ANSI M11.1-1980

American National Standard

for wire rope for mines

american national standards institute, inc.
1430 broadway, new york, new york 10018

ANSI M11.1-1980

ANSI®
M11.1-1980
Revision of
ANSI M11.1-1960

American National Standard for Wire Rope for Mines

Secretariat

American Mining Congress
Wire Rope Technical Board

Approved March 14, 1979

American National Standards Institute, Inc

American National Standard

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Foreword

(This Foreword is not a part of American National Standard for Wire Rope for Mines, ANSI M11.1-1980.)

This standard is a complete revision and updating of the 1960 edition. It takes into consideration the increased body of knowledge and present methods of mining. One outstanding feature is the inclusion of a substantial number of appendixes which, although not a part of the standard, contain information not easily retrievable by a user.

The 1980 edition was formulated by subcommittees, with numerous meetings of the full committee and massive correspondence, guided by the principle of consensus.

Suggestions for improvement of this standard will be welcome. They should be sent to the American National Standards Institute, 1430 Broadway, New York, N.Y. 10018.

This standard was processed and approved for submittal to ANSI by American National Standards Committee on Wire Rope for Mines, M11. Committee approval of the standard does not necessarily imply that all committee members voted for its approval. At the time it approved this standard, the M11 Committee had the following members:

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The aid of Deborah A. Kuhlman in editing and typing the manuscript is gratefully acknowledged.

This Edition is Dedicated to
Lonnie D. Thompson

Contents

SECTION PAGE

American National Standard for Wire Rope for Mines

1. General

1.1 Scope. This standard is intended to establish practical and adequate design features for, and safety recommendations for, the proper care and use of wire rope that is used in underground mining, surface mining (opencast), and related work areas where metals, nonmetals, coal, sand and gravel, stones, and minerals are mined. The standard represents a consensus effort of a cross section of both the mining industry and existing regulatory agencies; it is intended to form the basis for regulations and to serve as a guide for interested legal agencies and associations. Guidelines contained in this standard for the maintenance and removal of wire ropes shall apply to all wire ropes in use.

1.2 Existing Machines and Installations. The selection and usage of wire rope for any current application now installed and in operation prior to the issuance of this standard shall continue to be governed by the previous edition of this standard (ANSI M11.1-1960) until such time as the equipment is physically modified.

1.3 Interpretation of the Standard. Where clarification, additional explanations, or interpretations of this standard are required, such requests should be referred to American National Standards Committee M11.1, American National Standards Institute, 1430 Broadway, New York, N.Y. 10018.

1.4 References to Other Codes and Standards. Reference is made in this standard to the following publications, which may be obtained from the American National Standards Institute, 1430 Broadway, New York, N.Y. 10018.

ANSI Designation	*Equipment Covered*
A10.4-1975	Personnel hoists
A10.5-1975	Material hoists
A10.15-1974	Dredges
A17.1-1978	Elevators
A17.2-1979	Elevators – inspector's manual
B20.1-1976	Conveyors and related equipment
B30.2.0-1976	Overhead and gantry cranes
B30.4-1973	Portal, tower and pillar cranes
B30.5-1968	Crawler, locomotive and truck cranes
B30.6-1977	Derricks
B30.7-1977	Base mounted drum hoists
B30.8-1971	Floating cranes and floating derricks
B30.9-1971	Slings
B30.10-1975	Hooks
B30.11-1973	Monorail systems and underhung cranes
B30.14-1979	Side boom tractors
B30.15-1973	Mobile hydraulic cranes
B30.16-1973	Overhead hoists
–	Single girder top running cranes
–	Cableways

1.5 Mandatory and Advisory Rules. In this standard, the word "shall" is to be understood as denoting a mandatory requirement; the word "should" is advisory in nature and is to be understood as denoting a recommendation.

1.6 Authority Having Jurisdiction. The phrase "authority having jurisdiction" denotes the authorized public or private body enabled or empowered by law or by common agreement to enforce or interpret the provisions of this standard. Where no such body exists or where such a body is not so enabled or empowered, the phrase "authority having jurisdiction" shall be synonymous with "owner". The word "approved" means "approved by the authority having jurisdiction."

1.7 Definitions. (See also Section 2, General Rope Terminology.)

acceptable strength. See *strength (a).*

appointed person. One who by extensive knowledge, training, and experience has demonstrated the ability to interpret and solve problems and conditions related to inspections of wire rope and related equipment.

approved. See 1.6.

authority having jurisdiction. See 1.6.

balance rope. See *rope (e).*

boom. A member hinged or secured to the machine structure, the outer end of which may be supported by wire ropes or structural strand.

boom hoist. See *hoists (a).*

boom hoist sheaves. See *sheaves (a).*

cable. See *rope.*

counterweight. A dead weight used to offset the live load in a conveyance, usually equal to the weight of the conveyance plus one-half the weight of the load.

D/d ratio. The drum or sheave diameter divided by the nominal rope diameter, formula:

$$\frac{D}{d} = \frac{\text{Drum or sheave diameter}}{\text{Nominal rope diameter}}$$

where

D = pitch diameter for surface mines
D = tread or root diameter for underground mines

dead wraps. The rope turns that remain on the drum when the rope is extended to the machine's maximum specified operating range. Wraps are counted from the exit end of the anchor on the drum to the tangent point where the rope leaves the drum.

deflection sheave. See *sheaves (c).*

deflector sheaves. See *sheaves (b).*

design factor. The ratio of the nominal strength of the rope when new to the maximum static load imposed on the rope. See 4.1, 4.2, 4.3, 4.4, and 5.3.

drag rope. See *rope (a).*

drums. The cylindrical members around which ropes are wound for lifting, lowering, or otherwise moving a load.

drum hoist. See *hoists (b).*

end attachments. Fittings used to secure a wire rope or structural strand to the machine parts it operates or supports.

fleet angle. See *maximum fleet angle.*

friction hoist. See *hoists (c).*

guide rope. See *rope (b).*

guide sheaves. See *sheaves (b).*

head rope. See *rope (c).*

head sheaves. See *sheaves (d).*

hoist rope. See *rope (c).*

hoists.

(a) **boom hoist.** A rope reeving system used to raise and lower the boom.

(b) **drum hoist.** Any hoist that has one end of the rope or ropes attached to the drum and uses the drum for the transfer of force and rope storage.

(c) **friction hoist.** A hoist that uses friction between the rope or ropes and the drum or wheel to drive the ropes.

loads (dynamic). Loads introduced into a machine, its components, or a rope reeving system by forces induced by motion.

loads (static). Loads introduced into a machine, its components, or a rope reeving system by the static weight and payload.

loads (working). External loads, in pounds, applied to a machine, its components, or a rope reeving system, including the weight of load-attaching equipment such as blocks, buckets, dippers, shackles, and slings.

maximum angle. The angle between the position of the rope at the dead wrap or extreme end wrap on a drum and a line drawn perpendicular to the axis of the drum through the center of the nearest fixed sheave.

minimum acceptable strength. See *strength (a).*

nominal strength. See *strength (b).*

point sheaves. See *sheaves (e).*

recapping. The addition of a new termination to a hoisting system.

rollers. A cylindrical member generally of small diameter to guide the rope for alignment purposes or to keep rope from rubbing on a structure.

rope. Wire rope consisting of more than two strands of multiple wires spiralled around a core. The terms *rope, wire rope, cable,* and *wire lines* are interchangeable.

(a) **drag rope.** The rope or ropes used for providing movement and digging force to the bucket on a dragline.

(b) **guide rope.** Wire rope used for guiding conveyances in vertical shafts. Also known as *rope guides.*

(c) **hoist rope.** The main rope or ropes used for raising the load, regardless of the type of hoist or type of shaft. Also known as *head rope.*

(d) **rubbing ropes.** Ropes used in a vertical shaft to separate the ascending and descending conveyances so as to eliminate contact in passing.

(e) **tail rope.** Rope(s) used to counteract the weight of the hoist rope. Also known as *balance rope.*

rope guides. See *rope (b).*

rubbing ropes. See *rope (d).*

shall. See 1.5.

sheaves. Pulleys or wheels grooved for rope.
(a) *boom-hoist sheaves.* Sheaves contained in the boom hoist system.
(b) *deflector or guide sheaves.* Sheaves that deflect or guide the rope to maintain alignment and fleet angle.
(c) *deflection sheave.* A sheave sometimes used to deflect ropes from the centerline of the compartment.
(d) *head sheaves.* Sheaves at the top of the head frame.
(e) *point sheaves.* Sheaves at the end of the boom.

should. See 1.5.

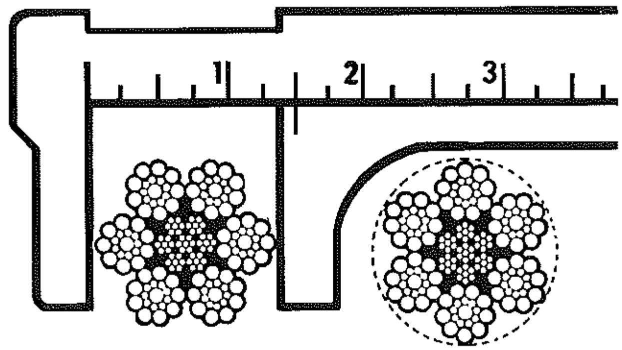
strand. A group of wires spiralled around a core wire.

strength.
(a) **minimum acceptance strength.** That strength which is 2-1/2% lower than the catalog or nominal strength. This tolerance is used to offset testing variables that exist when the test is made to determine the breaking strength of a specific sample of wire rope.
(b) **nominal strength.** The wire rope manufacturer's published catalog strength. The user should consider this to be the strength when making his design calculations.

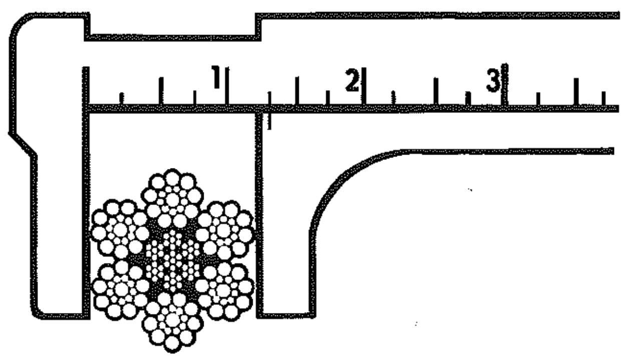
tail rope. See *rope (e).*

wire lines. See *rope.*

wire rope. See *rope.*



CORRECT WAY
(This position gives correct diameter)
(a)



INCORRECT WAY
(This position does not give correct diameter)
(b)

Fig. 1
Measuring the Diameter of Wire Rope

2. General Rope Terminology

2.1 Diameter of Wire Rope. The diameter of a rope is the diameter of its circumscribed circle. (See Fig. 1.) The amount by which the actual diameter of a new rope differs from the nominal diameter shall not be greater than the values in Table. 1. Rope diameter measurements should be made on a straight section with a load on the rope of no greater than 10% of its nominal strength.

2.2 Lay. (See Fig. 2)

2.2.1 General. The term *lay* is used in describing the direction in which the wires and strands spiral in a wire rope; it is also used in referring to the length of one spiral of a strand in a rope or one wire in a strand. When used in the first context, the terms *right* and *left* refer to the direction that the strands spiral around the rope. The terms *regular lay* and *lang lay* refer to the way the wires spiral in the strands in relation to the direction the strands spiral in the rope. In right lay, strands spiral clockwise away from the observer. Wires in a regular lay rope, spiral in a direction opposite to the direction in which the strands spiral around the rope, giving the appearance of being parallel to the main axis of the rope. Wires in a lang lay rope spiral in the same direction as the strands, giving the appearance of spiralling diagonally around the rope. If the lay directions of the wires in the strands alternate from strand to strand, the rope is called *alternate lay.* Ropes that resist rotation have two or more layers of strands that are *cross-laid* (laid contra-helically or in opposite directions).

Table 1
Maximum Wire Rope Diameters and Tolerances*
(Inches and Millimeters)

Fractional Diameter (inches)	Decimal Diameter (inches)	Maximum Decimal Diameter Including Tolerance (inches)	Approximate Metric Diameter (millimeters)	Maximum Metric Diameter Including Tolerance (millimeters)
1/2	0.500	0.525	13	13.52
9/16	0.563	0.591	14.5	15.08
5/8	0.625	0.656	16	16.64
3/4	0.750	0.788	19	19.76
7/8	0.875	0.919	22	22.88
1	1.000	1.050	26	27.04
1-1/8	1.125	1.181	29	30.16
1-1/4	1.250	1.313	32	33.28
1-3/8	1.375	1.444	35	36.40
1-1/2	1.500	1.575	38	39.52
1-5/8	1.625	1.706	42	43.68
1-3/4	1.750	1.838	45	46.80
1-7/8	1.875	1.969	48	49.92
2	2.000	2.100	51	53.04
2-1/8	2.125	2.231	54	56.16
2-1/4	2.250	2.363	57	59.28
2-3/8	2.375	2.494	61	63.44
2-1/2	2.500	2.625	64	66.56
2-5/8	2.625	2.756	67	69.68
2-3/4	2.750	2.888	70	72.80
2-7/8	2.875	3.019	74	76.96
3	3.000	3.150	77	80.08
3-1/8	3.125	3.281	80	83.20
3-1/4	3.250	3.413	83	86.32
3-3/8	3.375	3.544	86	89.44
3-1/2	3.500	3.675	90	93.60
3-3/4	3.750	3.938	96	99.84
4	4.000	4.200	103	107.12
4-1/4	4.250	4.463	109	113.36
4-1/2	4.500	4.725	115	119.60
4-3/4	4.750	4.988	122	126.88
5	5.000	5.250	128	133.12
5-1/4	5.250	5.513	135	140.40
5-1/2	5.500	5.775	141	146.64
5-3/4	5.750	6.038	148	153.92
6	6.000	6.300	154	160.16

*Diameter Tolerances:
Nominal inch diameter: –0% to +5%
Nominal millimeter diameter: –1% to +4%

2.2.2 **Rope Lay Length.** The length of lay of a rope is the distance parallel to the axis of the rope in which a strand makes one complete spiral around the axis of the rope.

2.2.3 **Strand Lay Length.** The strand lay length is the distance in which an outer wire makes one complete spiral about the axis of the strand.

2.3 **Wire and Strand Nomenclature.** When describing rope, notations are used to describe the number of strands in the rope; the construction or number of wires in each strand; the grade (strength); rope lay; and the rope core. For example, a preformed, six-strand, improved plow steel rope of 6 X 25 filler wire construction, with right regular lay and having a fiber core, can be expressed:

6 X 25 FW P/F IPS Right Regular lay F/C
(If nonpreformed rope is desired, this must be specified.)

2.4 **Classification of Wire Rope Constructions.** Wire ropes are classified according to construction for commercial convenience. The following listing covers those wire rope constructions most generally used in mining. For selection, consult the wire rope or machine manufacturer.

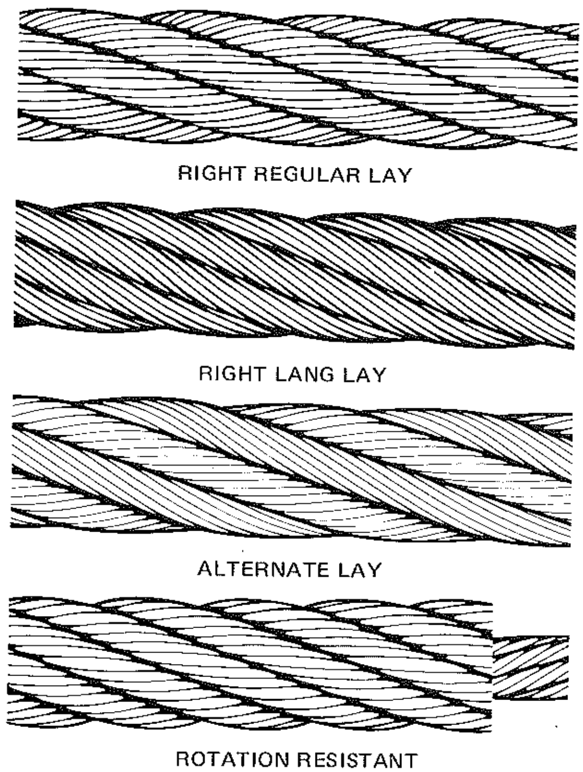


Fig. 2
Wire Rope Lay Identification

(1) ***Round-Strand Constructions*** – Strands are circular in cross-section. The centers of strands may consist of either a single wire or a strand of small wires.

(a) *6 X 7.* Ropes having 6 strands with 3 through 14 wires per strand but not more than 9 outer wires per strand.

(b) *6 X 19.* Ropes having 6 strands with 15 through 26 wires per strand but not more than 12 outer wires per strand.

(c) *6 X 37.* Ropes having 6 strands with 27 through 49 wires per strand but not more than 18 outer wires per strand.

(d) *6 X 61.* Ropes having 6 strands with 50 through 74 wires per strand but not more than 24 outer wires per strand.

(e) *6 X 91.* Ropes having 6 strands with 75 through 109 wires per strand but not more than 30 outer wires per strand.

(f) *6 X 127.* Ropes having 6 strands of more than 110 wires per strand but not more than 36 outer wires per strand.

(g) *8 X 19.* Ropes having 8 strands of 15 through 26 wires per strand but not more than 12 outer wires per strand.

(2) ***Flattened Strand Constructions*** -- Strands are triangular in cross-section.

(a) *6 X 8 Flattened Strand.* Ropes having 6 triangular strands with 8 wires per strand.

(b) *6 X 25 Flattened Strand; 6 X 27 Flattened Strand; 6 X 30 Flattened Strand.* Ropes having 6 triangular strands and 25, 27, and 30 wires, respectively, per strand.

(3) ***Rotation Resistant Ropes.*** (Formerly known as nonrotating or spin-resistant ropes). Special designs of round strand wire rope constructions not covered in 2.4(1) above.

(a) *18 X 7 and 19 X 7 Rotation Resistant Ropes.* Ropes having 12 outer strands cross-laid over either 6 or 7 inner strands with 7 wires per strand.

(b) *34 X 7 and 35 X 7 Rotation Resistant Ropes.* Ropes having 17 outer strands cross-laid over either 17 or 18 inner strands with 7 wires per strand.

(c) *8 X 19 Rotation Resistant Ropes.* Ropes having 8 outer strands cross-laid over the IWRC [see 2.5(3)].

(4) ***Three-Strand Constructions***

(a) *3 X 19.* Ropes having three circular strands with 15 to 26 wires per strand.

(b) 3 X *37.* Ropes having three circular strands with 27 through 49 wires per strand.

(5) ***Structural and Locked Coil Strand Construction***

(a) *Structural Strand.* A single strand consisting of all round wires.

(b) *Locked Coil Strand*

(i) *Half Locked Strand.* A strand with alternated round and shaped outer wires (H–O lock).

(ii) *Full Locked Strand.* A strand in which all outer wires are shaped (Z lock).

2.5 Wire Rope Cores. The following types of wire rope cores are commonly used:

(1) *Vegetable Fiber Cores.* Cores made of vegetable fibers such as sisal, manila, jute.

(2) *Synthetic or Plastic Cores.* Cores made of man-made fibers, such as polypropylene.

NOTE: In rope terminology synthetic or plastic cores are sometimes referred to simply as fiber core. The prefix synthetic should normally be used, however, to distinguish them from vegetable fiber cores.

(3) *Independent Wire Rope Core (IWRC).* A core which is a wire rope in itself and which may be made of various constructions.

(4) *Wire Strand Core (WSC).* A core which is a wire strand that usually has at least as many wires as are in the main strands of the rope.

2.6 Preforming. A process in the manufacture of wire rope in which the strands and their wires are permanently shaped during fabrication into the spiral form they assume in the finished wire rope or strand.

2.7 Grades of Wire Rope. The strength of wire rope is designated by the grade description – for example, plow steel, improved plow steel, extra improved plow steel, and others.

2.8 Prestretching (or Prestressing). The applicaton of a specified load to a wire rope or strand prior to installation to minimize constructional stretch and to establish uniform elastic properties of the rope or strand.

3. Storage, Handling, Installation, and Inspection of Wire Rope

3.1 Storage of Wire Rope. Rope not required for immediate use should be stored in a clean, dry place, preferably indoors, and shielded from weather, corrosive fumes, and excessive heat. If outdoor storage is unavoidable, the rope should be stored off the ground and should be protected from rain, snow, and condensation by a heavy layer of lubricant and a cover such as a tarpaulin. The rope should be checked periodically for moisture condensation that could cause corrosion.

3.2 Handling of Wire Rope. (See Fig. 3.)

3.2.1 Handling Rope Reels. When loading a reel on a railroad car, truck, or other conveyance, blocking should be placed against the reel flange and lashing should be effected through the center hole of the reel. Neither blocking nor lashing should contact the rope. If possible, a reel should be lifted by a shaft through its center hole. If a sling around the reel must be used, substantial wood blocks should be placed between the sling and the rope to prevent damaging the rope. Pry bars to move a reel should be used against the reel flanges, not against the rope. The reel should not be dropped from the car or truck or from a platform; to do so might break the reel or damage the rope. Also the reel should not be rolled over a hard or sharp object that may damage the rope. The reels should not be rolled over mud, dirt, cinders, or other substances that could damage the rope. If these conditions cannot be avoided, planking should be used to assist in moving the reel and protecting the rope.

3.2.2 Removal of Wire Rope from Storage

3.2.2.1 Coil or Light Reel. When removing coiled wire rope or rope wound on a light reel from storage, use a horizontal turntable if available, positioned so that the rope can be reeved directly onto the machine without dragging across the ground [see Fig. 3(a)].

If a turntable is not available, roll the coil or reel directly away from the machine with minimum dragging across the ground; avoid mud, grit, or other abrasive material [see Fig. 3(b)]. Do not pull rope from a stationary coil; this causes twisting, loops, and kinks to develop which cause permanent damage if the rope is pulled tight [see Fig. 3(c)].

3.2.2.2 Heavy Reel. When removing wire rope wound on a heavy reel from storage, mount the reel to rotate freely on a horizontal shaft through its center hole, placed so the rope may be reeved directly onto the machine without dragging across the ground. A board pressed against the reel flange, not the rope, will serve as a brake to prevent excess slack [see Fig. 3(d)]. Where possible, the reel should be placed so that coiling on the reel is in the same direction as the rope will be bent around sheaves or drum when reeved, thus avoiding reverse bending.

3.3 Installation of a Wire Rope

3.3.1 Inspection of Rope. Before installation, a new rope should be identified to make sure it is the size, construction, and grade specified by the machine or rope manufacturer. Length shall be sufficient to allow the machine to reach its specified operating range including the required number of dead wraps on the drum.

3.3.2 Inspection of Drums, Sheaves, and Rollers. Before installing a new rope, drums, sheaves, and rollers should be inspected for, and repaired or retired in the presence of, the following:

(1) Improper groove radii (see 3.4.1).

(2) Wear or roughness of surfaces that contact the rope.

(3) Bent or damaged flanges.

(4) Misalignment of drums, sheaves, or rollers.

(5) Worn or frozen bearings.

(6) Excessive wear and improper fit of guards.

Previously used end attachments should be inspected for, and repaired or retired in the presence of excessive wear or damage.

3.3.3 Reeving. When reeving a new rope:

(1) Grit or abrasive material collected during handling should be removed with a stiff brush; a solvent should not be used, as solvent may destroy rope lubricant.

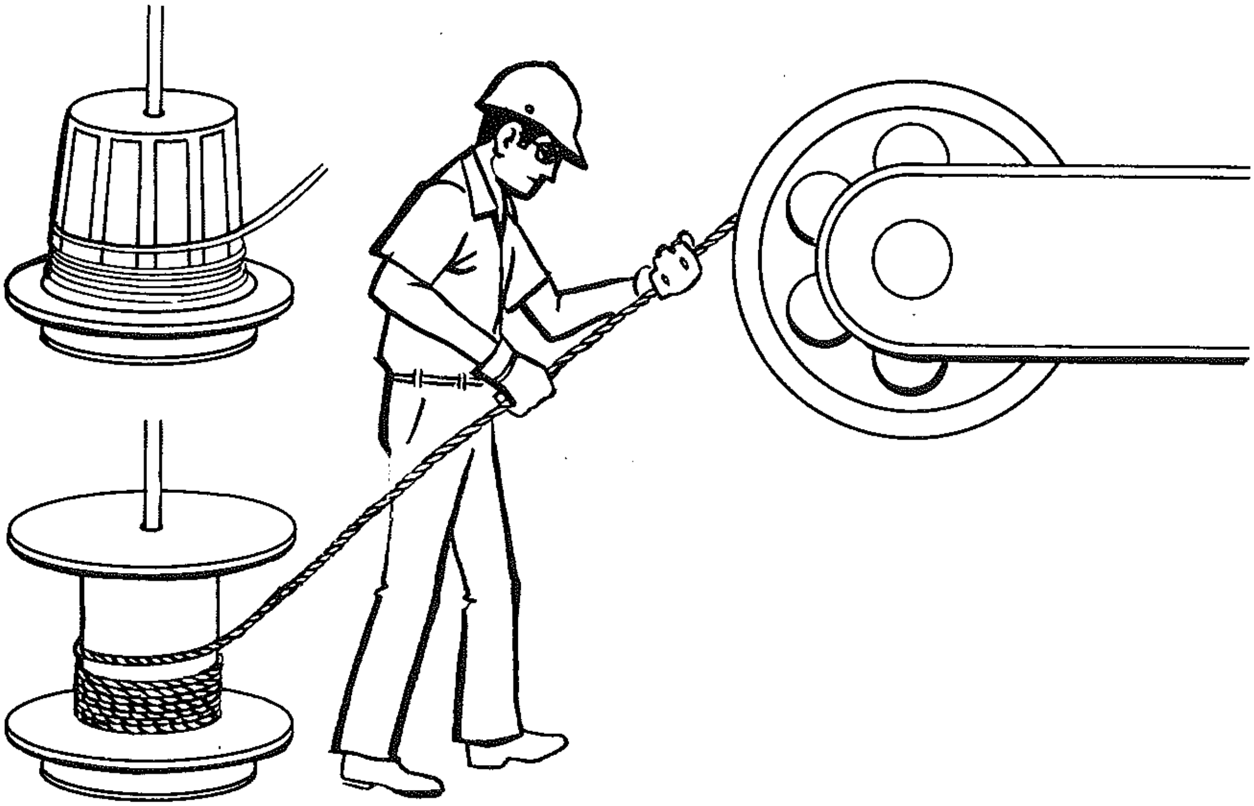
(2) The new coil or reel should be aligned with the initial sheave or drum to avoid unnecessary bending or chafing.

(3) Swivel sheaves or fairleads should be aligned with the rope direction to avoid unnecessary bending or chafing.

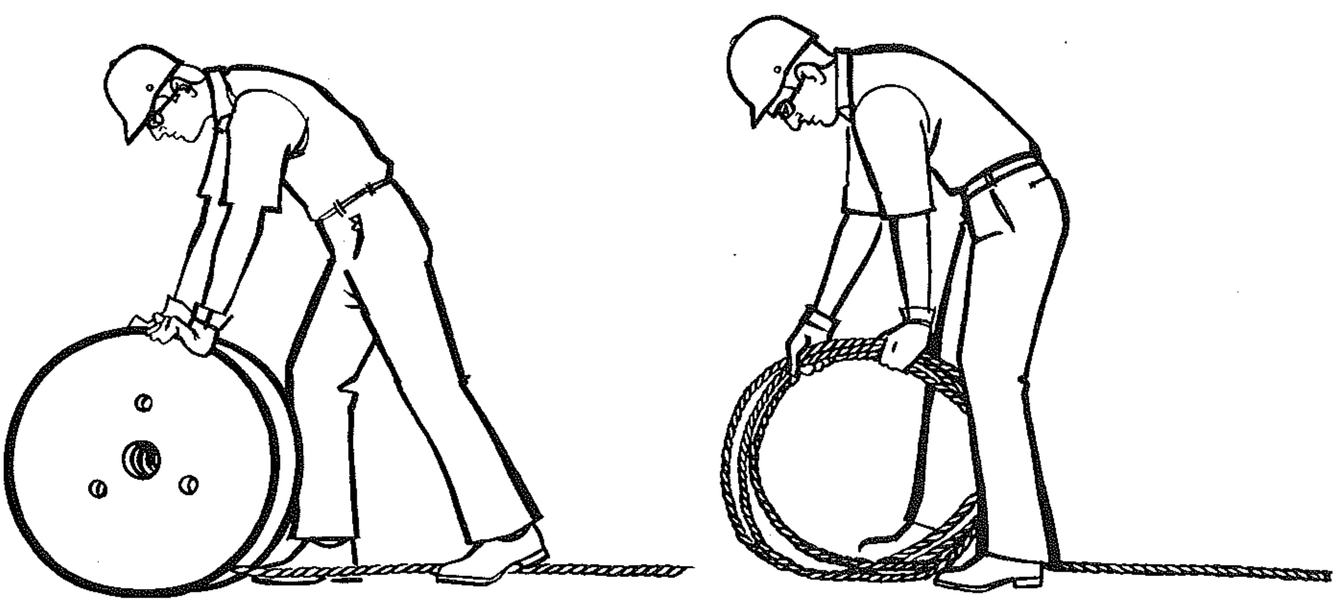
(4) The rope should be protected from the sharp edges of any structure with which it may come in contact.

(5) Care should be taken to avoid twisting the rope.

(6) When reeving the rope onto the drum, there should be enough tension to assure tight winding.

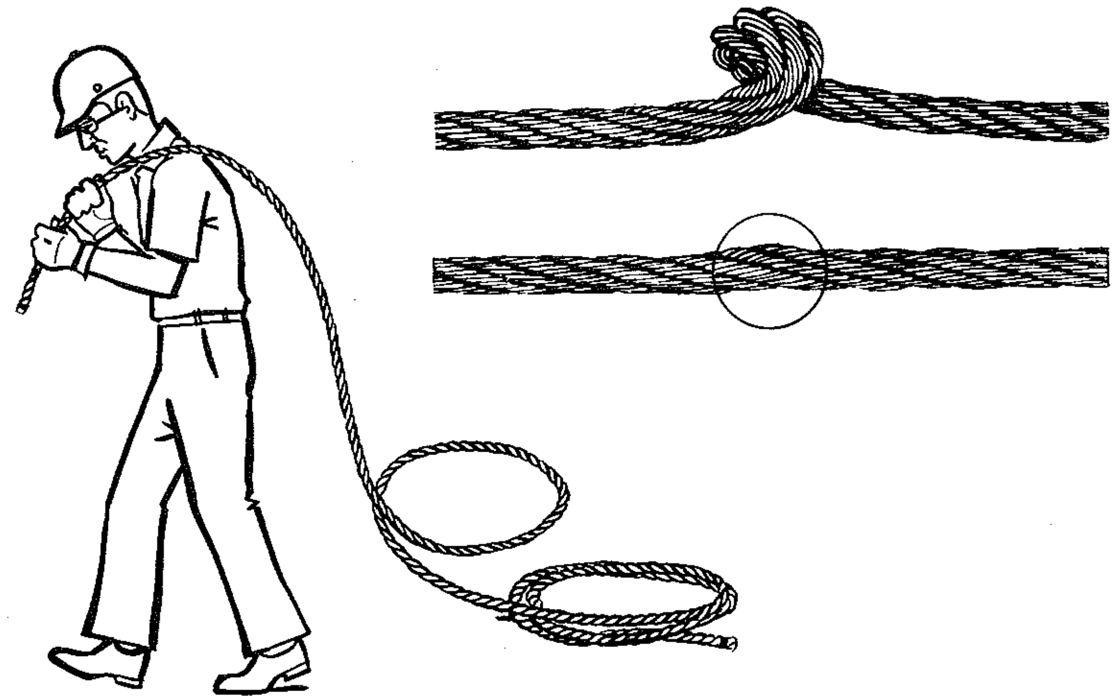


(a)

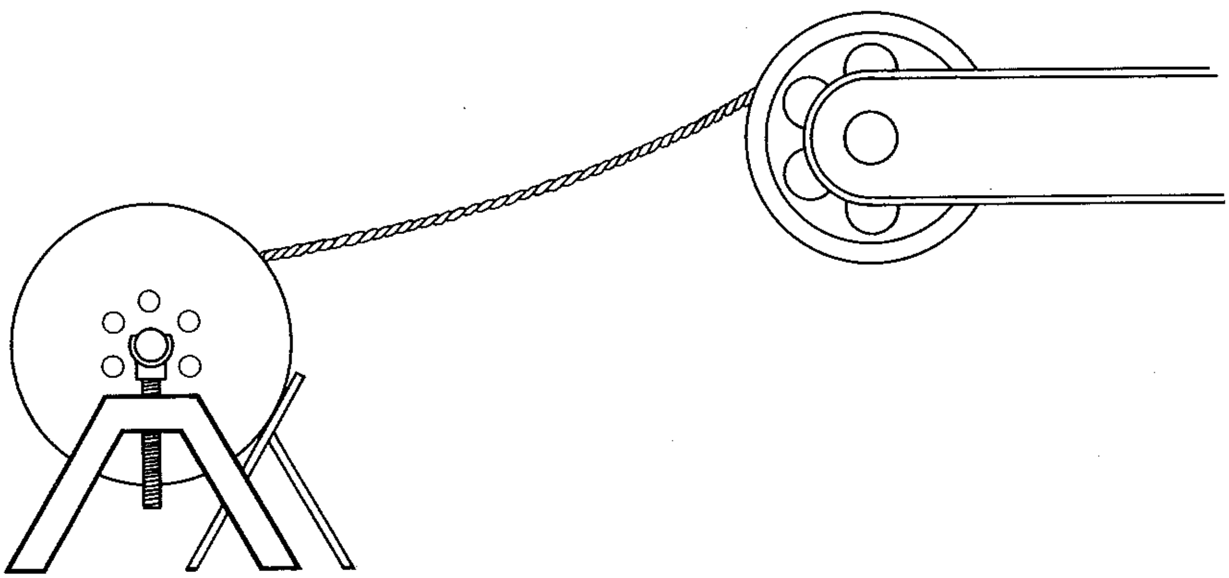


(b)

Fig. 3
Handling Wire Rope



(c)



(d)

Fig. 3 ***(Continued)***

(7) If it is necessary to guide the rope or to crowd wraps on the drum, use wood in contact with the rope to prevent damage.

(8) During reeving, inspect rope for possible damage.

(9) Whenever possible, the new rope should be operated through its full travel length bearing a light load for up to 10 cycles to aid its adjustment to working conditions.

3.4 Sheave Grooves and Drum Grooves

3.4.1 Groove Root Radius. See Table 2.

3.4.1.1 New and Reconditioned Grooves. Gauged grooves on new or reconditioned equipment shall fit the following gauge radii:

Nominal Rope Diameter	*Gauge Radius*
1/2 inch through 3 inches	0.5350 X nominal rope diameter
(13 mm through 77 mm)	0.5300 X nominal rope diameter
3-1/8 inches through 6 inches	0.5325 X nominal rope diameter
(80 mm through 154 mm)	0.5275 X nominal rope diameter

3.4.1.2 Worn Grooves. Gauged grooves that fall below the following minimum radii should be reconditioned or replaced:

Nominal Rope Diameter	*Gauge Radius*
1/2 inch through 6 inches	0.5125 X nominal rope diameter
(13 mm through 154 mm)	0.5075 X nominal rope diameter

3.4.2 Sheave Groove Geometry. See Fig. 4.

3.4.2.1 Groove Root Radius. See 3.4.1.

3.4.2.2 Groove Throat Angle. A 30° throat angle between flanges provides an optimum theoretical 150° support for the rope. If more than the average amount of rope whipping or off-lead is anticipated, a larger throat angle may be used to reduce rope and flange wear and to reduce the tendency of the rope to climb.

3.4.2.3 Groove Depth. A groove depth of 1.5 X the nominal rope diameter is preferred. Deviation from the preferred depth may be advisable under the following conditions:

(1) Greater depth may be necessary if more than the average amount of rope whipping or off-lead is anticipated

(2) Lesser depth may be necessary to reduce sheave inertia and rope slippage if rapid changes in the speed at which the rope will travel are anticipated and provided that the sheave is guarded

3.4.3 Drum Groove Geometry. See Fig. 5.

3.4.3.1 Groove Root Radius. See 3.4.1.

3.4.3.2 Groove Depth. A groove depth of 0.30 X the nominal rope diameter provides 130° support for the rope and is the maximum depth that allows a reasonable land width between grooves in the presence of normal groove pitch.

