Application, Care, and Use of Wire Rope for Oil Field Service

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1 Scope

This recommended practice (RP) covers typical wire rope applications for the oil and gas industry.

Typical practices in the application of wire rope to oil field service are indicated in Table 1, which shows the sizes and constructions commonly used. Because of the variety of equipment designs, the selection of constructions other than those shown is justifiable.

In oilfield service, wire rope is often referred to as wire line or cable. For the purpose of clarity, these various expressions are incorporated in this recommended practice.

2 Field Care and use of Wire Rope

2.1 Handling on Reel

2.1.1 Use of Binding or Lifting Chain

When handling wire rope on a reel with a binding or lifting chain, wooden blocks should always be used between the rope and the chain to prevent damage to the wire or distortion of the strands in the rope.

2.1.2 Use of Bars

Bars for moving the reel should be used against the reel flange, and not against the rope.

2.1.3 Sharp Objects

The reel should not be rolled over or dropped on any hard, sharp object in such a manner that the rope will be damaged.

2.1.4 Dropping

The reel should not be dropped. This may cause damage to the rope as well as break the reel.

2.1.5 Mud, Dirt, or Cinders

Rolling the reel in or allowing it to stand in any medium harmful to steel such as mud, dirt, or cinders should be avoided. Planking or cribbing will be of assistance in handling the reel as well as in protecting the rope against damage.

2.1.6 Lifting the Reel

The preferred method for lifting a reel with slings is to use a spreader bar that is of sufficient length to keep the sling legs from contacting the reel. This will prevent the flanges of the reel from being bent, distorted, broken, or damaged in any way by the slings.

2.1.7 Shaft through Arbor Holes

When lifting reels of wire rope, care must be taken that the shaft through the reel is of adequate length for the task, plus its wall thickness and diameter are of sufficient strength and size respectively to safely support the weight without damaging the center holes of the two flanges of the reel.

Table 1—Typical Sizes and Construction of Wire Rope for Oilfield Service

Wire Rope Application	Wire Rope Diameter		Wire Rope Description[a]
	(in.)	(mm)	
Rod and tubing lines	1/2 through 1 1/8	13 through 29	6×26WS RR or LR IWRC 6×31WS swaged RR or LR IWRC
Rod hanger lines	1/4	6.5	6×19 RR FC
Sand lines	1/4 through 5/8	6.5 through 16	6×7 bright or galvanized RR FC 5×7 bright or galvanized RR FC 5×7 swaged bright or galvanized FC
Drilling lines	7/8 through 2 1/4	22 through 57	6×19 class RR IWRC 8x19 class RR IWRC
	1 1/2 through 2 1/4	38 through 57	6x36 class RR IWRC 8X36 class RR IWRC
Winch lines	5/8 through 1 1/8	16 through 29	6×26WS or 6×31WS or 6×36WS RR IWRC
Horsehead pumping-units lines	1/2 through 1 1/8	13 through 29	6×19 class or 6×36 class FC or IWRC
Offshore anchorage lines	7/8 through 2 3/4	22 through 70	6×19 class bright/galvanized/drawn galvanized RR IWRC
	1 3/4 through 4 3/4	35 through 122	6×36 class bright/galvanized/drawn galvanized RR IWRC
Mast raising lines	Up through 1 3/8	Up through 35	6×19 class RR IWRC
	Over 1 3/8	Over 35	6×36 class RR or RL IWRC 8×36 class compacted strand RR or RL IWRC
Guideline tensioner line	3/4	19	6×19 class RR IWRC
Riser tensioner lines	1 1/2 through 3	38 through 76	6×36 class RL IWRC 8×36 class RL IWRC

These are general recommendations and may be modified due to operating conditions, rig requirements and/or rope characteristics. Consult your rope supplier for assistance.

Abbreviations:

FW	Filler wire	RR (sZ)	Right regular lay[b]	LL (sS)	Left lang lay[c]	FC	Fiber Core
S	Seale	LR (zS)	Left regular lay[d]	RA (aZ)	Right alternate lay[e]	IWRC	Independent wire rope core
WS	Warrington Seale	RL (zZ)	Right lang lay[f]	LA (aS)	Left alternate lay[g]		

[a] Typical rope descriptions shown include those with compacted strands, plastic coated IWRC; plastic impregnated IWRC; and plastic impregnated rope.

[b] Sometimes referred to as right-hand ordinary (designated RHO) and right regular lay (designated RRL).

[c] Sometimes referred to as left-hand langs (designated LHL) or left lang lay (designated LLL).

[d] Sometimes referred to as left-hand ordinary (designated LHO) and left regular lay (designated LRL).

[e] Formerly designated RAL.

[f] Sometimes referred to as right-hand langs (designated RHL) or right lang lay (designated RLL).

[g] Formerly designated LAL.

2.2 Handling During Installation

2.2.1 Stringing of Blocks

Blocks should be strung to give a minimum of wear against the sides of sheave grooves.

2.2.2 Changing Lines and Cutoff

It is good practice in changing lines to suspend the traveling block from the crown on a single line. This tends to limit the amount of rubbing on guards or spacers, as well as chances for kinks. This practice is also very effective in pull-through and cut-off procedure.

2.2.3 Rotation of Reel

The reel should be set up on a substantial horizontal axis so that it is free to rotate as the rope is pulled off, and in such a position that the rope will not rub against derrick members or other obstructions while being pulled over the crown. A snatch block with a suitable size sheave should be used to hold the rope away from such obstructions.

2.2.4 Jacking

The use of a suitable apparatus for jacking the reel off the floor and holding it so that it can turn on its axis is desirable.

2.2.5 Tension on Rope

For proper spooling, new ropes shall be installed under tension. This will reduce rope crushing and, if the tension is sufficient, prevent the “pulling-in” of upper layers in multiple layer spooling.

2.2.6 Twist in Rope

When installing a new rope, it is important that twist or torque not be in the installed rope. If twist or torque is apparent, the twist should be removed before the rope is anchored.

2.2.7 Kinking

Care should be taken to avoid kinking a wire rope since a kink is cause for removal of the wire rope or damaged section.

2.2.8 Striking with Hammer

Wire ropes should not be struck with any object such as a steel hammer, derrick hatchet, or crow bar which may cause wire displacement and distortion. Even when a soft metal hammer is used, it should be noted that a rope can be damaged by such blows. Therefore, when it is necessary to crowd wraps together, any such operation should be performed with the greatest of care; and a block of wood should be interposed between the hammer and rope.

2.2.9 Cleaning

The use of solvent may be detrimental to a wire rope. If a rope becomes covered with dirt or grit, it should be cleaned with a brush and followed by appropriate lubrication as necessary.

2.2.10 Excess or Dead Wraps

After properly securing the wire rope in the drum socket, the number of excess or dead wraps or turns specified by the equipment manufacturer should be maintained. For rigs with motion compensating equipment, enough additional rope shall be spooled on the drum to maintain the minimum number of dead wraps when the rope required by the compensator is at its maximum.

2.2.11 New Wire Rope

Whenever possible, a new wire rope should be run under controlled loads and speeds for a short period after it has been installed. This will help seat the strands around the core and adjust the rope to working conditions.

2.2.12 New Coring or Swabbing Line

If a new coring or swabbing line is excessively wavy when first installed, two to four sinker bars may be added on the first few trips to straighten the line.

2.3 Care of Wire Rope

2.3.1 Handling

The recommendations for handling as given in 2.1 and 2.2, inclusive, should be observed at all times during the life of the rope.

2.3.2 Storage

The storage reel shall be protected from weather, chemical fumes, steam, brine, and any other corrosive agents. The rope on the storage reel should not be in direct contact with the deck or the ground.

2.3.3 Design Factor

2.3.3.1 The design factor is determined by the following formula:

$$\text{Design Factor} = \frac{B}{W} \tag{1}$$

where

B is the minimum breaking force (MBF) of the new wire rope, lb;

W is the fast line tension, lb (see 2.3.3.4).

2.3.3.2 When a wire rope is operated close to the minimum design factor, care should be taken that the rope and related equipment are in good operating condition. At all times, the operating personnel should use diligent care to minimize shock, impact, and acceleration or deceleration of loads. Successful field operations indicate that the design factors in Table 2 should be regarded as minimum.

Table 2—Minimum Design Factors

Operation	Minimum Design Factor
Sand line	3
Rotary drilling line	3
Hoisting service other than rotary drilling	3
Mast raising and lowering line	2.5
Rotary drilling line when setting casing	2
Pulling on stuck pipe and similar infrequent operations	2

2.3.3.3 Wire rope life varies with the design factor; therefore, longer rope life can generally be expected when relatively high design factors are maintained.

2.3.3.4 To calculate the design factor for multipart string-ups, use Figure 1 and Figure 2 to determine the value of W in Equation (1). W is the fast line tension and equals the fast line factor times the hook load or weight indicator reading.

NOTE The fast line factor is calculated considering the tensions needed to overcome sheave-bearing friction.

EXAMPLE

Drilling Line	=	$1^3/_8$ in. (35 mm) EIPS
Number of Lines	=	10
Hook Load	=	400,000 lb (181.4 t)

Sheaves are roller bearing type. From Figure 2, Case A, the fast line factor is 0.123. The fast line tension is then 400,000 lb (181.4 t) 0.123 = 49,200 lb (22.3 t) W. Following the formula in Equation 1, the design factor is then the nominal strength of $1^3/_8$ in. (35 mm) EIPS drilling line divided by the fast line tension, or 192,000 lb (87.1 t) ÷ 49,200 lb (22.3 t) = 3.9.

2.3.3.5 When working near the minimum design factor, consideration should be given to the efficiencies of wire rope bent around sheaves, fittings, or drums. Figure 3 shows how rope can be affected by bending.

2.3.4 Winding on Drums

Rope should be kept tightly and evenly wound on the drums. Sufficient tension must be applied to the dead wraps on the drill line after making a cut or during installation to prevent it being forced from the lagging and crushed or damaged.

2.3.5 Application of Loads

Sudden, severe stresses are injurious to wire rope and such applications should be reduced to a minimum.

2.3.6 Operating Speed

Experience has indicated that wear increases with speed; economy results from moderately increasing the load and diminishing the speed.

2.3.7 Rope Speed

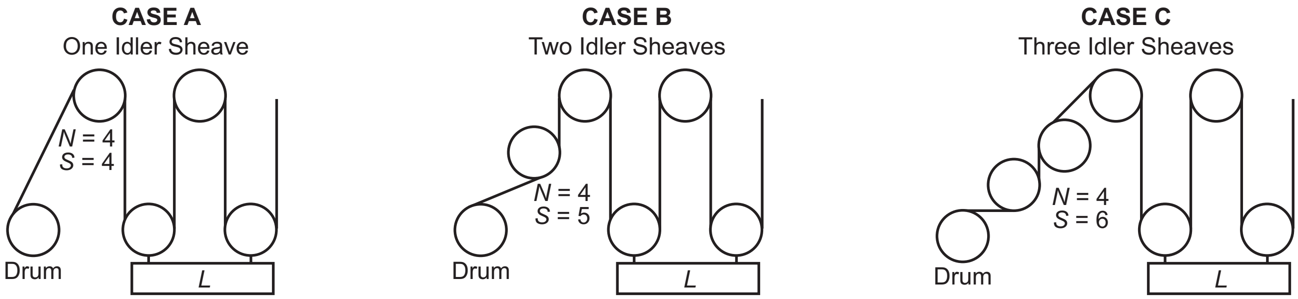
High speeds when running blocks under light load may cause damage to the wire rope. “Whipping” of the wire rope may cause contact with sheave guards or other structural members.

2.3.8 Lubrication of Wire Rope

Wire ropes are well lubricated when manufactured; however, the lubrication will not last throughout the entire service life of the rope. Periodically, therefore, the rope will need to be field lubricated. When necessary, lubricate the rope with a compatible lubricant which will penetrate and adhere to the rope, and which is free from acid or alkali.

2.3.9 Clamps and Rotary Line Dead-End Tie Down

The clamps used to fasten lines for dead-ending shall not kink, flatten, or crush the rope. The rotary line dead-end tie down is equal in importance to any other part of the system. The deadline anchorage system shall be equipped with a drum and clamping device strong enough to withstand the loading, and designed to prevent damage to the wire line that would affect service over the sheaves in the system. Consideration should be given to adding a second clamp at the deadline anchor when a plastic filled drill line is used to further reduce the likelihood of slippage.



