift safely, but a load which blocks can handle efficiently until worn out. Increasing the number of sheaves multiplies power at the sacrifice of speed in hoisting.

When blocks are used for heavy loads and fast hoisting, we strongly recommend roller or bronze bearings in the sheaves. For wire rope blocks, cast steel sheaves are recommended.

Regardless of the type or capacity of block selected ensure that the sheaves are the maximum possible diameter for the size of rope being used and that the blocks are clearly and permanently marked with their weight, where significant, and their rated capacity.

Remember also that the anchorage point for the tackle or blocks must be able to carry the total weight of the load plus the weight of the blocks, plus the pull exerted on the lead line.

Like any piece of equipment, all blocks require some attention. They cannot be abused and neglected without loss of effectiveness and life. Keep them clean. Remove the sheaves occasionally and clean and oil the center pins and inspect the sheaves for wear. When not in use store the blocks in a dry place.

The following inspection recommendations should be observed:

— Check the blocks for excessive wear on the beckets, end connections, sheave bearings and center pins.

— Ensure that the sheave grooves are smooth. If a wire rope sheave shows the imprint of the rope, excessive rope wear will occur.

— Look for signs of overloading; elongated links, eyes or shackles; bent shackle, link or center pins; enlarged hook throats. If such conditions are found, the block should be replaced.

— Check the sheaves for proper rotation.

— Ensure that all cable keepers are in place.

— Check the clearance between sheaves and cheek and partition plates. It should be small enough that there is no danger of the rope slipping between them.

CHAPTER 5

REEVING

The selection of blocks and their reeving for a particular application involves not only consideration of the working load, connections, sheaves, pins and other structural details, but also the mechanical advantage required. Both the size of the block, the rope size and the number of sheaves per block must be determined in relationship to the load to be lifted and the pull which can be applied to the lead line.

Blocks, when reeved, become a machine, which by definition is a device by which forces may be advantageously applied to do work. A multiple part reeved system is a device or machine by which the lead line pull is multiplied to lift the load, thus gaining a mechanical advantage (''purchase'').

Since this system is a machine, like all machines, it is not 100% efficient because of friction. As soon as the load being hoisted begins to move, part of the applied force to the lead line is lost in overcoming the friction of turning the sheave and bending the rope. Hence, the lead line pull must be increased to make up for this friction loss in the tackle. (Fig. 5.1)

This relationship is called the efficiency and is usually expressed in terms of per cent. For a greater number of sheaves and parts of line, the mechanical advantage is greater, but the friction loss is also greater and the efficiency lower. Conversely, the lesser the number of sheaves and parts of line, the lower the friction loss and the higher the efficiency, but the mechanical advantage is less.

The mechanical advantage of any multiple part reeved system is always equal to the number of parts of line supporting the running block (travelling block) and the load. The lead line should not be included. (Fig. 5.2)

The number of parts of line in a reeved system is determined as follows:

— Imagine that you are going to cut all the ropes just above the load (exclude the lead line).

— Count the cut ends.

— Your answer gives you the number of parts of line which, in turn, is equal to the mechanical advantage of the system.

The increase in load carrying ability, however, is accompanied by a corresponding decrease in speed of travel. The lead line must move four times as fast as the load for a mechanical advantage of 4. The travel of the lead line, divided by the travel of the load is also a measure of the mechanical advantage. (Fig. 5.3)

If this 6000 pound load is not only supported but is also raised, then it is necessary to exert more than 1500 pounds on the lead line be-

Fig. 5.1 Effect of Sheave Friction

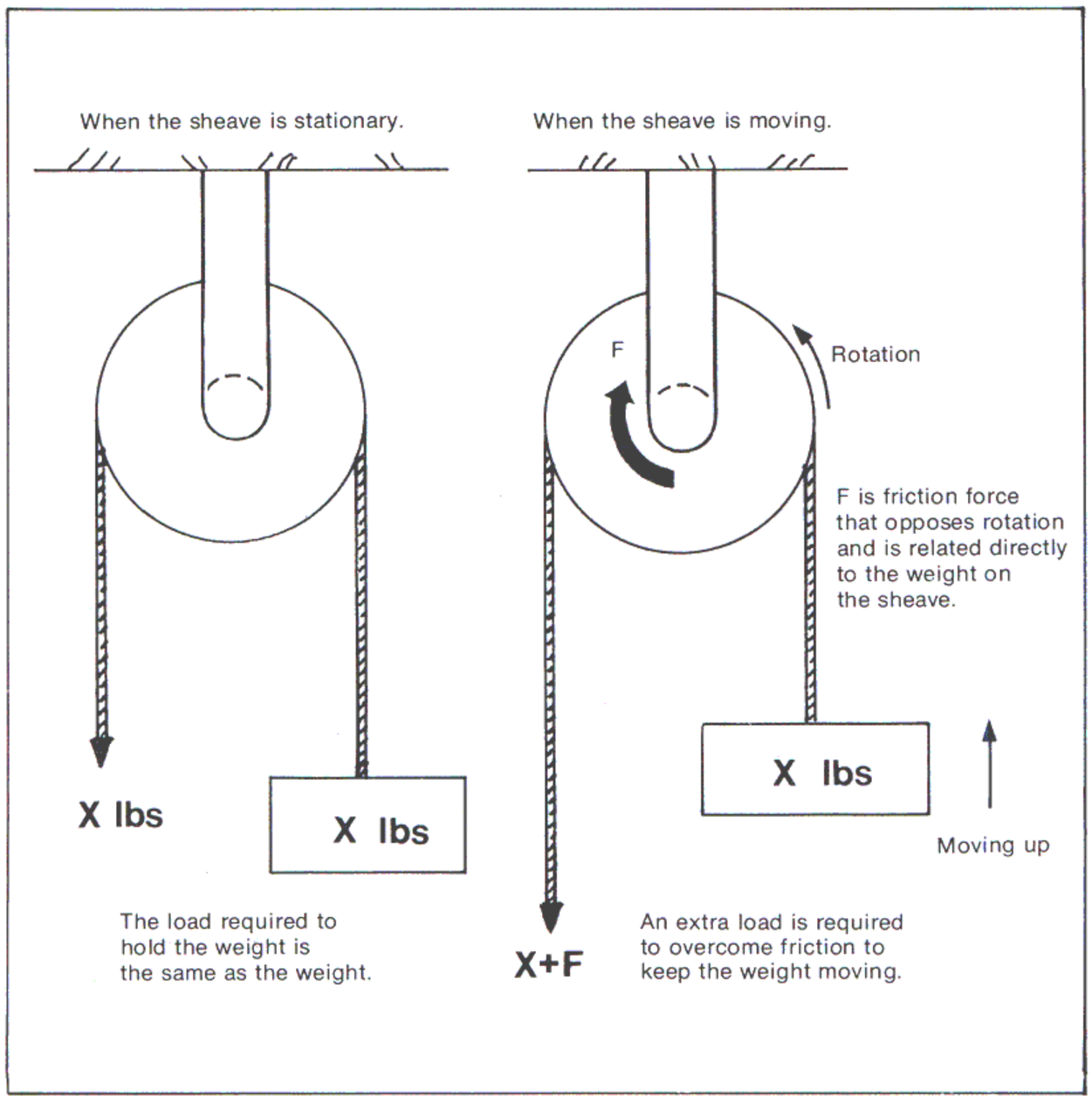


Fig. 5.2 Determination of Parts of Line

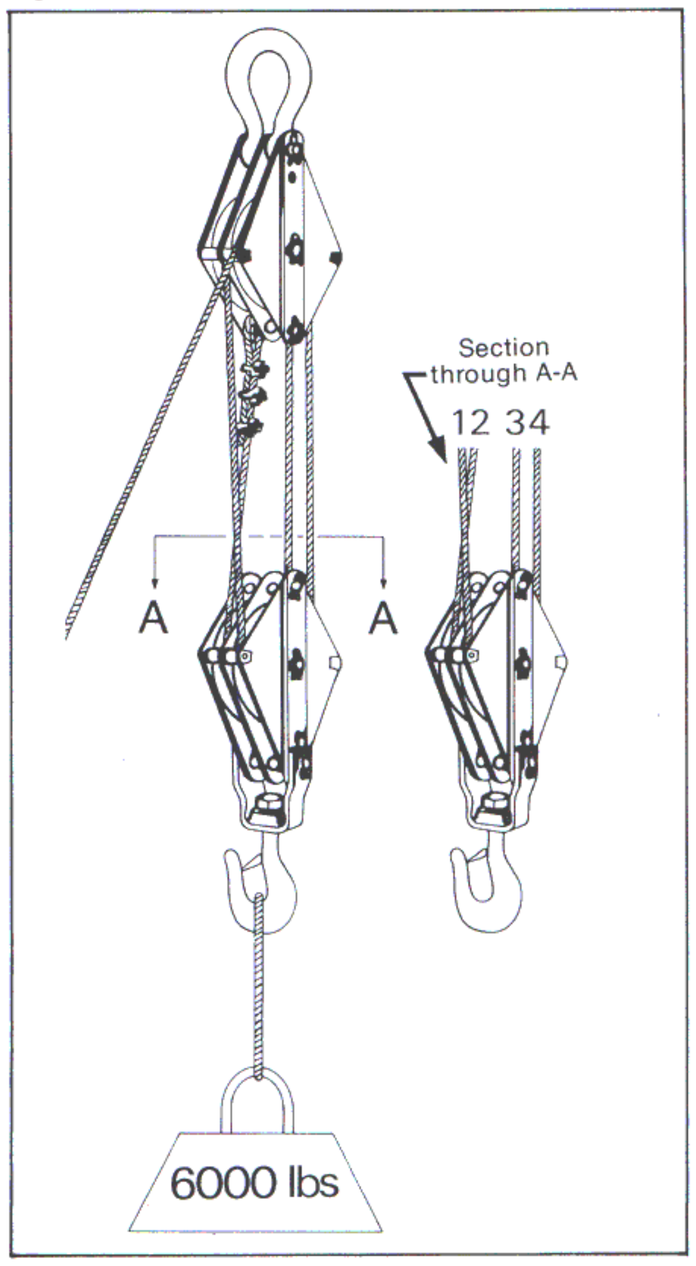


Fig. 5.3 Effect of Mechanical Advantage

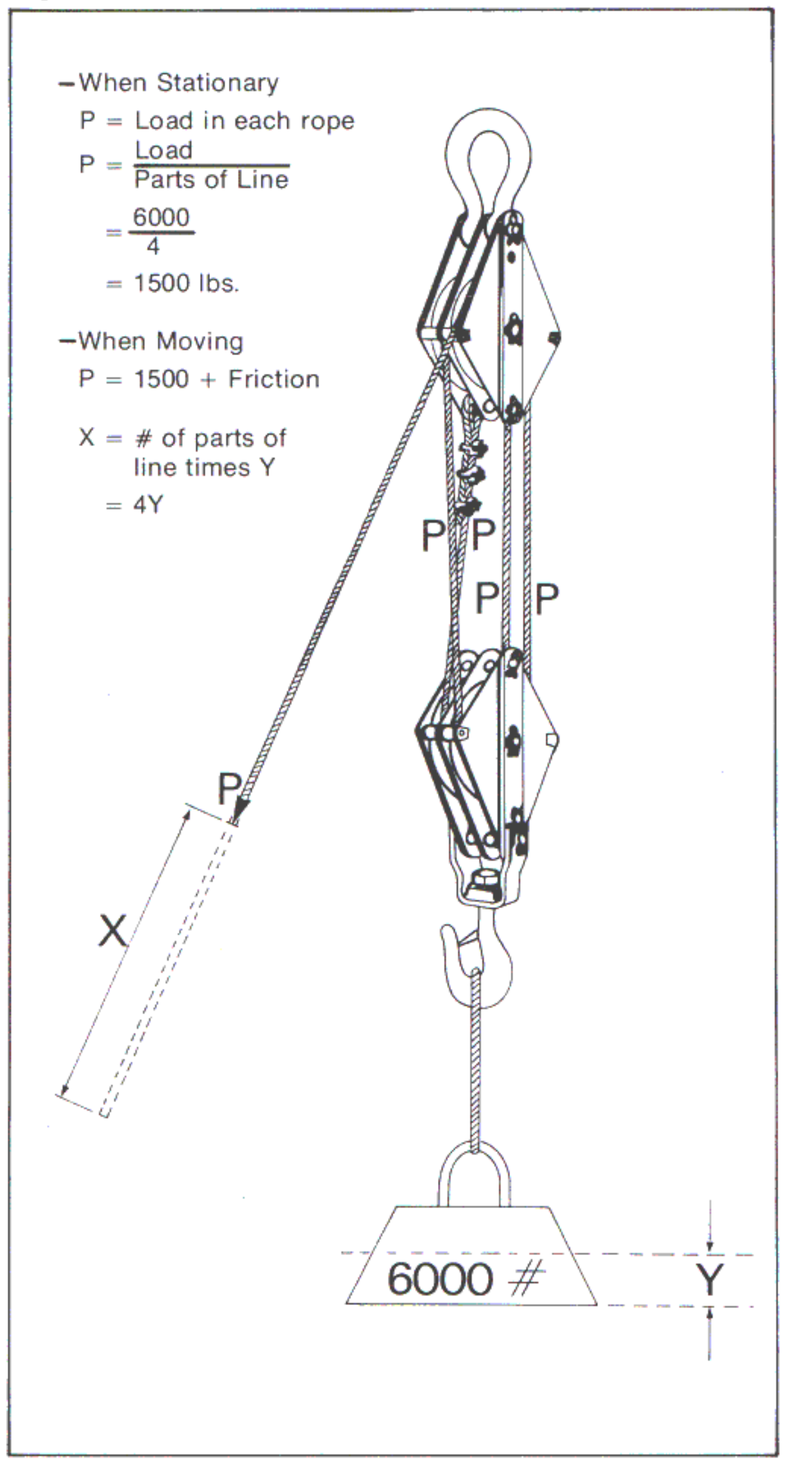
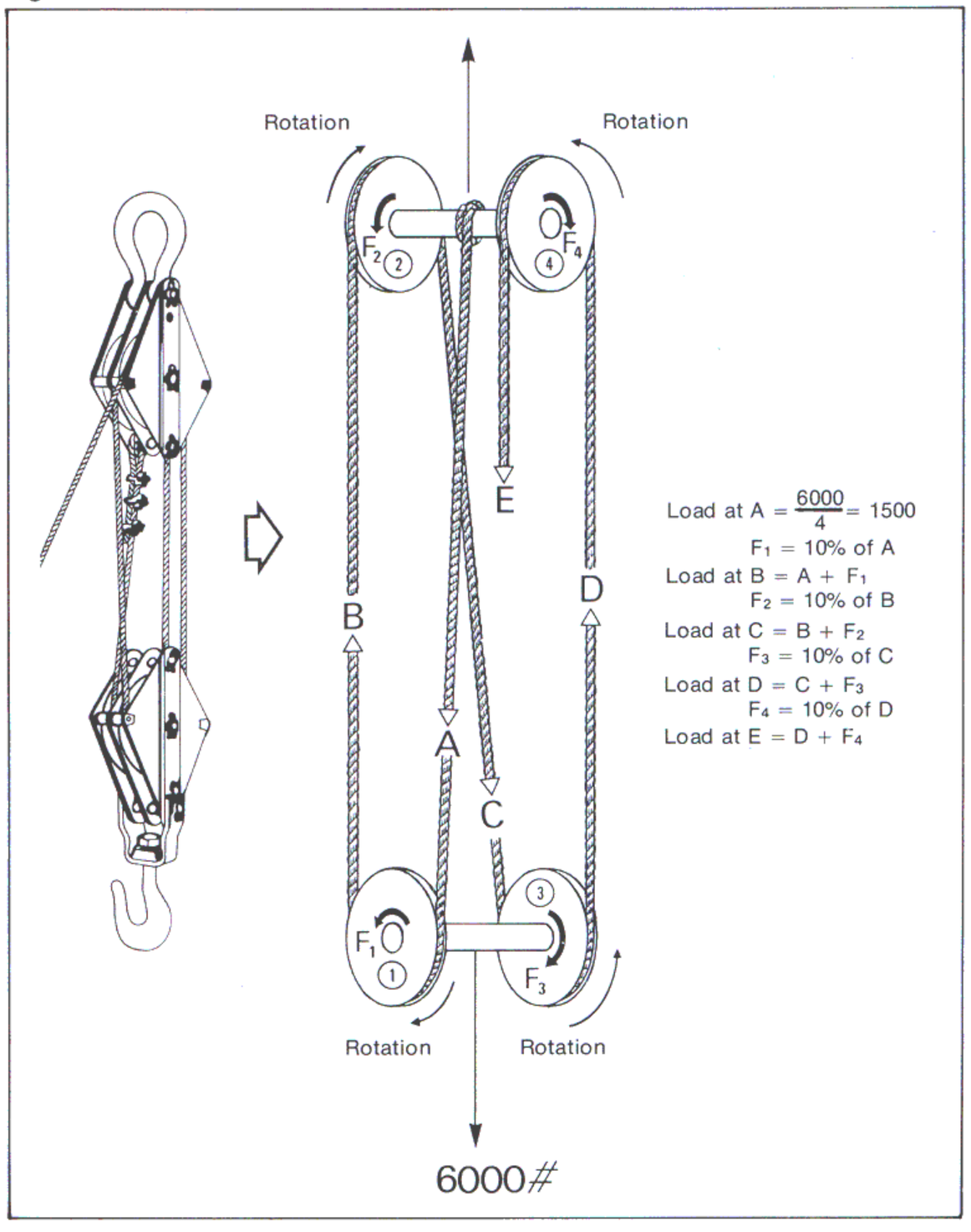


Fig. 5.4 Determination of Sheave Loads



cause of the extra forces necessary to overcome friction in the sheave bearings and the bending resistance of the rope as it passes over the sheaves. The mechanical advantage is decreased by the friction.

For practical purposes the sheave friction losses on well maintained sheaves are approximately 10% for each sheave in manila rope blocks (plain bore sheaves), about 5% for each sheave having bronze-bushings, and approximately 3% for sheaves having roller bearings.

When the load is lifted, each sheave introduces a friction force equal to either 10%, 5% or 3% **of the load it is carrying** (depending on the sheave bearings and how easily they rotate).

If the previously illustrated example was for sheaves having plain bores, (10% friction), the lead line load could be calculated as follows:

(See Fig. 5.4)

Load at A = 1500 lbs.

Load at B = 1500 lbs. + 10% of 1500 (friction @ sheave 1)
= 1650 lbs.

Load at C = 1650 lbs. + 10% of 1650 (friction @ sheave 2)
= 1815 lbs.

Load at D = 1815 lbs. + 10% of 1815 (friction @ sheave 3)
= 1996 lbs.

Load at E = 1996 lbs. + 10% of 1996 (friction @ sheave 4)
= 2196 lbs.
= Lead Line Load.

If you simply multiply the number of sheaves by 10% and then increase the static load on the lead line by that amount, the calculated lead line loads will be significantly *lower* than the actual loads.

The assessment and determination of friction loads requires a progressive type of calculation on a line-by-line basis.

To simplify matters, these calculations can be replaced with one calculation and the use of tables of multiplication factors and ratios.

$$\text{Lead Line Load} = \frac{\text{Load to be Lifted}}{\text{Parts of Line}} \times F$$

OR

$$\text{Lead Line Load} = \frac{\text{Load to be Lifted}}{R}$$

Values of F and R are provided in Tables 5.1, 5.2 or 5.3, depending on the sheaves.

TABLE 5.1

FACTORS TO ACCOUNT FOR SHEAVE FRICTION LOADS
FRICTION FORCE = 10% of Sheave Load
(Typical for plain bore sheaves and poorly maintained bronze bushing sheaves.)

Number of Parts of Line N	Multiplication Factor F	Ratio R (R = N/F) = Actual Mechanical Advantage
1	1.10	.91
2	1.21	1.65
3	1.33	2.26
4	1.46	2.74
5	1.61	3.11
6	1.77	3.39
7	1.94	3.61
8	2.14	3.74
9	2.36	3.81
10	2.60	3.85
11	2.85	3.86
12	3.14	3.82
13	3.45	3.77
14	3.80	3.68
15	4.18	3.59
16	4.60	3.48
17	5.06	3.36
18	5.56	3.23
19	6.12	3.11
20	6.73	2.97

Fig. 5.5 is a graph of the R values in the tables, and the number of parts of line. These graphs show the effect of the number of parts of line on the actual mechanical advantage *which considers friction. For example, for a* system having plain bore sheaves and 4 parts of line, the graph shows that the actual mechanical advantage is only 2.74, not 4. This is because the sheave friction has reduced the advantage of the extra parts of line. Increasing the number of parts of line on blocks having plain bore sheaves can work to a disadvantage beyond 10 or 11 parts of line and does not really help matters much beyond 6 or 7 parts of line. This, of course, is due to the cumulative effect of sheave friction. You rapidly reach the point where the largest portion of the input load is to overcome friction rather than move the load.

The situation is considerably better on blocks that have bronze bushings and roller bearings but they too, as shown in the graph, reach a point where the addition of more sheaves and parts of line does not help matters much. Remember too that a poorly maintained or lubricated sheave with either bronze bushings or roller bearings can have friction loads much higher than the values quoted.

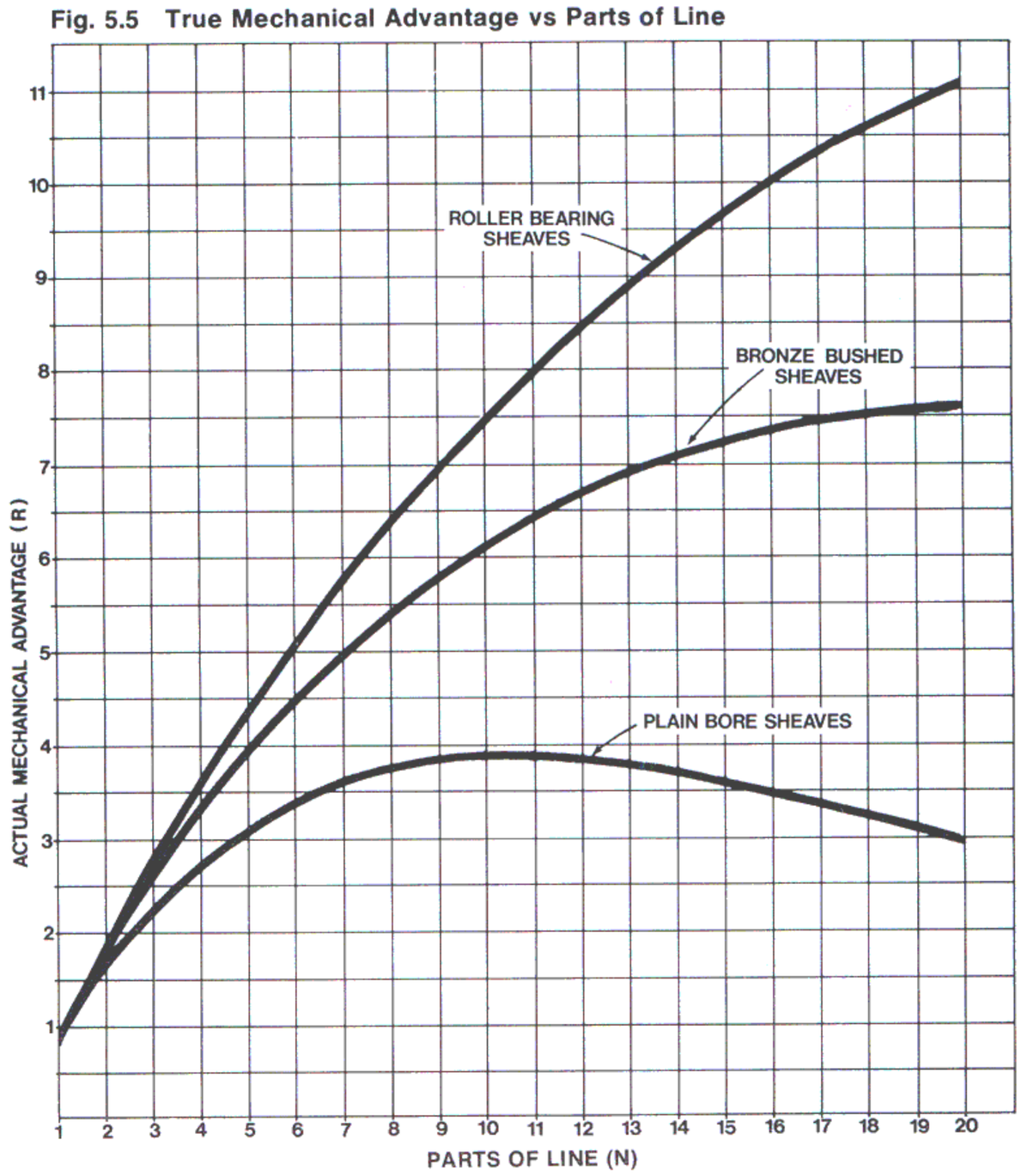
TABLE 5.2

FACTORS TO ACCOUNT FOR SHEAVE FRICTION LOADS FRICTION FORCE = 5% of Sheave Load (Typical for bronze bushing sheaves and stiff roller bearing sheaves.)		
Number of Parts of Line N	Multiplication Factor F	Ratio R (R = N/F) = Actual Mechanical Advantage
1	1.05	.95
2	1.10	1.82
3	1.16	2.59
4	1.22	3.28
5	1.28	3.91
6	1.34	4.48
7	1.41	4.96
8	1.48	5.41
9	1.55	5.81
10	1.63	6.13
11	1.71	6.43
12	1.80	6.67
13	1.89	6.88
14	1.98	7.07
15	2.08	7.21
16	2.18	7.34
17	2.29	7.42
18	2.41	7.47
19	2.53	7.51
20	2.65	7.55

TABLE 5.3

FACTORS TO ACCOUNT FOR SHEAVE FRICTION LOADS FRICTION FORCE = 3% of Sheave Load (Typical for good roller bearing sheaves.)		
Number of Parts of Line N	Multiplication Factor F	Ratio R (R = N/F) = Actual Mechanical Advantage
1	1.03	.97
2	1.06	1.89
3	1.09	2.75
4	1.13	3.54
5	1.16	4.31
6	1.20	5.00
7	1.23	5.69
8	1.27	6.30
9	1.31	6.87
10	1.35	7.41
11	1.39	7.91
12	1.43	8.39
13	1.47	8.84
14	1.51	9.27
15	1.56	9.62
16	1.61	9.94
17	1.65	10.30
18	1.70	10.59
19	1.76	10.80
20	1.81	11.05

Fig. 5.5 True Mechanical Advantage vs Parts of Line



These are three very important calculations that every rigger should know:

(a) How to determine the number of parts of line required to make a lift.

(b) How to determine the maximum load that can be lifted with a given reeving arrangement.

(c) How to determine the line pull needed when the load weight and number of parts of line are established.

1. To determine the number of parts of line required to make a lift:

—Determine the maximum safe working load of the rope and the maximum pulling load that you can or want to apply to the lead line. Use the smaller of the two values in the following calculation.

—Determine the weight of the load to be lifted.

—Calculate as follows:

$$\frac{\text{LOAD TO BE LIFTED}}{\text{ROPE SWL (OR DESIRED LEAD LINE PULL)}} = \text{R}$$

—Opposite R in the tables read the number of parts of line or make the determination from the graphs.

Example: Rope block sheaves have roller bearings and are well maintained. Crane to be rigged for capacity of 50 tons. Rope's safe working load is equal to 8.6 tons.

$$\frac{\text{LOAD}}{\text{SWL}} = \frac{50}{8.6} = 5.8 = \text{R}$$

By reading down the R column in the table for roller bearing sheaves we see that our R of 5.8 falls between the 5.69 and 6.30 figures — always go to the next highest figure which is 6.30 in this case. Opposite the 6.30 we see that this corresponds to 8 parts of line. Therefore, this machine requires 8 parts of line to make its lifts.

2. To determine the maximum load that can be lifted with a given reeving arrangement:

—Determine the number of parts of line.

—Find out what kind of sheave bearings are being used and how easily they rotate.

—Determine the maximum safe working load of the rope and the maximum pulling load that you can or want to apply to the lead line. Use the smallest of the two values in the calculation.

—Determine R from appropriate table opposite the number of parts of line.

—Calculate as follows:

MAXIMUM LOAD = ROPE SWL (OR LEAD LINE PULL) x R

Example: Tackle blocks have 4 parts of line and plain bore sheaves. $^5/_8$ inch diameter manila rope is used (SWL = 880 lbs.) but the maximum load that can be applied to the lead line is only 400 lbs.

From the table for plain bore sheaves or from the graph, opposite 4 parts of line, find that R = 2.74.

MAX. LOAD = 400 lbs. x 2.74
= 1095 lbs.

This means that 1095 lbs. is the maximum load that can be lifted.

Fig. 5.6 Block Orientation in a Reeved System

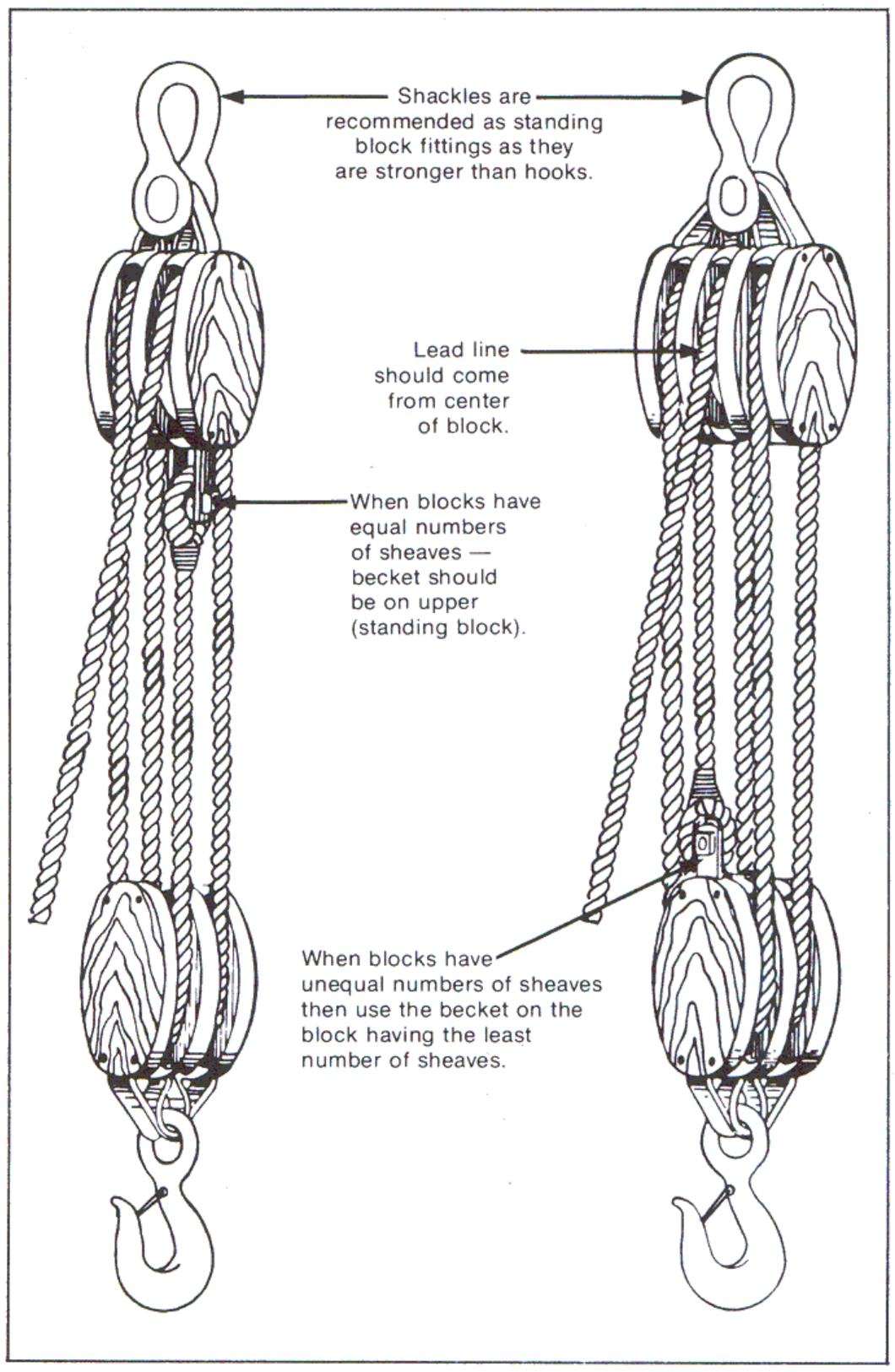
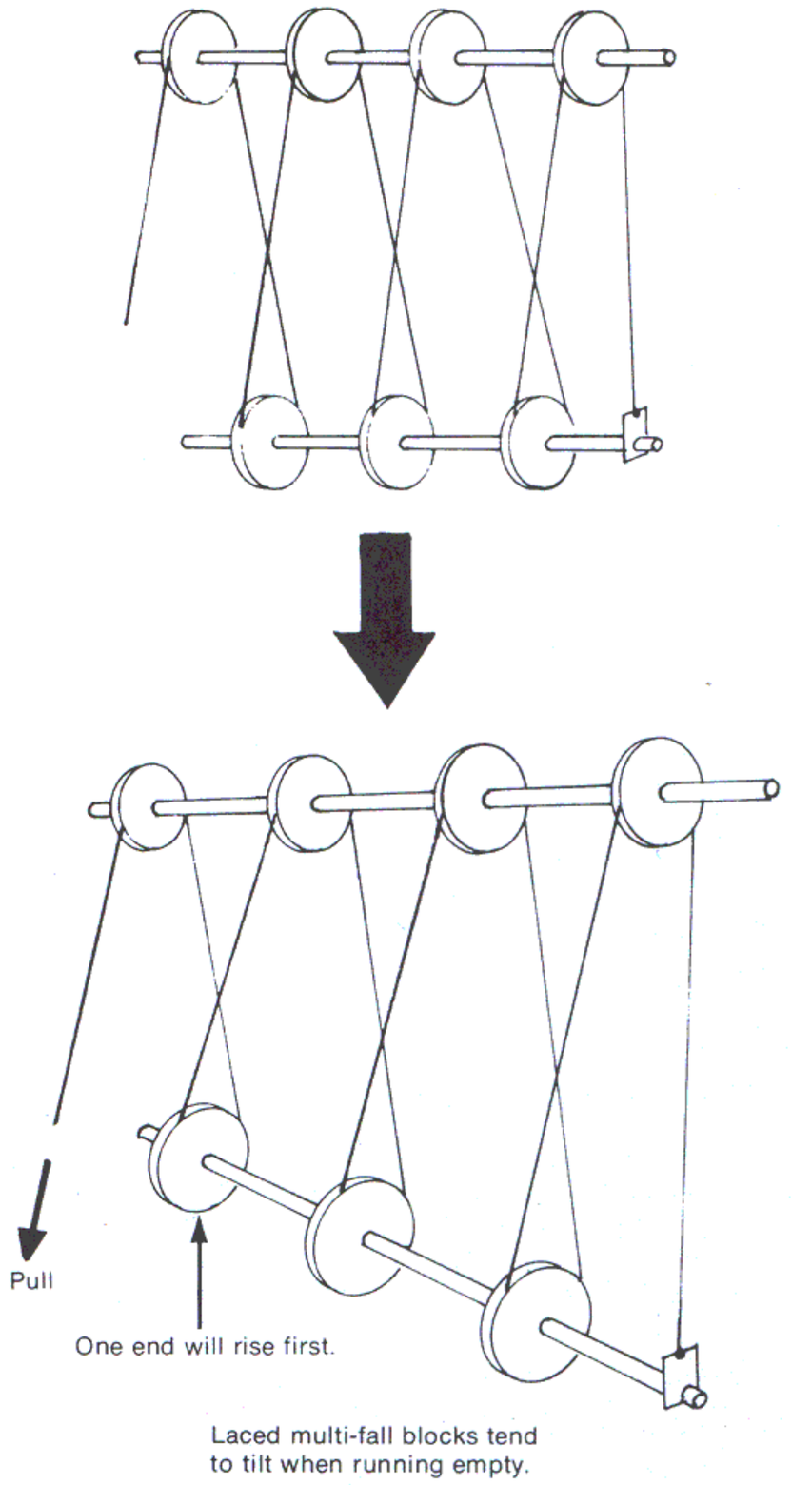
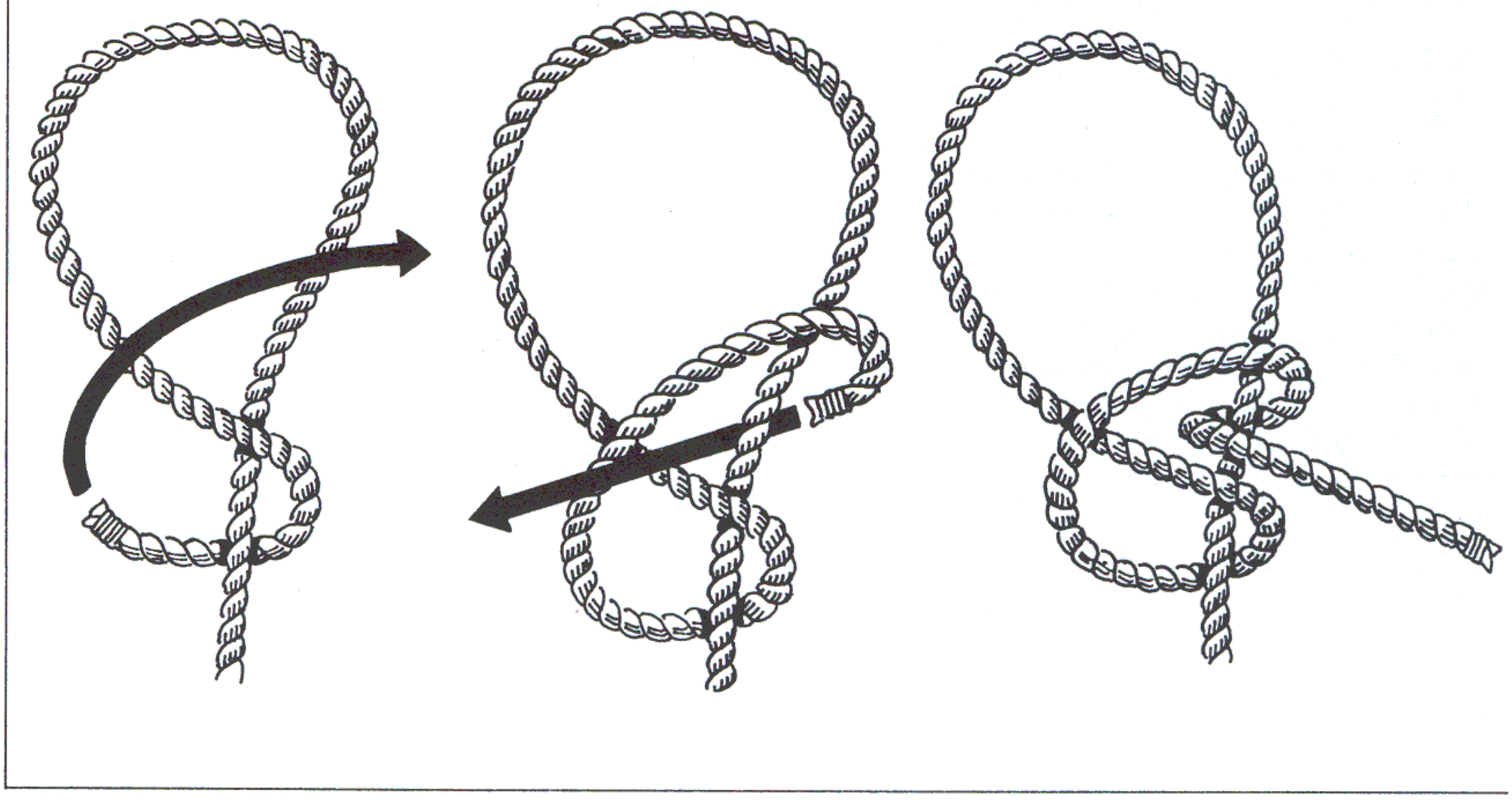


Fig. 5.7 Effect of Lacing Rather than Reeving Blocks



Laced multi-fall blocks tend to tilt when running empty.

Fig. 5.8 Becket Hitch



3. To determine the line pull (or rope size) needed when the load weight and number of parts of line are established:

—Determine the type of sheave bearings.
—Determine the load weight.
—Determine the number of parts of line.
—Divide the load weight by the R factor that applies to the number of parts of line and the type of sheave bearings.

$$\frac{\text{LOAD WEIGHT}}{R} = \text{LINE PULL}$$

Example: A hoist is rigged with 6 parts of line and the sheaves have bronze bushings. The load to be lifted weighs 27,000 lbs.

From the table or graph for bronze bearing sheaves and opposite 6 parts of line, read R = 4.48.

Therefore, the required line pull is:

$$\text{LINE PULL} = \frac{\text{LOAD WEIGHT}}{R} = \frac{27{,}000}{4.48} = 6{,}000 \text{ lbs.}$$

This means that the hoist winch must be able to exert a line pull of 6,000 lbs. if it is to lift the load. Ensure that the required line pull does not exceed the rated safe working load of the wire rope.

These recommendations and calculations apply not only to blocks but also to individual sheaves, idlers and snatch blocks. Every sheave that a rope is in contact with adds frictional loads to that rope. As has been demonstrated, when the friction is high and there are many sheaves these loads can combine to the point where they actually *exceed* the loading due to the weight of the object being hoisted.

It is important that blocks and reeved systems be of sufficient size and capacity to carry the loads to which they will be subjected. If the hook on a set of blocks shows signs of opening up then that is an indication that the blocks are being overloaded since the hook will usually begin to bend at approximately 70% of the maximum block strength. The best method to avoid overloads is to know exactly how reeved systems work, use the previously mentioned calculations and appreciate just how much effect friction plays on the total load.

If the blocks you are going to use have *equal* numbers of sheaves then the dead end of the rope should be fastened to the becket of the standing (upper) block. If they have *unequal* numbers of sheaves then the rope should be fastened to the becket of the block having the least number of sheaves. (Fig. 5.6) Make sure the rope termination at the becket is secure and develops as much strength as the rope itself. Refer to the chapters on wire rope and fibre rope to determine the best anchorage methods.

In reeving a pair of tackle blocks one of which has more than two sheaves, the hoisting rope should lead from one of the center sheaves of the upper block.

When reeved this way, the hoisting strain comes on the center of the blocks and they are prevented from toppling and twisting and causing injury to the rope by cutting across the edges of the block shell.

It is good practice to use a shackle block as the upper one of a pair and a hook block as the lower one. A shackle is much stronger than a hook of the same size. Also, the strain on the upper block is much greater than on the lower one. The lower block supports only the load whereas the upper block carries the load as well as the hoisting strain. A hook is more convenient on the lower block because it is easier to attach or detach it from the load.

When making up a set of falls or reeving a system having 5 or more parts of line, avoid lacing the blocks because they have a tendency to tilt the travelling block when running empty. (Fig. 5.7) This effect causes excessive wear and can damage the sheaves and rope. Whenever possible, Right Angle Reeving should be used. The blocks should be identical and square in relation to each other.

When reeving any kind of rope block it is extremely important that the dead end or becket connection be properly made and attached. On wire rope blocks use either a wedge socket or cable clips for the becket. On fibre rope blocks use the becket hitch to secure the dead end. (Fig. 5.8)

Two Part Falls: (Use two single sheave blocks) (Fig. 5.9) — Feed the lead line over the sheave of the stationary block, down in back of the travelling block, through the sheave and up to the becket on the stationary block. Secure to the becket.

