Recommended Practice on Application Care, and use of Wire Rope for Oil Field Service

API RECOMMENDED PRACTICE 9B
TWELFTH EDITION, JUNE 2005

American Petroleum Institute

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Upstream Segment

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SPECIAL NOTES

Page

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1 Scope

1.1 This recommended practice covers typical wire rope applications for the oil and gas industry.

1.2 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 other constructions than those shown is justifiable.

1.3 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 References

API
Spec 4F *Specification for Drilling and Well Servicing Structure*
Spec 8A *Specification for Drilling and Production Hoisting Equipment*
Spec 8C *Specification for Drilling and Production Hoisting Equipment*
Spec 9A *Specification for Wire Rope*

ASTM[1]
B-6 *Standard Specification for Zinc*

3 Field Care and Use of Wire Rope

3.1 HANDLING ON REEL

3.1.1 *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.

3.1.2 *Use of Bars.* Bars for moving the reel should be used against the reel flange, and not against the rope.

3.1.3 *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 bruised or nicked.

3.1.4 *Dropping.* The reel should not be dropped from a truck or platform. This may cause damage to the rope as well as break the reel.

3.1.5 *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.

3.1.6 *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.

3.1.7 *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.

3.2 HANDLING DURING INSTALLATION

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

3.2.2 *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.

[1] ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, Pennsylvania 19428-2959, www.astm.org.

3.2.3 *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.

3.2.4 *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.

3.2.5 *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.

3.2.6 *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.

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

3.2.8 *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 unnecessary nicks or bruises. 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.

3.2.9 *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.

3.2.10 *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.

3.2.11 *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 to adjust the rope to working conditions.

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

Service and Well Depth	Wire Rope Diameter (in.)	Wire Rope Diameter (mm)	Wire Rope Description
Rod and Tubing Lines	1/2 through 1-1/8	13 through 29	6X26WS or 6X31WS RR or LR IWRC
Rod Hanger Lines	1/4	6.5	6X19 RR FC
Sand Lines	1/4 through 5/8	6.5 through 16	6X7 Bright or Galvanized RR FC
Drilling Lines	7/8 through 2-1/8	22 through 54	6X19S or 6X26WS RR IWRC
Winch Lines	5/8 through 1-1/8	16 through 29	6X26WS or 6X31WS or 6X36WS RR IWRC
Horsehead Pumping-units Lines	1/2 through 1-1/8	13 through 29	6X19 class or 6X37 class FC or IWRC
Offshore Anchorage Lines	7/8 through 2-3/4 1-3/8 through 4-3/4 3-3/4 through 4-3/4	22 through 70 35 through 122	6X19 class RR IWRC 6X37 class RR IWRC
Mast Raising Lines	Up through 1-3/8 Over 1-3/8	Up through 35 Over 35	6X19 class RR IWRC 6X37 class RR IWRC
Guideline Tensioner Line	3/4	19	6X25FW RR IWRC
Riser Tensioner Lines	1-1/2 through 2	38 through 51	6X37 class RL IWRC

Abbreviations:

FW	Filler Wire	LR	Left Regular Lay	FC	Fiber Core
S	Seale	RL	Right Lang Lay	IWRC	Independent Wire Rope Core
WS	Warrington Seale	RR	Right Regular Lay		

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

3.2.12 *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.

3.3 CARE OF WIRE ROPE

3.3.1 *Handling.* The recommendations for handling as given under Sections 3.1 and 3.2, inclusive, should be observed at all times during the life of the rope.

3.3.2 *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.

3.3.3 *Design Factor.* The design factor should be determined by the following formula:

$$\text{Design Factor} = \frac{B}{W} \qquad (1)$$

where:

B = nominal strength of the wire rope, lb,
W = fast line tension (See 3.3.3.c).

a. 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 following design factors should be regarded as minimum.

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

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

c. To calculate the design factor for multipart string-ups, use Figures 2 and 3 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.

As an example:
Drilling Line = 1-$^{3}/_{8}$ in. (35 mm) EIPS
Number of Lines = 10
Hook Load = 400,000 lb (181.4t)

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 (181.4t) 0.123 = 49,200 lb (22.3t) W. Following the formula in Equation 1, the design factor is then the nominal strength of 13/8" (35 mm) EIPS drilling line divided by the fast line tension, or 192,000 lb (87.1t) ÷ 49,200 lb (22.3t) = 3.9.

d. When working near the minimum design factor, consideration should be given to the efficiencies of wire rope bent around sheaves, fittings or drums. Figure 1 shows how rope can be affected by bending.