L = load
S = number of sheaves
N = number of rope parts supporting load

Fast Line Tension = Fast Line Factor × Load

1	2	3	4	5	6	7	8	9	10	11	12	13
	Plain Bearing Sheaves K = 1.09[a]						**Roller Bearing Sheaves** K = 1.04[a]					
	Efficiency			**Fast Line Factor**			**Efficiency**			**Fast Line Factor**		
N	**Case A**	**Case B**	**Case C**	**Case A**	**Case B**	**Case C**	**Case A**	**Case B**	**Case C**	**Case A**	**Case B**	**Case C**
2	0.880	0.807	0.740	0.568	0.620	0.675	0.943	0.907	0.872	0.530	0.551	0.573
3	0.844	0.774	0.710	0.395	0.431	0.469	0.925	0.889	0.855	0.360	0.375	0.390
4	0.810	0.743	0.682	0.309	0.336	0.367	0.907	0.873	0.839	0.275	0.287	0.298
5	0.778	0.714	0.655	0.257	0.280	0.305	0.890	0.856	0.823	0.225	0.234	0.243
6	0.748	0.686	0.629	0.223	0.243	0.265	0.874	0.840	0.808	0.191	0.198	0.206
7	0.719	0.660	0.605	0.199	0.217	0.236	0.857	0.824	0.793	0.167	0.173	0.180
8	0.692	0.635	0.582	0.181	0.197	0.215	0.842	0.809	0.778	0.149	0.154	0.161
9	0.666	0.611	0.561	0.167	0.182	0.198	0.826	0.794	0.764	0.134	0.140	0.145
10	0.642	0.589	0.540	0.156	0.170	0.185	0.811	0.780	0.750	0.123	0.128	0.133
11	0.619	0.568	0.521	0.147	0.160	0.175	0.796	0.766	0.736	0.114	0.119	0.123
12	0.597	0.547	0.502	0.140	0.152	0.166	0.782	0.752	0.723	0.107	0.111	0.115
13	0.576	0.528	0.485	0.134	0.146	0.159	0.768	0.739	0.710	0.100	0.104	0.108
14	0.556	0.510	0.468	0.128	0.140	0.153	0.755	0.725	0.698	0.095	0.098	0.102
15	0.537	0.493	0.452	0.124	0.135	0.147	0.741	0.713	0.685	0.090	0.094	0.097
16	0.520	0.477	0.437	0.120	0.131	0.143	0.728	0.700	0.673	0.086	0.089	0.093
17	0.503	0.461	0.423	0.117	0.128	0.139	0.716	0.688	0.662	.0082	0.085	0.089
18	0.486	0.446	0.409	0.114	0.124	0.136	0.703	0.676	0.650	0.079	0.082	0.085
19	0.471	0.432	0.396	0.112	0.122	0.133	0.691	0.665	0.039	0.076	0.079	0.082
20	0.456	0.419	0.384	0.110	0.119	0.130	0.680	0.653	0.628	0.074	0.077	0.080

NOTE These cases apply also where the rope is dead ended at the lower or traveling block or derrick floor after passing over a dead sheave in the crown.

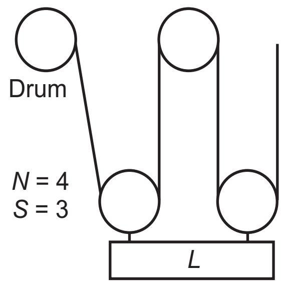
[a] In these tables, the *K*-factor for sheave friction is 1.09 for plain bearings and 1.04 for roller bearings. Other *K*-factors can be used if recommended by the equipment manufacturer.

$$\text{Efficiency} = \frac{K^N - 1}{K^S N(K-1)} \qquad \text{Fast Line Factor} = \frac{1}{N \times \text{Efficiency}}$$

Figure 1—Efficiency of Wire Rope Reeving for Multiple Sheave Blocks Cases A, B, and C (Fast Line and Efficiency Factors for Derricks, Booms, etc.)

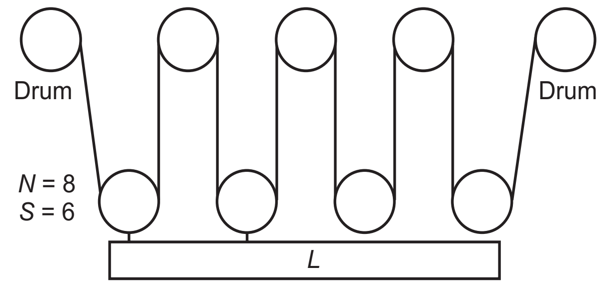
CASE D

Single Drum



CASE E

Double Drum with Equalizer



L = load
S = number of sheaves (not counting equalizer)
N = number of rope parts supporting load

	Efficiency		**Fast Line Factor**		**Efficiency**		**Fast Line Factor**	
N	**Case D**	**Case E**	**Case D**	**Case E**	**Case D**	**Case E**	**Case D**	**Case E**
2	0.959	1.000	0.522	0.500	0.981	1.000	0.510	0.500
3	0.920	—	0.362	—	0.962	—	0.346	—
4	0.883	0.959	0.283	0.261	0.944	0.981	0.265	0.255
5	0.848	—	0.236	—	0.926	—	0.216	—
6	0.815	0.920	0.205	0.181	0.909	0.962	0.183	0.173
7	0.784	—	0.182	—	0.892	—	0.160	—
8	0.754	0.883	0.166	0.142	0.875	0.944	0.143	0.132
9	0.726	—	0.153	—	0.859	—	0.129	—
10	0.700	0.848	0.143	0.118	0.844	0.926	0.119	0.108
11	0.674	—	0.135	—	0.828	—	0.110	—
12	0.650	0.815	0.128	0.102	0.813	0.909	0.102	0.092
13	0.628	—	0.123	—	0.799	—	0.096	—
14	0.606	0.784	0.118	0.091	0.785	0.892	0.091	0.080
15	0.586	—	0.114	—	0.771	—	0.086	—
16	0.566	0.754	0.110	0.083	0.757	0.875	0.083	0.071
17	0.548	—	0.107	—	0.744	—	0.079	—
18	0.530	0.726	0.105	0.077	0.731	0.859	0.076	0.065
19	0.513	—	0.103	—	0.719	—	0.073	—
20	0.498	0.700	0.101	0.071	0.707	0.844	0.071	0.059

NOTE The above cases apply also where the rope is dead ended at the lower or traveling block or derrick floor after passing over a dead sheave in the crown.

[a] In these tables, the *K*-factor for sheave friction is 1.09 for plain bearings and 1.04 for roller bearings. Other *K*-factors can be used if recommended by the equipment manufacturer.

$$\text{Case D Efficiency} = \frac{(K^N - 1)}{K^S N(K-1)} \qquad \text{Case E Efficiency} = \frac{2\left(K^{\frac{N}{2}} - 1\right)}{K^{\frac{S}{2}} N(K-1)}$$

$$\text{Fast Line Factor} = \frac{1}{N \times \text{Efficiency}} \qquad \text{Fast Line Factor} = \frac{1}{N \times \text{Efficiency}}$$

Figure 2—Efficiency of Wire Rope Reeving for Multiple Sheave Blocks Cases D and E (Fast Line and Efficiency Factors for Derricks, Booms, etc.)

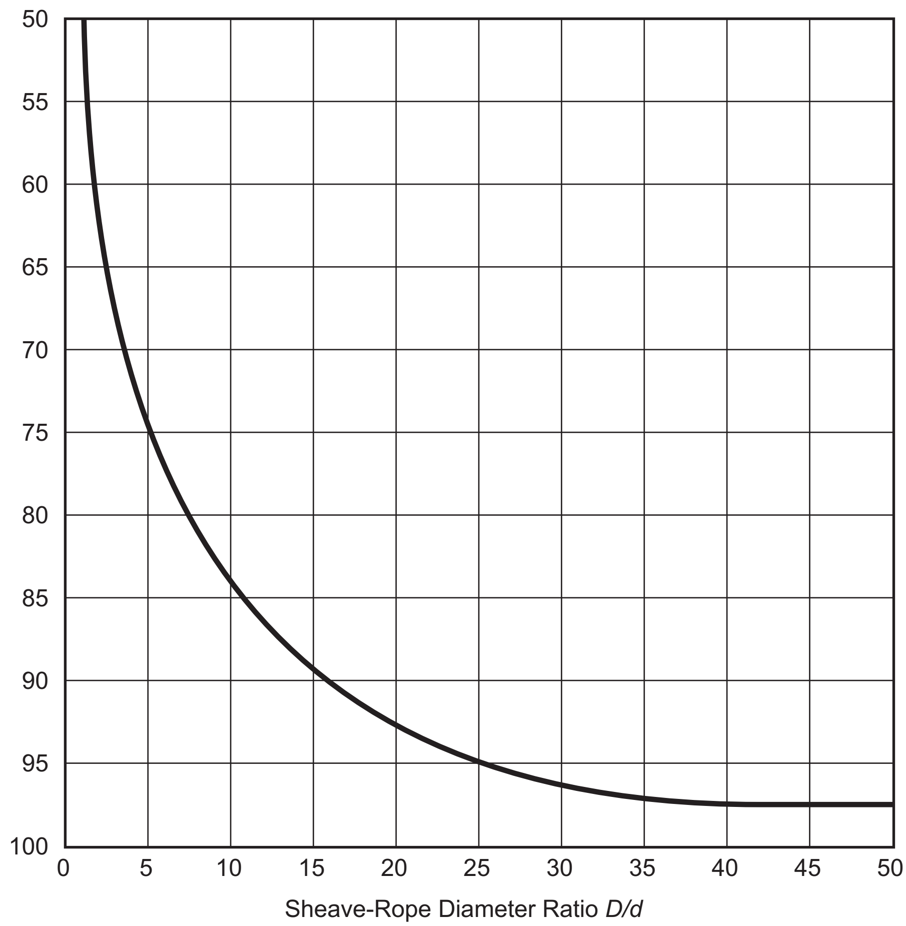


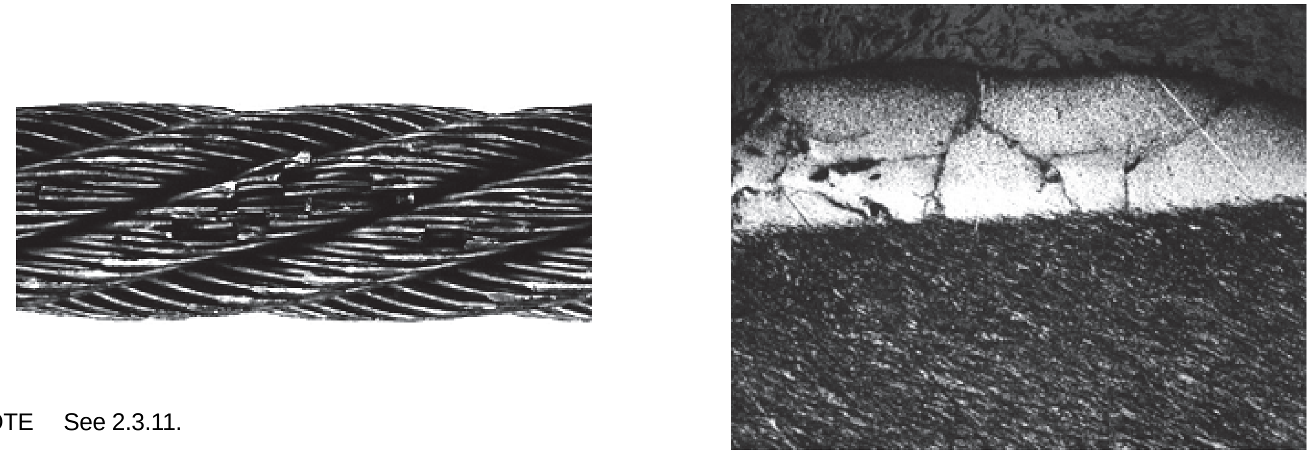
Figure 3—Efficiencies of Wire Ropes Bent Around Stationary Sheaves (Static Stresses Only)

2.3.10 Wire Breakage from Martensite in Drilling Lines

Care should be taken to maintain proper winding of rotary drilling lines on the drawworks drum in order to avoid excessive friction which may result in the formation of martensite. Martensite may be formed by excessive friction at kick over points on the drum, in worn grooves of sheaves, slippage in sheaves, or friction resulting from rubbing against a derrick member. A line guide should be employed between the drum and the fast line sheave to reduce vibration and keep the drilling line from rubbing against the derrick. On rigs with motion compensations, the high line speeds and sudden direction reversals can cause rope slippage in sheave grooves which can result in martensite formation.

NOTE 1 Martensite is a hard, nonductile micro constituent that is formed when steel is heated above its critical temperature and cooled rapidly. In the case of steel of the composition conventionally used for rope wire, martensite can be formed if the wire surface is heated to a temperature near or somewhat excess of 1400 °F (760 °C), and then cooled at a comparatively rapid rate. The presence of a martensite film at the surface of the outer wires of a rope that has been in service is evidence that sufficient frictional heat has been generated on the crown of the rope wires to momentarily raise the temperature of the wire surface to a point above the critical temperature range of the steel. The heated surface is then rapidly cooled by the adjacent cold metal within the wire and the rope structure and effective quenching results.

NOTE 2 Detail A of Figure 4 shows a rope, which has developed fatigue fractures at the crown in the outer wires, and Detail B of Figure 4 shows a photomicrograph (100× magnification) of a specimen cut from the crown of one of these outer wires. This photomicrograph clearly shows the depth of the martensitic layer and the cracks produced by the inability of the martensite to withstand the normal flexing of the rope. The initial cracks in the martensitic layer cause the failures appearing on the crown of the outer wires of this rope. The result is a disappointing service life for the rope. Most outer wire failures may be attributed to the presence of martensite, if this hard constituent is known to have been formed.



NOTE See 2.3.11.

Figure 4—Fatigue Fractures in Outer Wires Caused by the Formation of Martensite

2.3.11 Worn Sheave and Drum Grooves

Worn sheave and drum grooves cause excessive wear on the rope.

2.3.12 Sheave Alignment

All sheaves should be in proper alignment. The fast sheave should line up with the center of the hoisting drum.

2.3.13 Sheave Grooves

From the standpoint of wire rope life, the condition and contour of sheave grooves are important and should be checked periodically. The sheave groove should have a radius not less than that in Table 7; otherwise, a reduction in rope life can be expected. Reconditioned sheave grooves should conform to the recommended radii for new sheaves as given in Table 7. Each operator should establish the most economical point at which sheaves should be re-grooved or replaced by considering the loss in rope life which will result from worn sheaves as compared to the cost involved. Consult the sheave manufacturer for guidance on the re-grooving of their sheaves.

2.3.14 Installation of New Rope

When a new rope is to be installed on used sheaves, it is particularly important that the sheave grooves be checked as recommended in 2.3.13.