Three Part Falls: (Use a 2-sheave block and a single sheave block) (Fig. 5.10) — Feed the lead line through the front of the stationary

Fig. 5.9 2-Part Line

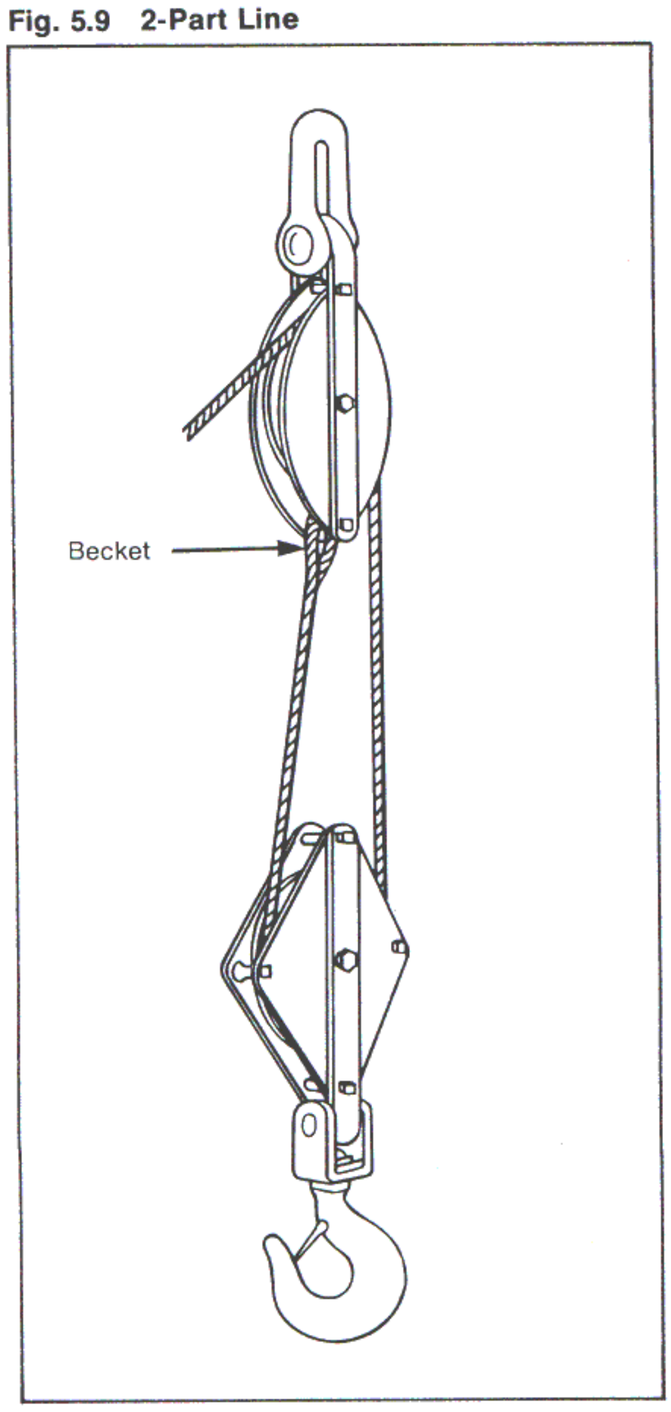


Fig. 5.10 3-Part Line

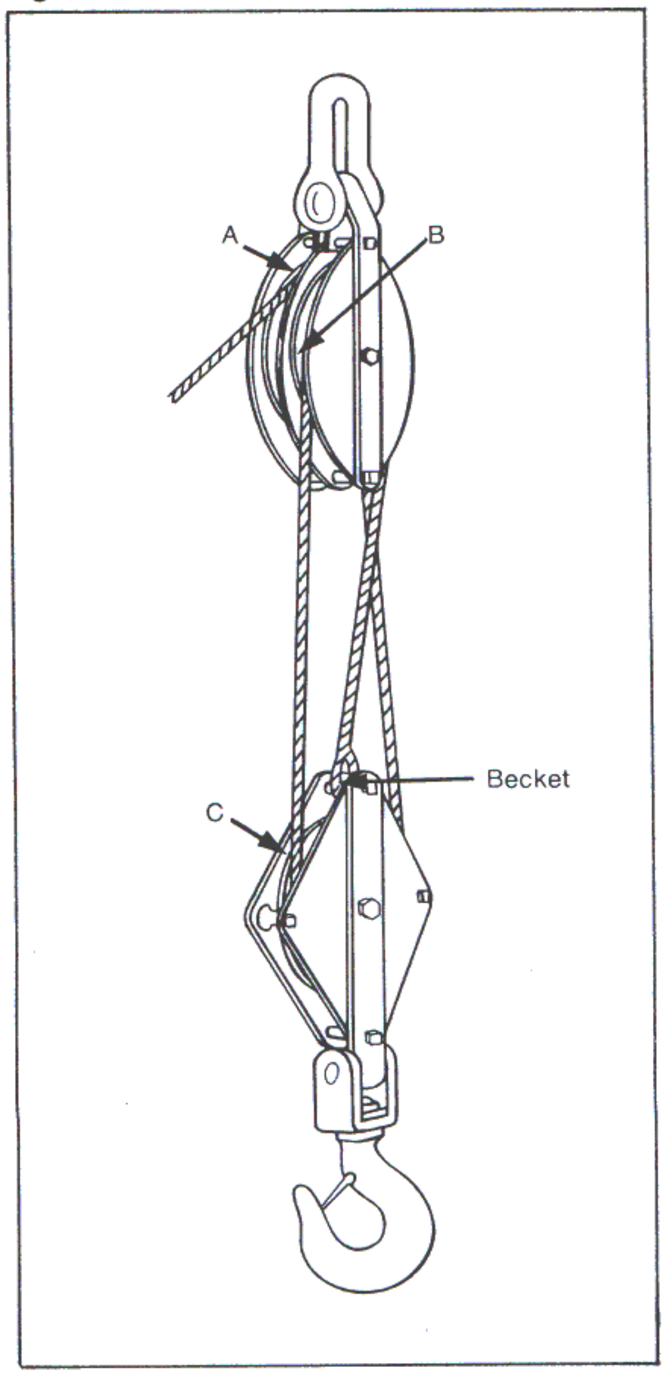


Fig. 5.11 4-Part Line

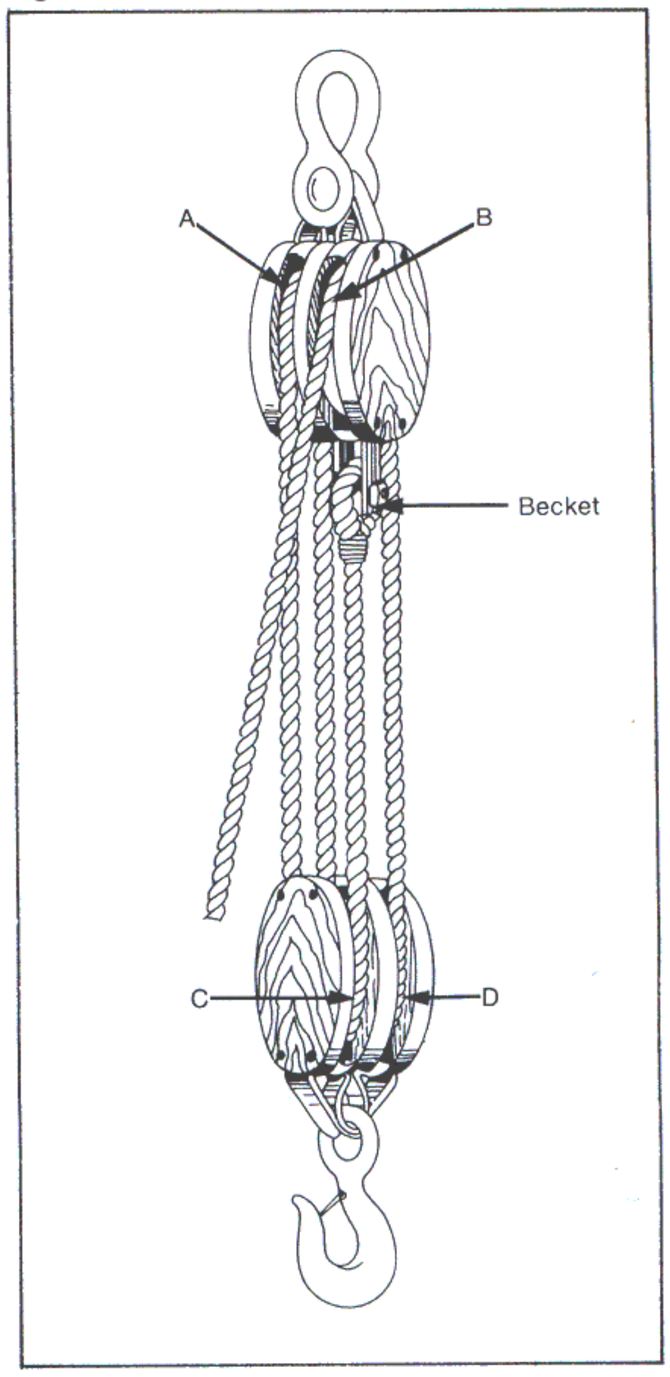


Fig. 5.12 5-Part Line

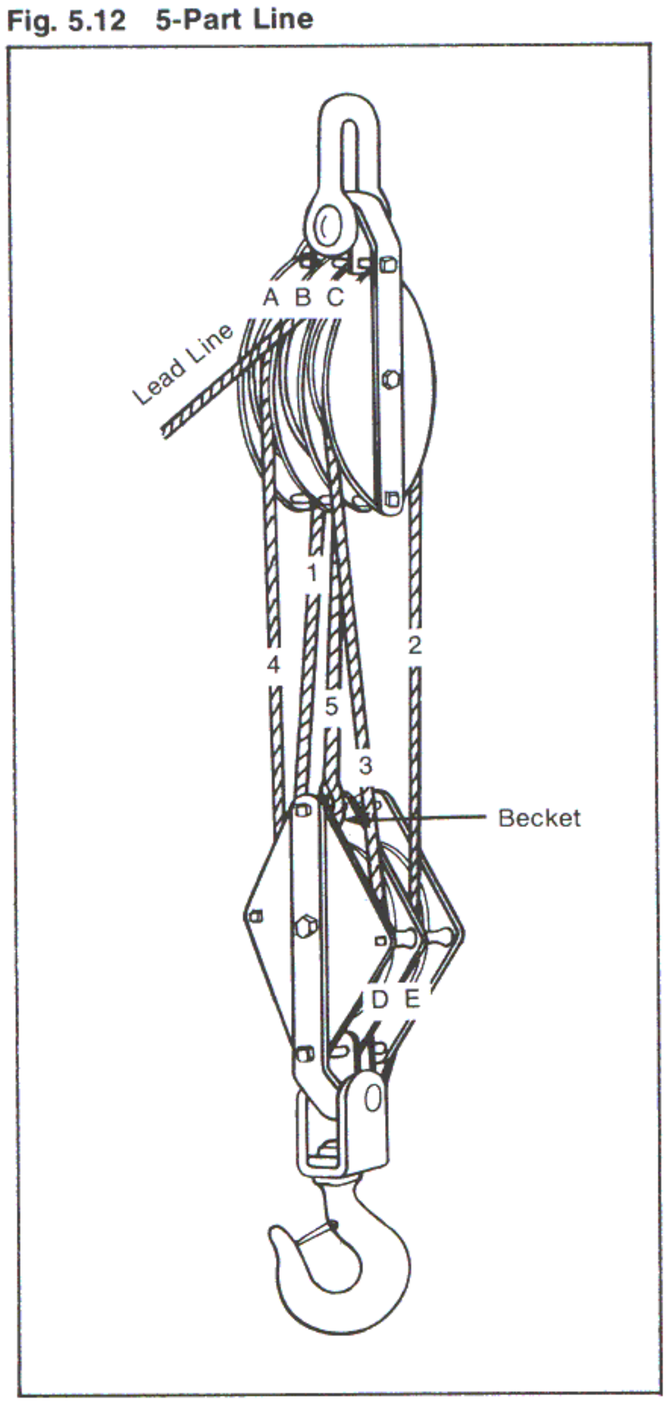


Fig. 5.13 6-Part Line

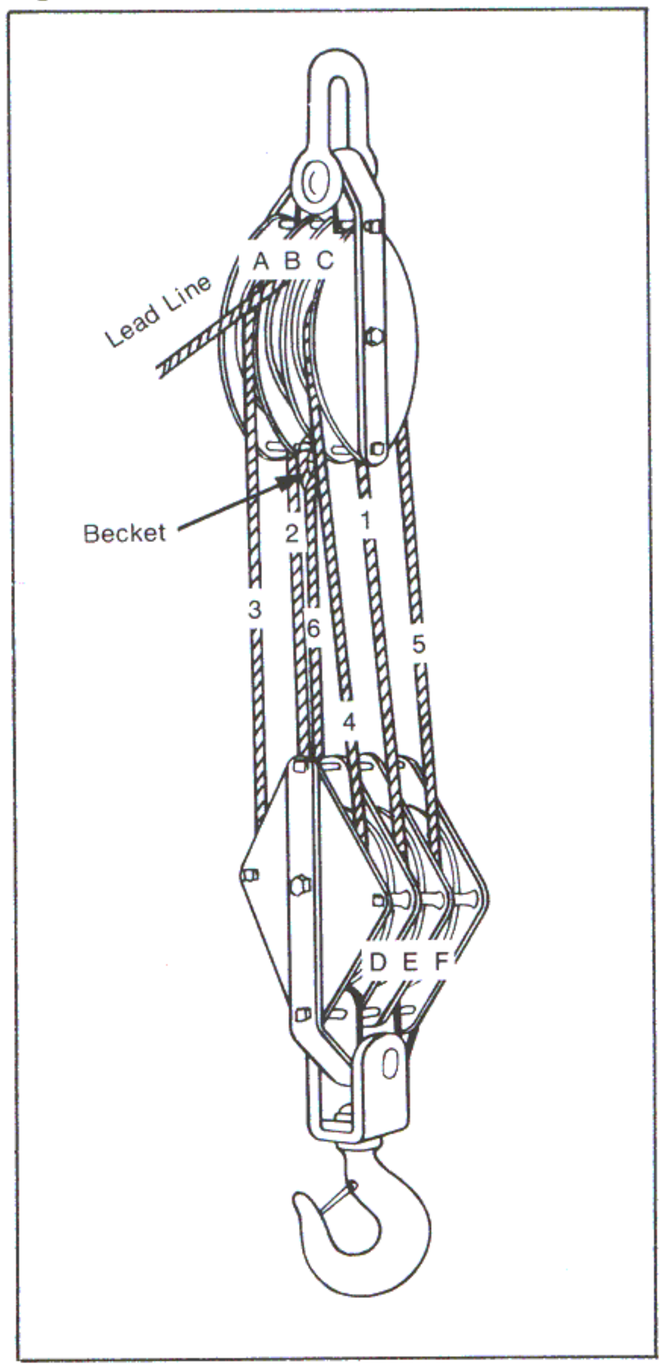
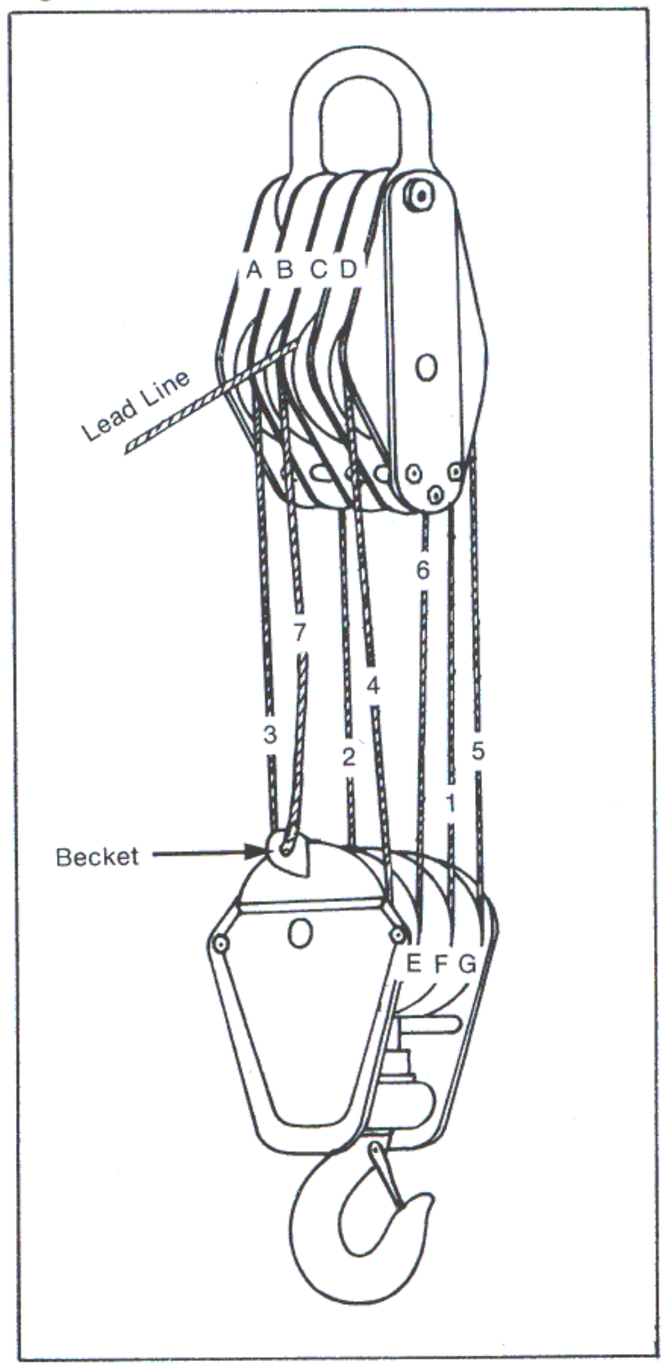


Fig. 5.14 7-Part Line



block at Sheave "A", then feed it down in back of the travelling block and through Sheave "C". Bring it up in front of the stationary block, pass it through Sheave "B" and down to the becket on the travelling block. Secure to the becket.

Four Part Falls: (Use a pair of 2-sheave blocks) (Fig. 5.11) — Arrange the blocks at right angles to each other. Feed the lead line through the front of the stationary block at Sheave "B", then feed it down in front of the travelling block and through Sheave "D". Bring it up in behind the stationary block and feed it through Sheave "A". Take the lead line down in behind the travelling block, pass it through Sheave "C" and bring it up to the becket on the stationary block. Secure to the becket.

Five Part Falls: (Use a 2-sheave block and a 3-sheave block) (Fig. 5.12) — Feed the lead line through the front of the stationary block at Sheave "B", then down in back of the travelling block, and through Sheave "E". Bring up behind the stationary block and through Sheave "C", down in front of travelling block and through at Sheave "D". Then bring it up in front of stationary block and through at Sheave "A", down to the travelling block and secure to the becket.

Six Part Falls: (Use a pair of 3-sheave blocks) (Fig. 5.13) — Feed the lead line through the front of the stationary block at Sheave "B", then down in front of the travelling block and through at Sheave "E". Bring it up behind the stationary block and through at Sheave "A", down behind the travelling block and through at Sheave "D". Then bring it up in front of the stationary block and through at Sheave "C", down in front of the travelling block, and through at Sheave "F". Finally, bring it up to the stationary block and secure to the becket.

Seven Part Falls: (Use a 3-sheave block and a 4-sheave block) (Fig. 5.14) — Feed the lead line through the front of the stationary block (4-sheave) at Sheave "C", down in front of the travelling block and through at Sheave "F". Bring up behind the stationary block and through at Sheave "A", down behind the travelling block and through at Sheave "E". Then up in front of the stationary block and through at Sheave "D", down in front of the travelling block and through at Sheave "G". Finally, up behind the stationary block and through at Sheave "B", then down to the travelling block and secure to the becket.

Eight Part Falls: (Use a pair of 4-sheave blocks) (Fig. 5.15) — Feed the lead line through the front of the stationary block at Sheave "C", down in front of the travelling block and through at Sheave "G". Next bring it up behind the stationary block and through at Sheave "A", down behind the travelling block and through at Sheave "E". Then up in front of the stationary block and through at Sheave "D", down in front of the travelling block and through at Sheave "H", up behind the stationary block and through at Sheave "B". Finally, bring it down behind the travelling block and through at Sheave "F", then up to the stationary block and secure to the becket.

If the blocks have more sheaves than are needed, ensure that they are symmetrically reeved with the rope as equally distributed across the block as possible to equalize the loads and prevent toppling. (Fig. 5.16)

If an auxiliary hook or line is run over the boom point or over a standing block, the main hook or line is generally reeved to one side of the boom point or block. This eccentric condition introduces severe torsional stresses in the boom and can cause blocks to topple. When approaching capacity loads, the blocks and boom point must be reeved in accordance with Fig. 5.17.

All tackles and reeved systems, particularly long new ones, are liable to twist primarily because of lay of the rope, not the method of reeving. If this happens, the power required to hoist increases and sheave damage and rope wear occur. Unfortunately, there is little that can be done other than using 2 in 1 braided fibre rope or non-rotating wire rope.

If the system is rigged with only a single rope fall there is always a tendency for the rope and hook to spin after the tension is removed from the hoist rope. To avoid being hit by the hook or load stay away from them until they are set down.

Another consideration in the use of reeved systems is that all sheaves in a set of blocks revolve at different rates of speed. The sheaves nearest the lead line rotate at the highest rates and consequently need more lubricant than the others and also wear out more rapidly.

Fig. 5.15 8-Part Falls

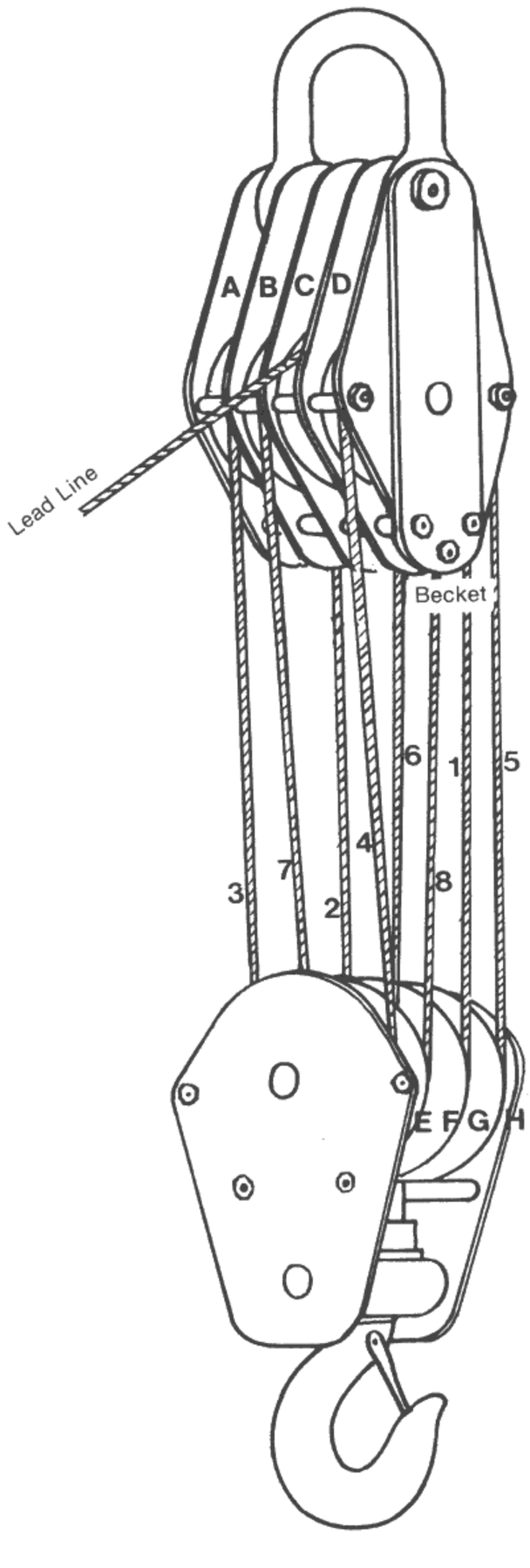
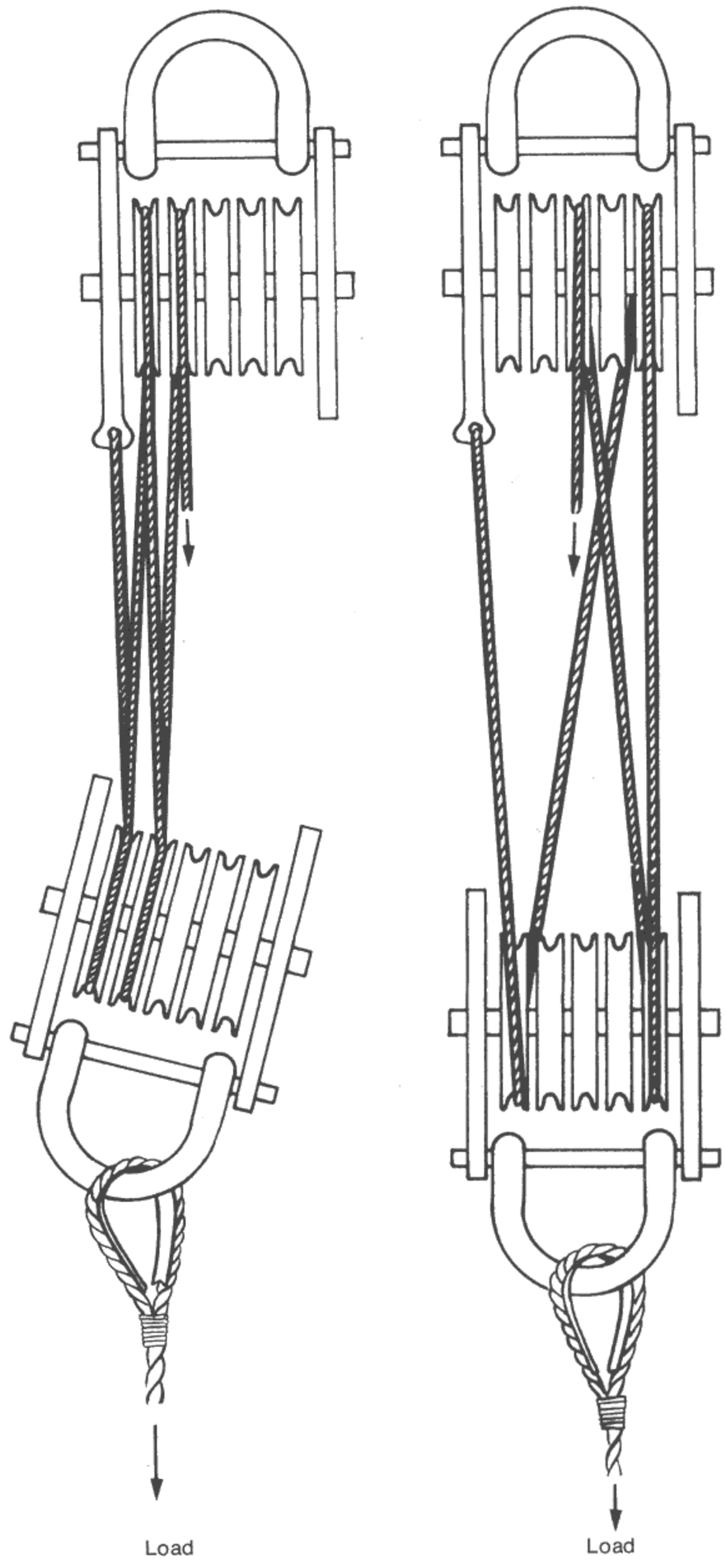


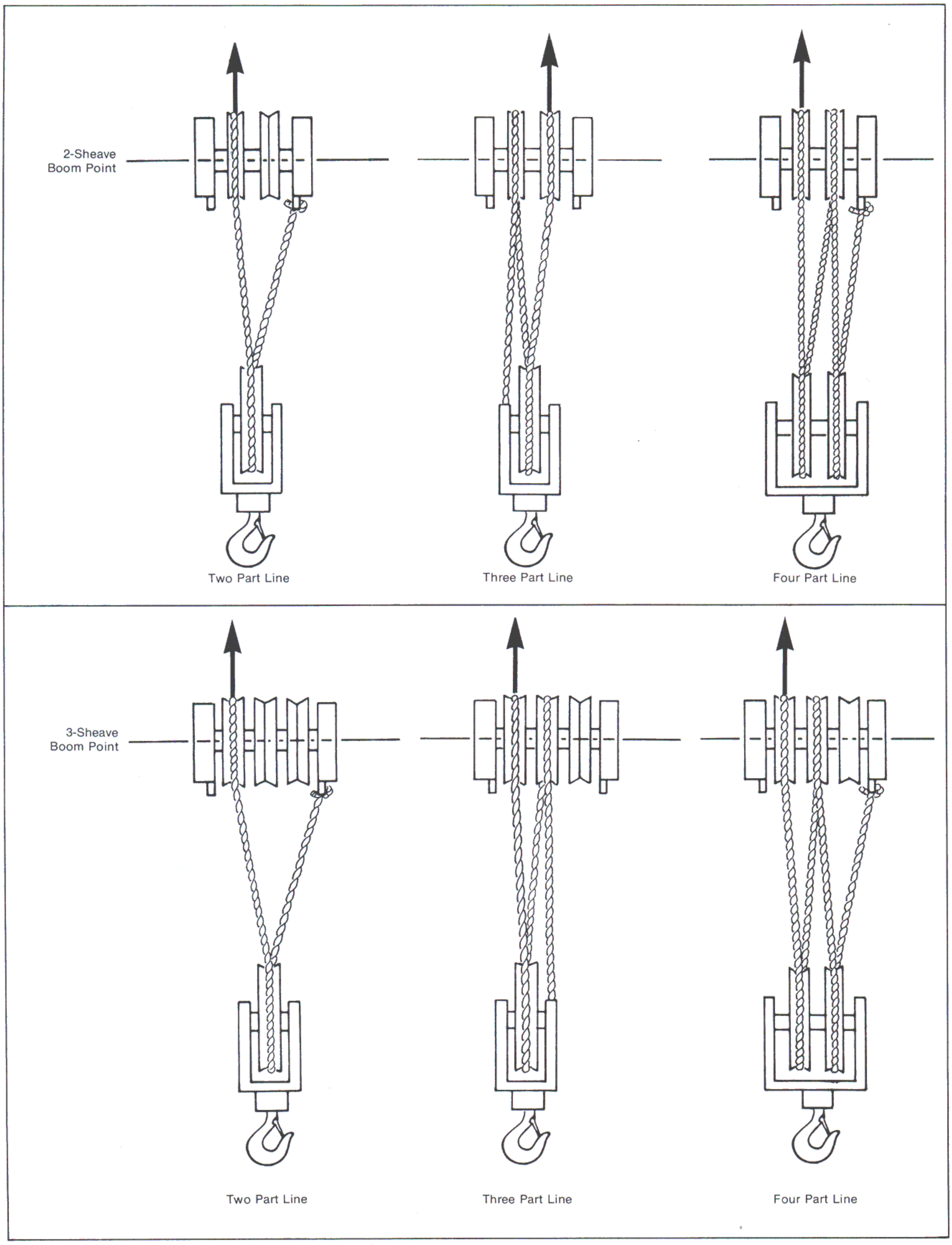
Fig. 5.16 Symmetrical Reeving



Unsymmetrically Reeved — Block Tilts

Symmetrical Reeving — Blocks Run True

Fig. 5.17 Symmetrical Boom Point Reeving



CHAPTER 6

SLINGS

Slings require special attention because they are almost always subjected to severe wear, abrasion, impact loading, crushing, kinking and overloading. They also merit special attention because seemingly insignificant changes in sling angle drastically affect the loading. When using slings exercise extreme caution because you are going to be developing unknown loads, under less than ideal circumstances, in less than perfect equipment.

Failure to provide blocking or protective pads will permit sharp corners to cut slings. Pulling slings from under loads will result in abrasion and kinking. Dropping loads on slings or running equipment over them will cause crushing. Sudden starts and stops when lifting loads will increase the stresses in them. Also, improper storage will result in deterioration.

Because of the severe service expected of slings, errors in determining load weight, and the effect of sling angle on the loading, it is recommended that all safe working loads be based on a factor of safety of at least 5:1.

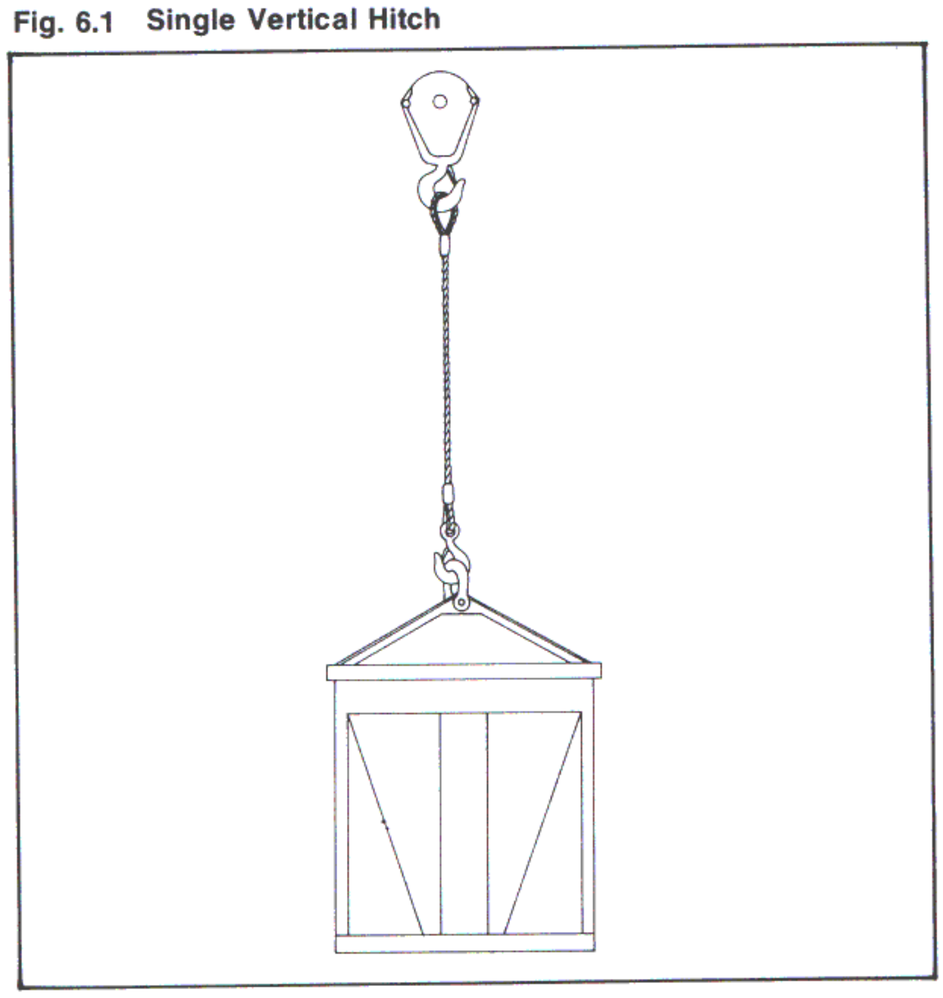
SLING CONFIGURATIONS:

The term "sling" includes a wide variety of configurations for all fibre ropes, wire ropes, chains and webs. The most commonly used types in construction rigging will be considered here because improper application can affect the safety of the lift.

Single Vertical Hitch (Fig. 6.1) is a method of supporting a load by a single vertical part or leg of the sling. The total weight of the load is carried by a single leg, the angle of the lift is 90° and the weight of the load can equal the maximum safe working load of the sling and fittings. The end fittings of the sling can vary but thimbles should be used in the eyes. Also, the eye splices on wire ropes should be Mechanical-Flemish Splices for best security. This sling configuration must not be used for lifting loose material, lengthy material or anything that will be difficult to balance. Use them only on items equipped with lifting eye bolts or shackles such as concrete buckets. They provide absolutely no control over the load be*cause they permit rotation.*

Bridle Hitch (Fig. 6.2, 6.3, 6.4) Two, three or four single hitches can be used together to form a bridle hitch for hoisting an object that has the necessary lifting lugs or attachments. They can be used with a wide assortment of end fittings. They provide excellent load stability when the load is distributed equally among the legs, when the hook is directly over the center of gravity of the load and the load is raised level. In order to distribute the load equally it may be necessary to adjust the leg lengths with turnbuckles. The use of a bridle sling requires that the sling angles be carefully determined to ensure that the individual legs are not overloaded.

Fig. 6.1 Single Vertical Hitch



Unless the load is flexible, it is wrong to assume that a 3 or 4 leg hitch will safely lift a load equal to the safe load on one leg multiplied by the number of legs because there is no way of knowing that each leg is carrying its share of the load. With slings having more than 2 legs and a rigid load, it is possible for two of the legs to take practically the full load while the others only balance it.

Single Basket Hitch (Fig. 6.5) is a method of supporting a load by hooking one end of a sling to a hook, wrapping it around the load and securing the other end to the hook. It cannot be used on any load that is difficult to balance because the load can tilt and slip out of the sling. On loads having inherent stabilizing characteristics the load on the sling will be automatically equalized with each leg supporting half the load. Ensure that the load does not

Fig. 6.2 2-Leg Bridle Hitches

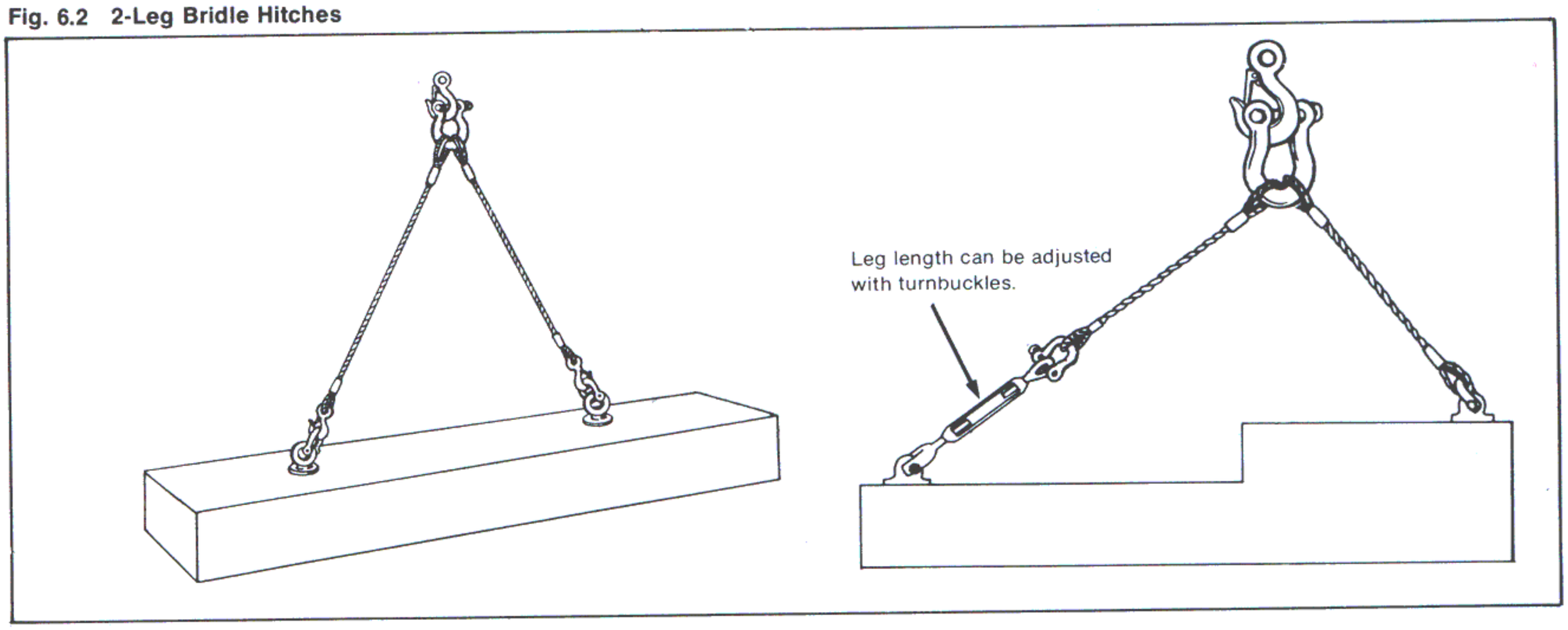
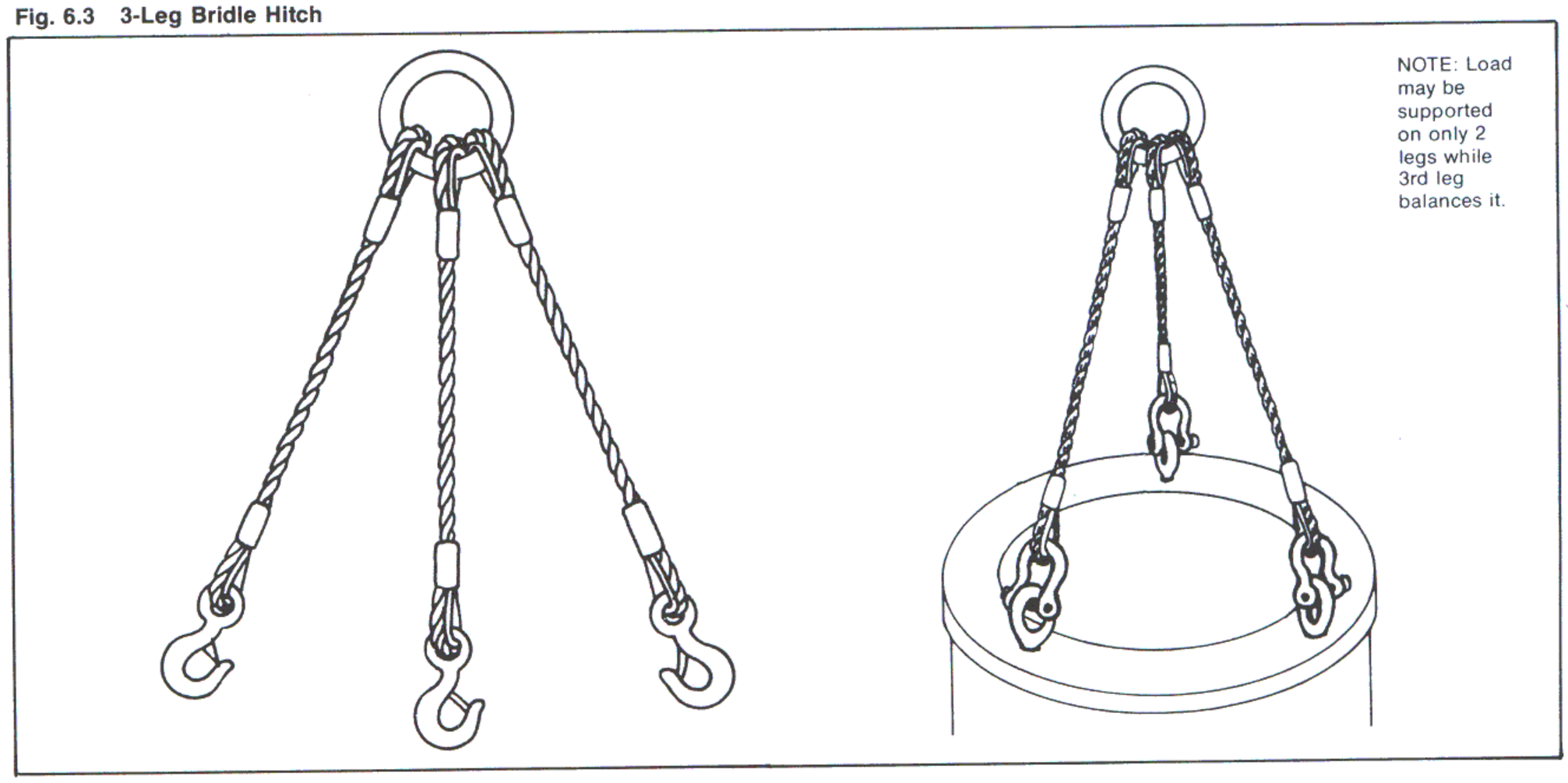


Fig. 6.3 3-Leg Bridle Hitch



turn or slide along the rope during a lift because both the load and rope will become damaged.

Double Basket Hitch (Fig. 6.6) consists of two single basket hitches passed under the load. They must be placed under the load so that it is properly balanced. The legs of the hitches must be kept far enough apart to provide balance but not so far apart that excessive angles are developed or to create a tendency for the legs to be pulled in toward the center. On smooth surfaces, both sides of the hitches should be snubbed against a step or change of contour to prevent the rope from slipping as load is applied. The angle between the load and the sling should be approximately 60° or greater to avoid slippage.

Fig. 6.4 4-Leg Bridle Hitch

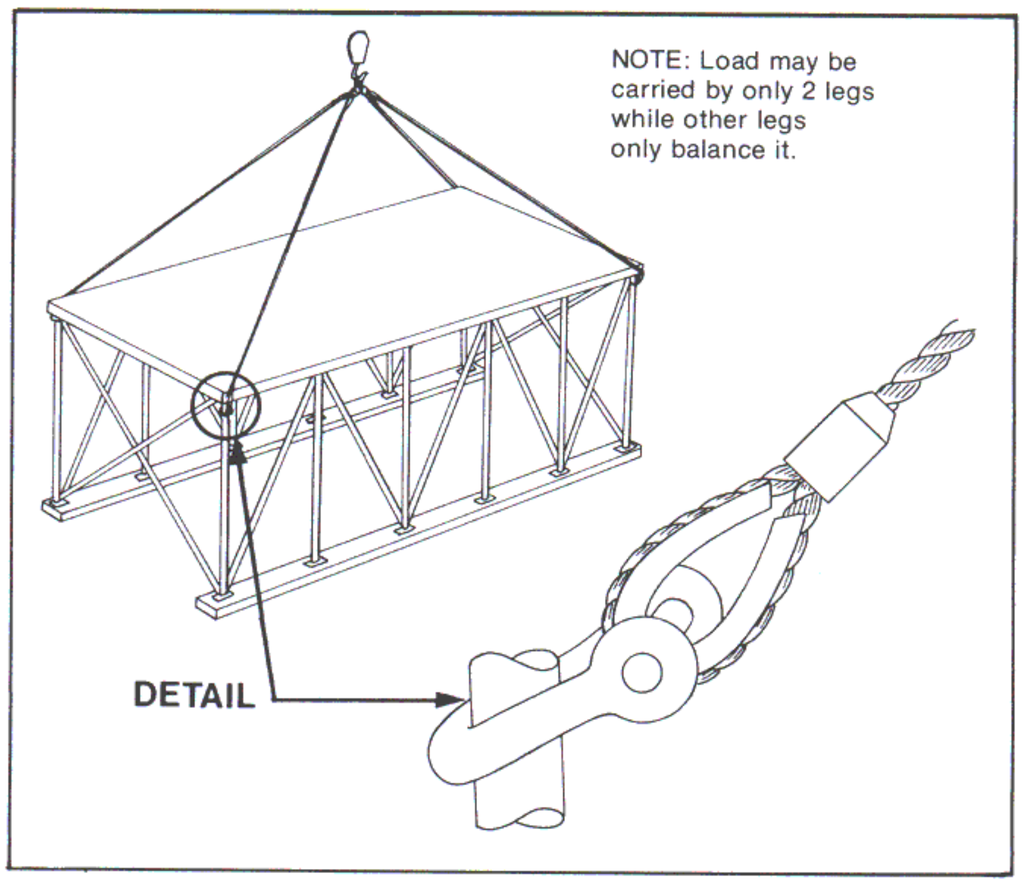


Fig. 6.5 Single Basket Hitch

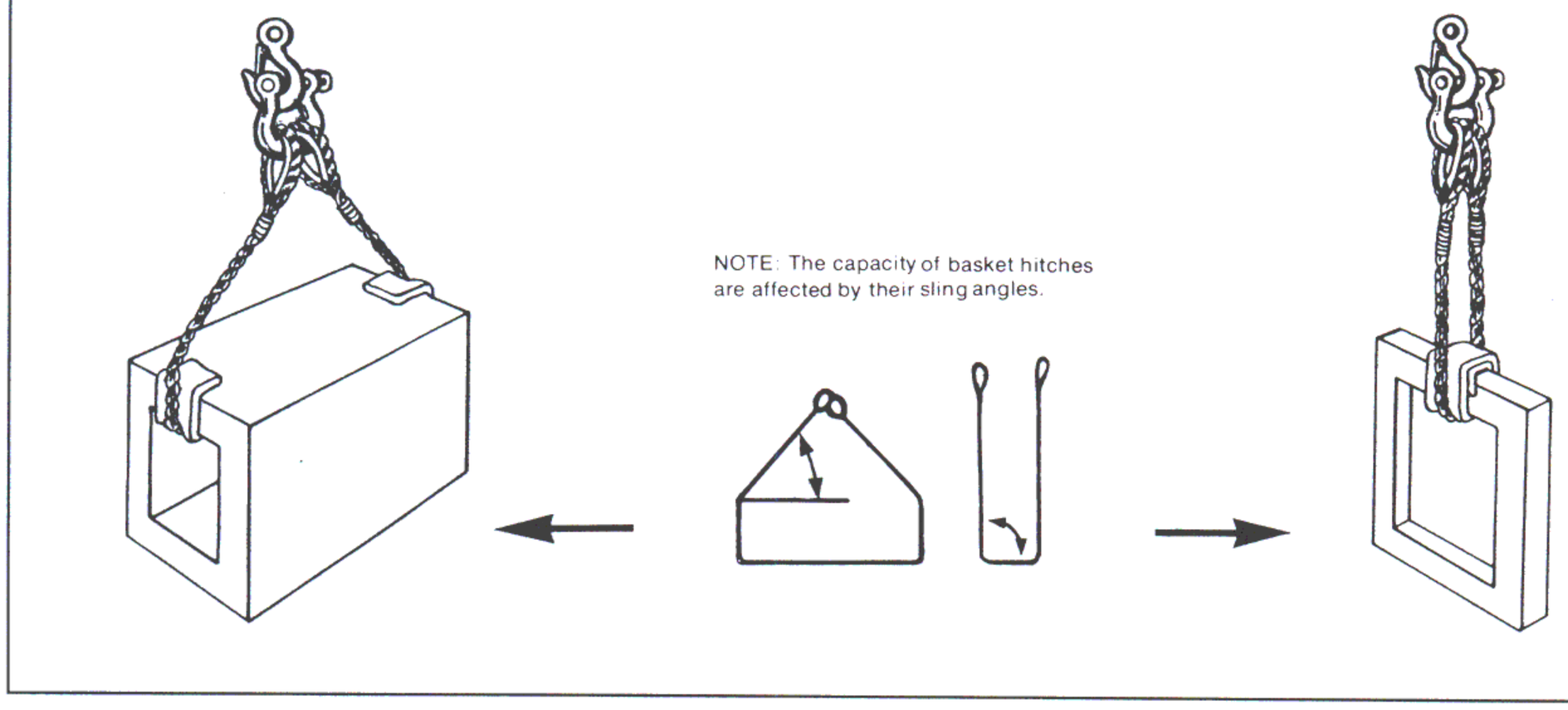


Fig. 6.6 Double Basket Hitches

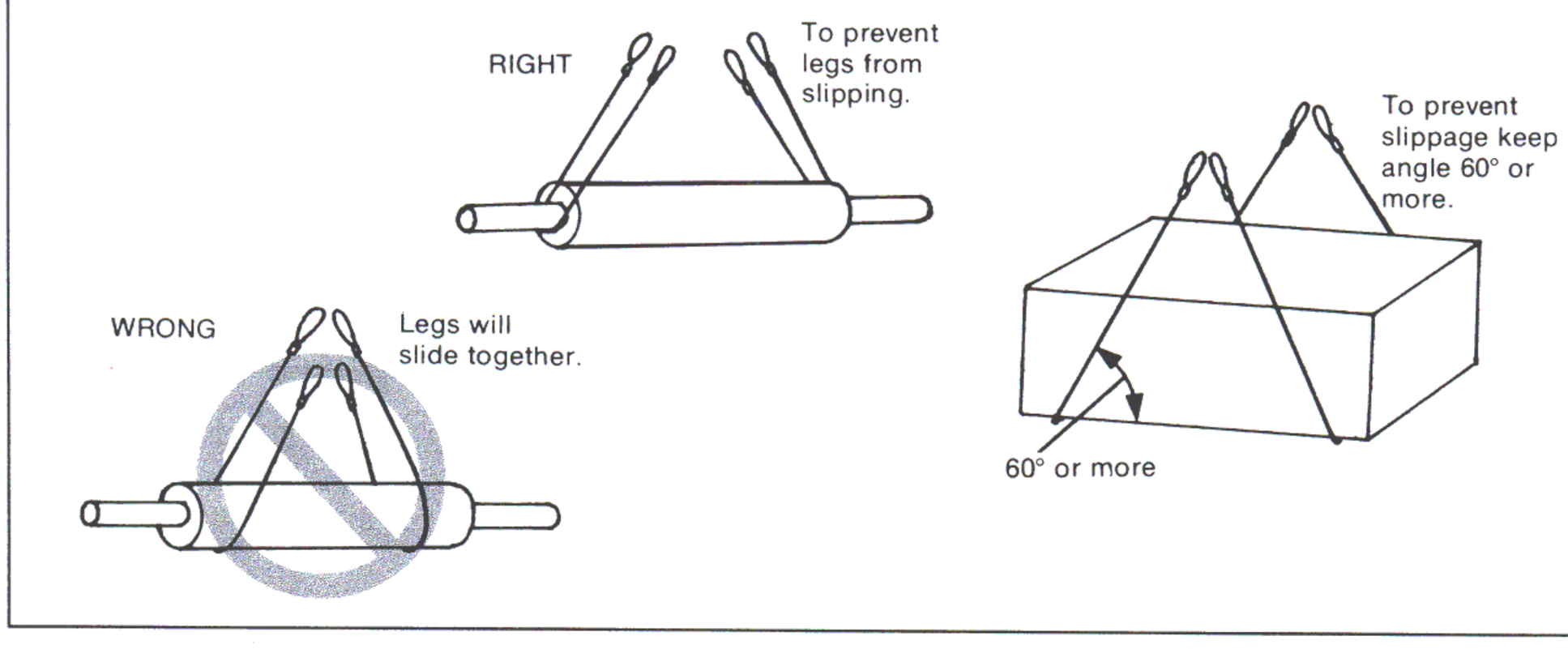
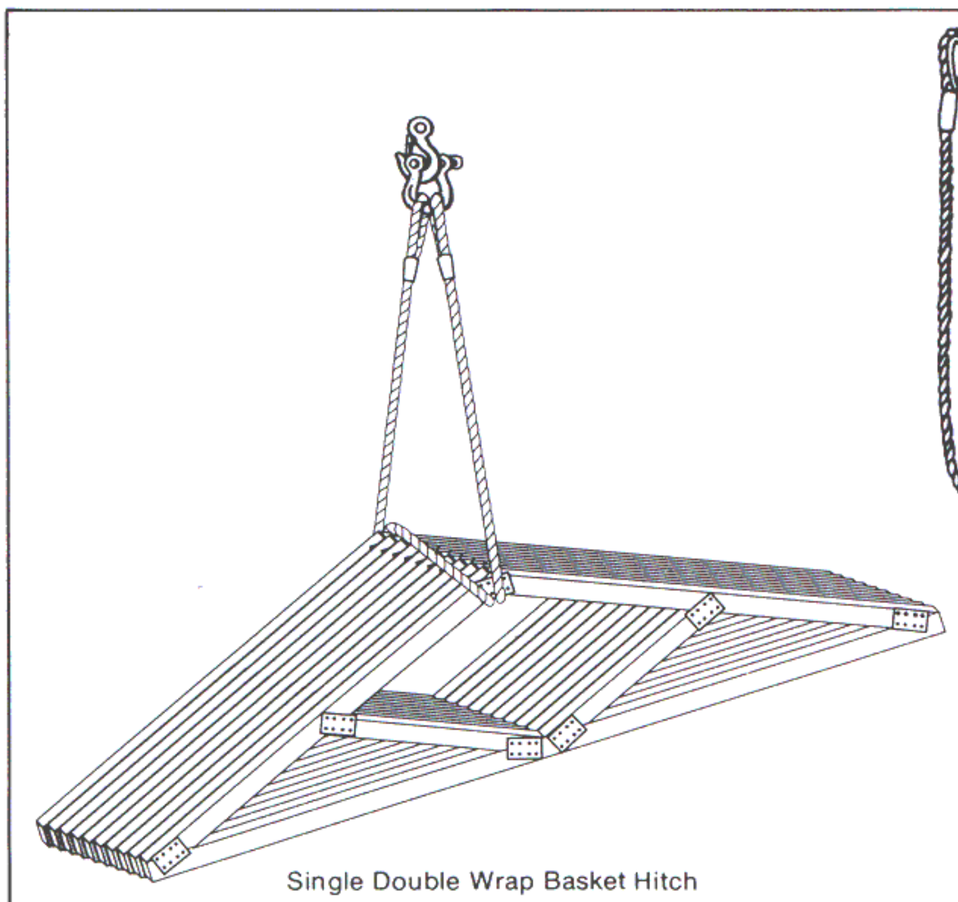
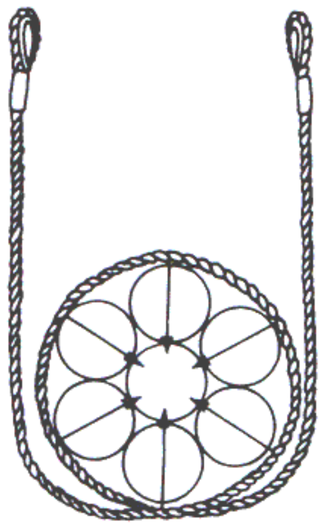


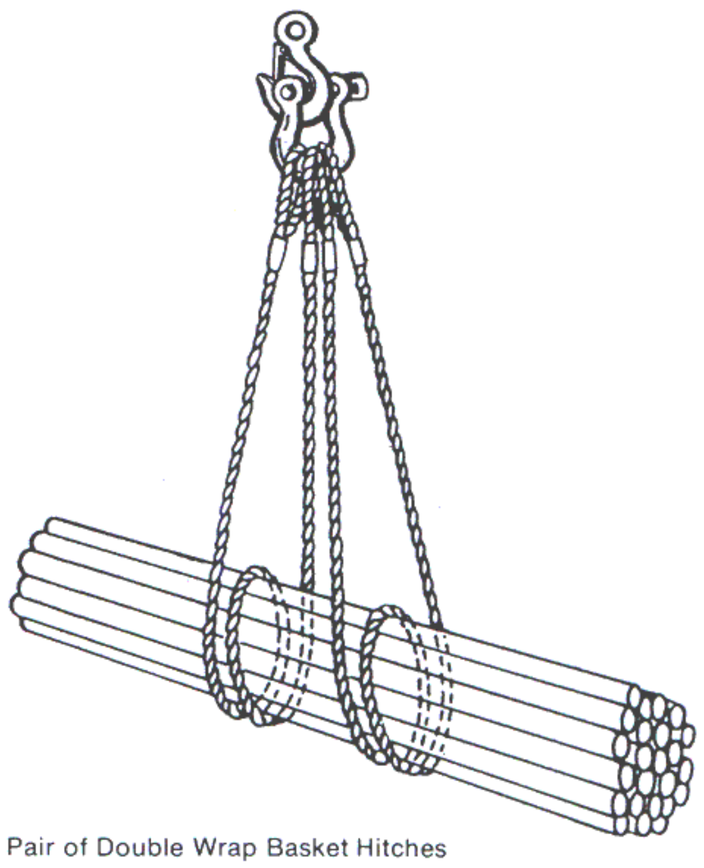
Fig. 6.7 Double Wrap Basket Hitch



Single Double Wrap Basket Hitch

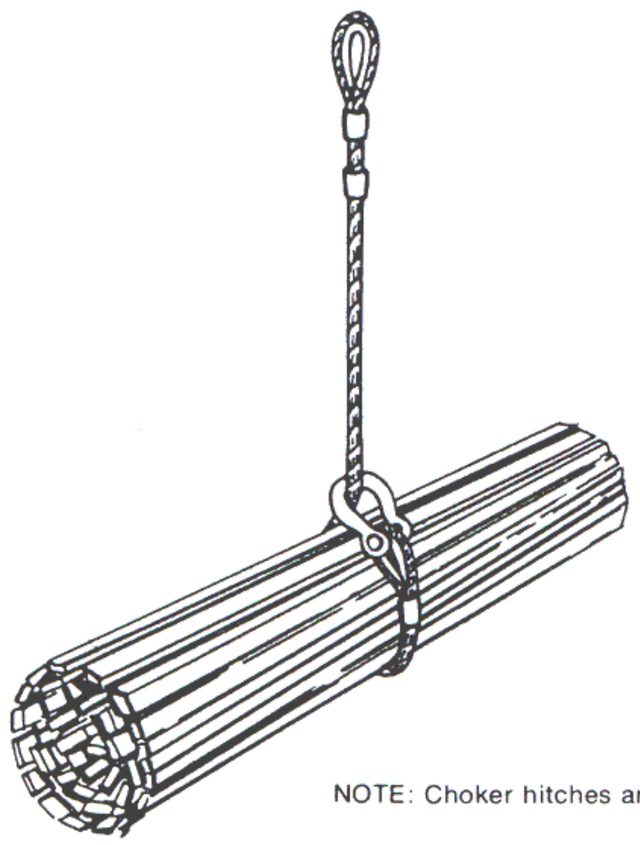


This hitch compresses the load and prevents it from slipping out of the slings.