3.3.4 *Winding on Drums.* Rope should be kept tightly and evenly wound on the drums.

3.3.5 *Application of Loads.* Sudden, severe stresses are injurious to wire rope and such applications should be reduced to a minimum.

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

3.3.7 *Rope Speed.* Excessive speeds when blocks are running up light may injure wire rope.

3.3.8 *Clamps.* Care should be taken to see that the clamps used to fasten the rope for dead ending do not kink, flatten, or crush the rope.

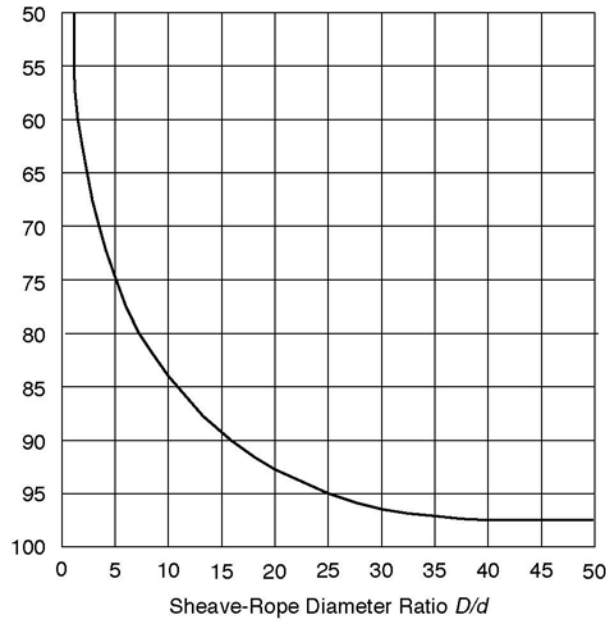


Figure 1—Efficiencies of Wire Ropes Bent Around Stationary Sheaves (Static Stresses Only)

3.3.9 *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 good grade of lubricant which will penetrate and adhere to the rope, and which is free from acid or alkali.

3.3.10 *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.

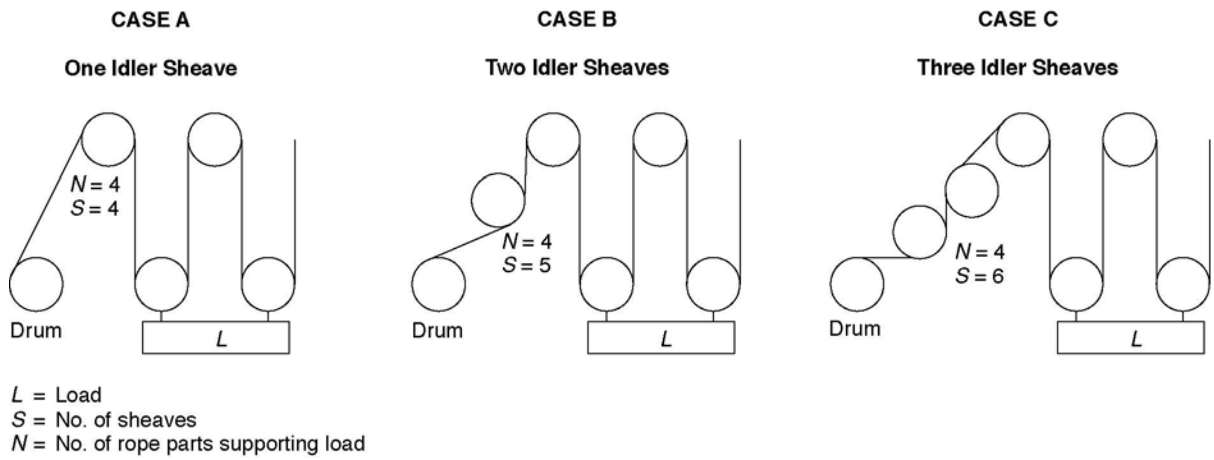
3.3.11 *Wire Breakage from martensite in Drilling Lines.* Care should be taken to maintain proper winding of rotary drilling lines on the drawworks drum in order to avoid excessive friction which may result in the formation of martensite. Martensite may also be formed by excessive friction in worn grooves of sheaves, slippage in sheaves, or excessive 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: 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 is 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.

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 X 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.

3.3.12 *Worn Sheave and Drum Grooves.* Worn sheave and drum grooves cause excessive wear on the rope.