2.3.15 Lubrication of Sheaves

To ensure a minimum turning effort and smooth rotation, all sheaves should be kept properly lubricated.

2.3.16 Sheave Bearings

Sheave bearings must maintain sheave alignment.

2.4 Seizing

2.4.1 Seizing Prior to Cutting

Prior to cutting, a wire rope should be securely seized on each side of the cut by serving with soft wire ties. For socketing, at least two additional seizings should be placed at a distance from the end equal to the length of the basket of the socket. The total length of the seizing should be at least two rope diameters and securely wrapped with a seizing iron. This is very important, as it prevents the rope from untwisting and insures equal tension in the strands when the load is applied.

2.4.2 Procedure

A recommended procedure for seizing a wire rope is as follows and is illustrated in Figure 5.

a) The seizing wire should be wound on the rope by hand as shown in Detail 1. The coils should be kept together and considerable tension maintained on the wire.

b) After the seizing wire has been wound on the rope, the ends of the wire should be twisted together by hand in a counterclockwise direction so that the twisted portion of the wires is near the middle of the seizing (see Detail 2).

c) Using “Carew” cutters, the twist should be tightened just enough to take up the slack (see Detail 3). Tightening the seizing by twisting should not be attempted.

d) The seizing should be tightened by prying the twist away from the axis of the rope with the cutters as shown in Detail 4.

e) The tightening of the seizing as explained in c and d above should be repeated as often as necessary to make the seizing tight.

f) To complete the seizing operation, the ends of the wire should be cut off as shown in Detail 5, and the twisted portion of the wire tapped flat against the rope. The appearance of the finished seizing is illustrated in Detail 6.

2.4.3 Other Seizing Methods

Other seizing methods that prevent strand movement and wire rope distortion during and after cutting the wire rope may be used.

2.5 Poured Sockets

2.5.1 Efficiency

Properly attached poured sockets, using either zinc or epoxy, will develop 100 % of the wire rope’s strength.

2.5.2 Attachment

Poured sockets should be attached by trained personnel following the socketing material manufacturer’s directions or a recognized socketing standard such as ISO 17558.

2.6 Attachment of Clips

2.6.1 Type and Strength

The clip method of making wire rope attachment is widely used. Drop-forged clips of either the U-bolt or the double-saddle type are recommended. When properly applied so described herein, the method develops about 80 % of the rope strength in the case of six strand ropes.

2.6.2 Turn Back

When attaching clips, the length of rope to be turned back when making a loop is dependent upon the size of the rope and the load to be handled. The recommended lengths, as measured from the base of the thimble, are given in Table 3 and Table 4.

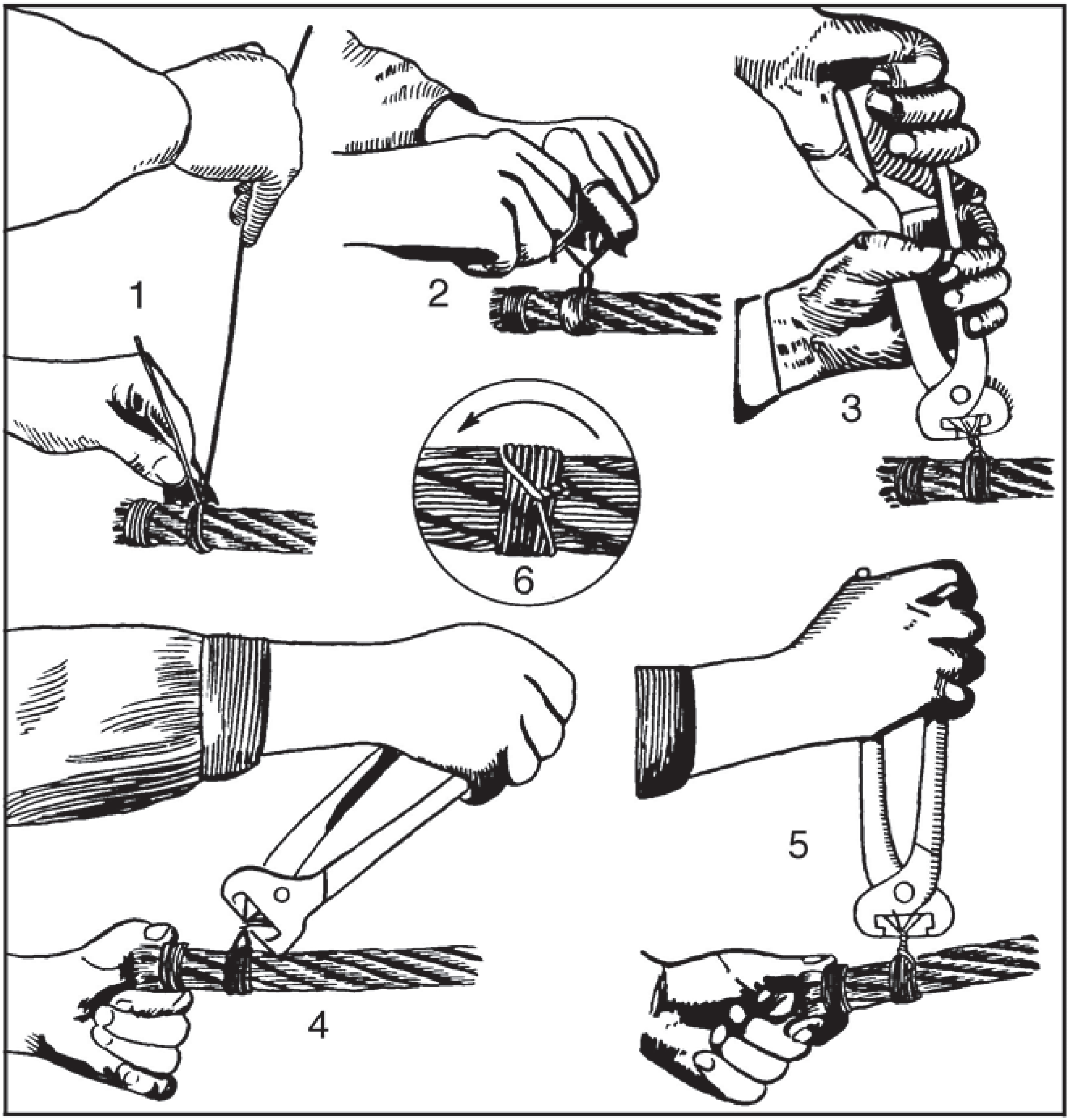


Figure 5—Putting a Seizing on a Wire Rope

2.6.3 Thimble

The thimble should first be wired to the rope at the desired point and the rope then bent around the thimble and temporarily secured by wiring the two rope members together.

2.6.4 Number and Attachment of Clips

2.6.4.1 Refer to Table 3 and Table 4 for minimum number of clips, and torque required. For U-bolt Clips, apply U-bolt over dead end of wire rope with live end resting in saddle. All U-bolt clips should be attached in the same manner (see Figure 6). The incorrect application of U-bolt clips is illustrated in Figure 7.

2.6.4.2 Apply first clip one base width from dead end of rope. Tighten nuts evenly, alternating from one nut to the other until reaching the recommended torque.

2.6.4.3 When two clips are required, apply the second clip as near the loop or thimble as possible. Tighten nuts evenly, alternating from one nut to the other until reaching the recommended torque.

Table 3—Attachment of Clips[a]

Diameter of Rope		Number of Clips	Length of Rope Turned Back		Torque	
in.	mm		in.	mm	ft-lb	N•m
1/8	3	2	3 1/4	83	4.5	6.1
3/16	5	2	3 3/4	95	7.5	10
1/4	6.5	2	4 3/4	121	15	20
5/16	8	2	5 1/4	133	30	41
3/8	9.5	2	6 1/2	165	45	61
7/16	11	2	7	178	65	88
1/2	13	3	11 1/2	292	65	88
9/16	14.5	3	12	305	95	129
5/8	16	3	12	305	95	129
3/4	19	4	18	457	130	176
7/8	22	4	19	483	225	305
1	26	5	26	660	225	305
1 1/8	29	6	34	864	225	305
1 1/4	32	7	44	1117	360	488
1 3/8	35	7	44	1120	360	488
1 1/2	38	8	54	1372	360	488
1 5/8	42	8	58	1473	430	583
1 3/4	45	8	61	1549	590	800
2	51	8	71	1800	750	1020
2 1/4	57	8	73	1850	750	1020
2 1/2	64	9	84	2130	750	1020
2 3/4	70	10	100	2540	750	1020
3	77	10	106	2690	1200	1630
3 1/2	89	12	149	3780	1200	1630

NOTE 1 If a pulley is used in place of a thimble for turning back the rope, add one additional clip.

NOTE 2 The table applies to 6 × 19 or 6 × 36 class, right regular or lang lay, IPS or EIPS, fiber or independent wire rope core; and 1 1/2 in. (38 mm) and smaller, 8 × 19 class, right regular lay, IPS, FC; and 1 3/4 in. (45 mm) and smaller, 18 × 7 or 19 × 7, right regular lay, IPS or EIPS, if Seale construction or similar large outer wire type construction in the 6 × 19 class are to be used in sizes 1 in. and larger, add one additional clip.

NOTE 2 If a greater number of clips are used than shown in the table, the amount of rope turned back should be increased proportionately.

NOTE 2 These values do not apply to plastic coated wire rope.

[a] See 2.6.2 and 2.6.4.

Table 4—Attachment of Double Saddle Clips[a]

Diameter of Rope		Number of Clips	Length of Rope Turned Back		Torque	
in.	mm		in.	mm	ft-lb	N•m
3/16	5	2	4	102	30	41
1/4	6.5	2	4	102	30	41
5/16	8	2	5	127	30	41
3/8	9.5	2	5 1/4	133	45	61
7/16	11	2	6 1/2	165	65	88
1/2	13	3	11	279	65	88
9/16	14.5	3	12 3/4	324	130	176
5/8	16	3	13 1/2	343	130	176
3/4	19	3	16	406	225	305
7/8	22	4	26	660	225	305
1	26	5	37	940	225	305
1 1/8	29	6	41	1041	360	488
1 1/4	32	6	55	1397	360	488
1 3/8	35	6	62	1575	500	678
1 1/2	38	7	78	1981	500	678

NOTE 1 If a pulley is used in place of a thimble for turning back the rope, add one additional clip.

NOTE 2 The table applies to 6 × 19 or 6 × 36 class, right regular or lang lay, IPS or EIPS, fiber or independent wire rope core; and 1 1/2 in. (38 mm) and smaller, 8 × 19 class, right regular lay, IPS, FC; and 1 3/4 in. (45 mm) and smaller, 18 × 7 or 19 × 7, right regular lay, IPS or EIPS, if Seale construction or similar large outer wire type construction in the 6 × 19 class are to be used in sizes 1 in. and larger, add one additional clip.

NOTE 3 If a greater number of clips are used than shown in the table, the amount of rope turned back should be increased proportionately.

NOTE 4 Above values do not apply to plastic coated wire rope.

[a] See 2.6.2 and 2.6.4.

Figure 6—Correct Method of Attaching Clips to Wire Rope

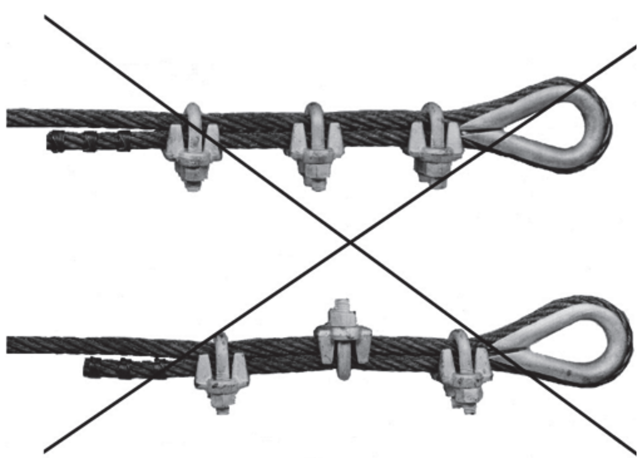


Figure 7—Incorrect Methods of Attaching Clips to Wire Rope

2.6.4.4 When more than two clips are required, apply the second clip as near the loop or thimble as possible, turn nuts on second clip firmly, but do not tighten. Space additional clips equally between the first two. Take up rope slack. Tighten nuts on each U-bolt evenly, alternating from one nut to the other until reaching recommended torque.

2.6.5 Application of Load and Retightening

Apply first load to the assembly. This load should be equal or greater than loads expected in use. Next, check and retighten nuts to recommended torque. In accordance with good rigging and maintenance practices, the wire rope and termination should be inspected periodically for wear, abuse, and general adequacy.

2.6.6 Use of Half Hitch

A half hitch, either with or without clips, shall not be used as it damages and weakens wire rope.

2.7 Casing-line and Drilling-line Reeving Practice

In the absence of a rig manufacturer specific reeving pattern, the diagram, Figure 8, illustrates in a simplified form the generally accepted methods of reeving (stringing up) in-line crown and traveling blocks, along with the location of the drawworks drum, monkey board, drill pipe fingers, and deadline anchor in relation to the various sides of the derrick. Ordinarily, the only two variables in reeving systems, as illustrated, are the number of sheaves in the crown and traveling blocks or the number required for handling the load, and the location of the deadline anchor. Table 5 gives the various arrangements possible for either left or right hand string ups. The reeving sequence for the left-hand reeving with 14-lines on an 8-sheave crown-block and 7-sheave traveling block illustrated in Figure 8 is given in Arrangement No. 1 of Table 5. The predominant practice is to use left-hand reeving and locate the deadline anchor to the left of the derrick vee. In selecting the best of the various possible methods for reeving casing or drilling lines, the following basic factors should be considered:

a) minimum fleet angle from the drawworks drum to the first sheave of the crown block, and from the crown block sheaves to the traveling block sheaves;

b) proper balancing of crown and traveling blocks;

c) convenience in changing from smaller to larger number of lines, or from larger to smaller numbers of lines;

d) locating of deadline on monkey board side for convenience and safety of derrick man;

e) location of deadline anchor, and its influence upon the maximum rated static hook load of derrick.