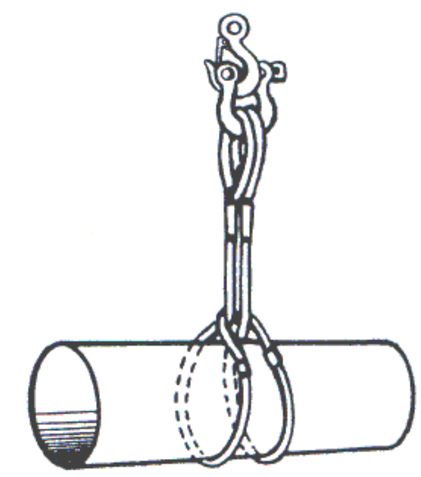
Pair of Double Wrap Basket Hitches

Fig. 6.8 Single Choker Hitches



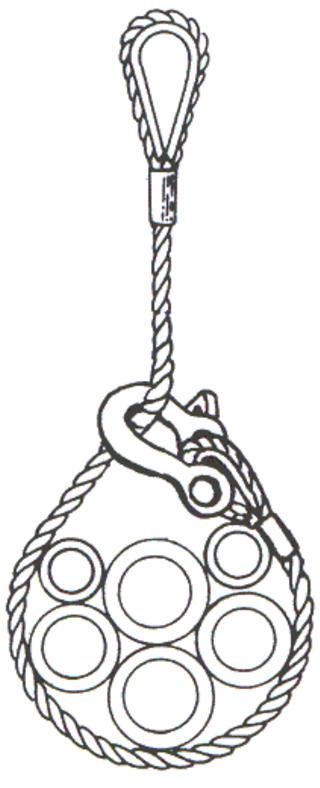
Not recommended when loads are long.

NOTE: Choker hitches are not suited to long loose bundles.

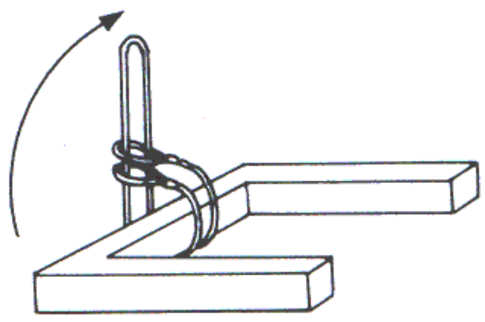


"Doubled" Choker

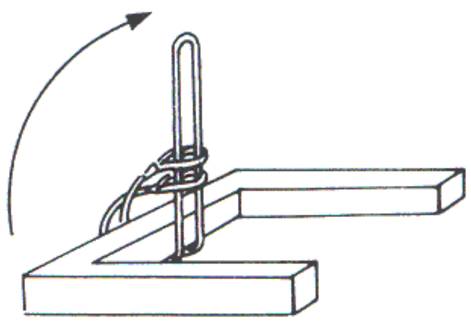
Use a "Doubled" Choker to turn loads



Chokers do not provide full support for loose loads — material can fall out.



RIGHT



WRONG.

Double Wrap Basket Hitch (Fig. 6.7) is a basket hitch that is wrapped completely around the load rather than just supporting as does the ordinary basket hitch. The double wrap basket hitch can be used in pairs like the double basket hitch. This method is excellent for handling loose material, pipe, rod or smooth cylindrical loads because the rope or chain exerts a full 360° contact with the load and tends to draw it together.

Single Choker Hitch (Fig. 6.8) forms a noose in the rope that tightens as the load is lifted. It does not provide full 360° contact with the load, however, and because of this it should not be used to lift loose bundles from which material can fall or loads that are difficult to balance. The single choker can also be doubled up (not to be confused with double choker hitch) as shown to provide twice the capacity or to turn a load. When it is necessary to turn a load, the choker is made by placing both eyes of the sling on top of the load with the eyes pointing in the direction opposite to the direction of turn. The center of the sling is passed around the load, through both eyes and up to the hook. This hitch provides complete control over the load during the entire turning operation, and the load automatically equalizes between the two supporting legs of the sling. Because the load is turned into a tight sling, there is no movement between the load and the sling. If it is incorrectly made and the two eyes are placed on the crane hook — the supporting legs of the sling may not be equal in length and the load may be imposed on one leg only.

Double Choker Hitch (Fig. 6.9) consists of two single chokers attached to the load and spread to provide load stability. They, like the single choker, do not completely grip the load but because the load is less likely to tip they are better suited for handling loose bundles, pipes, rods, etc.

Fig. 6.9 Double Choker Hitches

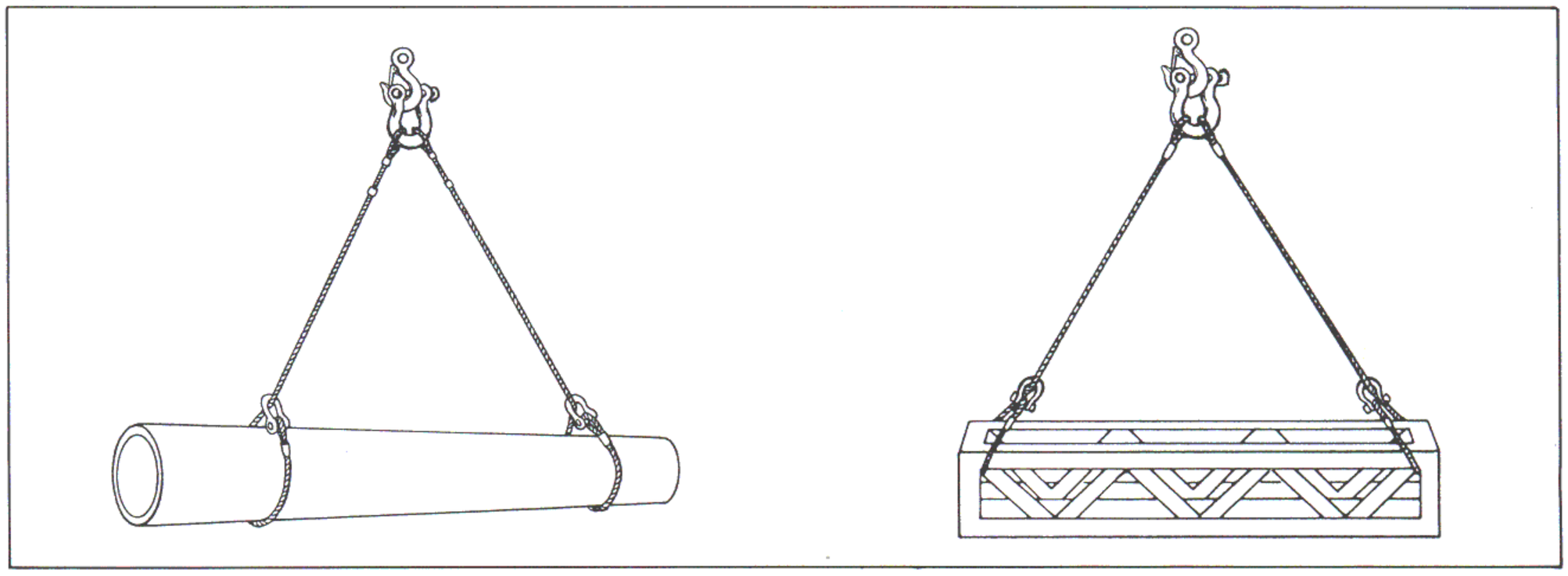


Fig. 6.10 Double Wrap Choker Hitches

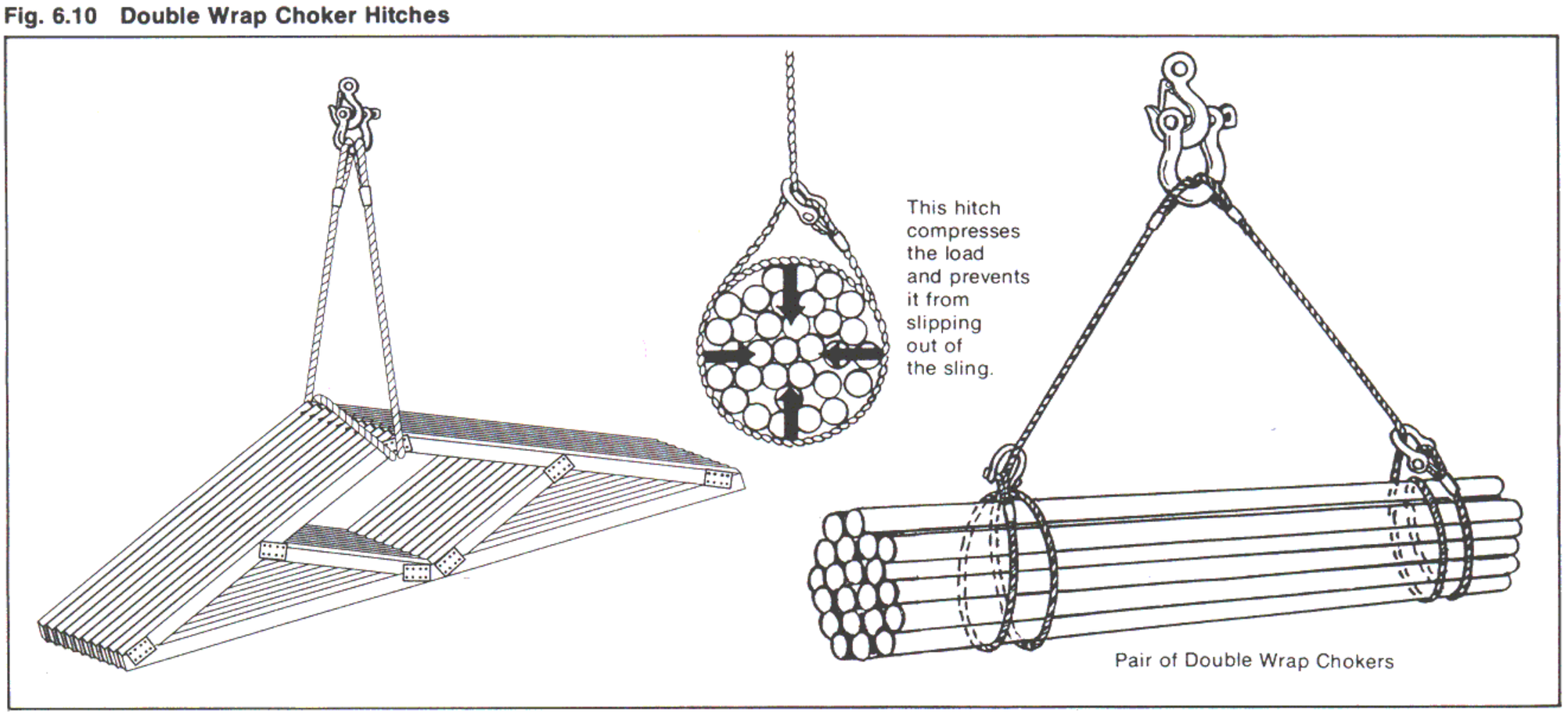


Fig. 6.11 Endless Slings or Grommet Slings

NOTE: Ensure that the splice is always clear of the hooks and load.

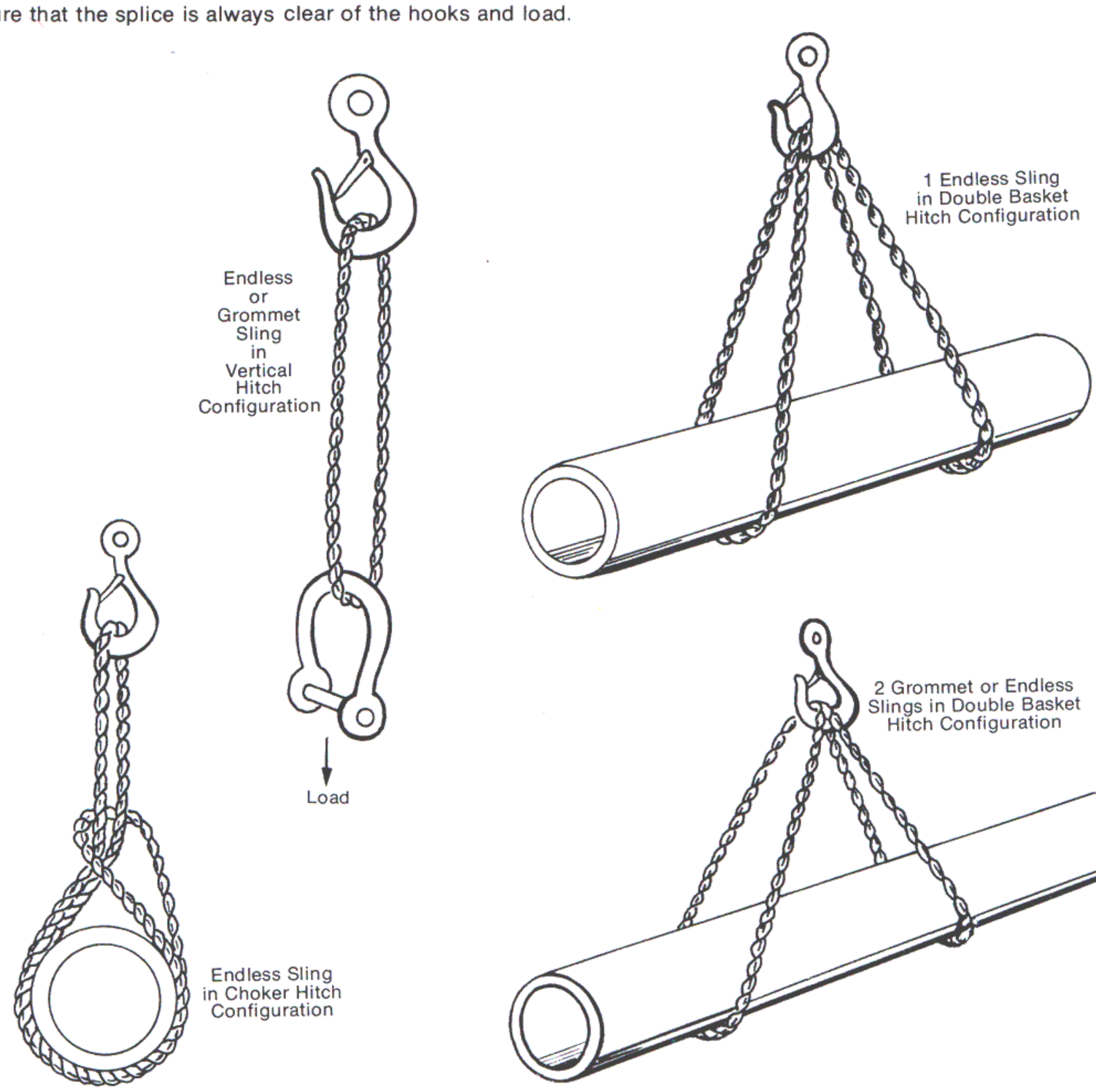
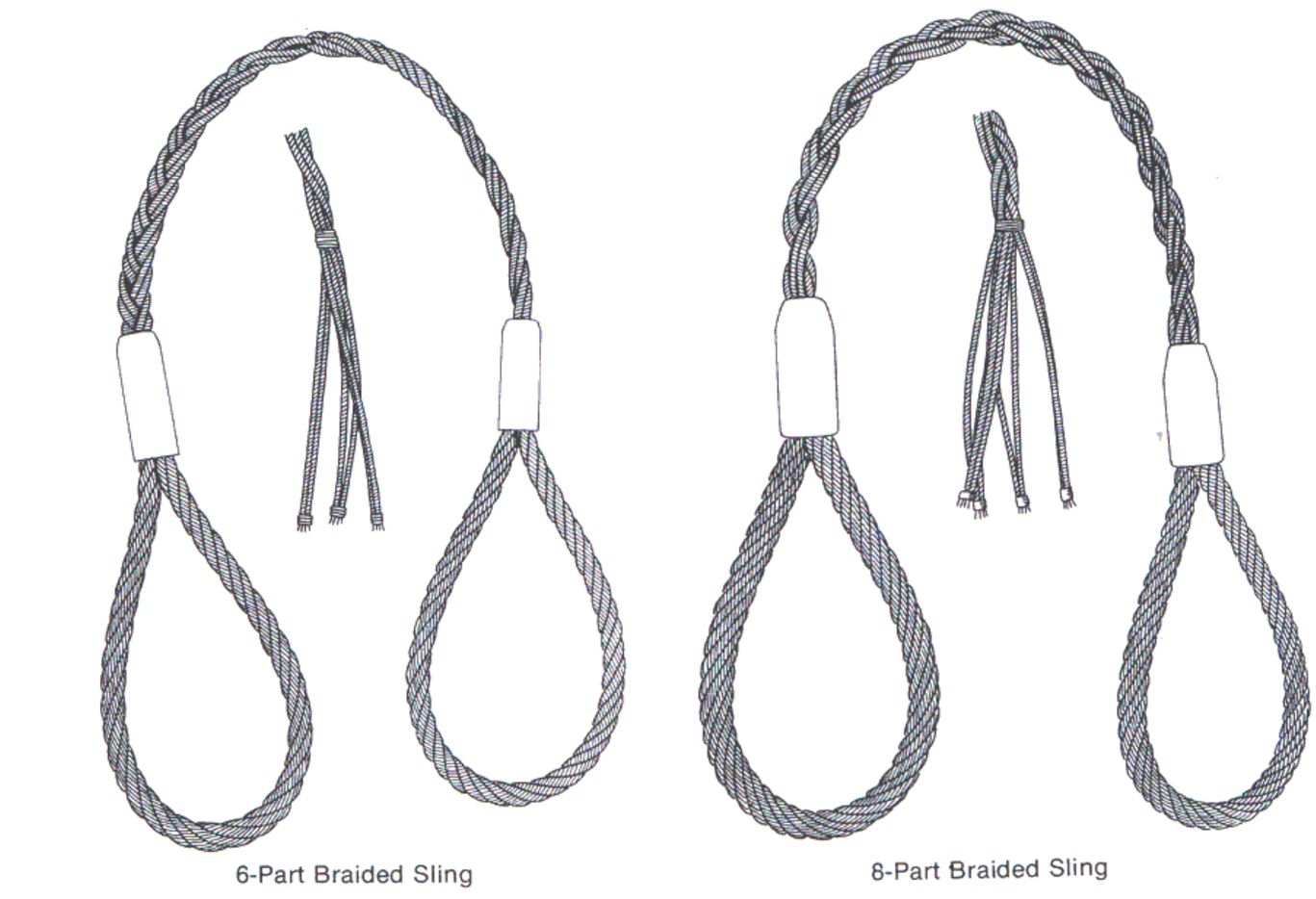


Fig. 6.12 Braided Slings



Double Wrap Choker Hitch (Fig. 6.10) is one in which the rope or chain is wrapped completely around the load before being hooked into the vertical part of the sling. This hitch is in full contact with the load and tends to draw it tightly together. It can be used either singly on short, easily balanced loads or in pairs on longer loads.

Endless Slings or Grommet Slings (Fig. 6.11) are endless ropes that are made from one strand of a rope laid or twisted around itself on each successive loop. There is only one tuck in the entire circumference where the two ends enter the rope. These slings can be used in a number of configurations, as vertical hitches, basket hitches, choker hitches and all combinations of these basic configurations. They are very flexible but tend to wear and deteriorate more rapidly than the other slings because they are not normally equipped with fittings and thus are deformed when bent over hooks and bear against themselves at the bight.

Braided Slings (Fig. 6.12) are fabricated from usually 6 or 8 small diameter ropes braided together to form a single rope that provides a large bearing surface, tremendous strength and flexibility in all directions. They are very easy to handle and almost impossible to kink. The braided sling can be used in all the standard configurations and combinations but is especially useful for basket hitches where low bearing pressure is desirable or where the bend is extremely sharp.

SLING ANGLES:

The rated capacity of any sling depends on its size, its configuration and the angles formed by the legs of the sling and the horizontal. A sling with two legs that is used to lift a 1000 pound object will have a 500 pound load in each leg when the sling angle is 90°. The load in each leg will increase as the angle is decreased and at 30° the load will be 1000 pounds in each leg. (Fig. 6.13)

If possible, keep the sling angles greater than 45°; sling angles approaching 30° should be considered extremely hazardous and avoided at all costs. The sharp increase in loading at low angles is clearly shown in Fig. 6.14.

Some load tables list sling angles as low as 15° but the use of any sling at an angle less than 30° is extremely dangerous. This is not only because of the high loads associated with them but because of the effect on the load of an error in sling angle measurement of as little as 5°. Table 6.1 illustrates the effect of a 5° error in sling angle measurement on the sling load.

You can see that there is almost a 50% error in the assumed load at the 15° sling angle. This illustrates how cautious you must be in not only ensuring the angle is greater than 45°, but the importance of measuring it accurately. The easiest and most accurate way to determine the angle is by measuring it with a large plywood measure graduated in degrees.

SAFE WORKING LOADS:

The remaining sections of this chapter contain many tables of safe working loads. It would be a very difficult task to remember all load, size and sling angle combinations, but the following rules of thumb work well for estimating the loads in the most common sling configurations.

Each of the rules of thumb for a given sling configuration, material and size, is based on the safe working load of the single vertical hitch of that sling. The efficiencies of whatever

TABLE 6.1

EFFECT OF SLING ANGLE MEASUREMENT ERROR ON LOADS

Assumed Sling Angle	Assumed Load (Pounds Per Leg)	Actual Angle (is 5° Less Than Assumed Angle)	Actual Load (Pounds Per Leg)	Error %
90°	500	85°	502	0.4
75°	518	70°	532	2.8
60°	577	55°	610	5.7
45°	707	40°	778	9.1
30°	1,000	25°	1,183	18.3
15°	1,932	10°	2,880	49.0

Fig. 6.13 Effect of Sling Angle on Sling Load

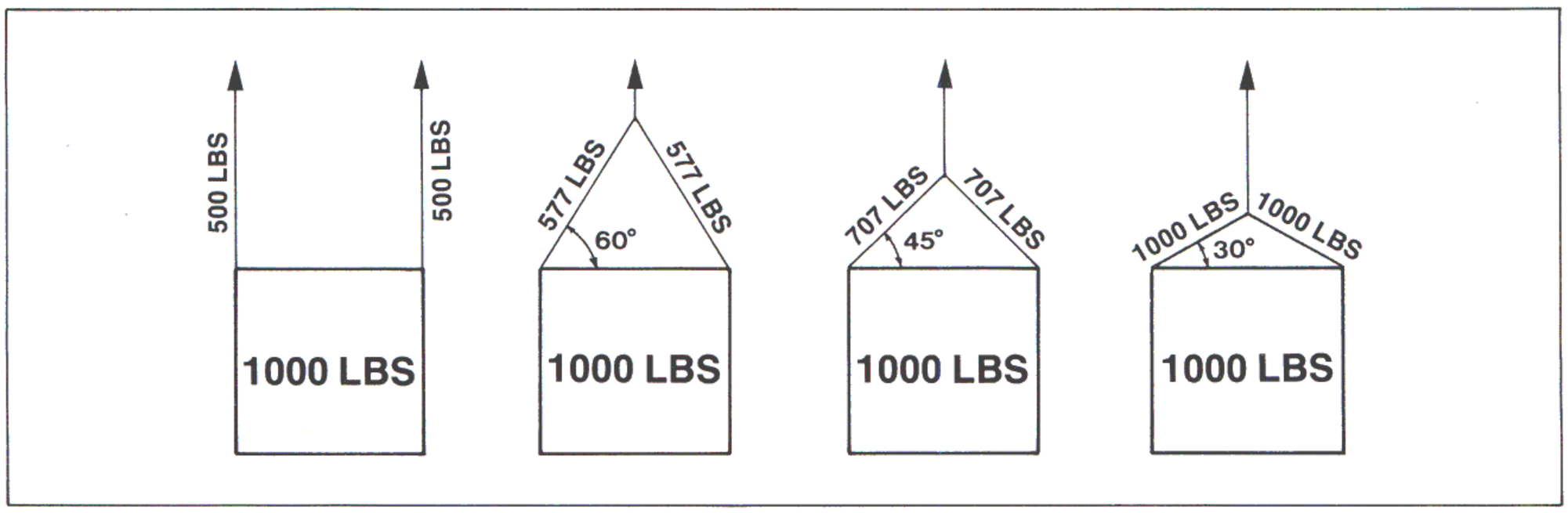
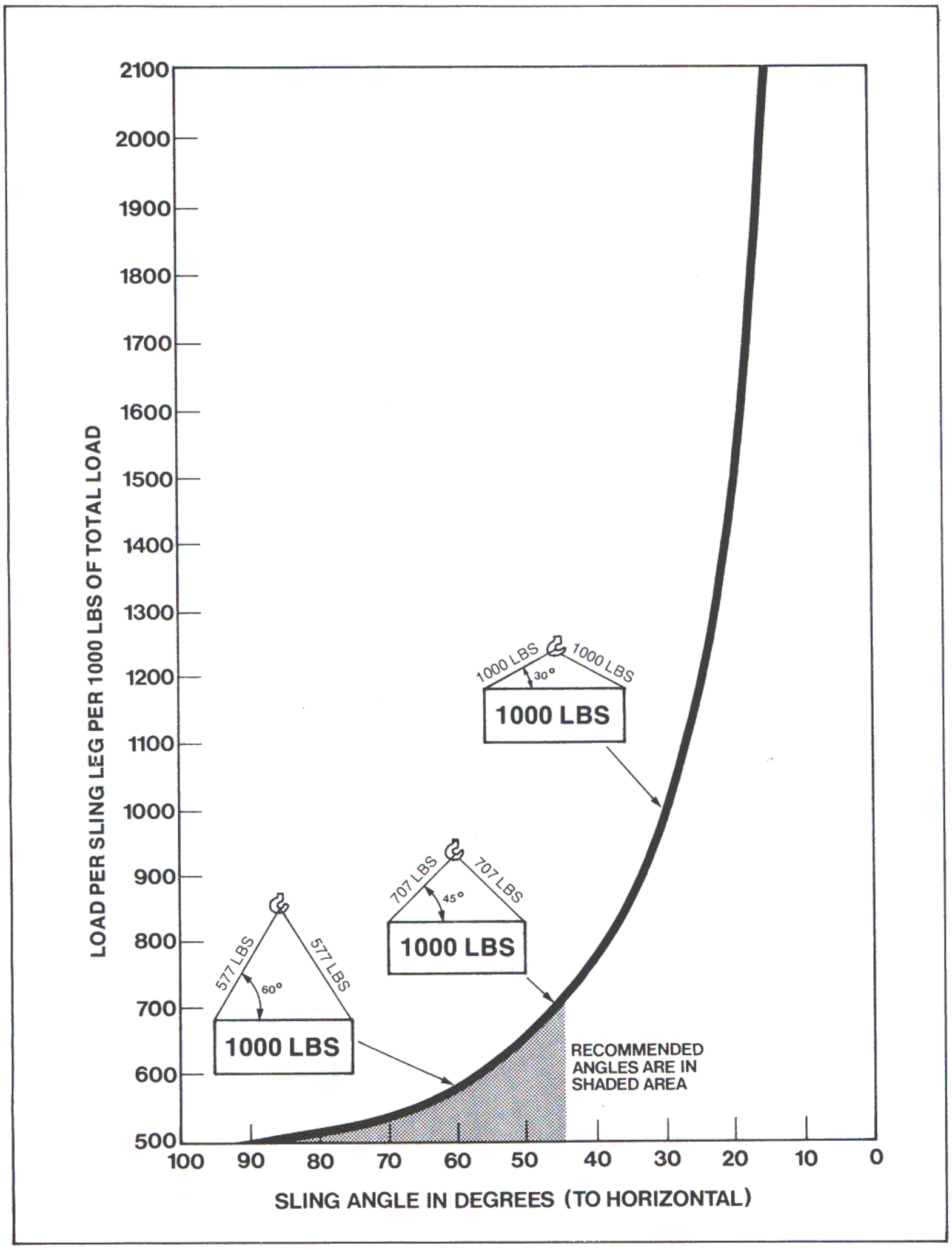


Fig. 6.14 Effect of Sling Angle on Sling Load



end fittings are used must also be considered to determine the capacity of the combination.

—**Bridle Hitches** (Figs. 6.15, 6.16, 6.17)
Measure the length of sling legs (= L) and the head room between hook and load (= H).

2-Leg Bridle Hitch

S.W.L. = S.W.L. (of single vertical hitch)
$= \frac{H}{L} \times 2$

3- and 4-Leg Bridle Hitches

S.W.L. = S.W.L. (of single vertical hitch)
$= \frac{H}{L} \times 3$

Generally, 4-leg bridle hitches should be rated as 3-leg hitches because there is no way of knowing that all four legs are sharing the load. It is possible for only three legs to carry the load while the fourth merely balances it.

Fig. 6.15 Determination of Capacity of 2-Leg Bridle Hitches

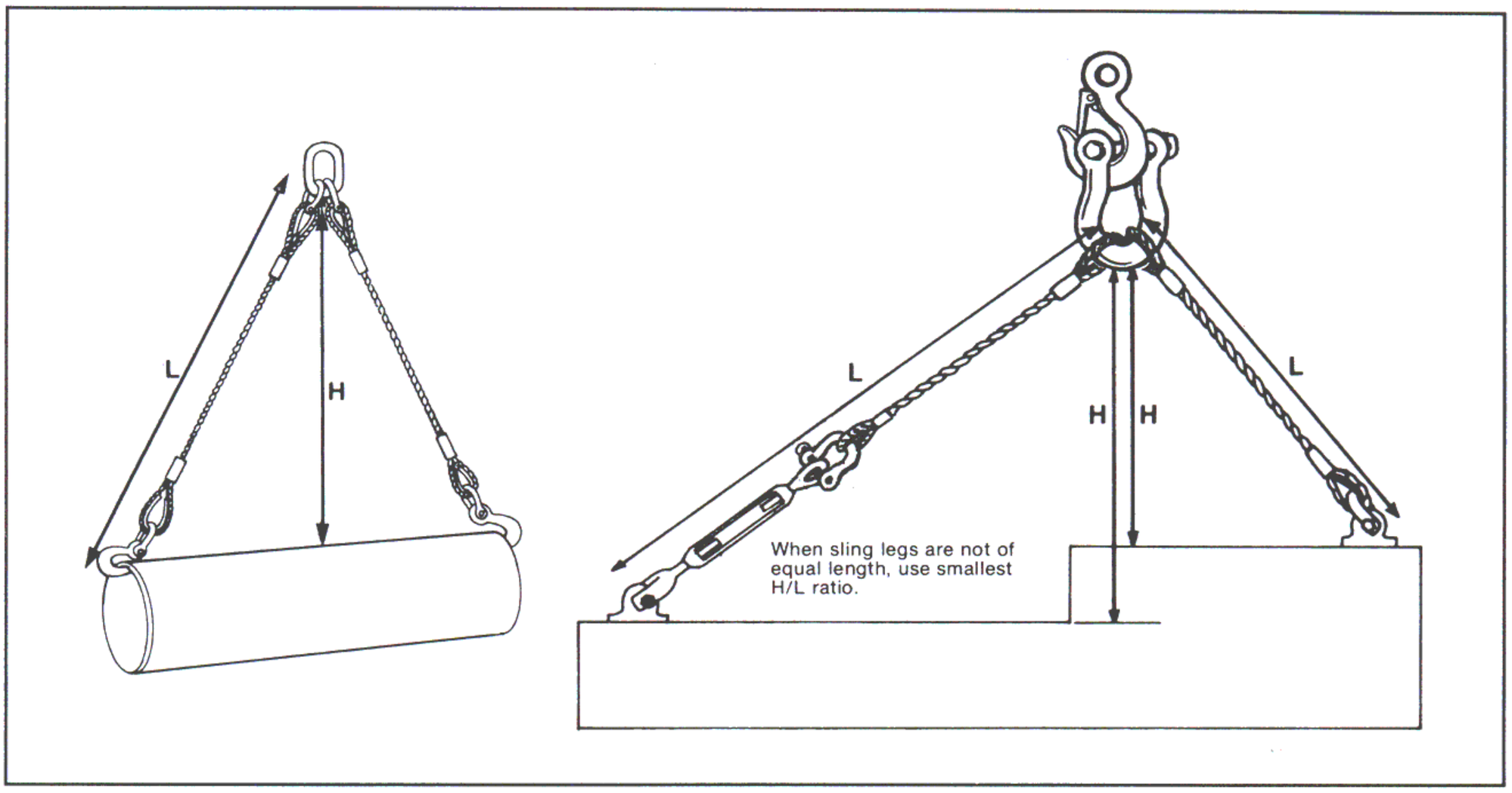
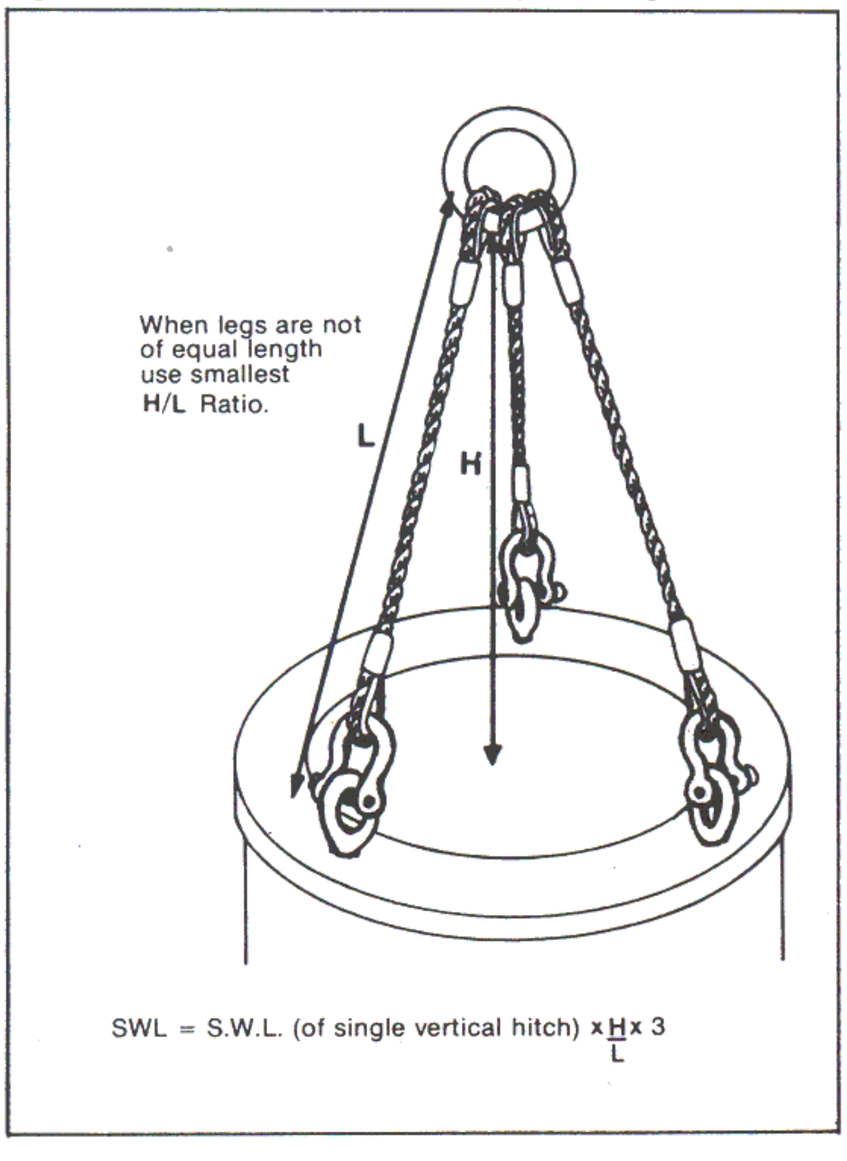
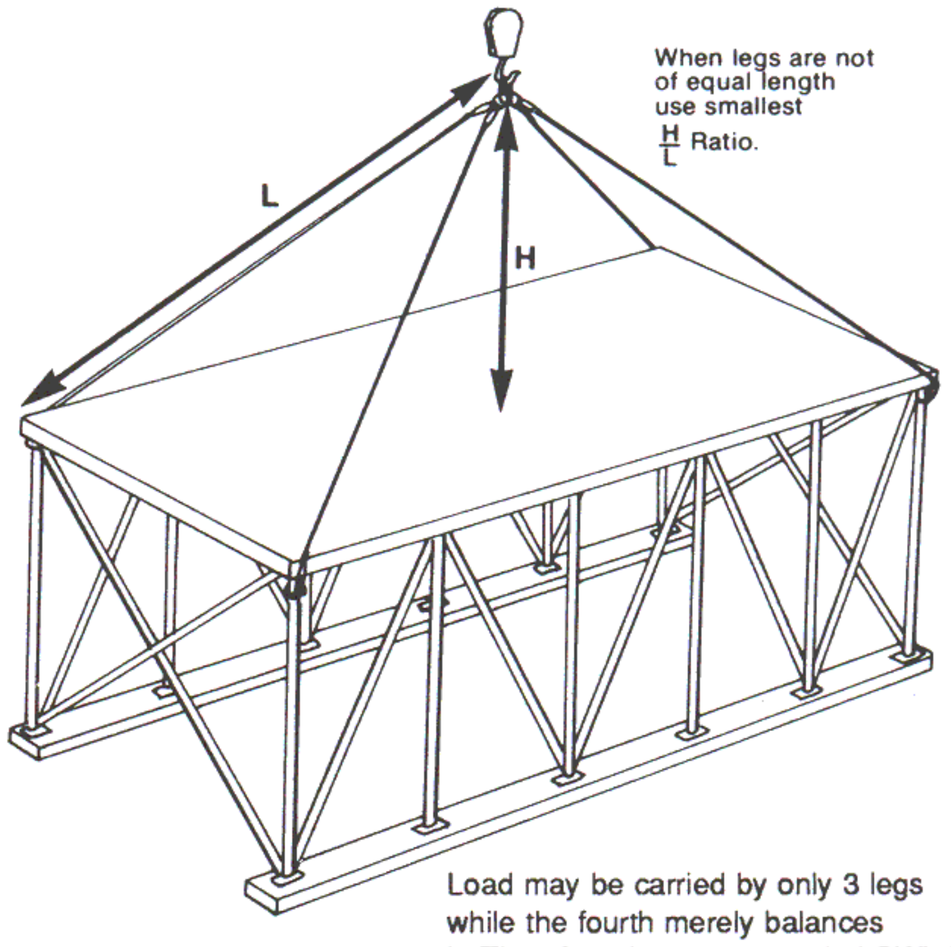


Fig. 6.16 Determination of Capacity of 3-Leg Bridle Hitch



SWL = S.W.L. (of single vertical hitch) $\times \frac{H}{L} \times 3$

Fig. 6.17 Determination of Capacity of 4-Leg Bridle Hitch



Load may be carried by only 3 legs while the fourth merely balances it. Therefore the recommended SWL is

SWL = SWL (of single vertical hitch) $\times \frac{H}{L} \times 3$

—Single Basket Hitch: (Fig. 6.18)

For vertical legs — S.W.L. = S.W.L. (of Single Vertical Hitch) x 2.
For inclined legs — S.W.L. = S.W.L. (of Single Vertical Hitch) x $\frac{H}{L}$ x 2.

—Double Basket Hitch: (Fig. 6.19)

For vertical legs — S.W.L. = S.W.L. (of Single Vertical Hitch) x 4.
For inclined legs — S.W.L. = S.W.L. (of Single Vertical Hitch) x $\frac{H}{L}$ x 4.

—Double Wrap Basket Hitch:

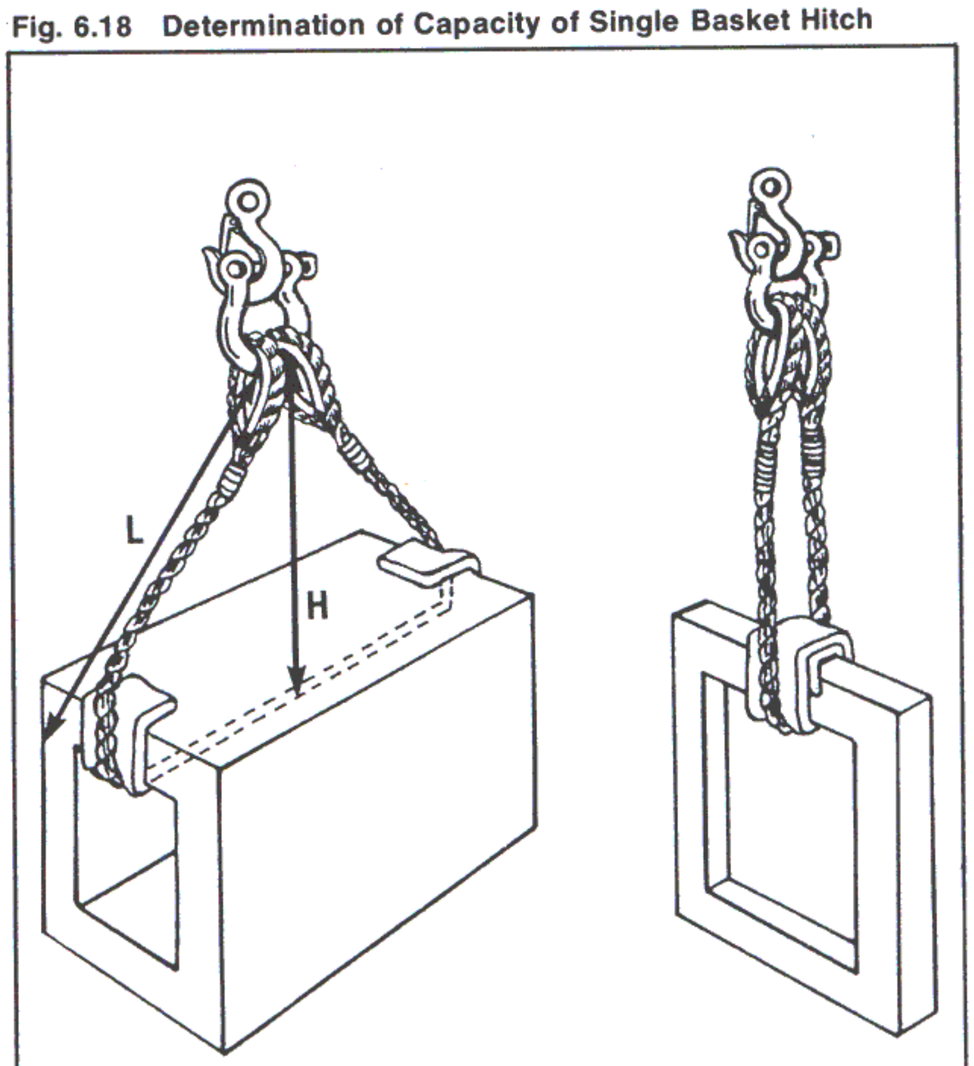
Depending on the configurations, the safe working loads are the same as for the Single Basket Hitch or the Double Basket Hitch.

—Single Choker Hitch: (Fig. 6.20)

For sling angles of 45° or more,
S.W.L. = S.W.L. (of Single Vertical Hitch) x $^{3}/_{4}$.

Sling angles of less than 45° are not recommended, however, if they must be used the formula is:
S.W.L. = S.W.L. (of Single Vertical Hitch) x A/B.

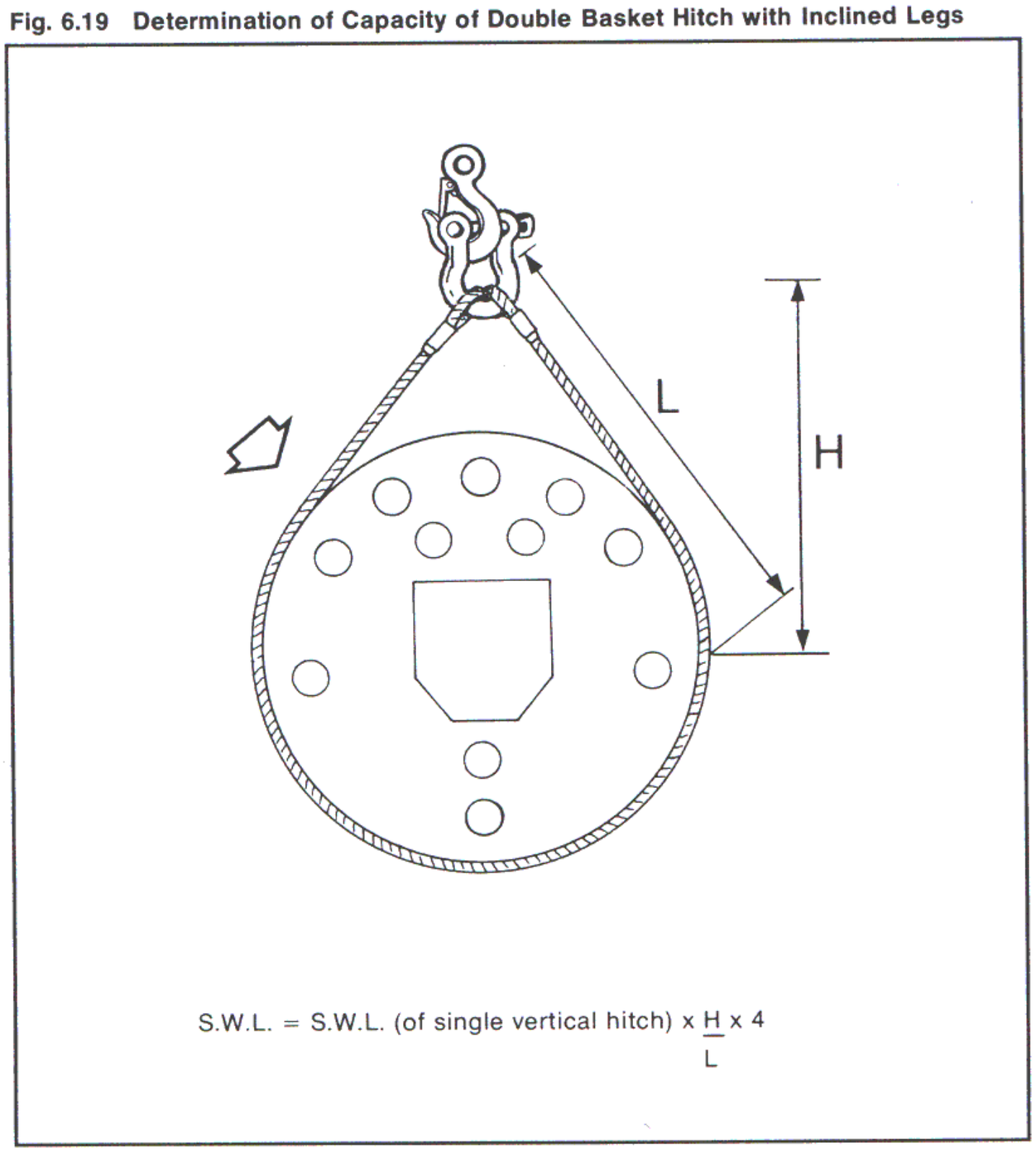
Fig. 6.18 Determination of Capacity of Single Basket Hitch



Inclined Legs
S.W.L. = S.W.L.
(of single vertical hitch)
x $\frac{H}{L}$ x 2

Vertical Legs
S.W.L. = S.W.L.
(of single vertical hitch) x 2

Fig. 6.19 Determination of Capacity of Double Basket Hitch with Inclined Legs



S.W.L. = S.W.L. (of single vertical hitch) x $\frac{H}{L}$ x 4

— Double Choker Hitch: (Fig. 6.21)

For sling angles of 45° or more (formed by the choker),

S.W.L. = S.W.L. (of Single Vertical Hitch) x $\frac{3}{4} \times \frac{H}{L} \times 2$

Sling angles of less than 45° (formed by the choker) are not recommended, however, if they must be used the formula is:

S.W.L. = S.W.L. (of Single Vertical Hitch) x $\frac{A}{B} \times \frac{H}{L} \times 2$

— Double Wrap Choker Hitch:

Depending on the configuration, the safe working loads are the same as for the Single Choker Hitch or the Double Choker Hitch.