3.4.4 Maximum Fleet Angle and Groove Pitch for Helically Grooved Drums. See Fig. 6. The maximum fleet angle is the angle between the position of the rope at the dead wrap or extreme end wrap on a drum and a line drawn perpendicular to the axis of the drum through the center of the nearest fixed sheave. The fleet angle and the groove pitch for helically grooved drums should be selected to avoid the scrubbing of the rope leading to the drum against the adjacent wrap already on the drum. This can be done either by increasing the fleet angle, by increasing the groove pitch, or by a combination of both.

3.5 Length of New Rope

3.5.1 Underground-Mine Hoists. A new rope used in connection with drum hoists in underground mining shall allow sufficient length beyond the distance from the drum to the cage, skip, car, or other conveyance at maximum hoisting depth, to provide allowance for periodic cutoffs at both the conveyance end and the drum end and to provide a minimum of three dead wraps on the drum after the final cut when the rope is extended to its maximum distance. Lesser numbers of dead wraps can be used if so designed and recommended by the equipment manufacturer.

For friction hoists, a new rope should be prestretched and measured to a length that allows sufficient rope beyond fasteners for adjustment purposes.

3.5.2 Surface-Mining Machinery. A new rope used in connection with surface-mining machinery shall allow sufficient length beyond the specified operating range of the machine to provide allowance for the minimum number of recommended dead wraps on the drum (see Table 3 for the recommended number of dead wraps for surface-mining machines) and to provide for the turning of the rope end-for-end or for cut-offs, or for both, to minimize localized wear and to increase service life.

3.6 Cutting Wire Rope. Wire rope may be cut by mechanical or hydraulic shears, or by abrasive-wheel or flame-cutting procedures. All three methods are acceptable.

Seizings should be applied on each side of the expected cut to prevent unlaying of strands (see 3.7). Seizing may be replaced by strapping or other methods if such replacement prevents unlaying of strands.

3.7 Seizing Wire Rope.

3.7.1 Quantity of Seizings. Annealed steel seizing

Table 2
Groove Radii for Sheave and Drum Gauges

Nominal Rope Diameter		New and Reconditioned Groove Radius		Worn Groove Radius	
inches	millimeters	inches	millimeters	inches	millimeters
1/2	13	0.267	6.89	0.256	6.56
9/16	14.5	0.300	7.69	0.288	7.36
5/8	16	0.334	8.48	0.320	8.12
3/4	19	0.401	10.07	0.384	9.64
7/8	22	0.468	11.66	0.448	11.17
1	26	0.535	13.78	0.513	13.20
1-1/8	29	0.601	15.37	0.577	14.71
1-1/4	32	0.669	16.96	0.641	16.24
1-3/8	35	0.736	18.55	0.704	17.76
1-1/2	38	0.803	20.14	0.769	19.29
1-5/8	42	0.869	22.26	0.833	21.31
1-3/4	45	0.936	23.85	0.897	22.83
1-7/8	48	1.003	25.44	0.961	24.36
2	51	1.070	27.03	1.025	25.88
2-1/8	54	1.137	28.62	1.089	27.41
2-1/4	57	1.204	30.21	1.153	28.92
2-3/8	61	1.271	32.33	1.217	30.95
2-1/2	64	1.338	33.92	1.281	32.48
2-5/8	67	1.404	35.51	1.345	34.00
2-3/4	70	1.471	37.10	1.409	35.53
2-7/8	74	1.538	39.22	1.473	37.55
3	77	1.605	40.81	1.538	39.08
3-1/8	80	1.664	42.20	1.602	40.60
3-1/4	83	1.731	43.78	1.666	42.12
3-3/8	86	1.797	45.37	1.730	43.65
3-1/2	90	1.864	47.48	1.794	45.67
3-3/4	96	1.997	50.64	1.922	48.72
4	103	2.130	54.33	2.050	52.27
4-1/4	109	2.264	57.50	2.178	55.32
4-1/2	115	2.396	60.66	2.306	58.36
4-3/4	122	2.529	64.36	2.434	61.91
5	128	2.663	67.52	2.563	64.96
5-1/4	135	2.804	71.21	2.691	68.51
5-1/2	141	2.929	74.38	2.817	71.56
5-3/4	148	3.062	77.54	2.947	75.11
6	154	3.195	81.24	3.075	78.16

wire or seizing strand shall be wound in a close helix around the wire rope in accordance with the requirements of 3.7.1.1 through 3.7.1.3.

3.7.1.1 Preformed Rope. For preformed rope, one seizing shall be applied on each side of the proposed cut.

3.7.1.2 Nonpreformed Rope. For nonpreformed ropes 7/8 inch (22 mm) in diameter and smaller, two seizings shall be applied on each side of the proposed cut. For nonpreformed ropes 1 inch (26 mm) in diameter and larger, three seizings shall be applied on each side of the proposed cut.

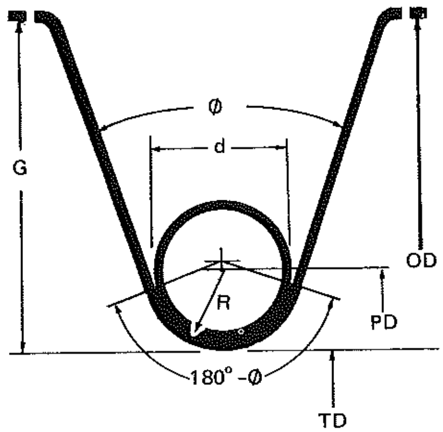
3.7.1.3 Rotation-Resistant Ropes. For 18 X 7, 19 X 7, and 8 X 19 rotation-resistant ropes, three seizings shall be applied on each side of the proposed cut.

3.7.2 Methods of Seizing

3.7.2.1 Method A "Bar Seizings". The method for bar seizings is illustrated in Fig. 7. In the valley between two strands, lay one end of the seizing and tightly wrap the other end in a close helix over the portion in the valley. A seizing iron should be used to wrap the seizing tightly and both ends should be twisted tightly together. The appearance of a complete seizing is shown in Fig. 7. The length of each seizing should not be less than the rope diameter.

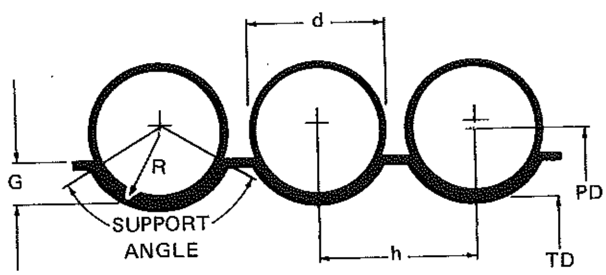
3.7.2.2 Method B "Wrapped Seizings". The method for wrapped seizings is illustrated in Fig. 8.

(1) Wrap the seizing as tightly as possible in a close helix for a length of approximately one rope diameter around the rope.



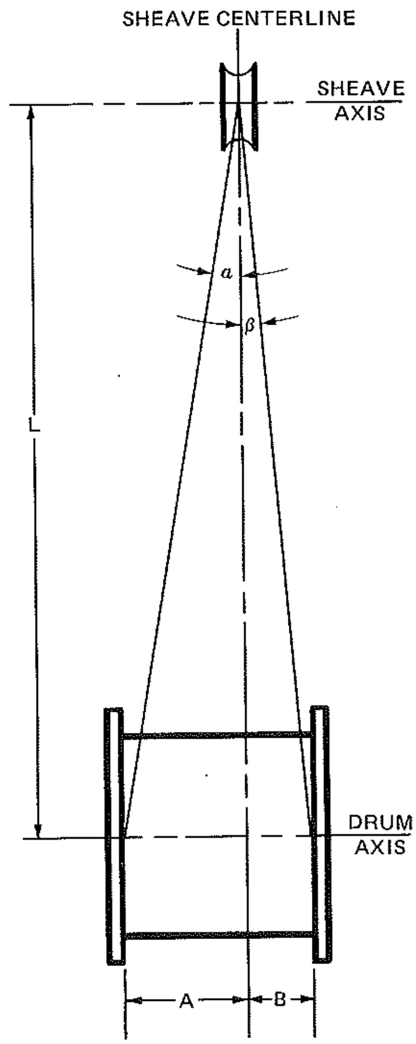
d = nominal rope diameter
G = groove depth
R = groove radius
OD = outside diameter
PD = pitch diameter
TD = tread diameter
Ø = throat angle

Fig. 4
Sheave Groove Geometry



d = nominal rope diameter
G = groove depth
R = groove radius
PD = pitch diameter
TD = tread diameter
h = groove pitch

Fig. 5
Drum Groove Geometry



L = distance from drum axis to head sheave axis
A = distance from sheave centerline on drum to left flange
B = distance from sheave centerline on drum to right flange

Left fleet angle ($\tan \alpha$) = $\frac{A}{L}$

Right fleet angle ($\tan \beta$) = $\frac{B}{L}$

Fig. 6
Drum Fleet Angle

Table 3
Design Criteria for Wire Rope Systems

Machine Types and Rope Function	Column I Minimum Design Factor (Note 1)	Column II Minimum Diameter Ratio Drum or Sheave (Pitch Diameter) (Note 2)	Column III Minimum Dead Wraps of Rope
Clamshells			
Large			
Closing rope	4.0 A	18	2.0
Holding rope	3.0 A	18	2.0
Boom hoist rope	4.0 A	15	1.0
Boom suspension rope or strand	4.0 A	–	–
Tagline rope	1.5 A	15	2.0
Construction Type (Note 3)			
Closing rope	4.0 A	18	2.0
Holding rope	3.0 A	18	2.0
Boom hoist rope	4.0 A	15	2.0
Boom pendant rope or strand	3.0 A	–	–
Tagline rope	1.5 A	15	2.0
Draglines			
Stripping			
Hoist rope	4.0 A	24	1.0
Drag rope	3.0 B	22	1.0
Boom hoist rope	3.0 A	15	1.0
Boom suspension strand	4.0 A	–	–
A-Frame safety strand	3.0 A	–	–
Dump rope	4.0 A	15	–
Intermediate			
Hoist rope	4.0 A	20	1.0
Drag rope	3.0 B	18	1.0
Boom suspension rope or strand	4.0 A	–	–
Boom hoist rope	3.0 A	15	1.0
Dump rope	4.0 A	15	–
Construction Type (Note 3)			
Hoist rope	4.0 A	18	2.0
Drag rope	3.0 B	18	2.0
Boom hoist rope	3.0 A	15	2.0
Boom pendant rope or strand	3.0 A	–	–
Dump rope	4.0 A	15	–
Drills			
Rotary			
Pull down rope	3.0 B	18	1.0
Sand line rope	3.5 A	15	2.0
Hoist rope	3.5 A	18	1.0
Auxiliary rope	3.5 A	18	1.0
Cable			
Bull rope	3.0 B	18	1.0
Sand line rope	3.5 A	15	2.0
Casing line rope	3.5 A	18	1.0
Shovels			
Stripping			
Hoist rope	4.0 B	24	1.0
Crowd and retract ropes	4.0 B	22	0.5
Boom hoist rope	3.0 A	15	1.0
Counter-Balance rope	4.0 A	22	0.5
Boom suspension strand	5.0 B	–	–
A-Frame safety strand	3.0 B	–	–
Dipper trip rope	3.0 B	15	2.0

Continued

Table 3 (*Continued*)
Design Criteria for Wire Rope Systems

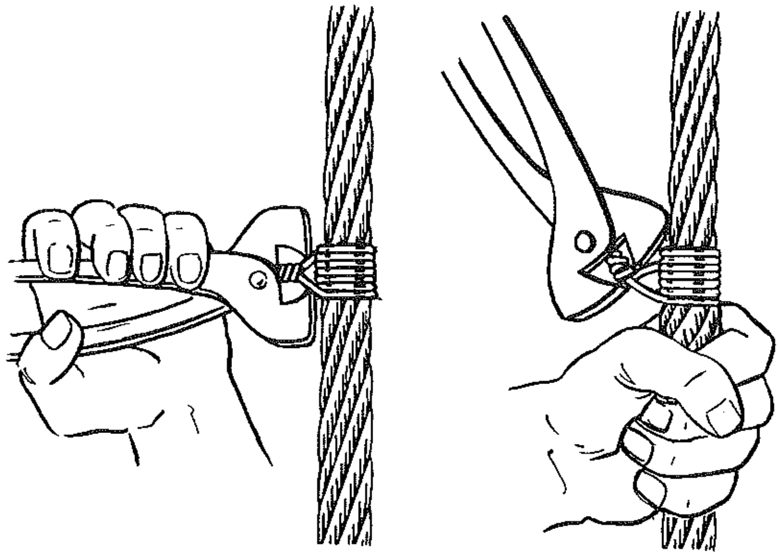
	Column I	Column II	Column III
Machine Types and Rope Function	Minimum Design Factor (Note 1)	Minimum Diameter Ratio Drum or Sheave (Pitch Diameter) (Note 2)	Minimum Dead Wraps of Rope
Shovels (Continued)			
Mining			
Hoist rope	4.0 B	20	1.0
Crowd and retract ropes	4.0 B	18	0.5
Boom hoist rope	3.0 A	15	1.0
Boom suspension rope or strand	5.0 B	–	–
Dipper trip rope	3.0 B	15	2.0
Construction Type (Note 3)			
Hoist rope	3.0 B	18	2.0
Crowd and retract ropes	3.0 B	16	0.5
Boom hoist rope	3.0 B	15	1.0
Dipper trip rope	3.0 B	15	–
Stacker			
Boom hoist rope	4.0 A	18	1.0
Counterweight rope	4.0 A	15	1.0
Pendant rope or strand	4.0 A	–	–
Stacker hoist rope	3.0 A	15	1.0
Conveyor belt counterweight rope	4.0 A	15	1.0
Wheel Excavator			
Stripping			
Wheel ladder hoist rope	4.0 B	18	1.0
Stacker suspension ropes	4.0 A	–	–
A-Frame guy strand	4.0 A	–	–
Loading			
Wheel ladder hoist rope	4.0 B	18	1.0
Stacker suspension rope	4.0 A	–	–
Miscellaneous			
Bulldozer			
Blade hoist rope	3.0 B	15	2.0
Dump Wagon			
Bottom door rope	3.0 B	15	2.0
Tower Excavator			
Drag rope	3.0 B	18	2.0
Haul-Back rope	4.0 A	18	2.0
Hoes			
Hoist rope	3.5 A	18	2.0
Drag rope	3.0 B	18	2.0
Mast hoist rope	3.5 A	15	2.0

"A" denotes the load imposed on a rope by the static weight of the structure and the live load.
"B" denotes the load imposed on a rope by the maximum stall force from the power source.
NOTES:

(1) Design Factors should be increased by 1/3 when rotation-resistant (nonrotating) ropes are used. A minimum design factor of five should be used with rotation-resistant rope.

(2) Drum and sheave to rope diameter ratios. The D/d Ratios are minimum. Larger D/d Ratios should be used where possible. D/d Ratios listed do not apply to deflecting and idler sheaves.

(3) A Construction Type Machine is defined as one with a *maximum equivalent hoist rope diameter of 2 inches.*



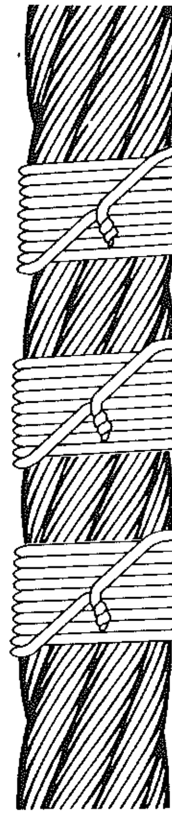
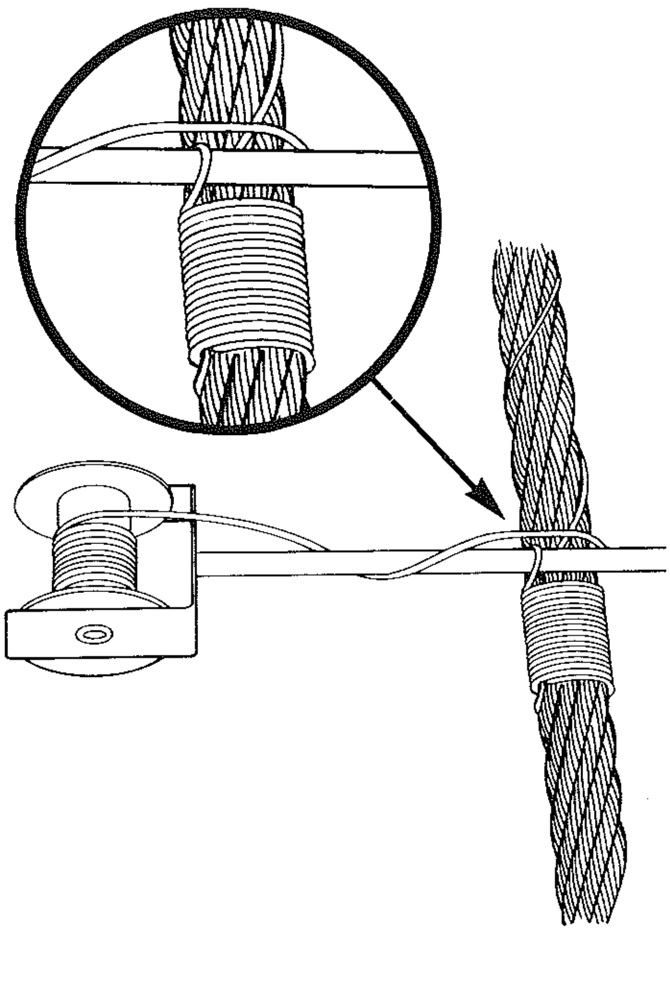


Fig. 8
Seizing Wire Rope –
Method B:
Wrapped Seizings



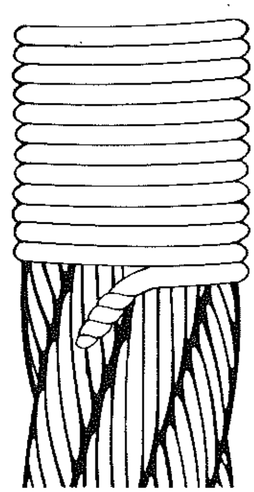


Fig. 7
Seizing Wire Rope –
Method A:
Bar Seizing

(2) Twist the ends together by hand so that the twist concentrates in the middle of the seizing.

(3) Using a suitable (carew-type) cutter, tighten seizing by twisting, and tighten further by prying the twist away from the rope axis with cutters.

(4) Tighten the twist again as in step (3).

(5) Repeat final tightening steps as often as necessary to make seizing tight. Cut off the ends of the wire and pound the twist into contact with the seizing.

3.7.3 Recommended Sizes of Seizing Wire. The following sizes of seizing wire are recommended:

Nominal Rope Diameter	*Approximate Diameter of Seizing Wire*
1/2 inch and smaller (13 mm and smaller)	0.030 inch (0.8 mm)
9/16 inch to 7/8 inch (14.5 mm to 22 mm)	0.041 inch (1 mm)
1 inch to 1-1/2 inches (26 mm to 38 mm)	0.080 inch (2 mm)
1-5/8 inches to 2 inches (42 mm to 51 mm)	0.106 inch (2.5 mm)
2-1/8 inches and larger (54 mm and larger)	0.135 inch (3.5 mm)

3.8 End Attachments

3.8.1 General. There are numerous types of fittings and methods of attaching or anchoring wire rope. Attachment efficiency values are shown in Appendix A. It should be noted that efficiency alone should not be the single criterion for assessing the safety of an attachment: attachment efficiency values are calculated for new (unused) rope bearing a static load; when subjected to dynamic or shock loading, these efficiencies are reduced. For this and similar reasons, the machine or rope manufacturer should be consulted on end attachments for different types of service requirements.

3.8.2 Wire-Rope Clips and Thimbles.

3.8.2.1 Types and Strengths. Clips can be either U-bolt or fist-grip types. (See Appendix B for U-bolt clip information). The clip manufacturer should be consulted for specific recommendations and efficiencies.

3.8.2.2 Thimble and Clip Attachment of Vertical Shaft Hoist Ropes. Vertical shaft hoist ropes are frequently attached to a conveyance using an extra-large cast-steel thimble. These thimbles should have a machined pin hole for the conveyance attachment. The thimble should be installed so that the hole for the pin is offset one-half the diameter of the rope from the centerline of the thimble, thus allowing the pull on the hoisting rope to be in direct line with the pin. (See Appendix C for thimble details and for a view of a completed attachment. For the number of clips recommended and their proper spacing see Appendix B.)

3.8.3 Zinc-Poured Socketing. The procedure for applying zinc-poured sockets, which is outlined in Fig. 9, is as follows:

(1) *Measure the rope ends for socketing and apply serving at the base of the socket.* As indicated in Fig. 9(a), the length of the rope end should be such that the ends of the wires when unlaid from the strands will be at the top of the socket basket. Apply a tight wire serving band for a length of two rope diameters beginning at the base of the socket and extending away from it.

(2) *Broom out strands and wires in the strands.* See Fig. 9(b) and (c). Unlay and straighten the individual strands of the rope and spread them evenly so they form an included angle of approximately 60°. If the rope has a fiber core, cut out and remove the core as close to the serving band as possible. Unlay the wires from each individual strand for the full length of the rope end, being careful not to disturb or change the lay of the wires and strands under the serving band. If the rope has an independent wire rope core (IWRC), unlay the wires of the IWRC in the same manner.

(3) *Clean the broomed-out ends.* See Fig. 9(d). A suggested solvent for cleaning is SC-5 Methyl Chloroform. This solvent is also known under the names of Chlorothane VG or 1,1,1-trichloroethane.

CAUTION: Breathing the vapor of chlorinated solvents is harmful; use only with adequate ventilation. Follow the solvent manufacturer's instructions; observe the label instructions.

When using a solvent, swish the broomed-out rope end in the solvent and vigorously brush away all grease and dirt making sure to clean all the wires of the broomed-out portion to a point close to the serving band. A solution of hydrochloric (muriatic acid) may be used for additional cleaning. However, if acid is used, the broomed-out ends of the rope should be subsequently rinsed in a solution of bicarbonate of soda to neutralize any acid that may remain on the rope. Care should also be exercised that acid does not enter the core, particularly if the rope has a fiber core. Ultrasonic cleaning is a preferred method for cleaning rope ends for socketing.

After cleaning, put the broomed-out ends upright in a vise until it is certain that all the solvent has evaporated and the wires are dry.

(4) *Dip the broomed-out rope ends in flux.* See Fig. 9(e). Make a hot solution of zinc-ammonium chloride flux such as Zalcon K. Use a concentration of one pound of zinc-ammonium chloride in one gallon of water and maintain the solution at a temperature of

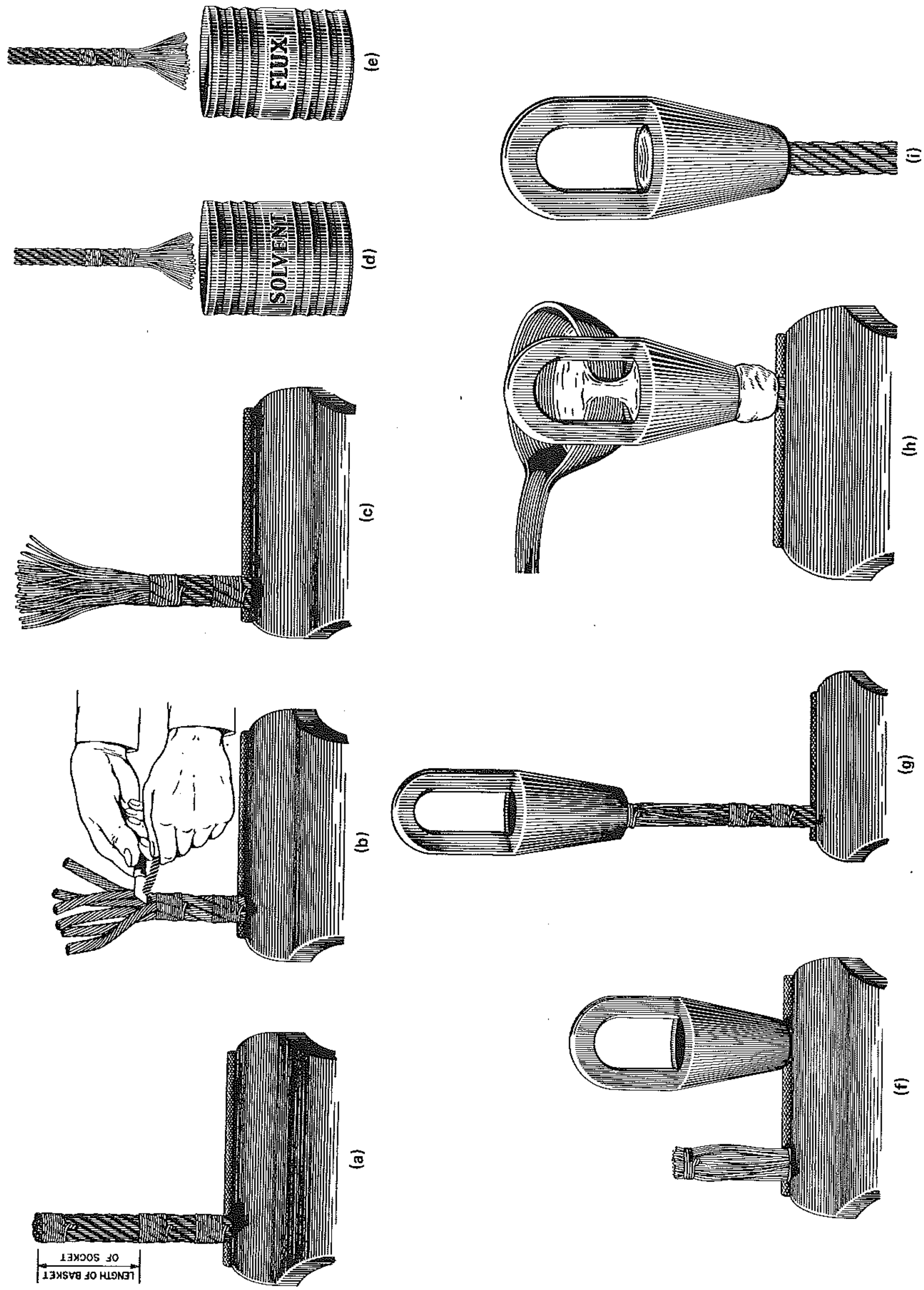


Fig. 9
Attaching Wire Rope Sockets

180° to 200° F. Switch the broomed-out end in the flux solution, put the rope end upright in the vise, and permit all wires to dry thoroughly.

(5) *Close rope ends and install the socket.* See Fig. 9(f) and Fig. 9(g). Use clean wire to compress the broomed-out rope end into a tight bundle so that the socket can be slipped over the wires. A socket should always be clean and heated before placing it on the rope. The heating is necessary to dispel any moisture and to prevent premature cooling of the zinc.

CAUTION: Never heat a socket after it has been placed on the rope because of the hazard of heat damage to the wire rope.

When the socket has been put on the rope end, the wires should be evenly distributed in the socket basket so that zinc can surround every wire. Use utmost care to align the socket with the centerline of the rope and to ensure that there is a vertical straight length of rope exiting the socket that is equal to a minimum of 30 rope diameters. Seal the base of the socket with fire clay or putty, but be sure this material is not inserted into the base of the socket; if this were done, it would prevent the zinc from penetrating the full length of the socket basket and would create a void which would collect moisture when the socket is placed into service.

(6) *Pour the zinc.* See Fig. 9(h). Use zinc that meets the requirements in ANSI/ASTM B6-70, Specification for Zinc Metal (Slab Zinc), for "high grade" or Federal Specification QQ-Z-351-a Amendment 1, interim Amendment 2. Pour the zinc at a temperature of approximately 950°F to 975°F making allowances for cooling if the zinc pot is more than 25 feet from the socket.

CAUTION: Do not heat zinc above 1100°F or its bonding properties will be lost.

The temperature of the zinc may be measured with a portable pyrometer or a Tempilstik. Remove all dross before pouring. Pour the zinc in one continuous pour to the top of the socket basket so that all the wire ends are covered; there should be no "capping" of the socket.

(7) *Remove the serving band.* See Fig. 9(i). Remove the serving band from the base of the socket and check to see that zinc has penetrated to the base of the socket.

(8) *Lubricate the rope.* Apply a wire rope lubricant to the rope at the base of the socket and on any section of the rope from which the original lubricant has been removed.

3.8.4 **Resin Poured Sockets.** Resin poured sockets may be used in accordance with the wire-rope manufacturer's recommendation. See Appendix D.

3.8.5 **Wedge Sockets.** Use caution when installing wedge sockets to prevent distortion of the rope and to position the wedge properly. If wire rope clips are used, they should not be attached to the live end of the rope.

3.8.6 **Swaged Sockets.** Swaged sockets may be used provided they are attached by a wire rope manufacturer or by a qualified rigger.

3.8.7 **Cappels.** Cappels may be used for rope end attachments. If used, the manufacturer's recommendations for the particular size and construction of rope shall be followed carefully.

3.9 **Refastening.** The attachment end of a wire rope tethered to a skip, bucket, cage, car or other conveyance is subjected to fatigue from dynamic loads and vibration; consequently, careful examination for degradation is required at regular intervals because damage due to fatigue may accumulate rapidly. Wire breaks may occur inside the socket entrance where detection is difficult. It is recommended that periodically the attachments, including at least a three foot section of rope adjacent to the attachments, be cut and the attachments refastened in order to remove that portion of the rope affected by degradation.

3.10 **Drum-End Shaft Hoist Rope Cutoffs.** The drum ends of shaft-hoist ropes are subject to degradation in the presence of dynamic loads and vibration at the headsheave and the drum. Loads and vibrations are shared and dampened by the dead wraps and the drum mass and degradation is therefore apt to be less serious at these points than at the conveyance ends. However, since there still exists the possibility of some degradation (particularly in ropes with long service experience), it is recommended that periodically a length should be cut off at the drum attachment and the rope pulled through and fastened. This is particularly important for hoists operating in deep shafts that have multiple layers of ropes on their drums.

3.11 **Wire Rope Inspection and Removal Criteria**

3.11.1 **Appointed Person.** Each mine shall provide for inspection of wire ropes and structural strands by an appointed person (or persons) who is responsible for reporting and for retaining a record of the findings of such inspections.

3.11.2 **Inspection Procedures.** An inspection procedure should be established for each wire rope application on mining machinery. Procedures will differ depending on the operating conditions, the severity of service, and the environment.

3.11.2.1 **Frequency of Inspection.** The frequency of inspection shall be established on the basis of operating shifts, days, weeks, or months, depending on anticipated rope life.

3.11.2.2 Average Rope Life. An average rope life shall be established based on the number of cycles the rope has operated, the total distance over which the rope has operated, or the volume or weight of material the rope has handled, (or combinations thereof, such as number of ton-miles), depending on which of these best represents the rope's service.

3.11.2.3 Increased Inspection Frequency Due to Abuse of Rope. More frequent inspection is advisable for operations that cause ropes to be dragged over rocks or through abrasive material, to be struck by falling rocks, or to be subject to similar abuse when such conditions cannot be avoided.

3.11.3 Visual Evidence of Rope Degradation. In addition to the regularly scheduled inspections, the machine's operating personnel should report any visual evidence of rope degradation, such as:

(1) Severe abrasion, scrubbing, peening, or kinking, or broken outer wires

(2) Crushing or other damage that distorts the rope's structure

(3) Severe reduction of rope diameter or an observable increase in rope lay.

(4) Bird-caging or other distortion indicating uneven distribution of load between rope strands

(5) Evidence of severe corrosion, particularly in the vicinity of attachments

(6) Uneven stretch of multiple ropes

(7) Evidence of heat damage from a torch or arcing from contact with an electrical conductor

(8) A rapid increase in the number of broken wires

(9) Lack of lubrication

3.11.4 Regularly Scheduled Inspections

3.11.4.1 Equalizer and Tackle Sheaves. Rope damage may develop at equalizer sheaves and at sheaves in tackles that are stationary during operation. Particular care should be taken to inspect ropes at these points. If practical, a stationary tackle should be used to move the rope enough to expose, for better inspection, sections of rope normally in contact with sheaves.

3.11.4.2 Rope-System Components. The conditions of drum grooves and sheave grooves should be inspected and reported. Other parts contacted by the rope, as well as the condition of sheave bearings and sheave/rope alignment, should also be reported so that maintenance or replacement may be scheduled in advance of critical deterioration.

3.11.5 Inspection During Installation, Equalizer Movement. When a new rope is installed, it shall be inspected to ensure that it is reeved according to the manufacturer's specifications. See 3.3 for inspection procedures to be followed during installation of new rope. If the equalizer approaches the end of its travel, the ropes should be readjusted.

3.11.6 Inspection to Determine Need for Rope Cutoffs and Rope Reversals. Premature failure of a rope due to damage at an end attachment may be prevented in some cases by cutting off and resocketing the rope or by turning the rope end for end. In some cases, regularly scheduled rope cutoffs and resocketing or rope reversal will be beneficial. (see further discussion under 3.9 and 3.10.)

3.11.7 Replacement of Structural Strand. Replacement of a structural strand in a multiple strand system should be based on the average deterioration of all strands in the system rather than on the deterioration of one particular strand.

3.11.8 Reuse of End Attachments. Reuseable attachments should be inspected for wear or other damage before they are installed.

4. Underground Mining – Selection, Usage, Maintenance, Inspection, and Removal of Wire Rope Used on Vertical Shaft Hoists and Incline Slope Hoists

4.1 Drum Hoists

4.1.1 Design Factors. The calculated design factors for drum hoist ropes shall apply for both service hoists and production hoists. Static loads are used in conjunction with design factors.

For the purpose of this section, the design factor of a vertical shaft rope for drum hoists is the value obtained by the following formula:

$$\text{design factor} = 7.0 - 0.001\, l$$

where

l = maximum suspended rope length in feet

A design factor of 4.0 shall be the minimum for a suspended rope of 3000 feet or longer.

4.1.2 Total Force on Vertical Shaft Hoist Ropes

4.1.2.1 Static and Dynamic Forces. The total force acting on a hoist rope is composed of static and dynamic components.

Static forces are composed of the following:

(1) Mass of suspended rope

(2) Mass of conveyance and attachments

(3) Mass of payload

(4) Mass of tail rope (if used)

Dynamic forces are composed of the following:

(1) Acceleration forces

(2) Deceleration forces

(3) Dynamic bending stresses

(4) Forces due to winding, vibration, and oscillation

(5) Forces due to loading and unloading of conveyances

(6) Forces due to friction elements acting on the conveyance, the rope guiding devices, and the support rollers

Appendix E describes how to calculate the total forces acting on drum hoist ropes.

4.1.3 Equipment

4.1.3.1 Sheave and Drum-to-Rope Diameter Ratios. The tread daimeter of the sheave (or drum) divided by the rope diameter (D/d ratio) governs the hoist drums, the head sheaves, and the deflection sheaves.

4.1.3.1.1 Vertical Shaft Hoist Ropes. For vertical hoist ropes one inch in diameter and greater, the D/d ratio shall not be less than 80 times the rope diameter. For ropes less than one inch in diameter, the D/d ratio shall not be less than 60 times the rope diameter. For locked coil ropes, the D/d ratio shall not be less than 100 times the rope diameter.

4.1.3.1.2 Special Applications. Some mine equipment must utilize sheave and drum diameter factors that are smaller than those for primary vertical and slope-shaft hoists in order to achieve the necessary portability, reduction in weight, economy of design, etc. The minimum D/d ratios for these special applications are listed in Table 4.

4.1.3.2 Groove Radius. (See 3.4.1)

4.1.3.2.1 Sheaves and Drums. It is essential that head sheaves and other sheaves have grooves that support the rope properly. Prior to installation of new rope, the radius of the sheave grooves should be inspected; where necessary, the grooves should be machined to proper contour and groove radius in accordance with recommendations of the hoist/sheave manufacturer. Groove radii shall not be less than those cited in 3.4.1.

4.1.3.3 Material of Sheaves and Drums. Thorough consideration should be given to the type of material of which sheaves and drums are made. To keep wear and groove corrugations to a minimum, it is desirable to give consideration to the radial pressure of the rope on sheaves and drums. Radial pressure is calculated as follows:

$$P = \frac{2T}{D \times d}$$

where

P = Radial pressure in pounds per square inch

T = Rope tension in pounds

D = Sheave or drum tread diameter in inches

d = Rope diameter in inches

See Appendix J for radial pressures for selected materials.

Table 4
Minimum *D/d* Ratios for Special Applications*

Rope Construction	Minimum Tread Diameter of Sheave or Drum
6 X 7 classification	72 X rope diameter
6 X 19 classification	45 X rope diameter
6 X 37 classification	27 X rope diameter
6 X 25 (Type B); 6 X 27 (Type H); 6 X 30 (Type G) flattened strand	45 X rope diameter
Rotation resistant	51 X rope diameter

*Conditions may exist where further reduction may be necessary. Under such conditions, service life would be affected and due precautions should be exercised. If possible, the hoist/sheave manufacturer should be consulted for guidance.