3 Recommended Design Features

NOTE See API 8C for specifications on sheaves.

3.1 Importance of Design

The proper design of sheaves, drums, and other equipment on which wire rope is used is of greatest importance to the service life of wire rope. It is strongly urged that the purchaser specify on the order that such material shall conform to recommendations set forth in this section.

3.2 Socket Baskets

The inside diameter of socket and swivel-socket baskets should be $^5/_{32}$ in. larger than the nominal diameter of the wire rope which is inserted.

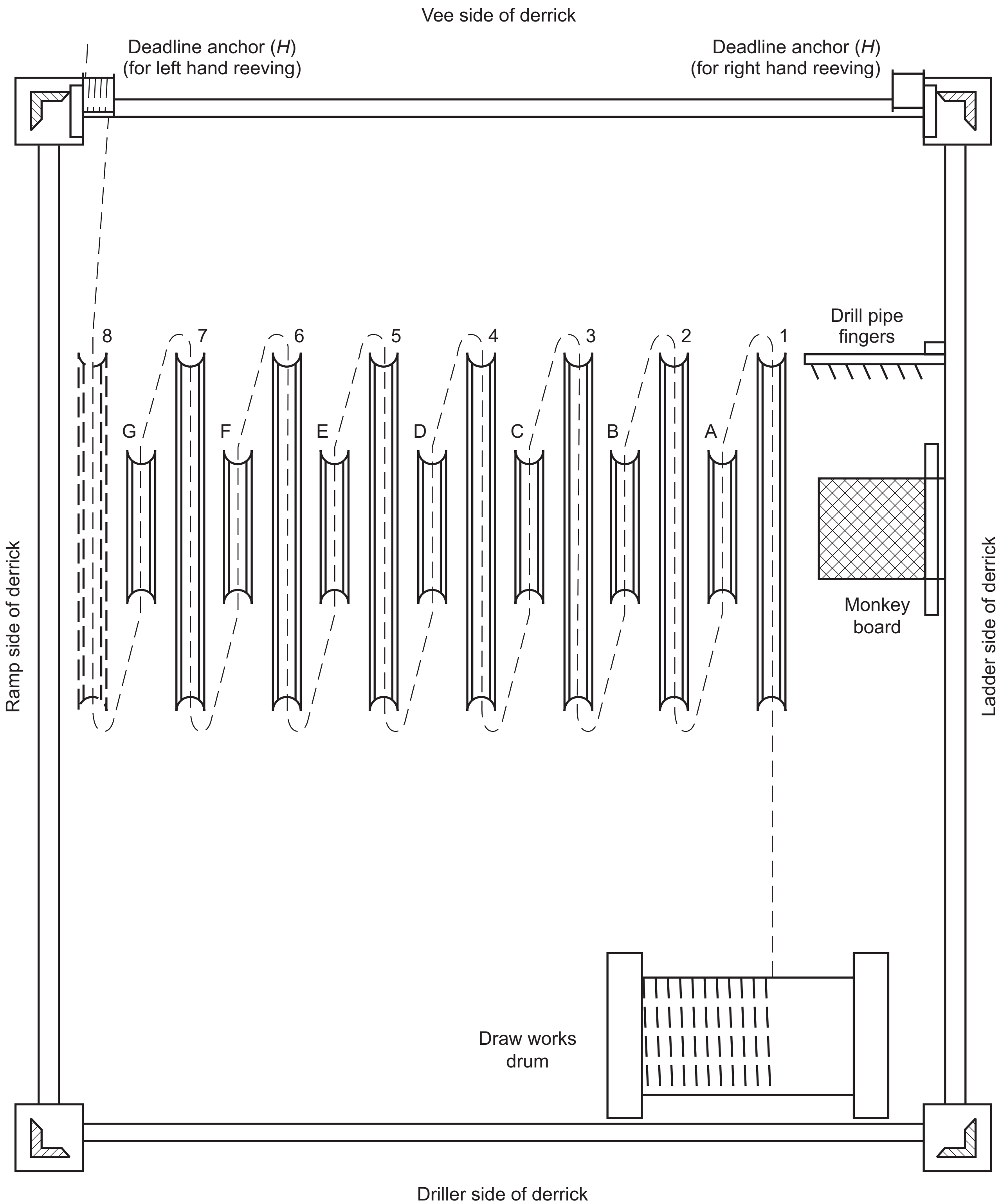


Figure 8—Typical Reeving Diagram for a 14-Line String-up with 8-Sheave Crown Block and 7-Sheave Traveling Block: Left Hand Reeving (See Arrangement No. 1 in Table 5)

Table 5—Typical Reeving Arrangements for 14, 12, 10, 9, and 6-Line String-ups Using 8-Sheave Crown Blocks with 7-Sheave Traveling Blocks, 7-Sheave Crown Blocks with 6-Sheave Traveling Blocks, and 6-Sheave Crown Blocks with 5-Sheave Traveling Blocks

Arrange-ment No.	No. of Sheaves		Type of String-up	No. of Lines to	Reeving Sequence[a]															
	Crown Block	Trav. Block																		
1	8	7	Left hand	14	Crown block	1		2		3		4		5		6		7		8
					Trav. block		A		B		C		D		E		F		G	
2	8	7	Right hand	14	Crown block	8		7		6		5		4		3		2		1
					Trav. block		G		F		E		D		C		B		A	
3	7	6	Left hand	12	Crown block	1		2		3		4		5		6		7		
					Trav. block		A		B		C		D		E		F			
4	7	6	Right hand	12	Crown block	7		6		5		4		3		2		1		
					Trav. block		F		E		D		C		B		A			
5	7	6	Left hand	10	Crown block	1		2		3				5		6		7		
					Trav. block		A		B				D		E		F			
6	7	6	Right hand	10	Crown block	7		6		5				3		2		1		
					Trav. block		F		E				C		B		A			
7	6	5	Left hand	10	Crown block	1		2		3		4		5		6				
					Trav. block		A		B		C		D		E					
8	6	5	Right hand	10	Crown block	6		5		4		3		2		1				
					Trav. block		E		D		C		B		A					
9	6	5	Left hand	8	Crown block	1		2		3				5		6				
					Trav. block		A		B				D		E					
10	6	5	Right hand	8	Crown block	6		5		4				2		1				
					Trav. block		E		D				B		A					
11	6	5	Left hand	8	Crown block	1		2		3		4		5						
					Trav. block		A		B		C		D							
12	6	5	Right hand	8	Crown block	6		5		4		3		2						
					Trav. block		E		D		C		B							
13	6	5	Left hand	6	Crown block			2		3		4		5						
					Trav. block				B		C		D							
14	6	5	Right hand	6	Crown block			5		4		3		2						
					Trav. block				D		C		B							
15	6	5	Left hand	6	Crown block	1				3		4				6				
					Trav. block		A				C				E					
16	6	5	Right hand	6	Crown block	6				4		3				1				
					Trav. block		E				C				A					

[a] Read from left to right starting with crown block and going alternately from crown to traveling to crown.

3.3 Material for Sheave Grooves

It is recommended that replacement sheaves be of the same type and meet the same specification as the original sheaves.

3.4 Bearings

Anti-friction bearings are recommended for all rotating sheaves.

3.5 Diameter of Drums

Drums should be large enough to handle the rope with the smallest possible number of layers. Drums having a diameter of 20 times the nominal wire rope diameter should be considered minimum for economical practice. Larger diameters than this are preferable. For well-measuring wire, the drum diameter should be as large as the design of the equipment will permit, but should not be less than 100 times the wire diameter.

3.6 Drum Grooves

The recommended grooving for wire rope drums is as follows.

a) On drums designed for multiple-layer winding, the distance between groove centerlines should be approximately equal to the nominal diameter of the wire rope plus one-half the specified oversized tolerance. For the best spooling condition, this dimension can vary according to the type of operation.

b) The radius of curvature of the groove profile should be equal to the radii listed in Table 8.

c) The depth of groove should be approximately 30 % of the nominal diameter of the wire rope. The crests between grooves should be rounded off to provide the recommended groove depth.

3.7 Diameter of Sheaves

3.7.1 Variations for Different Service Applications

3.7.1.1 General

Because of the diversification of types of equipment using wire rope, this subject must be considered in terms of the end use of the wire rope. Wire ropes used for oil-field service have their ultimate life affected by a combination of operating conditions. Among these are bending over sheaves, bending and crushing on drums, loading conditions, rope speed, abrasion, corrosion, etc. When bending conditions over sheaves predominate in controlling rope life, sheaves should be as large as possible after consideration has been given to economy of design, portability, etc. When conditions other than bending over sheaves predominate, as in the case of hoisting service for rotary drilling when the wire rope is retired due to deterioration on the drum, the size of the sheaves may be reduced without seriously affecting rope life.

The following recommendations are offered as a guide to designers and users in selecting the proper sheave size.

The following formula applies:

$$D_T = d \times F$$

where

D_T is the tread diameter of sheave, in inches (millimeters) (see Figure 10);

d is the nominal rope diameter, in inches (millimeters);

F is the sheave-diameter factor, selected from Table 6.

Table 6—Sheave-Diameter Factors

Rope Classification	Factor F		
	Condition A	Condition B	Condition C
6 × 7	72	42	See Figure 9 and Table 7
6 × 7 Seale	56	33	—
6 × 19 Seale	51	30	—
6 × 21 Filler wire	45	26	—
6 × 25 Filler wire	41	24	—
6 × 31	38	22	—
6 × 37	33	18	—
8 × 19 Seale	36	21	—
8 × 19 Warrington	31	18	—
8 × 36 Warrington Seale	33	18	—
18 × 7 and 19 × 7	51	36	—
Flattened strand	51	45	Follow manufacturer's recommendations

3.7.1.2 Condition A

Where bending over sheaves is of major importance, sheaves at least as large as those determined by factors under Condition A are recommended.

3.7.1.3 Condition B

Where bending over sheaves is important, but some sacrifice in rope life is acceptable to achieve portability, reduction in weight, economy of design, etc. sheaves at least as large as those determined by factors under Condition B are recommended.

3.7.1.4 Condition C

Some equipment is used under operating conditions which do not reflect the advantage of the selection of sheaves by factors under Conditions A or B. In such cases, sheave-diameter factors may be selected from Figure 9 and Table 7. As smaller factors are selected, the bending life of the wire rope is reduced and it becomes an increasingly important condition of rope service. Some conception of relative rope service with different rope constructions and/or different sheave sizes may be obtained by multiplying the ordinate found in Figure 9 by the proper construction factor indicated in Table 7.

It should be stressed that if sheave design is based on Condition C, fatigue due to severe bending can occur rapidly. If other conditions of operation are not present to cause the rope to be removed from service, fatigue of this type is apt to result in wires breaking where they are not readily visible to external examination. Any condition resulting in rope deterioration of a type which is difficult to judge by examination during service should certainly be avoided.

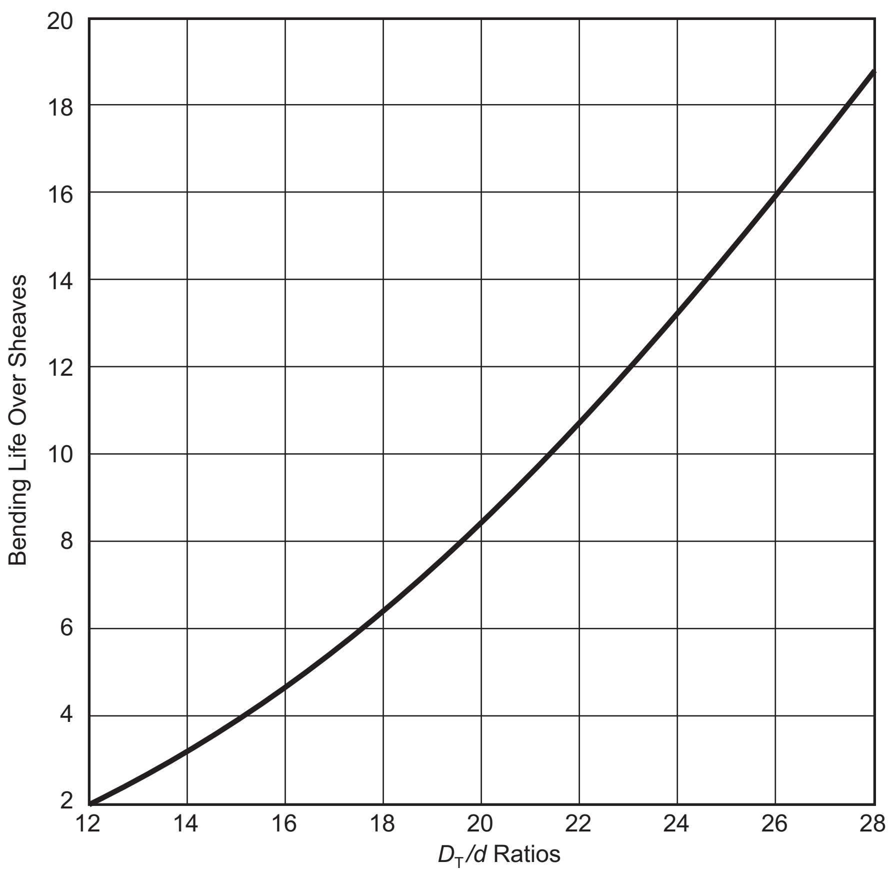
3.7.2 Sheaves for Well-measuring Wire

The diameter of sheaves for well-measuring wire should be as large as the design of the equipment will permit but not less than 100 times the diameter of the wire.