— Endless Slings and Grommets:

Depending on the configuration, the safe working loads are 2 times the values for the previous configurations.

Fig. 6.20 Determination of Capacity of Single Choker Hitch

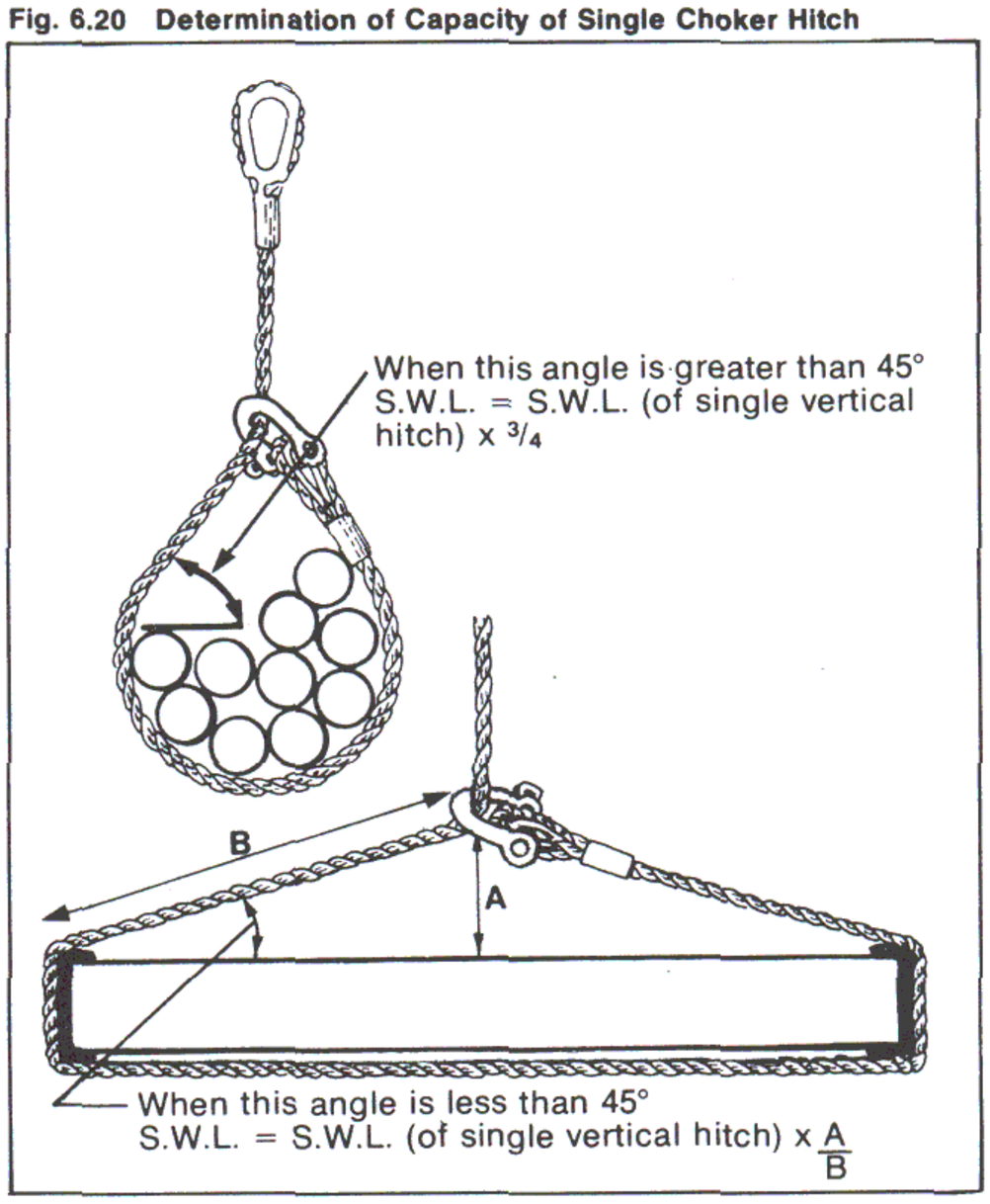
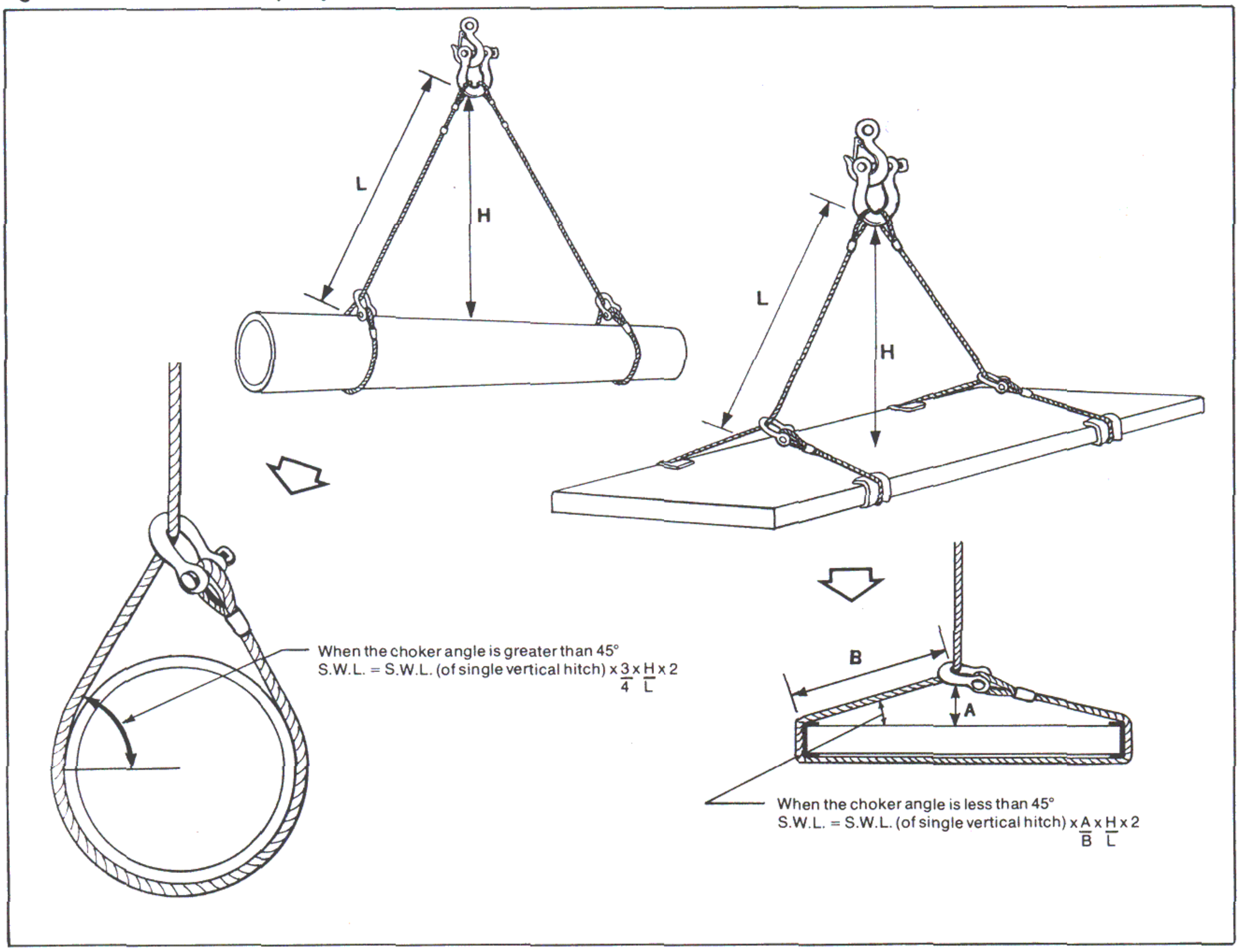


Fig. 6.21 Determination of Capacity of Double Choker Hitch



FIBRE ROPE SLINGS:

Fibre rope slings are preferred for some applications because they are pliant, they grip the load well and they do not mar the surface of the load. They should be used only on light loads, however, and must not be used on objects that have sharp edges capable of cutting the rope or in applications where the sling will be exposed to high temperatures, severe abrasion or acids.

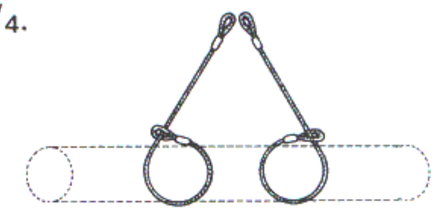
The choice of the rope type and size will depend upon the application, the weight to be lifted and the sling angle. Before lifting any load with a fibre rope sling be sure to inspect

TABLE 6.2

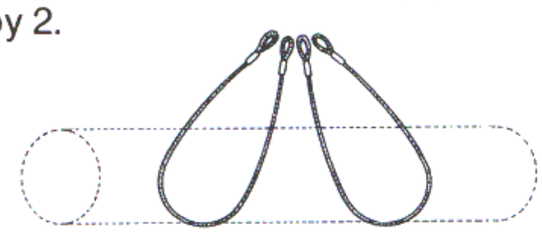
MANILA ROPE SLINGS
Spliced Eyes in Both Ends

Rope Diameter (Inches)	MAXIMUM SAFE WORKING LOADS — POUNDS (Safety Factor = 5)					
	Single Vertical Hitch	Single Choker Hitch	Single Basket Hitch (Vertical Legs)	2-Leg Bridle Hitch & Single Basket Hitch With Legs Inclined		
				60°	45°	30°
3/16	100	75	200	170	140	100
1/4	120	90	240	210	170	120
5/16	200	150	400	350	280	200
3/8	270	200	540	470	380	270
1/2	530	400	1,060	920	750	530
9/16	680	500	1,360	1,180	960	680
5/8	880	660	1,760	1,520	1,240	880
3/4	1,080	800	2,160	1,870	1,530	1,080
13/16	1,300	980	2,600	2,250	1,840	1,300
7/8	1,540	1,150	3,080	2,670	2,180	1,540
1	1,800	1,350	3,600	3,100	2,550	1,800
1 1/16	2,100	1,580	4,200	3,600	2,970	2,100
1 1/8	2,400	1,800	4,800	4,150	3,400	2,400
1 1/4	2,700	2,000	5,400	4,670	3,800	2,700
1 5/16	3,000	2,250	6,000	5,200	4,200	3,000
1 1/2	3,700	2,800	7,400	6,400	5,250	3,700
1 5/8	4,500	3,400	9,000	7,800	6,350	4,500
1 3/4	5,300	4,000	10,600	9,200	7,500	5,300
2	6,200	4,650	12,400	10,700	8,800	6,200
2 1/8	7,200	5,400	14,400	12,500	10,200	7,200
2 1/4	8,200	6,150	16,400	14,200	11,600	8,200
2 1/2	9,300	7,000	18,600	16,100	13,200	9,300
2 5/8	10,400	7,800	20,800	18,000	14,700	10,400

If used with Choker Hitch multiply above values by 3/4.



For Double Basket Hitch multiply above values by 2.



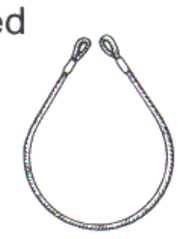
Note: For Safe Working Loads of Endless or Grommet Slings, Multiply Above Values by 2.

the sling carefully because they deteriorate far more rapidly than wire rope slings and their actual strength is very difficult to estimate.

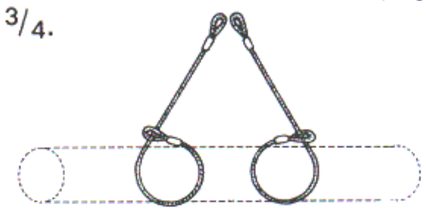
The safe working loads in the following tables (6.2, 6.3, 6.4, 6.5) are approximate only and are based on a 5:1 factor of safety. They refer to new unknotted ropes and they assume that the loads are symmetrical and balanced, that the sling legs are of equal length, that the rope splices and fittings used to couple the slings to the load are strong enough and that padding is used to protect the slings when lifting objects with sharp corners.

TABLE 6.3

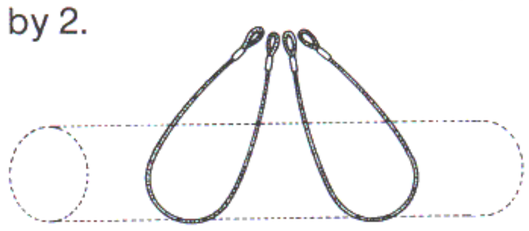
NYLON ROPE SLINGS
Spliced Eyes in Both Ends

Rope Diameter (Inches)	MAXIMUM SAFE WORKING LOADS — POUNDS (Safety Factor = 5)					
	Single Vertical Hitch	Single Choker Hitch	Single Basket Hitch (Vertical Legs)	2-Leg Bridle Hitch & Single Basket Hitch With Legs Inclined 		
				60°	45°	30°
3/16	200	150	400	350	280	200
1/4	300	225	600	520	420	300
5/16	500	375	1,000	870	700	500
3/8	700	525	1,400	1,200	1,000	700
1/2	1,250	940	2,500	2,200	1,770	1,250
9/16	1,500	1,125	3,000	2,600	2,100	1,500
5/8	2,000	1,500	4,000	3,500	2,800	2,000
3/4	2,800	2,100	5,600	4,850	4,000	2,800
13/16	3,200	2,400	6,600	5,500	4,500	3,200
7/8	3,800	2,850	7,600	6,600	5,400	3,800
1	4,800	3,600	9,600	8,300	6,800	4,800
1 1/16	5,500	4,125	11,000	9,500	7,800	5,500
1 1/8	6,300	4,725	12,600	10,900	8,900	6,300
1 1/4	7,200	5,400	14,400	12,500	10,200	7,200
1 5/16	8,200	6,150	16,400	14,200	11,600	8,200
1 1/2	10,200	7,650	20,400	17,700	14,400	10,200
1 5/8	12,400	9,300	24,800	21,500	17,500	12,400
1 3/4	15,000	11,250	30,000	26,000	21,200	15,000
2	17,900	13,400	35,800	31,000	25,300	17,900
2 1/8	20,200	15,150	40,400	35,000	28,600	20,200
2 1/4	23,800	17,850	47,600	41,200	33,700	23,800
2 1/2	26,600	20,000	53,200	46,100	37,600	26,600
2 5/8	30,700	23,000	61,400	53,200	43,400	30,700

If used with Choker Hitch multiply above values by 3/4.



For Double Basket Hitch multiply above values by 2.



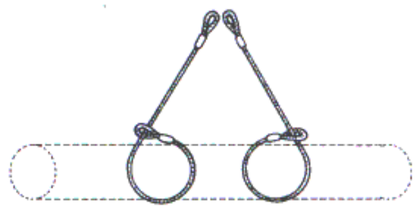
Note: For Safe Working Loads of Endless or Grommet Slings, Multiply Above Values by 2.

TABLE 6.4

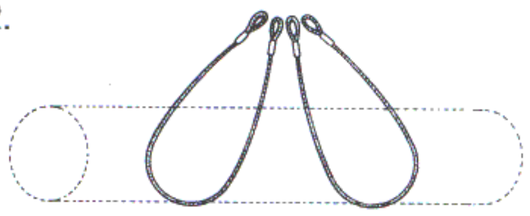
POLYPROPYLENE ROPE SLINGS
Spliced Eyes in Both Ends

Rope Diameter (Inches)	MAXIMUM SAFE WORKING LOADS — POUNDS (Safety Factor = 5)					
	Single Vertical Hitch	Single Choker Hitch	Single Basket Hitch (Vertical Legs)	2-Leg Bridle Hitch & Single Basket Hitch With Legs Inclined		
				60°	45°	30°
3/16	150	110	300	260	210	150
1/4	250	190	500	430	350	250
5/16	400	300	800	700	560	400
3/8	500	375	1,000	860	700	500
1/2	830	620	1,660	1,400	1,200	830
9/16	960	720	1,920	1,700	1,350	960
5/8	1,300	975	2,600	2,250	1,800	1,300
3/4	1,700	1,275	3,400	2,900	2,400	1,700
13/16	1,900	1,425	3,800	3,300	2,700	1,900
7/8	2,200	1,650	4,400	3,800	3,100	2,200
1	2,900	2,175	5,800	5,000	4,100	2,900
1 1/16	3,000	2,250	6,000	5,200	4,200	3,000
1 1/8	3,750	2,800	7,500	6,500	5,300	3,750
1 1/4	4,200	3,150	8,400	7,300	5,900	4,200
1 5/16	4,400	3,300	8,800	7,600	6,200	4,400
1 1/2	6,000	4,500	12,000	10,400	8,500	6,000
1 5/8	7,300	5,500	14,600	12,600	10,300	7,300
1 3/4	8,700	6,500	17,400	15,100	12,300	8,700
2	10,400	7,800	20,800	18,000	14,700	10,400
2 1/8	11,500	8,600	23,000	19,900	16,300	11,500
2 1/4	13,200	9,900	26,400	22,900	18,700	13,200
2 1/2	15,100	11,300	30,200	26,200	21,400	15,100
2 5/8	17,000	12,750	34,000	29,400	24,000	17,000

If used with Choker Hitch multiply above values by 3/4.



For Double Basket Hitch multiply above values by 2.



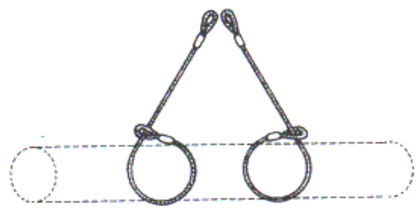
Note: For Safe Working Loads of Endless or Grommet Slings, Multiply Above Values by 2.

TABLE 6.5

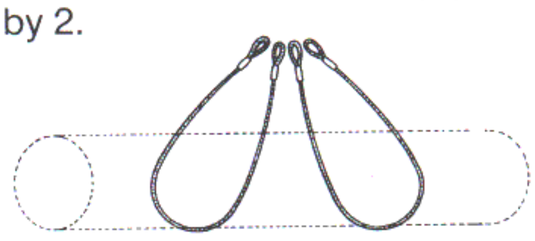
POLYESTER ROPE SLINGS
Spliced Eyes in Both Ends

Rope Diameter (Inches)	MAXIMUM SAFE WORKING LOADS — POUNDS (Safety Factor = 5)					
	Single Vertical Hitch	Single Choker Hitch	Single Basket Hitch (Vertical Legs)	2-Leg Bridle Hitch & Single Basket Hitch With Legs Inclined		
				60°	45°	30°
3/16	200	150	400	350	280	200
1/4	300	225	600	520	420	300
5/16	500	375	1,000	870	700	500
3/8	700	525	1,400	1,200	1,000	700
1/2	1,200	900	2,400	2,100	1,700	1,200
9/16	1,500	1,125	3,000	2,600	2,100	1,500
5/8	1,900	1,425	3,800	3,300	2,700	1,900
3/4	2,400	1,800	4,800	4,150	3,400	2,400
13/16	2,950	2,200	5,900	5,100	4,200	2,950
7/8	3,400	2,550	6,800	5,900	4,800	3,400
1	4,200	3,150	8,400	7,300	5,900	4,200
1 1/16	4,900	3,675	9,800	8,500	6,900	4,900
1 1/8	5,600	4,200	11,200	9,700	7,900	5,600
1 1/4	6,300	4,725	12,600	10,900	8,900	6,300
1 5/16	7,100	5,325	14,200	12,300	10,000	7,100
1 1/2	8,900	6,675	17,800	15,400	12,600	8,900
1 5/8	10,800	8,100	21,600	18,700	15,300	10,800
1 3/4	12,900	9,675	25,800	22,300	18,200	12,900
2	15,200	11,400	30,400	26,300	21,500	15,200
2 1/8	17,400	13,050	34,800	30,100	24,600	17,400
2 1/4	20,400	15,300	40,800	35,300	28,800	20,400
2 1/2	23,200	17,400	46,400	40,200	32,800	23,200
2 5/8	26,000	19,500	52,000	45,000	36,800	26,000

If used with Choker Hitch multiply above values by 3/4.



For Double Basket Hitch multiply above values by 2.



Note: For Safe Working Loads of Endless or Grommet Slings, Multiply Above Values by 2.

SYNTHETIC WEBBING SLINGS:

Synthetic webbing slings offer a number of advantages for rigging purposes:

— Their relative softness and width mean they have much less tendency to mar or scratch finely machined, highly polished or painted surfaces and have less tendency to crush fragile objects than do fibre rope, wire rope or chain slings. (Fig. 6.22)

— Because of their flexibility, they tend to mold themselves to the shape of the load. (Fig. 6.23)

— They are not affected by moisture and certain chemicals.

— They do not rust and thus do not stain ornamental precast concrete or stone.

— They are non-sparking and can be used safely in explosive atmospheres.

— They minimize twisting and spinning during lifting.

— Their light weight permits ease of rigging, their softness precludes hand cuts, and the danger of harm from a bump by a free-swinging sling is minimal.

— They are elastic and stretch under load more than either wire rope or chain and are thus able to absorb heavy shocks and cushion the load. In cases where sling stretching must be minimized, a sling of larger load capacity or a polyester sling should be used.

Synthetic webbing slings are available in a number of configurations that find application in the industry.

— **Endless or Grommet Sling** — both ends of one piece of webbing are lapped and sewn to form a continuous piece. They can be used as vertical hitches, bridle hitches, in choker arrangements or as basket slings. Because load contact points can be shifted with every lift, wear is evenly distributed and sling life is extended. (Fig. 6.24)

— **Standard Eye and Eye** — webbing assembled and sewn to form a flat body sling with an eye at each end and the eye openings in the same plane as the sling body. The eyes may either be full web width or may be tapered by being folded and sewn to a width narrower than the webbing width. (Fig. 6.25)

— **Twisted Eye** — an eye and eye type with twisted terminations at both ends. The eye openings are at 90° to the plane of the sling body. This configuration is also available with either full width or tapered eyes. (Fig. 6.26)

In place of the sewn eyes, the slings are also available with metal end fittings. The most common are triangle and choker hardware. Combination hardware consists of a triangle for one end of the sling and a triangle/rectangle (choker attachment) for the other end. With this arrangement, both choker and basket as well as straight hitches may be rigged. They help reduce wear in the sling eyes and thus lengthen sling life. (Fig. 6.27)

Despite their inherent toughness, synthetic webbing slings can be cut by repeated use around sharp-cornered objects and they eventually show signs of abrasion when rough-surfaced products are continually hoisted. There are, however, protective devices offered by most sling manufacturers that minimize these effects. (Fig. 6.28)

— Buffer strips of leather, nylon, or other materials sewn on the body of a sling protect against wear. Leather pads are the most resistant to wear and cutting, but are subject to weathering and gradual deterioration. They are not recommended in lengths over 6 feet due to the different stretch characteristics of leather and webbing. On the other hand, nylon web wear pads are more resistant to weathering, oils, grease, most alkalies; and they stretch in the same ratio as the sling body.

— Edge guards are also available and consist of strips of webbing or leather sewn around each edge of the sling. This is necessary for certain applications where the sling edges are subject to damage.

— Sleeve or sliding tube type wear pads are available for slings used to handle material having sharp edges. They can be positioned on the sling where required, don't move when the sling stretches, adjust to the load and cover both sides of the sling.

— Reinforcing strips can be sewn into the sling eyes that double or triple the eye thickness and greatly increase the life and safety.

— Coatings can be applied to provide added abrasion and chemical resistance. These treatments also increase the coefficient of friction, affording a better grip when loads with slippery surfaces are to be handled. These coatings can be brightly coloured for safety or load rating purposes.

Fig. 6.22 Synthetic Web Slings do not Damage or Crush Like Wire Ropes or Chain

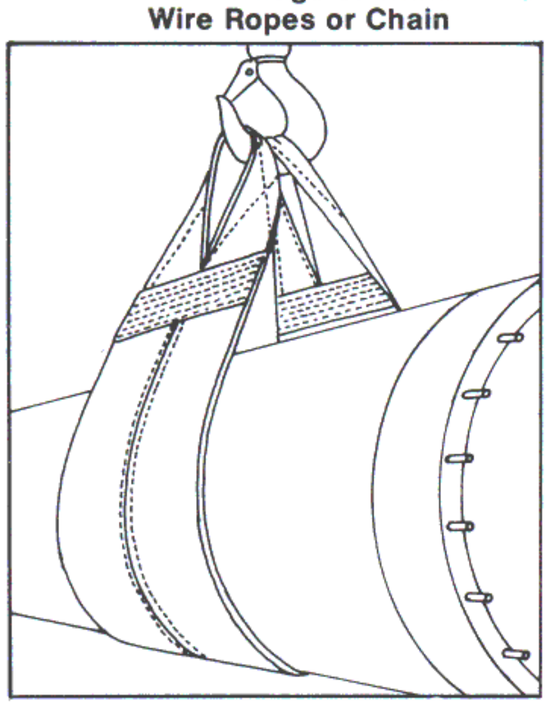


Fig. 6.23 Pipe handling illustrates the tendency of webbing slings to mold themselves to the load. This allows handling irregularly shaped loads securely.

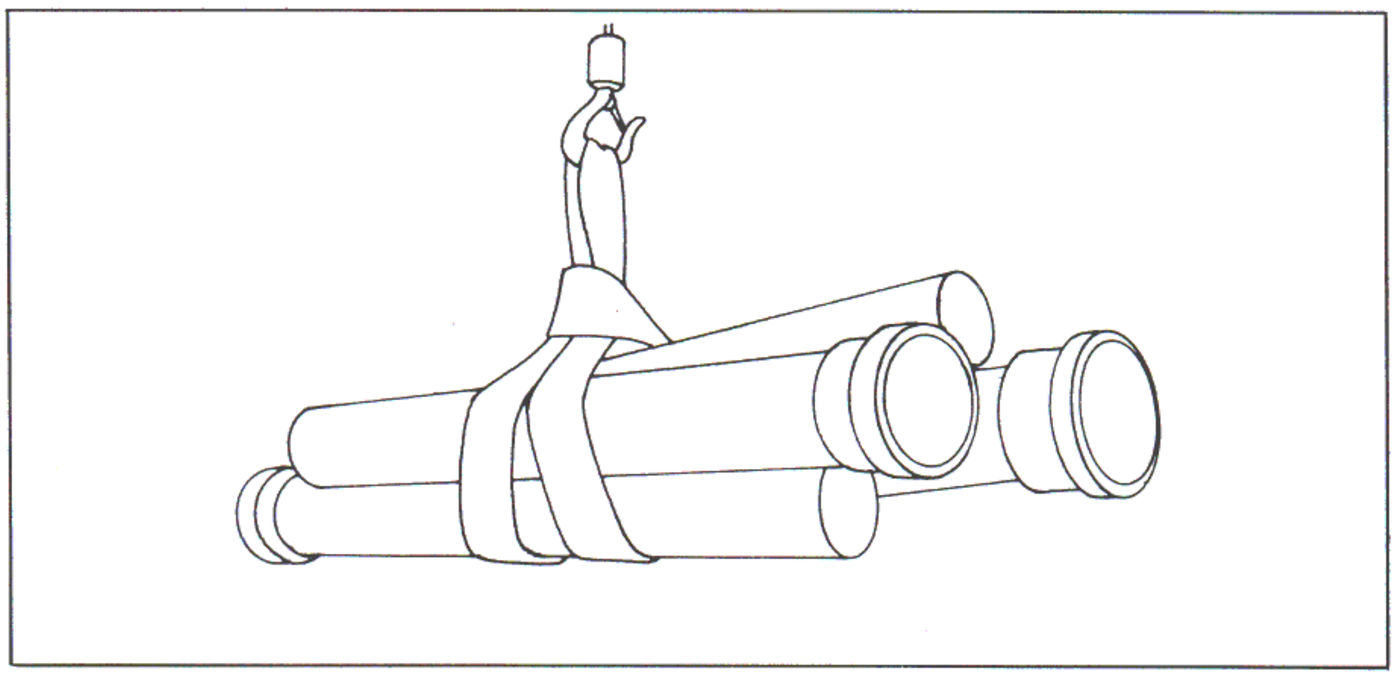


Fig. 6.24 Endless or Grommet Sling

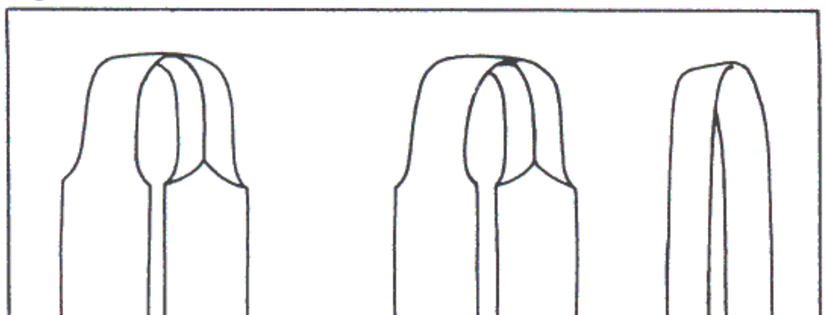


Fig. 6.25 Standard Eye and Eye Slings

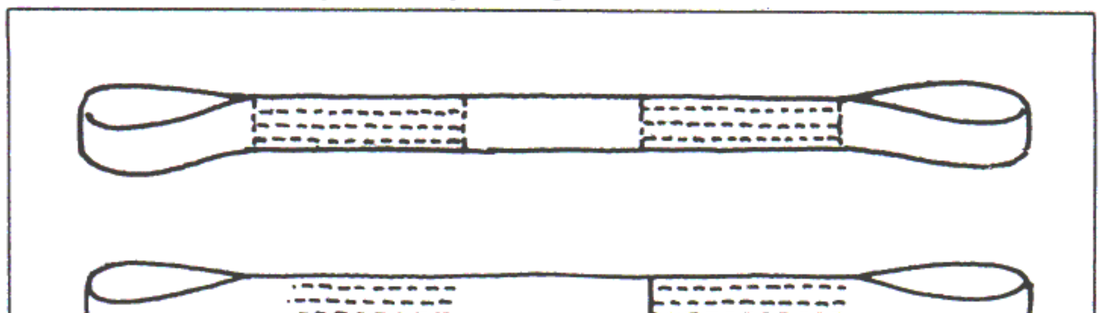


Fig. 6.26 Twisted Eye Slings

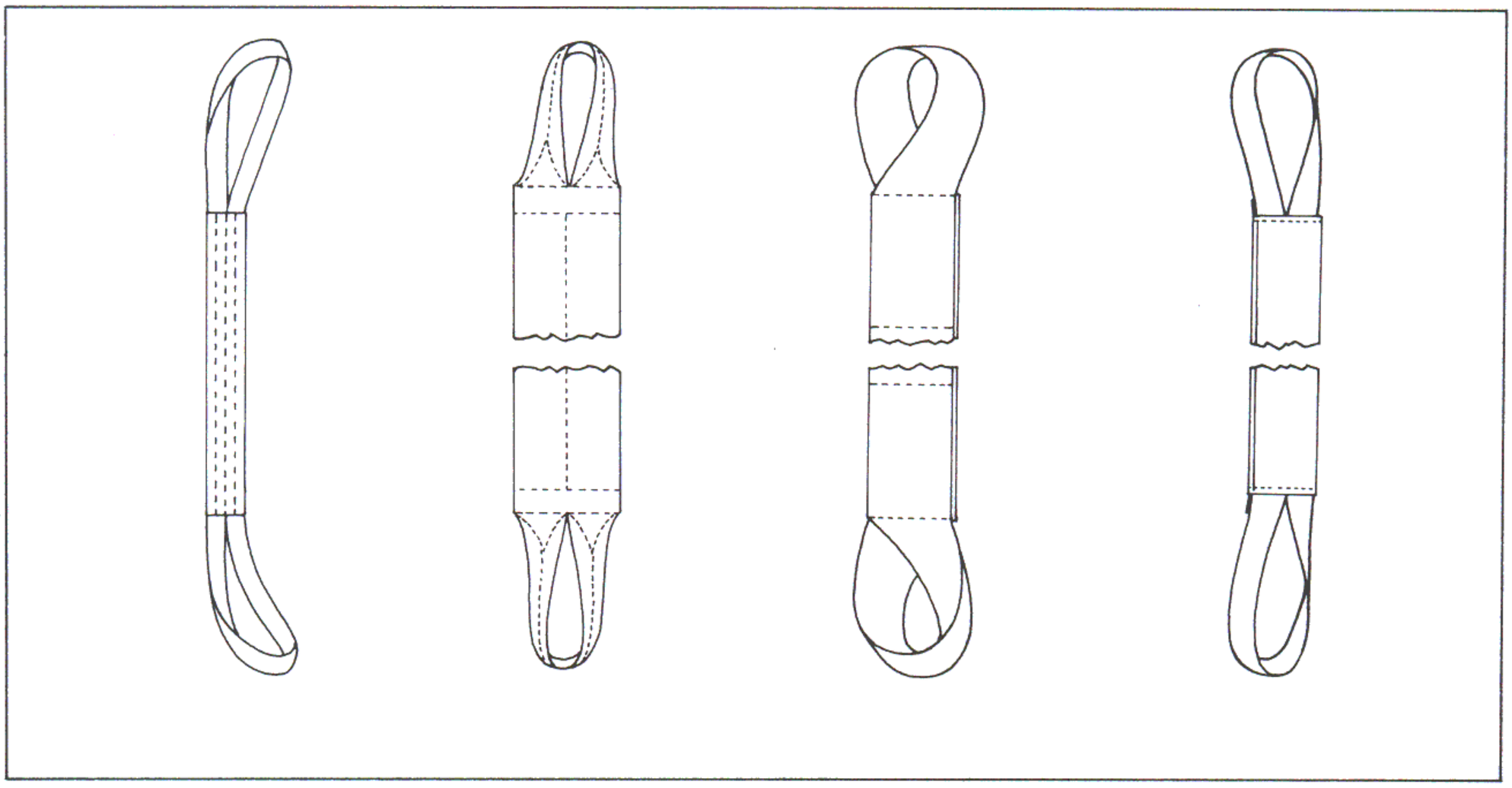
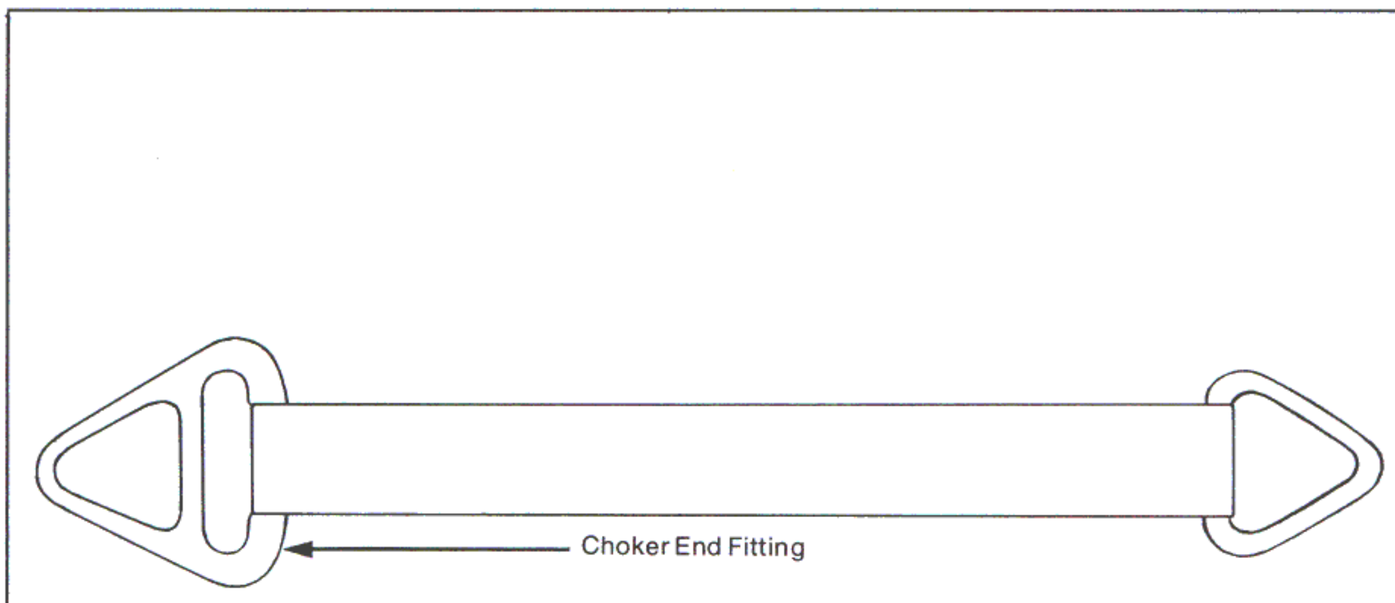
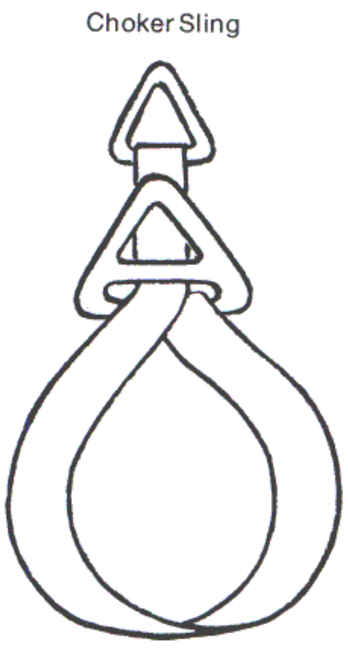
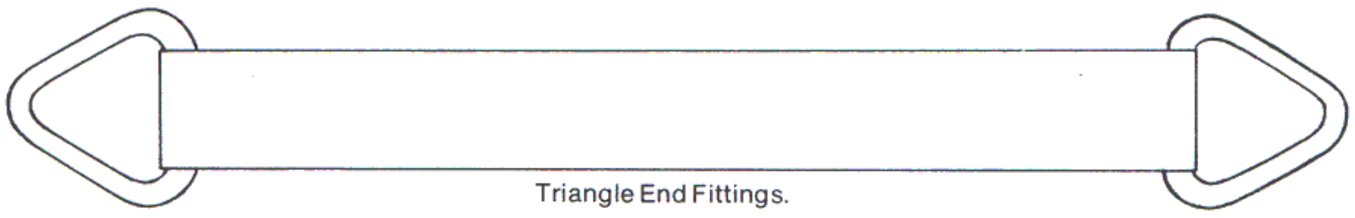


Fig. 6.27 Metal End Fittings







Triangle End Fittings.

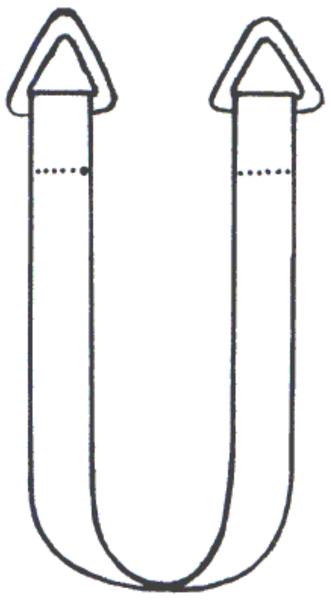
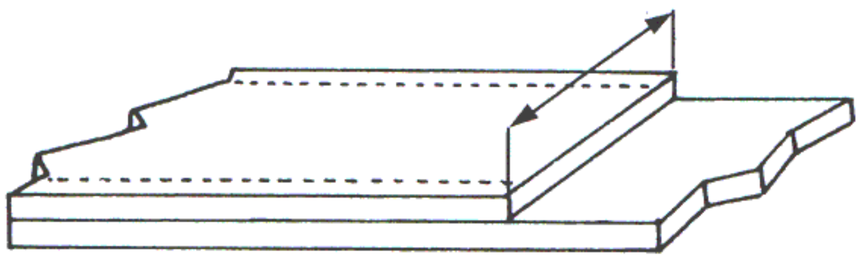
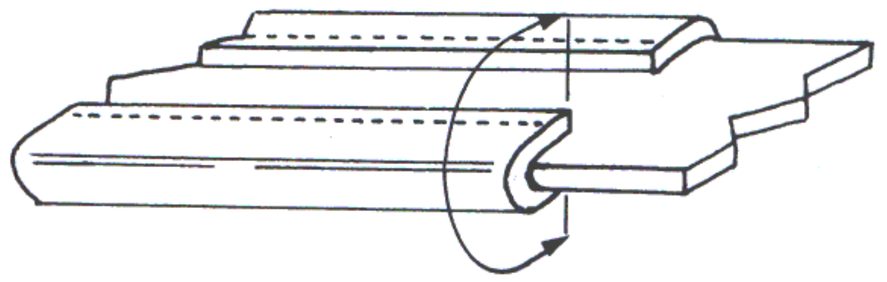


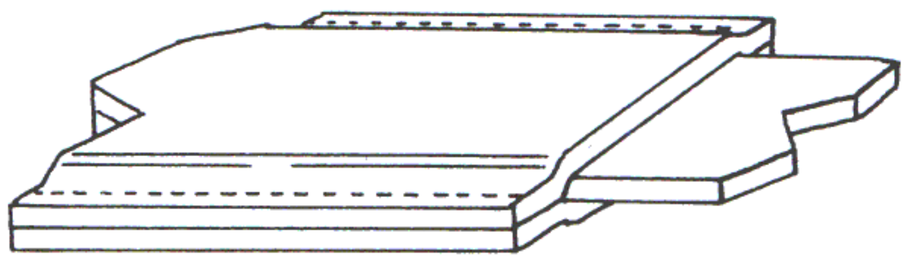
Fig. 6.28 Web and Edge Protectors



REGULAR. This is the type that is sewn on to give fixed protection at expected wear points. They can be sewn anywhere on the sling, at any length on one side or on both sides.



EDGEGUARD. A strip of webbing or leather is sewn around each edge of the sling. This is necessary for certain applications where the sling edges are subject to damage.



SLEEVE. Sometimes called sliding sleeve or tube type wear pads, these pads are ideal for handling material with sharp edges because the sleeve doesn't move when the sling stretches and adjusts to the load. Sleeves cover both sides of the sling and can be shifted to points of expected maximum wear.

— Some manufacturers offer a cotton-faced nylon webbing for hoisting granite and other rough surfaced material.

The sling capacities quoted in Tables 6.6, 6.7 and 6.8 are approximate only and are based on nylon webbing having breaking strengths of 8000 lb/inch of webbing width and 6000 lb/inch of width and Dacron having a breaking strength of 5000 lb/inch of webbing width. The capacities are also based on a 5:1 factor of safety and assume that the end fittings are of adequate strength.

Although safe working loads for bridle hitches in the choker or double basket configuration hitches are provided, we advise they be used only with extreme caution because as the sling angle decreases one edge of the web will take all the load with risk of tearing. (Fig. 6.29)

The importance of inspection of the slings must not be underestimated even though in general, if they look good they probably are good. Their damage is usually easy to detect; worn eyes and worn or distorted fittings, cuts, holes, punches, tears, frayed material, broken stitching and acid, caustic or heat burns — all are immediately evident and indicate that the slings should be replaced. Do not attempt to repair them yourself.

Fig. 6.29 Effect of Low Sling Angle on Webbing

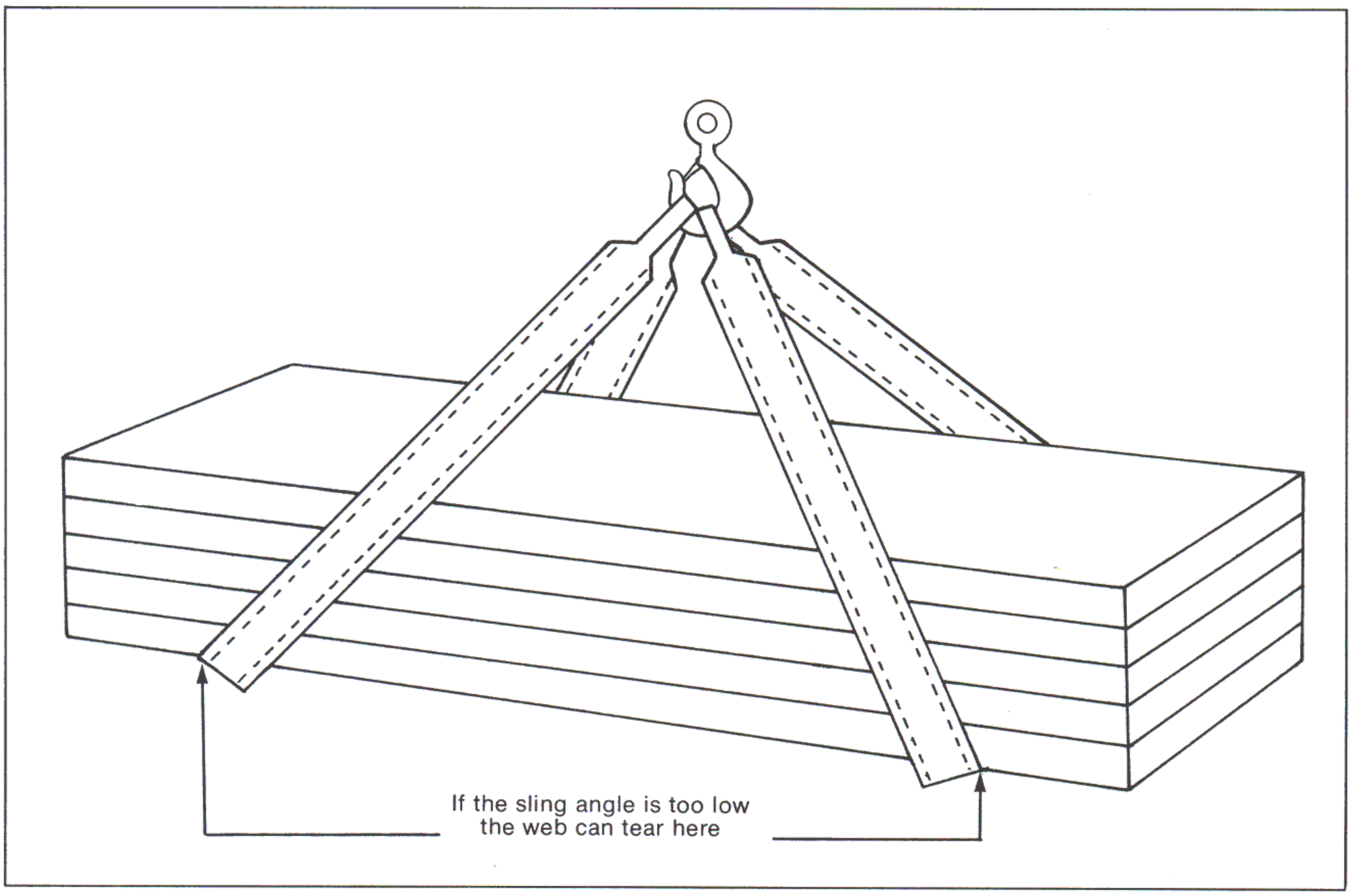
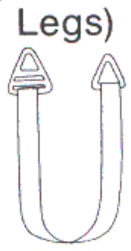
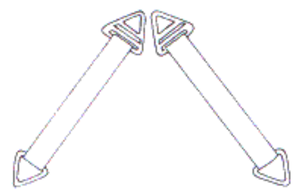
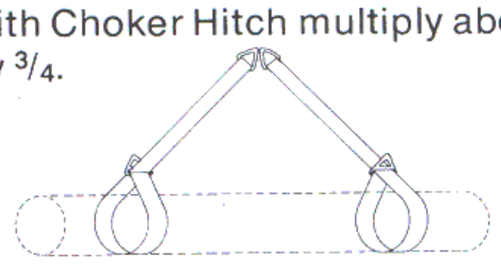


TABLE 6.6

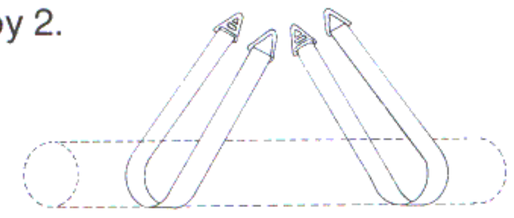
NYLON WEB SLINGS
(8000 lb/in Material)

Web Width (Inches)	MAXIMUM SAFE WORKING LOADS — POUNDS (SAFETY FACTOR = 5) (Eye & Eye, Twisted Eye, Triangle Fittings, Choker Fittings)					
	Single Vertical Hitch	Single Choker Hitch	Single Basket Hitch (Vertical Legs) 	2-Leg Bridle Hitch & Single Basket Hitch With Legs Inclined 		
				60°	45°	30°
1	1,600	1,200	3,200	2,770	2,260	1,600
2	3,200	2,400	6,400	5,550	4,520	3,200
3	4,800	3,600	9,600	8,300	6,800	4,800
4	6,400	4,800	12,800	11,100	9,050	6,400
5	8,000	6,000	16,000	13,850	11,300	8,000
6	9,600	7,200	19,200	16,600	13,600	9,600
7	11,200	8,400	22,400	19,400	15,800	11,200
8	12,800	9,600	25,600	22,200	18,100	12,800
9	14,400	10,800	28,800	25,000	20,400	14,400
10	16,000	12,000	32,000	27,700	22,600	16,000
11	17,600	13,200	35,200	30,500	24,900	17,600
12	19,200	14,400	38,400	33,300	27,200	19,200

If used with Choker Hitch multiply above values by 3/4.



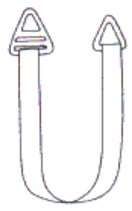
For Double Basket Hitch multiply above values by 2.



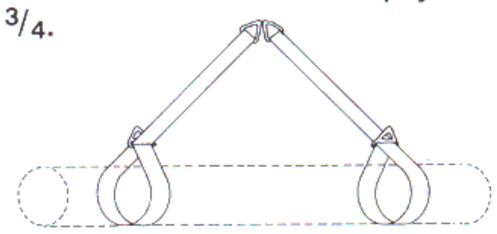
Note: For Safe Working Loads of Endless or Grommet Slings, Multiply Above Values by 2.