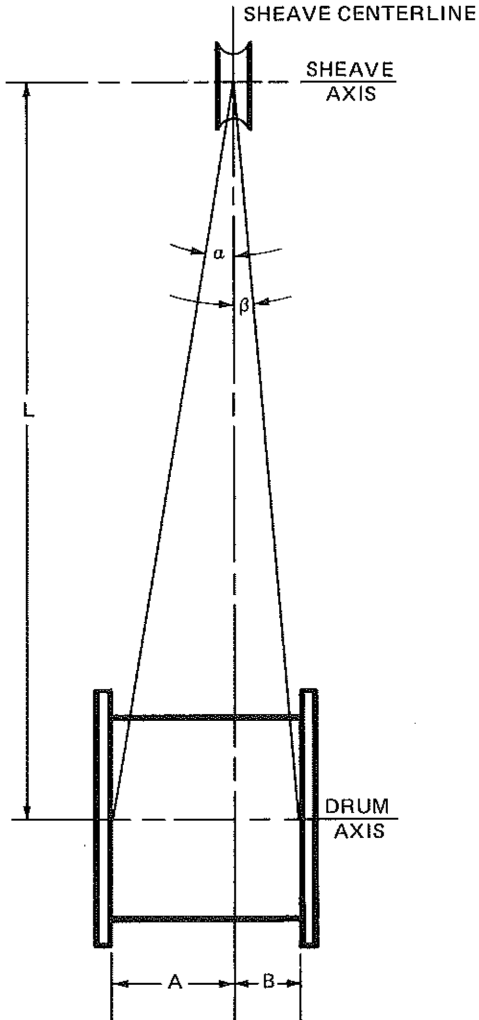
4.1.3.4 Drum Fleet Angles. (See Fig. 10).

4.1.3.4.1 General. The fleet angle has a significant effect on the operational life of a rope because of the scrubbing that can occur against the sheave flanges. In the case of a rope winding on a drum, an incorrect fleet angle may not only increase rope scrubbing but may also lead to improper spooling. The drum fleet angle is shown in Fig. 10. This angle is controlled by the distance *L* between the head or first sheave axis and the drum axis, the location of the sheave centerline relative to the drum, and the width between drum flanges.

4.1.3.4.2 Maximum and Minimum Fleet Angle. The fleet angle on a drum can be either too large or too small. Care should be taken to avoid these extremes. To insure consistent and uniform winding, particularly at the transition from one rope layer to the next, the maximum fleet angle should not exceed 1.5° (except in the case of very large drum diameters, where the maximum allowable fleet angle may be somewhat less). To assure that the rope will cross back and start each layer without piling up, the minimum fleet angle should be no less than 0.5°.

4.1.3.4.3 Helix Angle. If the rope is wound on the drum with a uniform helix, calculation of the maximum fleet angle must be modified to take the helix angle into account. The tangent of the helix angle is equal to the groove (or rope winding) pitch divided by the drum-tread circumference. The actual fleet angle may be calculated, as in Fig. 10, by adding or subtracting the helix angle from the initially calculated fleet angle.

4.1.3.4.4 Total Fleet Angles. The total fleet angle should in most cases be kept within the maximum and minimum values recommended in 4.1.3.4.2. For large drums, the total fleet angle may be sufficient to cause the rope to scrub against the adjacent wrap on the drum, even when the fleet angle is less than the



L = distance from drum axis to head sheave axis

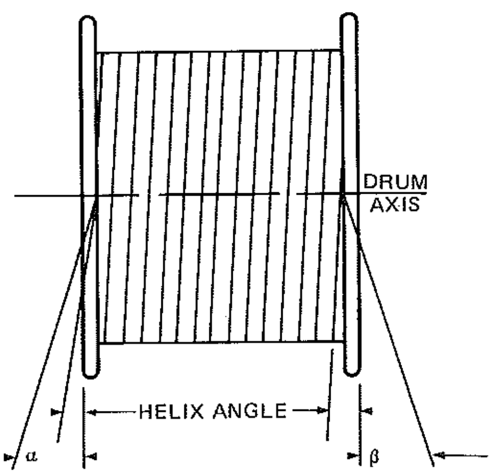
A = distance from sheave centerline on drum to left flange

B = distance from sheave centerline on drum to right flange

Left fleet angle $(\tan \alpha) = \frac{A}{L}$

Right fleet angle $(\tan \beta) = \frac{B}{L}$

Drum Fleet Angles
(a)



Left total fleet angle $(\phi L) = \alpha$ – helix angle

Right total fleet angle $(\phi R) = \beta$ + helix angle

Total Drum Fleet Angle
(b)

Fig. 10
Drum Fleet Angles

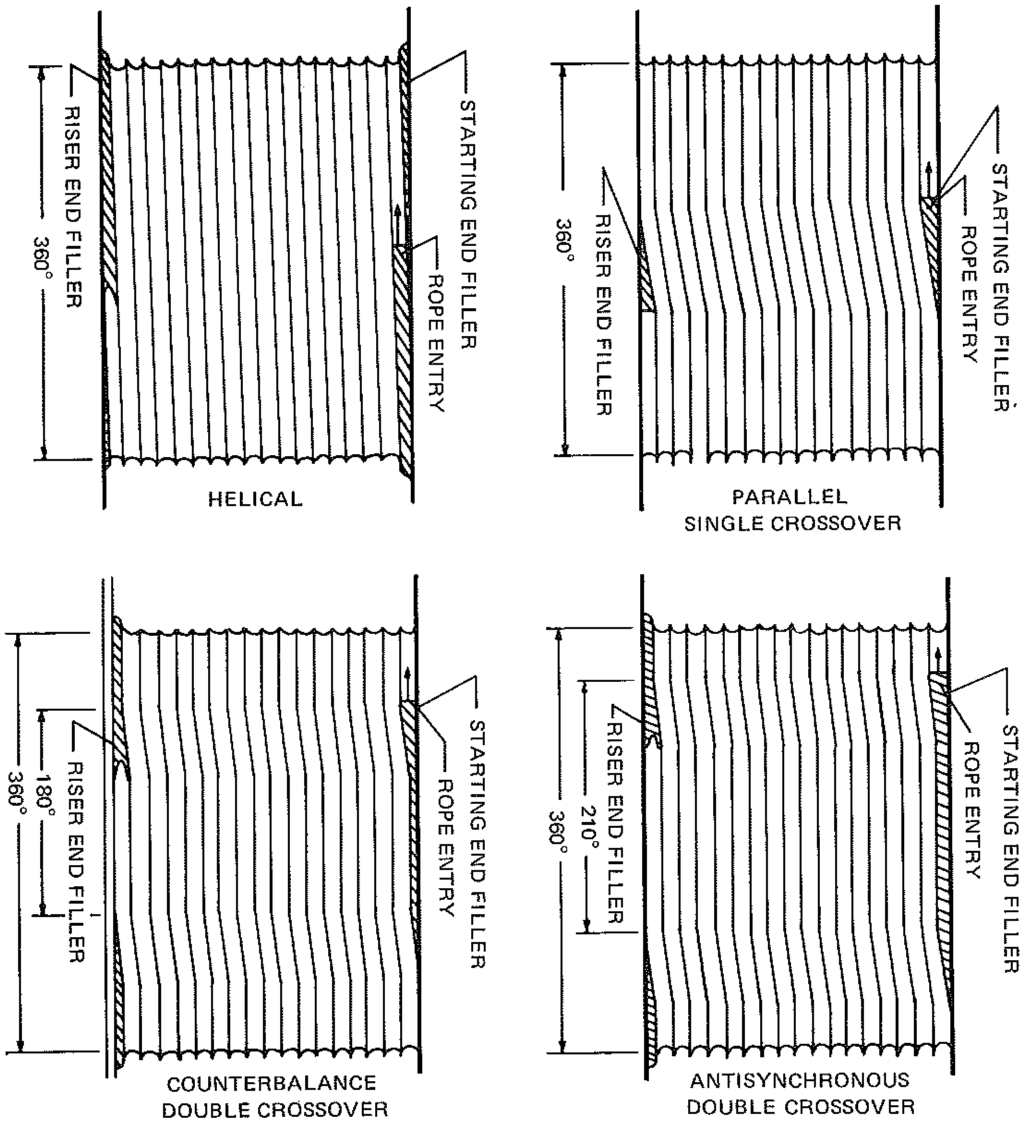


Fig. 11
Basic Methods of Wire Rope Spooling

recommended 1.5°. The formula for the total fleet angle that will cause minimum contact is given as follows:

$$\tan \phi = \frac{X}{\sqrt{Y^2 + Y(D + d)}}$$

where

$$X = \frac{3h - \sqrt{h^2 + 8d^2}}{2}$$

$$Y = \sqrt{d^2 - (X - h)^2}$$

D = Drum diameter in inches
d = Rope diameter in inches
h = Groove pitch in inches

This equation applies only when the lead rope is pulled toward the adjacent wrap, as in the total fleet angle shown in Fig. 10(a).

4.1.3.5 Spooling

4.1.3.5.1 General. Spooling is sometimes called coiling, reeving, or winding. There are three basic methods of spooling or coiling wire rope on a drum (see Fig. 11). They are (1) helical, (2) parallel single crossover, and (3) parallel double or two crossover. There are also variations of these three methods induced by the design of end-filler strips – both starting and rising – and by the location of crossover sections. These methods can be used on grooved or ungrooved drums by properly designing the end-filler strips –

both starting and rising types. See Appendix F for further information regarding rope-spooling methods.

4.1.3.5.2 Tailored Cutoffs of Wire Rope. When spooling wire rope on any hoist drum using any of the three basic methods of spooling, a good wire rope pull-in or cutoff program should be used. It is important that the critical wire rope points on the drum be moved frequently; such critical points include (1) the load pickup position, (2) crossover areas, and (3) riser points. Since these critical areas differ with each type of spooling system, the cutoff program should be worked out with the assistance of an engineer from the equipment or wire rope manufacturer. The time interval between cutoffs should be frequent enough to keep broken wires to a minimum, with no excessive flattening of the wire rope in any of the critical areas. The average frequency between cutoffs or pull-ins for most mine hoists is 90 to 120 days. The frequency varies with the use and size of the hoist and can be established by good inspection practices.

4.2 Friction Hoist Ropes

4.2.1 Design Factors

4.2.1.1 General. The calculated design factors for friction hoist ropes as given in 4.2.1.2 through 4.2.1.4 shall apply for both service hoists and production hoists. Static loads are used in the calculation of design factors.

4.2.1.2 Friction Hoist Ropes. For the purpose of this section, the design factor of a shaft hoisting rope is the value obtained by the following formula:

$$\text{design factor} = 7.0 - 0.0005\, l$$

where

l = maximum suspended rope length in feet

A design factor of 5.0 shall be the minimum for a suspended rope length of 4000 feet or longer.

4.2.1.3 Tail (Balance) Ropes. The design factor for tail (balance) ropes shall be a minimum of 7.0.

4.2.1.4 Guide and Rubbing Ropes. The design factor for guide and rubbing ropes shall be a minimum of 5.0.

4.2.2 Total Force on Hoist Ropes. The total force acting on a hoist rope is composed of static and dynamic components. Static forces are composed of the following:

(1) Mass of suspended rope
(2) Mass of conveyance and attachments
(3) Mass of payload
(4) Mass of tail rope

Dynamic forces are composed of the following:

(1) Acceleration forces
(2) Deceleration forces
(3) Dynamic bending stresses
(4) Forces due to winding, vibration, and oscillation
(5) Forces due to loading and unloading conveyances
(6) Forces due to friction acting on the conveyance, the rope guiding devices, and the support rollers. See 4.1.2.1.

Appendix E describes how to calculate the total forces acting on friction hoist ropes.

4.2.3 Tail (Balance) Ropes – Weights per Foot. Swivels should be used on both ends of tail ropes only where tail sheaves are used. Where tail ropes are not guided by tail sheaves, they shall be prevented from looping by using a suitable device such as a timber divider.

The weight per foot of tail rope(s) should normally be equal to the weight per foot of the hoist rope(s) being balanced.

4.2.4 Guide and Rubbing Ropes

4.2.4.1 General. Guide ropes are used for guiding the conveyance or counterweight (or both). Guide ropes are typically stiffer than hoist ropes and tail ropes; half locked coil or full locked coil constructions are normally used.

4.2.4.2 Guide Rope Selection. Individual shaft conditions should govern the selection of guide ropes. The rope diameter will depend upon the depth of the shaft and the tension load required.

4.2.4.3 Harmonic Resonance. Tension of the individual guide ropes shall be varied to prevent harmonic resonance.

4.2.4.4 Galvanized Guide Ropes. Guide ropes can be furnished galvanized or bright.

4.2.4.5 Exclusion of Used Rope. Used hoist ropes shall not be used as guide ropes.

4.2.4.6 Rubbing Ropes. Rubbing ropes are used primarily to give added protection against accidental contact between two adjacent conveyances within a shaft. Information covering guide ropes also applies to rubbing ropes with the exception that rubbing ropes should be tensioned slightly more than guide ropes.

4.2.5 Equipment

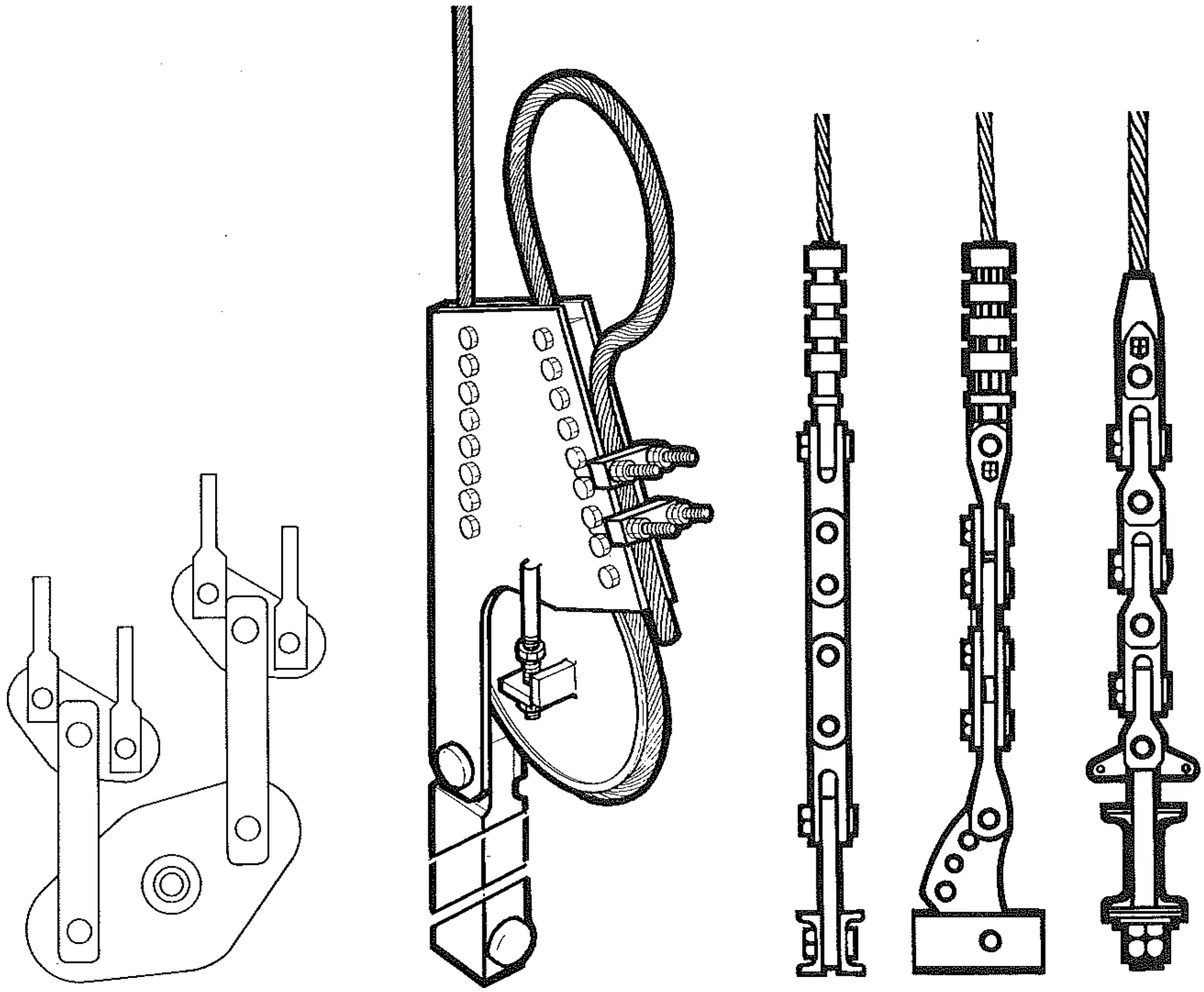
4.2.5.1 Ratios of Sheave and Wheel-to-Rope Diameters. The tread diameter of the sheave or wheel (drum) divided by the diameter of the rope (D/d ratio) governs the design of the head sheave, the hoist wheel, and the deflection sheave.

4.2.5.2 D/d Ratios – Vertical Shaft Ropes

(1) For flattened strand hoist ropes, the D/d ratio shall not be less than 80 times the rope diameter.

(2) For locked coil ropes, the D/d ratio shall not be less than 100 times the rope diameter.

4.2.5.3 Influence of Deflection Sheaves. The D/d ratio shall be increased if the distance between the hoist wheel and the deflection sheave is less than 200



Rope Balance
(a)

Adjustable Short Coupled Thimble
(b)

Adjustable Links
(c)

Fig. 12
Tension Equalizers for Friction Hoist Ropes

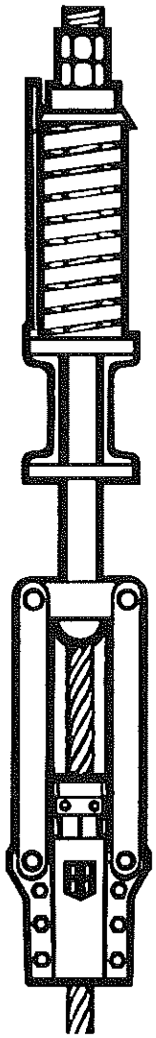
times the diameter of the hoist rope: For stranded rope, the D/d ratio increases +10%; for locked coil rope, the D/d ratio increases +25%.

4.2.5.4 **Special Applications.** Some mine equipment must utilize sheave and drum diameter factors that are smaller than those for primary vertical and slope-shaft hoists in order to achieve the necessary portability, reduction in weight, economy of design, etc. The minimum D/d ratios for these special applications are listed in Table 4.

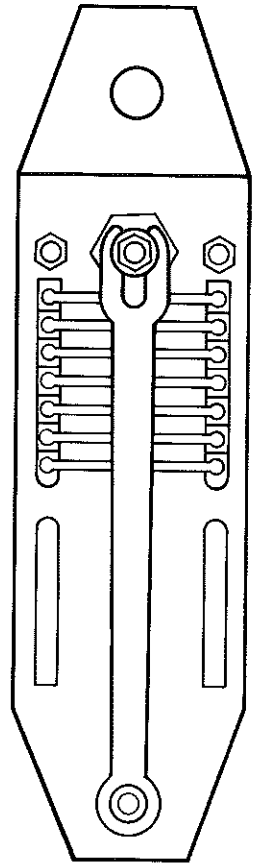
4.2.5.5 **Friction Hoists – Effective Wheel Groove-Diameter.** In order for the ropes of a multi-rope friction hoist to distribute the load evenly during a complete hoisting cycle, each revolution of the wheel must advance the same amount of rope for each of the grooves. The amount of rope advanced is dependent upon the circumference of the groove, the rope diameter, and the elasticity of the friction material in the groove. Suggested procedures for the measurements and adjustment of rope grooves of multirope friction hoists can be found in Appendix G.

4.2.5.6 **Friction-Hoist Tread Regrooving.** The rope-tread material is normally regrooved from time to time to true up the rope grooves and to maintain equal rope tensions. Various types of regrooving tools can be used for this purpose so long as they are the correct size for the hoist ropes.

4.2.5.7 **Load Deviation.** See Fig. 12. The force



Spring Tension
Guide Rope
(d)



Hydraulic Tension
(e)

Fig. 12 (*Continued*)

on a single hoist rope of a multirope friction hoist should not deviate more than ±10% from the average force during any part of a hoisting cycle. Several methods of load compensation can be used. Among these are:

(1) Adjustment links
(2) Compensation with hydraulic cylinders
(3) Compensation with a rope balance

4.2.5.8 **Measurement of Load Distribution in Hoist Ropes and Adjustment of Wheel Groove Diameters.** A procedure for measuring the load distribution and the differences in rope lengths for multirope friction hoists is given in Appendix H. Load distribution should be checked weekly using the wave-measurement technique. When necessary, rope-length adjustments using adjusters for each rope should be made, preferably at each attachment point of the conveyance (or counterweight). Uneven load distribution is caused either by differences in effective wheel groove diameters or by differences in the length of the hoist ropes. Uneven load distribution due to differences in wheel groove diameters can be minimized by their regular control and adjustment.

4.2.5.9 **Installation.** There are many considerations that must be made when installing, replacing, and recapping friction hoist ropes. Consult the equipment manufacturer for recommended methods. See Appendix I for one method.

4.3 Incline Shaft (Slope) Drum Hoist Ropes

4.3.1 Design Factors. The calculated design factors for incline shaft (slope) drum hoist ropes shall apply for both service hoists and production hoists. Static loads are used in conjunction with design factors. For the purpose of this section, the design factor of an incline shaft (slope) hoist rope is the value obtained by the following formula:

$$\text{design factor} = 7.0 - 0.001\, l$$

where

l = Maximum suspended distance in feet of the inclined plane (slope)

A design factor of 4.0 shall be the minimum for a suspended rope length of 3000 feet or longer.

4.3.2 Total Force on Slope-Hoist Ropes. (See Appendix E). The total load on a wire rope hauling a load on an incline or slope is dependent upon the following factors:

(1) Pitch (grade) of the incline
(2) Gravity components
  (a) Load (car and ore)
  (b) Rope weight
(3) Friction
  (a) Friction of the conveyance (against rails, etc)
  (b) Friction of the rope (against roller, etc)
(4) Whether the load is subject to acceleration or deceleration

4.3.3 Equipment

4.3.3.1 Ratios of Sheave and Drum Diameters to Rope Diameter. The tread diameter of the sheave or drum divided by the diameter of the rope (D/d ratio) governs the design of the hoist drum, the head sheaves, and the deflection sheaves.

4.3.3.2 D/d Ratio for Slope Shaft Sheaves and Drums. The D/d ratio shall not be less than 60 times the rope diameter for all rope constructions.

4.3.3.3 Special Applications. Some mine equipment must utilize sheave- and drum-diameter factors that are smaller than those for primary vertical and slope-shaft hoists in order to achieve the necessary portability, reduction in weight, economy of design, etc. The minimum D/d ratios for these special applications are listed in Table 4.

4.3.3.4 Groove Radius for Sheaves and Drums. It is essential that head, idler, knuckle, and curve sheaves have grooves that support the rope properly. Prior to installation of a new rope, the groove dimensions should be inspected and, where necessary, they should be machined to proper contour and groove radius in accordance with recommendations of the machine manufacturer. Groove radii should not be less than those cited in 3.4.1.

4.3.3.5 Slope Rollers.

4.3.3.5.1 General. Slope rollers prevent the rope from dragging on the ground or over ties, rails, or any object repeated contact with which would result in heavy rope abrasion. They should be used to support the rope only where the path of travel is straight and where the angle of vertical departure is less than 1°. Rollers should be spaced closely enough to support the rope properly, but should also be spaced at irregular intervals in order to minimize rhythmic vibrations in the rope.

4.3.3.5.2 Minimum Diameter – Slope Rollers. By making the diameter of slope rollers at least 9 times the nominal rope diameter, chattering, vibration, and pounding will be controlled to a great extent.

4.3.3.5.3 Minimum Diameter – Grooved Rollers. Grooved rollers should have a diameter at least 7 times the nominal rope diameter.

4.3.3.5.4 Roller Materials and Weights. Rollers should be as light in weight as practical in order that the effects of inertia can be avoided and in order that the rollers can thereby adapt themselves to the rope speed more readily. It is preferable to have rollers made of steel rather than cast iron. Operating conditions are improved by the use of a natural-rubber surface or synthetic rubber sleeves that make the rollers lighter, wear the rope to a lesser degree, and provide greater friction between the rope and the rollers.

4.3.3.6 Material of Sheaves and Drums. Thorough consideration should be given to the type of material of which sheaves and drums are made. To keep wear and groove corrugations to a minimum, it is desirable to give consideration to the radial pressure of the rope on sheaves and drums. Radial pressure is calculated as follows:

$$P = \frac{2T}{D \times d}$$

where

P = Radial pressure in pounds per square inch
T = Rope tension in pounds
D = Sheave or drum tread diameter in inches
d = Rope diameter in inches

See Appendix J for radial pressures for selected materials.

4.3.3.7 Drum Fleet Angle. See Fig. 10.

4.3.3.7.1 General. The fleet angle has a significant effect on the operational life of a rope because of the scrubbing that can occur against the sheave flanges. In the case of a rope winding on a drum, an incorrect fleet angle may not only increase rope scrubbing but may also lead to improper spooling. The drum fleet angle is shown in Fig. 10. This angle is controlled by the distance *L* between the head or first sheave axis and the drum axis, the location of the sheave centerline relative to the drum, and the width between drum flanges.

4.3.3.7.2 Maximum and Minimum Fleet Angle. The fleet angle on a drum can be either too large or too small. Care should be taken to avoid these extremes. To insure consistent and uniform winding, particularly at the transition from one rope layer to the next, the maximum fleet angle should not exceed 1.5° (except in the case of very large drum diameters, where the maximum allowable fleet angle may be somewhat less). To ensure that the rope will cross back and start each layer without piling up, the minimum fleet angle should be no less than 0.5°.

4.3.3.7.3 Helix Angle. If the rope is wound on the drum with a uniform helix, calculation of the maximum fleet angle must be modified to take the helix angle into account. The tangent of the helix angle is equal to the groove (or rope winding) pitch divided by the drum tread circumference. The actual fleet angle may be calculated, as in Fig. 10, by adding or subtracting the helix angle from the initially calculated fleet angle.

4.3.3.7.4 Total Fleet Angles. The total fleet angle should in most cases be kept within the maximum and minimum values recommended in 4.3.3.7.1. For large drums, the total fleet angle may be sufficient to cause the rope to scrub against the adjacent wrap on the drum, even when the fleet angle is less than the recommended 1.5°. The formula for the total fleet angle that will cause minimum contact is:

$$\tan \phi = \frac{X}{\sqrt{Y^2 + Y(D + d)}}$$

where

$$X = \frac{3h - \sqrt{h^2 + 8d^2}}{2}$$

$$Y = \sqrt{d^2 - (X - h)^2}$$

D = drum diameter in inches
d = rope diameter in inches
h = groove pitch in inches

This equation applies only when the lead rope is pulled toward the adjacent wrap, as in the total fleet angle of Fig. 10(a).

4.3.3.8 Spooling

4.3.3.8.1 General. "Spooling" is sometimes called coiling, reeving or winding. There are three basic methods of spooling or coiling wire rope on a drum (see Fig. 11). They are (1) helical, (2) parallel single crossover, and (3) parallel double or two crossover. There are also variations of these three methods induced by the design of end-filler strips – both starting and rising – and by the location of crossover sections. These methods can be used on grooved or ungrooved drums with use of properly designed end filler strips – both starting and rising. See Appendix F for further information regarding rope spooling methods.

4.3.3.8.2 Tailored Cutoffs of Wire Rope. When spooling wire rope on any hoist drum using any of the three basic methods of spooling, a good wire rope pull-in or cutoff program should be used. It is important that the critical wire rope points on the drum be moved frequently; such critical points include (1) load pickup position, (2) crossover areas, and (3) riser points. Since these critical areas differ with each type of spooling system, the cutoff program should be worked out with the assistance of an engineer from the equipment or wire-rope manufacturer. The time interval between cutoffs should be frequent enough to keep broken wires to a minimum, with no excessive flattening of the wire rope in any of the critical areas. The average frequency between cutoffs or pull-ins for most mine hoists is 90 to 120 days. The frequency varies with the use and size of the hoist and can be established by good inspection practices.

The usual procedure is to cut a length equal to 1-1/4 turns around the drum so that the crossover points and change of layers will be shifted from their previous location. On very large drums, 3/4 of a drum turn may be satisfactory.

4.3.3.9 Curve and Knuckle Sheaves for Slope Shafts. Where a slope makes a horizontal or vertical change in direction, the use of more than one sheave to guide the rope around the curve is sometimes required. The number of sheaves required is governed by the degree of curvature, the total curve angle of departure, and the necessity of placing the sheaves where there will be proper clearance. In general, it is preferable to use as few sheaves as possible and to use sheaves having the largest diameters that the space will allow.

4.4 Head Ropes for Shaft-Sinking Operations

4.4.1 Headropes

4.4.1.1 Minimum Design Factor for Free Loads. In shaft sinking, where lifting or lowering free loads using a single part line without guides is common practice, rotation resistant stranded rope shall be used. Examples of rotation resistant rope include: 19 X 7 rotation resistant rope (formerly known as nonrotating) and 8 X 19 rotation resistant rope (formerly known as spin resistance rope). A minimum design factor of 10.0 is recommended for these ropes. Static loads are used in conjunction with design factors.

4.4.1.2 Minimum Design Factor for a Suspended Platform. In shaft-sinking operations where a platform is suspended by wire ropes, such ropes shall have a minimum design factor of $7.0 - 0.001\ l$, where l is equal to the maximum suspended rope length in feet. A design factor of 4.0 shall be the minimum for a suspended rope of 3000 feet or longer. Static loads are used in conjunction with design factors.

4.4.2 Headrope Connecting Devices

4.4.2.1 Open Hooks. Open hooks shall not be used to hoist buckets or other conveyances.

4.4.2.2 Rope Connecting Devices. The rope connecting device between the hoist rope and the bucket, cage, skip, counterweight, or other device shall be of such a nature that the risk of accidental disconnection is reduced to a minimum.

4.5 Maintenance

4.5.1 Relief of Twist in Shaft Hoist Ropes. Newly installed shaft hoist ropes, particularly lang lay ropes, develop a torque or accumulation of lay toward the skip or cage attachment. The rigidity of the attachment may be sufficient to increase guide friction and cause uneven drum winding. This condition should be relieved by removing twist from the rope at the skip or cage attachment under controlled conditions. The twist should never be permitted to run out freely; to do so would prevent restoration of the rope to its original balance. Excessive removal of twist may further unbalance the rope and impair its operational characteristics and service life. The best technique for removing twist involves landing the skip or cage at a level near the halfway point in the shaft. Before detaching the rope, a bar should be placed through the thimble or socket in order to control the rope rotation or a special spinning crosshead should be utilized. If there is no halfway level in the shaft, position the skip or cage (1) at the shaft collar (preferably) or (2) at the bottom of the shaft. The amount of twist that should be removed at any one time should be limited preferably to not more than one 360° turn for each 100 feet of shaft depth. (The amount of twist will be less when the operation takes place at the collar.) It is better to repeat the operation a few times rather than risk unbalancing the rope by removing too many turns at one time. Care should be taken not to remove an excess of torque from a rope since this will result in loss of its ability to stretch and thus reduce its elasticity and strength.

After the skip or cage has been reconnected, it should be lowered to the bottom of the shaft and at least two complete trips should be made with no more than a light load to allow the change in lay to distribute itself throughout the entire length of rope.

4.5.2 Lubication. See Appendix K for lubrication information.

4.6 Inspection and Retirement of Rope Used in Underground Mining

4.6.1 Inspection. (See Section 3.11).

4.6.1.1 General. The decision concerning the proper time to retire a wire rope from service is difficult to make because of a significant lack of rope retirement criteria related to mining; the recommended inspection procedures of 3.11 and of 4.6.1.2 through 4.6.1.4 should, however, be followed.

4.6.1.2 Inspection to Detect Rope-Strength Degradation. Inspections should be performed to detect, and rope should be retired in the presence of, rope degradation in the following critical areas:

(1) At the head sheave, deflection sheaves, and curve and knuckle sheaves when the conveyance is at the dump and loading stations and at the top and bottom of the shaft and parking stations. This includes sheaves atop counterweights or above conveyances of any kind that are suspended with a multiple-part reeve.

(2) The section going onto and off the drum during acceleration from and braking to approach the above stations.

(3) The dead wraps, including those that become live during the rope's service life.

(4) At and near the drum spout (rope entrance into the drum).

(5) At drum crossovers.

(6) At drum change-of-layer regions.

(7) Near the conveyance end, in general, especially for ropes commonly disconnected from conveyances.

For friction hoists, inspections should be made for and rope should be retired in the presence of rope degradation just below the drive wheel and just below the deflection sheaves and head sheaves when the conveyance is at its highest normal station.

4.6.1.3 Other Inspections. See Appendix L. Visual inspecton should be performed to detect, and rope retirement should be considered in the presence of, the following conditions:

(1) Broken wires. (Inspection by touch, by using a cotton rag, is also advisable.)

(2) Severe reduction of rope diameter with an observable increase in rope lay.

(3) Corrosion on outer wire surfaces, in strand valleys, and in the vicinity of attachments.

(4) Structural damage such as kinks, doglegs, birdcages, loose or high strands, and a protruding core.

4.6.1.4 Nondestructive Testing (NDT) Techniques. Electromagnetic, nondestructive testing (NDT) devices of significant value are sufficiently developed and readily available for use in inspecting wire rope. They are sensitive to broken wires and to the loss of metallic area through wear, peening, and corrosion. During inspection with these devices, ropes are usually run at speeds of 200 to 300 feet per minute; such speeds significantly reduce the time required for an inspection relative to that required for a thorough inspection using conventional manual/visual procedures. Nondestructive testing devices should only be regarded as supplementary tools and should be used only as an adjunct to visual inspection. The procedure should be as follows:

(1) Obtain an NDT record for new ropes after the initial constructional stretch has occurred – typically after several days of use. These data are very important; they are the basis for comparing subsequent NDT data as for all practical purposes they indicate the condition of the rope when new.

(2) Periodically obtain other NDT data as the rope is used. By comparison with the original record compiled in step (1), convert the new data to estimates of the rope strength or strength loss in weakening areas. How often these tests need to be made must be determined for each installation. The objective is to obtain enough data to establish the degradation-versus-time pattern with some confidence. Initially, at least, NDT inspection is suggested every 4 months over the life of a rope. With experience and confidence, NDT inspection could be less frequent but should be done at least once every 6 months.

(3) After each NDT test, visually examine the rope wherever the NDT record indicates a developing weakness or an obvious peculiarity; record the observations.

(4) Consider removal of the rope if the results of NDT testing indicate a strength loss of 10% or more at any point, whether or not anything is visible at those points. This is a signal to start watching the condition of the rope more closely.

(5) Consider removal of the rope if the rope design factor computed using the rope strength estimated from the NDT data reaches or goes below the recommended minimum design factors for removal. See 4.1.1, 4.2.1 and 4.3.1.

It is good practice, in conjunction with the use of NDT devices, to perform tensile tests of new and retired ropes to failure. Especially important in this regard are breaking tests for sections of retired ropes that are shown by NDT data to be the weakest points in these ropes. Actual breaking-strength values provide a data base with which to compare the strength estimated from NDT data; such comparisons provide a continuing basis for instrument improvement and a means by which confidence in the technique can be obtained.

4.6.2 Retirement Criteria

4.6.2.1 Causes for Rope Retirement. The following are causes for removal of wire rope:

(1) *Visible Wire Breaks.* More than six randomly distributed broken wires on one rope lay or three broken wires in one strand in one rope lay.

(2) *Worn Wires.*

(3) *Evidence of Loss of Strength.* An estimation of from 10%–25% loss of rope strength (based upon measurements of rope diameter, wear pattern dimensions, corrosion, and the number of broken wires), estimated with a series of charts and graphs; charts and graphs may be provided by a wire rope or equipment manufacturer. Electromagnetic or other nondestructive testing devices may be used as a supplement but not as a substitute for recommended inspection and tests.

(4) *Evidence of Rope Abuse.* The following are typical evidences of rope abuse: a kink (a pulled-out twisted loop); a dogleg (a simple, permanent bend); a birdcage (strands separated and ballooned out); loose or high strand(s); a badly out of round section; a crushed or flattened section with abraded or broken wires; loose or looped wires with no visible breaks; a protruding core; a local section with an unusually small diameter; or a local section with an unusually short or unusually long lay length. It should be noted that these conditions are all evidence of *radical* changes – that is, constructional upsets – in the structure of the rope. Removal is not required if the abuse can be removed by an end cut.