Table 7—Relative Bending Life Factors for Various Construction[a]

Construction	Factor
6 × 7	0.57
18 × 7 and 19 × 7	0.67
6 × 17 Seale	0.73
6 × 19 Seale	0.80
Flattened strand	0.80
6 × 21 Filler wire	0.92
6 × 25 Filler wire	1.00
6 × 31	1.09
8 × 19 Seale	1.14
6 × 37	1.33
8 × 19 Warrington	1.33
8 × 36 Warrington Seale	1.33

[a] Based on laboratory tests involving systems consisting of sheaves only.



where

D_T is the tread diameter of sheave, in inches (mm) (see Figure 10);

d is the nominal rope diameter, in inches (mm).

NOTE Based on laboratory tests involving systems consisting of sheaves only.

Figure 9—Relative Service for Various D_T/d Ratios for Sheaves

3.8 Sheave Grooves

3.8.1 General

On all sheaves, the arc of the bottom of the groove should be smooth and concentric with the bore or shaft of the sheave. The centerline of the groove should be in a plane perpendicular to the axis of the bore or shaft of the sheave.

3.8.2 Drilling and Casing Line Sheaves

Grooves for drilling and casing line sheaves shall be made for the rope size specified by the purchaser (see API 8C). The bottom of the groove shall have a radius R, Table 8, subtending an arc of 150 degrees. The sides of the groove shall be tangent to the ends of the bottom arc. Total groove depth for new sheaves shall be a minimum of 1.33d and a maximum of 1.75d, where d is the nominal rope diameter shown in Figure 10, Detail A.

Table 8—Grove Radii for Sheaves [a]

Nominal Wire Rope Diameter		Groove Radius Minimum Worn		Groove Radius Minimum New		Groove Radius Maximum	
in.	mm	in.	mm	in.	mm	in.	mm
0.250	6.5	0.128	3.25	0.134	3.40	0.138	3.51
0.313	8.0	0.160	4.06	0.167	4.24	0.172	4.37
0.375	9.5	0.192	4.88	0.199	5.05	0.206	5.23
0.438	11.0	0.224	5.69	0.232	5.89	0.241	6.12
0.500	13.0	0.256	6.50	0.265	6.73	0.275	6.99
0.563	14.5	0.288	7.32	0.298	7.57	0.309	7.85
0.625	16.0	0.320	8.13	0.331	8.41	0.344	8.74
0.750	19.0	0.384	9.75	0.398	10.11	0.413	10.49
0.875	22.0	0.448	11.38	0.464	11.79	0.481	12.22
1.000	26.0	0.513	13.03	0.530	13.46	0.550	13.97
1.125	29.0	0.577	14.66	0.596	15.14	0.619	15.72
1.250	32.0	0.641	16.28	0.663	16.84	0.688	17.48
1.375	35.0	0.705	17.91	0.729	18.52	0.756	19.20
1.500	38.0	0.769	19.53	0.795	20.19	0.825	20.96
1.625	42.0	0.833	21.16	0.861	21.87	0.894	22.71
1.750	45.0	0.897	22.78	0.928	23.57	0.963	24.46
1.875	48.0	0.961	24.41	0.994	25.25	1.031	26.19
2.000	52.0	1.025	26.04	1.060	26.92	1.100	27.94
2.125	54.0	1.089	27.66	1.126	28.60	1.169	29.69
2.250	58.0	1.153	29.29	1.193	30.30	1.238	31.45
2.375	60.0	1.217	30.91	1.259	31.98	1.306	33.17
2.500	64.0	1.281	32.54	1.325	33.66	1.375	34.93
2.625	67.0	1.345	34.16	1.391	35.33	1.444	36.68
2.750	71.0	1.409	35.79	1.458	37.03	1.513	38.43
2.875	74.0	1.473	37.41	1.524	38.71	1.581	40.16
3.000	77.0	1.537	39.04	1.590	40.39	1.650	41.91
3.125	80.0	1.602	40.69	1.656	42.06	1.719	43.66
3.250	83.0	1.666	42.32	1.723	43.76	1.788	45.42

Table 8—Grove Radii for Sheaves [a] (Continued)

Nominal Wire Rope Diameter		Groove Radius Minimum Worn		Groove Radius Minimum New		Groove Radius Maximum	
in.	mm	in.	mm	in.	mm	in.	mm
3.375	86.0	1.730	43.94	1.789	45.44	1.856	47.14
3.500	90.0	1.794	45.57	1.855	47.12	1.925	48.89
3.750	96.0	1.922	48.82	1.988	50.50	2.063	52.40
4.000	103.0	2.050	52.07	2.120	53.85	2.200	55.88
4.250	109.0	2.178	55.32	2.253	57.23	2.338	59.39
4.500	115.0	2.306	58.57	2.385	60.58	2.475	62.87
4.750	122.0	2.434	61.82	2.518	63.96	2.613	66.37
5.000	128.0	2.563	65.10	2.650	67.31	2.750	69.85
5.250	135.0	2.691	68.35	2.783	70.69	2.888	73.36
5.500	141.0	2.819	71.60	2.915	74.04	3.025	76.84
5.750	148.0	2.947	74.85	3.048	77.42	3.163	80.34
6.000	154.0	3.075	78.11	3.180	80.77	3.300	83.82

NOTE For wire rope sizes 0.375 in. (9.5 mm) and larger not found in this table use the following equations:

Minimum worn groove radius = nominal rope radius + $2^1/_2$ %

Minimum new groove radius = nominal rope radius + 6 %

Maximum groove radius = nominal rope radius + 10 %

[a] See Figure 10.

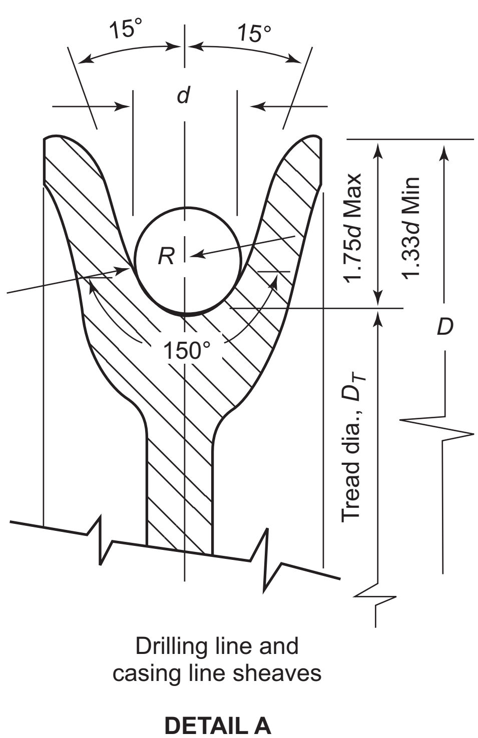


Figure 10—New Sheave Grooves

3.8.3 Sand-Line Sheaves

Grooves for sand-line sheaves shall be made for the rope size specified by the purchaser (see API 8C). The bottom of the groove shall have a radius R, Table 8, subtending an arc of 150 degrees. The sides of the groove shall be tangent to the ends of the bottom arc. Total groove depth for new sheaves shall be a minimum of $1.75d$ and a maximum of $3d$, where d is nominal rope diameter shown in Figure 10, Detail B.

3.8.4 Oil-saver Rollers

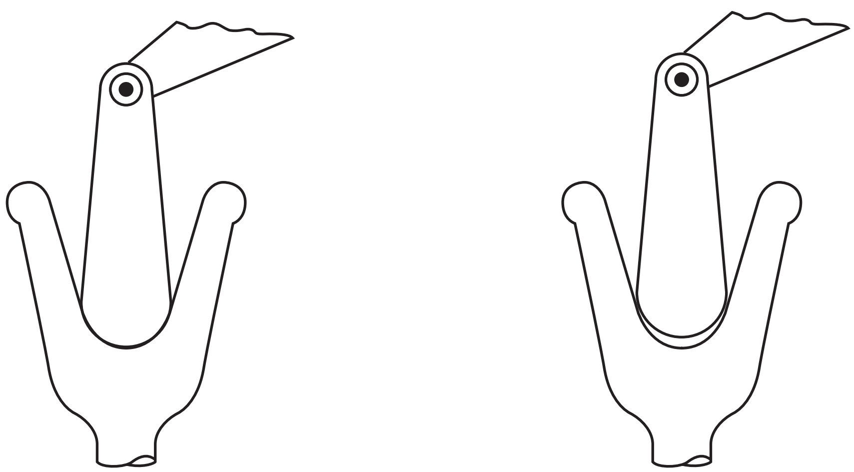
Grooves on rollers of oil savers should be made to the same tolerances as the grooves on the sheaves.

3.8.5 Worn Sheaves

Sheaves should be replaced or reworked when the groove radius is below the minimum worn values or above the maximum values shown in Table 8. Sheave manufacturers should provide guidance on limitations for removal of material on re-grooved sheaves.

3.8.6 Sheave Gages

Use sheave gages as shown in Figure 11. Detail A shows a sheave with a minimum groove radius. Detail B shows a sheave with a tight groove, which should be replaced or reworked.



DETAIL A DETAIL B

Figure 11—Use of Sheave Gage

4 Evaluation of Rotary Drilling Line

4.1 Total Service Performed

The total service performed by a rotary drilling line can be evaluated by taking into account the amount of work done by the line in the various drilling operations (drilling, coring, fishing, setting casing, etc.), and by evaluating such factors as the stresses imposed by acceleration and deceleration loadings, vibration stresses, stresses imposed by friction forces of the line in contact with drum and sheave surfaces, and other even more indeterminate loads. However, for comparative purposes, an approximate evaluation can be obtained by computing only the work done by the line in raising and lowering the applied loads in making round trips, and in the operations of drilling, coring, setting casing, and short trips.

4.2 Round-trip Operations

Most of the work done by a drilling line is that performed in making round trips (or half-trips) involving running the string of drill pipe into the hole and pulling the string out of the hole. The amount of work performed per round trip should be determined by use of the following formula.

$$T_r = \frac{D(L_s + D)W_m}{10,560,000} + \frac{D\left(M + \frac{1}{2}C\right)}{2,640,000} \tag{2}$$

where

T_r is the ton-miles [weight in tons (2000 lb) times distance moved in miles];

D is the depth of hole, in ft;

L_s is the length of drill-pipe stand, in ft;

N is the number of stands of drill-pipe;

W_m is the effective (buoyed) weight per foot of drill-pipe in drilling fluid, in lb/ft;

M is the total weight of traveling block-elevator assembly and top drive (if used), in lb;

C is the effective (buoyed) weight of drill collar assembly in drilling fluid minus the effective (buoyed) weight of the same length of drill-pipe in drilling fluid, in lb/ft.

The formula for ton-miles per round trip as above is based on the following derivation.

In making a round trip, work is done in raising and lowering the traveling block assembly and in running and pulling the drill stem, including the drill collar assembly and bit. The calculations are simplified by considering the drill pipe as extending to the bottom of the hole and making separate calculations for the excess weight of the drill collar-bit assembly over that of the same length of drill pipe.

In running the string, the traveling block assembly, which includes the traveling block, hook, links, and elevator (weight M), moves a distance equal (approximately) to twice the length of the stand ($2L_s$), for each stand. The amount of work done is equal to $2ML_sN$. In pulling the string, a similar amount of work is done; therefore, the total amount of work done in moving the traveling block assembly, during one complete round trip is equal to $4ML_sN$. Because the drill pipe is assumed to extend to the bottom of the hole, making L_sN equal to D, the total work can be expressed as $4DM$ in pound-feet or

$$\frac{4DM}{5280 \times 2000}\text{, in ton-miles} \tag{3}$$

In lowering the drill pipe into the hole, the amount of work done is equal to the average of the weights lowered times the distance (D). The average weight is equal to one-half the sum of one stand of drill pipe (the initial load) plus the weight of N stands (the final load). Since the weight of the drill pipe is decreased by the buoyant effect of the drilling fluid, an allowance must be made for buoyancy. The work done in pound-feet is therefore equal to

$$1/2\,(W_m L_s + W_m L_s N)D,$$

or

$$1/2\,(W_m L_s + W_m L_s D)D$$

Assuming the friction loss is the same in going into the hole as in coming out, the work done in raising the drill pipe is the same as in lowering, so for a round trip, the work done in ton-miles is equal to

$$\frac{DW_\mathrm{m}(L_\mathrm{s}+D)}{5280 \times 2000} \tag{4}$$

Because the drill collars and bit weigh more per foot than drill pipe, a correction factor must be introduced for the added work done in lowering and lifting this assembly. This amount is equal to the excess weight of the drill collar assembly, including subs and bits (C), times and distance moved (D). For a round trip the work done (in ton-miles) would be

$$\frac{2 \times C \times D}{5280 \times 2000} \tag{5}$$

The total work done in making a round trip would be equal to the sum of the amounts expressed in Equation (3), Equation (4), and Equation (5); namely

$$T_\mathrm{r} = \frac{4DM}{5280 \times 2000} + \frac{DW_\mathrm{m}(L_\mathrm{s}+D)}{5280 \times 2000} + \frac{2CD}{5280 \times 2000} \tag{6}$$

This can be rewritten as

$$T_r = \frac{D(L_s+D)W_m}{5280 \times 2000} + \frac{4D\left(M+\frac{1}{2}C\right)}{5280 \times 2000}$$

or

$$T_r = \frac{D(L_s+D)W_m}{10{,}560{,}000} + \frac{D\left(M+\frac{1}{2}C\right)}{2{,}640{,}000} \tag{7}$$

4.3 Drilling Operations

The ton-miles of work performed in drilling operations is expressed in terms of work performed in making round trips, since there is a direct relationship as illustrated in the following cycle of drilling operations:

a) drill ahead length of the kelly,

b) pull up length of the kelly,

c) ream ahead length of the kelly,

d) pull up length of the kelly to add single or double,

e) put kelly in rat hole,

f) pick up single or double,

g) lower drill stem in hole,

h) pick up kelly.