TABLE 6.7

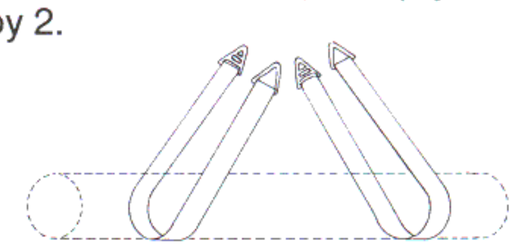
NYLON WEB SLINGS
(6000 lb/in Material)

Web Width (Inches)	MAXIMUM SAFE WORKING LOADS — POUNDS (SAFETY FACTOR = 5) (Eye & Eye, Twisted Eye, Triangle Fittings, Choker Fittings)					
	Single Vertical Hitch	Single Choker Hitch	Single Basket Hitch (Vertical Legs) 	2-Leg Bridle Hitch & Single Basket Hitch With Legs Inclined		
				60°	45°	30°
1	1,200	900	2,400	2,080	1,700	1,200
2	2,400	1,800	4,800	4,160	3,400	2,400
3	3,600	2,700	7,200	6,240	5,100	3,600
4	4,800	3,600	9,600	8,300	6,800	4,800
5	6,000	4,500	12,000	10,400	8,500	6,000
6	7,200	5,400	14,400	12,500	10,200	7,200
7	8,400	6,300	16,800	14,550	11,900	8,400
8	9,600	7,200	19,200	16,600	13,600	9,600
9	10,800	8,100	21,600	18,700	15,300	10,800
10	12,000	9,000	24,000	20,800	17,000	12,000
11	13,200	9,900	26,400	22,900	18,650	13,200
12	14,400	10,800	28,800	25,000	20,400	14,400

If used with Choker Hitch multiply above values by 3/4.



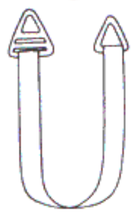
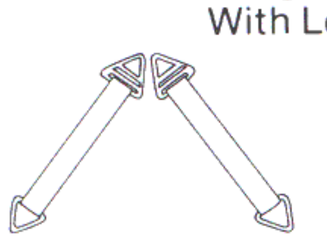
For Double Basket Hitch multiply above values by 2.



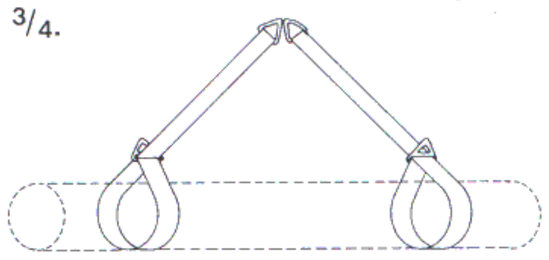
Note: For Safe Working Loads of Endless or Grommet Slings, Multiply Above Values by 2.

TABLE 6.8

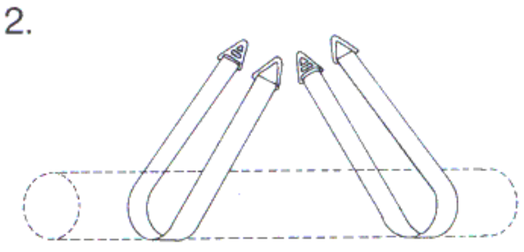
DACRON WEB SLINGS
(5000 lb/in Material)

Web Width (Inches)	MAXIMUM SAFE WORKING LOADS — POUNDS (SAFETY FACTOR = 5) (Eye & Eye, Twisted Eye, Triangle Fittings, Choker Fittings)					
	Single Vertical Hitch	Single Choker Hitch	Single Basket Hitch (Vertical Legs) 	2-Leg Bridle Hitch & Single Basket Hitch With Legs Inclined 		
				60°	45°	30°
1	1,000	750	2,000	1,730	1,400	1,000
2	2,000	1,500	4,000	3,460	2,830	2,000
3	3,000	2,250	6,000	5,200	4,250	3,000
4	4,000	3,000	8,000	6,950	5,650	4,000
5	5,000	3,750	10,000	8,660	7,070	5,000
6	6,000	4,500	12,000	10,400	8,500	6,000
7	7,000	5,250	14,000	12,100	9,900	7,000
8	8,000	6,000	16,000	13,850	11,300	8,000
9	9,000	6,750	18,000	15,600	12,700	9,000
10	10,000	7,500	20,000	17,350	14,100	10,000
11	11,000	8,250	22,000	19,100	15,500	11,000
12	12,000	9,000	24,000	20,800	17,000	12,000

If used with Choker Hitch multiply above values by 3/4.



For Double Basket Hitch multiply above values by 2.



Note: For Safe Working Loads of Endless or Grommet Slings, Multiply Above Values by 2.

METAL (WIRE OR CHAIN) MESH SLINGS

Wire or metal mesh slings are well adapted for use where the loads are abrasive, hot or tend to cut fabric slings and wire ropes. They resist abrasion and cutting, grip the load firmly without stretching and can withstand temperatures of up to 550°F. They have smooth, flat bearing surfaces, they conform to irregular shapes, do not kink or tangle and resist corrosion. (Fig. 6.30)

They are available in three mesh sizes: 10 Gauge mesh (heavy duty) recommended for general purpose lifting because it combines strength and abrasion resistance with flexibility; 12 Gauge mesh for medium duty applications and 14 Gauge mesh for very light duty.

For handling materials that would damage the wire mesh, or for handling loads with finishes that the mesh would damage, the slings can be coated with rubber of plastic. See Table 6.9 for their safe working loads.

CHAIN SLINGS:

Chain slings find application in those areas where the primary requirements are ruggedness, abrasion resistance and high temperature resistance. They should not be used, however, if it is possible to use wire rope or other materials because of their susceptibility to sudden failure.

The only chain suitable for overhead lifting is fabricated from alloy steel and identified by a letter, usually A, marked on each link. See Chapter 3 for guidelines on the safe use of chain.

They should be padded where they bear on sharp edges of metal parts otherwise some of the links will be subjected to bending stresses for which they were not designed. The chain may also damage the material being lifted if it is not padded.

Whenever a chain sling is hooked back on itself (into the chain rather than the master link or master coupling link) the capacity of the sling should be reduced by 1/4. For this reason, the choker hitch ratings in the following table are 1/4 less than the Vertical Hitch ratings. Whenever using chain slings in the basket hitch configuration, ensure that they are hooked back into the master link, not the chain or the coupling link, and also ensure that the master link is capable of carrying the imposed load. (Fig. 6.31) See Table 6.10 for their rated safe working loads.

WIRE ROPE SLINGS:

The use of steel wire rope slings for lifting materials provides several advantages over other materials. Great strength and a minimum of weight are combined with flexibility. Warning occurs before failure by the breaking of outer wires. Reserve strength is provided in that the inner wires are protected by the outer wires and possess sufficient strength to carry the load if a reasonable factor of safety is allowed for the sling.

Properly fabricated wire rope slings are the safest type available for general construction usage. They do not wear as rapidly as fibre rope slings and they are not susceptible to the weakest link ailment of chains. Wire rope slings show, by inspection, their true condition and the appearance of broken wires clearly indicates the extent of fatigue, wear, abrasion and the like.

However, they must be carefully selected for the application and service in which they are to be placed as they also have limitations. The procedures and precautions outlined in the chapter on wire rope must be followed regardless of the sling type or application.

All wire rope slings should be made of improved plow steel and should have independent wire rope cores to reduce the possibility of the rope being crushed in service.

It is recommended that all eyes in wire rope slings be equipped with thimbles and that the eyes be formed with the Flemish Splice and secured by swaged or pressed mechanical sleeves or fittings. With the exception of socketed connections, this is the **only** method that produces an eye that is as strong as the rope itself and provides reserve strength should the mechanical sleeve or fitting fail or loosen.

Tables 6.11-6.21 are provided for information only on the more commonly used types of wire rope slings. For actual safe working loads of slings consult with the sling manufacturer. These tables are based on safety factors of 5:1 and assume that the slings are in excellent condition. Any deterioration, such as described in the chapter on wire rope, reduces the capacity of the sling.

Fig. 6.30 Chain Mesh Slings

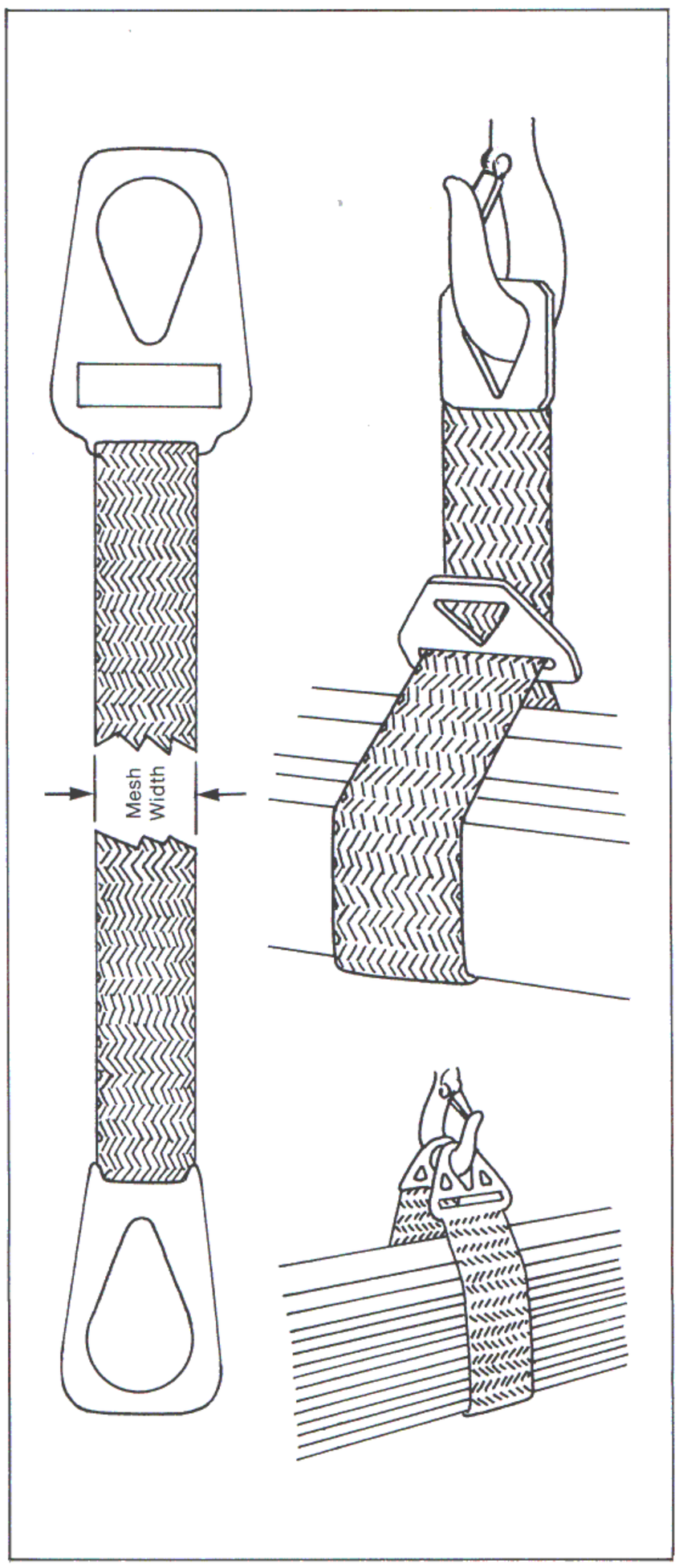


Fig. 6.31 Chain Slings

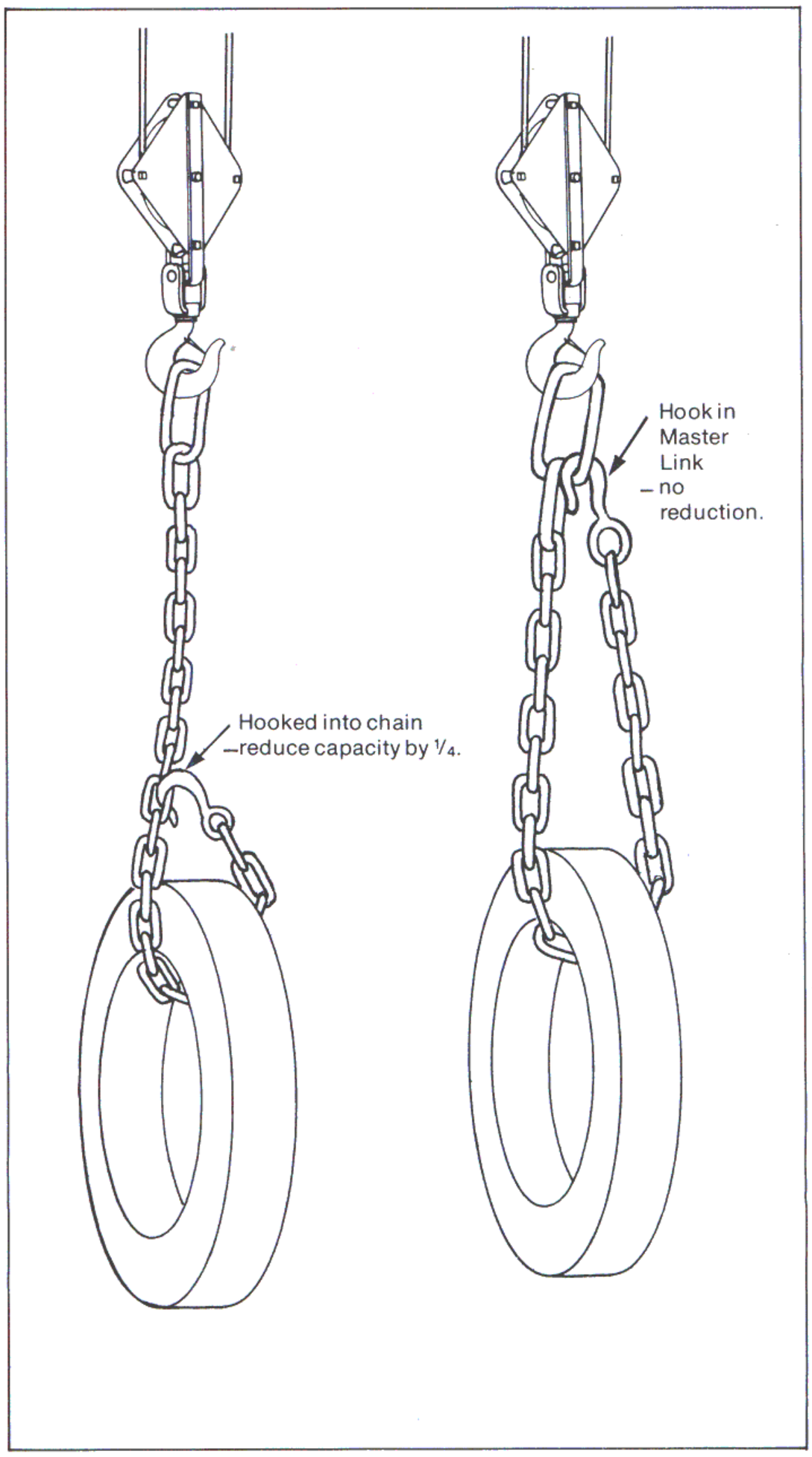
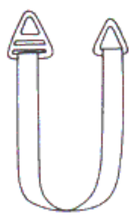
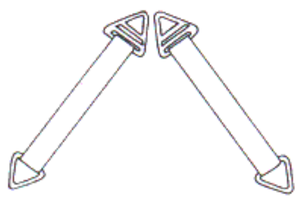
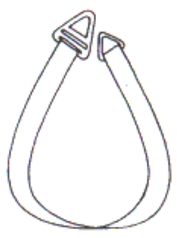
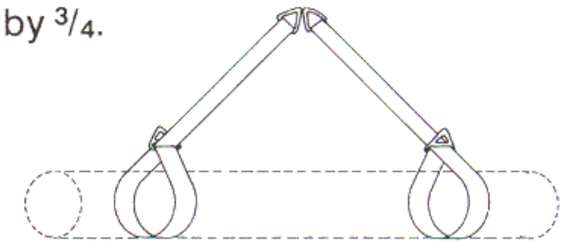


TABLE 6.9

METAL (WIRE OR CHAIN) MESH SLINGS

Sling Width (Inches)	MAXIMUM SAFE WORKING LOADS — POUNDS (Safety Factor = 5)					
	Single Vertical Hitch	Single Choker Hitch	Single Basket Hitch (Vertical Legs) 	2-Leg Bridle Hitch & Single Basket Hitch Non Vertical Legs  		
				60°	45°	30°
HEAVY DUTY CLASSIFICATION (10 GAUGE MESH)						
2	1,500	1,100	3,000	2,600	2,100	1,500
3	2,700	2,000	5,400	4,700	3,800	2,700
4	4,000	3,000	8,000	6,900	5,600	4,000
6	6,000	4,500	12,000	10,400	8,500	6,000
8	8,000	6,000	16,000	13,800	11,300	8,000
10	10,000	7,500	20,000	17,300	14,100	10,000
12	12,000	9,000	24,000	20,800	17,000	12,000
MEDIUM DUTY CLASSIFICATION (12 GAUGE MESH)						
2	1,350	1,000	2,700	2,300	1,900	1,350
3	2,000	1,500	4,000	3,500	2,800	2,000
4	2,700	2,000	5,400	4,700	3,800	2,700
6	4,500	3,400	9,000	7,800	6,400	4,500
8	6,000	4,500	12,000	10,400	8,500	6,000
10	7,500	5,600	15,000	13,000	10,600	7,500
12	9,000	6,750	18,000	15,600	12,700	9,000
LIGHT DUTY CLASSIFICATION (14 GAUGE MESH)						
2	900	700	1,800	1,600	1,300	900
3	1,400	1,000	2,800	2,400	2,000	1,400
4	2,000	1,500	4,000	3,500	2,800	2,000
6	3,000	2,250	6,000	5,200	4,200	3,000
8	4,000	3,000	8,000	6,900	5,700	4,000
10	5,000	3,750	10,000	8,600	7,100	5,000
12	6,000	4,500	12,000	10,400	8,500	6,000

If used with Choker Hitch multiply above values by $^3/_4$.



For Double Basket Hitch multiply above values by 2.

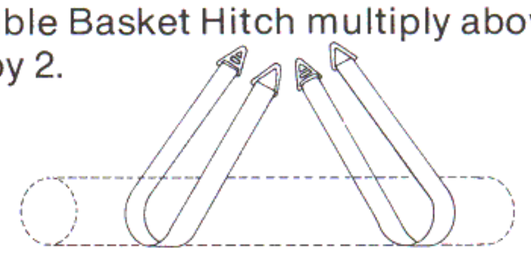
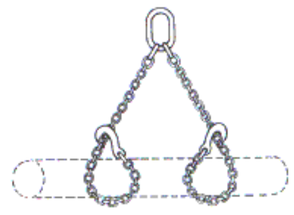


TABLE 6.10

CHAIN SLINGS (ALLOY STEEL)						
Chain Size (Inches)	MAXIMUM SAFE WORKING LOADS — POUNDS					
	Single Vertical Hitch	Single Choker Hitch	Single Basket Hitch (Vertical Legs)	2-Leg Bridle Hitch & Single Basket Hitch With Legs Inclined		
				60°	45°	30°
1/4	3,250	2,440	6,500	5,600	4,600	3,250
3/8	6,600	4,950	13,200	11,400	9,300	6,600
1/2	11,250	8,400	22,500	19,500	15,900	11,250
5/8	16,500	12,400	33,000	28,600	23,300	16,500
3/4	23,000	17,200	46,000	39,800	32,500	23,000
7/8	28,750	21,500	57,500	49,800	40,600	28,750
1	38,750	29,000	77,500	67,100	54,800	38,750
1 1/8	44,500	33,400	89,000	77,000	63,000	44,500
1 1/4	57,500	43,000	115,000	99,500	81,000	57,500
1 3/8	67,000	50,000	134,000	116,000	94,500	67,000
1 1/2	80,000	60,000	160,000	138,000	113,000	80,000
1 3/4	100,000	75,000	200,000	173,000	141,000	100,000

If used with Choker Hitch multiply above values by 3/4.



For Double Basket Hitch multiply above values by 2.

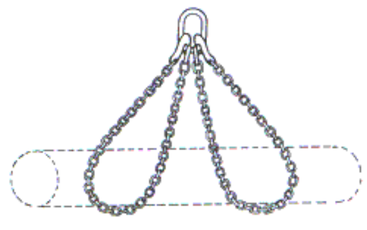
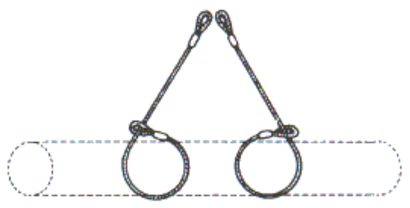


TABLE 6.11

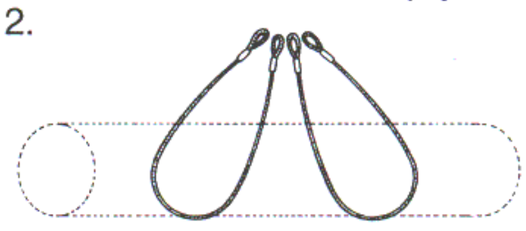
WIRE ROPE SLINGS
6 x 19 Classification Group, Improved Plow Steel, Fibre Core

Rope Diameter (Inches)	MAXIMUM SAFE WORKING LOADS — POUNDS (Safety Factor = 5)					
	Single Vertical Hitch	Single Choker Hitch	Single Basket Hitch (Vertical Legs)	2-Leg Bridle Hitch & Single Basket Hitch With Legs Inclined		
				60°	45°	30°
3/16	600	450	1,200	1,050	850	600
1/4	1,100	825	2,200	1,900	1,550	1,100
5/16	1,650	1,250	3,300	2,850	2,350	1,650
3/8	2,400	1,800	4,800	4,150	3,400	2,400
7/16	3,200	2,400	6,400	5,550	4,500	3,200
1/2	4,400	3,300	8,800	7,600	6,200	4,400
9/16	5,300	4,000	10,600	9,200	7,500	5,300
5/8	6,600	4,950	13,200	11,400	9,350	6,600
3/4	9,500	7,100	19,000	16,500	13,400	9,500
7/8	12,800	9,600	25,600	22,200	18,100	12,800
1	16,700	12,500	33,400	28,900	23,600	16,700
1 1/8	21,200	15,900	42,400	36,700	30,000	21,200
1 1/4	26,200	19,700	52,400	45,400	37,000	26,200
1 3/8	32,400	24,300	64,800	56,100	45,800	32,400
1 1/2	38,400	28,800	76,800	66,500	54,300	38,400
1 5/8	45,200	33,900	90,400	78,300	63,900	45,200
1 3/4	52,000	39,000	104,000	90,000	73,500	52,000
1 7/8	60,800	45,600	121,600	105,300	86,000	60,800
2	67,600	50,700	135,200	117,100	95,600	67,600
2 1/4	84,000	63,000	168,000	145,500	118,800	84,000
2 1/2	104,000	78,000	208,000	180,100	147,000	104,000
2 3/4	122,000	91,500	244,000	211,300	172,500	122,000

If used with Choker Hitch multiply above values by 3/4.



For Double Basket Hitch multiply above values by 2.

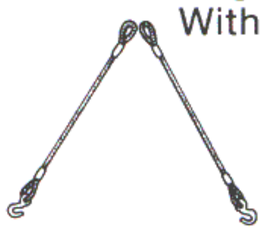


Note: Table values are for slings with eyes and thimbles in both ends, Flemish Spliced Eyes and mechanical sleeves.

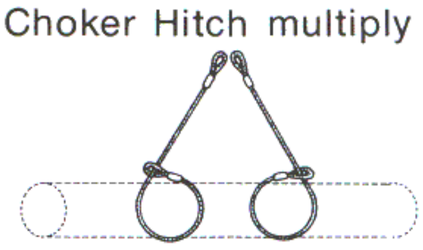
Hand tucked spliced eyes — reduce loads according to table 1.11, page 47.
Eyes formed by cable clips — reduce loads by 20%.

TABLE 6.12

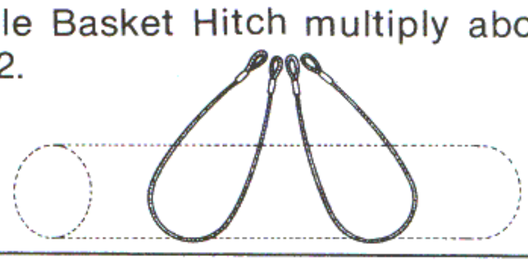
WIRE ROPE SLINGS
6 x 19 Classification Group, Improved Plow Steel, IWRC

Rope Diameter (Inches)	MAXIMUM SAFE WORKING LOADS — POUNDS (Safety Factor = 5)					
	Single Vertical Hitch	Single Choker Hitch	Single Basket Hitch (Vertical Legs)	2-Leg Bridle Hitch & Single Basket Hitch With Legs Inclined 		
				60°	45°	30°
3/16	650	480	1,300	1,100	900	650
1/4	1,150	860	2,300	2,000	1,600	1,150
5/16	1,750	1,300	3,500	3,000	2,500	1,750
3/8	2,550	1,900	5,100	4,400	3,600	2,550
7/16	3,450	2,600	6,900	6,000	4,900	3,450
1/2	4,700	3,500	9,400	8,150	6,650	4,700
9/16	5,700	4,200	11,400	9,900	8,050	5,700
5/8	7,100	5,300	14,200	12,300	10,000	7,100
3/4	10,200	7,650	20,400	17,700	14,400	10,200
7/8	13,750	10,300	27,500	23,800	19,400	13,750
1	17,950	13,450	35,900	31,100	25,400	17,950
1 1/8	22,750	17,000	45,500	39,400	32,200	22,750
1 1/4	28,200	21,200	56,400	48,800	39,900	28,200
1 3/8	34,800	26,100	69,600	60,300	49,200	34,800
1 1/2	41,300	31,000	82,600	71,500	58,400	41,300
1 5/8	48,600	36,400	97,200	84,200	68,700	48,600
1 3/4	55,900	41,900	111,800	96,800	79,000	55,900
1 7/8	65,400	49,000	130,800	113,300	92,500	65,400
2	72,600	54,500	145,200	125,700	102,700	72,600
2 1/4	90,300	67,600	180,600	156,400	127,700	90,300
2 1/2	111,800	83,700	223,600	193,600	158,100	111,800
2 3/4	131,100	98,200	262,200	227,000	185,400	131,100

If used with Choker Hitch multiply above values by 3/4.



For Double Basket Hitch multiply above values by 2.



Note: **Table values are for slings with eyes and thimbles in both ends, Flemish Spliced Eyes and mechanical sleeves.**

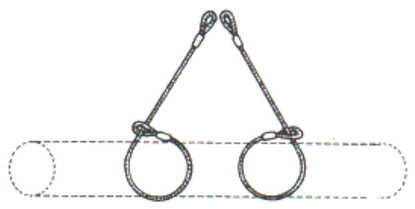
Hand tucked spliced eyes — reduce loads according to table 1.11, page 47.
Eyes formed by cable clips — reduce loads by 20%.

TABLE 6.13

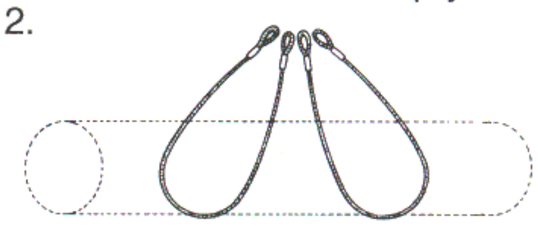
WIRE ROPE SLINGS
6 x 37 Classification Group, Improved Plow Steel, Fibre Core

Rope Diameter (Inches)	MAXIMUM SAFE WORKING LOADS — POUNDS (Safety Factor = 5)					
	Single Vertical Hitch	Single Choker Hitch	Single Basket Hitch (Vertical Legs)	2-Leg Bridle Hitch & Single Basket Hitch With Legs Inclined		
				60°	45°	30°
1/4	1,000	750	2,000	1,750	1,400	1,000
5/16	1,600	1,200	3,200	2,750	2,250	1,600
3/8	2,200	1,650	4,400	3,800	3,100	2,200
7/16	3,000	2,250	6,000	5,200	4,250	3,000
1/2	4,000	3,000	8,000	6,900	5,650	4,000
9/16	5,000	3,750	10,000	8,650	7,100	5,000
5/8	6,400	4,800	12,800	11,100	9,050	6,400
3/4	8,900	6,700	17,800	15,400	12,600	8,900
7/8	12,100	9,100	24,200	21,000	17,100	12,100
1	15,800	11,900	31,600	27,400	22,300	15,800
1 1/8	19,600	14,700	39,200	33,900	27,700	19,600
1 1/4	24,400	18,300	48,800	42,300	34,500	24,400
1 3/8	29,800	22,400	59,600	51,600	42,100	29,800
1 1/2	36,000	27,000	72,000	62,400	50,900	36,000
1 5/8	42,200	31,700	84,400	73,100	59,700	42,200
1 3/4	48,400	36,300	96,800	83,800	68,400	48,400
1 7/8	56,800	42,600	113,600	98,400	80,300	56,800
2	62,000	46,500	124,000	107,400	87,700	62,000
2 1/4	80,400	60,300	160,800	139,300	113,700	80,400
2 1/2	98,000	73,500	196,000	169,700	138,600	98,000
2 3/4	117,200	87,900	234,400	203,000	165,700	117,200

If used with Choker Hitch multiply above values by 3/4.



For Double Basket Hitch multiply above values by 2.



Note: **Table values are for slings with eyes and thimbles in both ends, Flemish Spliced Eyes and mechanical sleeves.**

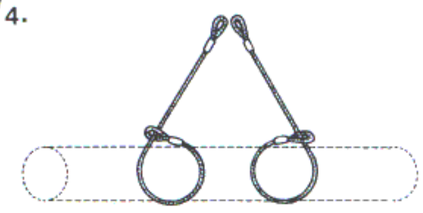
Hand tucked spliced eyes — reduce loads according to table 1.11, page 47.
Eyes formed by cable clips — reduced loads by 20%.

TABLE 6.14

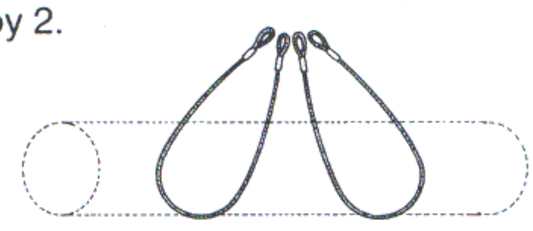
WIRE ROPE SLINGS
6 x 37 Classification Group, Improved Plow Steel, IWRC

Rope Diameter (Inches)	MAXIMUM SAFE WORKING LOADS — POUNDS (Safety Factor = 5)					
	Single Vertical Hitch	Single Choker Hitch	Single Basket Hitch (Vertical Legs)	2-Leg Bridle Hitch & Single Basket Hitch With Legs Inclined		
				60°	45°	30°
1/4	1,050	800	2,100	1,800	1,500	1,050
5/16	1,700	1,300	3,400	2,950	2,400	1,700
3/8	2,350	1,750	4,700	4,100	3,300	2,350
7/16	3,200	2,400	6,400	5,550	4,500	3,700
1/2	4,300	3,200	8,600	7,450	6,100	4,300
9/16	5,350	4,000	10,700	9,250	7,550	5,350
5/8	6,900	5,200	13,800	11,950	9,750	6,900
3/4	9,500	7,100	19,000	16,450	13,400	9,500
7/8	13,000	9,750	26,000	22,500	18,400	13,000
1	17,000	12,750	34,000	29,450	24,000	17,000
1 1/8	21,000	15,750	42,000	36,400	29,700	21,000
1 1/4	26,200	19,650	52,400	45,400	37,000	26,200
1 3/8	32,000	24,000	64,000	55,400	45,200	32,000
1 1/2	39,500	29,600	79,000	68,400	55,900	39,500
1 5/8	45,400	34,000	90,800	78,600	64,200	45,400
1 3/4	52,000	39,000	104,000	90,000	73,500	52,000
1 7/8	61,000	45,750	122,000	105,700	86,300	61,000
2	66,600	49,950	133,200	115,400	94,200	66,600
2 1/4	86,400	64,800	172,800	149,600	122,200	86,400
2 1/2	105,300	79,000	210,600	182,400	148,900	105,300
2 3/4	126,000	94,500	252,000	218,200	178,200	126,000

If used with Choker Hitch multiply above values by 3/4.



For Double Basket Hitch multiply above values by 2.



Note: **Table values are for slings with eyes and thimbles in both ends, Flemish Spliced Eyes and mechanical sleeves.**

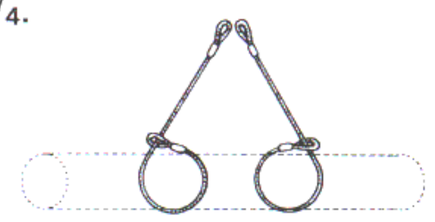
Hand tucked spliced eyes — reduce loads according to table 1.11, page 47.
Eyes formed by cable clips — reduce loads by 20%.

TABLE 6.15

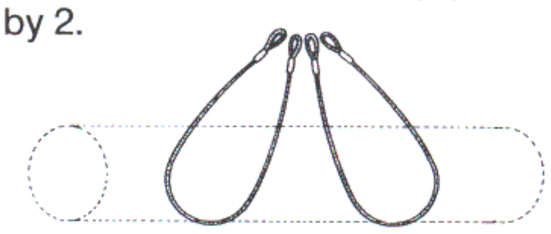
BRAIDED WIRE ROPE SLINGS
6-Part Braided Rope
6 x 19 Classification Group, Improved Plow Steel

Component Rope Diameter (Inches)	MAXIMUM SAFE WORKING LOADS — POUNDS (Safety Factor = 5)					
	Single Vertical Hitch	Single Choker Hitch	Single Basket Hitch (Vertical Legs)	2-Leg Bridle Hitch & Single Basket Hitch With Legs Inclined		
				60°	45°	30°
3/16	2,600	1,950	5,200	4,500	3,700	2,600
1/4	4,600	3,450	9,200	7,950	6,500	4,600
5/16	7,200	5,400	14,400	12,500	10,200	7,200
3/8	10,200	7,650	20,400	17,700	14,400	10,200
7/16	13,800	10,400	27,600	23,900	19,500	13,800
1/2	18,000	13,500	36,000	31,200	25,500	18,000
9/16	22,000	16,500	44,000	38,100	31,100	22,000
5/8	28,000	21,000	56,000	48,500	39,600	28,000
3/4	40,000	30,000	80,000	69,300	56,600	40,000
7/8	54,000	40,500	108,000	93,500	76,400	54,000
1	70,000	52,500	140,000	121,200	99,000	70,000

If used with Choker Hitch multiply above values by 3/4.



For Double Basket Hitch multiply above values by 2.



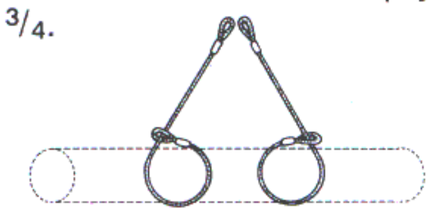
Note: Table values are for braided slings with eyes and thimbles in both ends. Eyes formed by hand tucking ropes and securing with mechanical sleeves.

TABLE 6.16

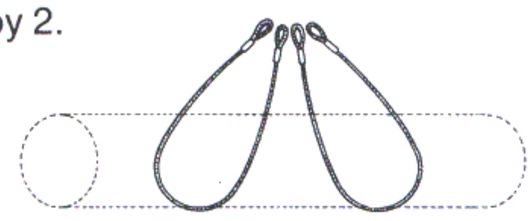
BRAIDED WIRE ROPE SLINGS
8-Part Braided Rope
6 x 19 Classification Group, Improved Plow Steel

Component Rope Diameter (Inches)	MAXIMUM SAFE WORKING LOADS — POUNDS (Safety Factor = 5)					
	Single Vertical Hitch	Single Choker Hitch	Single Basket Hitch (Vertical Legs)	2-Leg Bridle Hitch & Single Basket Hitch With Legs Inclined		
				60°	45°	30°
3/16	3,400	2,550	6,800	5,900	4,800	3,400
1/4	6,200	4,650	12,400	10,700	8,750	6,200
5/16	9,600	7,200	19,200	16,600	13,600	9,600
3/8	13,600	10,200	27,200	23,600	19,200	13,600
7/16	18,600	14,000	37,200	32,200	26,300	18,600
1/2	24,000	18,000	48,000	41,600	33,900	24,000
9/16	30,000	22,500	60,000	52,000	42,400	30,000
5/8	38,000	28,500	76,000	65,800	53,700	38,000
3/4	54,000	40,500	108,000	93,500	76,400	54,000
7/8	72,000	54,000	144,000	124,700	101,800	72,000
1	94,000	70,500	188,000	162,800	132,900	94,000

If used with Choker Hitch multiply above values by 3/4.



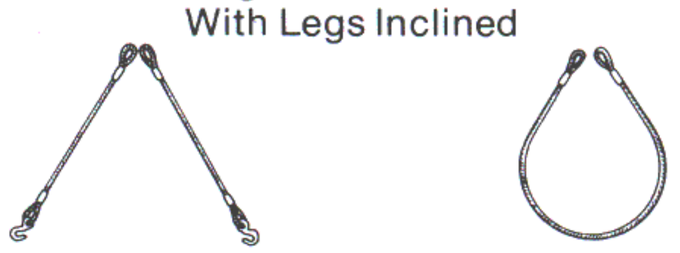
For Double Basket Hitch multiply above values by 2.



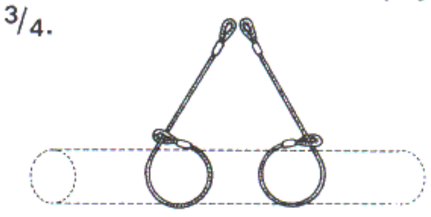
Note: Table values are for braided slings with eyes and thimbles in both ends. Eyes formed by hand tucking ropes and securing with mechanical sleeves.

TABLE 6.17

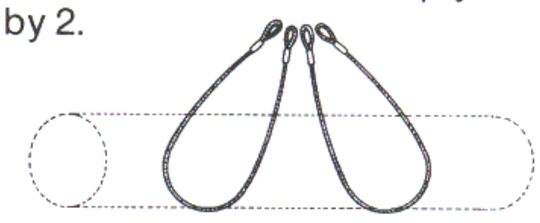
CABLE LAID WIRE ROPE SLINGS
Mechanical Splices

Cable Body Diameter (Inches)	MAXIMUM SAFE WORKING LOADS — POUNDS (Safety Factor = 5)					
	Single Vertical Hitch	Single Choker Hitch	Single Basket Hitch (Vertical Legs)	2-Leg Bridle Hitch & Single Basket Hitch With Legs Inclined 		
				60°	45°	30°
1/4	1,000	750	2,000	1,750	1,400	1,000
3/8	2,200	1,650	4,400	3,800	3,100	2,200
1/2	3,600	2,700	7,200	6,250	5,100	3,600
5/8	5,600	4,200	11,200	9,700	7,900	5,600
3/4	7,600	5,700	15,200	13,200	10,700	7,600
7/8	10,000	7,500	20,000	17,300	14,100	10,000
1	12,800	9,600	25,600	22,200	18,100	12,800
1 1/8	15,400	11,600	30,800	26,700	21,800	15,400
1 1/4	18,400	13,800	36,800	31,900	26,000	18,400
1 3/8	22,000	16,500	44,000	38,100	31,100	22,000
1 1/2	26,000	19,500	52,000	45,000	36,800	26,000

If used with Choker Hitch multiply above values by 3/4.



For Double Basket Hitch multiply above values by 2.



Note: Cable laid wire rope slings with mechanical splices are slings made from cable and having eyes fabricated by pressing or swaging one or more metal sleeves over the rope junction at the eyes. The cable consists of 6 individual wire ropes wrapped around a 7th wire rope which forms the core. For cable body diameters of 1/4 - 5/8″ the construction is 7 x 7 x 7 (i.e., 7 wire ropes of 7 x 7 construction) and for diameters above 5/8″ it is 7 x 6 x 19 IWRC (i.e., 7 wire ropes of 6 x 19 IWRC construction).

The table values are for slings with eyes and thimbles in both ends.

TABLE 6.18

STRAND LAID GROMMET SLINGS
Hand Tucked, Improved Plow Steel

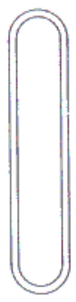
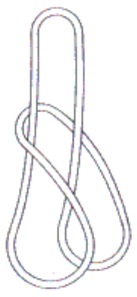
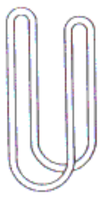
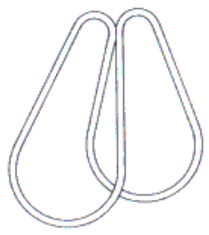
Rope Body Diameter (Inches)	MAXIMUM SAFE WORKING LOADS — POUNDS (Safety Factor = 5)					
	Single Vertical Hitch	Single Choker Hitch	Single Basket Hitch (Vertical Legs)	Single Basket Hitch With Legs Inclined		
				60°	45°	30°
1/4	1,700	1,275	3,400	2,950	2,400	1,700
5/16	2,600	1,950	5,200	4,500	3,700	2,600
3/8	3,800	2,850	7,600	6,600	5,400	3,800
7/16	5,200	3,900	10,400	9,000	7,350	5,200
1/2	7,000	5,250	14,000	12,100	9,900	7,000
9/16	8,400	6,300	16,800	14,500	11,900	8,400
5/8	10,400	7,800	20,800	18,000	14,700	10,400
3/4	14,800	11,100	29,600	25,600	20,900	14,800
7/8	20,000	15,000	40,000	34,600	28,300	20,000
1	26,000	19,500	52,000	45,000	36,800	26,000
1 1/8	29,800	22,400	59,600	51,600	42,100	29,800
1 1/4	35,000	26,300	70,000	60,600	49,500	35,000
1 3/8	42,600	32,000	85,200	73,800	60,200	42,600
1 1/2	51,600	38,700	103,200	89,400	73,000	51,600
1 5/8	56,600	42,500	113,200	98,000	80,000	56,600
1 3/4	65,000	48,800	130,000	112,600	91,900	65,000
1 7/8	76,000	57,000	152,000	131,600	107,500	76,000
2	83,000	62,300	166,000	143,800	117,400	83,000
2 1/4	101,000	75,800	202,000	174,900	142,800	101,000

For Double Basket Hitch multiply above values by 2.

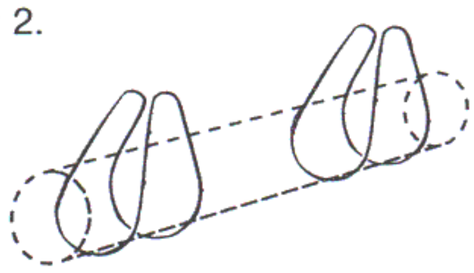
Note: A strand laid grommet is an endless wire rope sling fabricated from a single strand that is wrapped six times. After wrapping the two free strand ends are tucked inside the wraps to form the core of the grommet. Grommet diameters up to and including 1″ are fabricated from strands of 6 x 19 rope and grommet diameters of 1-1/8″ and greater are fabricated from strands of 6 x 37 rope.

TABLE 6.19

CABLE LAID GROMMET SLINGS
Hand Tucked, Improved Plow Steel

Cable Body Diameter Inches)	MAXIMUM SAFE WORKING LOADS — POUNDS (Safety Factor = 5)					
	Single Vertical Hitch 	Single Choker Hitch 	Single Basket Hitch (Vertical Legs) 	Single Basket Hitch With Legs Inclined 		
				60°	45°	30°
3/8	2,600	1,950	5,200	4,500	3,700	2,600
9/16	5,600	4,200	11,200	9,700	7,900	5,600
5/8	7,800	5,850	15,600	13,500	11,000	7,800
3/4	10,200	7,650	20,400	17,700	14,400	10,200
15/16	15,800	11,900	31,600	27,400	22,300	15,800
1 1/8	22,000	16,500	44,000	38,100	31,100	22,000
1 5/16	30,000	22,500	60,000	52,000	42,400	30,000
1 1/2	38,000	28,500	76,000	65,800	53,700	38,000
1 11/16	48,000	36,000	96,000	83,100	67,900	48,000
1 7/8	60,000	45,000	120,000	103,900	84,800	60,000
2 1/4	84,000	63,000	168,000	145,500	118,800	84,000
2 5/8	112,000	84,000	224,000	194,000	158,400	112,000

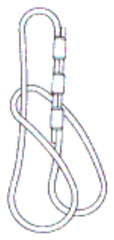
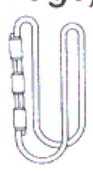
For Double Basket Hitch multiply above values by 2.



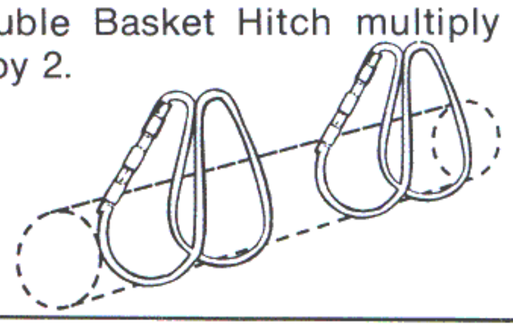
Note: A cable laid, hand tucked grommet is an endless wire rope sling fabricated from a single wire rope that is wrapped six times. After wrapping, the two free ends of the rope are tucked inside the wraps to form the core of the grommet. It is very similar to the strand laid grommet except that a complete rope rather than a strand is used to form the grommet. For cable body diameters of 3/8 and 9/16″ the construction is 7 x 6 x 7 (the first figure denotes 6 rope wraps plus 1 rope core, and the second two digits indicates that the rope used is 6 x 7). For diameters of 5/8″ and up the construction is 7 x 6 x 19 (i.e., 6 rope wraps plus 1 rope core, all of 6 x 19 rope).

TABLE 6.20

STRAND LAID ENDLESS SLINGS
Mechanical Splice, Improved Plow Steel

Rope Body Diameter (Inches)	MAXIMUM SAFE WORKING LOADS — POUNDS (Safety Factor = 5)					
	Single Vertical Hitch	Single Choker Hitch 	Single Basket Hitch (Vertical Legs) 	Single Basket Hitch With Legs Inclined		
				60°	45°	30°
1/4	1,850	1,400	3,700	3,200	2,600	1,850
3/8	4,000	3,000	8,000	6,900	5,650	4,000
1/2	7,200	5,400	14,400	12,500	10,200	7,200
5/8	11,200	8,400	22,400	19,400	15,800	11,200
3/4	16,000	12,000	32,000	27,700	22,600	16,000
7/8	22,000	16,500	44,000	38,100	31,100	22,000
1	28,000	21,000	56,000	48,500	39,600	28,000
1 1/8	36,000	27,000	72,000	62,400	50,900	36,000
1 1/4	42,000	31,500	84,000	72,700	59,400	42,000
1 3/8	50,000	37,500	100,000	86,600	70,700	50,000
1 1/2	58,000	43,500	116,000	100,500	82,000	58,000

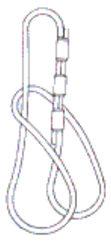
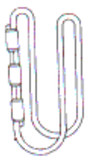
For Double Basket Hitch multiply above values by 2.



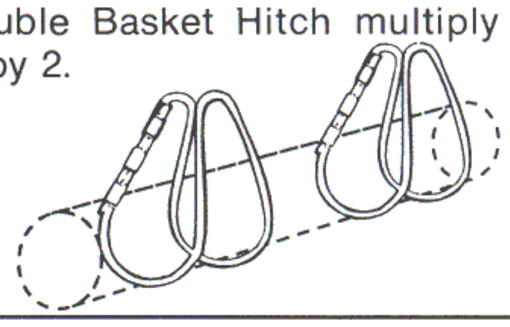
Note: A strand laid endless sling with mechanical splice is a sling fabricated from a single wire rope that is bent into a loop and whose ends are attached to each other by means of one or more mechanical fittings. For rope diameters up to and including 1-1/8″ the rope used is 6 x 19 IWRC and for diameters greater than 1-1/8″ it is 6 x 37 IWRC.

TABLE 6.21

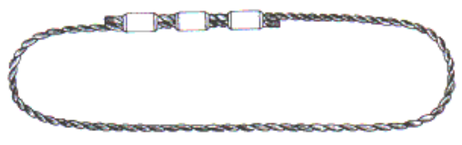
CABLE LAID ENDLESS SLINGS
Mechanical Splice

Cable Body Diameter (Inches)	MAXIMUM SAFE WORKING LOADS — POUNDS (Safety Factor = 5)					
	Single Vertical Hitch	Single Choker Hitch 	Single Basket Hitch (Vertical Legs) 	Single Basket Hitch With Legs Inclined		
				60°	45°	30°
1/4	1,650	1,250	3,300	2,850	2,350	1,650
3/8	3,600	2,700	7,200	6,250	5,100	3,600
1/2	6,000	4,500	12,000	10,400	8,500	6,000
5/8	9,000	6,750	18,000	15,600	12,700	9,000
3/4	12,400	9,300	24,800	21,500	17,500	12,400
7/8	16,600	12,500	33,200	28,800	23,500	16,600
1	20,000	15,000	40,000	34,600	28,300	20,000
1 1/8	26,000	19,500	52,000	45,000	36,800	26,000
1 1/4	32,000	24,000	64,000	55,400	45,200	32,000
1 3/8	36,000	27,000	72,000	62,400	50,900	36,000
1 1/2	44,000	33,000	88,000	76,200	62,200	44,000

For Double Basket Hitch multiply above values by 2.



Note: Cable laid endless slings with mechanical splices are endless slings fabricated from cable that is bent into a loop and whose ends are attached to each other by means of one or more mechanical fittings. The cable is composed of 6 individual wire ropes wrapped around a 7th wire rope which forms the core. For cable body diameters of 1/4 - 5/8″ the construction is 7 x 7 x 7 (i.e., 7 wire ropes of 7 x 7 construction) and for diameters above 5/8″ it is 7 x 6 x 19 IWRC (i.e., 7 wire ropes of 6 x 19 IWRC construction).



CHAPTER 7

RIGGING PROCEDURES AND PRECAUTIONS

RESPONSIBILITIES:

It is not only the men on the job who have responsibilities for their own and their fellow workers' safety. Management also have responsibilities that must be accounted for.

It is the responsibility of management and supervision to ensure that the men who prepare the equipment, use the equipment and work with or around it are well trained in both safety and operating procedures.

The employer must ensure that all hoisting equipment is operated only by trained, experienced and competent operators.

The employer must also ensure that the men who direct, rig and handle the loads have received training in the principles of the operation, are able to establish weights and judge distances, heights and clearances, are capable of selecting tackle and lifting gear suitable for the loads to be lifted, and are capable of directing the movement of the crane and load to ensure the safety of all personnel.

The employer is also responsible for putting together a safety program, educating all personnel in safe practices and the assignment to the rigging crews of definite, individual safety responsibilities.