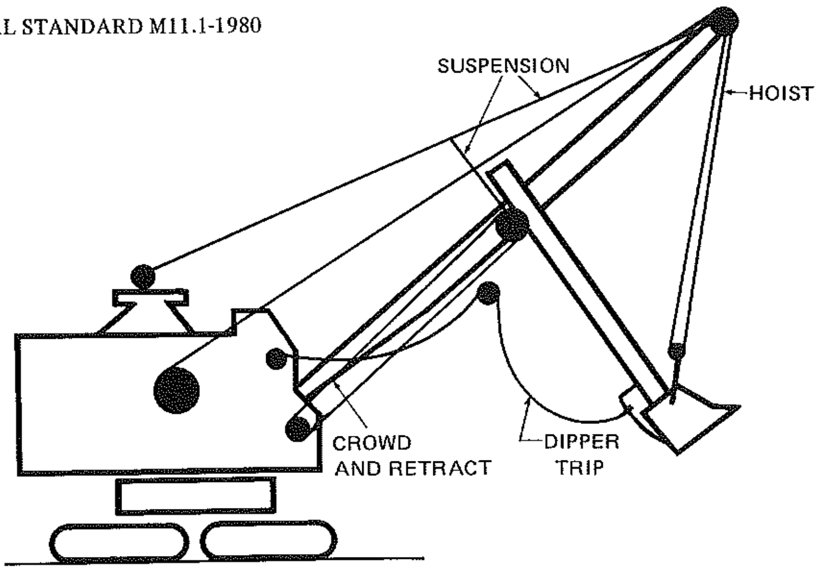
5. Surface Mining – Selection, Usage, Maintenance, Inspection, and Removal of Wire Rope Used on Surface Mining Machines

5.1 Scope – Inclusions and Exclusions

5.1.1 Machines Covered. The requirements of this section cover machines used in the surface excavation or in the stockpiling of overburden, coal, ore, sand and gravel, stone, or other minerals.

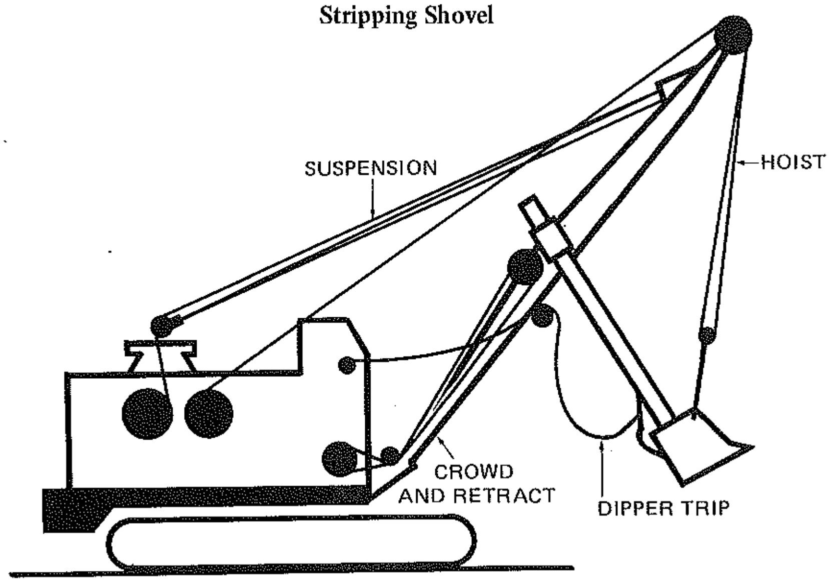
5.1.2 Machines Not Covered. The requirements of this section do not cover machines used in the initial development of a surface mine property or in the construction and maintenance of road and track systems, drainage systems, and the like; machines used in the transport, storage, stockpiling, or recovery of a partially refined product on a surface mine property; or machines used in the land reclamation of mined-out areas.

5.1.3 Machine Types and Rope Designations. The types of machines frequently used in surface-mining operations, and the rope required by them, are shown in Fig. 13 through 28. American National Standards that cover other types of machines and equipment in common use are listed in 1.4.



NOTES:
(1) Shovels with rack and pinion crowds
(2) Shovels with boom hoist (removed)
(3) Shovels with counterbalance ropes

Fig. 13
Stripping Shovel



NOTES:
(1) Shovels with rack and pinion crowds
(2) Shovels with rope or strand suspension
(3) Shovels with boom hoist removed

Fig. 14
Shovel

5.2 Wire Rope Recommendations. For wire rope construction generally used in mining operations, their available sizes, and their nominal strengths, consult wire rope industry catalogs.

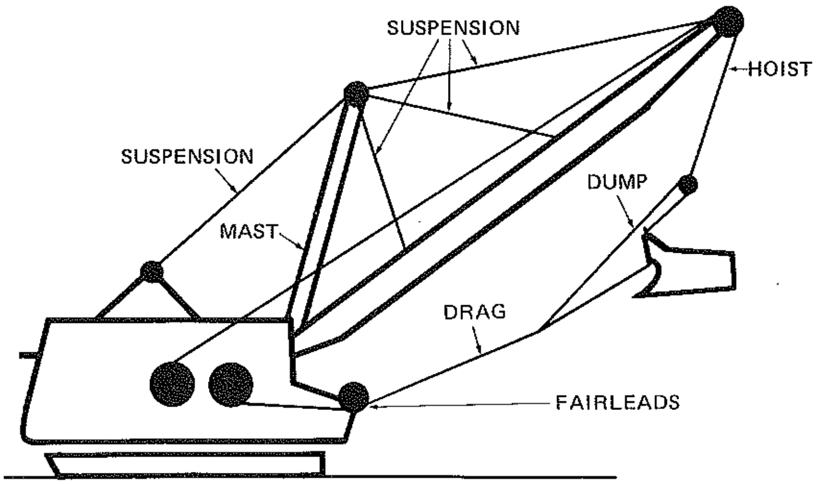
5.3 Design Factors for Wire Rope Used on Surface Mining Machines

5.3.1 Definition. The design factor for wire ropes used on surface mining machines is obtained by dividing the nominal strength of the rope by the static load on the rope.

5.3.2 Load on Rope. See 5.3.3.

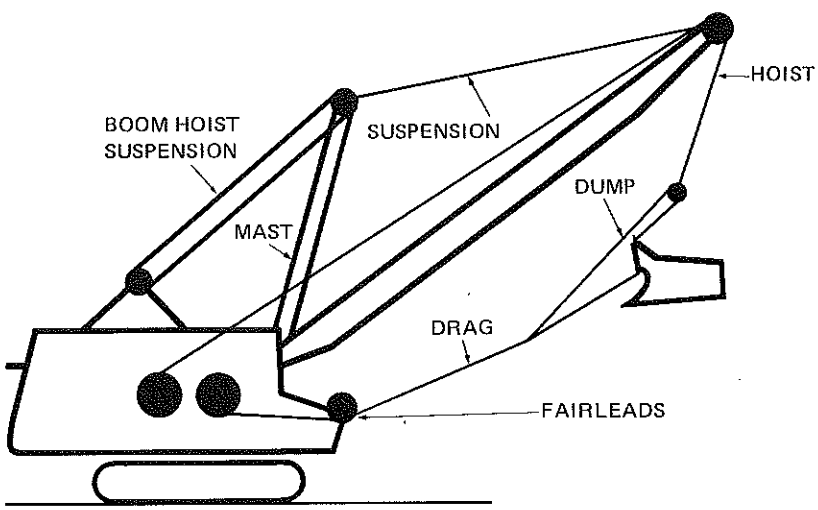
5.3.3 Minimum Design Factors

5.3.3.1 General. Table 3, Column I, lists the minimum design factors for the wire ropes used on surface mining machines. In Table 3, Column I, the load (static) designated (A) is the load imposed on a rope by the static weight of the structure and the live load;



NOTES:
(1) Draglines without masts
(2) Draglines without suspension
(3) Draglines with boom hoist removed

Fig. 15
Walking Dragline



NOTES:
(1) Draglines without masts
(2) Draglines without boom hoist suspension

Fig. 16
Crawler Dragline

the load (stall) designated (B) is the load imposed on a rope by the maximum stall force from the power source.

5.3.3.2 **Variations from Minimum Design Factors**

5.3.3.2.1 **Nonequalized Rope Systems.** When two nonequalized rope systems are used to stabilize a structure or an implement, the design factors of Table 3 should be increased in accordance with the probable load distribution.

5.3.3.2.2 **Equalized Rope Systems.** When two equalized rope systems support an applied load, the design factors of Table 3 should be adjusted in accordance with the effectiveness of the equalization.

5.4 Ratios of Drum and Sheave Diameters to Rope Diameters.

5.4.1 **Definition.** The diameter of the sheave or drum divided by the diameter of the rope (D/d ratio) governs the design of the hoist drum, the head sheaves, and the deflection sheaves, where

D = *pitch* diameter (centerline to centerline of rope) on drum or sheave
d = *nominal* diameter of rope

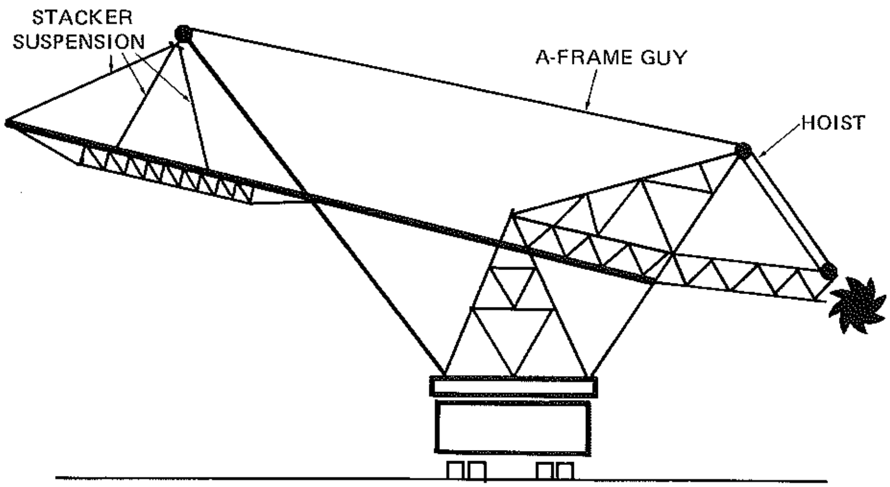


Fig. 17
Stripping Wheel

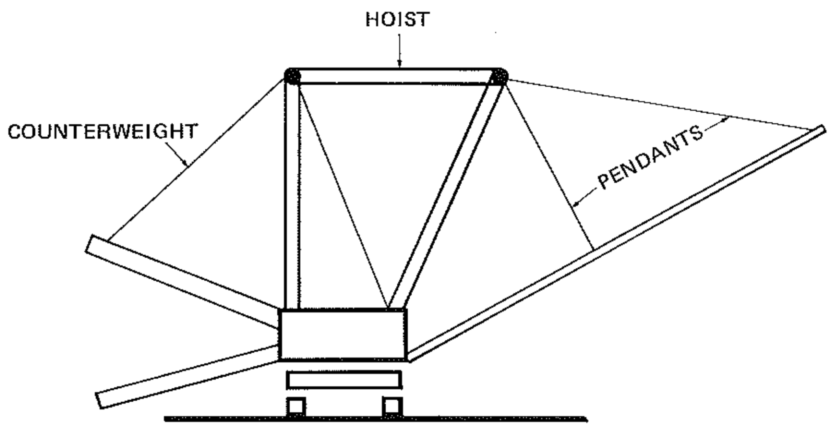


Fig. 18
Stacker

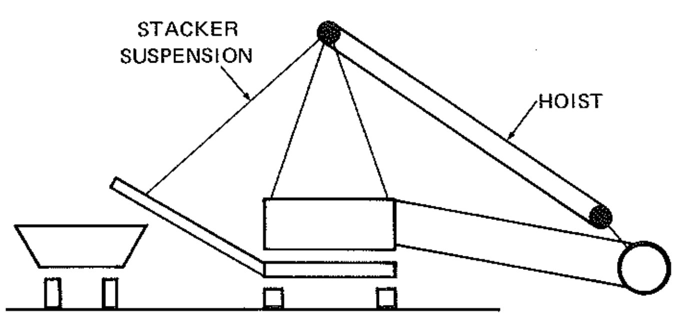


Fig. 19
Loading Wheel

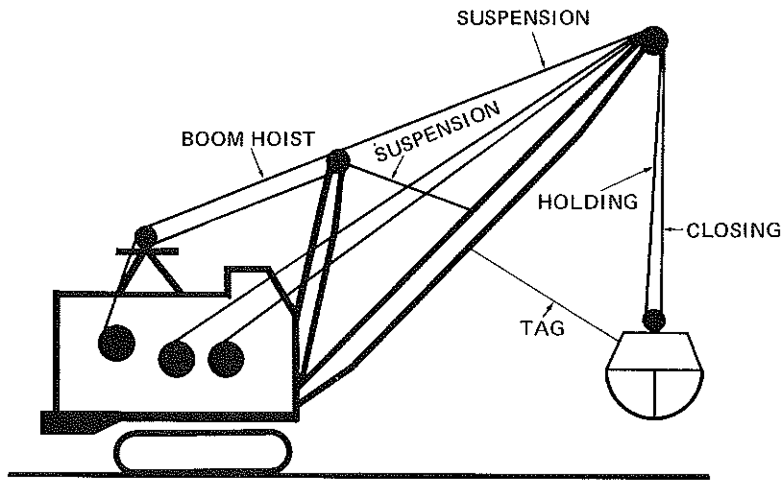
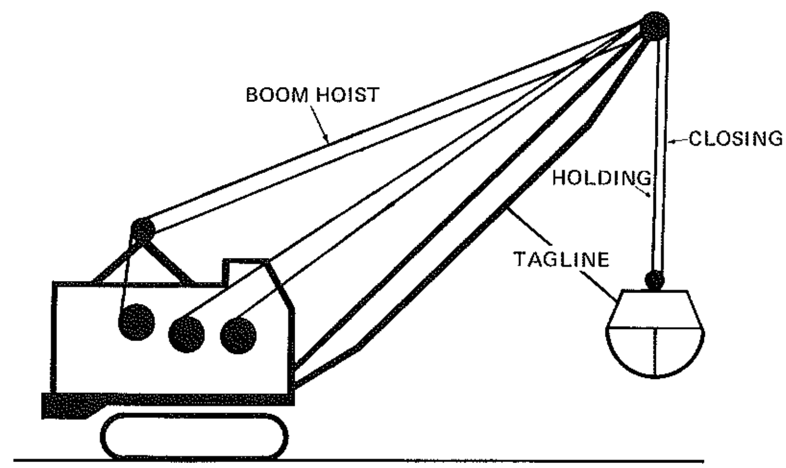


Fig. 20
Mining-Type Clamshell



NOTE: Clamshells with strand suspensions

Fig. 21
Construction-Type Clamshell

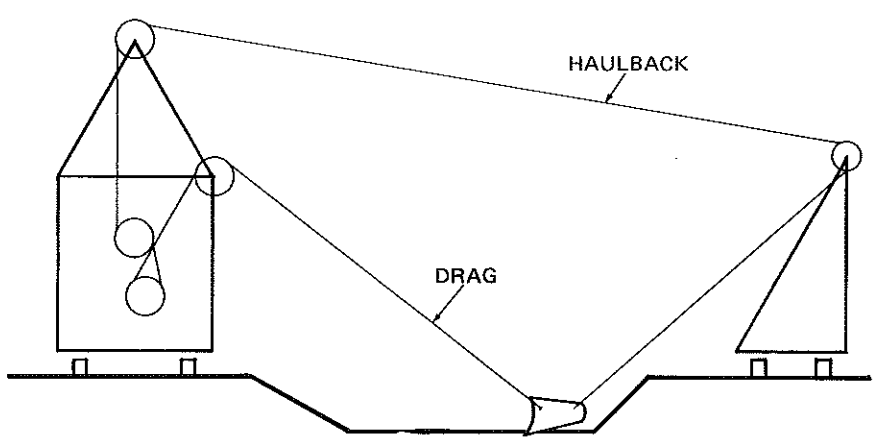


Fig. 22
Tower Excavator

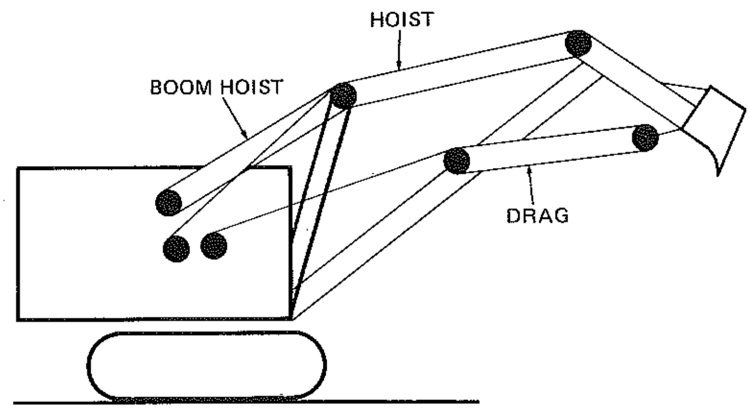


Fig. 23
Hoes

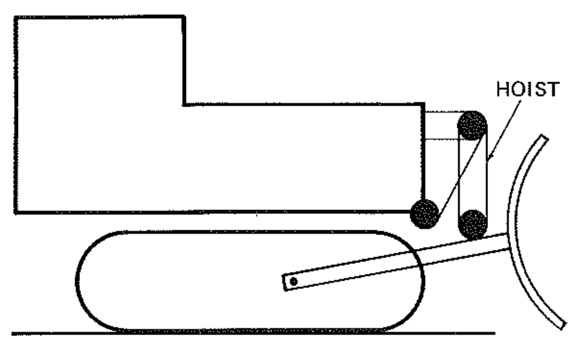


Fig. 24
Bulldozer

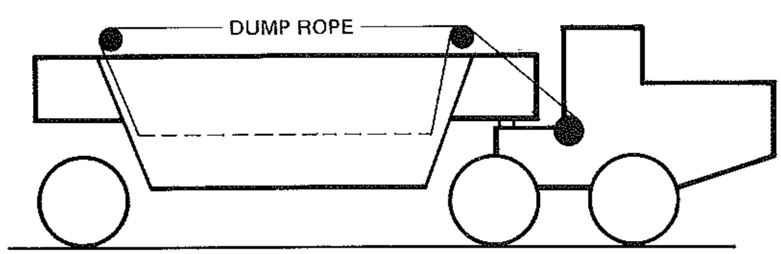
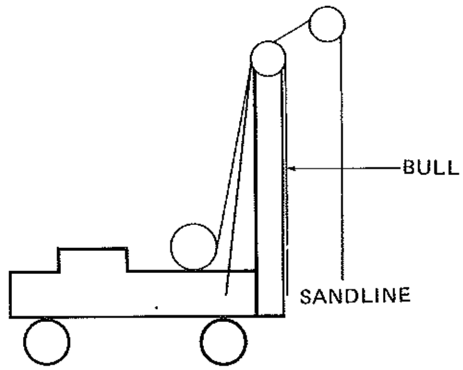
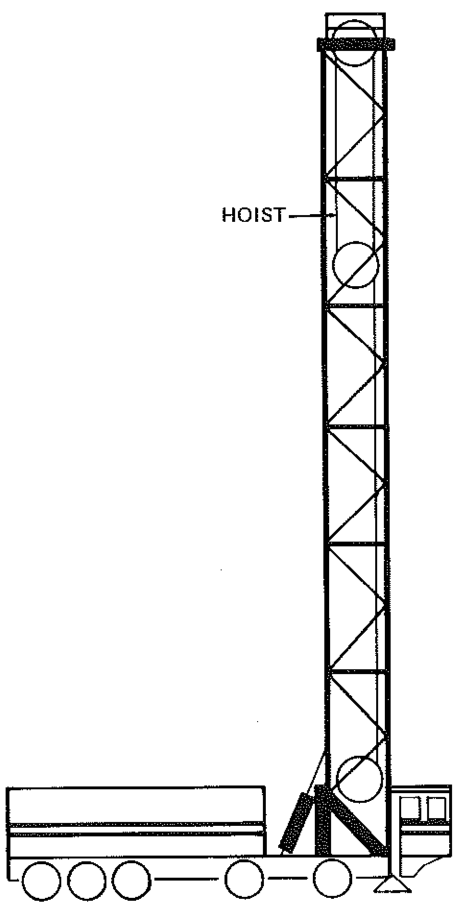


Fig. 25
Dump Wagon



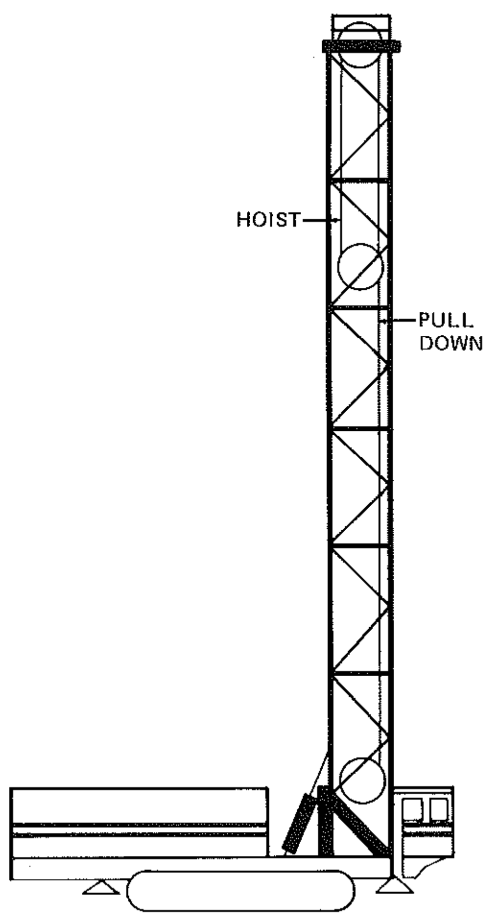
NOTE: Cable tool drillers with casing lines.

Fig. 26
Cable Tool Well Drill



NOTES:
(1) Blast hole drillers with sandline
(2) Blast hole drillers with auxiliary hoists

Fig. 27
Blast Hole Drill – Wheel Mounted



NOTE: Blast hole drillers with sandline

Fig. 28
Blast Hole Drill

5.4.2 Minimum D/d Ratios. Table 3, Column II, lists minimum D/d ratios for drums and sheaves used on surface mining machines. These values are minimum values and should only be used in situations where it is absolutely necessary to reduce machine size for operation in restricted spaces, to reduce machine weight for mobility over ground that provides limited support, or to achieve economy of design. Larger D/d ratios should be used wherever possible.

5.4.3 Fairlead. See Appendix M for typical fairlead designs. The D/d ratios for deflecting sheaves and idler sheaves or for rollers can be less than those shown in Table 3, Column II, if space limitations are severe; larger D/d ratios will lead to increased rope life.

5.5 Minimum Dead Wraps on a Drum.

5.5.1 General. Table 3, Column III, lists the minimum number of wraps that should remain on the drum for a rope used without cutoff and resocketing or for a rope that is cutoff and resocketed one or more times while in service.

5.5.2 Conditions Appropriate for Less than One Dead Wrap on a Drum. Rope systems may be operated with fewer than one effective dead wrap remaining on the drum only when there is positive control of rope payout, as in the case of limit switches, crowd stops, and similar devices where the rope termination on the drum is as efficient as the one used on the working end of the rope.

5.5.3 Deviation from Minimum Wraps. Any other deviation from the minimum dead wraps as specified in Table 3, Column III, shall be in accordance with the equipment manufacturer's recommendation.

5.6 Drum Fleet Angle and Sheave Off-Lead

5.6.1 General. Most surface mining machines are mobile units that are frequently required to operate in restricted spaces and on ground that provides limited support; overall dimensions and weight are critical to the performance of their assigned tasks. For some rope systems, it is not always possible to locate the first lead sheave far enough from the drum to achieve a low drum fleet angle and to achieve low sheave off-leads.

5.6.2 Drum Fleet Angle. (See Fig. 10). When the distance between the drum and the sheave is short, grooved drums are used for continuously operating ropes; these drums spool the entire rope length in a single layer. In some cases, increased groove pitch may reduce chafing between the lead rope and wraps on the drum.

5.7 Types of Wire Rope End Attachments and Drum Anchors Commonly Used on Surface Mining Machines. See Fig. 29. The approximate efficiences of end attachments are listed in Appendix A.

5.8 Lubrication of Wire Rope. Lubrication is a vital maintenance activity because it protects wire rope from corrosion. Lubrication also maintains the flexibility that is necessary in normal usage of wire rope. For guidance regarding lubrication procedures, follow the equipment manufacturer's instructions. See Appendix K for further information.

5.9 Inspection and Retirement of Wire Rope Used on Surface Mining Machines

5.9.1 Appointed Person. Each surface mine shall provide for inspection of wire ropes and structural strands by an appointed person (or persons) who is responsible for reporting and for retaining a record of the findings of such inspections. See Appendix N for suggested reporting forms.

5.9.2 Inspection Procedures. An inspection procedure should be established for each wire rope application on surface mining machines. Procedures will differ depending on the operating conditions, the severity of service, and the environment.

5.9.2.1 Frequency of Inspection. The frequency of inspection shall be established on the basis of operating shifts, days, weeks, or months, depending on anticipated rope life.

5.9.2.2 Average Rope Life. An average rope life shall be established based on the number of cycles the rope has operated, or on the volume or weight of material the rope has handled, depending on which of these best represents the rope's service.

5.9.2.3 Increased Inspection Frequency Due to Abuse of Rope. More frequent inspection is advisable for operations which cause ropes to be dragged over rocks or through abrasive material, to be struck by falling rocks, or to be subject to similar abuse when such conditions cannot be avoided.

5.9.3 Visual Evidence of Rope Degradation. In addition to the regularly scheduled inspection, the machine's operating personnel should report any visual evidence of rope degradation, such as:

(1) Severe abrasion, scrubbing, peening, or kinking, or broken outer wires

(2) Crushing, or other damage that distorts the rope's structure

(3) Severe reduction of rope diameter or an observable increase in rope lay

(4) Bird-caging or other distortion indicating uneven distribution of load between rope strands

(5) Evidence of severe corrosion, particularly in the vicinity of attachments

(6) Uneven stretch of multiple ropes

(7) Evidence of heat damage from a torch or arcing from contact with an electrical conductor

(8) A rapid increase in the number of broken wires

(9) Lack of lubrication

5.9.4 Regularly Scheduled Inspections.

5.9.4.1 Equalizer and Tackle Sheaves. Rope damage may develop at equalizer sheaves and at sheaves in tackles that are stationary during operation. Particular care should be taken to inspect ropes at these points. If practical, a stationary tackle should be used to move the rope enough to expose, for better inspection, sections of rope normally in contact with sheaves.

5.9.4.2 Rope System Components. The conditions of drum and sheave grooves should be inspected and reported..Other parts contacted by the rope, as well as the condition of sheave bearings and sheave/rope alignment, should also be reported so that maintenance or replacement may be scheduled in advance of critical deteriorations.

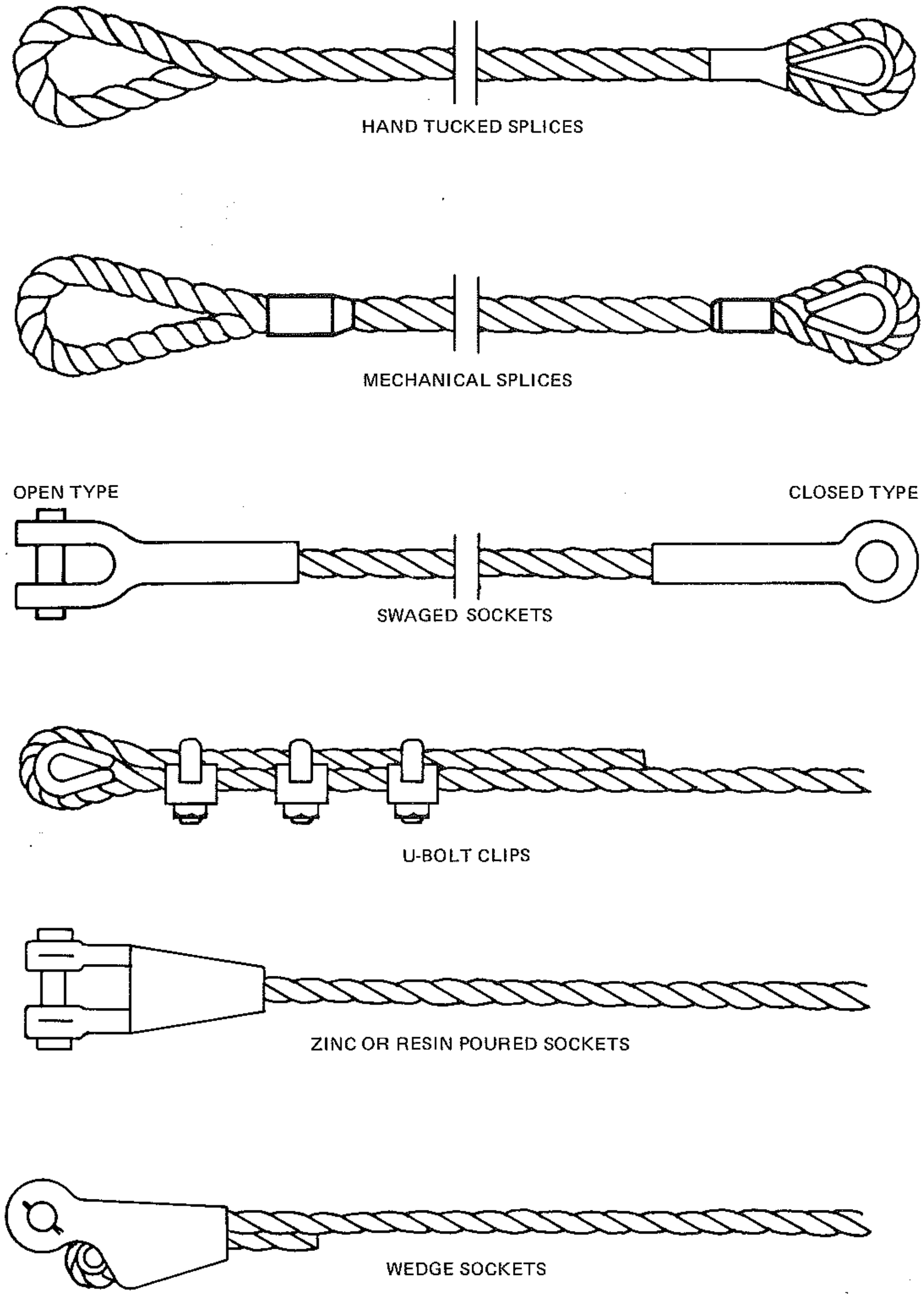
5.9.5 Inspection During Installation; Equalizer Movement. When a new rope is installed, it shall be inspected to insure that it is reeved according to the manufacturer's specifications. See 3.3 for inspection procedures to be followed during installation of new rope.

If the equalizer approaches the end of its travel, the ropes should be readjusted.

5.9.6 Inspection to Determine the Need for Rope Cutoffs and Rope Reversals. Premature failure of a rope due to damage at an end attachment may be prevented in some cases by cutting off and resocketing the rope or by turning the rope end for end. In some cases, regularly scheduled rope cutoffs and resocketing or rope reversal will be beneficial. (See further discussion under 3.9 and 3.10.)

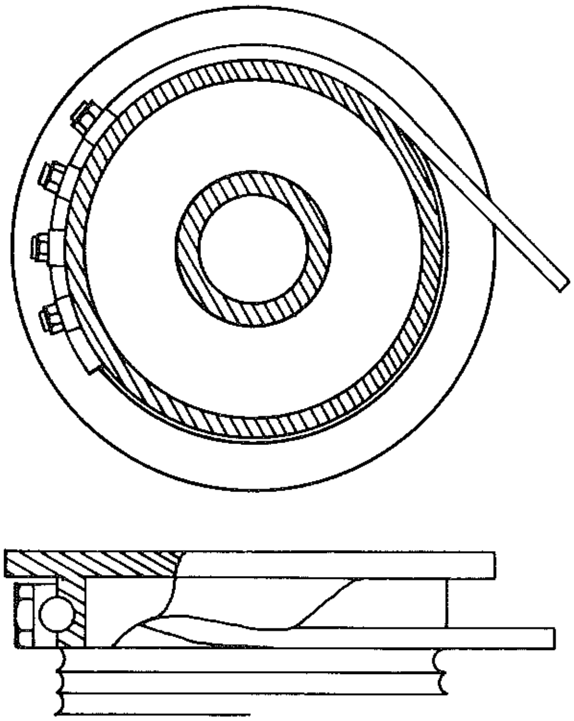
5.9.7 Replacement of Structural Strand. Replacement of a structural strand in a multiple-strand system should be based on the average deterioration of all strands in the system rather than on the deterioration of a particular strand.

5.9.8 Reuse of End Attachments. Reuseable attachments should be inspected for wear or other damage before they are installed.

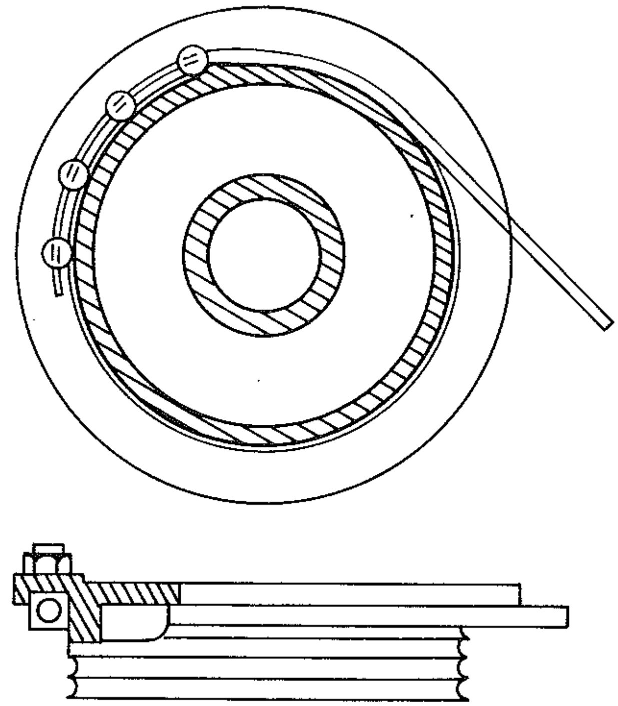


NOTE: The approximate efficiencies of end attachments are listed in Appendix A.

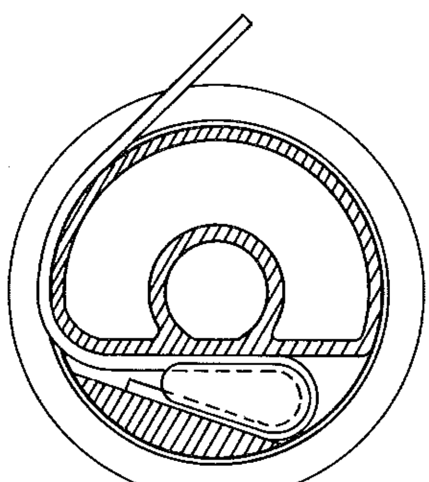
Fig. 29
Wire Rope End Attachments and Drum Anchors Commonly used on Surface Mining Machines



CLAMPS



ANCHOR BOLTS



WEDGE

Fig. 29 (*Continued*)

Appendixes

(These Appendixes are not a part of American National Standard for Wire Rope for Mines, ANSI M11.1-1979, but are included for information purposes only.)

Appendix A
Terminal Efficiency Ratings
Based on Nominal Rope Strengths and Static Loading

Efficiency Rating of End Attachments

Not all end attachments develop the full strength of the wire rope. Through extensive testing, the wire rope industry has determined the terminal efficiencies for the various types of end attachments; see Table A1. With this table of efficiencies, the holding power of the more popular end fittings can be calculated for any size, grade, and construction of wire rope.

Table A1
Terminal Efficiency Ratings
Based on Nominal Rope Strengths and Static Loading

	Approximate Efficiency	
Method of Attachment	IWRC Rope*	FC Rope†
Zinc-poured or resin poured wire rope socket	100%	100%
Swaged socket		
(regular lay ropes)	95–100%	(Not Established)
Mechanical splices		
1 inch in diameter and smaller	95%	92-1/2%
1-1/8 inches through 1-7/8 inches in diameter	92-1/2%	90%
2 inches in diameter and larger	90%	87-1/2%
Hand-tucked splices		
1/4 inch in diameter	90%	90%
5/16 inch in diameter	89%	89%
3/8 inch in diameter	88%	88%
7/16 inch in diameter	87%	87%
1/2 inch in diameter	86%	86%
5/8 inch in diameter	84%	84%
3/4 inch in diameter	82%	82%
7/8 inch through 2-1/2 inches in diameter	80%	80%
Wedge sockets and cappels		
(consult manufacturer)	75 to 90%	75 to 90%
Rope clips†		
(U-bolt or fist grip)		
(Number of clips varies with size of rope)	80%	80%

*IWRC = Independent Wire Rope Core
† FC = Fiber Core
‡Typical values when properly applied. Consult manufacturer for exact values.