Analysis of the cycle of operations shows that for any one hole, the sum of all operations a) and b) is equal to one round trip; the sum of all operations c) and d) is equal to another round trip; the sum of all operations g) is equal to one-half a round trip; and the sum of all operations e), f), and h) may, and in this case does, equal another one-half round trip, thereby making the work of drilling the hole equivalent to three round trips to bottom. This relationship can be expressed as follows:

$$T_d = 3(T_2 - T_1) \tag{8}$$

where

T_d is the ton-miles drilling;

T_1 is the ton-miles for one round trip at depth D_1 (depth where drilling started after going in hole, in ft);

T_2 is the ton-miles for one round trip at depth D_2 (depth where drilling stopped before coming out of hole, in ft).

If operations c) and d) are omitted, then Equation (8) becomes:

$$T_d = 2(T_2 - T_1) \tag{9}$$

If a top drive is used, Equation (8) becomes:

$$T_d = T_2 - T_1 \tag{10}$$

If reaming is done between connections with a top drive then Equation (8) becomes:

$$T_d = 2(T_2 - T_1) \tag{11}$$

4.4 Coring Operations

The ton-miles of work performed in coring operations, as for drilling operations, is expressed in terms of work performed in making round trips, since there is a direct relationship that is illustrated in the following cycle of coring operations:

a) core ahead length of core barrel,

b) pull up length of kelly,

c) put kelly in rat hole,

d) pick up single,

e) lower drill stem in hole,

f) pick up kelly.

Analysis of the cycle of operation shows that for any one hole the sum of all operations a) and b) is equal to one round trip; the sum of all operations e. is equal to one-half a round trip; and the sum of all operations c), d), and f) may, and in this case does, equal another one-half round trip, thereby making the work of drilling the hole equivalent to two round trips to bottom. This relationship can be expressed as follows:

$$T_c = 2(T_4 - T_3) \tag{12}$$

where

T_c is the ton-miles coring;

T_3 is the ton-miles for one round trip at depth, D_3 (depth where coring started after going in hole, in ft);

T_4 is the ton-miles for one round trip at depth D_4 (depth where coring stopped before coming out of hole, in ft).

NOTE Extended coring operations are ordinarily not encountered.

4.5 Setting Casing Operations

The calculation of the ton-miles for the operation of setting casing should be determined as in 4.2, as for drill pipe, but with the effective weight of the casing being used, and with the result being multiplied by one-half, since setting casing is a one-way ($^1/_2$ round-trip) operation. Ton-miles for setting casing can be determined from the following formula:

$$T_s = \left(\frac{D(L_{cs} + D)W_{cm}}{10{,}560{,}000} + \frac{D\left(M + \frac{1}{2}C\right)}{2{,}640{,}000} \right) \times \frac{1}{2} \tag{13}$$

Since no excess weight for drill collars need be considered, this formula becomes:

$$T_s = \left(\frac{D(L_{cs} + D)W_{cm}}{10{,}560{,}000} + \frac{DM}{2{,}640{,}000} \right) \times \frac{1}{2} \tag{14}$$

where

T_s is the ton-miles setting casing;

L_{cs} is the length of joint of casing, in ft;

W_{cm} is the effective weight per foot of casing, in lb.

The effective weight per foot of casing, W_{cm}, may be calculated as

$$W_{cm} = W_{ca}\,(1 - 0.015B)$$

where

W_{ca} is the weight per foot of casing in air, in lb;

B is the weight of drilling fluid, in lb/gal.

4.6 Short Trip Operations

The ton-miles of work performed in short trip operations, as for drilling and coring operations, is also expressed in terms of round trips. Analysis shows that the ton-miles of work done in making a short trip is equal to the difference in round trip ton-miles for the two depths in question. This can be expressed as follows:

$$T_{ST} = T_6 - T_5 \tag{15}$$

where

T_{ST} is the ton-miles for short trip;

T_5 is the ton-miles for one round trip at depth D_5 (shallower depth);

T_6 is the ton-miles for one round trip at depth D_6 (deeper depth).

4.7 Other Operations

There are other operations that work the drilling line that need to be accounted for in the ton-mile accumulation. They include operations such as: motion compensation devices, working casing, setting casing with landing string, jarring, pulling on stuck pipe and running riser.

4.8 Evaluation of Service

For comparative evaluation of service from rotary drill lines, the ton miles for all operations should be totaled. Divide the total ton miles by the length of drill line purchased minus the string-up length.

4.9 Rotary Drilling Line Ton-Mile Calculators

Drilling contractors and wire rope manufactures use or supply different calculators that utilize the API formulas to calculate ton-miles for the different rig operations.

4.10 Rotary Drilling Line Service Record Form

Figure 12 is an example of a drilling line service record form. The form should be modified to conform to the needs of the drilling contractor.

5 Cutoff Practice for Rotary Drilling Lines

5.1 Service Life

The service life of drilling lines can be greatly increased by the use of a planned cutoff program. A cutoff program removes the most heavily worn wire rope from the string-up by introducing new rope from the storage reel into the system. Using only visual inspection to determine when to cutoff will result in uneven wear, trouble with spooling (line “cutting in” on the drum), and long cuts—thus decreasing the wire rope’s service life. A cutoff program, based on accumulated ton-miles, should be used.

5.2 Initial Length of Line

The relationship between initial lengths of rotary lines and their normal service life expectancies is shown in Figure 13. Possible savings by the use of a longer line may be offset by an increased cost of handling for a longer line.

5.3 Service Goal

The most accurate goal is based on past records of a rig or from similar rigs using the same size drill line and having the same diameter drawworks drum. The goal should be selected by agreement between the drilling contractor and the drill line manufacturer. The goal can be adjusted after each drill line is replaced. Table 9 gives an initial goal for different size drill lines based on drum diameter. The diameter and configuration of the sheaves may be taken into considerations to slightly adjust the goal.

Drilling Co ______
Rig # ______
Toolpusher ______
Well ______

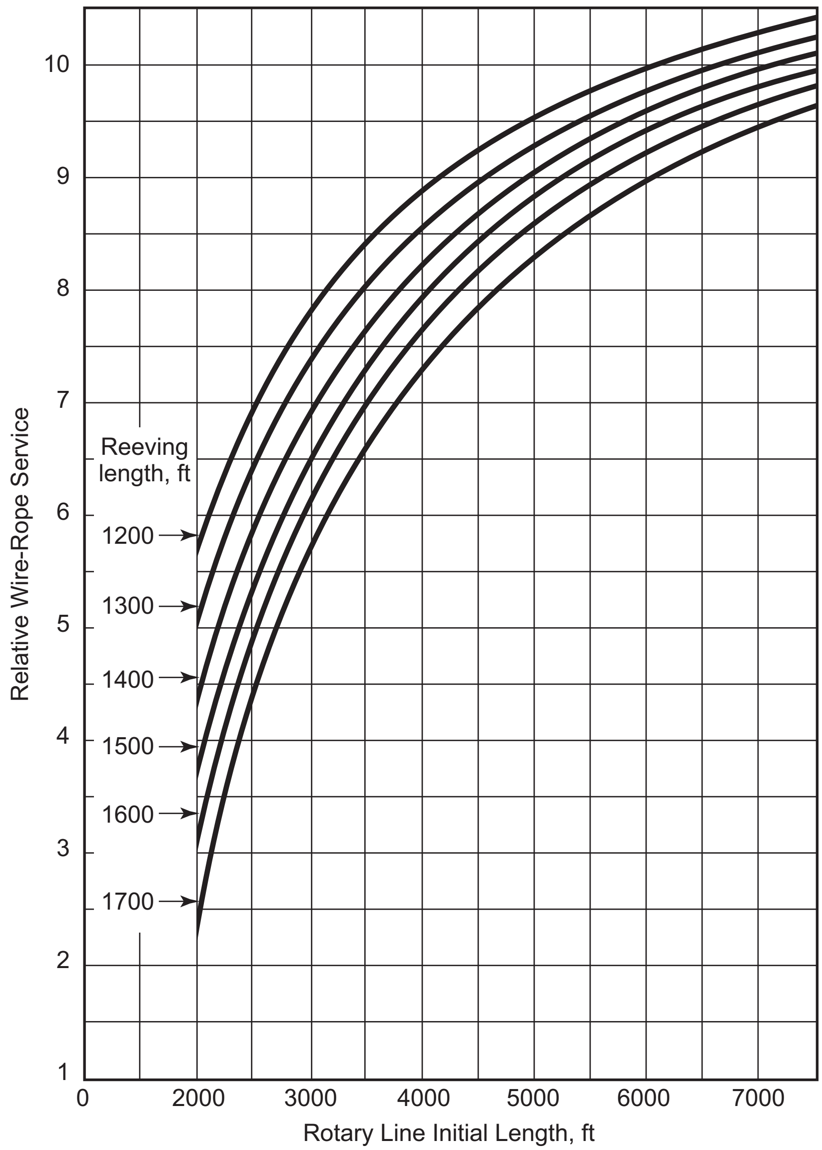
Draw Works ______
Drum Dia. ______
Derrick Height ______
Crown Sheave Diam. ______
Travelling Sheave Diam. ______
Weight of T.B.A. ______

Rope Manufacturer ______
Size & Length ______
Grade ______
Reel # ______
Date On ______
Date Off ______

T-M Goal Per Foot Cut ______

Date	Trip No.	Depth	No. Lines	Wt. Ind. Reading	Design Factor	Drill Pipe		Drill Collars			Wt. Factor Due to Collars	Total Weight Factor	Trip T-M	Drlg. T-M	Total T-M This Trip	T-M Since Last Cut	Accum. T-M Online	Length		Comment
						Size	Wt/Ft	Size	Wt/Ft	No.Ft								Cut	Left	

Figure 12—Facsimile of Rotary Drilling Line Service Record Form



NOTE Empirical curves developed from general field experience.

Figure 13—Relationship between Rotary-line Initial Length and Service Life

5.4 Variations in Line Services

The goals in Table 9 are for normal operations when the drill line is operated around a design factor of 5. Continued operation with design factors higher than 7.0 or lower than 4.0 will affect the service life of the drill line. The goal may have to be lowered to prevent a long cut.

5.5 Cutoff Length

The following factors should be considered in determining a cutoff length.

a) Load pick up points from reeving diagram.

b) Drum diameter and crossover point on the drum.

c) Maximum ton miles accumulated between cuts.

Care should be taken to prevent the duplication of crossover points of the drum. This can be accomplished by adding $^1/_8$ of a drum circumference. Cut off lengths should be based on the service goal. The ton-miles accumulated since the last cut divided by the service goal equals the length of the rope to cut. Do not cut the same length each time or make cuts that are multiples of the distance between sheave pick-up points.

Table 9—Ton-Mile Goal per Foot of Rope[a]

Drum Diameter in.	**Rope Diameter (in.)**									
	1	**1 1/8**	**1 1/4**	**1 3/8**	**1 1/2**	**1 5/8**	**1 3/4**	**2**	**2 1/8**	**2 1/4**
18	6	9								
19	6	9								
20	7	9								
21	7	10								
22	7	10								
23	8	10	13							
24	8	10	13	17						
25	8	10	14	17						
26	9	11	14	17						
27	9	12	15	18						
28		12	15	18						
29		12	15	18						
30		13	16	19	20					
31			16	19	21					
32			17	20	22					
33			17	20	23					
34			18	21	24					
35				21	25					
36				22	25	28	30			
42						29	34	36		
48							37	39		
60								45	48	50
72								50	51	53
76									53	55
82										56

[a] Premium ropes, such as those with plastic impregnation, compacted strands, plastic impregnated IWRC or plastic coated IWRC, may provide additional service.

6 Inspection and Retirement

6.1 Inspection Requirements

6.1.1 General

Inspection requirements are typically based on the application in which the wire rope is used. On the same site, a drilling line will have different requirements than operating ropes in other applications or than stationary ropes used for structural purposes. The following will provide information on various aspects of inspection and some basic removal criteria to use if no other sources are available.

6.1.2 Inspection Frequency

6.1.2.1 General

There are typically two or more types of inspection. The most frequent inspections are for the most obvious damage and are less detailed. The less frequent inspections are more detailed and typically require that the results of the inspection be recorded and kept.

6.1.2.2 Daily Visual Inspections

These are done daily prior to operating the equipment. They are to detect obvious signs of deterioration, significant changes in the wire rope's condition, to observe areas that have previously been identified as approaching removal criteria and to verify proper rope reeving and spooling on the drum. This is typically an inspection by the equipment operator at the beginning of the each shift and is recorded on a checklist as completed.

6.1.2.3 Monthly inspections

These are much more detailed and are of the active length of the rope (rope that experiences tension). They are to detect progression of normal wire rope wear as well as locating areas of damage or abuse in the wire rope. These will include measurements of the rope's diameter, counting of broken wires in the area of heaviest concentration, examining the wire rope at expected wear locations, looking for damage to the wire rope structure and checking for corrosion. The signed, dated inspection report for this inspection is to be filed with the equipment's maintenance records.