These responsibilities must be assigned by management to on-the-job personnel. Job titles may vary, but the essential responsibilities can be allocated as follows:

(a) Planning: Major rigging operations must be **planned** and supervised by competent personnel to ensure that the best methods and most suitable equipment and tackle are employed.

(b) Supply and Care of Rigging Equipment: Job management must ensure that:
- — Proper rigging equipment is available.
- — Correct load ratings are available for the material and equipment used for rigging.
- — Rigging material and equipment are maintained in proper working condition.

(c) Rigging Operation: The supervisor of the rigging operation should be responsible for:
- — Proper rigging of the load.
- — Supervision of the rigging crew.
- — Ensuring that the rigging material and equipment have the necessary capacity for the job and are in safe condition.
- — Ensuring correct assembly of rigging material or equipment as required during the operation, such as the correct installation of lifting bolts.
- — Safety of the rigging crew and other personnel as they are affected by the rigging operation.

PROCEDURES AND PRECAUTIONS:

The single most important rigging precaution is to determine the weight of all loads before attempting to lift them, making ample allowances for unknown factors, and determining the available capacity of the equipment being used. In cases where the assessment of load weight is difficult, safe load indicators or weighing devices should be fitted. This chapter also includes a section dealing with the estimation of load weights.

It is equally important to rig the load so that it is stable. Unless the center of gravity of the load is below the hook, the load will shift. A separate section dealing with centers of gravity has been included in this chapter.

The safety of personnel involved in rigging and hoisting operations largely depends upon care and common sense. Remember these safe practices:

— Know the safe working load of the equipment and tackle being used. Never exceed this limit. (Fig. 7.1)

— Determine the load weight before rigging it.

— Examine all hardware, equipment, tackle and slings before using it and **destroy** defective components. Discarded equipment may be used by someone not aware of the hazards or defects. (Fig. 7.2)

— No one who has reasonable cause to believe that any equipment or tackle which has been assigned to him is unsafe or unsuited to the job should use or operate it until he has reported the defect or hazard to his supervisor, safe conditions have been assured, and orders to proceed have been issued by some person in authority who is then responsible for the safety of all personnel exposed to the unsafe conditions.

— Never carry out any rigging or hoisting operation when the weather conditions are such that hazards to personnel, property or the public are created. The size and shape of the loads being lifted must be carefully examined to determine if a safety hazard exists during high wind speeds. Avoid handling loads presenting large wind catching surfaces which could result in loss of control of the load during times of high or gusty winds, even though the weight of the load is within the normal capacity of the equipment. Wind loading can be critical on the manner in which the load is landed and the safety of the men handling it. When winds reach 25-30 mph consider limiting operations. (Fig. 7.3)

— If the visibility of the riggers or hoist crew is impaired by dust, darkness, snow, fog or rain, strict supervision of the operation must be exercised and, if necessary, it should be suspended. (Fig. 7.4)

— Whenever the temperature is below freezing (32°F), extreme caution must be exercised to ensure that no part of the hoist or crane structure or tackle is shock loaded or impacted as brittle fracture of the steel can result.

— **The most repeated killer of riggers and those persons handling loads is electrocution caused by the contact of the boom, load line or load of a crane with electric power lines.** When working with or around cranes that are within a boom's length of any power line ensure that a competent signalman is stationed at all times within view of the operator to warn him when any part of the machine or its load is approaching the minimum safe distance (10-20 feet depending on the line voltage) from the power line. Caution must also be exercised when working near overhead lines having long spans as they tend to swing laterally due to the wind and accidental contact could occur. (Fig. 7.5)

— The safe working loads of all hoisting and rigging equipment, hardware and tackle are based on almost ideal conditions seldom achieved under actual working conditions, and as such it is important to recognize the factors which can reduce the capacity of the equipment.

— The safe working loads of hoisting equipment apply only to freely-suspended loads on plumb hoist lines. If the hoist line is not plumb at all times when handling loads then additional side loads will hazard the stability of the equipment and introduce stresses for which it has not been designed. In circumstances such as this, structural failures can result without any warning. (Fig. 7.6)

— Rapid swinging of suspended loads also subjects the equipment to additional stresses which can cause collapse. The force of the swinging action causes the load to drift away from the machine increasing the radius and side loading the equipment. The load must always be kept directly

below the boom point or upper load block. (Fig. 7.7)

— The safe working loads also apply only to equipment in good condition, having undamaged and unkinked structural members. If any equipment becomes damaged in service it should be taken out of service until the necessary repairs have been effected.

— The maximum safe working loads of most rigging and hoisting equipment are determined from static loads and the safety factor is applied to account for dynamic motions of the load and equipment. In order to ensure that the safe working load is not exceeded during operation, allowances should be made for wind loading and dynamic forces set up by the normal operational movements of the machine and load. It is essential to avoid sudden snatching, swinging and stopping of suspended loads since rapid acceleration and deceleration will greatly increase the stresses in the equipment and tackle.

— The rated loads of most hoisting equipment do not generally account for the weight of hook blocks, hooks, slings, equalizer beams, material handling equipment and other elements of lifting tackle. Their combined weight must be subtracted from the load capacity of the equipment to determine the maximum allowable load to be lifted. (Fig. 7.8)

The life and safety of slings and their contribution to the security of hoisting operations can be greatly increased by taking care in their application.

— Never use kinked or damaged slings or hoist ropes. To provide maximum operating efficiency and safety, all slings and fittings should be given thorough periodic inspections as well as daily inspections for signs of wear and abrasion, broken wires, worn or cracked fittings, loose seizings and splices, kinking, crushing, flattening, and corrosion. Special care should be taken in inspecting the areas around thimbles and fittings.

— All slings should be identified with an identification number and their maximum capacity on a flat ferrule or ring, permanently attached to the sling. Mark the capacity of the sling for a vertical load or at an angle of 45°, but be certain that all employees are aware of how the rating system works. (Fig. 7.9)

Fig. 7.1 Know the Load Weight and Tackle Capacity

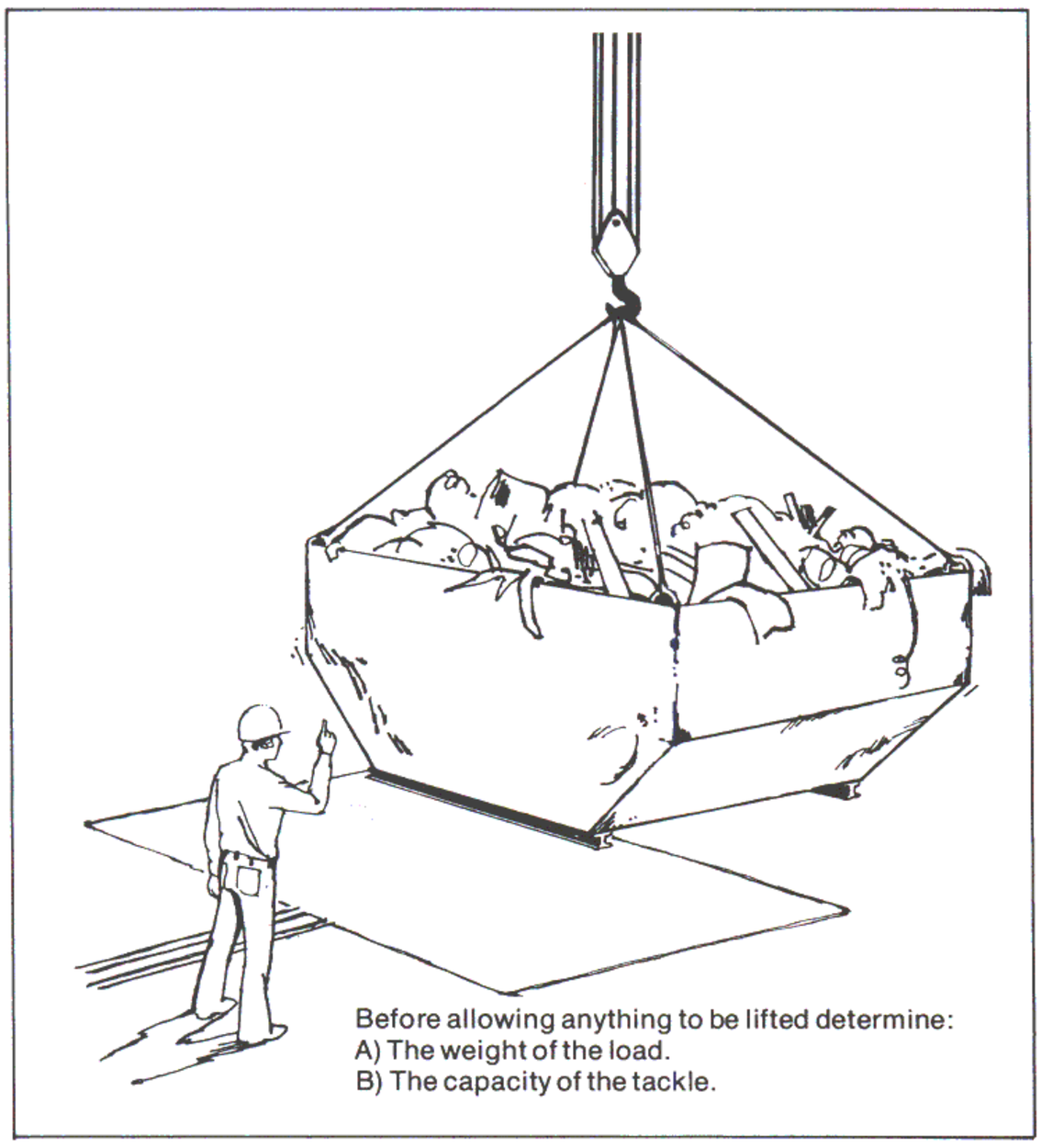


Fig. 7.2 Destroy Defective Components

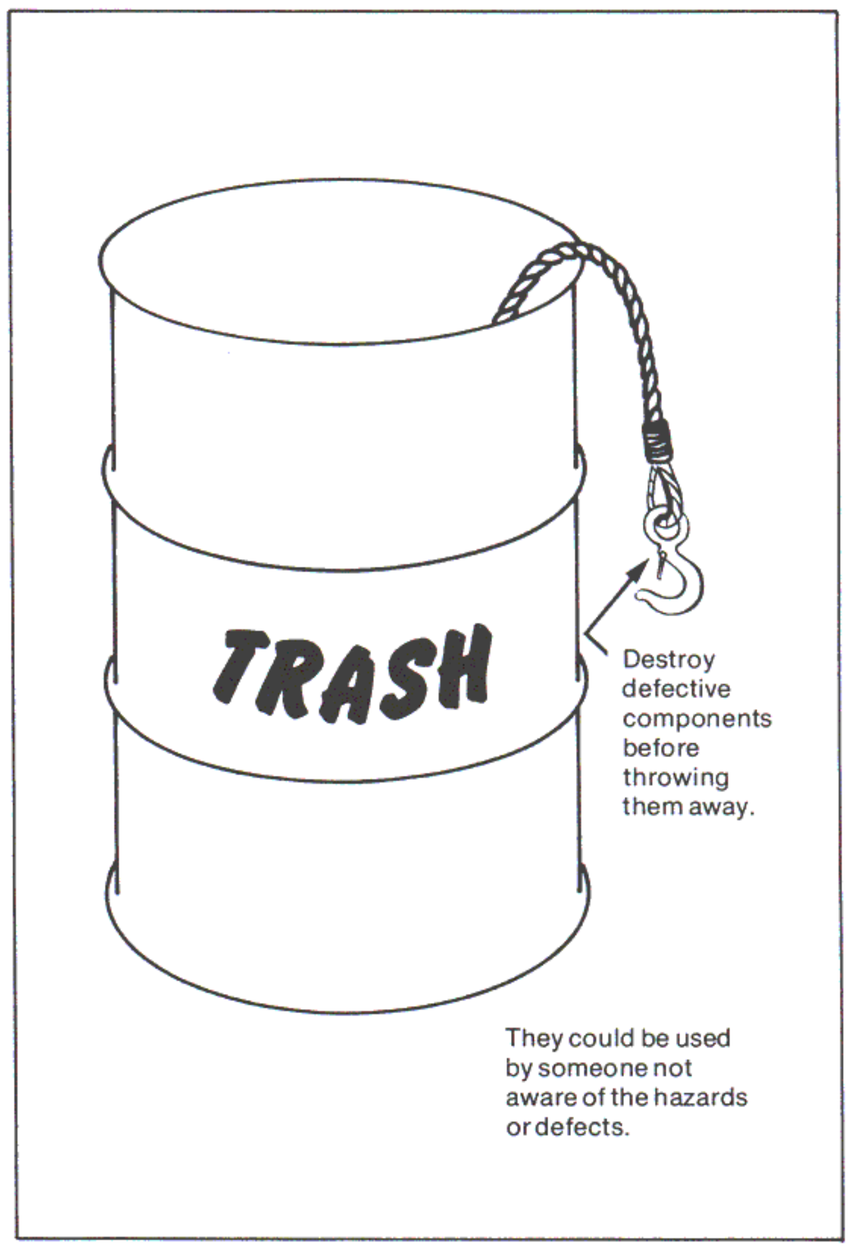


Fig. 7.3 Effect of the Wind on a Load can be Severe

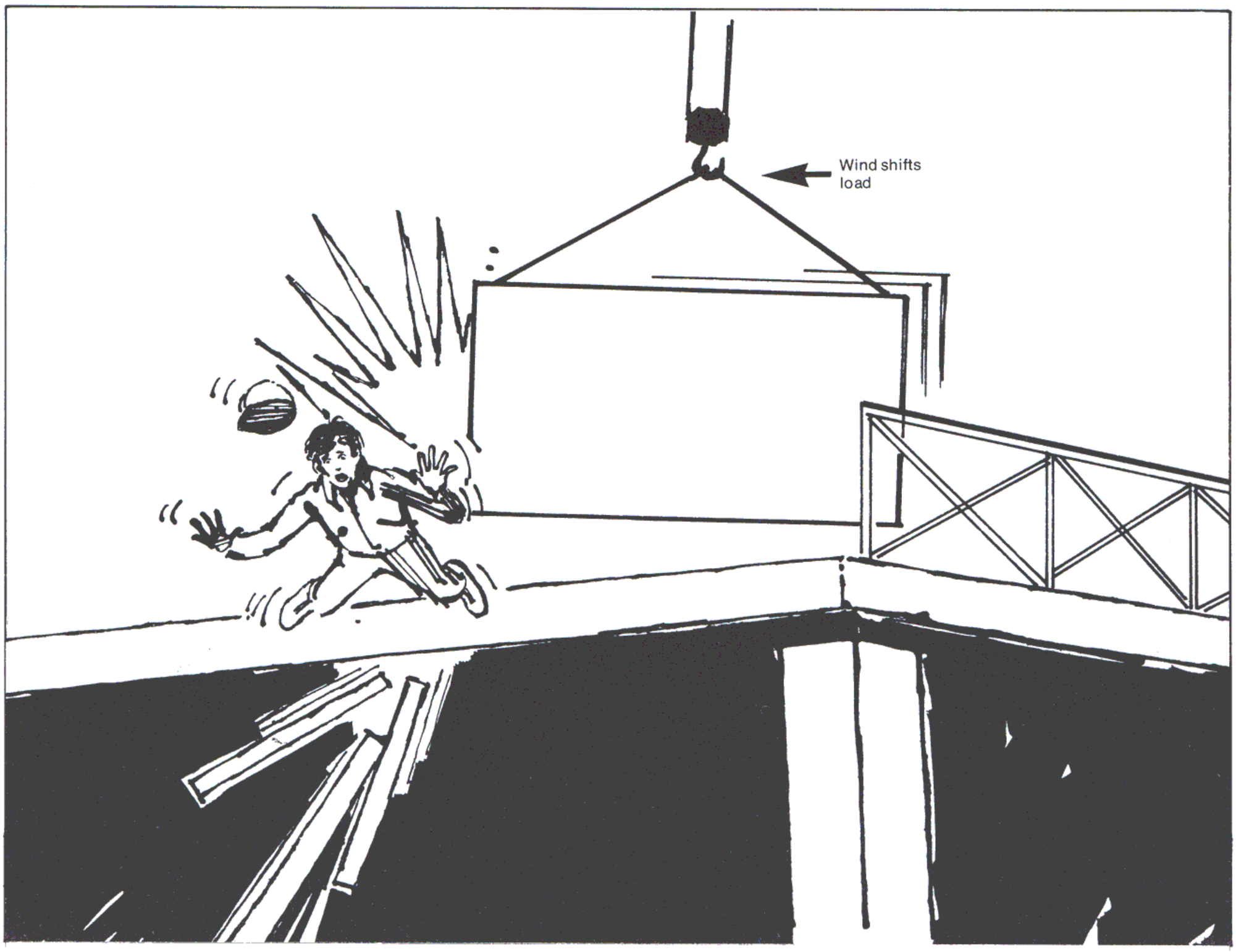


Fig. 7.4 Ensure that Adequate Lighting is Available for All Night Operations.

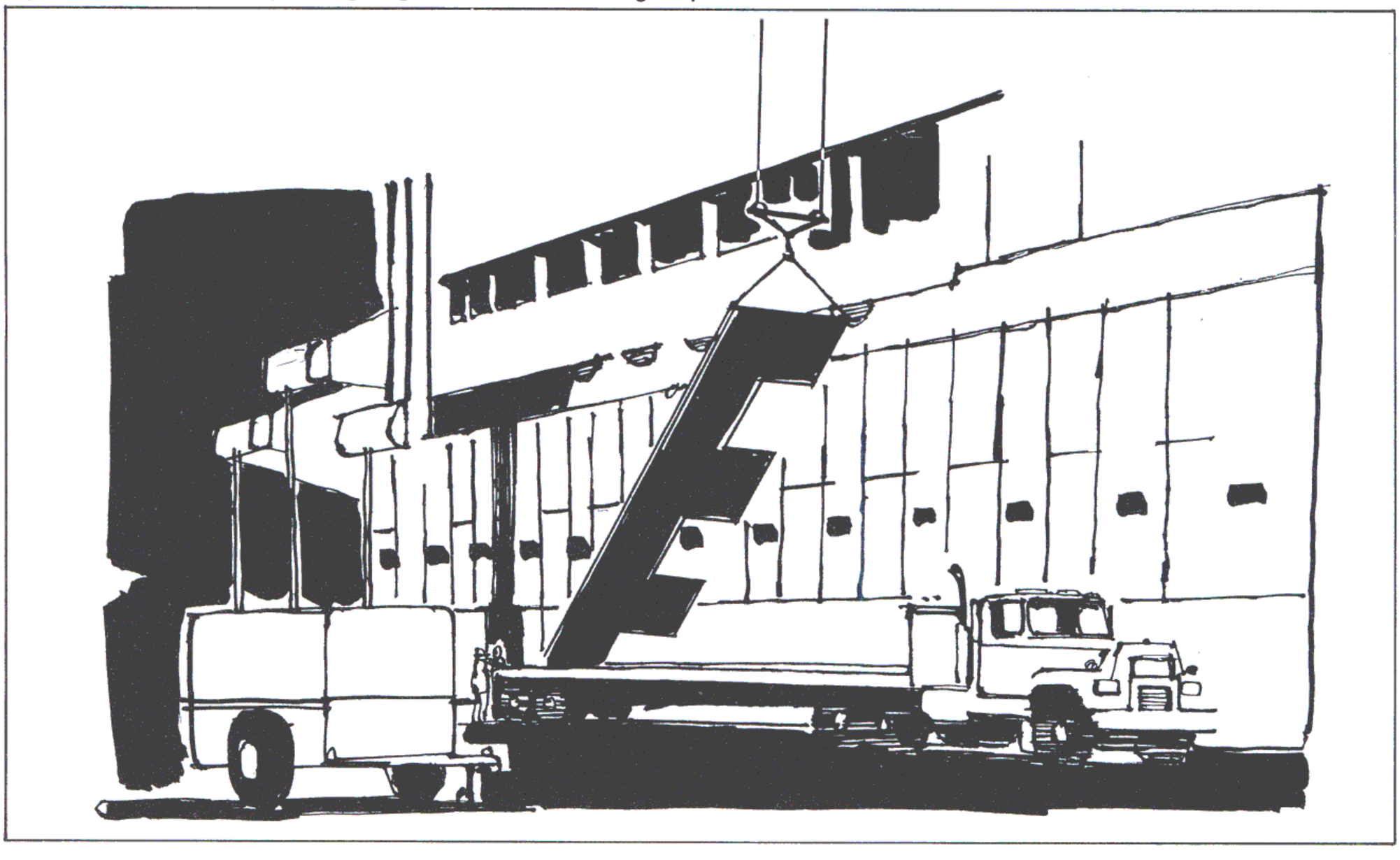
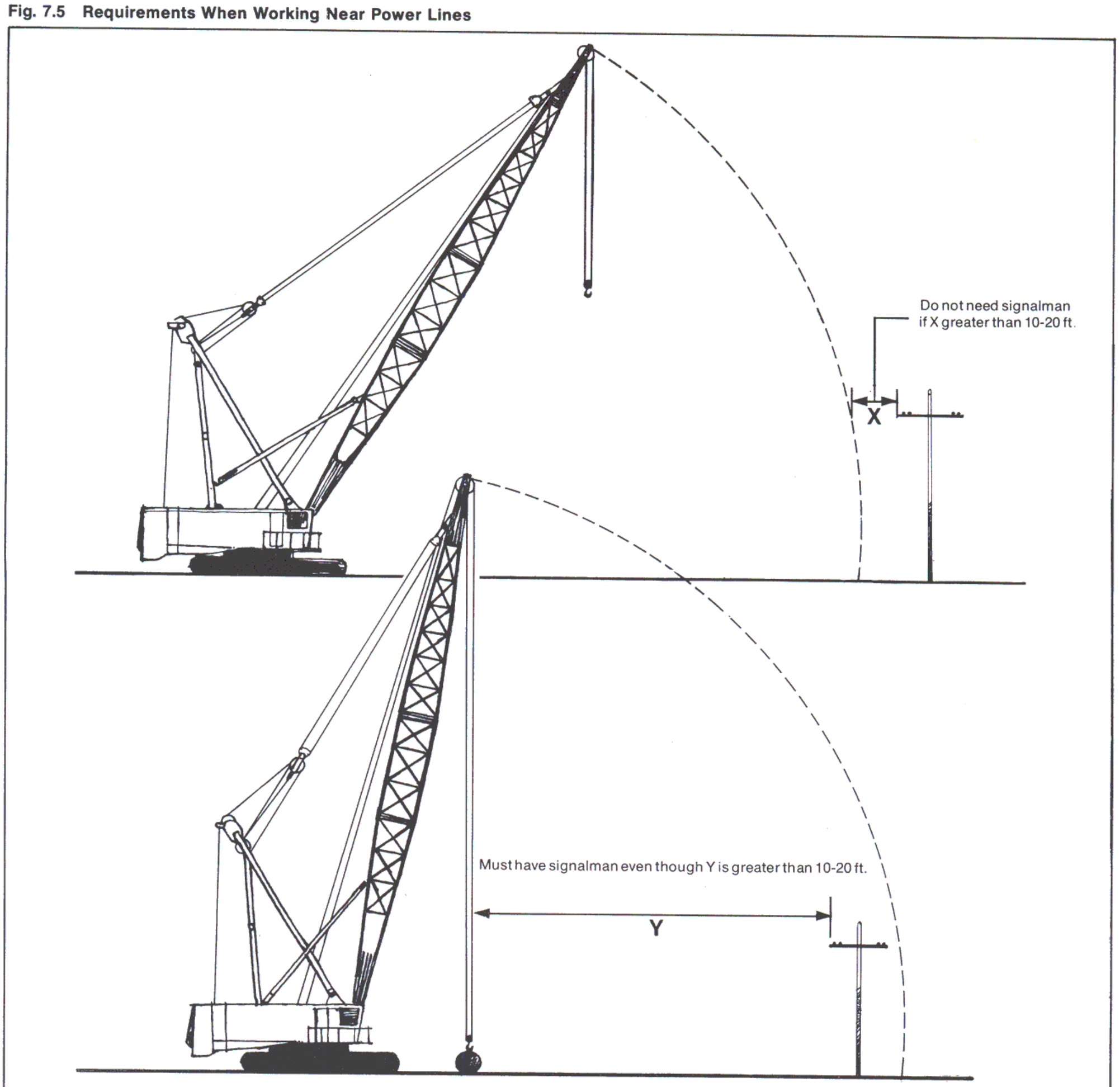
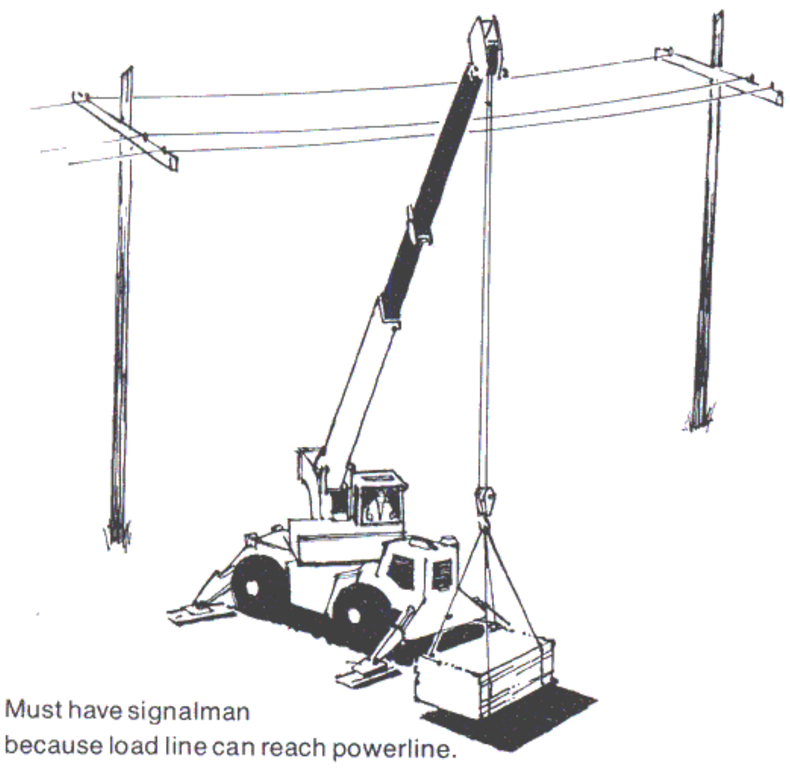


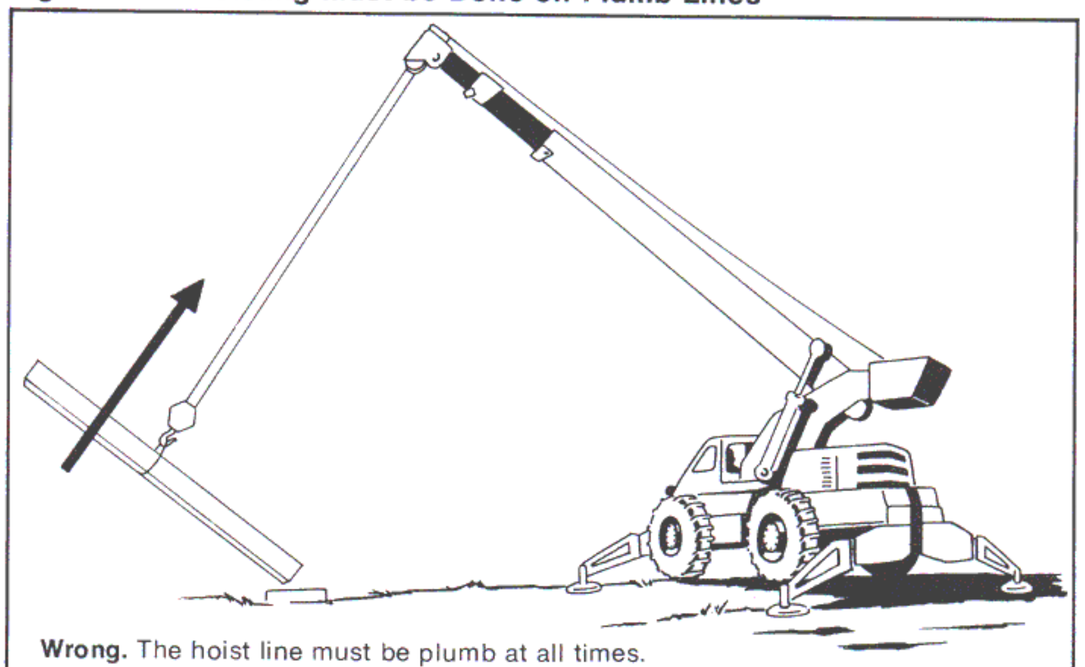
Fig. 7.5 Requirements When Working Near Power Lines





Must have signalman
because load line can reach powerline.

Fig. 7.6 All Hoisting Must be Done on Plumb Lines



Wrong. The hoist line must be plumb at all times.

Fig. 7.7 Keep the Load Under Control at All Times

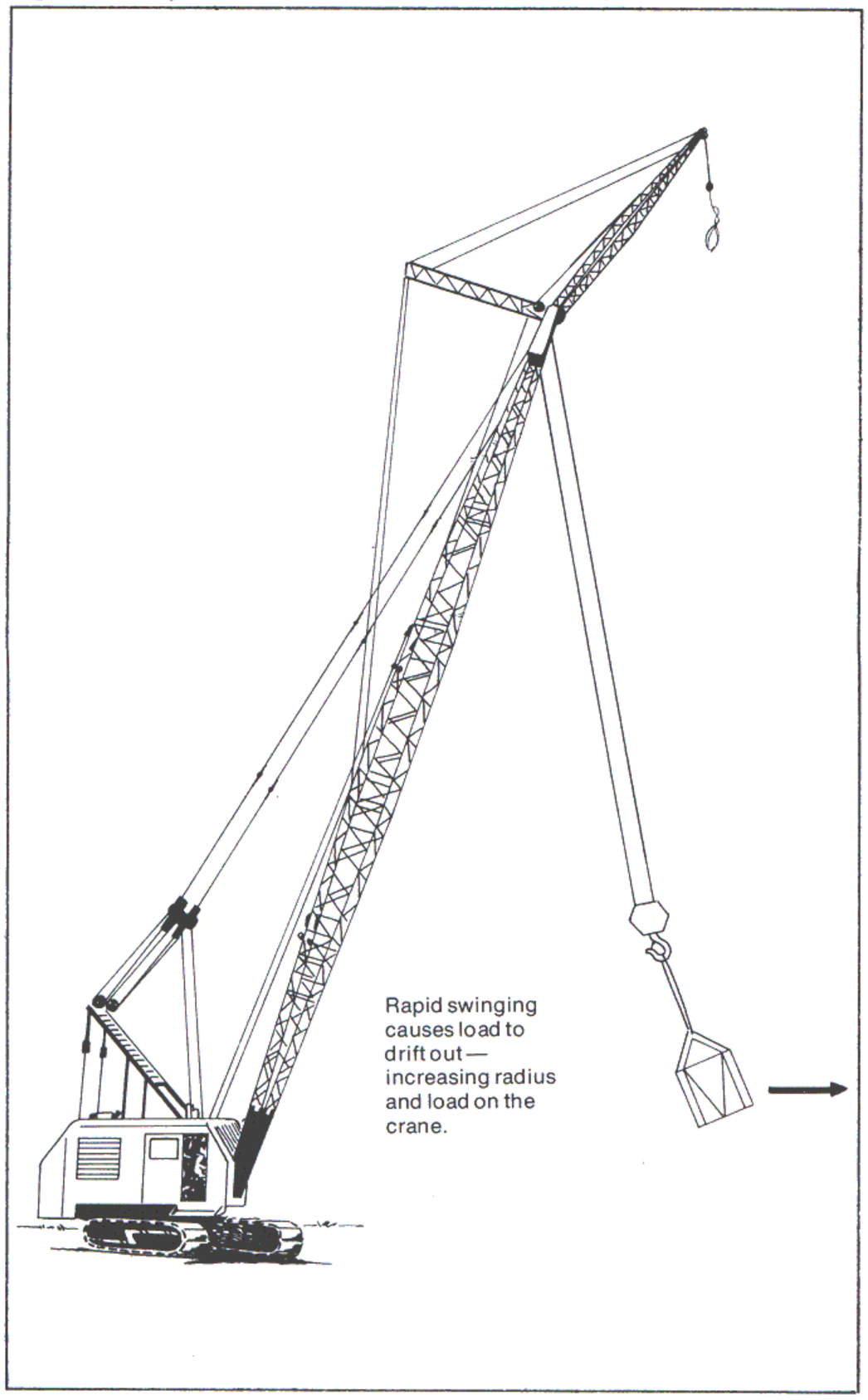


Fig. 7.8 All Rigging Equipment Must be Counted as Part of the Load

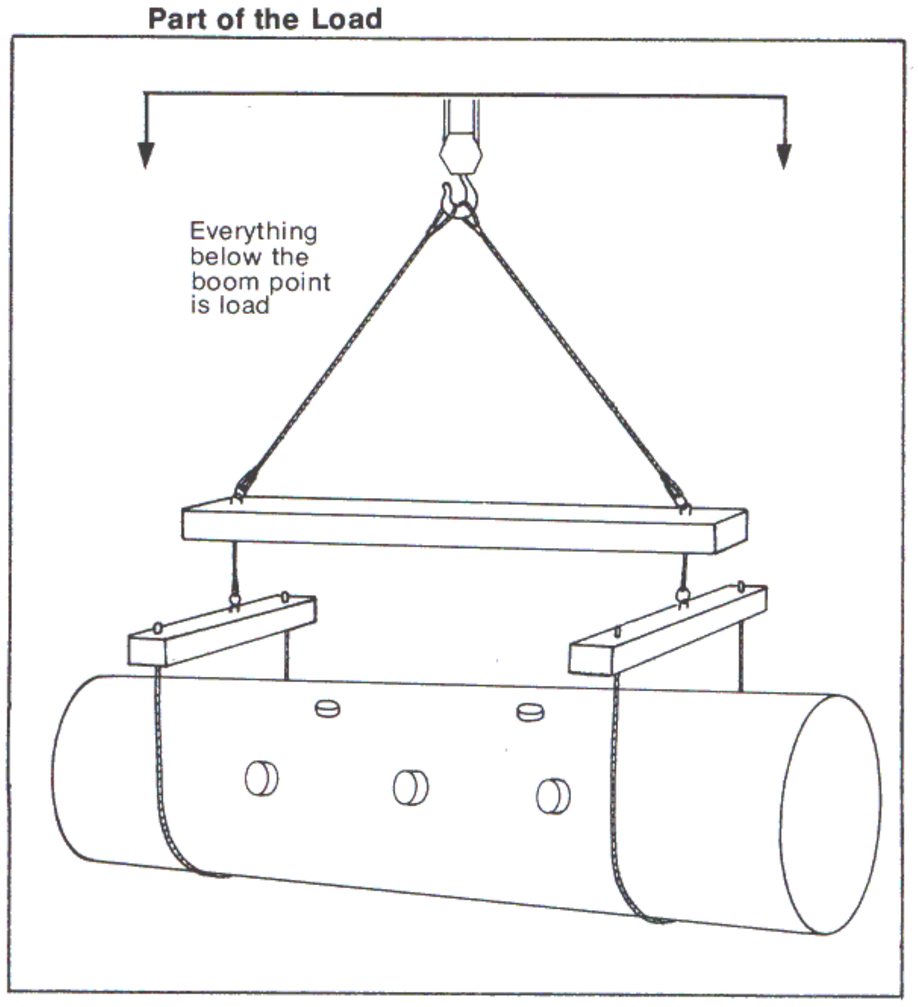


Fig. 7.9 All Slings Should Carry Identification Tags

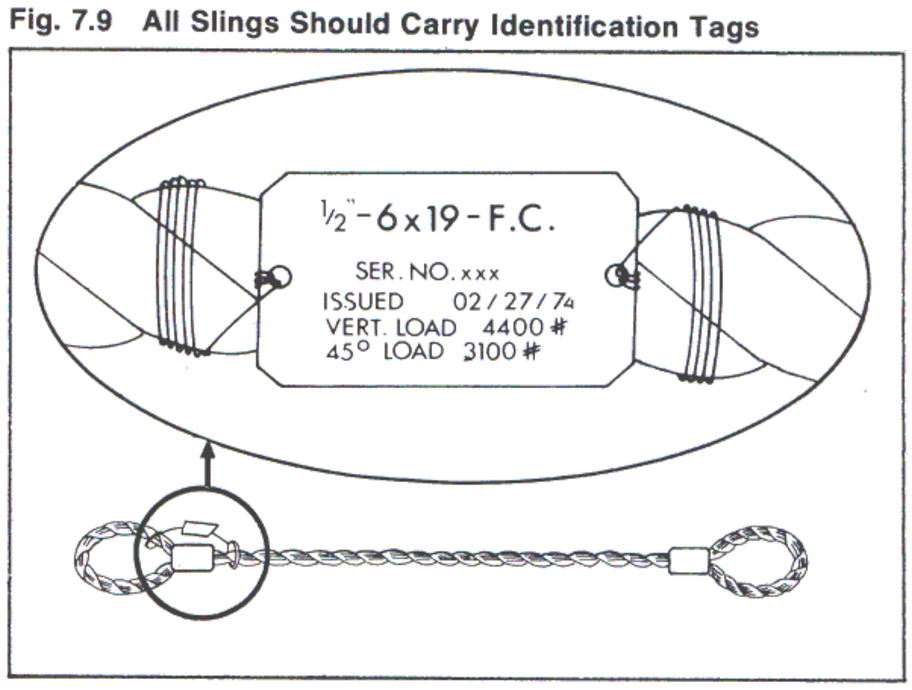
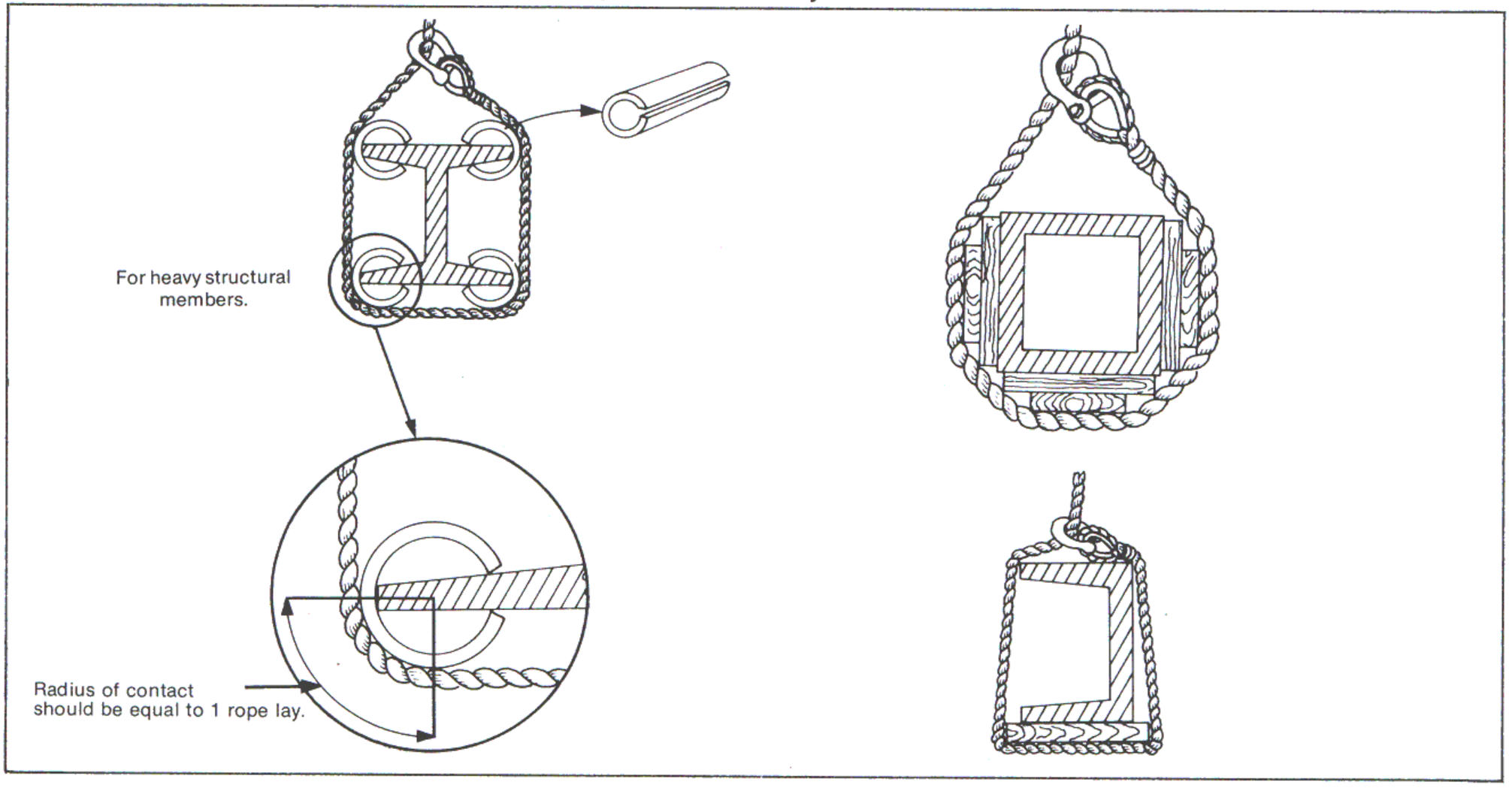


Fig. 7.10 Ensure that Slings are Protected at All Sharp Corners on Heavy Items



— Sharp bends, pinching and crushing must be avoided. Loops and thimbles should be used at all times. Corner pads that prevent the sling from being sharply bent or cut can consist of large diameter split pipe sections, corner saddles, padding or blocking. (Fig. 7.10)

It's a good rule to make sure that the length of the arc of contact of the rope is at least equal to one rope lay (about seven times the rope diameter). When the bend is of this length, each of the strands has been on the inner and outer sides of the rope bend and the slippage of the strands relative to each other minimizes the stress. On the other hand, if the bend is very short, the strands on the outer side of the rope bend will have to stretch and this stretch will usually be permanent and will leave a sharp bend or kink in the sling.

— Never allow wire rope to lie on the ground for any length of time or on damp or wet surfaces, rusty steel or near corrosive substances.

— Avoid dragging rope slings from beneath loads.

— Keep all rope away from flame cutting and electric welding operations.

— Avoid contact with solvents and chemicals.

— Knotted and kinked slings are permanently damaged and should not be used.

— Never use discarded hoist rope as sling material.

— Avoid using single leg wire rope slings with hand spliced eyes. The load can spin causing the rope to unlay allowing the splice to pull out. Slings having Flemish Spliced Eyes should be used.

— Never wrap a wire rope completely around a hook. The sharp radius will damage the sling. (Fig. 7.11)

— Avoid bending the eye section of wire rope slings around corners. The bend will weaken the splice or swaging. There must be no bending near any attached fitting. (Fig. 7.12)

— Ensure that the sling angle is always greater than 45°. To make sure that the angle is adequate once a load is rigged, check that the horizontal distance between the attachment points on the load is less than

Fig. 7.11 Never Wrap a Rope Around a Hook

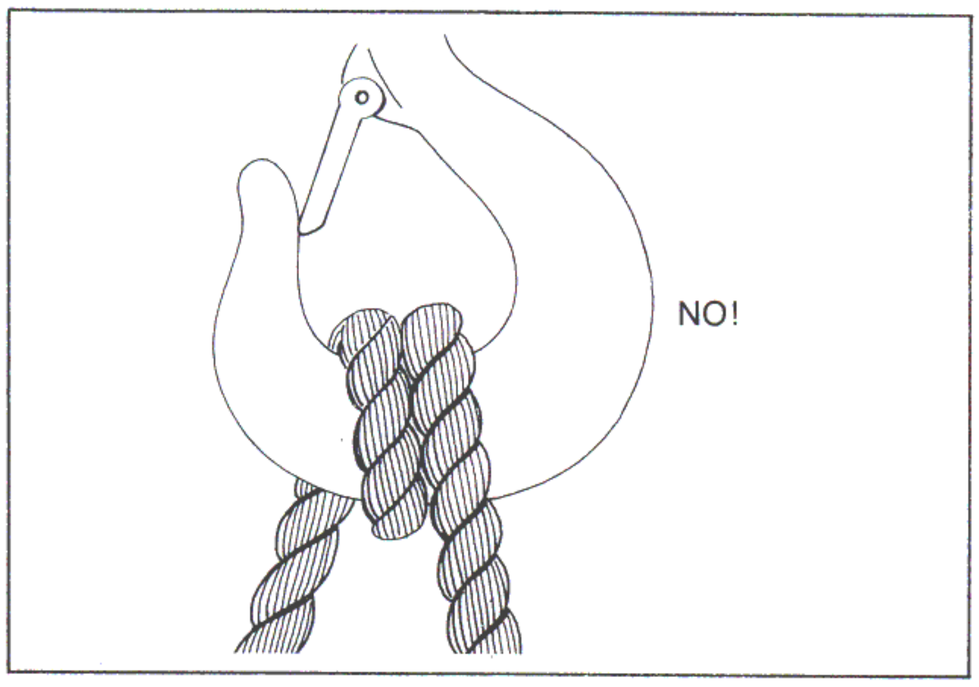


Fig. 7.13 Check on Sling Angle

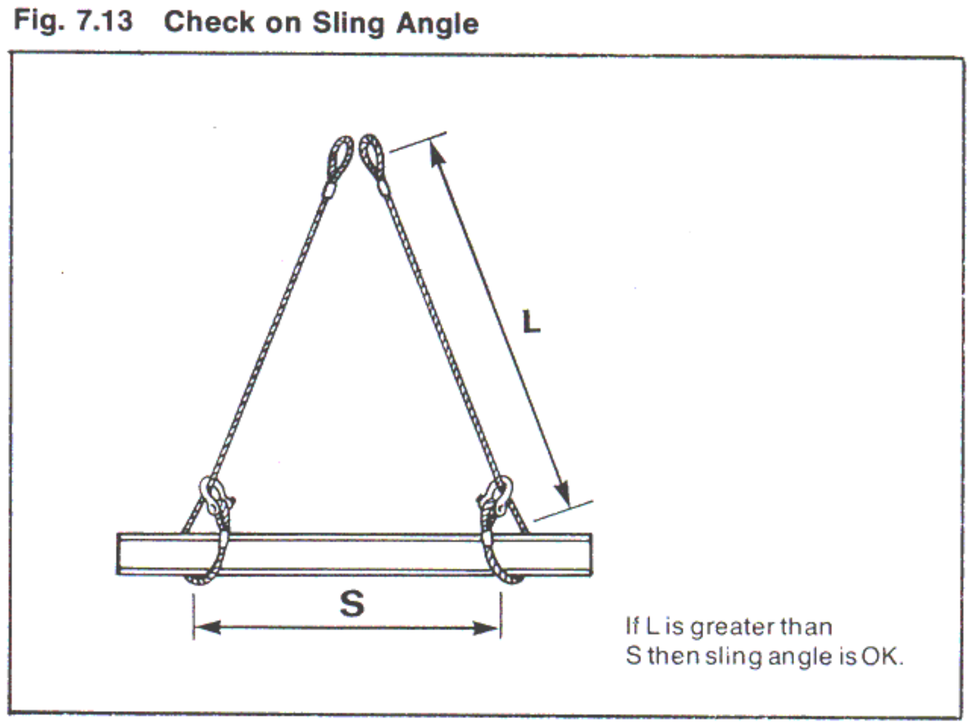
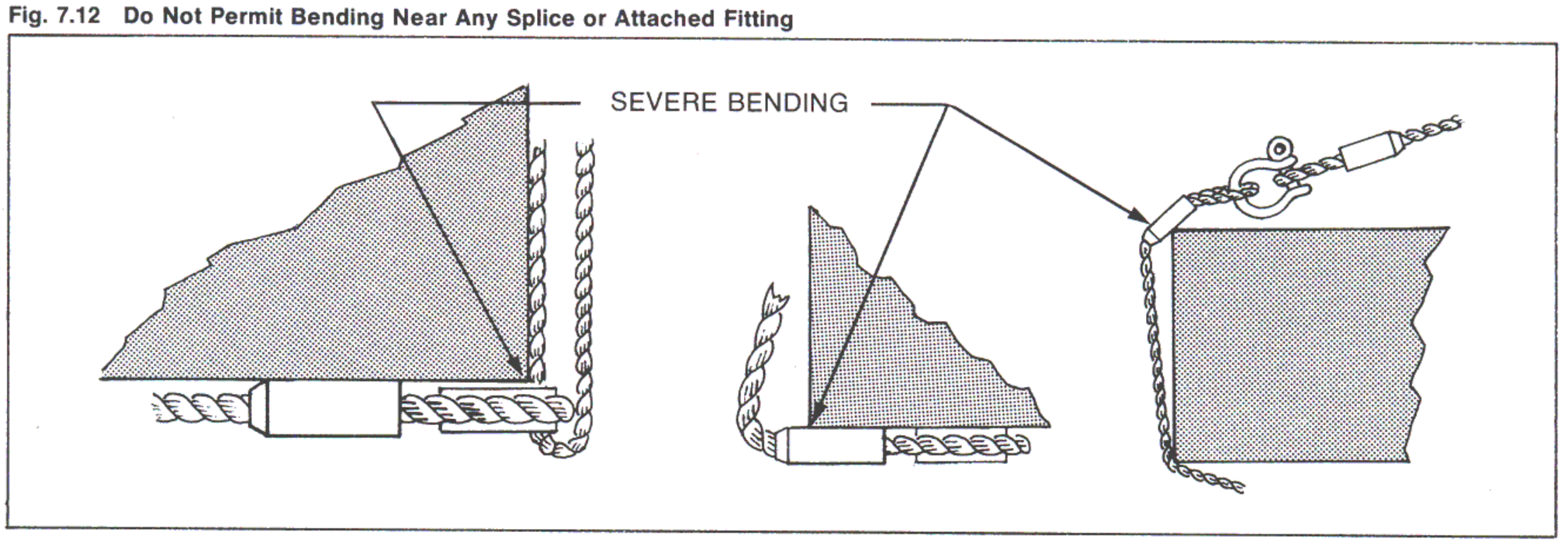


Fig. 7.12 Do Not Permit Bending Near Any Splice or Attached Fitting



the length of the shortest sling leg. If this is the case then the angle is greater than 60°. (Fig. 7.13)

— Do not assume that a multi-legged bridle sling will safely lift a load equal to the safe load on one leg multiplied by the number of legs. There is no way of knowing that each leg is carrying its share of the load. With slings having more than 2 legs and a rigid load, it is possible for two of the legs to take practically the full load while the others only balance it. Due consideration with regard to this has been given in computing the safe working load tables for three and four legged bridle slings which are only given the same safe load as a two legged sling. (Fig. 7.14)

When lifting rigid objects with slings having three or four legs, any two of the slings must be capable of supporting the total load. In other words, after considering the angle between the legs, the slings should be considered as having only two legs when estimating the size required. Where the object is flexible and able to bend to adjust itself to the sling legs, each leg can be assumed to take its own share of the load.