Appendix B

Wire-Rope Clips – U-Bolt Type

The following method of application is recommended in order to obtain maximum holding power from the a U-bolt clip.

(1) Turn back the specified amount of rope from the thimble. (See Appendix C for an illustration of turnback.) Apply the first clip one base width from the dead end of the wire rope. The U-bolt must be placed over the dead end of the rope; the clip saddle or base must be placed over the live end of the rope. Tighten nuts evenly to recommended torque.

(2) Apply the next clip at the junction of the loop. Turn nuts firmly but do not tighten.

(3) Space additional clips, if required, equally between the first two. Turn nuts, take up rope slack, and then tighten all nuts evenly on all clips to the recommended torque.

(4) Note! Apply the initial load and retighten the nuts to the recommended torque. Rope will stretch and thus shrink in diameter when loads are applied. Periodically inspect and retighten the nuts.

A termination made in accordance with the above instructions and using the number of clips shown in Table B1 has an efficiency rating of approximately 80%. This rating is based upon the nominal strength of wire rope. If a pulley is used in place of a thimble for turning back the rope, add one additional clip.

The number of clips shown in Table B1 is based upon using right regular or lang lay wire rope, 6 X 19 class or 6 X 37 class, fibre core or IWRC, IPS or EIP. If Seale construction or similar large-outer-wire-type construction in the 6 X 19 class is used for sizes 1 inch and larger, add one additional clip.

The number of clips shown in Table B1 also applies to right regular lay wire rope, 8 X 19 class, fibre core, IPS, sizes 1-1/2 inch and smaller; and the right regular lay wire rope, 18 X 7 class, fibre core, IPS or EIP, sizes 1-3/4 and smaller.

For other classes of wire rope not mentioned above, it may be necessary to add additional clips to the number shown in Table B1.

IMPORTANT: Failure to make a termination in accordance with the aforementioned instructions, or failure to periodically check and retighten to the recommended torque, will cause a reduction in the efficiency of the end attachment.

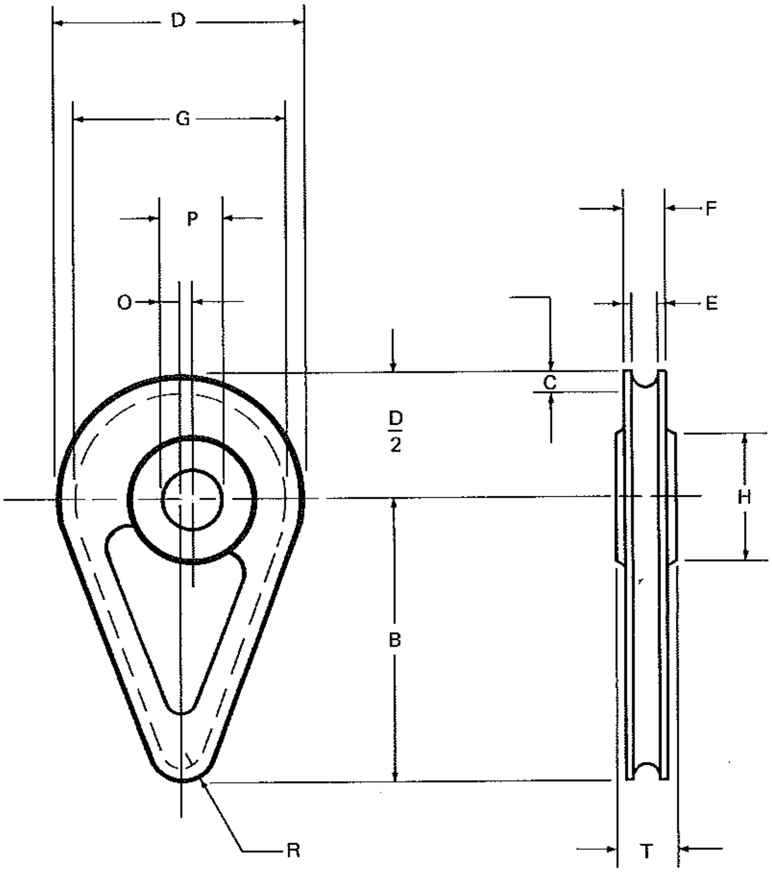
Table B1
Wire-Rope Clips – U-Bolt Type

Clip Size	Minimum Number of Clips*	Amount of Rope to Turn Back	Torque (lb_f)	Weight (Pounds per 100 Clips)
1/8	2	3-1/4	4.5	5
3/16	2	3-3/4	7.5	9
1/4	2	4-3/4	15	18
5/16	2	5-1/4	30	30
3/8	2	6-1/2	45	42
7/16	2	7	65	70
1/2	3	11-1/2	65	75
9/16	3	12	95	100
5/8	3	12	95	100
3/4	4	18	130	150
7/8	4	19	225	240
1	5	26	225	250
1-1/8	6	34	225	310
1-1/4	6	37	360	460
1-3/8	7	44	360	520
1-1/2	7	48	360	590
1-5/8	7	51	430	730
1-3/4	7	53	590	980
2	8	71	750	1340
2-1/4	8	73	750	1570
2-1/2	9	84	750	1790
2-3/4	10	100	750	2200
3	10	106	1200	3200

*If a greater number of clips are used than shown in the table, the amount of rope turnback should be increased proportionately. *The figures above are based on the use of clips on new rope.*

Appendix C

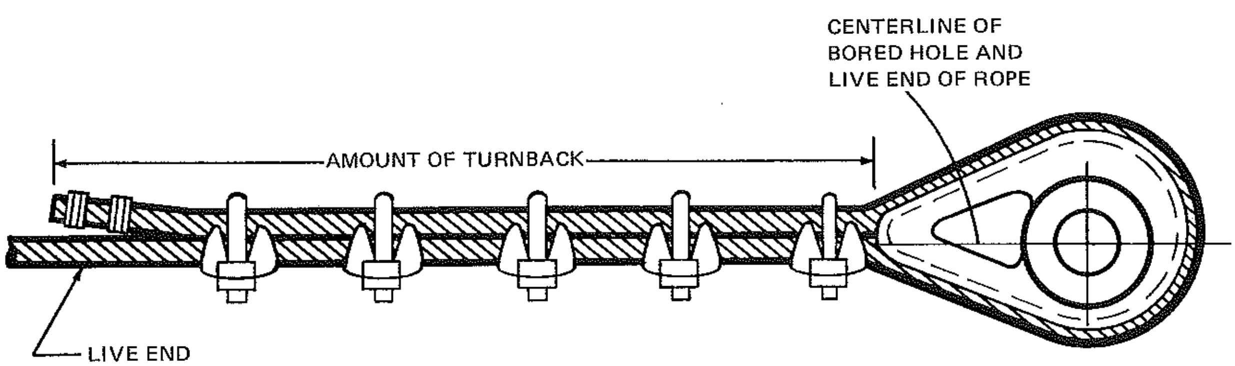
Standard Shaft Hoist Thimble Clip Attachment



P = 2.0 X diameter
G = 8.0 X diameter
D = 9.5 X diameter
B = 11.0 X diameter
O = 0.5 X diameter
R = 1.25 X diameter
E = 1.06 X diameter
F = 1.75 X diameter
C = 0.75 X diameter
T = 2.0 X diameter
H = 4.5 X diameter

NOTES:
(1) Dimensions vary with manufacturer.
(2) Diameter refers to nominal diameter of wire rope with which the thimble will be used.

STEEL CASTING SHAFT HOIST THIMBLE



NOTE: Number of clips required, amount of turnback and torque valves, and other application information on U-Bolt clips is shown in Appendix B.

INSTALLATION OF CLIPS AND THIMBLES

Appendix D

Procedure for Thermoset Resin Socketing of Wire Rope

D1 General

Before proceeding with thermoset resin socketing, the manufacturer's instructions for using this product should be carefully read. Particular attention should be given to sockets that have been designed specifically for resin socketing.

D2 Seizing and Cutting the Rope

The rope manufacturer's directions for a particular size or construction of rope should be followed with regard to the number, position, length of seizings, and the seizing wire size to be used. The seizing which will be located at the base of the installed fitting must be positioned so that the ends of the wires to be embedded will be slightly below the level of the top of the fitting's basket. Cutting the rope can best be accomplished by using an abrasive wheel.

D3 Opening and Brooming the Rope End

Prior to opening the rope end, place a short temporary seizing directly above the seizing that represents the base of the broom. The temporary seizing is used to prevent brooming the wires the full length of the basket and also to prevent the loss of lay in the strands and rope outside the socket. Remove all seizings between the end of the rope and the temporary seizing. Unlay the strands comprising the rope. Starting with the IWRC, or strand core, open each strand of the rope and broom or unlay the individual wires.

NOTE: A fiber core in the rope may be cut at the base of the seizing; some prefer to leave the core in. Consult the manufacturer's instructions.

When the brooming is completed the wires should be distributed evenly within a cone so that they form an included angle of approximately 60°. Some types of sockets require a different brooming procedure and the manufacturer's instructions should be followed.

D4 Cleaning the Wires and Fittings

Different types of resin with different characteristics require varying degrees of cleanliness. For some, the use of a soluble oil for cleaning wires has been found to be effective. For one type of polyester resin on which over 800 tensile tests on ropes in sizes 1/4 to 3-1/2 inches in diameter were made without experiencing any failure in the resin socket attachment, the cleaning procedure was as follows:

Thorough cleaning of the wires is required to obtain resin adhesion. Ultrasonic cleaning in recommended solvents such as trichloroethlylene or 1-1-1 trichloroethane or other non-flammable grease-cutting solvents is the preferred method of cleaning the wires in accordance with OSHA Standards. Where ultrasonic cleaning is not available, brush or dip-cleaning in trichloroethane may be used; but fresh solvent should be used for each rope and fitting and discarded after use. After cleaning, the broom should be dried with clean compressed air or in some other suitable fashion before proceeding to the next step. The use of acid to etch the wires before resin socketing is *unnecessary and not recommended.* Also, the use of a flux on the wires before pouring the resin should be avoided since *this adversely affects bonding of the resin to the steel wires.* Since there is a variation in the properties of different resins, the manufacturer's instructions should be carefully followed.

D5 Placement of the Fitting

Place the rope in a vertical position with the broom up. Close and compact the broom to permit insertion of the broomed rope end into the base of the fitting. Slip on the fitting, removing any temporary banding or seizing as required. Make sure the broomed wires are uniformly spaced in the basket with the wire ends slightly below the top edge of the basket; make sure that the axis of the rope and the fitting are aligned. Seal the annular space between the base of the fitting and the existing rope to prevent leakage of the resin from the basket. A nonhardening butyl rubber-base sealant gives satisfactory performance. Make sure that the sealant does not enter the base of the socket so that the resin may fill the complete depth of the socket basket.

D6 Pouring the Resin

Controlled heat-curing (*but without open flame*) at a temperature range of 250°–300° F is recommended – and is essential if ambient temperatures are less than 60° F. When controlled heat curing is not available and ambient temperatures are not less than 60° F, the attachment should not be disturbed and tension should not be applied to the socketed assembly for at least 24 hours.

D7 Lubrication of Wire Rope after Socket Attachment

After the resin has cured, relubricate the wire rope at the base of the socket to replace the lubricant that was removed during the cleaning operation.

D8 Description of the Resin

D8.1 General. Resins vary considerably according to the manufacturer; it is important to refer to manufacturer's instructions before using resins as no general rules about them can be established.

Properly formulated thermo-set resins are acceptable for socketing. These resin formulations, when mixed, form a pourable material that hardens at ambient temperatures or upon the application of moderate heat. No open-flame or molten-metal hazards exist with resin socketing since heat-curing, when necessary, can only be carried out at a relatively low temperature (250°–300° F) that can be supplied by electric-resistance heating.

Tests have shown satisfactory wire rope socketing performance by resins having the properties of a liquid thermoset material that hardens after mixing with the correct proportion of catalyst or curing agent.

D8.2 Properties of Liquid (Uncured) Material. Resin and catalyst are normally supplied in two separate containers, the complete contents of which, after thorough mixing, can be poured into the socket basket. Liquid resins and catalysts should have the following properties:

(1) *Viscosity of Resin–Catalyst Mixture.* The viscosity of the resin–catalyst mixture should be 30 000–40 000 CPS at 75° F immediately after mixing. Viscosity will increase at lower ambient temperatures and resin may need warming prior to mixing in the catalyst if ambient temperatures drop below 40° F.

(2) *Flash Point.* Both resin and catalyst should have a minimum flash point of 100°F.

(3) *Shelf Life.* Unmixed resin and catalyst should have a minimum of one-year shelf life at 70° F.

(4) *Pot Life and Cure Time.* After mixing, the resin–catalyst blend should be pourable for a minimum of eight minutes at 60° F and should harden in 15 minutes. Heating of the resin in the socket to a maximum temperature of 250° F is permissible to obtain full cure.

D8.3 Properties of Cured Resin

(1) *Socket Performance.* Resin should exhibit sufficient bonding to solvent-washed wire in typical wire rope end fittings to develop the nominal strength of all types and grades of rope. No slippage of wire is permissible when testing resin-filled rope socket assemblies in tension; however, after testing, some "seating" of the resin cone may be apparent and is acceptable. Resin adhesion to wires shall also be capable of withstanding tensile shock loading.

(2) *Compressive Strength.* The minimum compressive strength for fully cured resin should be 12 000 lb/in^2.

(3) *Shrinkage.* Fully cured resin may shrink a maximum of 2%. The use of an inert filler in the resin is permissible to control shrinkage if the viscosity provisions specified for the liquid resin in D8.2(1) are met.

(4) *Hardness.* A desired hardness of the resin is in the range of Barcol 40–55.

D9 Resin Socketing Compositions

Manufacturer's directions should be followed in handling, mixing, and pouring the resin composition.

D10 Performance of Cured Resin Sockets

Poured resin sockets may be moved when the resin is hardened. After the ambient or elevated temperature cure recommended by the manufacturer, resin sockets should develop the nominal strength of the rope unless tested at mine ambient temperature, and should also withstand shock loading sufficient to break the rope without cracking or breakage. Resin socketing materials that have not been tested to these criteria by the manufacturer should not be used.

Appendix E
Calculating Total Forces on Hoist Ropes

E1 General

Since many states have statutory regulations that govern design factors for hoist ropes, static loading conditions are usually known to a fair degree of accuracy. Apart from confirming the fact that a satisfactory design factor exists, however, the static loading conditions cannot give any indication of the suitability of the rope in use.

This appendix is intended as a guide for a simple method of estimating the total forces involved for both static and dynamic loads.

E2 Static Loads

The maximum static tension in a hoisting rope usually exists in the section of rope positioned (1) on a headsheave in the case of a drum hoist or a ground-mounted friction hoist or (2) on the driving sheave of a tower-mounted friction hoist. This tension (T_1) is due to:

(1) The weight of the conveyance and attachments (W_c)

(2) The weight of the load in the conveyance (W_L)

(3) The weight of suspended rope (or ropes) (W_R)

Thus $T_1 = W_c + W_L + W_R$ and the design factor is calculated as follows:

$$\text{design factor} = \frac{\text{nominal strength}}{W_c + W_L + W_R}$$

E3 Dynamic Loads

When the mass consisting of the conveyance and attachments, the load in the conveyance, and the weight of the suspended rope(s) is accelerated upwards away from the bottom of the shaft, static tension is increased by an additional acceleration force which is proportional to the rate of acceleration. However, because the rope is an elastic medium, the conveyance will oscillate vertically in the shaft on the end of the rope and its reactive acceleration will vary from that of the drum (which for all practical purposes can be considered constant).

Experience with reactive conveyance acceleration in shafts indicates that the variation in conveyance acceleration is usually from 50% to 150% of the drum or mean acceleration; for calculation purposes, the latter value must be used, as follows:

Increase in tension due to acceleration

$$= \frac{T_1 \times a \times 1.5}{g}$$

where
a = The average drum acceleration
g = The gravitational constant

Therefore the total tension (T_2) at the headsheave will become

$$T_2 = T_1 + \frac{T_1 \times a \times 1.5}{g}$$

$$= (W_c + W_L + W_R)\left(1 + 1.5\,\frac{a}{g}\right)$$

E4 Bending Loads

As the rope is bent over the headsheave or drum, an additional force is induced that must be added to the static- and dynamic-tension calculations to obtain the total force imposed. There are many methods of calculation for determining bending force, although the one most commonly used is:

$$\text{bending force} = \frac{E \times d \times A}{D}$$

where
E = Elastic Modulus as given in Table E1
d = Diameter of outer wire in rope
A = Area of rope as given in Table E2
D = Diameter of sheave or drum

Table E1
Approximate Moduli of Elasticity of Wire Rope

	Pounds per Square Inch
6 Strand Ropes	10 000 000 to 14 000 000
8 Strand Ropes	8 000 000 to 10 000 000
Structural Strand with Wire Core	14 000 000 to 16 000 000
Structural Strands	16 000 000 to 19 000 000
Structural Strands (Pre-Stretched)	22 000 000 to 25 000 000

Table E2
Approximate Metallic Area of Wire Rope

Rope Construction	Approximate Metallic Area (square inches)
6 X 7	$0.380d^2$
6 X 17	$0.385d^2$
6 X 19 Seale	$0.395d^2$
6 X 21 Filler Wire	
6 X 19 Warrington	$0.405d^2$
6 X 25 Filler Wire	
6 X 37	$0.400d^2$
6 X 25 Flattened Strand Style "B"	$0.400d^2$
6 X 30 Flattened Strand Style "G"	$0.440d^2$
8 X 19	$0.352d^2$

NOTES:
(1) Metallic area of a wire rope or strand is the sum of the cross sectional areas of the individual wires of which it is made.
(2) Add 15% for IWRC – 6 Round Strand Ropes
Add 20% for WSC – 6 Round Strand Ropes
Add 10% for IWRC – Flattened Strand Ropes

Experience under laboratory conditions shows that the fatigue limit of hoisting ropes is about 25% of the actual breaking load when taking into account the summation of the static and dynamic loads and the bending force. It must be pointed out that this value for bending force is of no value in itself, but should only be used in conjunction with the static- and dynamic-load values.

The total load in the rope being bent over the headsheave or drum under acceleration conditions will be:

$$\text{Total load } T_3 = (W_c + W_L + W_R)\left(1 + 1.5\ \frac{a}{g}\right) + \frac{E \times d \times A}{D}$$

To obtain the maximum life in a shaft under normal conditions, this value should be less than 25% of the actual breaking load of the rope.

It should be recognized that the fatigue life of a rope can be seriously affected by corrosion or excessive wear. Therefore, satisfactory lubrication and good mechanical conditions are also extremely important in maximizing rope life.

E5 Incline Haulages

The tension in the haulage rope on an incline is due to two factors: (1) the gravitational pull on the total weight of the rope and load and (2) the frictional resistance to motion of these two masses.

The gravitational force here is dependent upon the gradient: the steeper the incline, the greater is the tension in the rope. For accurate calculations, the sine of the angle of gradient must be taken into account, but for all practical purposes, the ratio of vertical rise to horizontal travel need only be considered.

For all but very steep inclines, it may be assumed that the values of both car and rope friction are constant; unless actual values are known it is suggested that the following figures are used:

Car friction: 2.5% of total car weight
Rope friction: 10% of rope weight

In addition, an extra load will be imposed on the rope when the system is accelerated, and a further increase of 10% should be allowed for rope speeds up to a maximum of 9.8 feet per second. For higher rope speeds, the increased acceleration force should be more accurately calculated.

In cases where the gradient is variable along the length of haul, the tension should be calculated with the cars on each gradient, making due allowance for the length of rope coiled on the drum. For endless haulages, a further load is also applied to the rope by the tension weight; this further load should be considered as a pre-load on the system.

When the cars are traveling down the incline, the calculated values for friction should be subtracted from the gravitational forces.

Appendix F

Rope Spooling Methods

F1 Ungrooved Drum Spooling

Wire rope should be attached at the correct location on an ungrooved drum in order that the wire rope will spool evenly, with the turns lying snugly against each other in even layers. If the rope is wound on an ungrooved drum in the wrong direction, turns in the first layer will tend to spread apart on the drum. This causes the second layer of rope to wedge between the open coils, thus crushing and flattening the rope as successive layers are spooled.

The method illustrated in Fig. F1 may be used to determine the proper direction of rope lay for spooling or winding on flat or smooth face drums.

If an ungrooved drum has been cut or scored by a previous rope or ropes, the method shown may not apply. In such cases, the equipment or wire rope manufacturer should be consulted.

Spooling wire rope on a plain drum is more difficult and less advantageous than on grooved drums, except where frequent changes in wire rope sizes are necessary, in which case plain drum spooling can be advantageous. In all cases, care must be taken to ensure the rope is properly spooled and tight on the drum and extra wire rope must be used as dead wraps. Where more than one layer is spooled, a full layer of dead wraps should be used so the wire rope can be used to form the groove and groove pattern for the upper layers to spool upon. In this case, parallel single crossover type spooling using a properly designed starting and riser end filler with the correct crossover for the drum size and rope construction is recommended. The drum width should be made to accommodate the exact number of wraps of wire rope being used; on drums already in service, this can be done by using flange plates to make the width of the drum equal to an exact number of rope diameters.

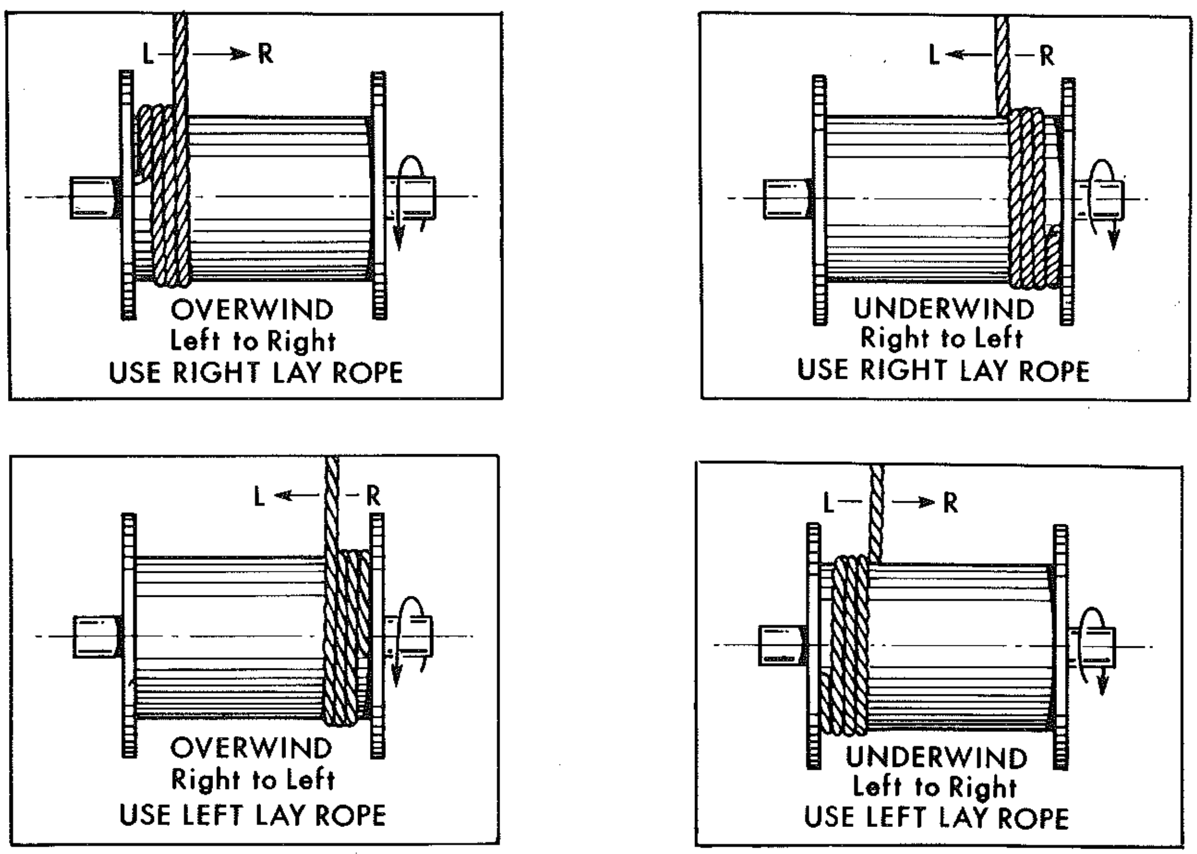


Fig. F1
Spooling on Ungrooved Drums

When spooling on and off a plain drum in a single layer, use helical-type spooling with a properly designed starting helical end filler. To prevent the wire rope from opening or separating between coils, a wire rope of the opposite lay to the hand of spooling should be used.

F2 Grooved Drums

All three basic spooling methods can be used on grooved drums with continuous groove patterns. Grooves can be attached to the drum by bolting or welding or both. The grooves on a drum serve three specific functions: (1) They set the pattern by which the wire rope will spool; that is, a helical pattern or parallel single crossover or parallel double crossover type; (2) they establish the proper spacing of the wire rope; and (3) they support the wire rope with a groove deep enough to give proper support. See 3.4.1.

F3 Groove Pitch

The groove pitch is the distance between the centerlines of the grooves or the spacing of the wire rope centers along the drum. The pitch is very important to proper spooling and wire rope service and must be selected based upon rope size, drum width and diameter, number of layers of wire rope to be spooled, fleet angle, and use of the hoisting application. For instance, when a single layer is used, helical grooving is recommended using a groove pitch of the maximum rope size plus clearance for fleet angle and groove helix angle. In multilayer spooling using parallel single or double crossover type grooving, the pitch of the grooves is reduced to match the wire rope and the application of the hoist. For mine hoists, the pitch is usually equal to the maximum size of the wire rope. For proper guidance, the equipment manufacturer should be consulted.

F4 Groove Depth

The groove depth should make a 130° contact angle with the groove. Since continuous grooving can now be achieved, it is no longer necessary to use a shallow groove with parallel single or double crossover spooling. A shallow groove is best used only with helical or spiral grooves where single-layer spooling is used; even then, however, rope service will not be as good as on a drum with proper groove depth.

F5 Helical Grooving

The pattern formed by helical grooving resembles that formed by the threads of a screw – that is, helical grooving forms a helical path upon which the rope can progress across the drum at a uniform rate. It spirals one rope diameter with each revolution of the drum either to the right or left. Helical grooving is recommended when a single layer of rope is to be used. Since the advancement of the rope is uniform and smooth, the wire rope is less likely to develop whip or harmonic motion between the drum and the head frame sheave. Helical grooving also lends itself to high-speed spooling.

On the other hand, helical grooving is not recommended for multilayer spooling due to the necessity of spooling the second layer against the helix formed by the first layer. This causes the cable to cross over the rope below it twice, each time moving forward at 1/2 pitch and then backing up with the helix and moving forward again at 1/2 pitch in order to advance one diameter, thus inducing extra movement in the rope and often causing severe wire-rope whip between the drum and the head frame sheave. Since the second layer no longer spools in the path of a helix, the groove pattern for the third layer is not consistent and usually does not spool. Due to the long helix, one rope diameter per revolution, a long void is created at each flange making it possible for the third layer to drop to the second layer when spooling; this also causes the rope to misspool. In fact, due to misspooling and wire rope whip, rope service is usually very poor when helical grooving is used for multilayer coiling.

F6 Parallel or Single Crossover Grooving

Parallel or single crossover grooving can be used for multilayer spooling. Since the rope spools most of one revolution (except for the crossover length) parallel to the flange, it must cross to the next pitch in a single movement. With parallel or single crossover grooving, this pattern of spooling can be retained for many layers; however, due to the movement of the rope induced by the crossover, it can also produce rope whip at high speeds. Single crossover spooling is more inclined to produce harmonic motion in the rope. As the rope rises from one layer to the next, it also crosses over two diameters of rope on the layer below, causing more wear to the crown wires in the rope than the double crossover system of spooling. Single crossover spooling has become obsolete with the development of counterbalance double crossover parallel grooving but is still a good method for multilayer spooling on a plain or ungrooved drum because of its simplicity and because the placement of end fillers to control the crossover section provide uniformity of wraps and, thus, spooling.

F7 Parallel Double Crossover Spooling, Counterbalance and Anti-Synchronous

Parallel double crossover spooling is similar to parallel single crossover spooling in that most of the rope is spooled parallel to the drum flanges. It differs in that the crossover is divided into two sections, 180 degrees apart, each crossing the rope 1/2 pitch. The significant feature of this design is that in each crossover area the rope crosses over one diameter of the wire rope below, thus reducing the severity of the wear on the lower ropes. It also reduces the side movement of the wire rope by one half, thus reducing the tendency to develop wire rope whip between the drum and the head frame. The basic pattern causes the rope to repeat its own spooling pattern and is thus ideal for multilayer spooling as well as for increased rope speeds. It is subject to harmonic motion but less severely so than with single crossover spooling.

In cases where harmonics are suspected to be a factor, antisynchronous double crossover parallel spooling can be used. It is the same as counterbalance spooling except the crossover sections are 150 degrees and 210 degrees apart rather than 180 degrees. Rope service can be expected to be the same with either method. For multilayer spooling the double crossover parallel type is preferred for better spooling, higher speeds, and best rope service.

Appendix G

Measuring and Adjusting Drum Groove Diameters on A Multiple Rope Friction Hoist

G1 Load Distribution

In order for the ropes of a multirope friction hoist to distribute the load evenly during a hoisting cycle, each revolution of the friction wheel must advance the same amount of rope for all grooves. This advance is dependent upon the circumference of the groove, the elasticity of the friction liner, and the rope diameter. In order to compensate for differences in rope diameter and in the elasticity of friction lining material, individual grooves are turned to different circumferences. As a result, the same average distance between the center line of the friction wheel and the center line of the individual ropes is attained and an equal amount of rope is advanced for each revolution of the friction pulley. The average distance between the center line of the friction wheel and the center line of the rope is sometimes referred to as the effective radius of the groove, and the effective diameter, respectively.

G2 Adjustment of Effective Radius

The following procedures should be used to determine if adjustment of the effective radius of the rope grooves is necessary:

(1) Hoist the main conveyance or skip to its normal minimum distance from the friction pulley.

(2) Move the conveyance to the middle of the shaft.

(3) Affix pieces of tape on all ropes at the same height adjacent to the friction wheel. See Fig. G1.

(4) Move the conveyance to the bottom of the shaft.

(5) Hoist the conveyance back to the middle of the shaft. See Fig. G2.

(6) Measure the height difference ΔL between the bottom mark and all other marks. The bottom mark corresponds to the smallest groove diameter on the friction wheel.

G3 Criteria for Effective Groove Adjustment

Adjustment of the effective groove radius is required when ΔL corresponding to the different depths of hoisting L exceeds the amount shown in Table G1. The minimum distance between the center line of the friction wheel and the top of the conveyance should be equal to that shown in the third column L_0.

G4 Procedures for Adjustment

If turning is required, the rope marks should first be moved so that the distance to the bottom mark will be one half of what it was for each rope. After this movement, the height difference between the marks will be zero when the conveyance is in its end positions.

For each of the grooves the difference in effective diameter can be calculated from the height difference ΔL and the following formula:

$$d - d_{min} = 1.4 \times \Delta L \times (D/L)$$

where

d = actual effective diameter in mm

d_{min} = minimum effective diameter in mm

D = friction wheel diameter in meters

L = total hoisting distance in meters

ΔL = difference between lowest rope mark and mark on rope of groove being measured

G5 Checking Results of Groove Adjustment

The effective diameters of the grooves are turned until the height difference between the marks is effectively zero when the conveyances are moved to either the top or bottom of the shaft and returned to midshaft position independent of the direction of movement. The more exacting the results the better, but turning is considered sufficient if ΔL doesn't exceed ΔL_{max} divided by the number of ropes for any hoisting direction. See Fig. G3.

Table G1
Maximum Height Differentials

L (meters)	ΔL_{max}* (millimeters)	L_0 (meters)
100	15	10
200	25	10
400	40	15
800	70	15
1600	120	15

*ΔL_{max} is the maximum difference between the lowest rope mark and the mark on the rope of the groove being measured.