When a rig is moved to a new location, a 'monthly' inspection shall be done on all wire ropes immediately prior to the rig being placed in service. With the tear down, transportation and subsequent reinstallation of wire ropes on a rig there are many opportunities for wire rope to be damaged or improperly installed, thus necessitating the detailed inspection of the wire ropes.

6.1.2.4 Yearly inspections

They are conducted by an outside third party inspection firm and may be required in some applications or by regulatory bodies. The inspection report from the third party inspection firm is to be filed with the equipment's maintenance records.

6.2 Wire Rope Removal Criteria

6.2.1 General

The removal criteria for many applications is specified in regulations for the application and can include consideration for type of application, design factor used and consequences of failure. Following are typical removal criteria for wire rope in general hoisting operations. If deterioration of multiple types is occurring, an aggregation of the conditions needs to be made to determine if rope retirement is necessary. Descriptions of common types of wire rope deterioration are given in Section 7.

6.2.2 Reduction in Diameter

Reduction 5 % or more from the wire rope's nominal diameter.

6.2.3 Broken Wires

The wire rope retirement criteria are dependent on the number of broken wires, the location of the broken wires, and the type of wire rope.

— In standard operating ropes, three crown wire breaks in one strand in one rope lay or six crown wire breaks total in one rope lay.

— In rotation resistant operating wire ropes, two crown wire breaks in a length equal to six rope diameters or four crown wire breaks in 30 rope diameters.

— If two valley wire break are found in the rope active length, it must be retired.

— In standing ropes, more than one broken wire at or adjacent to an end connection.

NOTE Special attention must be paid to the wire rope in and adjacent to idler sheaves and end terminations for fatigue wire breaks.

6.2.4 Corrosion

Evidence of pitting corrosion or fretting corrosion. Pay special attention to end terminations.

6.2.5 Heat Damage

Any evidence that the rope has been subjected to heat damage or arcing.

6.2.6 Change of Lay Length

An increase in the rate of lay length change (comparison of measurements made during multiple inspections), a localized lengthening of lay (indication of loss of core support) or a large general lengthening of lay.

6.2.7 Rope Distortion

Evidence of severe scrubbing, crushing, waviness, or permanent bend.

6.2.8 Kinks

The area with the kink must be removed by shortening the wire rope or the wire rope retired.

NOTE In some applications, if the condition necessitating removal is localized and near one end of the rope, the area exceeding the retirement criteria can be cut off and the remainder of the wire rope left in service.

7 Common Types of Wire Rope Deterioration

7.1 General

This is not an exhaustive list, but a description of some commonly encountered types of wear and deterioration.

7.2 Wire Wear

7.2.1 General

There are two type of wire wear that cause flattening of the wires on the surface of the wire rope when it contacts objects. In both cases, the harder the object that the wire rope contacts, the more rapid and significant is the damage that occurs.

7.2.2 Abrasion

Abrasion (see Figure 14) causes a flat wire surface by wearing away the circular crown of the wire due to the wire rope's sliding contact with another object.

Figure 14—Example of Abrasion of the Outer Wires

7.2.3 Peening

Peening (see Figure 15) causes a flattening of the wire surface by metal movement due to the wire rope impact or 'slapping' against another object.

Figure 15—Example of Peening of the Outer Wires

7.3 Broken Wires

7.3.1 General

Broken wires are an important indication of wire rope condition. There are different types of wire breaks and different causes for each of them. All wire breaks have the same effect of lowering the remaining strength of the rope, but because of the difficulty in detecting valley wire breaks there is more stringent removal criteria for valley breaks. Following are descriptions of the most common types.

7.3.2 Crown Wire Breaks

Crown wire breaks (see Figure 16) occur on the top of the strands on the outside of the wire rope and are normally related to fatigue or fatigue in combination with wear on the wires. These are easily discernible in a wire rope inspection. These may occur with little or no wire wear or in wire ropes showing heavy wire wear.

Figure 16—Example of Single Broken Wire on the Crown of a Wire Rope

7.3.3 Valley Wire Breaks

Valley wire breaks (see Figure 17) occur at the contact points with adjacent strands or with the core of the wire rope. The origination of valley breaks is normally associated with nicks that were created in the wire from the high contact stresses at the contact points. The nicks are stress risers and fatigue type wire failures can result.

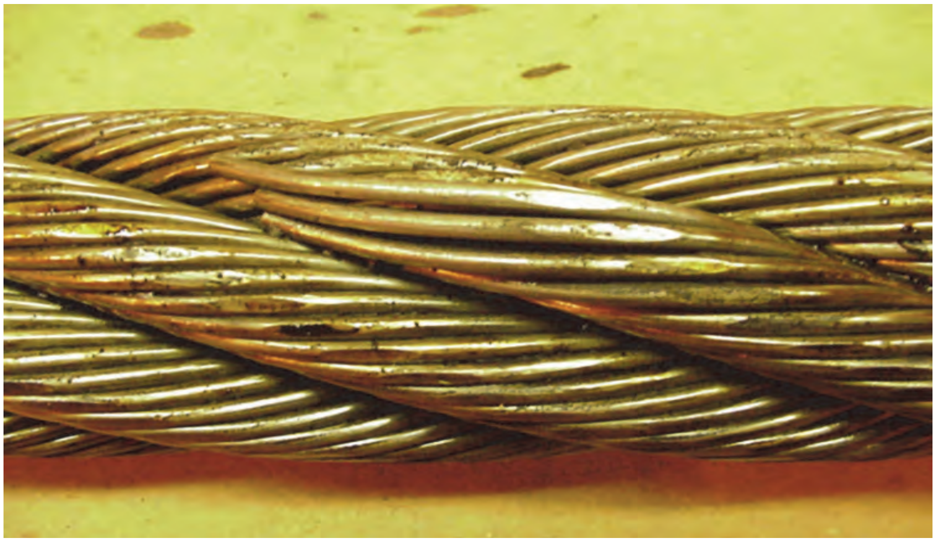


Figure 17—Example of Valley Wire Breaks that are Displaced from their Unbroken Position

7.3.4 Damaged Wire Breaks

Wire breaks or wire displacement from external wire rope damage or abuse are not considered a normal type of deterioration (see Figure 18). The cause of this must be corrected. Scrubbing is a normal cause of damaged wire breaks.

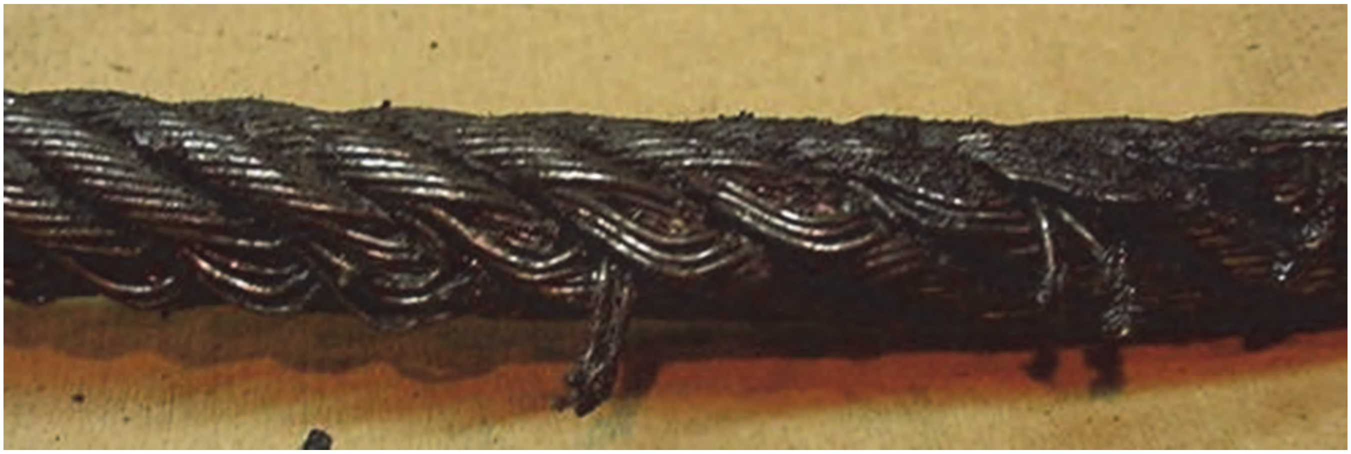


Figure 18—Example of External Damage Resulting in Broken Wires

7.4 Drum Wear

7.4.1 General

All wire rope that spools on a drum is subjected to bending fatigue. Rope that spools in multiple layers on a drum experiences fatigue, scrubbing and crushing. These occur in proper “thread-laid” spooling where the rope on each layer primarily follows the valley between two adjacent wraps on the layer below. Where rope spooling is uncontrolled and not thread-laid, rapid deterioration of the rope will occur. Equipment with uncontrolled spooling must not be used until the spooling condition is corrected.

7.4.2 Scrubbing

Scrubbing occurs when rope on a layer (other than the bottom layer) comes to the point where there is a previous wrap already in that valley between the two ropes on the layer below. The rope coming onto the drum contacts the rope already on the drum and slides or “scrubs” against it. This contact forces the rope coming onto the drum to cross over to the next valley on the drum. This scrubbing contact occurs on the side of the rope and can cause damaged, displaced and/or broken wires but does not significantly affect the roundness of the wire rope.

7.4.3 Crushing

Crushing occurs at the same location in the length of the rope as scrubbing but occurs on the top and bottom of the rope (see Figure 19 and Figure 20). Because the rope goes from having two lines of contact when resting in the valley to a single point of contact during the cross over, the contact pressure is twice as high. This commonly leads to crushing of the rope at the cross over point. This will distort the roundness of the rope structure and damage individual wires. In addition to the damage, this inhibits the free movement of the wires and strand thus affecting fatigue life. The more layers of wire rope on a drum, the more likely that crushing will occur. In some severe operating conditions, crushing can occur where the rope rests in a valley.

Figure 19—Example of Pattern of Drum Crushing

Figure 20—Example of Crushing on a Wire Rope

7.4.4 Change of Layer Point

The change of layer point occurs at the end of a layer where the rope goes from one layer to the next higher layer. If there is no riser strip, the rope is ‘pinched’ between the preceding wrap and the drum flange to force it to the next layer. This pinching action can cause wire damage and distort the roundness of the rope.

7.5 Corrosion

7.5.1 General

Corrosion occurs progressively and can be slowed or stopped if action is taken before it progresses too far. Two stages of corrosion are described below. Proper rope selection and maintenance can reduce the likelihood of corrosion.

7.5.2 Surface Corrosion

Surface corrosion (see Figure 21) is the beginning of corrosion and it can be wiped off the wires and the wire remains smooth and shiny. Once the rope is cleaned and the rust removed, application of a field lubricant to the rope will enable it to continue to be used.

Figure 21—Example of Surface Corrosion on a Wire Rope

7.5.3 Pitting Corrosion

If the surface of the rope is cleaned and the wire is no longer smooth and shiny, pitting has occurred (see Figure 22). Corrosion that has ‘pitted’ the surface of the wire requires retirement of the rope.

Figure 22—Example of Pitting Corrosion on a Wire Rope

7.5.4 Fretting Corrosion

When dry, red dust is seen in the valleys of the rope, check the particles with a magnet. When attracted to the magnet, there is internal fretting and/or corrosion in the rope (see Figure 23). There is not an easy way to evaluate the severity of this condition and the rope must be retired. (Note that Figure 23 also shows some valley wire breaks.)

Figure 23—Example of Fretting Corrosion in a Wire Rope

7.5.5 Corrosion at End Terminations

Corrosion at end terminations is especially critical because of the effect of corrosion on wire fatigue life. The damping of vibrations at this point is a normal fatigue location and corrosion accelerates this. If corrosion is localized at this point and there is sufficient rope length available, the affected area can be removed and a new end attachment made.

7.6 Rope Distortion

7.6.1 Kink

A kink (see Figure 24) is a deformation created by a loop in the rope that has been tightened without allowing for rotation about its axis. This causes permanent, irreparable damage to the wire rope. The wire rope must either immediately be shortened to remove the area containing the kink or retired. Depending on the direction of the twist that caused the loop in the wire rope, a kink may either be a tightening (shorter wire rope lay) or a loosening (longer wire rope lay) kink.

Figure 24—Example of a Kink in a Wire Rope

7.6.2 Permanent Bends (Dog Legs)

Permanent bends (see Figure 25) in a rope are where the unloaded rope has a point where the rope changes direction. This is like a kink in that the wires at this point have been plastically deformed, but there is no change in the wire rope lay length at this point. This will be a point of more rapid wear and fatigue and is a reason for retirement if the deflection is greater than 30 degrees or it causes problems in the sheaves or spooling.

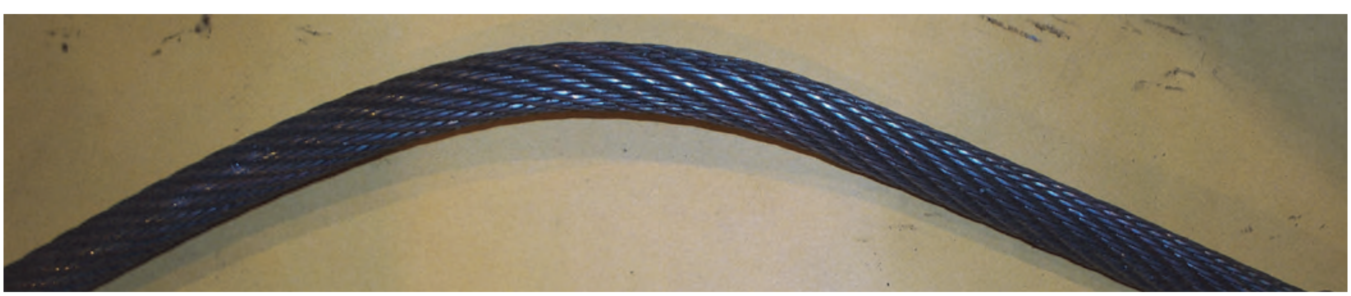


Figure 25—Example of a Permanent Bend in a Wire Rope

7.6.3 Waviness

Waviness (see Figure 26) is when the rope has a repeating pattern of undulation. Slight waviness often causes no operating problems. If the amplitude of the wave is greater than either 110 % of the nominal rope diameter in sections of the wire rope that pass over sheaves or spools on a drum or 133 % of the nominal rope diameter in areas of the wire rope that do not pass over sheaves or drums, retire the wire rope.