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



Fast Line Tension = Fast Line Factor × Load

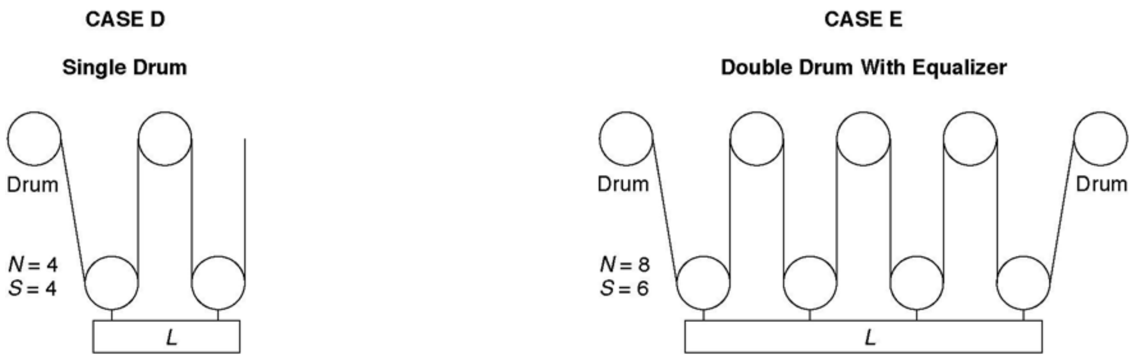
1	2	3	4	5	6	7	8	9	10	11	12	13
	Plain Bearing Sheaves K = 1.09[a]						Roller Bearing Sheaves K = 1.04[a]					
	Efficency			Fast Line Factor			Efficiency			Fast Line Factor		
N	Case A	Case B	Case C	Case A	Case B	Case C	Case A	Case B	Case C	Case A	Case B	Case C
2	0.880	0.807	0.740	0.568	0.620	0.675	0.943	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

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

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.

Figure 2—Efficiency of Wire Rope Reeving for Multiple Sheave Blocks Cases A, B and C (Fast Line and Efficiency Factors for Derricks, Booms, Etc.)



L = Load
S = No. of sheaves (not counting equalizer)
N = No. of rope parts supporting load

Fast Line Tension = Fast Line Factor × Load

1	2	3	4	5	6	7	8	9
	Plain Bearing Sheaves K = 1.09[a]				Roller Bearing Sheaves K = 1.04[a]			
	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

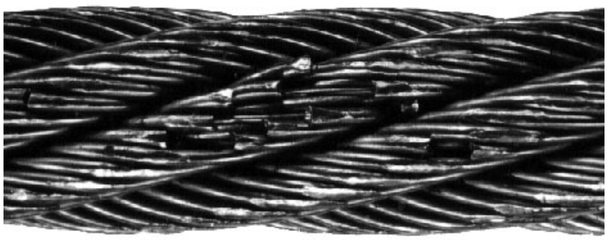
$$\text{Case D Efficiency} = \frac{(K^N - 1)}{K^S N(K-1)} \qquad \text{Case E Efficiency} = \frac{2\left(K^{\frac{N}{2}} - 1\right)}{K^{\frac{S}{2}} N(K-1)}$$

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

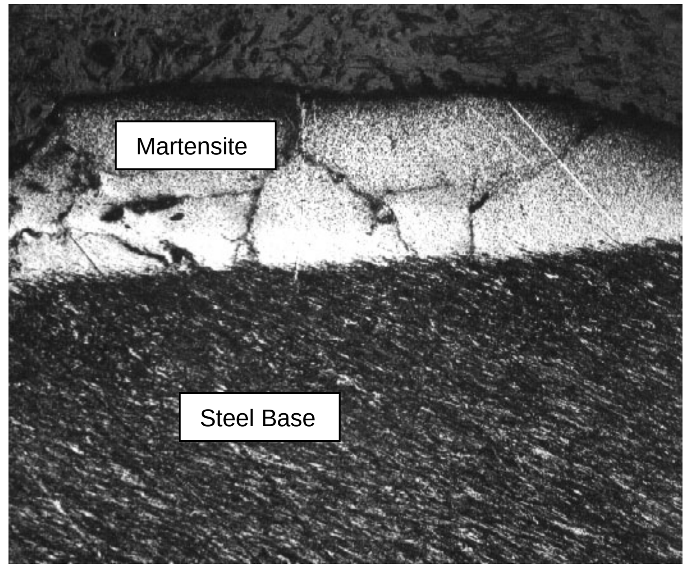
Note: The above cases apply also where the rope is dead ended at the lower or traveling block or derrick floor after passing over a dead sheave in the crown.

[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.

Figure 3—Efficiency of Wire Rope Reeving for Multiple Sheave Blocks Cases D and E (Fast Line and Efficiency Factors for Derricks, Booms, Etc.)