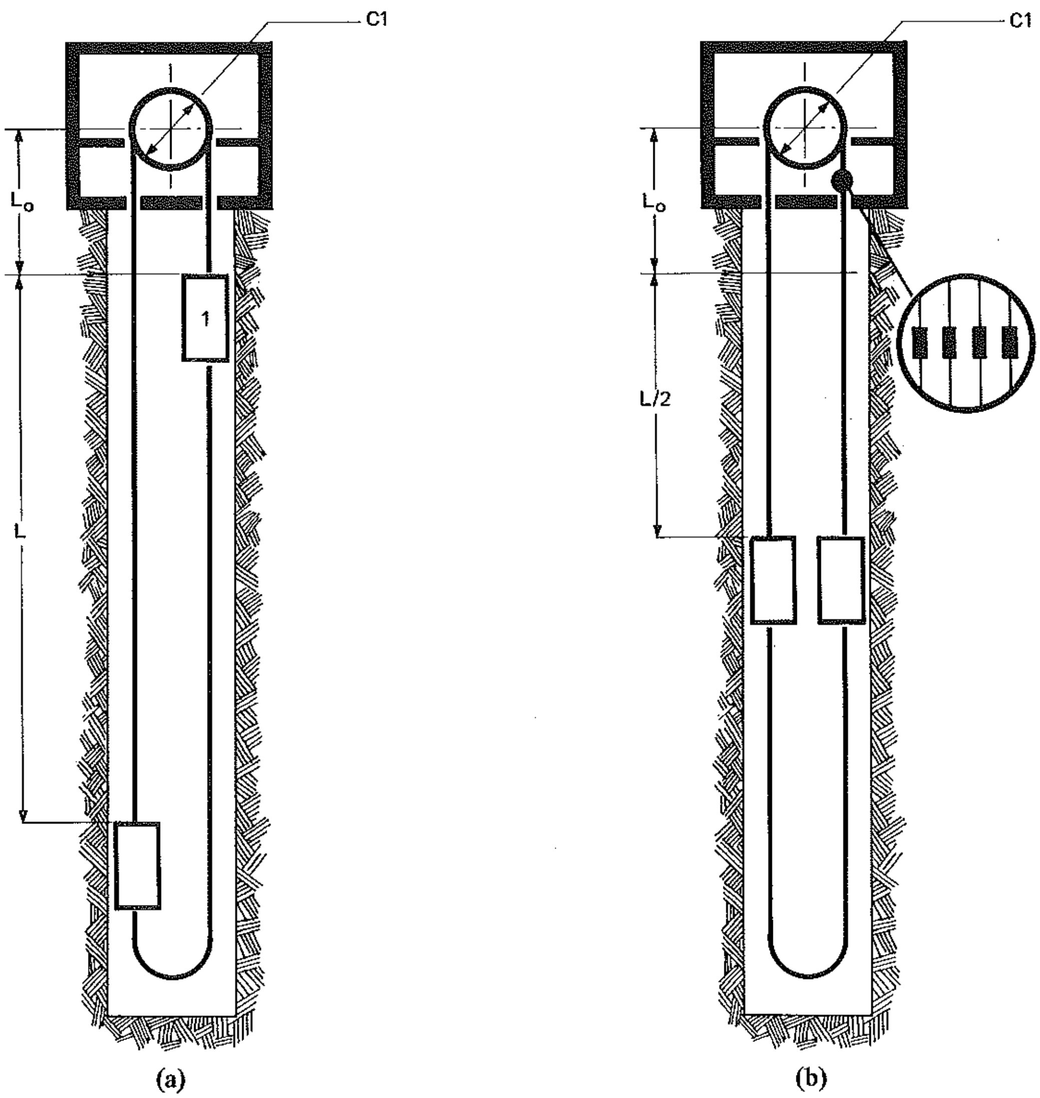


Fig. G1
Determining Effective Diameter

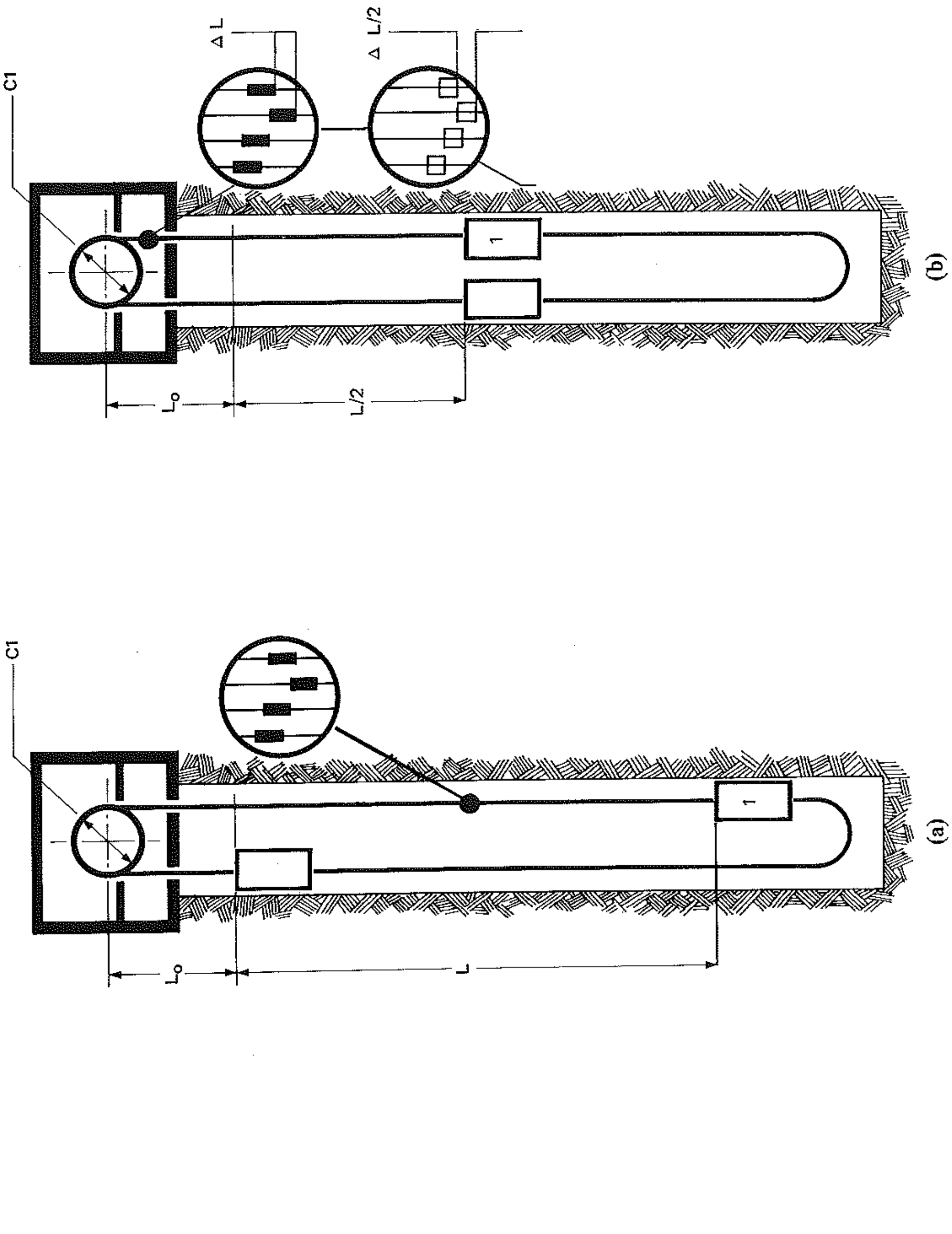


Fig. G2
Determining Adjustment of
Effective Groove Radius

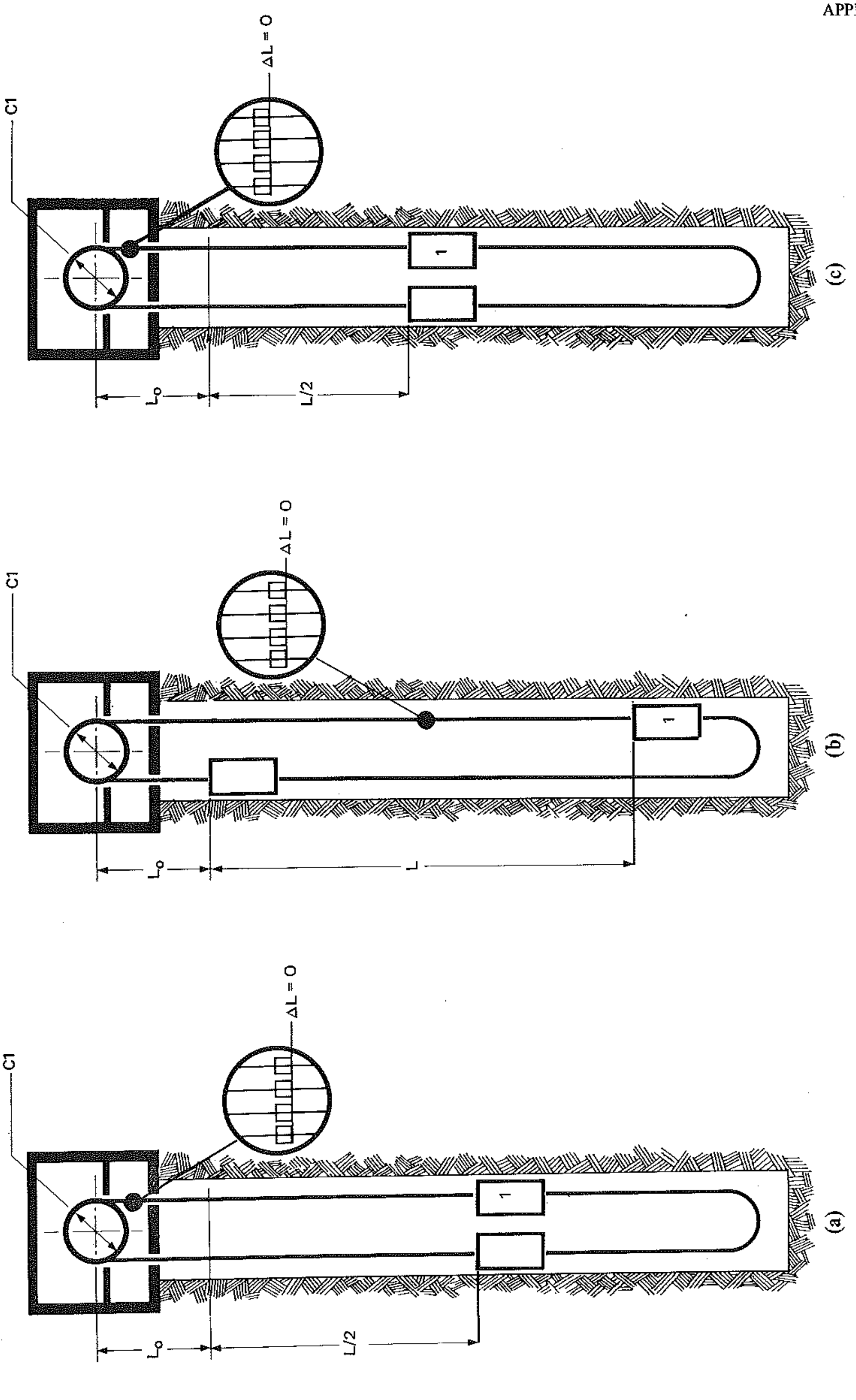


Fig. G3
Proper Effective Diameters

Appendix H

Measuring the Load Distribution and Differences In Rope Lengths for Multiple Rope Hoists

H1 Measuring Load Distribution and Rope Length Differential

This appendix applies primarily to rope attachments without rope balances. To measure the load distribution and difference in the rope length, the following procedure is recommended:

(1) Place the loaded conveyance at the bottom shaft station.

(2) Strike the rope with a rubber or wooden mallet at the level below the friction pulley while at the same time starting a stop watch with the other hand. Keep one hand on the rope.

(3) The pulse that has been induced in the rope by the mallet will propagate along the rope in the shape of a wave that will be reflected when it reaches the rope attachment at the bottom of the shaft. When the reflected wave is sensed by the hand on the rope, stop the watch. The wave will travel back and forth at a speed of approximately 100 meters per second.

H2 Determining Load on Rope

The load on the rope can be determined from the following formula:

$$Q = q\left(\frac{4L^2}{T^2\,g} + \frac{T^2\,g}{64} - L/2\right)$$

where

Q = The load on the hoist rope excluding the weight of the rope itself, in kilograms – that is, the weight of that part of the rope carrying the weight of the conveyance, the weight of the working load, the weights of the rope attachments, and the weight of the tail ropes.

q = the weight of the rope, in kilograms per meter

T = measured time for the reflective wave, in seconds

L = length of the rope, in meters

g = acceleration of gravity, in meters per second per second (9.807).

H3 Testing Other Ropes

The same test is given to all other ropes.

H4 Determining Total Load

The sum of the values of Q will give the total load on the ropes. The average load Q_a is the sum of all individual Q values divided by the number of ropes.

$$Q_a = \sum \frac{Q}{M}$$

H5 Determining the Required Adjustment

The difference between the average load and the load calculated above, that is, $Q_a - Q$, will give the required adjustment for each rope.

H6 Length Correction

The length of rope that needs to be corrected is calculated from the following formula:

$$\Delta L = \frac{10L}{E} \times \frac{Q_{max} - Q}{A}$$

where

Q_{max} = The calculated load on the shortest rope, in kilograms

E = The modulus of elasticity for the rope, in newtons per square centimeters

L = The length of rope, in meters

Q = The load on the hoist rope, excluding the weight of the rope itself, in kilograms

A = The steel area of the rope, in square centimeters

H7 Measured Time Deviation

The measured time for the wave is shorter for higher loads on the rope. If the measured times deviate more than ±10%, the lengths of the ropes should be corrected.

Appendix I

Example of One Method for Installing, Replacing, and Recapping Friction-Hoist, Hoist, and Tail Ropes For Tower-Mounted Units

I1 Installation of Hoist Ropes

(1) The pilot rope is drawn from the ground level through the counterweight space up to the hoist and then through a hole in the driving pulley; the rope is then drawn around the pulley hub and clamped. The first hoisting rope is then clamped to the pilot rope. See Fig. I1.

It is possible to use a small hoist with its rope drawn over the driving pulley and down to ground level instead of using a pilot rope.

(2) The hoist rope is then operated at a very slow speed so that the pilot rope is wound up on the driving pulley and the first hoisting rope is drawn up behind it sufficiently into the hoist room so that it can be fixed to the hub of the driving pulley.

The hoist rope is fixed to the head frame in the hoist room with a rope clamp and is then detached from the pilot rope. The pilot rope is then unwound and removed.

If an auxiliary hoist is used, the main winder and auxiliary hoist motor are driven simultaneously.

After the driving pulley is covered by wooden lagging, the free end of the hoisting rope is pulled through the hole in the pulley and is laid around the hub and clamped. See Fig. I2.

(3) The hoist rope clamp is now removed and the hoist rope is wound onto the driving pulley until its other end is free from the cable drum.

In order to wind the rope more tightly on the friction pulley, a weight is affixed to it; after which, the rope and the weight are lowered into the shaft after all rope is paid out; then the rope is again rewound onto the pulley. The weight is used to prevent the rope from oscilating and catching in the shaft during this operation.

During the final winding operation care should be taken to ensure that the turns are close to one another on the friction pulley. See Fig. I3.

(4) After the hoist rope has been rewound onto the friction pulley, the weight is removed and the rope is fitted with its connection thimble.

The rope is fixed to the counterweight or to the skip bridle if a balanced hoisting system is used. See Fig. I4.

The hoist is then used to lift the counterweight to its highest position where it is supported on cross beams.

(5) The rope is now freed from the counterweight, laid over a deflection sheave and lowered to its full length in the conveyance shaft. See Fig. I5.

(6) The rope is now wound onto the driving pulley again but in the opposite direction. It is then used to lower the reel (or reels) containing the tail rope(s) to the lowest level. See Fig. I6.

(7) When the tail rope has been lowered, the hoist rope is fixed to the main conveyance. The main conveyance is then lowered to its lowest level. See Fig. I7.

The cage is supported as far above the lowest level as corresponds to the calculated rope stretch, plus an additional length of rope required to form slack rope so that the counterweight or other conveyances can easily be fixed to the other end of the rope. See Fig. I8.

(8) It is now possible to install additional head ropes.

The rope previously attached to the main conveyance is removed. The end of the second hoist rope is then affixed to the first rope by means of clamps. See Fig. I9.

When the rope has been raised by a length sufficient to affix it to the hub of the driving pulley, it is once again fixed to the first rope with further clamps.

When preparing the hoisting ropes for installation, care must be taken to ensure that they are in the correct order – that is, every other rope is to have an opposite lay from the preceding rope.

(9) The second hoist rope (and each subsequent hoisting rope) is raised until the first clamps are close to the hoist pulley, at which point they are removed.

After this, the rope is raised until the other clamps are above the clamping level near the hoist. Each subsequent rope is then clamped to the head frame. See Fig. I10. The free end of the rope is laid on the hoistroom floor. The first rope is lowered and used to fetch the remaining hoisting ropes in the same manner.

(10) After all hoisting ropes have been raised into the hoist room and clamped to the head frame, the first rope is lowered to the bottom of the shaft where it is finally affixed to the main conveyance.

The rope is then tensioned until the rope balance takes a horizontal position, after which the rope is clamped to the head frame with sufficient force to support its own weight. The remaining part of the first rope is then removed from the hoist pulley and laid in loops on the hoist-room floor. See Fig. I11.

The free end of the next hoisting rope is then fixed around the hub of the hoist pulley. The rope is then wound onto the hoist pulley until its other end is free from the cable drum.

The rope is then fitted with its thimble, lowered into the shaft, and fixed to the main conveyance.

The rope is then tensioned and clamped to the head frame near the hoist; the remaining rope is then unwound from the pulley and laid in loops on the hoist-room floor.

The same procedure is followed for each of the remaining ropes. After all ropes have been attached to the main conveyance, the wooden lagging on the driving pulley is removed. The free ends of the hoist ropes are fitted into the grooves in the driving pulley, are fitted with termination thimbles, and are then affixed to the counterweight or balance conveyance. See Fig. I12.

(12) After all ropes have been fitted to the counterweight, the clamps supporting the ropes are removed. The ropes will then slide over the hoisting pulley and become tensioned on the counterweight side.

The counterweight is then lifted with the hoist, with the aid of a crane in the hoist room if necessary, until the supports under the counterweight can be removed. See Fig. I13.

The counterweight is then lowered until all ropes are tensioned and the cage has lifted sufficiently that the supports beneath it can be removed.

I2 Installing the Tail Ropes

(1) Using the tail rope reels now in place at the lowest level, the tail ropes are fitted with their thimbles and fixed beneath the lowest conveyance.

When this is accomplished, the cage is operated so that the tail rope is unreeled from its drum and drawn up into the shaft. See Fig. I14.

If the tail rope consists of more than one rope, all ropes are drawn up simultaneously.

The preceding comments apply to counterweight hoisting with a maximum motor torque of twice the normal load torque and a weight of the rope (or ropes) less than or at most equal to 1.5 times the normal load.

If the weight of the hoisting rope is greater than 1.5 times the normal load, the tail rope must consist of several parallel ropes drawn up one at a time. In the case of balance hoisting using skips in balance with a maximum motor torque of twice the normal torque, the weight of the rope (or ropes) must not exceed twice the normal load. If the weight of the rope (or ropes) is greater than twice the normal load, the downward traveling cage must be loaded with a weight equal to the difference between the weight of the ropes and twice the normal load.

If the rope weight is greater than three times the normal load – that is, if the load in the downward traveling conveyance would be greater than the normal load – the tail rope must consist of several parallel ropes which must be raised one at a time.

(2) When the counterweight reaches its lowest level, tail rope lengths are adjusted and tail ropes are fitted with thimbles and then affixed underneath the counterweight. See Fig. I15.

I3. Replacing Hoisting Ropes

(1) When replacing old hoisting ropes, the reels with the new ropes and a corresponding number of empty reels of suitable size to receive the old ropes are taken to a level that corresponds as nearly as possible to half the depth of the shaft.

The cage is driven to the same level as the reels and is then lowered below that level by an amount which corresponds to calculated rope stretch plus an additional length of rope corresponding to the length required to form slack rope so that the counterweight or other conveyance can easily be fitted to the other end of the ropes. The counterweight or other conveyance is likewise supported at or near this position. See Fig. I16.

(2) A clamp powerful enough to carry the main conveyance and half of the weight of the hoist rope is fitted across all of the ropes on the main conveyance side close to the hoist. Sufficient space must be left to raise the main conveyance to the proper level for chairing.

With the aid of this clamp and the hoist-room crane and while the hoist is being driven in a corresponding direction, the main conveyance is raised to the selected chairing level, at which point it is supported on chairs and the rope clamps are removed. See Fig. I17.

(3) The old hoisting ropes are then removed from the main conveyance and the counterweight. They cannot slide as they hang across the driving pulley in a very nearly balanced condition. The ends of the old ropes on one side are fixed to the empty cable drums; the ends of the ropes on the other side are affixed to the new hoisting rope.

The hoist is then driven slowly in such a direction that the new ropes will be wound off of their drums at the same time as the old ropes are wound up onto empty drums.

All ropes will remain in balance during this process. See Fig. I18.

(4) After the new ropes have been adjusted to the correct length and fitted with their thimbles, they are affixed to the main conveyance and a counterweight or counter balancing conveyance. See Fig. I19.

After this the rope clamp and crane are again used to raise the main conveyance so that the supporting beams can be removed. The main conveyance is then lowered until the ropes are taut.

After the clamp has been removed, the counterweight or counter balancing conveyance is lifted by means of the hoist so that the supports can be removed.

I4 Replacement of Tail Ropes

(1) The reel with the new tail rope, along with an empty reel for the old rope are transported to the lowest level.

The old tail rope is freed from the main conveyance and the thimble is placed on the new rope and then fitted to the cage.

The free end of the old rope is then fixed to the empty drum. See Fig. I20.

(2) While the main conveyance is slowly raised, the new rope is unwound from its reel while at the same time the old rope is wound up to the empty reel.

When the counterweight or counter balancing conveyance has arrived at its lowest level, the old rope is removed, after which the new rope is adjusted for length and fitted in its place.

If the tail rope consists of several ropes, all ropes are changed simultaneously.

I5 Recapping of Ropes (New Terminations)

(1) If the hoisting rope (or ropes) are to be recapped on the counterweight side, the cage is first raised to a level sufficient to provide the necessary slack rope for cutting and for handling. In order to accomplish this the counterweight must be chaired. See Fig. I21.

(2) Using the hoist and, if necessary, the hoist room crane, the main conveyance is raised to a level sufficient to give necessary slack rope above the counterweight.

Only the weight of the empty conveyance need be lifted because all ropes are in balance.

When the rope (or ropes) are recapped and reaffixed to the counterweight, the main conveyance is raised and its supports are removed; it is then lowered until the rope (or ropes) are taut.

The counterweight is then raised and the supports are removed.

When recapping ropes on the main conveyance side, the counterweight, rather than the main conveyance, is raised to the highest position.

The same procedure is followed for conveyances in balance.