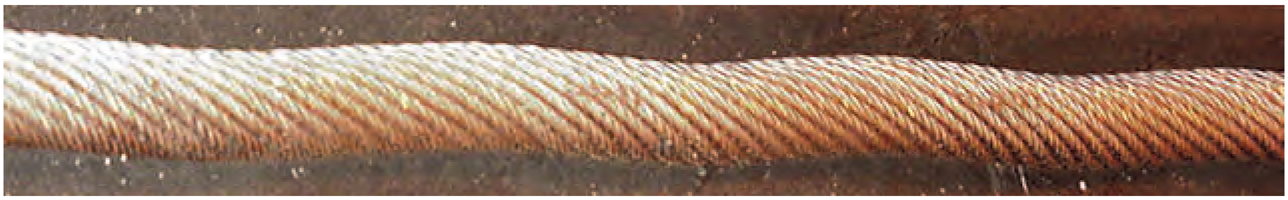


Figure 26—Example of Waviness in a Wire Rope

7.7 Lay Length

7.7.1 General

The lay length of a wire rope (see Figure 27) is the distance that it takes one outer strand to make a complete revolution around the wire rope. Wire ropes are designed with a specific lay length that enables all the wires and strands to share their proportion of the load.

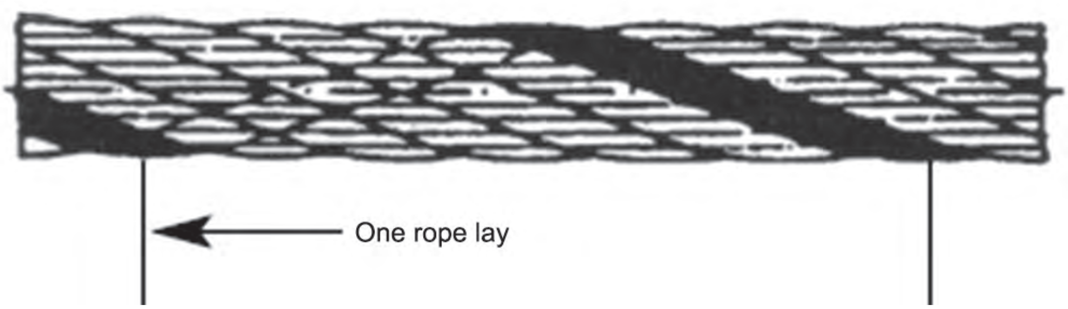


Figure 27—Diagram Showing the Lay Length of a 6-Strand Wire Rope

7.7.2 Rope Stretch

Rope stretch in normal loading conditions can be divided into 'constructional' stretch and 'elastic' stretch. Constructional stretch occurs during the initial loadings and use of the wire rope as the wires and strands adjust around the axis of the wire rope. This is normal, non-recoverable stretch that will result in a slight increase of lay length. Elastic stretch occurs during the normal loading of a wire rope as the steel stretches due to the applied load. When the load is removed, the wire rope returns to the pre-load length. Neither of these types of stretch cause a loss of wire rope strength under normal operating conditions.

7.7.3 Rope Rotation

Wire rope rotation occurs when a wire rope is loaded and it is terminated in a swivel or a single part line that is lifting an unrestrained load. An axial load on a wire rope creates torque within the wire rope because the wires and strands are laid at an angle to the axis of the wire rope. Except in specially designed wire ropes, this load induced torque and the end of the rope free to rotate, cause the rope to rotate. This causes a change in the load sharing of individual wires and strands which results in a significant reduction in the wire rope's breaking strength. Except for very low torque ropes (Category 1 rotation resistant ropes) every effort should be made to operate wire ropes in conditions where wire rope rotation cannot occur.

7.8 Diameter Reductions

7.8.1 General

Measuring the diameter of a wire rope (see Figure 28) is one of the primary evaluation tools in wire rope inspection. To have meaningful comparisons, the measurement must be made at the areas where the greatest wear is expected or is being experienced. Each subsequent inspection must have the diameter measurements made at the same locations so that rate of diameter change can be observed.

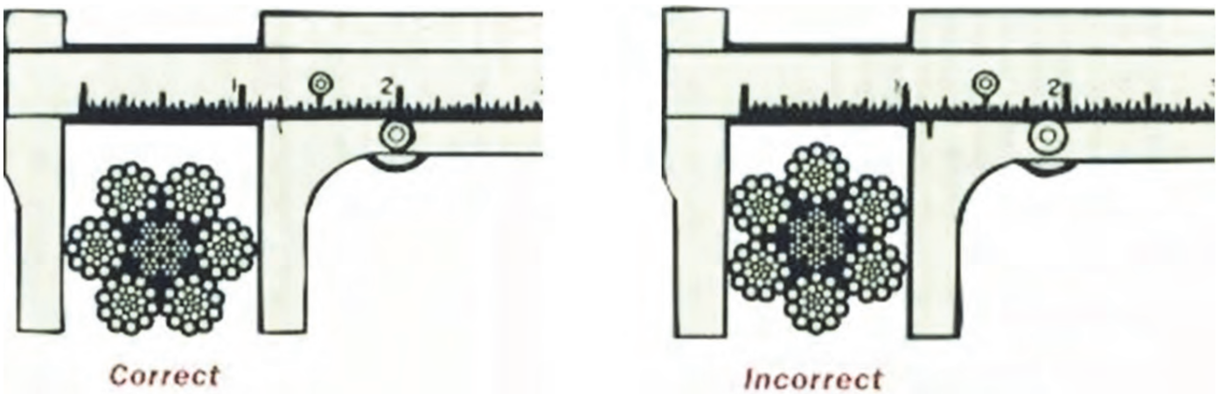


Figure 28—Diagram Showing Correct and Incorrect Ways to Measure Wire Rope Diameter

7.8.2 Seating of Rope

The ‘seating’ of a wire rope is the initial reduction in diameter that occurs when a wire rope is placed into service. At the time the constructional stretch is removed, the wire rope has a slight diameter reduction.

7.8.3 Rope Wear

Rope wear, whether from abrasion or peening, reduces the diameter of the outer wire with a corresponding reduction in the wire rope diameter.

7.8.4 Wire Nicking

Wire nicking of individual wires occurs at the strand-to-strand and strand-to-IWRC contact points. Over time, loading and bending around sheaves and drums causes these contact points to wear. Extreme loading, small diameter sheaves and sheaves with tight grooves will accelerate this wear. The wearing of these internal wire rope contact points will result in a reduction of the wire rope’s diameter.

7.8.5 Loss of Core Support

Loss of core support is typically identified when the diameter of the rope decreases significantly with no externally obvious reason for the change (see Figure 29). The wire rope must be retired.

Figure 29—Example of Loss of Core Support Resulting in Localized Diameter Reduction

7.9 Heat Damage

7.9.1 General

Heat damage from high temperatures can cause a variety of problems with different parts of a wire rope.

7.9.2 Fiber Core

Fiber cores (normally polypropylene) must not be used in conditions with temperatures higher than 180 °F (82 °C). Higher temperatures will cause core deterioration and loss of core support. Retire a fiber core rope if temperatures have exceeded this value.

7.9.3 Lubricants

Standard wire rope lubricants will melt at about 180 °F (82 °C). If a rope is subjected to temperatures higher than this, it needs to be inspected for corrosion and properly field lubricated before continued use.

7.9.4 Steel

Steel used in wire ropes is typically high carbon unalloyed steel that has undergone significant cold-working to achieve the required strength. The properties (strength and fatigue resistance) of steel rope wire are affected at temperatures above 400°F (200 °C). Wire ropes should not be used for applications where the temperature will exceed these values and must be retired if this limit is exceeded.

7.9.5 Arcing

Arcing occurs when an electrical current passes either to a wire rope or from a wire rope to another object. This creates a localized area of heating that changes the properties of the wire rope at that point (see Figure 30). There is no positive way to measure or detect this in a rope in service. Any rope that is suspected of being subjected to arcing must be retired. Some typical causes of arcing are contact with electrical wires, lightning, or using a wire rope to ground an electric arc welder.

Figure 30—Example of Electrical Arc Causing Severe Wire Rope Damage

7.10 Extraordinary Wear/Damage

This is wear, damage or distortion that occurs to the wire rope in a manner that is not typically encountered in a wire rope's routine operation. This can occur due to misuse, unforeseen occurrences, or failure of other parts of the equipment. All inspectors must be on the alert for things that "don't look right". When found, the condition must be evaluated to determine if the wire rope can remain in service. It may be necessary to seek guidance of personnel with greater knowledge and experience in wire rope inspections for this evaluation. If in doubt, retire the wire rope.

8 Field Troubles and Their Causes

All wire rope will eventually deteriorate in operation or have to be removed simply by virtue of the loads and reversals of load applied in normal service. There are, however, many conditions of service or inadvertent abuse, which will materially shorten the normal life of a wire rope of proper construction although it is properly applied. Table 10 provides some of the field conditions and practices which result in the premature replacement of wire rope. It should be noted that in all cases the contributory cause of removal may be one or more of these practices or conditions.

Table 10—Field Troubles and Their Causes

Field Troubles	Possible Cause
Rope broken (all strands)	Overloading, kinking, damage, localized wear, weakening of one or more strands, or rust-bound condition, loss of elasticity or loss of metallic area due to broken wires.
One or more whole strands parted	Overloading, kinking, divider interference, localized wear, or rust-bound condition. Fatigue, excessive speed, slipping, or running too loosely. Concentration of vibration at dead sheave or dead-end anchor.
Excessive corrosion	Lack of lubrication. Exposure to salt spray, corrosive gases, alkaline water, acid water, mud, or dirt. Period of inactivity without adequate protection.
Rope damage by careless handling in hauling to the well or location	Rolling reel over obstruction or dropping the reel. The use of chains for lashing, or the use of lever against rope instead of flange. Nailing through rope to flange.
Damage by improper socketing	Improper seizing which allows slack from one or more strands to work back into rope; improper method of socketing or poor workmanship in socketing, frequently shown by rope being untwisted at socket, loose or drawn.
Kink	Kinking the rope and pulling out the loops such as in improper coiling or unreeling.
Permanent bends ("dog legs") or other distorted places	Improper winding on the drum. Improper tie down. Open-drum reels having longitudinal spokes too widely spaced. The addition of improperly spaced cleats to increase the shipping reel diameter. Stressing while rope is over small sheave or obstacle.
Damage or failure on a fishing job	Rope improperly used on a fishing job, resulting in damage or failure as a result of the nature of the work.
Lengthening of lay and reduction of diameter	Allowing a wire rope to rotate (single part line or wire ropes dead ended in a swivel) or produced by some type of overloading, such as an overload resulting in a collapse of the fiber core in swabbing lines.

Table 10—Field Troubles and Their Causes (Continued)

Field Troubles	Possible Cause
Excessive wear in spots	Kick over points and change of layer points on the drum. Kinks or bends in rope due to improper handling during installation or service. Divider interference; also, wear against casing or hard shells or abrasive formations in a crooked hole. Too infrequent cut-offs on working end.
Spliced rope	A splice is never as good as a continuous piece of rope, and slack is liable to work back and cause irregular wear.
Abrasion and broken wires in a straight line, drawn or loosened strands, or rapid fatigue breaks	Damage due to slipping rope through clamps.
Reduction in tensile strength	Excessive heat due to careless exposure to fire, torch or electrical arc. All wear and deterioration of a wire rope during its service life reduces the wire rope's strength.
Distortion of wire rope	Damage due to improperly attached clamps or wire rope clips. Drum crushing.
High strands	Slipping through clamps, improper seizing, improper socketing, or splicing kinks, doglegs, and core popping.
Wear by abrasion	Lack of lubrication. Slipping clamp unduly. Sandy or gritty working conditions. Rubbing against stationary object or abrasive surface. Faulty alignment. Undersized grooves in sheaves. Occurs in normal operation over time.
Fatigue breaks in wires	Normal wear mode that may be accelerated by excessive vibration due to poor drilling conditions, i.e., high speed, rope slipping, concentration of vibration at dead sheave or dead-end anchor, undersized grooves and sheaves, and improper selection of rope construction.
Spiraling or curling ("pig tail")	Allowing rope to drag or rub over pipe, sill, or any object during installation or operation. It is recommended that a block with sheave diameter 16 times the nominal wire rope diameter, or larger, be used during installation of the line.
Excessive flattening or crushing	Heavy load, loose winding on drum, or cross winding.
Bird-caging or core popping	Sudden unloading of line such as hitting fluid with excessive speed. Improper drilling motion or jar action. Use of sheaves of too small diameter or passing line around sharp bend.
Whipping of rope	Wire rope run at high speeds with light loads. Harmonics. Running without line guides or stabilizers.
Cutting in on drum	Lower wraps on drum not spooled with sufficient tension. Improper cutoff and moving program for rotary drilling lines. Improper or worn drum grooving or line turnback plate.

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