— When using multi-legged slings to lift loads in which one end is much heavier than the other the tension in the most heavily loaded leg is much more important than the total weight. The sling must be selected to suit the most heavily loaded leg rather than the total weight. (Fig. 7.15)

— When using choker hitches, do not force the eye down towards the load once tension is applied. Rope damage is the invariable result. (Fig. 7.16)

— Whenever two or more rope eyes must be placed over a hook, install a shackle on the hook with the shackle pin resting in the hook and hook the rope eyes to the shackle. This will prevent the spread of the sling legs from opening up the hook and also prevent the eyes from damaging each other when under load. (Fig. 7.17)

The following procedures and precautions should be observed whenever loads are to be handled:

— All loads must be properly rigged to prevent the dislodgement of any part. Suspended loads should be securely slung and properly balanced before they are set in motion.

— The load must be kept under control at all times. Where necessary, when personnel may be endangered by the rotation, one or more guide ropes or tag lines should be used to prevent the rotation or uncontrolled motion. (Fig. 7.18)

— Loads must be safely landed and properly blocked before being unhooked and unslung. (Fig. 7.19)

— Lifting beams should be plainly marked with their weight and designed working loads and should only be used for the purpose for which they were designed.

— The hoist rope must never be wrapped around the load. The load should be attached to the hook by slings or other rigging devices that are adequate for the load being lifted.

— Multiple part lines must not be twisted around each other.

— The load line should be brought over the center of gravity of load before the lift is started.

— If there has been a slack rope condition, determine that the rope is properly seated on the drum and in the sheaves.

— Materials and equipment being hoisted must be loaded and secured to prevent any movement which could create a hazard in transit. (Fig. 7.20)

— Keep hands away from pinch points as the slack is being taken up.

— Wear gloves when handling wire rope.

— Make sure that all personnel stand clear while loads are being lifted and lowered or while the slings are being drawn from beneath the load. The hooks may catch under the load and suddenly fly free. (Fig. 7.21)

— Before making a lift, check to see that the sling is properly attached to the load.

— Avoid impact loading caused by sudden jerking when lifting or lowering. Lift the sling gradually until the slack is eliminated.

— Never ride on a load that is being lifted.

— Never allow the load to be carried over the heads of any personnel.

— Never work under a suspended load unless the load has been adequately supported from the floor and all conditions have been

Fig. 7.14 On a Rigid Object the Load Could Be Carried On Only 2 Legs or Sling While Other Legs Only Serve to Balance.

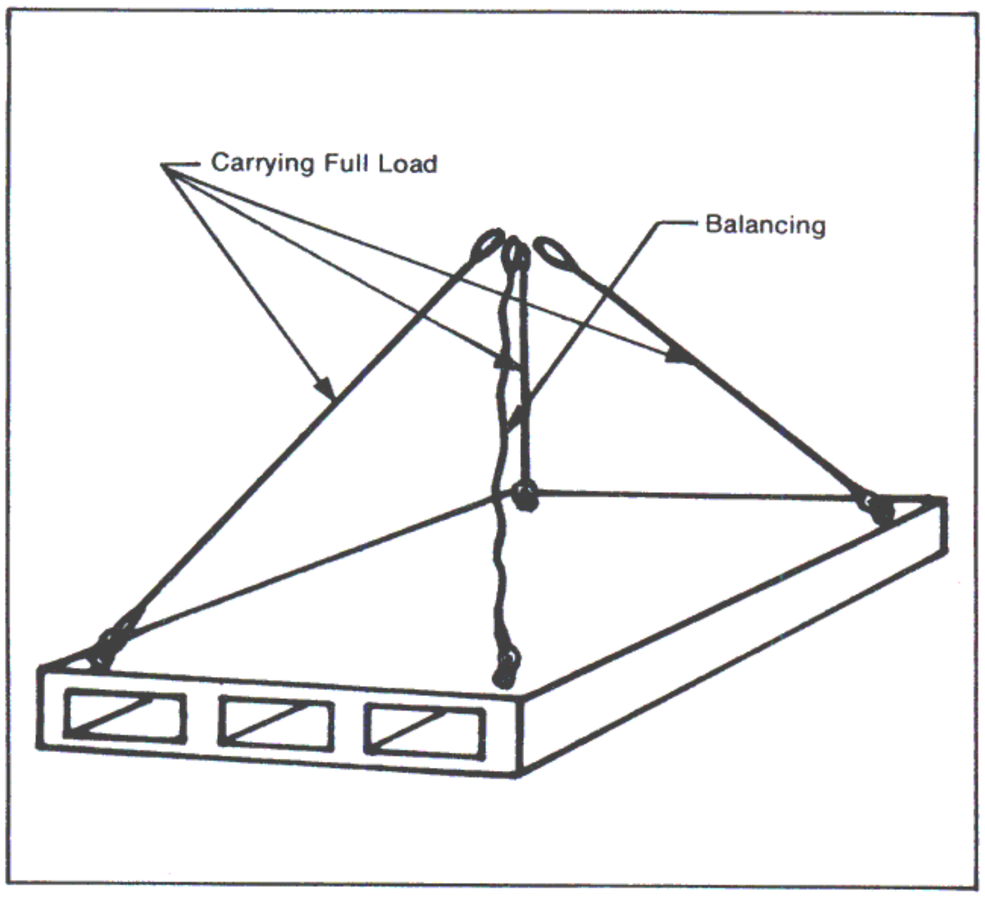


Fig. 7.15 Know What the Load in Each Sling Leg will be Before the Lift is Made

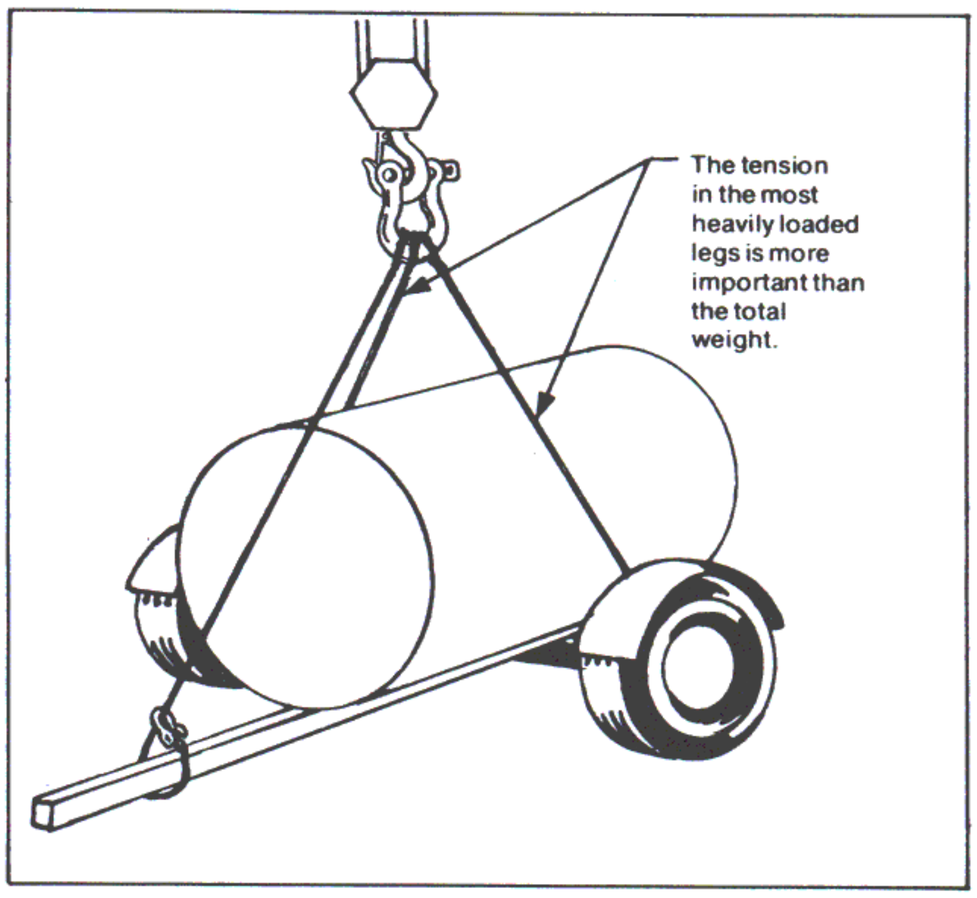
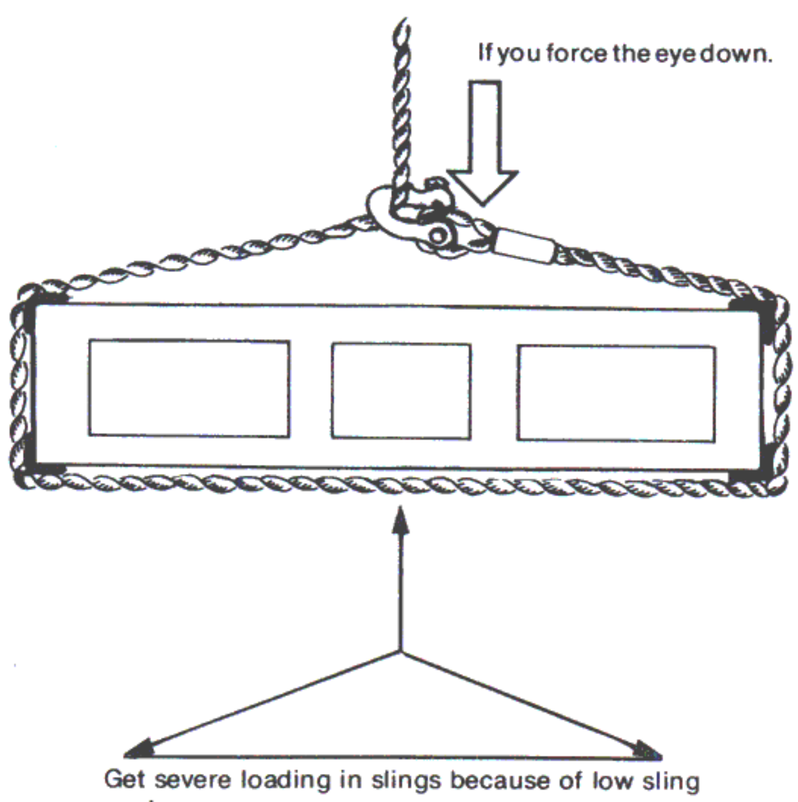
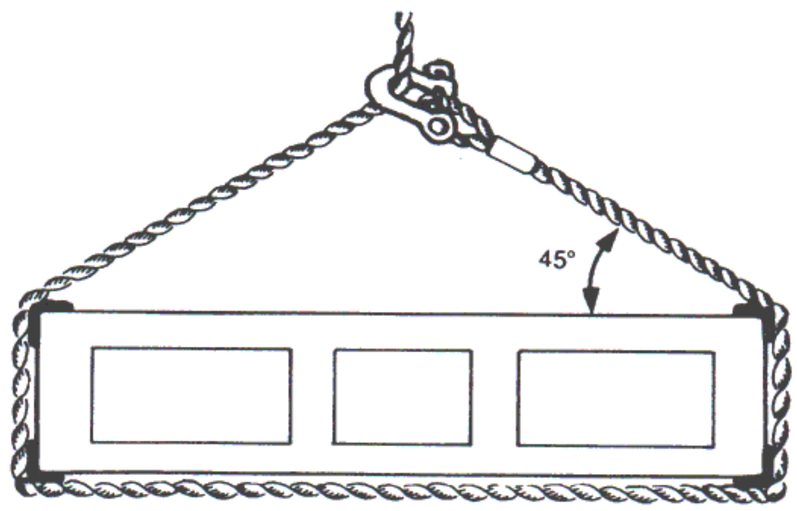


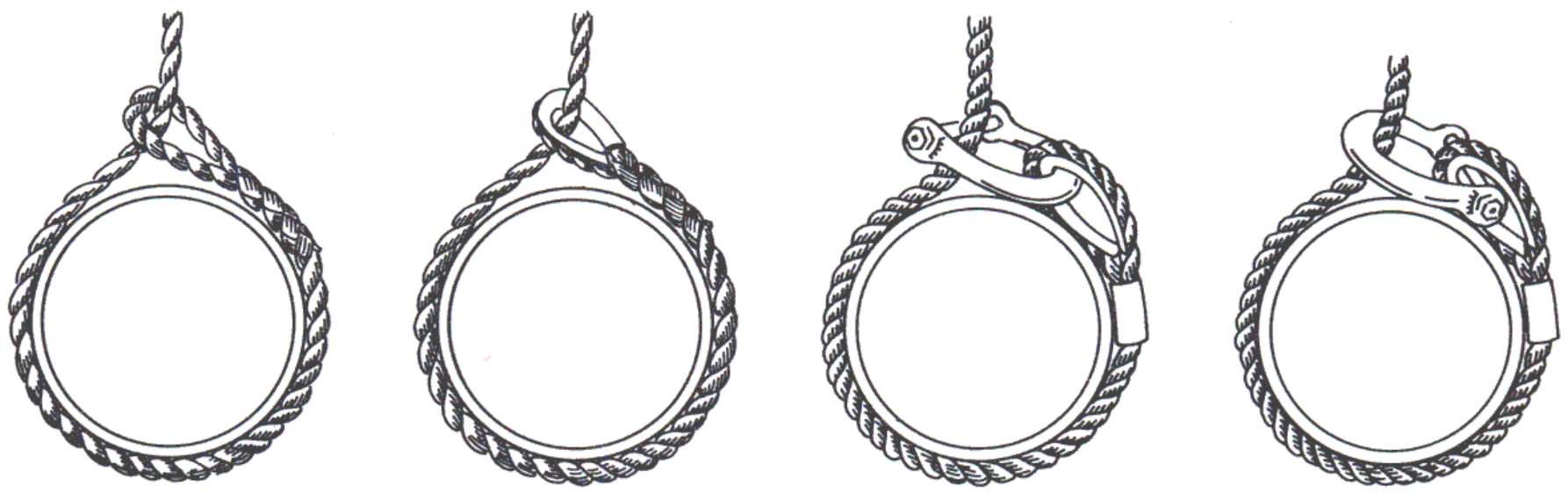
Fig. 7.16



Get severe loading in slings because of low sling angles.



Let the eye ride higher and keep this angle approx. 45° or more.



Incorrect — Cutting action of eye splice on running line.

Correct — Use thimbles in the eyes.

Incorrect — Shackle pin bearing on running line can work loose.

Correct — Shackle pin cannot turn.

Fig. 7.17 Whenever 2 or more ropes are to be Placed Over a Hook — Use a Shackle

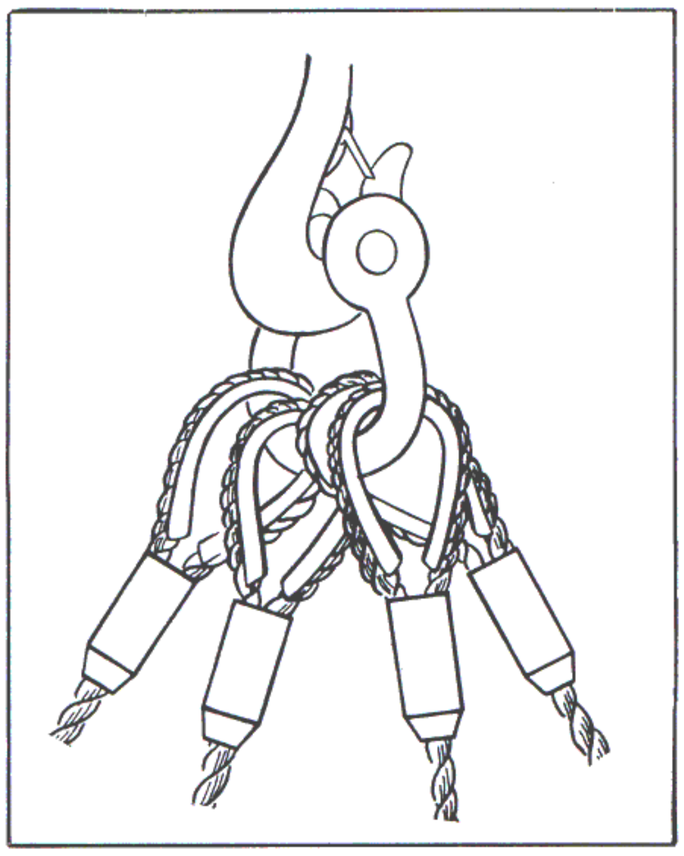


Fig. 7.18 Use Tag Lines to Control All Loads

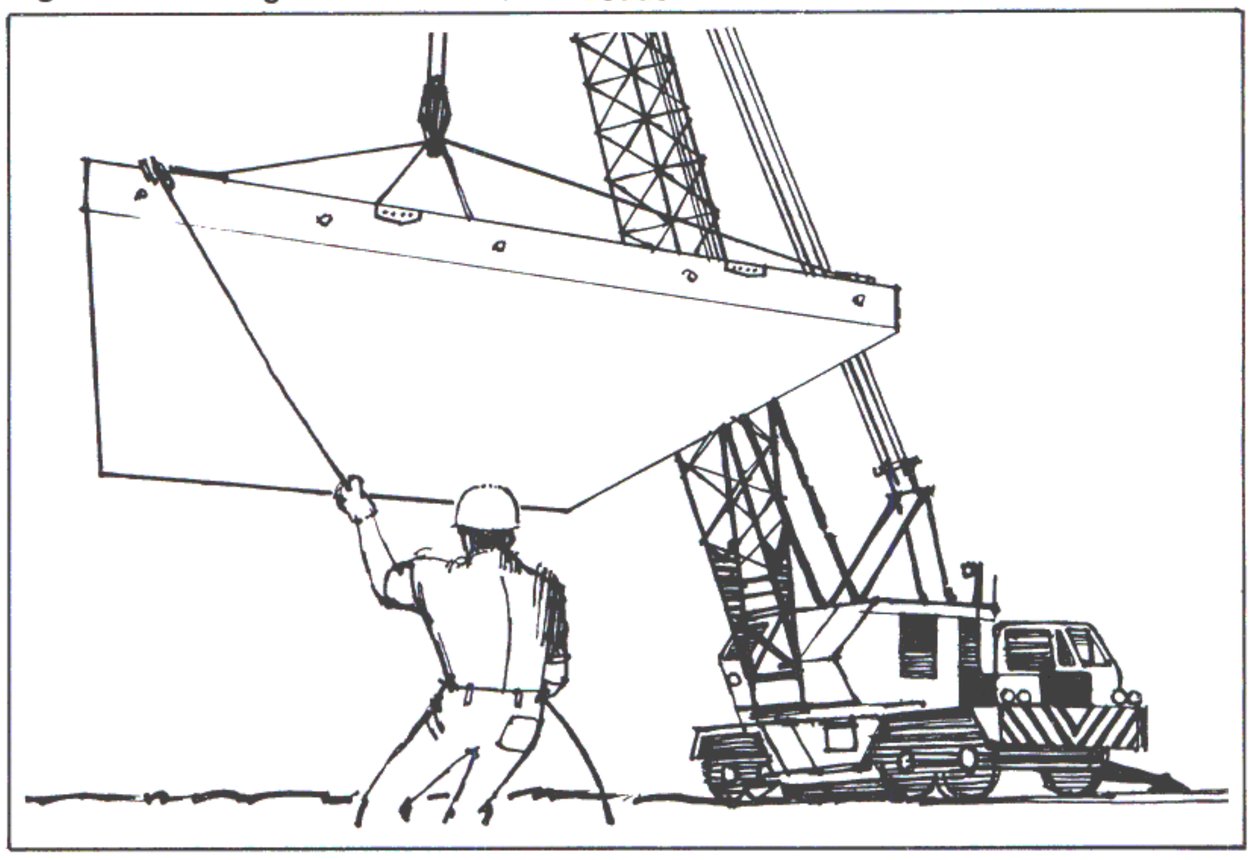


Fig. 7.19 Before Being Unhooked All Loads Must Be Safely Landed and Properly Blocked

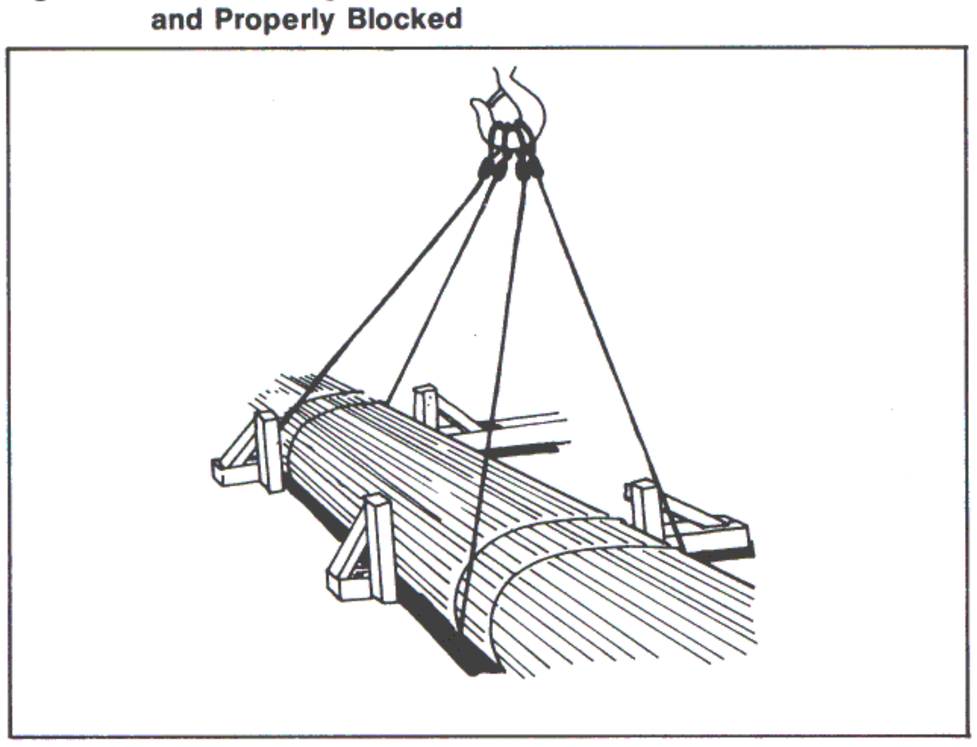


Fig. 7.20 Load and Secure All Materials so as to Prevent Any Movement or Possibility of Dislodgement

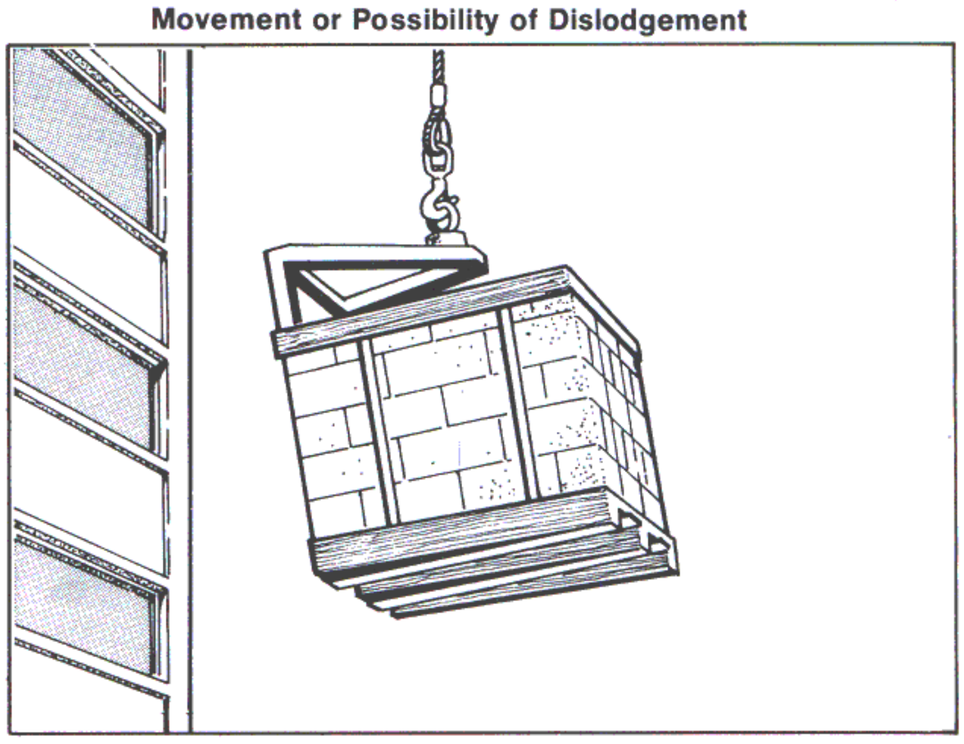
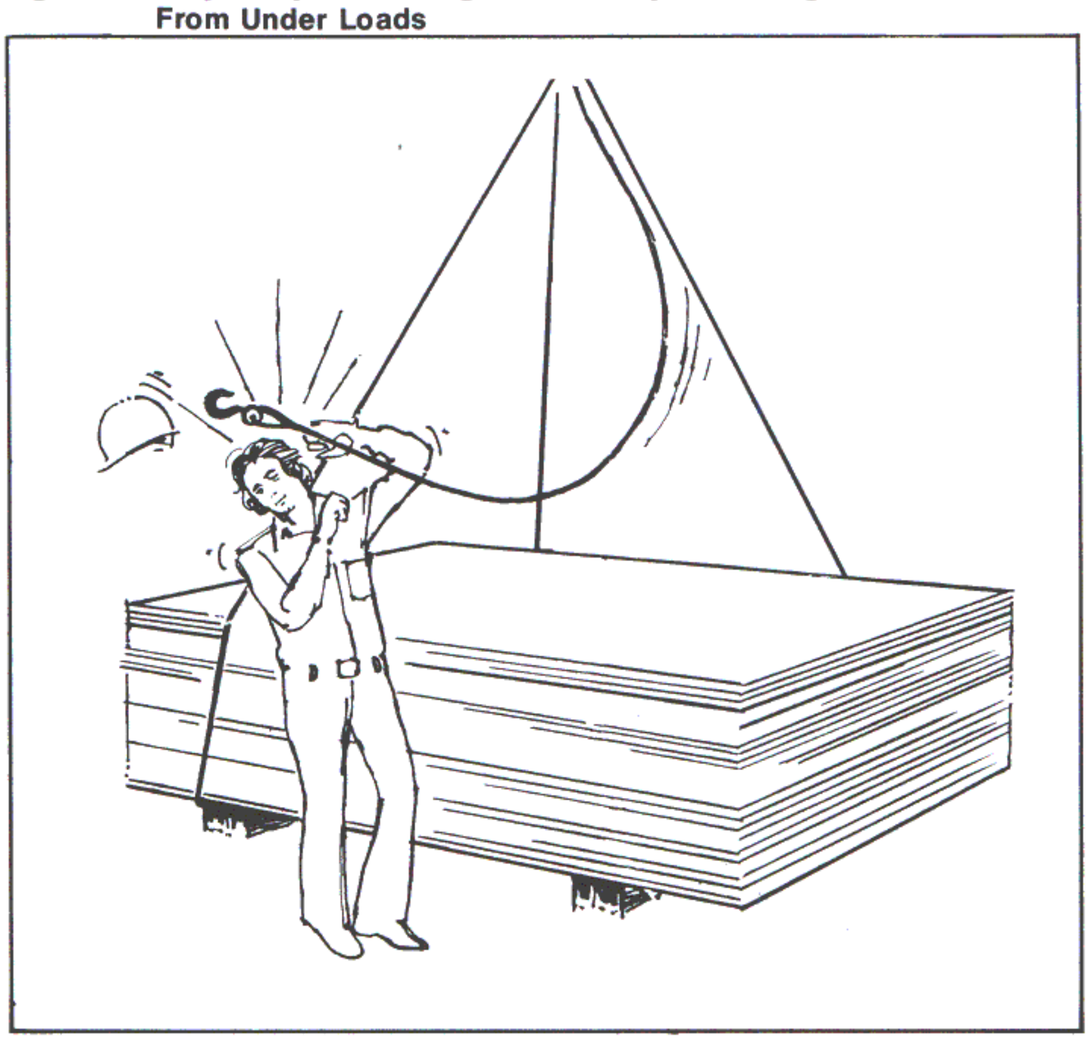


Fig. 7.21 Stay Away From Slings When They Are Being Pulled Out From Under Loads



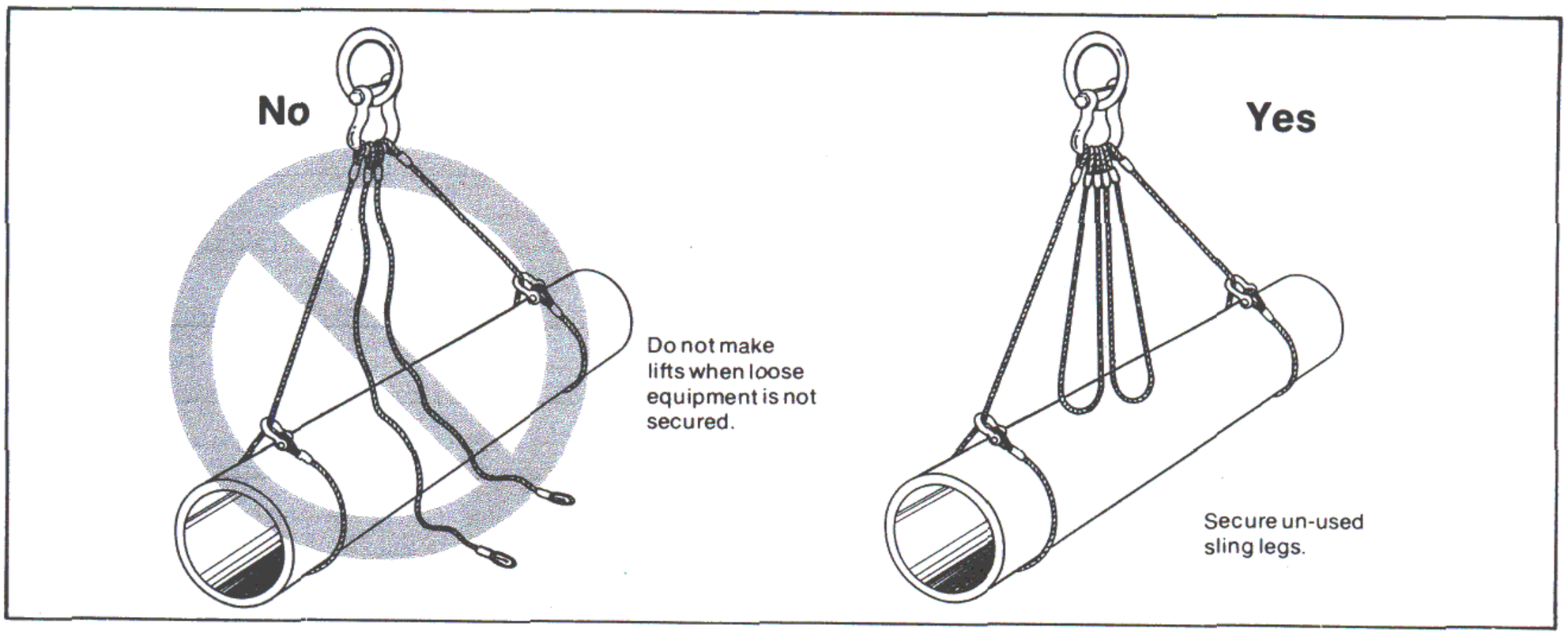
approved by the supervisor in charge of the operation.

— Never leave a load suspended in the air when the hoist or crane is unattended.

— Never make temporary repairs to a sling. Procedures for proper repairs to a damaged sling should be established and followed.

— Never lift loads with one leg of a multi-leg sling until the unused legs are made secure. (Fig. 7.22)

Fig. 7.22 Secure All Unused Sling Legs



— Never point load a hook unless it is especially designed and rated for such use.

— Remove or secure all loose pieces of material from the load before it is moved.

— Make sure that the load is free before lifting and that all sling legs are taking the load.

— When using two or more slings on a load ensure that all slings are made from the same materials.

— Lower the loads on to adequate blocking to prevent damage to the slings.

DETERMINING LOAD WEIGHTS:

The most important step in any rigging operation is the determination of the weight of the load to be hoisted. If this information cannot be obtained from shipping papers, design plans, catalogue data or from other dependable sources, it may be necessary to calculate the weight.

On erection plans, the size of steel beams is usually supplied together with their weight per foot of length and the length of the member, so it is easy to compute the weight of any member to be lifted. Where angle, plate, or built up members are involved, however, the weights must be calculated and the memorization of one basic weight and two formulae will give a reasonably accurate estimation of the weight.

The basic weight is that of 1 square foot of steel an inch thick and is approximately 40 lbs. Thus, 2 plates of steel each measuring $1\frac{1}{2}'' \times 3' \times 6'$ (Fig. 7.23) would weight a total of

$$2 \times 1.5 \times 3 \times 6 \times 40 = 2{,}160 \text{ lbs.}$$

The weights of angles also can be approximated with close enough results for safe job use. An angle is a structural shape which can be considered as a bent plate with some additional metal at the center for strength and a lesser amount of metal at the tips for ease in rolling. If the angle is flattened out, a plate results (Fig. 7.24). For example, a 5 by 3 by $\frac{1}{4}$ in. angle would flatten out to approximately an 8 by $\frac{1}{4}$ in. plate. This should weigh 40 lb. x $\frac{8}{12}$ x $\frac{1}{4}$, or 6.65 lb. per ft.

Weights of any structural shape can be computed in this manner by separating the parts of flattening them into rectangles which, in turn, become parts or multiples of a square foot of steel an inch thick.

Plates, however, are often rolled into tanks or other shapes which must be handled. It is necessary to determine the square foot area of such parts before the weight can be calculated. This necessitates learning the two simple formulae for computing the circumference and the area of a circle. The circumference (Fig. 7.25) or distance around the edge of a circle, is found by multiplying the diameter by the number 3.14.

Fig. 7.23 Load Weight Determination

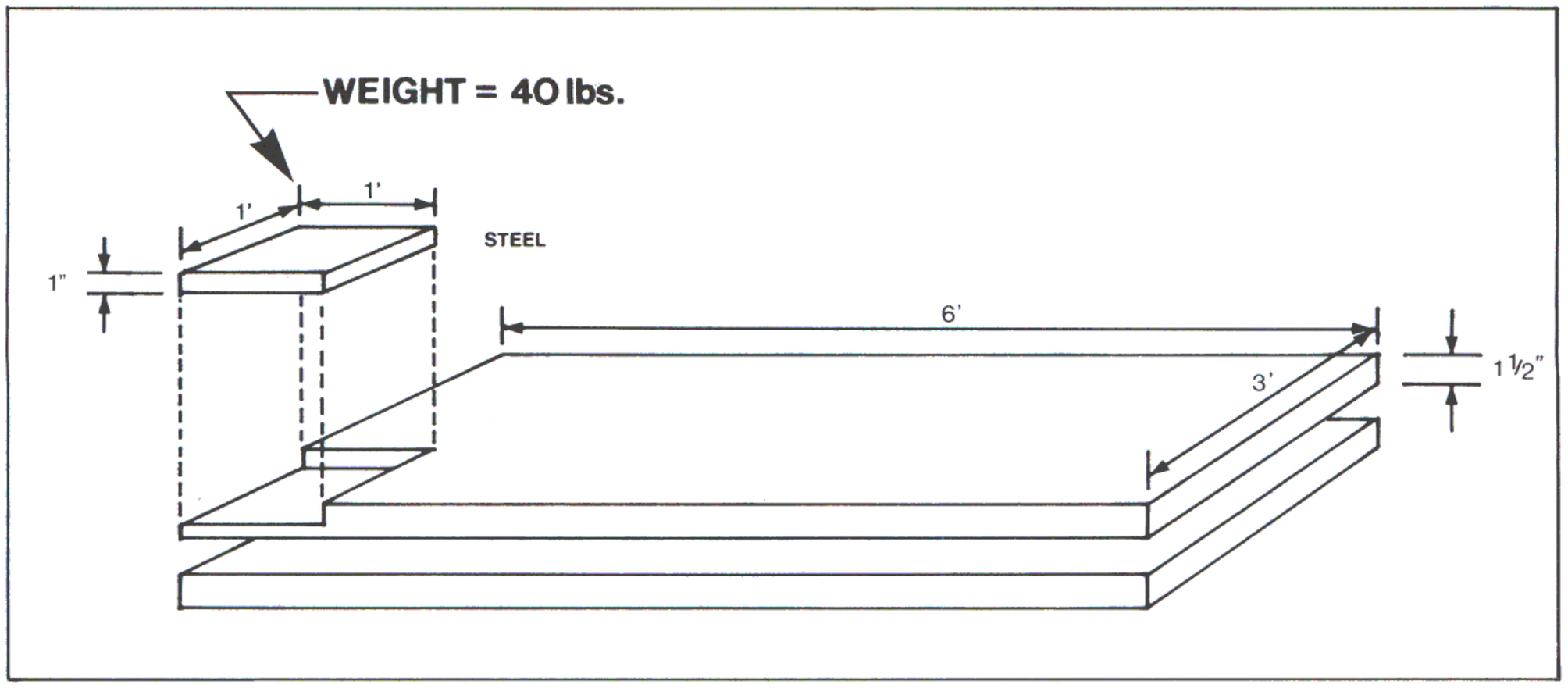


Fig. 7.24 Load Weight Determination

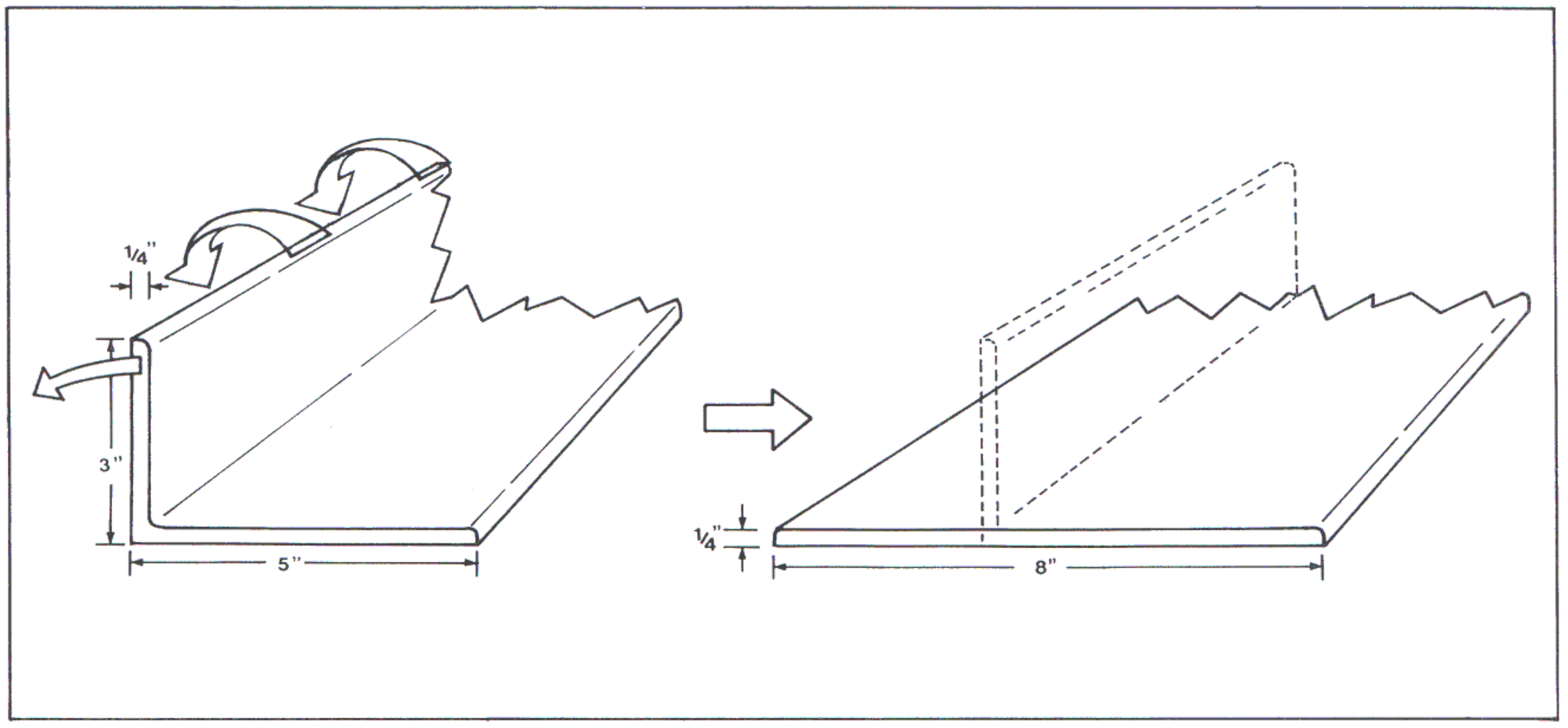


Fig. 7.25 Load Weight Determination

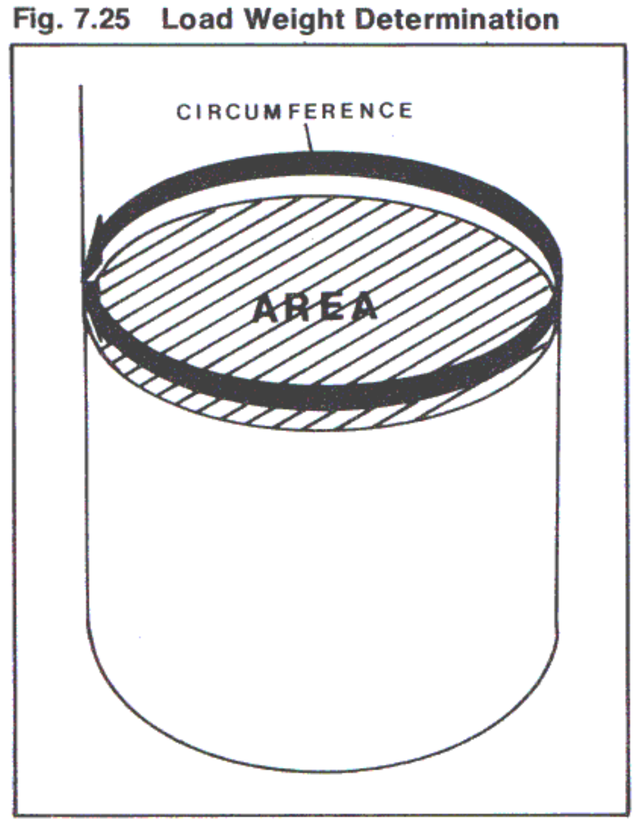
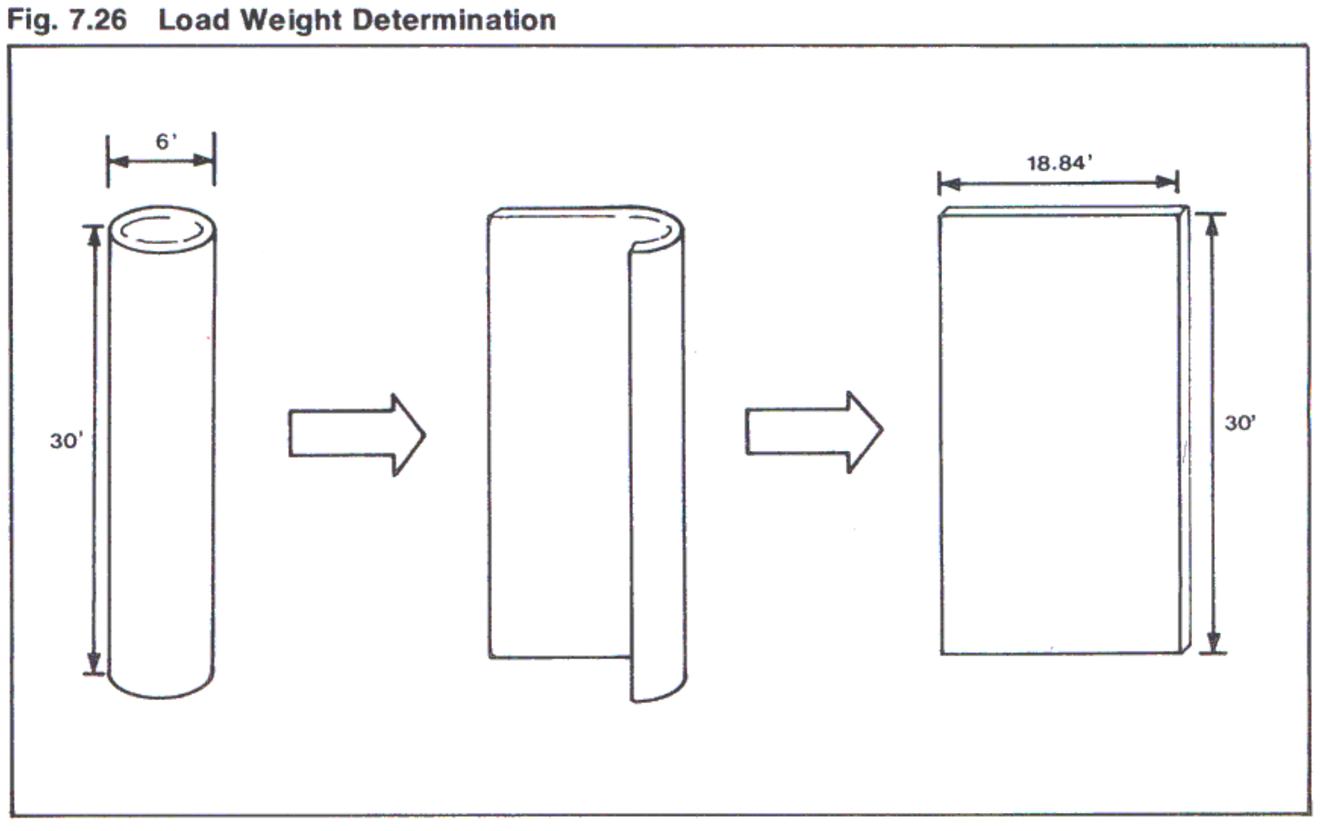


Fig. 7.26 Load Weight Determination



A stack 6 ft. in diameter would have a circumference of 6 ft. x 3.14, or 18.84 ft. To compute the weight of this stack, if it were 30 ft. high and made of ⅜ in. plate, mentally unroll it and flatten it out (Fig. 7.26). This gives a plate 18.84 ft. wide by 30 ft. long by ⅜" thick. The weight is:

$$18.84 \times 30 \times \frac{3}{8} \times 40 = 8{,}478 \text{ lbs.}$$

The second formula gives the area of circular objects.

$$\text{AREA} = 3.14 \times \frac{\text{diameter}}{2} \times \frac{\text{diameter}}{2}$$

Thus, if the stack had an end cap ⅜" thick and 6 ft. in diameter it would have a surface area:

$$\text{AREA} = 3.14 \times \frac{6}{2} \times \frac{6}{2} = 28.3 \text{ sq. ft.}$$

and would weigh

$$28.3 \times 3 \times \frac{40}{8} = 425 \text{ lbs.}$$ (Fig. 7.27)

For other materials the weights are normally based on their weight per cubic foot, so you have to determine how many cubic feet of material (the volume) you are hoisting in order to estimate the weight.

For example, suppose you have a bundle of spruce lumber to hoist and the bundle is 12 ft. long, 3′ high and 4′ wide. (Fig. 7.28) The weight per cubic foot from table 7.2 is 28 lbs. so the weight of this bundle is 12 x 3 x 4 x 28 = 4,032 lbs.

The time taken to calculate the approximate weight of any object, whether steel, plates, columns, girders, castings, bedplates, etc. is time well spent and may save a serious accident through failure of lifting gear. The following tables of weights of various materials (Tables 7.1, 7.2, 7.3) should enable any rigger to compute the approximate weight of a given load. When in doubt, do not hesitate to seek advice from an engineer or foreman on the job. Do not take a chance where the safety of men is involved.