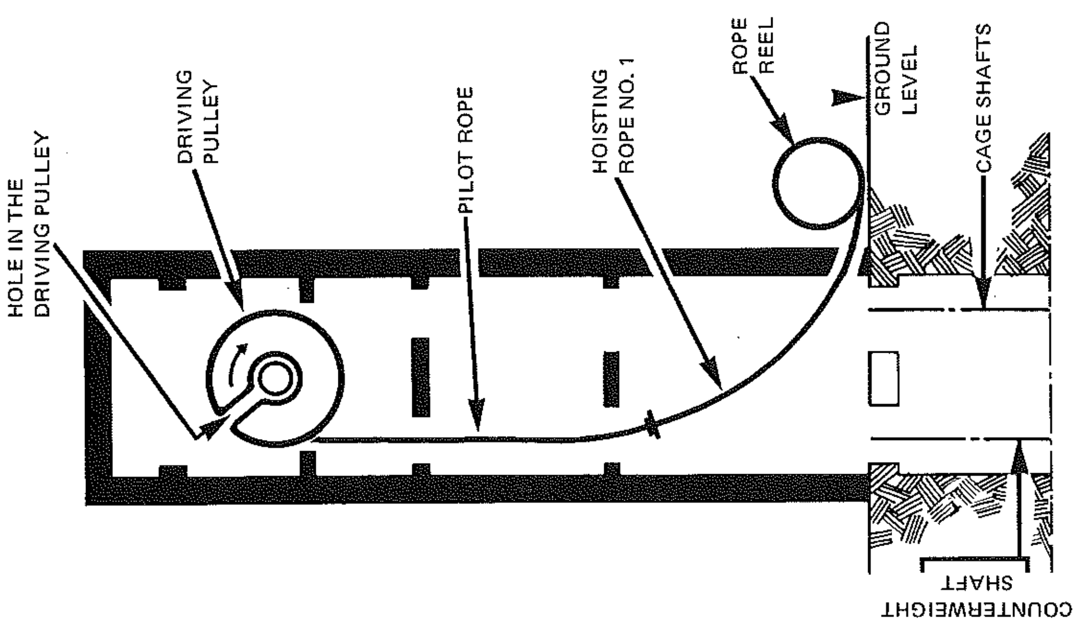


Fig. I1
Attachment to Pilot Rope

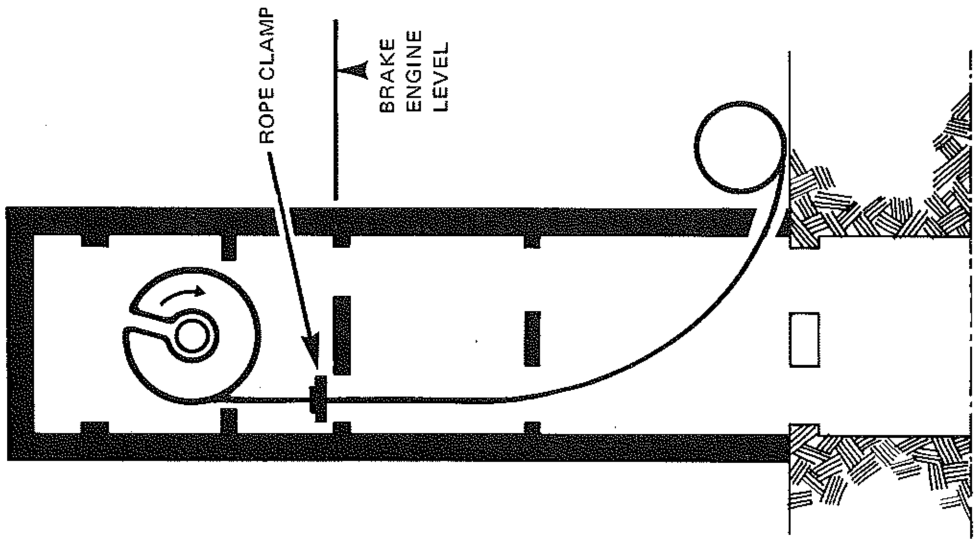


Fig. I2
Removing Pilot Rope and Securing Hoist Rope

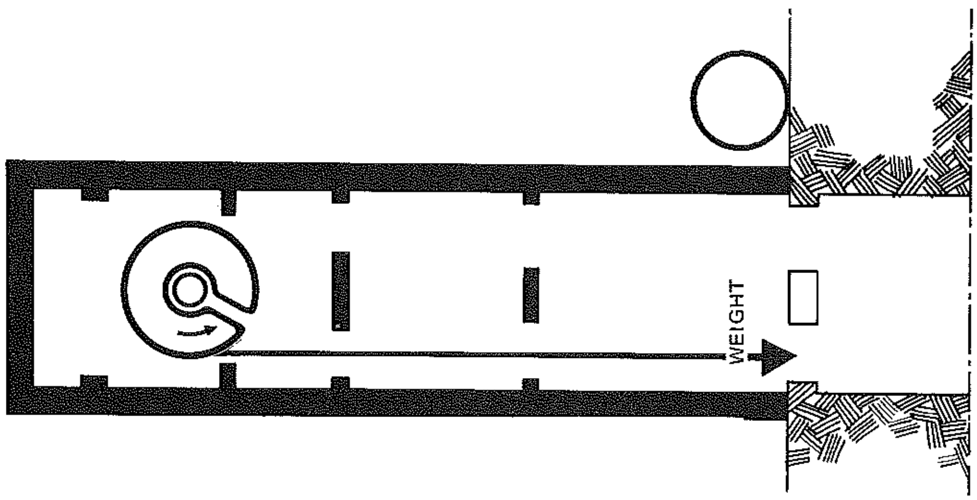


Fig. I3
Winding Hoist
Rope Tightly

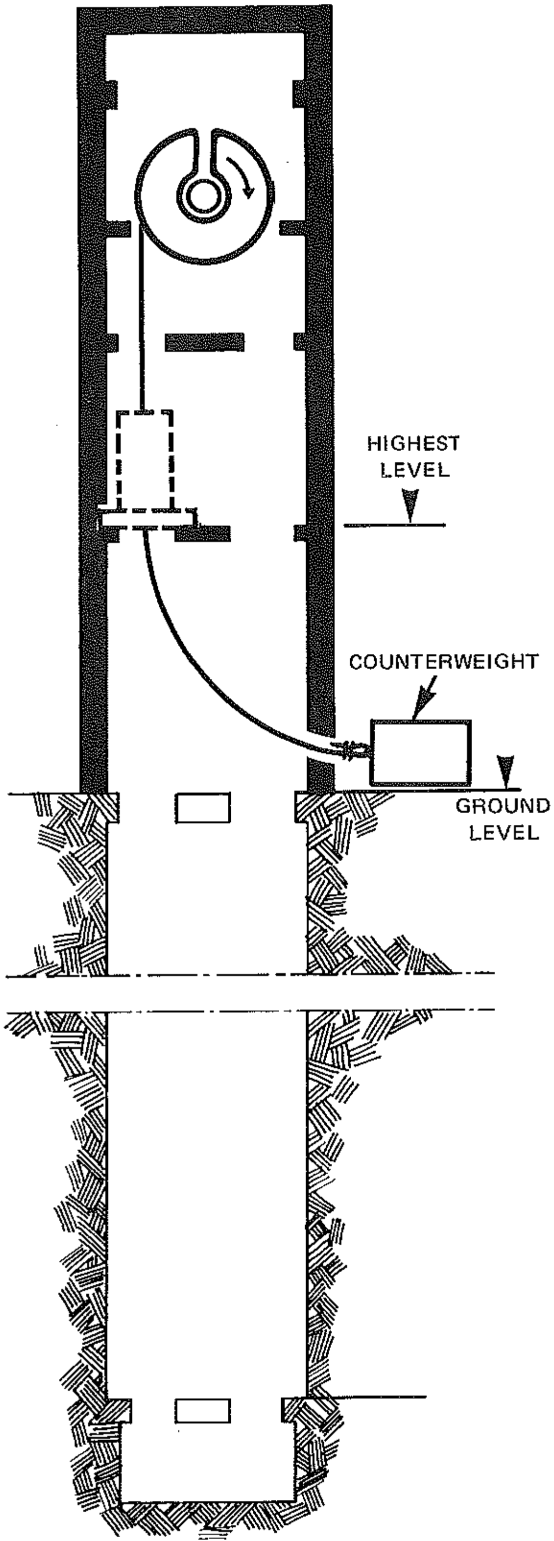


Fig. I4
Attaching Hoist Rope

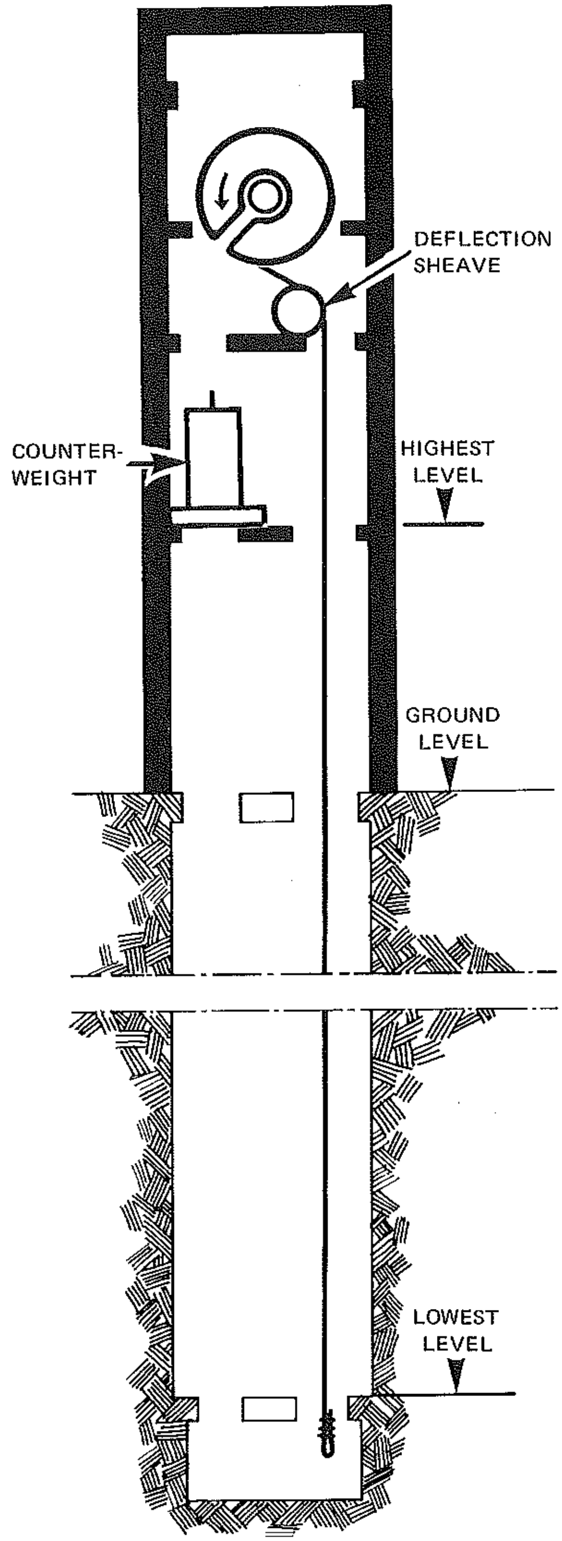


Fig. I5
Lowering Hoist Rope

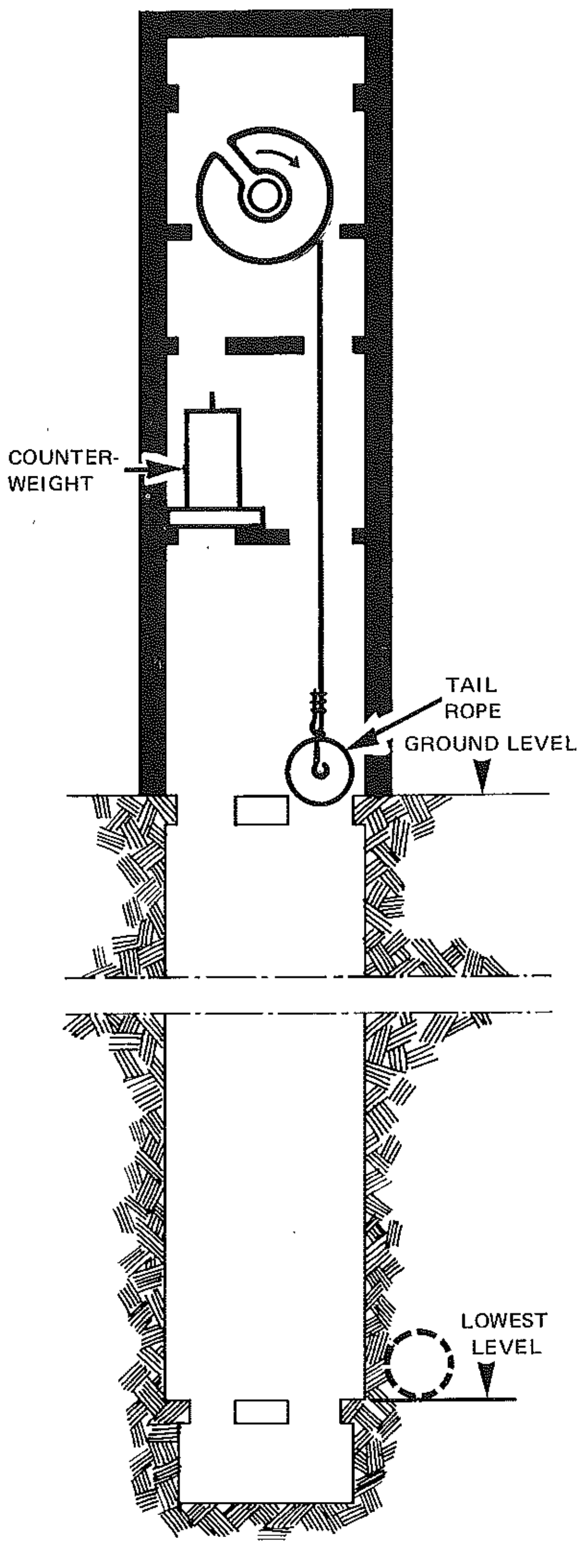


Fig. I6
Lowering Tail Rope

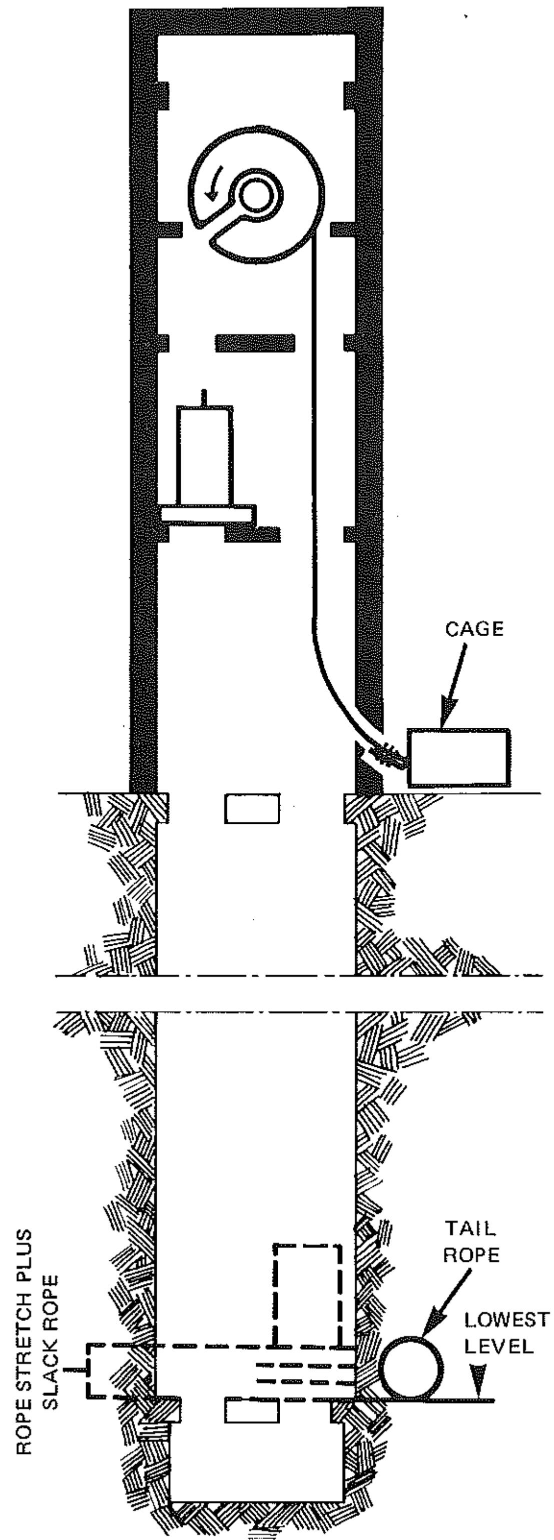


Fig. I7
Attaching Hoist Rope to Conveyance

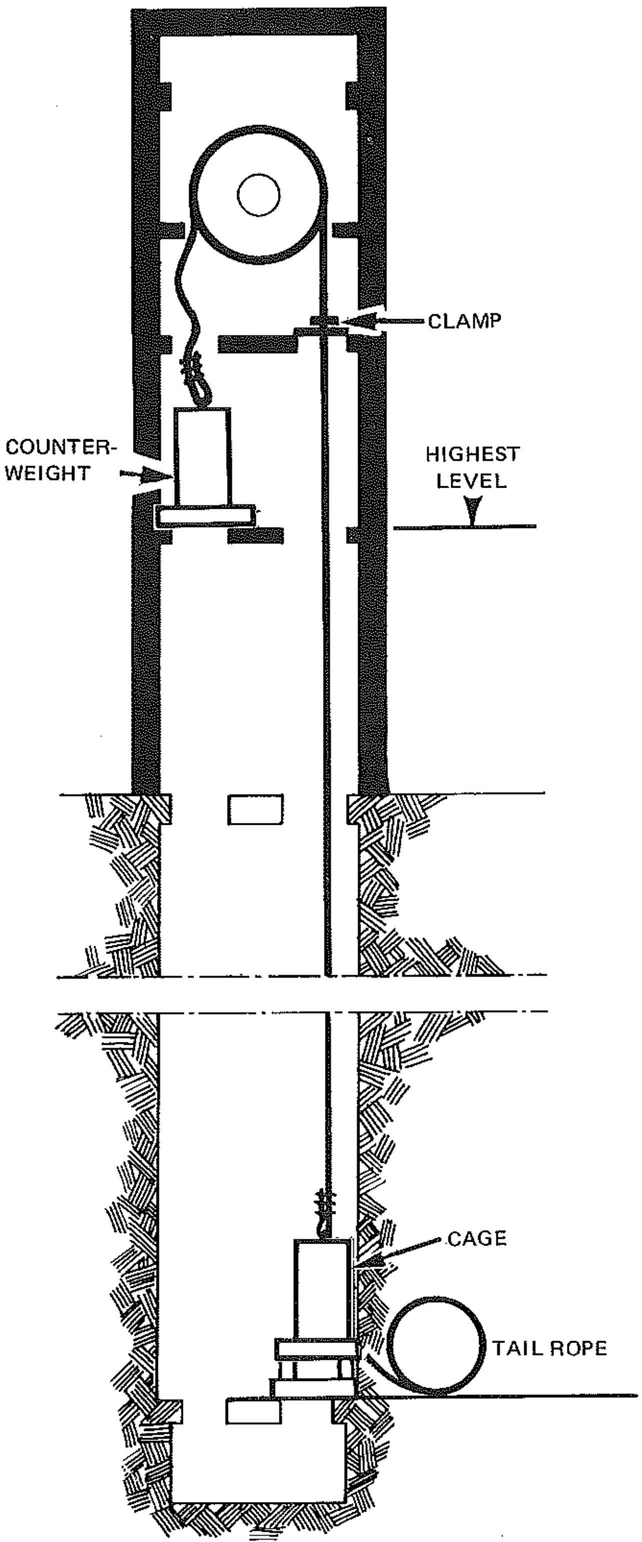


Fig. I8
Attaching Counterweight
or Other Conveyances

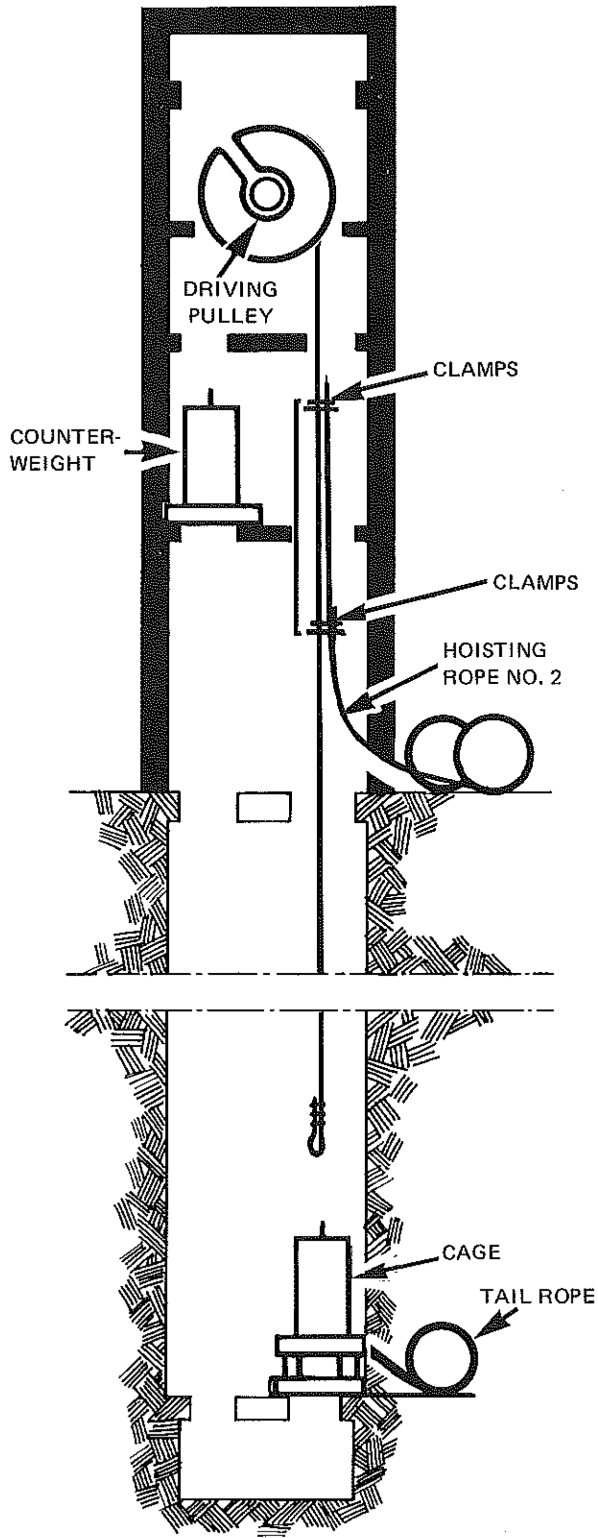


Fig. I9
Installing Additional
Head Ropes

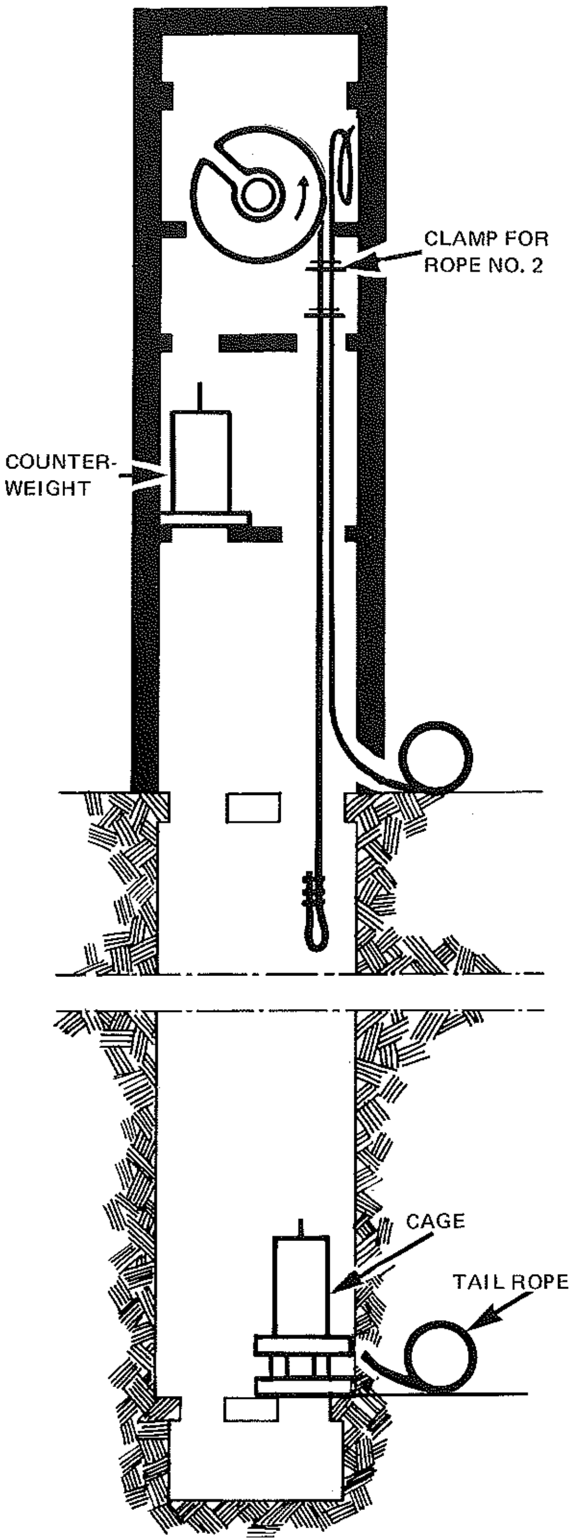


Fig. I10
Clamping Additional Head Ropes

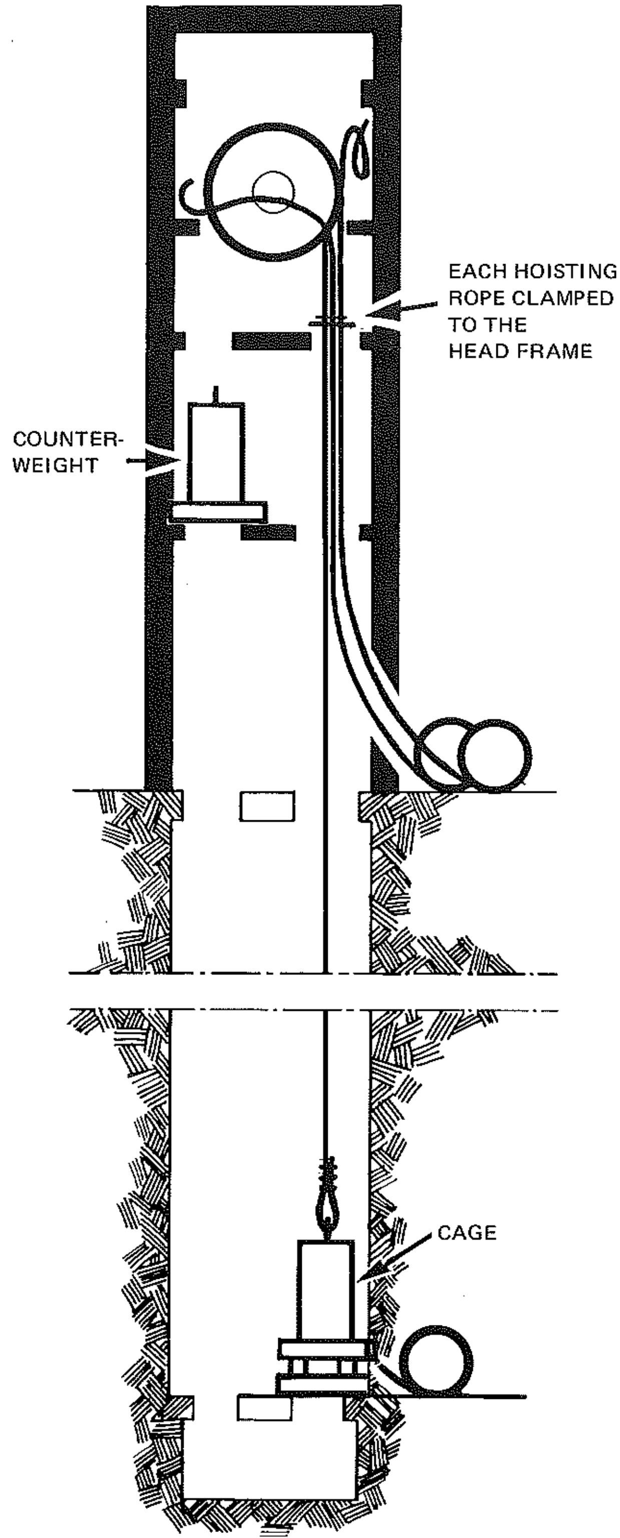


Fig. I11
Clamping Ropes to Head Frame and Lowering First Rope

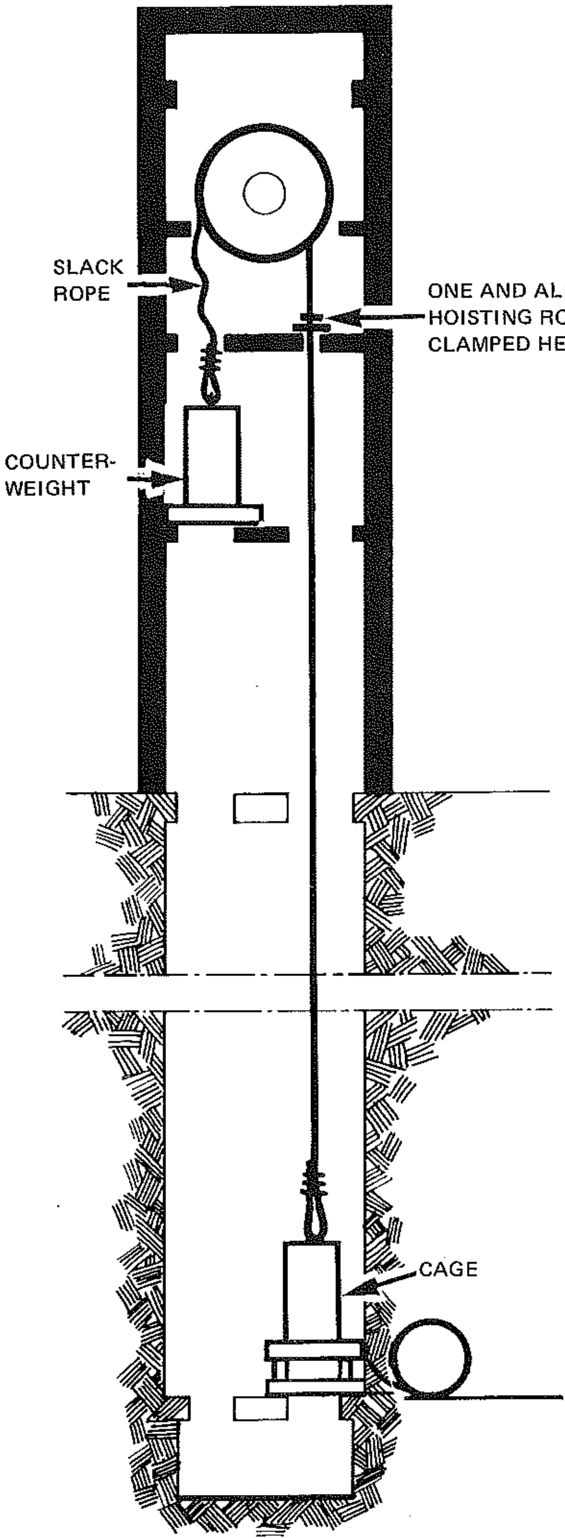


Fig. I12
Lowering Subsequent Ropes

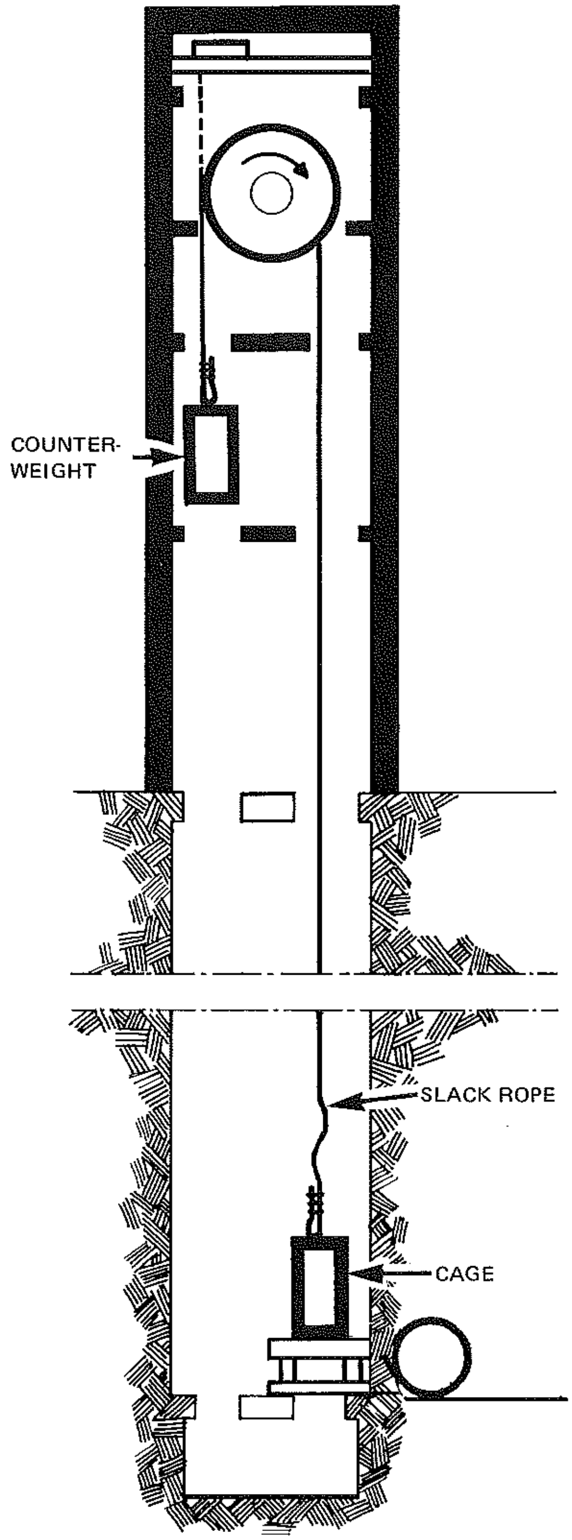


Fig. I13
Handling Counterweight

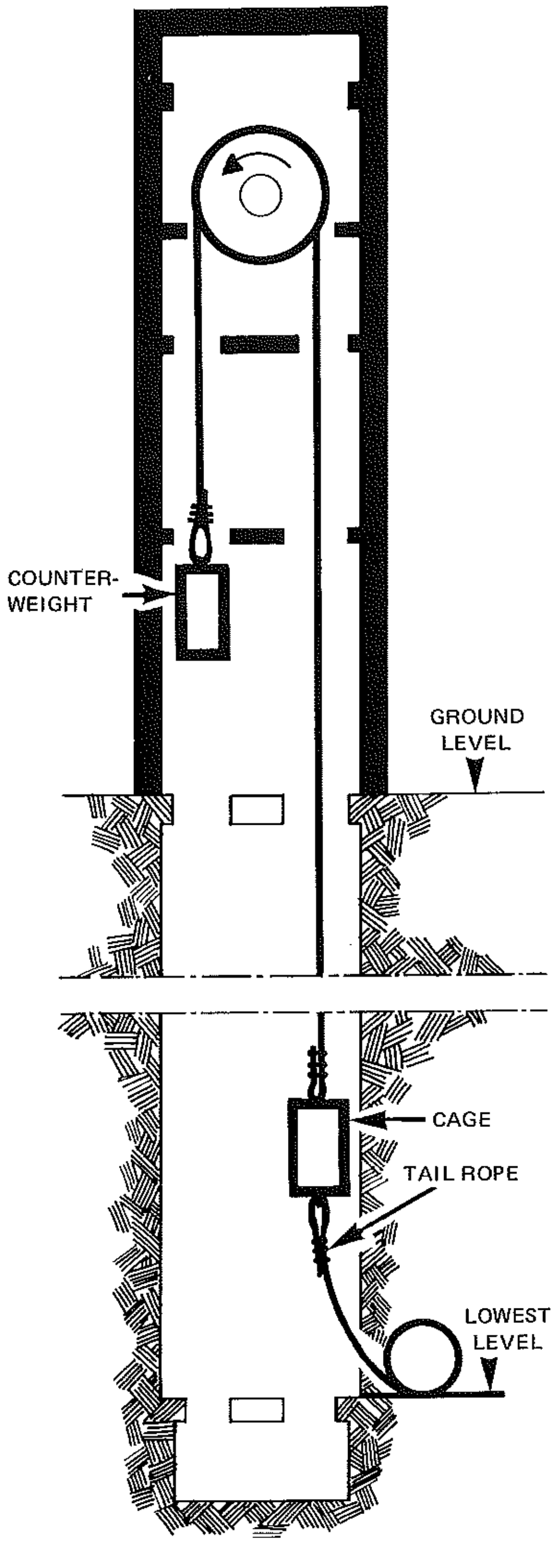


Fig. I14
Unreeling Tail Rope

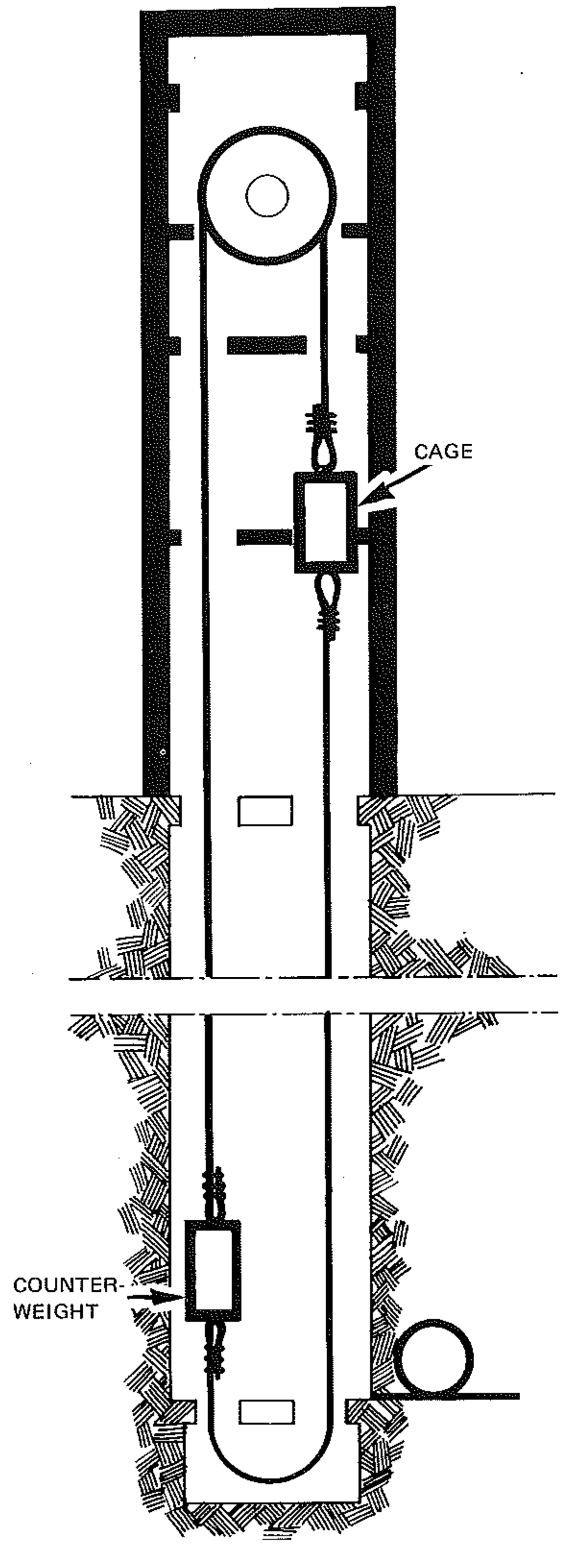


Fig. I15
Completing Tail-Rope Connections

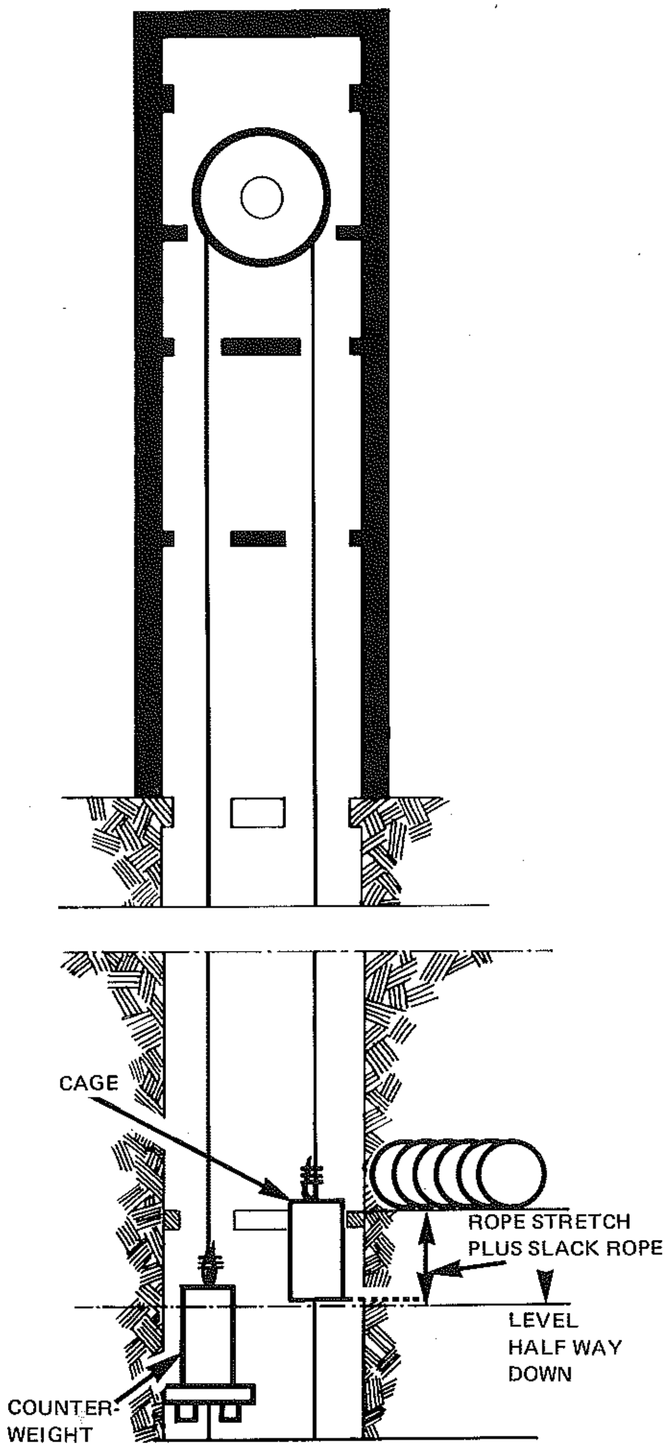


Fig. I16
Positioning Conveyances or Counterweights

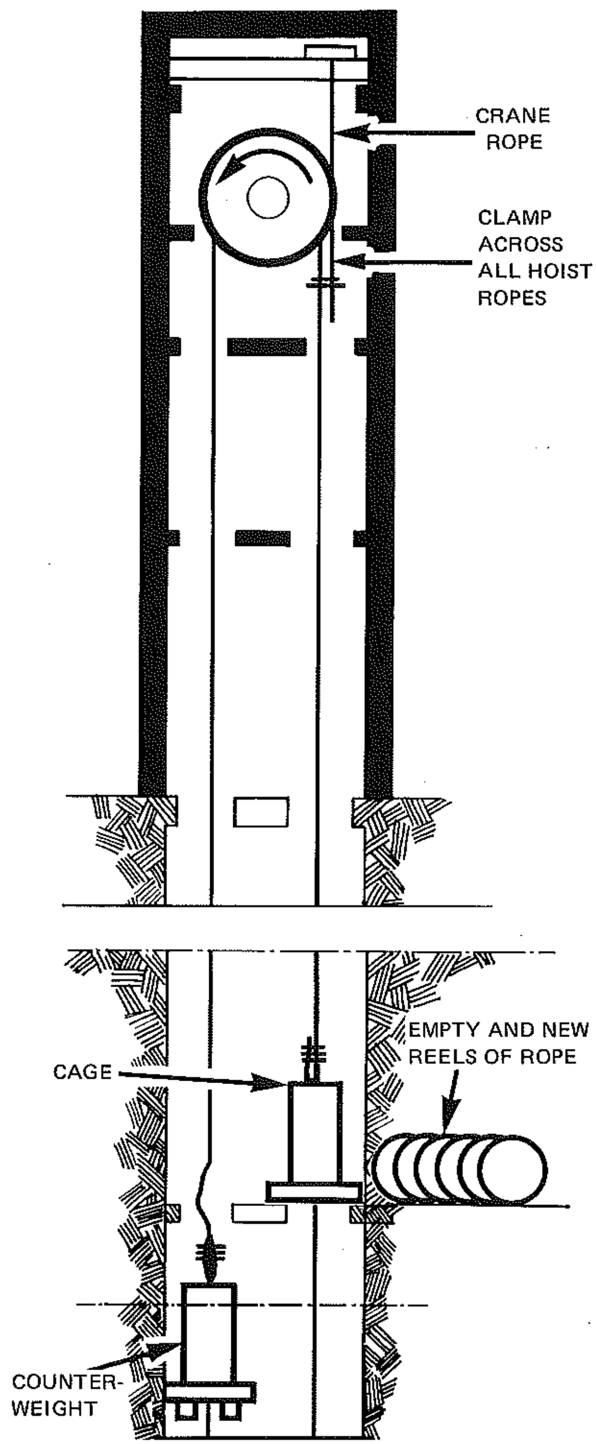


Fig. I17
Clamping Hoist Ropes

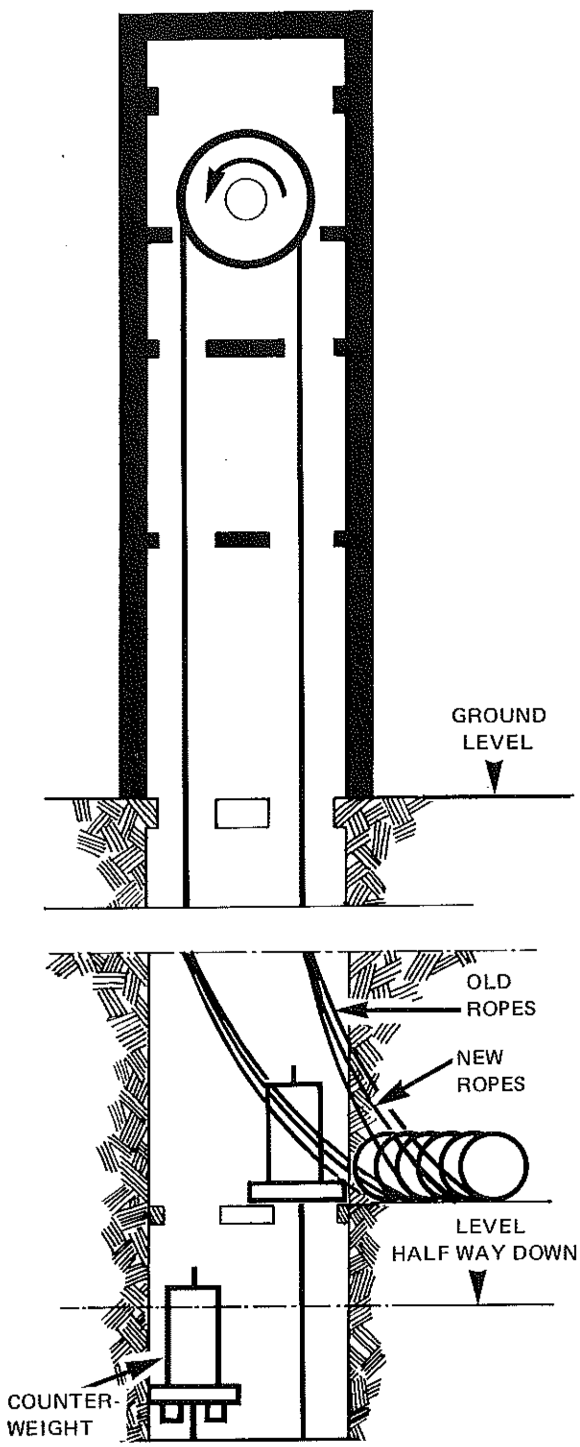


Fig. I18
Simultaneous Installation and Removal of Hoist Ropes

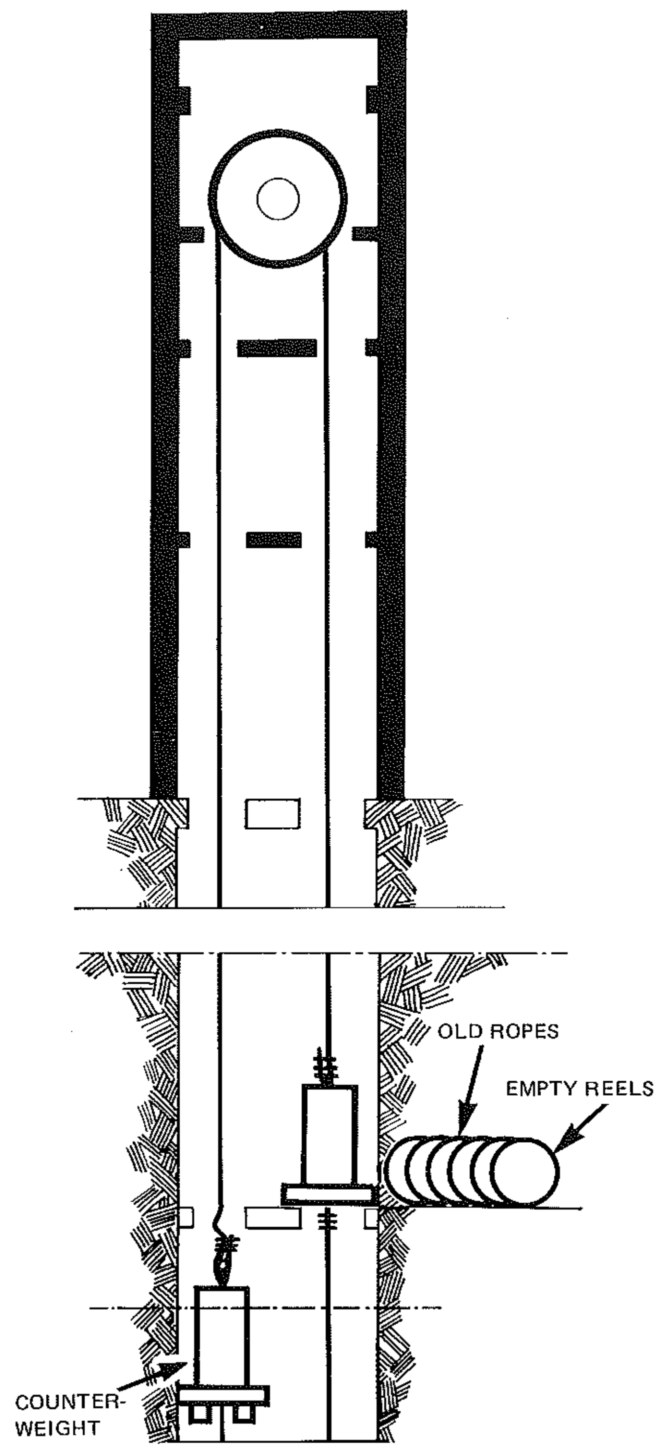


Fig. I19
Attaching New Ropes to Conveyances and Counterweights

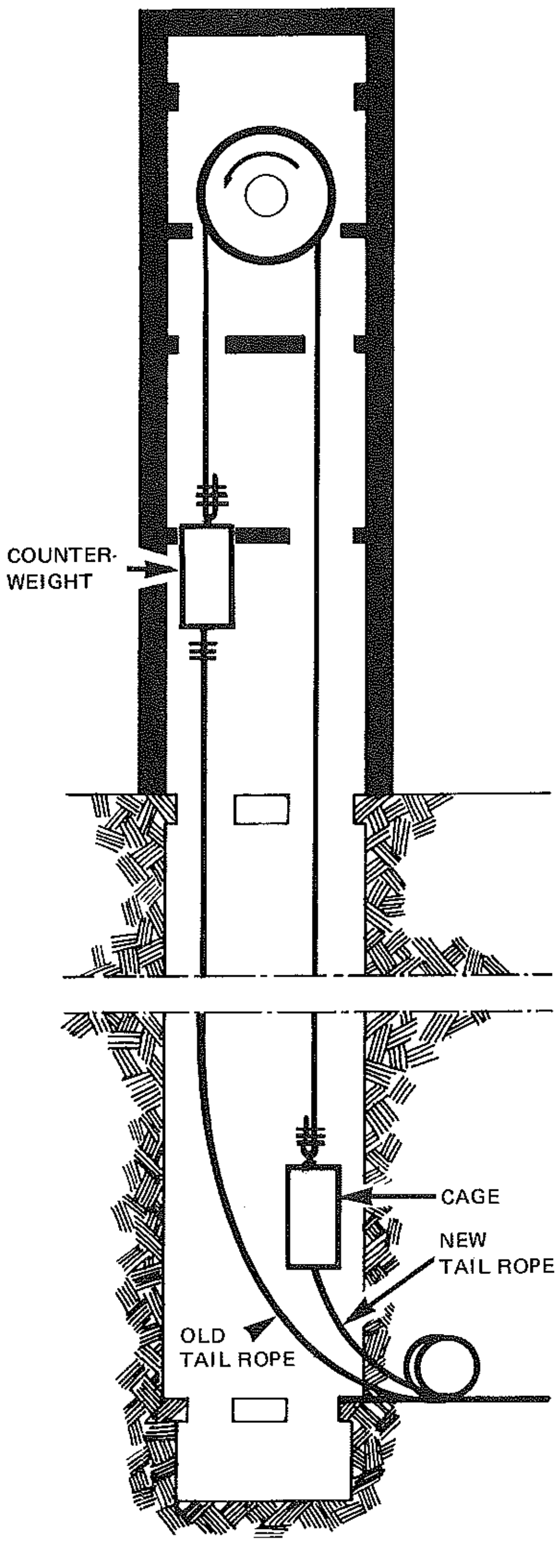


Fig. I20
Attaching Tail Ropes

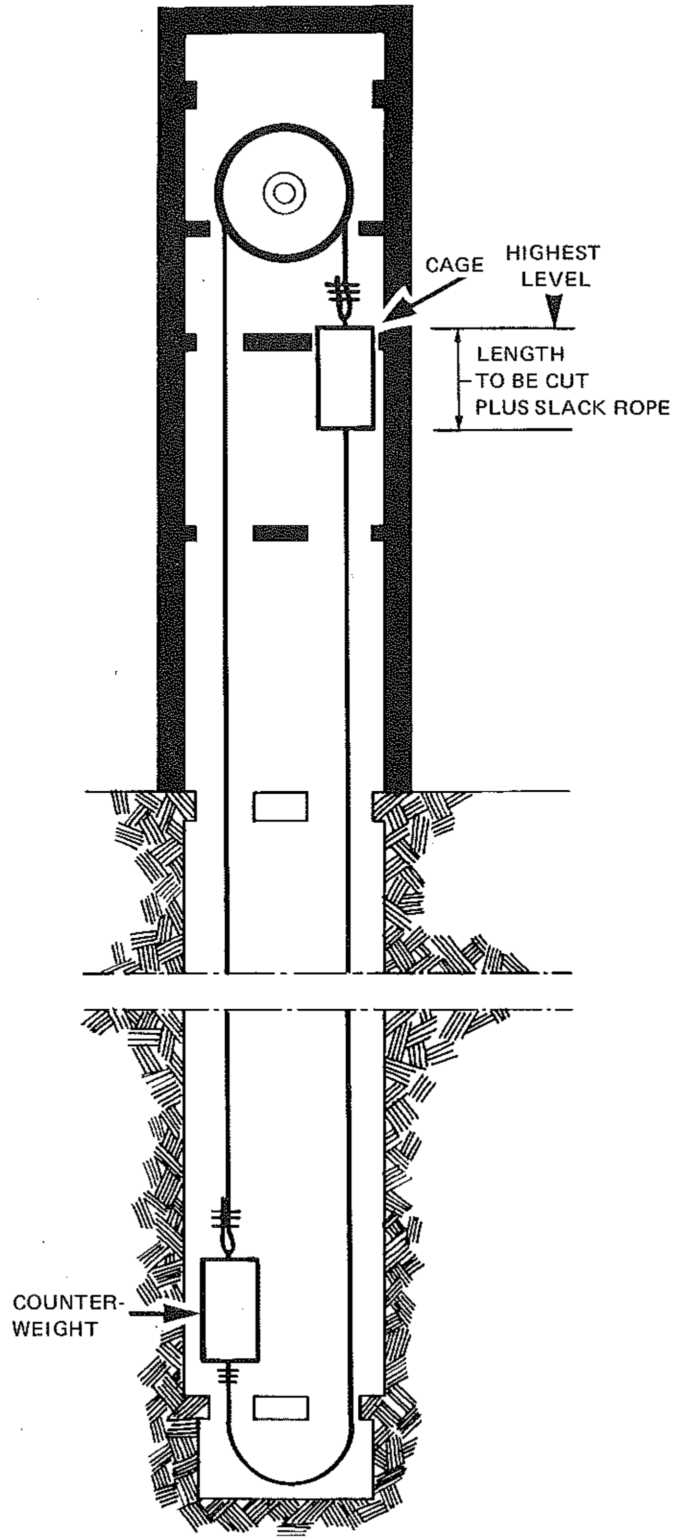


Fig. I21
Recapping Ropes
(New Terminations)

Appendix J

Allowable Radial Pressures for Selected Groove Materials

Table J1
Allowable Radial Pressures for Selected Groove Materials

	Sheave and Material		
Rope Construction	Cast Iron (psi)*	Cast Steel (psi)*	Manganese Steel (11%–13% Mn) (psi)*
6 X 7	300	500	1500
6 X 19	500	900	2500
6 X 37	600	1075	3000
6 X 8 Flattened Strand	450	850	2200
6 X 25 Flattened Strand	800	1450	4000
6 X 37 Flattened Strand	800	1450	4000
6 X 30 Flattened Strand	800	1450	4000

*psi = pounds per square inch.

NOTES:

(1) The above 6 X 7 and 6 X 19 values are for regular lay rope; for lang lay rope these values may be increased 15%. No increase is necessary for flattened strand rope, which is usually lang lay.

(2) For some applications it has been found that certain types of hardened cast steel have wear characteristics comparable with manganese steel.

(3) If the pressure is high, the compressive strength of the groove material in the groove may be insufficient to prevent excessive wear and indentation which can affect service life by damaging outer wires.

If the calculated pressure exceeds the allowable radial pressure, consideration should be given to (a) increasing the sheave or drum diameter or (b) changing the material.

(4) This data on estimation of pressure assumes that the contact area of the rope embodies the full rope diameter; actually, only the crown wires are in contact with the groove. Local pressures at the contact points may be many times greater. Therefore, values given cannot be related to the compressive strength of the groove material.

Appendix K

Field Application of Lubricants for Wire Rope Used in Underground Mines

K1 General

Wires in wire rope move relative to one another in service; therefore, rope lubrication during service is of paramount importance if satisfactory rope life is to be attained. As the rope operates under a load over sheaves and drums, its wires are subjected to contact stresses that are considerably higher than those for machine bearings.

The lubricant used by the wire rope manufacturer during fabrication is selected to meet the initial service requirements to which the rope will be subjected. It is important that the lubricant used by the mine operator shall be compatible with the original lubricant and to this end the wire rope manufacturer should be consulted.

K2 Choosing a Lubricant

There are two basic types of lubricants:

(1) Highly viscous asphaltic and petrolatum-base materials

(2) Low-viscosity oils and cutbacks

Generally, the high-viscosity materials are intended to offer corrosion protection by sealing the wires against the ingress of water. However, such materials tend to build up and crack when the rope is flexed and their adhesion to rope wires in relative motion can be poor. For this reason, use of highly viscous lubricants should be restricted to storage protection applications. For operating conditions, low-viscosity lubricants are normally recommended.

Low-viscosity lubricants contain additives to increase their boundary lubrication performance, their corrosion-inhibition ability, and their other functions. In addition to being effective lubricants for preventing corrosion and for reducing friction and wear in operating ropes, low-viscosity lubricants tend to pick up less grit, tend to cake less, and afford better visibility of the rope for inspection purposes.

K3 How to Apply Lubricants

K3.1 High-Viscosity Lubricants. High-viscosity lubricants should be heated before application. To achieve best adhesion, the rope must be clean, moisture-free, and relatively warm. In one technique for applying high-viscosity lubricants, the warm rope is guided into a trough containing the heated lubricant. The rope should be moved slowly through the trough. As it comes out it should be wiped with leather, gloves, rags, or sheepskin to remove excess lubricant.

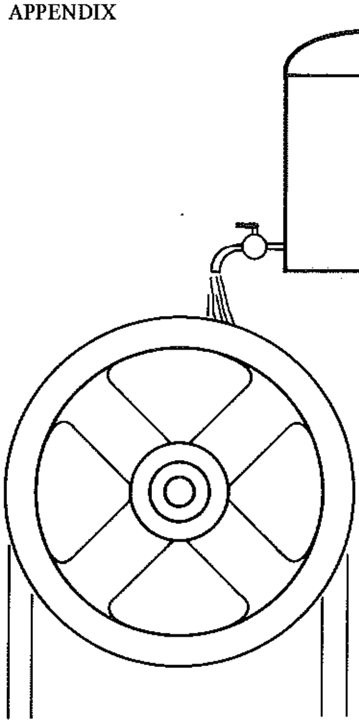
High-viscosity lubricants may also be painted on ropes or applied with gloves or rags. Always apply a lubricant after rather than before the rope passes over a sheave in order to avoid catching rags, brushes, and fingers in equipment. Another technique is to pour lubricant over a rope on a drum, letting is stand for a length of time. After the lubricant has penetrated, the drum is rotated one-quarter turn and then left to stand again. The process is repeated until the lubricant has penetrated the entire rope.

K3.2 Low-Viscosity Lubricants. It is most convenient to use an automatic device to apply low-viscosity lubricants. Equipment downtime for lubrication is all but eliminated, and automatic lubrication allows the best possible application schedule: light, frequent lubrication.

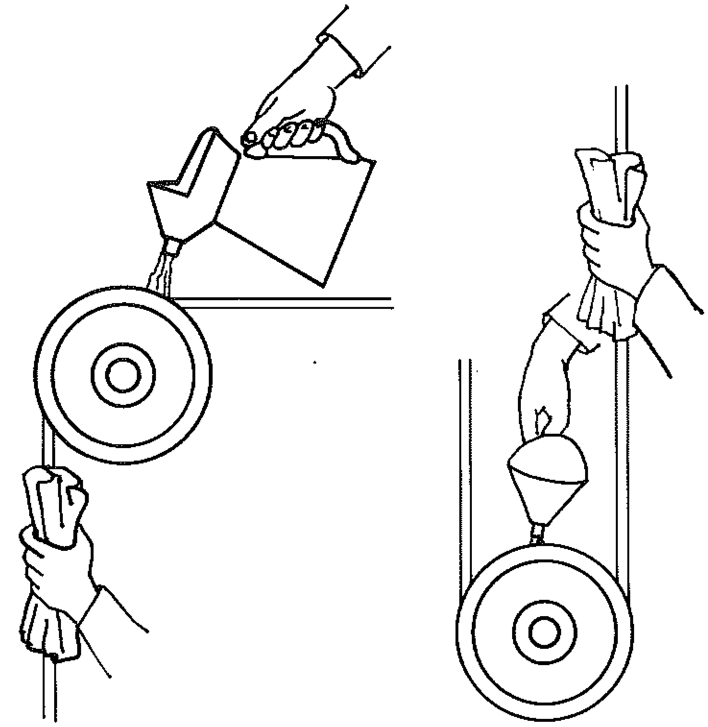
The simplest automatic lubricator is a box which fits around the rope. The box is filled with lubricants or lubricant-soaked absorbent material. The hole where the rope leaves the box is lined with burlap or some other liner. For the boxes in which the rope is oriented vertically, this lining seals the rope, preventing excessive lubricant leakage as well as minimizing rope abrasion in the hole. The rope moves slowly into the box, picks up the lubricant, and is wiped as it leaves.

Other automatic devices can be used which drip lubricant onto the rope as it passes over a sheave (see Fig. K1(a)). Lubricating at a bend improves penetration because the strands part slightly. Lubricant may also be dripped by hand from a container (see Fig. K1(b)). The rope should be wiped after it has passed over the sheave.

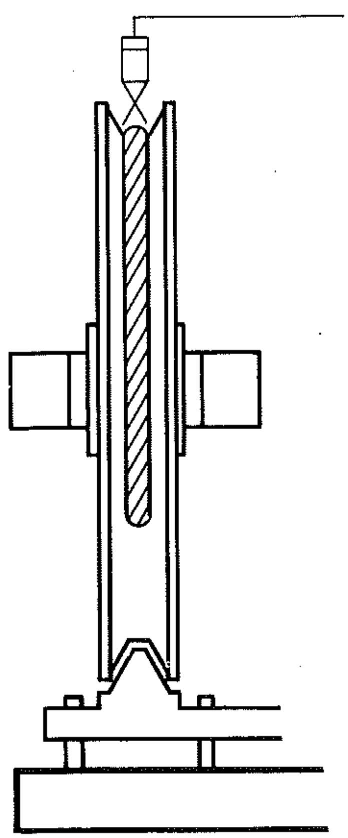
A nozzle may be used to spray light lubricant continuously or intermittently over a rope (see Fig. K1(c)). As with drip devices, these automatic lubricators should be mounted at the beginning of a bend over a sheave. The intensity and duration of spray is often adjustable and may be controlled automatically or



(a)
Automatic Drip Lubrication



(b)
Hand-Drip Lubrication



(c)
Automatic Spray Lubrication

Fig K1
Methods of Lubrication

by hand. It is important that the position of a spray nozzle be far enough away that the application completely covers the full diameter of the rope.

K3.3 Frequency of Lubrication. The decision about how often and how much to lubricate is highly dependent on the characteristics of rope operation. In general, the higher the rope speed, operating load, and number of bends, and the greater the exposure to corrosive conditions, the more frequently should relubrication be carried out. Ropes should be well lubricated upon installation to ease the breaking-in process. As the rope is operated, the internal lubricant gradually comes to the rope surface where it is contaminated and is no longer effective; therefore, lubrication should be carried out at frequent intervals for continuously operated ropes. In general, it is better to lubricate lightly and frequently, rather than occasionally and heavily. Frequency in automatic systems should be adjusted to effect lubricant saturation of the rope without excessive runoff.

Inactive ropes require special care, as they are particularly susceptible to corrosion.

Determine how often to lubricate by checking ropes frequently for signs of wear, corrosion, amount of remaining lubricant, and the general condition of the core. The followng symptoms indicate that lubrication is needed.

(1) rope cracking

(2) sparks flying off sheaves in the system, visible in dim light

(3) loss of elasticity without noticeable lay-length elongation

(4) patches of corrosion on ropes

(5) drying and cracking of the existing lubricant (applies mainly to ropes in storage).

If any of the above problems are noted, the frequency of lubrication should be increased.

Appendix L

Visual and Manual Inspection Techniques

The following visual-manual inspection techniques are used in determining the condition of hoist ropes:

L1 Broken Wires

Broken wires are easily missed. Adequate cleaning and careful inspection are a must.

(1) Encircle rope with a rag or cotton waste and run the hoist slowly. If broken wire ends protrude and catch the rag, either the rag or bits of it will show the location of broken wires. It is best to face in the direction the rope is moving when holding the rag so it is pulled away from the holder if it snags on broken wires. A bare or gloved hand rather than a rag or cotton waste can be dangerous. A rope speed of 50 ft per minute or less is usually suggested.

Soaking the cotton waste or a rag with solvent can be of value except when inspecting friction hoist ropes; the rag is less likely to burn away, and the solvent will carry some lubricant into the rope.

This time-honored approach will work only if broken wires protrude somewhat; valley breaks may go undetected.

(2) Look at an area several feet distant while sighting more or less along the rope as it moves slowly by; broken wires, from valley breaks in particular, may protrude just enough above the surface to be seen.

(3) The cleaner the rope the better the chances of finding broken wires with either method. The heavier the lubricant, the more difficult it is to detect broken wires other than those on the crown, particularly if the lubricant fills the valleys and the rope looks like a smooth black rod with some shiny areas on the surface. Rope segments that do not pass over head or other heavily loaded sheaves are likely to be totally covered with drying or dried-out lubricant. These segments will have to be cleaned if broken wires are to be detected.

L2 Diameter and Lay Length

Diameter and lay-length measurements are most easily made at the same time and at the same locations along the rope.

Since the geometry of a rope will change rapidly during the break-in periods, measurements should not be made at the time of installation unless stretch curves are to be maintained. The first set of measurements should be made after the constructional adjustment period but before significant wear begins. This first set of data is important since it serves as the basis for comparing all subsequent data. Furthermore, all subsequent measurements should be made under the same conditions to the extent possible. For example, do not measure with a full conveyance one time and an empty one the next. On slope systems where it is normal to detach the conveyances from the rope, measurements should always be made with the same conveyances attached and loading the rope.

(1) Measure rope diameters with calipers (See Fig. 1) across the crowns, not across the "flats", and across all three crown diameters. The average diameter is all that need be recorded unless the three differ appreciably, indicating a developing flattening or distortion that needs watching.

Check for localized diameter reductions or enlargements all along the rope while looking for broken wires. Localized diameter differences can often be felt; with the rag method they can be heard sometimes as a change in the noise the rope makes while running through the rag.

NOTE: Removal criteria dealing with crown-wire diameter wear has little practical value; the diameter of the wire cannot be directly measured easily nor accurately enough in most cases and, realistically, not at all if peening is present.

(2) Measure lay length with a tape graduated in 64ths of an inch. Place the end of the tape at the center and highest part of a strand and call this strand Strand No. 1. Count off the strands and read once, twice, or three times the lay length from the tape at the center and highest part of Strand No. 7, No. 13, or No. 19 for 6X ropes; or of Strand No. 13, No. 25, or No. 37 for 18X and 19X ropes. The strand numbers refer to Strand No. 1 after it makes 1, 2, and 3 complete revolutions of the rope; that is, at the end of 1, 2, and 3 lay lengths (18X and 19X ropes have 12 outer strands). For accuracy, it is better to measure over 2 or 3 lay lengths and divide by the number of lay lengths to obtain an average value.

Special lay-length measuring devices have been constructed that are more accurate than a tape and eliminate miscounting the strands. The essential features of such devices are a length of angle iron that straddles the rope and a fixed, centered reference point inside the angle at one end that fits into the rope valley; near the other end of the angle a moveable point fits into the valley at the other end of the lay. The sliding point includes a reference mark that lines up with a graduated scale attached to the outside of the angle. Adjustable blocks on either side of the sliding point limit the motion of the sliding point. These points are set a short distance to either side of the nominal lay length. The device is placed over the rope with the fixed reference point in a valley and the sliding point moved until it, too, settles into a valley; the lay length is then read directly off the scale.

Placing a length of plain paper over the rope and taking a pencil, pen, or crayon rubbing will give measureable impressions with patterns. Diameter and lay length should be measured at regular intervals along the rope. In addition, diameter should be measured at and near the worst crossovers on each layer and at any apparent irregularity. Regular intervals along the rope are typically determined by shaft stations, or by a specified number of drum revolutions. Usually the same spotting procedure is used each time measurements are made, even though rope cuts bring previously unmeasured areas to the measuring station. Sometimes "odd" shaft stations are used for spotting the rope for measurements, while the "even" stations are used the next time. Whatever the procedure used, it is suggested that measurements be made at least at 10 locations along the length of the rope. Measurments at regular intervals are not sufficient because localized difference can be completely missed, and a localized diameter and lay-length change, whether large or small, can be a symptom of serious internal degradation. Thus, measurements at regular discrete points should always be supplemented by looking for local diameter variations over the entire length and measuring diameter and lay length at these locations when found. Localized diameter reductions and lay-length changes may indicate one or more of the following:

(a) Core damage or failure
(b) Serious internal corrosion
(c) Serious internal crushing or wear

L3 Corrosion

(1) Look for scale or pitting on the outer surface of wires. Note that wear and peening may erase these indicators.

(2) Look for pitting or scale in the strand valleys where these indicators are not easily erased by wear and peening; corrosion here may be the only sign of corrosion inside the rope.

(3) Look for corrosion at and under attachments (for example, glands) and at the near end terminations.

Unless corrosion is visible on the surface it can easily go undetected. Signs of corrosion can easily be hidden beneath the rope lubricant, particularly if the lubricant piles up, soft or caked in the valleys. Dig out the lubricant, wipe off the area with a solvent-soaked rag, and then inspect the wires carefully.

In some places it has been the practice to slack a rope and carefully unlay it with a marlin-spike-like tool to inspect for interior corrosion. However, it is too easy to damage the rope structurally in the process; this approach should not be used.

L4 Structural Damage

Structural damage is fairly easy to spot. The types that call for *immediate* rope removal, if they cannot be removed by cutting off the ends of the rope, include kinks, doglegs, birdcages, loose or high strands, and protruding core.

Ropes are sometimes run if doglegs (bends, not kinks) are not thought to be too serious, but in general this practice is risky and should not be followed.

Kinks are also sometimes purposely taken out and the rope kept in service. However, a true kink severely twists the wires; taking it out will not undo the damage. The place where it "was" can always be felt if not seen. Running with an "unkinked" kink is even riskier than running with a dogleg.

The development of waviness in a rope must be watched very closely. Loose wires with no visible breaks, loose strands, and birdcages may develop out of waviness. Waviness in friction-hoist head ropes usually means unequal wheel groove diameters or rope lengths. When these contributors are corrected, the waviness may dissipate over a large area or just stop growing. If it dissipates, or stops growing and the problem is not severe, the ropes may run for a long time with no further problems. Structural variations must be closely watched. Waviness on drum-hoist ropes is likely to grow into something more serious, and the causes cannot usually be corrected. However, if waviness appears in dead wraps, retensioning may eliminate further problems.

Appendix M

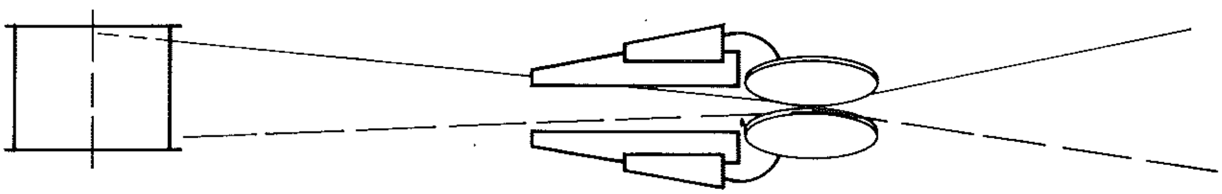
Fairlead Designs

The principal use of fairleads on surface mining machinery is on draglines to control the drag rope(s) where it enters the machinery house and to maintain proper lead to the drum. Four basic types are used, with various modifications, on today's surface mining machines.

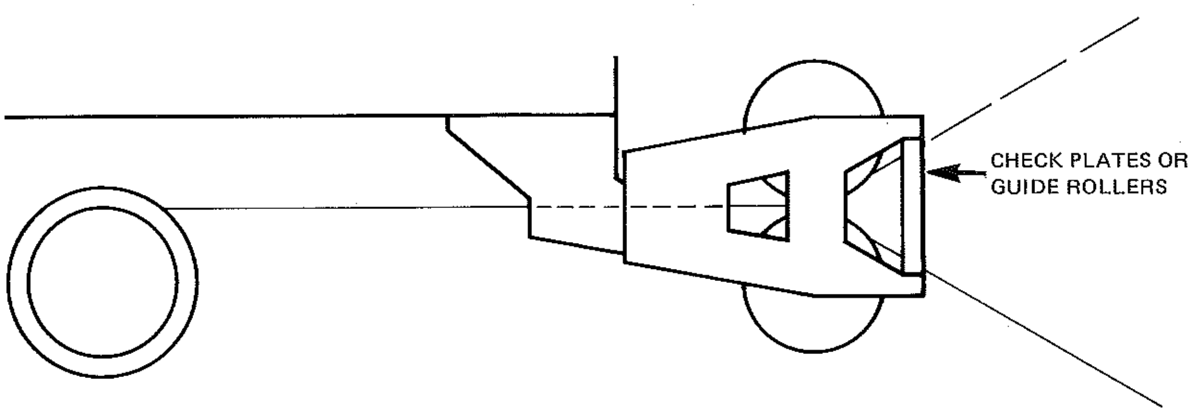
Types 1 and 2 are in general use on draglines having a single drag rope.

The size, weight, and inertia of Type 1 may become excessive when providing for the diameter and loading of large-diameter ropes. For this reason accepting the extra sheaves in Type 2 may be unavoidable.

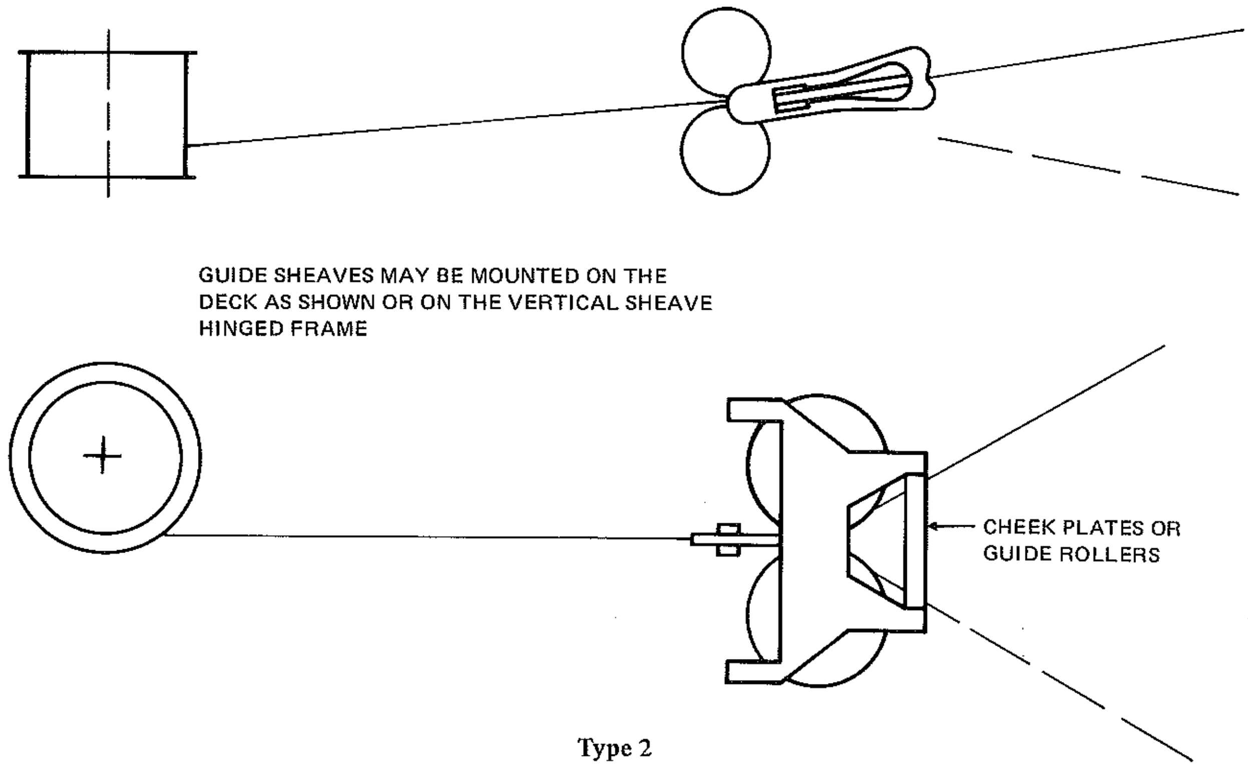
In either type the line between the vertical sheave centers may or may not be normal to the rope lead from the drum.



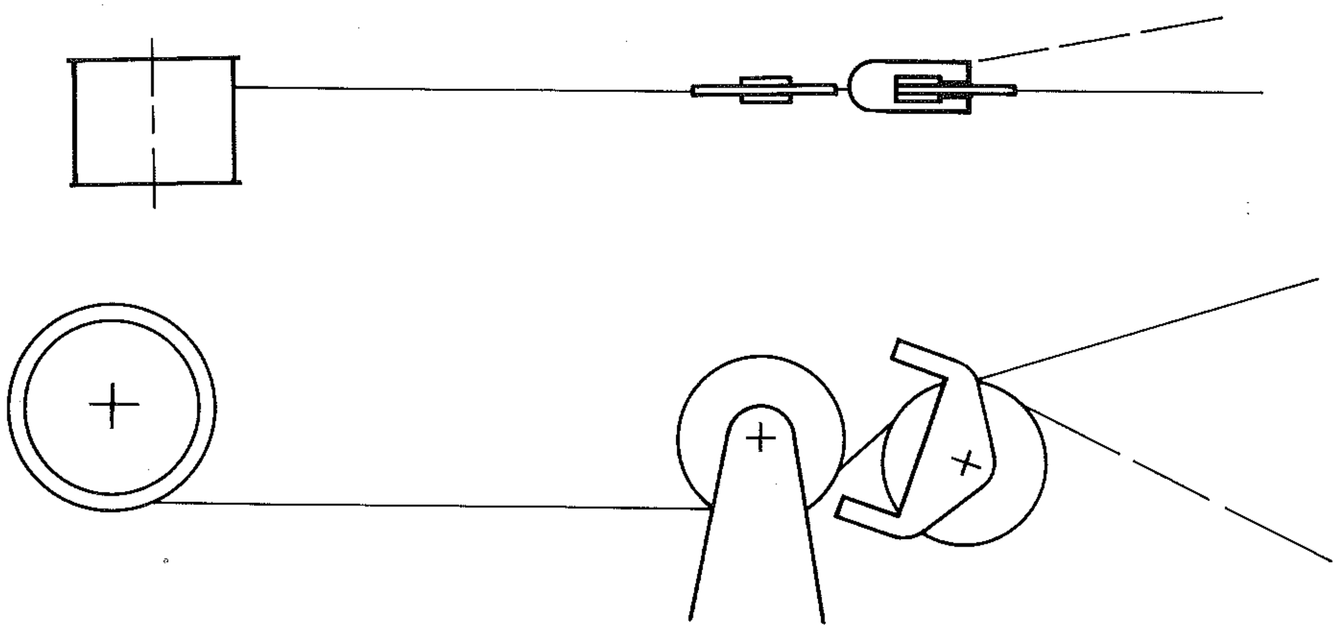
FAIRLEAD ROTATES ABOUT AXIS; SHEAVES LIE IN PLANE OF ENTERING AND EXITING ROPES FOR ZERO OFF-LEAD ON SHEAVES.



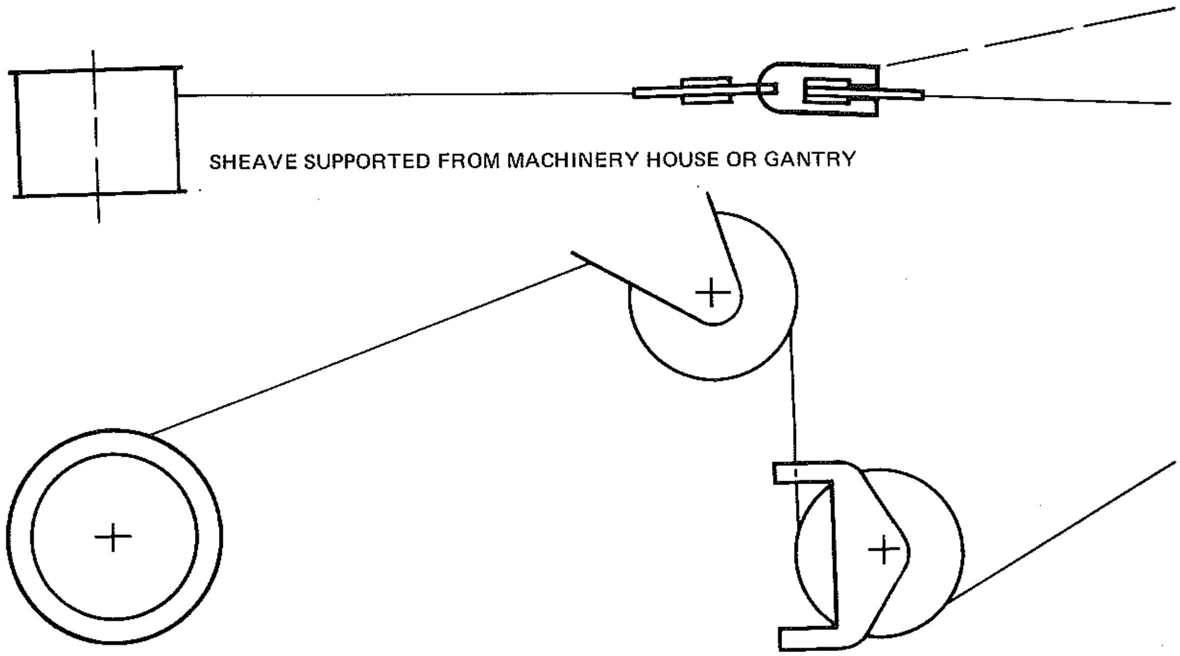
Type 1


GUIDE SHEAVES MAY BE MOUNTED ON THE DECK AS SHOWN OR ON THE VERTICAL SHEAVE HINGED FRAME
CHEEK PLATES OR GUIDE ROLLERS

Type 2



Type 3



Type 4

Appendix N

Inspection Report Forms for Wire Rope Used on Surface Mining Machines

It is not the intent in this appendix to propose a "standard" form to be used for rope-inspection reports at all surface mine sites. Due to wide variations in the number of machines at various sites, in the types and sizes of such machines, and because of differences in the loads on ropes and the differing bases for establishing rope-life estimates individual mines are best able to develop forms which best suit their particular conditions.

Three sample forms are suggested.

Form 1. Form 1 provides a complete record for the rope or ropes in each rope system; a separate report is required for each system on each machine. The report defines where the rope is used items (3) through (7), when it was installed (8), its complete description (9) through (13), its normal life (14), and the date of each inspection and rope service since installation (15) through (17).

Form 2. Form 2 provides a record of all rope systems on a machine; a separate report is required for each inspection. A master sheet should be available to state when each rope was installed (Item 8 Form 1) and to provide a complete description of it (Items 9 through 13 Form 1).

Form 3. Form 3 is the simplest of the sample report forms.

Interpretation of Form 1 –

(1) Mine owner and mine name
(2) Bureau of Mines identification number
(3) Machine manufacturer and model number
(4) Manufacturer's serial number
(5) Number assigned by mine
(6) Hoist, drag, suspension, etc
(7) Number identifying position in rope system (see sketch below)
(8) Date rope was installed
(9) Rope diameter
(10) Length of rope as installed
(11) Rope manufacturer
(12) Rope construction (example = 6 X 37 Seale)
(13) Rope grade (example = EIP)
(14) Normal life (see 5.9.2.2)
(15) Inspector's initials and date of inspection
(16) Shifts, days, yards or tons since installation
(17) Condition of rope, sheaves, etc (see 5.9.3, 5.9.4, 5.9.5, 5.9.6, 5.9.7, and 5.9.8)

Note cut-offs and resocketing

Last entry should be "Rope Removed"

Form 1
Wire Rope Inspection Form

Mine (1) ______	I.D. No (2) ______	
Machine (3) ______	Serial No (4) ______	Mine No (5) ______
Rope function (6) ______	Position (7) ______	Installed (8) ______
	______	______
	______	______
	______	______

Position	Diameter	Length	Manufacturer	Construction	Grade	Normal Life
(7)	(9)	(10)	(11)	(12)	(13)	(14)
______	______	______	______	______	______	______
______	______	______	______	______	______	______
______	______	______	______	______	______	______

Position	Inspected By Date	Service	Comments
(7)	(15)	(16)	(17)
______	______	______	______
______	______	______	______
______	______	______	______
______	______	______	______
______	______	______	______
______	______	______	______
______	______	______	______

Form 2
Stripping Shovel

Date ____________________ Inspected by ____________________

Machine ____________________ Machine Number ____________________

Manufacturer's Serial No ____________________ Dipper Capacity ____________ Cubic Yards

Frequency of Inspection ____________________ Material Being Handled ____________________

Boom Suspension Ropes or Strands

	Reeving Correct	*Condition or Remarks*
Left outer side and socket ends		
Upper	________	________
Center	________	________
Lower	________	________
Left inner side and socket ends		
Upper	________	________
Center	________	________
Lower	________	________
Right inner side and socket ends		
Upper	________	________
Center	________	________
Lower	________	________
Right outer side and socket ends		
Upper	________	________
Center	________	________
Lower	________	________
Operating Ropes		
Left hoist, outer	________	________
Left hoist, inner	________	________
Right hoist, inner	________	________
Right hoist, outer	________	________
Crowd	________	________
Retract	________	________
Dipper trip	________	________

Form 2
Crawler Dragline

Date __________	Inspected by __________	
Machine __________	Machine Number __________	
Manufacturer's Serial No __________	Bucket Capacity __________ Cubic Yards	
Frequency of Inspection __________	Material Being Handled __________	
Boom Suspension Ropes (with mast)	*Reeving Correct*	*Condition or Remarks*
Left side		
Right side		
Boom hoist rope (used with or without mast)		
Left side parts of rope		
Right side parts of rope		
Operating ropes		
Hoist.		
Drag		
Dump		

Form 2
Loading Shovel

Date ______________________ Inspected by ______________________

Machine ______________________ Machine Number ______________________

Manufacturer's Serial No ______________________ Dipper Capacity ______________ Cubic Yards

Frequency of Inspection ______________________ Material Being Handled ______________________

Boom Suspension Ropes or Strands

	Reeving Correct	*Condition or Remarks*
Left side and socket ends		
Upper	______	______
Lower	______	______
Right side and socket ends		
Upper	______	______
Lower	______	______
Boom hoist (if live boom hoist)		
Left side parts of rope	______	______
Right side parts of rope	______	______
Operating Ropes		
Left Hoist	______	______
Right Hoist	______	______
Crowd	______	______
Retract	______	______
Dipper Trip	______	______

Note Tightness of

Crowd Rope: Tight ______________ Loose ______________ Satisfactory ______________

Retract Rope: Tight ______________ Loose ______________ Satisfactory ______________

Form 3
Inspection Form

Inspected By			Date
Machine	I.D. No.	Serial No.	Machine Mine No

Rope Size	Length	Type	Rope Position	Condition or Remarks

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