TABLE 7.1

APPROXIMATE WEIGHT PER FOOT OF LENGTH OF ROUND STEEL BARS AND RODS

Diameter (Inches)	Weight (Lbs.) Per Ft. of Length	Diameter (Inches)	Weight (Lbs.) Per Ft. of Length
3/16	.094	1 3/8	5.05
1/4	.167	1 1/2	6.01
5/16	.261	1 5/8	7.05
3/8	.376	1 3/4	8.18
7/16	.511	1 7/8	9.39
1/2	.668	2	10.68
9/16	.845	2 1/8	12.06
5/8	1.04	2 1/4	13.52
3/4	1.50	2 3/8	15.06
7/8	2.04	2 1/2	16.69
1	2.67	2 5/8	18.40
1 1/8	3.38	2 3/4	20.20
1 3/16	3.77	2 7/8	22.07
1 1/4	4.17	3	24.03

Fig. 7.27 Load Weight Determination

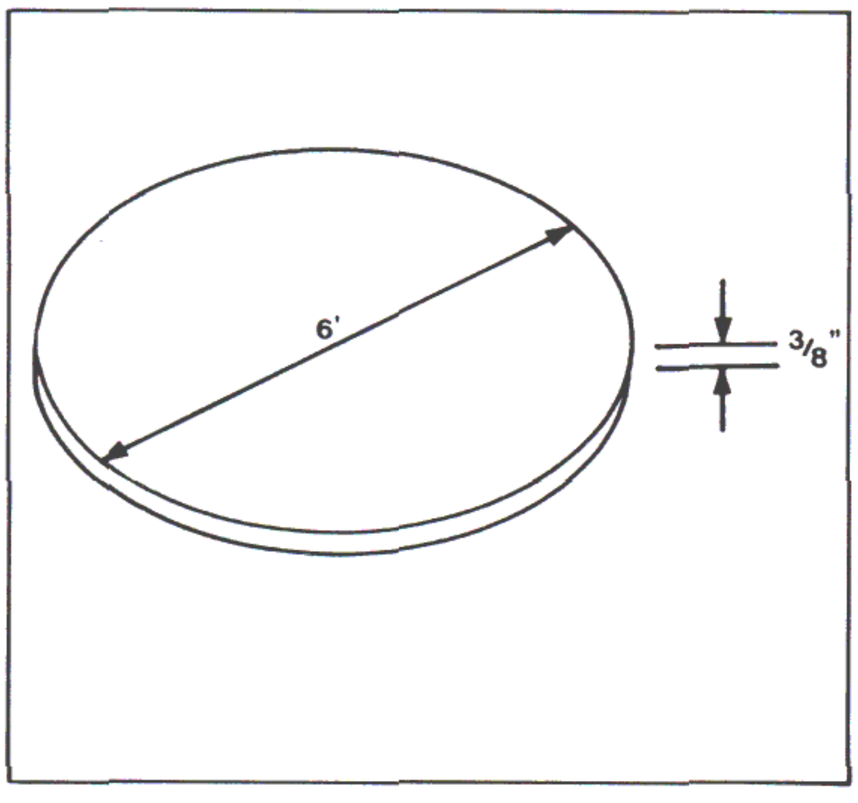


Fig. 7.28 Load Weight Determination

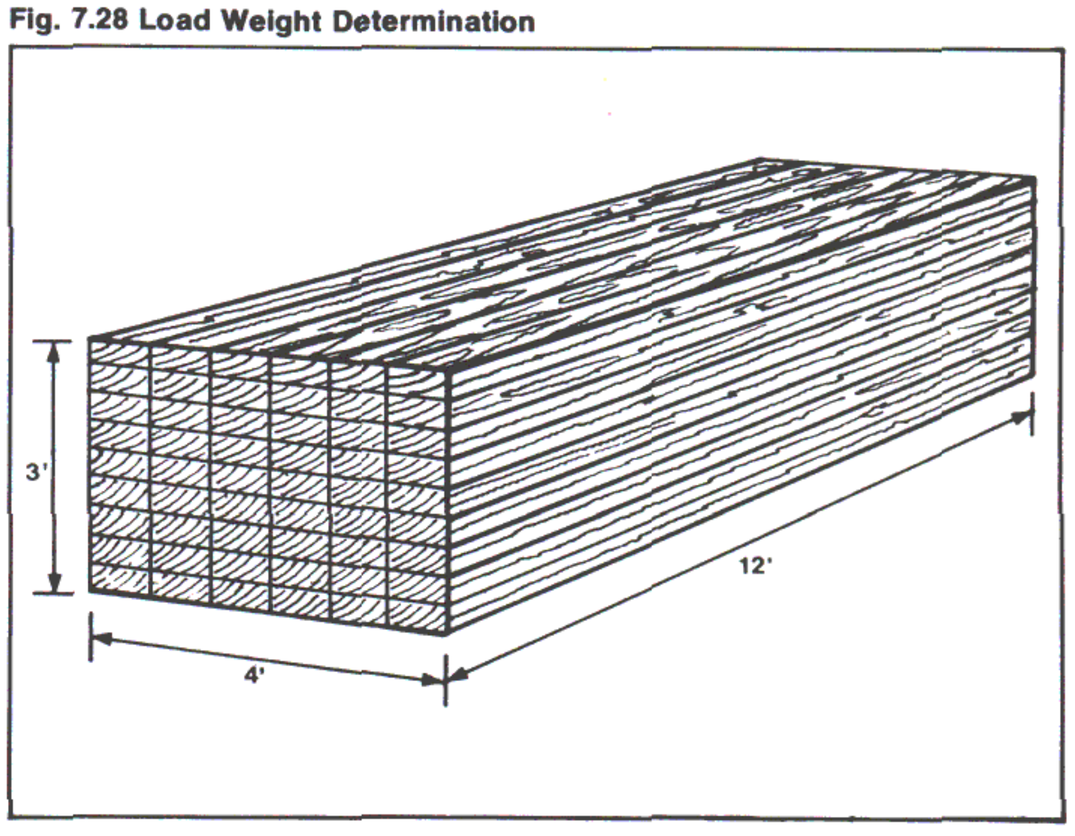


TABLE 7.2

WEIGHTS OF MATERIALS (Based On Volume)			
Material	Approximate Weight Lbs. Per Cubic Foot	Material	Approximate Weight Lbs. Per Cubic Foot
METALS		**TIMBER, AIR-DRY**	
Aluminum	165	Cedar	22
Brass	535	Fir, Douglas, seasoned	34
Bronze	500	Fir, Douglas, unseasoned	40
Copper	560	Fir, Douglas, wet	50
Iron	480	Fir, Douglas, glue laminated	34
Lead	710	Hemlock	30
Steel	490	Pine	30
Tin	460	Poplar	30
MASONRY		Spruce	28
Ashlar masonry	140-160	**LIQUIDS**	
Brick masonry, soft	110	Alcohol, pure	49
Brick masonry, common (about 3 tons per thousand)	125	Gasoline	42
		Oils	58
Brick masonry, pressed	140	Water	62
Clay tile masonry, average	60	**EARTH**	
Rubble masonry	130-155	Earth, wet	100
Concrete, cinder, haydite	100-110	Earth, dry (about 2050 lbs. per cu. yd.)	75
Concrete, slag	130	Sand and gravel, wet	120
Concrete, stone	144	Sand and gravel, dry	105
Concrete, stone, reinforced (4050 lbs. per cu. yd.)	150	River sand (about 3240 lbs. per cu. yd.)	120
ICE AND SNOW		**VARIOUS BUILDING MATERIALS**	
Ice	56		
Snow, dry, fresh fallen	8	Cement, portland, loose	94
Snow, dry, packed	12-25	Cement, portland, set	183
Snow, wet	27-40	Lime, gypsum, loose	53-64
MISCELLANEOUS		Mortar, cement-lime, set	103
Asphalt	80	Crushed rock (about 2565 lbs. per cu. yd.)	90-110
Tar	75		
Glass	160		
Paper	60		

TABLE 7.3

WEIGHTS OF MATERIALS (Based on Surface Area)

Material	Approximate Weight Lbs. Per Square Foot
CEILINGS	
(Per Inch of Thickness)	
Plaster board	5
Acoustic and fire resistive tile	2
Plaster, gypsum-sand	8
Plaster, light aggregate	4
Plaster, cement sand	12
ROOFING	
Three-ply felt and gravel	5.5
Five-ply felt and gravel	6.5
Three-ply felt, no gravel	3
Five-ply felt, no gravel	4
Shingles, wood	2
Shingles, asbestos	3
Shingles, asphalt	2.5
Shingles, 1/4 inch slate	10
Shingles, tile	14
PARTITIONS	
Steel partitions	4
Solid 2″ gypsum-sand plaster	20
Solid 2″ gypsum-light agg. plaster	12
Metal studs, metal lath, 3/4″ plaster both sides	18
Metal or wood studs, plaster board and 1/2″ plaster both sides	18
Plaster 1/2″	4
Hollow clay tile 2 inch	13
3 inch	16
4 inch	18
5 inch	20
6 inch	25
Hollow slag concrete block 4 inch	24
6 inch	35
Hollow gypsum block 3 inch	10
4 inch	13
5 inch	15.5
6 inch	16.5
Solid gypsum block 2 inch	9.5
3 inch	13
MASONRY WALLS	
(Per 4 Inch of Thickness)	
Brick	40
Glass brick	20
Hollow concrete block	30
Hollow slag concrete block	24
Hollow cinder concrete block	20
Hollow haydite block	22
Stone, average	55
Bearing hollow clay tile	23

Material	Approximate Weight Lbs. Per Square Foot
FLOORING	
(Per Inch of Thickness)	
Hardwood	5
Sheathing	2.5
Plywood, fir	3
Wood block, treated	4
Concrete, finish or fill	12
Mastic base	12
Mortar base	10
Terrazzo	12.5
Tile, vinyl 1/8 inch	1.5
Tile, linoleum 3/16 inch	1
Tile, cork, per 1/16 inch	0.5
Tile, rubber or asphalt 3/16 inch	2
Tile, ceramic or quarry 3/4 inch	11
Carpeting	2
DECKS AND SLABS	
Steel roof deck 1 1/2″ — 14 ga.	5
— 16 ga.	4
— 18 ga.	3
— 20 ga.	2.5
— 22 ga.	2
Steel cellular deck 1 1/2″ — 12/12 ga.	11
— 14/14 ga.	8
— 16/16 ga.	6.5
— 18/18 ga.	5
— 20/20 ga.	3.5
Steel cellular deck 3″ — 12/12 ga.	12.5
— 14/14 ga.	9.5
— 16/16 ga.	7.5
— 18/18 ga.	6
— 20/20 ga.	4.5
Concrete, reinforced, per inch	12.5
Concrete, gypsum, per inch	5
Concrete, lightweight, per inch	5-10
MISCELLANEOUS	
Windows, glass, frame	8
Skylight, glass, frame	12
Corrugated asbestos 1/4 inch	3.5
Glass, plate 1/4 inch	3.5
Glass, common	1.5
Plastic sheet 1/4 inch	1.5
Corrugated steel sheet, galv.	
— 12 ga.	5.5
— 14 ga.	4
— 16 ga.	3
— 18 ga.	2.5
— 20 ga.	2
— 22 ga.	1.5
Wood Joists — 16″ ctrs. 2 x 12	3.5
2 x 10	3
2 x 8	2.5
Steel plate (per inch of thickness)	40

CENTER OF GRAVITY:

It is always important in rigging practice to rig the load so that it is stable. A stable load is one in which the center of gravity of the load is directly below the main hook and below the lowest point of attachment of the slings. (Fig. 7.29)

The center of gravity of an object is that point at which the object will balance. The entire weight may be considered as concentrated at this point. A suspended object will always move so that the center of gravity is below the point of support. In order to make a level or stable lift, the crane or hook block must be directly above this point. Thus a load which is slung above and through the center of gravity will be stable and will not tend to topple or slide out of the slings. (Fig. 7.30)

On objects having uniform shapes and compositions there is no problem in determining where the center of gravity lies since it is at the center of the shape or object, but on odd shaped bodies where it cannot be easily determined, the rigger must guess where it lies, try to lift with the hook over that point and then correct it by trial and error methods, moving the hook, load and sling suspension a little at a time until a satisfactory result is obtained. The object will always tilt until the center of gravity is directly beneath the load hook, so there is an indication of the direction in which to shift the slings. Remember too that when the center of gravity is closer to one point of sling attachment than to the other, the sling legs will have to be of unequal

Fig. 7.29 Effect of Location of Loads Center of Gravity on the Lift

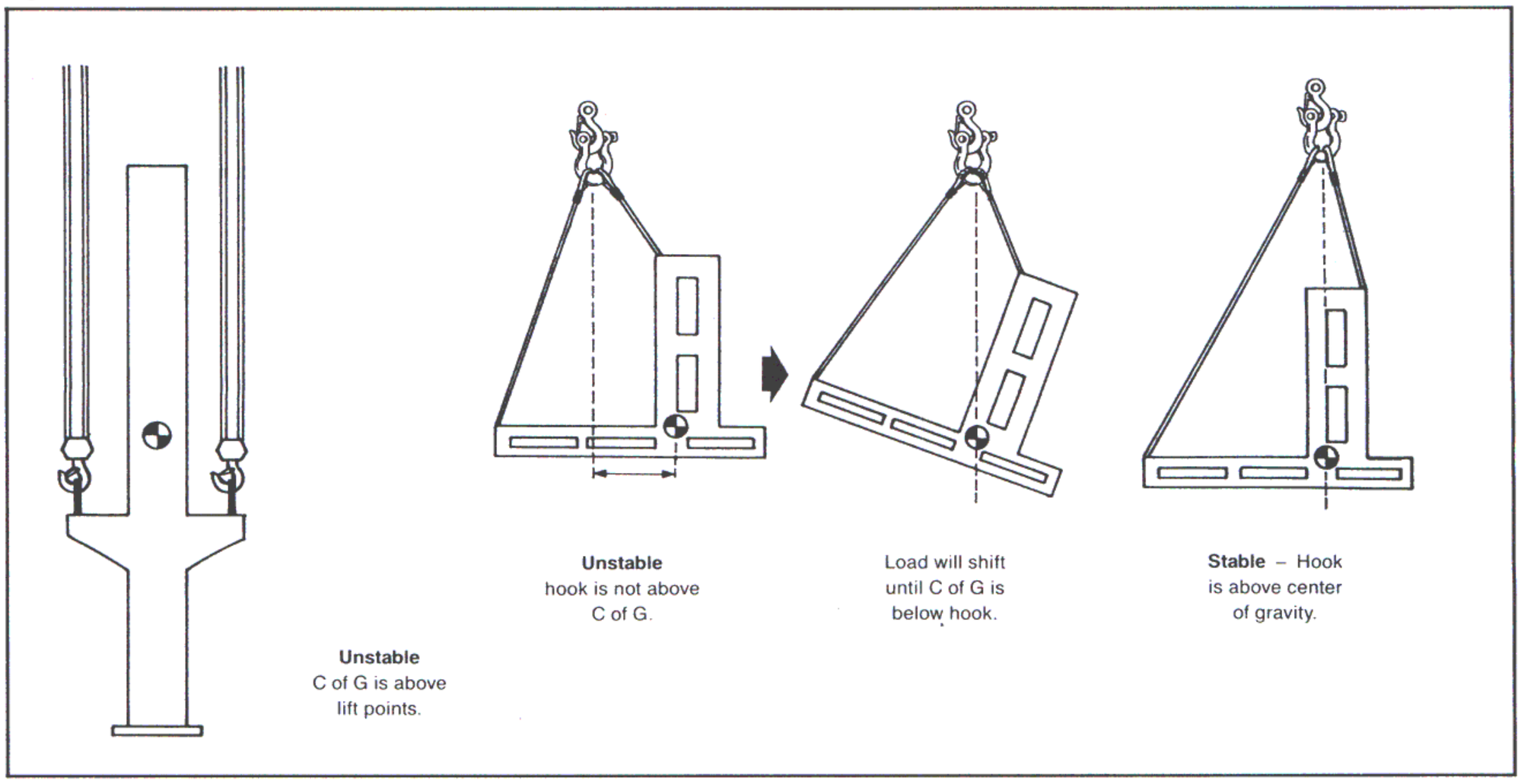
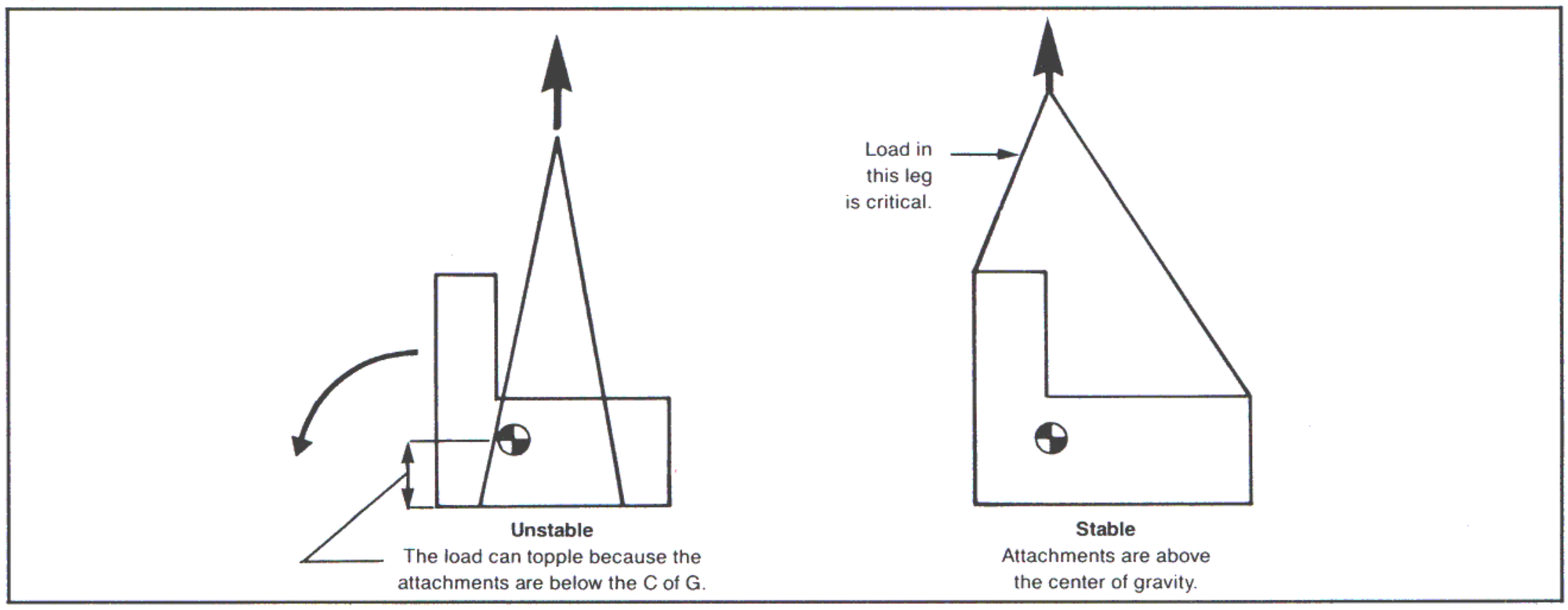


Fig. 7.30 Effect of the Location of the Loads Center of Gravity on the Lift



length which means that their angles and loads will also be unequal.

If a load tilts when it is lifted and it is not corrected then one leg of the sling will see a large load increase and the load on the other will decrease. If any load tilts more than 5° after it is lifted clear of the ground it should be landed and re-rigged.

It is equally important to ensure that the points of support of a load (i.e. where the slings are attached to the load) lie above the center of gravity and not below it for the center of gravity will always tend to move to the lowest point possible below the point of support.

This precaution is impossible when lifting pallets, skids or the base of any object. A load lifted from the bottom (below the center of gravity) always tends to topple, no matter where slings are placed. But stability improves when the sling angles are much larger than the angle formed between the plane of support and the line through the center of gravity (Fig. 7.31).

Some manufacturers and suppliers mark the center of gravity on loads, as well as sling angles and attachment points. (Fig. 7.32)

Fig. 7.31 Relationship between Load Stability and Location of loads center of gravity and Sling Angle

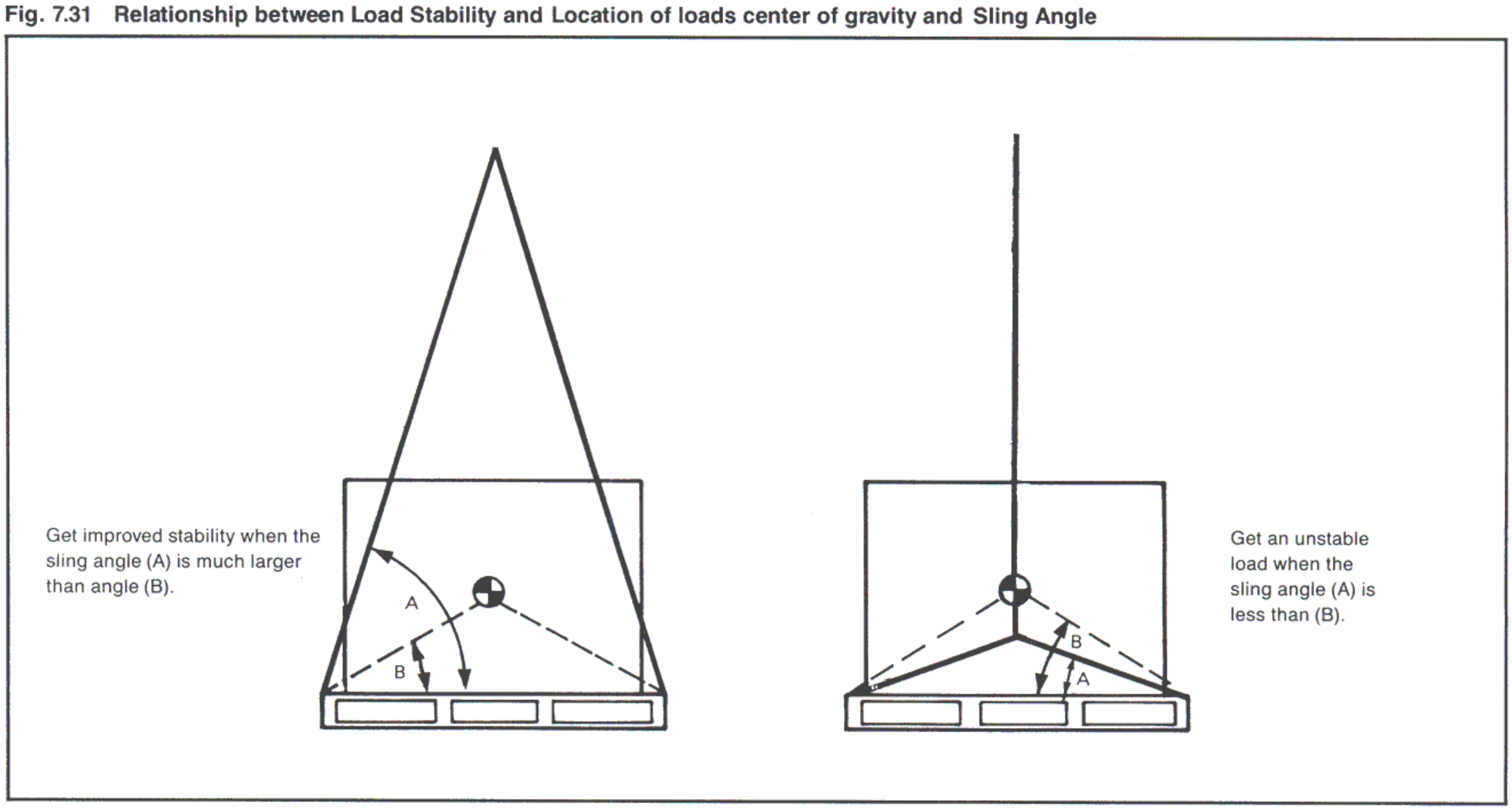


Fig. 7.32 Loads pre-marked with center of gravity and sling angles and attachment points

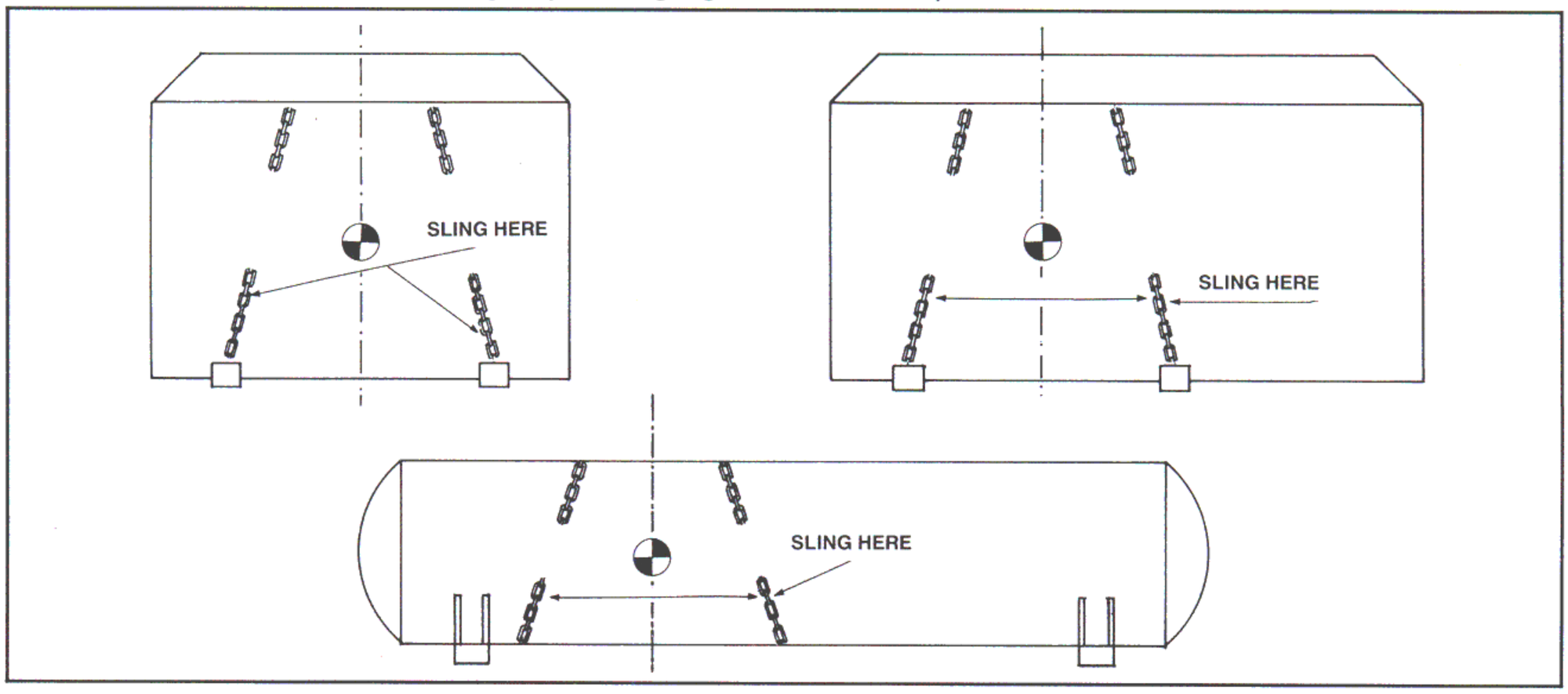
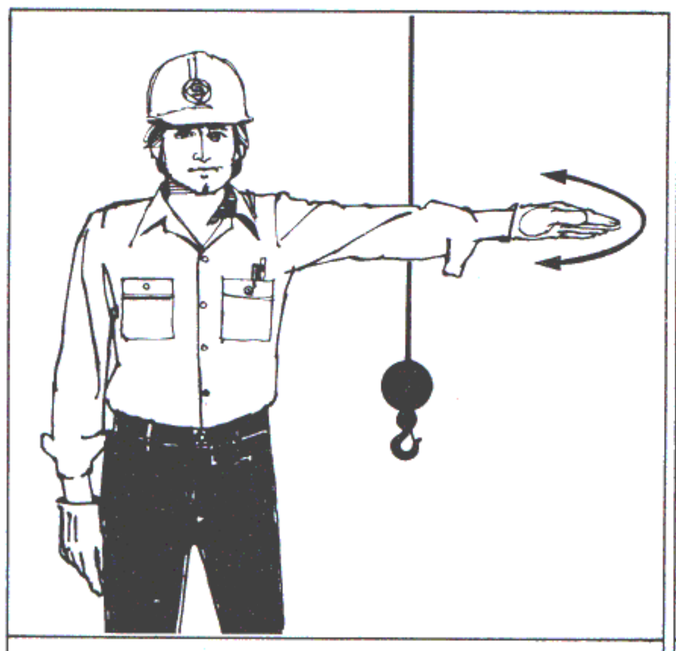
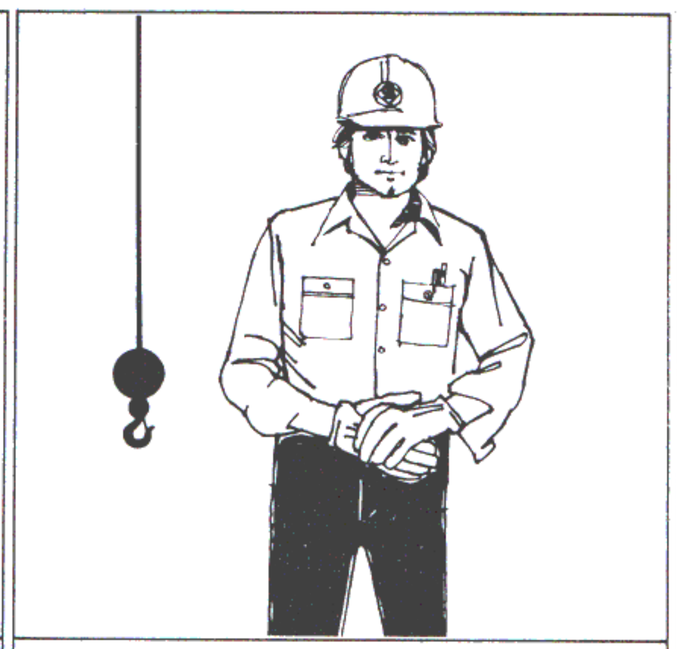


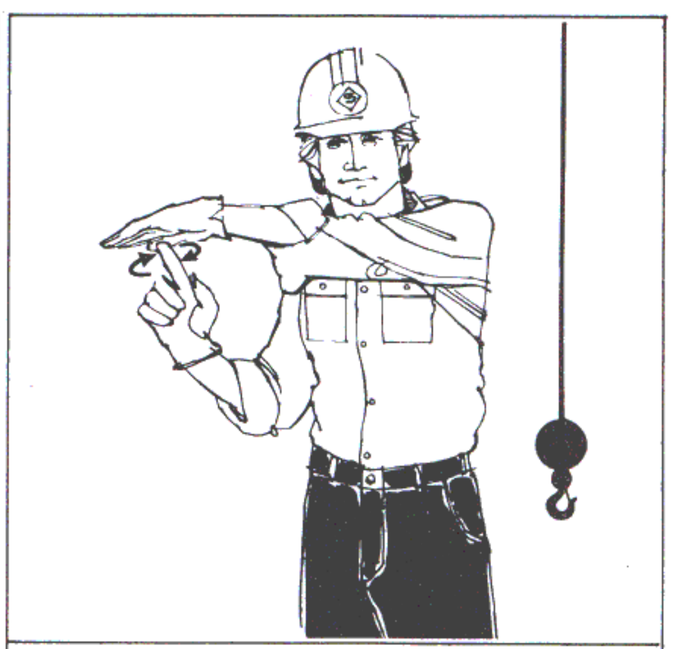
Fig. 7.32 Hand Signals for Controlling Crane Operations



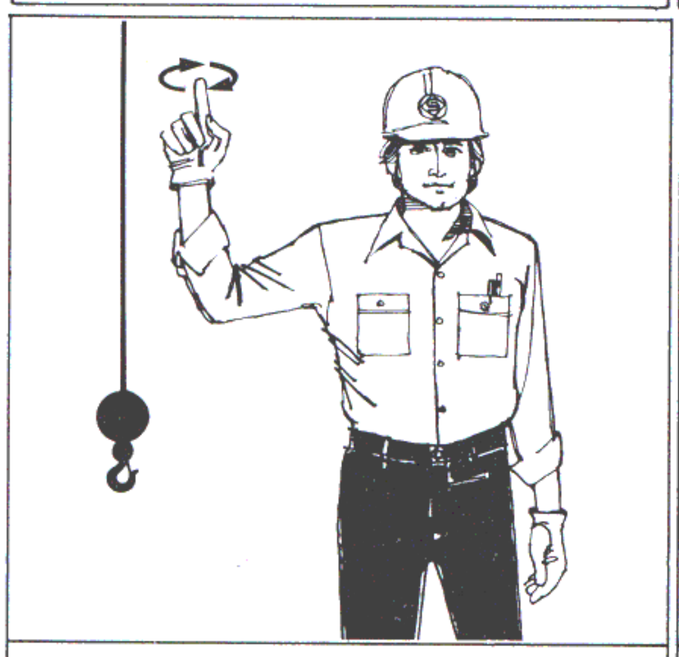
STOP. Arm extended, palm down, move hand right and left.



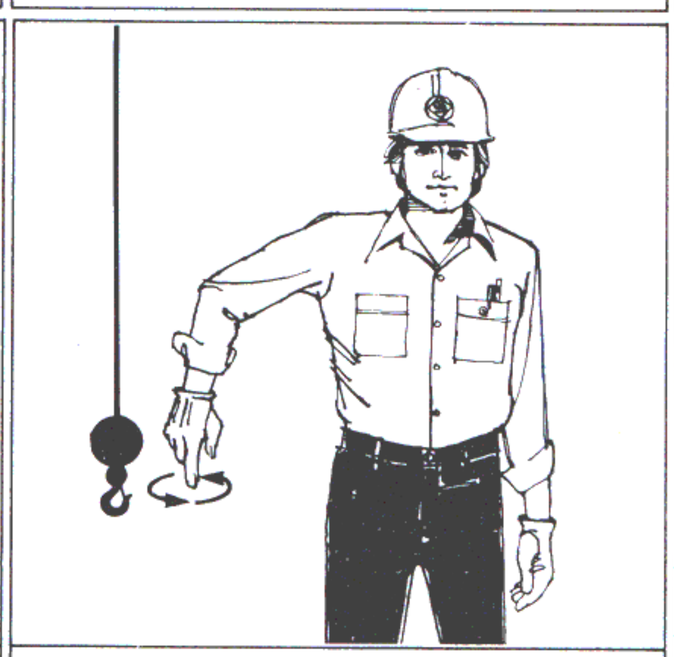
DOG EVERYTHING. Clasp hands in front of body.



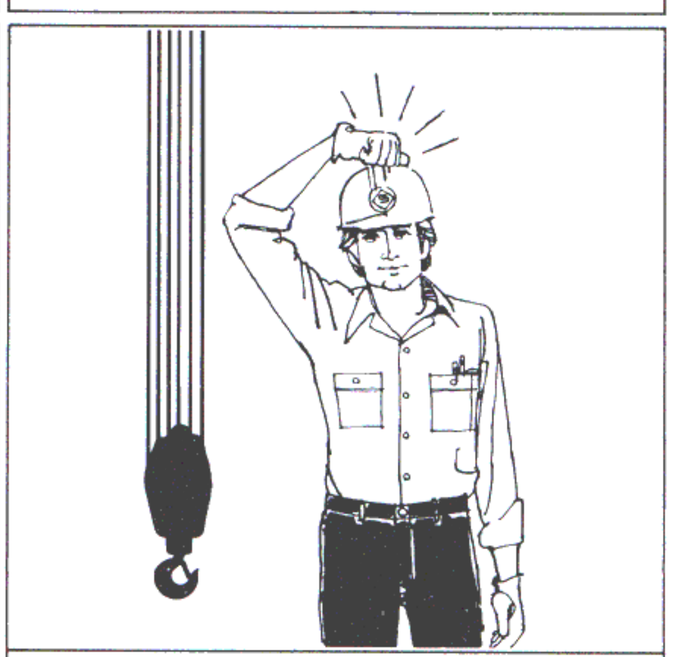
MOVE SLOWLY. Use one hand to give any motion signal and place other hand motionless in front of hand giving the motion signal. (HOIST SLOWLY SHOWN AS EXAMPLE.)



HOIST. With forearm vertical, forefinger pointing up, move hand in small horizontal circles.

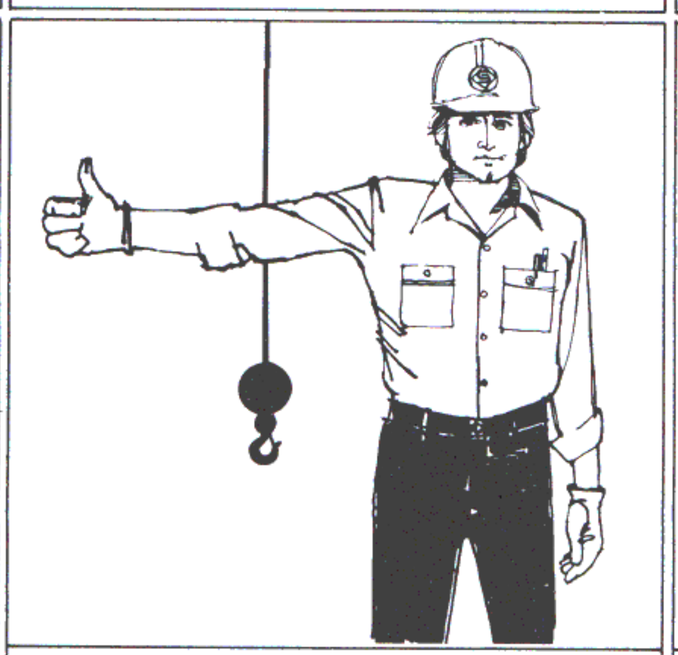


LOWER. With arm extended downward, forefinger pointing down, move hand in small horizontal circles.

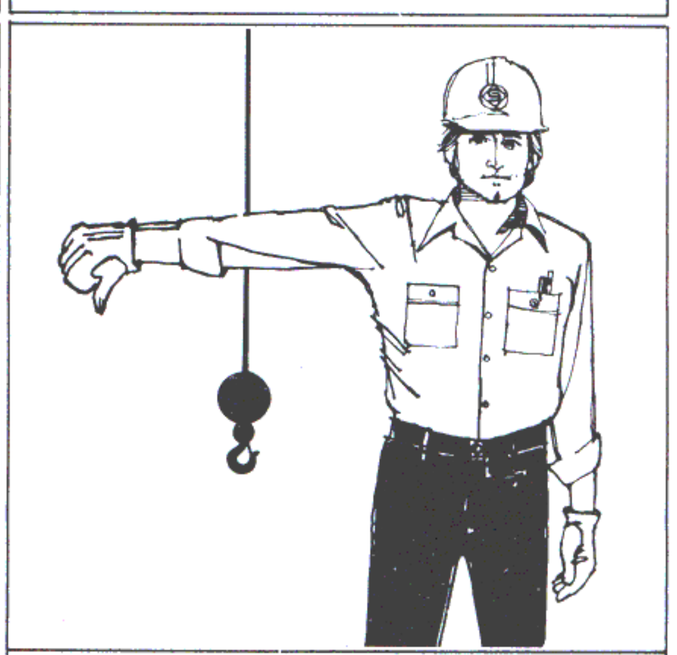


USE MAIN HOIST. Tap fist on head; then use regular signals.

USE WHIPLINE. (Auxiliary hoist.) Tap elbow with one hand; then use regular signals.

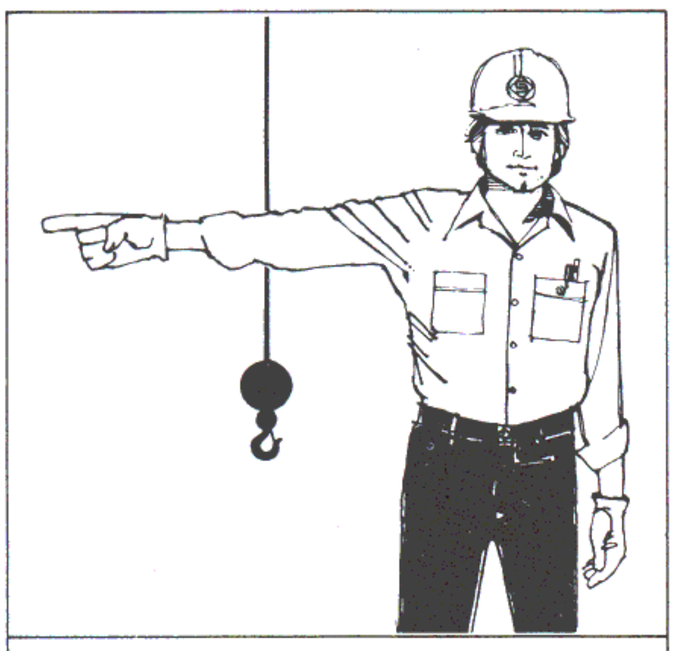


RAISE BOOM. Arm extended, fingers closed, thumb pointing upward.

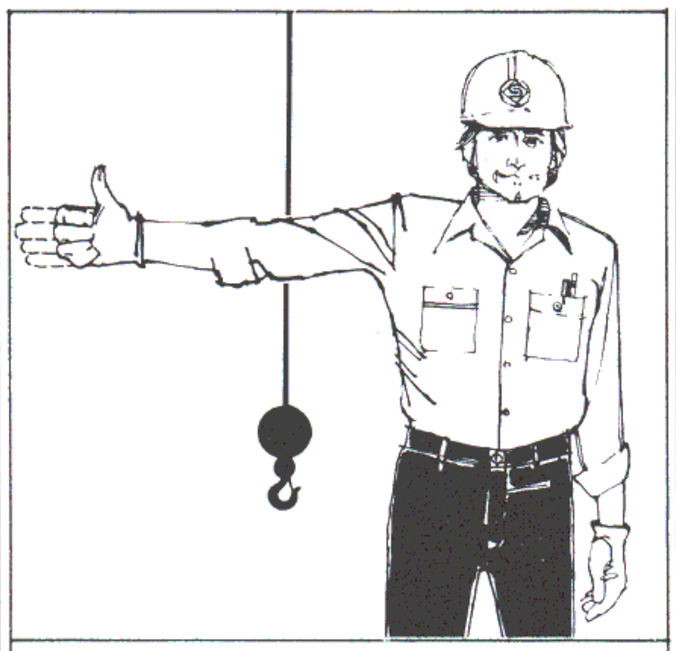


LOWER BOOM. Arm extended, fingers closed, thumb pointing downward.

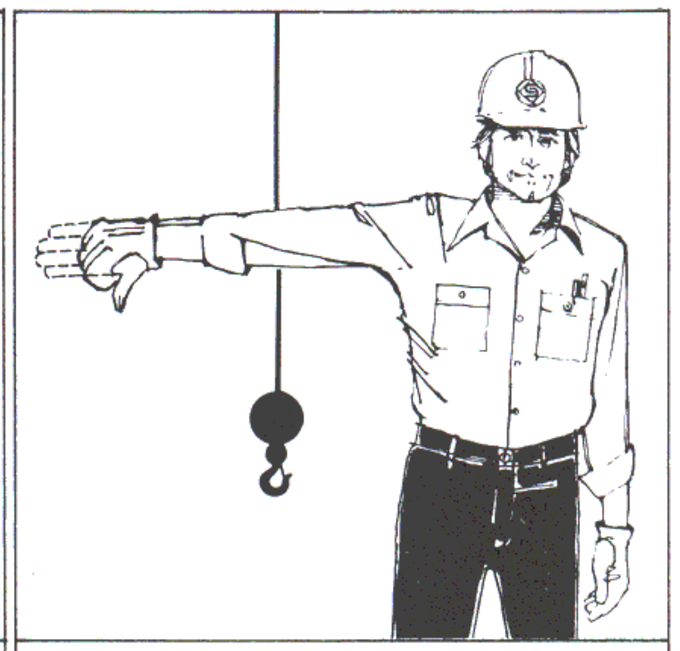
Fig. 7.32 continued



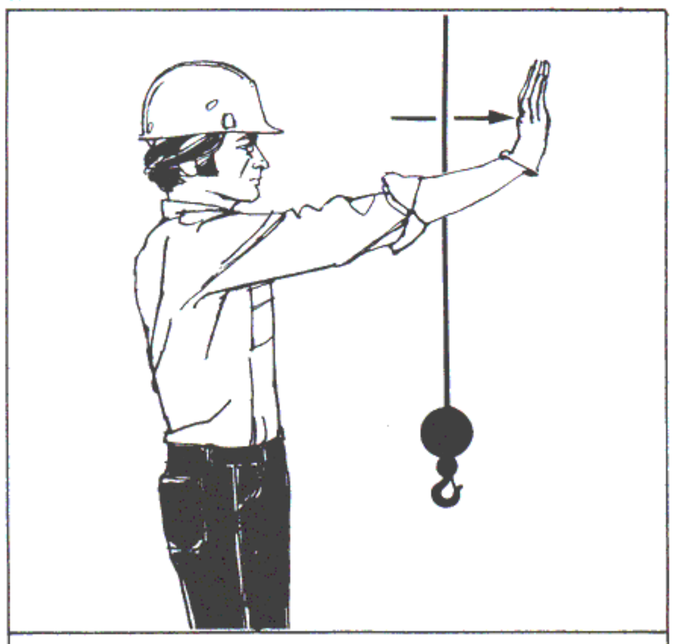
SWING. Arm extended, point with finger in direction of swing of boom.



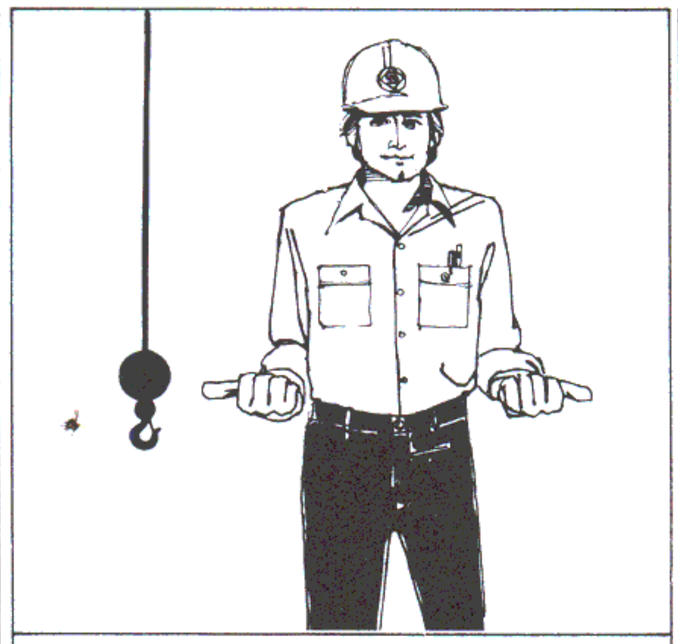
RAISE THE BOOM AND LOWER THE LOAD. With arm extended thumb pointing up, flex fingers in and out as long as load movement is desired.



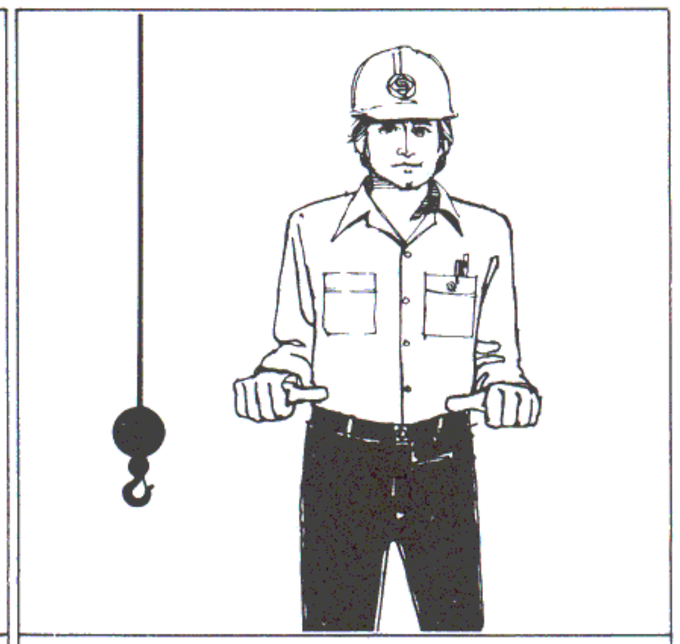
LOWER THE BOOM AND RAISE THE LOAD. With arm extended, thumb pointing down, flex fingers in and out as long as load movement is desired.



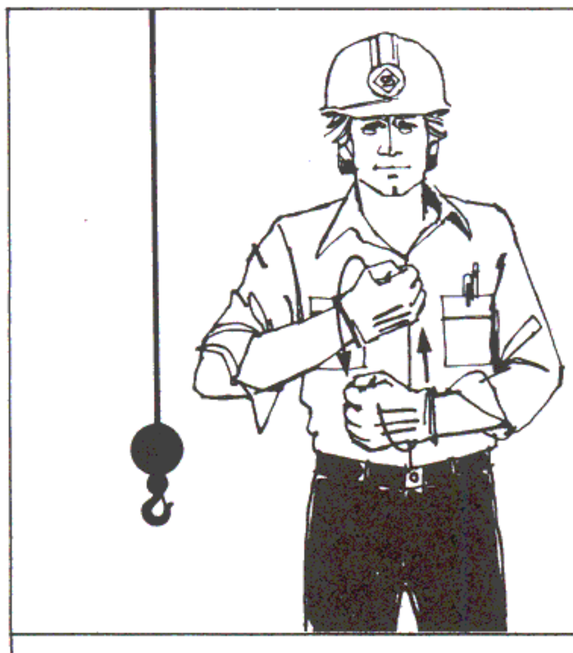
TRAVEL. (Rail Mount or trolley) Arm extended forward, hand open and slightly raised, making pushing motion in direction of travel.



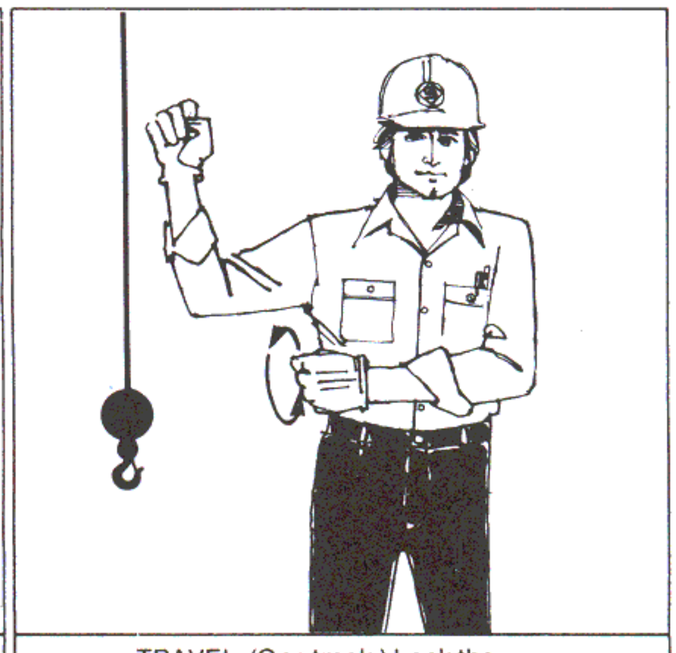
EXTEND BOOM. (Telescoping booms.) Both fists in front of body with thumbs pointing outward.



RETRACT BOOM. (Telescoping booms.) Both fists in front of body with thumbs pointing toward each other.



TRAVEL. (Both tracks.) Use both fists in front of body, making a circular motion about each other, indicating direction of travel; forward or backward. (For crawler cranes only.)



TRAVEL. (One track.) Lock the track on side indicated by raised first. Travel opposite track in direction indicated by circular motion of other fist, rotated vertically in front of body. (For crawler cranes only.)

SIGNALLING:

Riggers are frequently required to act as signalmen for crane or hoist operators and there are a number of precautions and procedures that should be observed in these operations.

Whenever the operator is obstructed in his view of the path of travel of any part of the equipment, its load or components, a competent signalman is required to be stationed:

— In full view of the operator.

— With a full view of the intended path of travel of the equipment, load or components, yet clear of the intended path of travel and should assist the operator by keeping that part of the equipment under observation when it is out of view of the operator and by communicating with the operator by the use of pre-arranged visual signals or a suitable communication system.

The signalman must:

— Be fully qualified by experience with the operation.

— Wear high visibility gloves.

— Use hand signals only when conditions are such that his signals are clearly visible to the operator.

— Be made responsible for keeping the public and all unauthorized personnel outside the crane's operating radius.

— Direct the load so that it never passes over anyone.

This signalman must be in constant communication with the crane operator, either visually with hand signals or audibly by radio throughout the operation. If the operator loses contact with the signalman for any reason, he must stop the movement of the crane until communication is restored. Where loads are picked up at one point and lowered at another, two signalmen may be required, one to direct the lift and one to direct the descent.

If it is desired to give instructions to the operator, other than provided by the established signal system, the operator should be instructed to first stop all hoisting motions.

Hand signals can be used effectively when the distance between the operator and the signalman is not great, but 2-way radios should be used when the distance or atmospheric conditions prevent clear visibility. Adequate lighting and signalling arrangements must be available during night work and the equipment must not be operated when either is inadequate.

When two or more cranes or hoists are used to lift one load, one qualified person should be responsible for the operation. He should analyze the operation and instruct all personnel involved in the proper positioning, rigging of the load, and the movement to be made. He should also ensure that the operators of the units and the signalman are able to communicate with each other via audio systems.