DETAIL A



DETAIL B

Figure 4—Fatigue Fractures in Outer Wires Caused by the Formation of Martensite (See 3.3.11)

3.3.14 *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 by considering the loss in rope life which will result from worn sheaves as compared to the cost involved in re-grooving.

3.3.15 *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 3.3.14.

3.3.16 *Lubrication of Sheaves.* To insure a minimum turning effort, all sheaves should be kept properly lubricated.

3.4 SEIZING

3.4.1 *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.

3.4.2 *Procedure.* The 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.

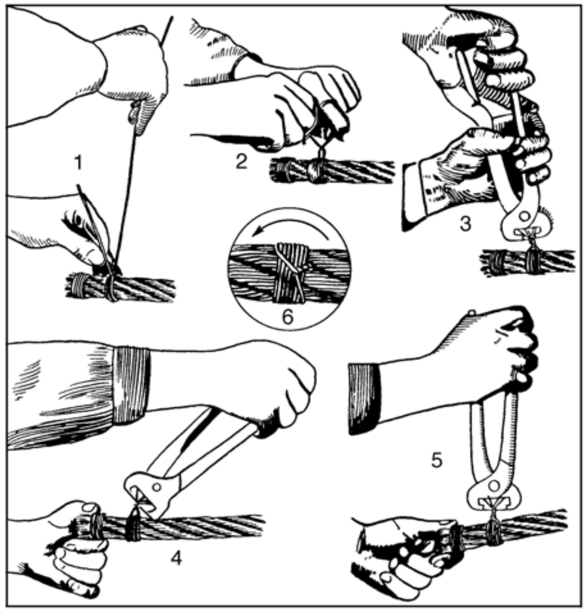


Figure 5—Putting a Seizing on a Wire Rope

3.5 ZINC-POURED SPELTER SOCKETING

3.5.1 Measure the Rope Ends to be Socketed

The rope end should be of sufficient length so that the ends of the unlaid wires (from the strands) will be at the top of the socket basket (See 4.2).

3.5.2 Apply Serving at Base of Socket

Apply a tight serving band for a length of two rope diameters, at the point where the socket base will be, to eliminate any distortion below the band of the wires and strands.

3.5.3 Broom Out Strand Wires

Unlay and straighten the individual rope strands and spread them evenly so that they form an included angle of approximately 60 degrees. Unlay the wires of 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. Unlay the wires of the independent wire rope core (IWRC) in the same manner. A fiber core should be cut out and removed as close to the serving band as possible.

3.5.4 Clean the Broomed-out Ends

A cleaning solvent recommended by a solvent supplier for the type of lubrication on the wire rope should be chosen. If there are questions about the type of lubrication on the wire rope, contact the supplier of the wire rope. Follow the solvent supplier’s recommendations for cleaning the broomed end. Make certain that all grease and dirt is removed from the wires to the very bottom of the broom up to the serving band. After cleaning, place the broomed-out end pointing downward, allowing it to remain until all solvent has evaporated and the wires are dry. Solvent should never be permitted to remain on the rope or on the serving band since it will run down the wires when the rope is turned upright.

3.5.5 Dip the Broomed-out Rope Ends in Flux

Prepare a flux comparable to hot zinc-ammonium chloride. Use a concentration of 1lb of zinc-ammonium chloride to 1 gallon of water. Maintain the solution at a temperature of 180°F to 200°F. Swish the broomed-out end in the flux solution, then point the rope end downward until such time as the wires have dried thoroughly.

3.5.6 Close Rope Ends and Place Socket

Use clean seizing wire to compress the broomed-end into a tight bundle which will permit the socket to be slipped easily over the wires. Before placing the socket on the rope, make certain the socket is clean and no moisture is present inside the bowl of the socket. Heating the socket will dispel any residual moisture and will also prevent the zinc from freezing or cooling prematurely.

Another method of placing the socket onto the rope is to first cover the end of the rope with a wrapping or split tubing; then slide the socket onto this section of covered rope, this will prevent contamination of the inner surface of the socket by the wire rope lubricant. Once the end of the wire rope is cleaned and broomed, the socket can be slid into position and the wrapping or split tubing can be removed.

CAUTION: Never heat a socket after it has been placed on the rope-this could cause damage to the rope.

After the socket is on the rope, the wires should be distributed evenly in the socket basket so the zinc can surround each wire. Use extreme care in aligning the socket with the rope's centerline, and in making certain there is a minimum vertical length of rope extending from the socket equal to about 30 rope diameters. This vertical length is necessary for rope balance. Premature wire breaks at the socket can occur if the rope is not balanced at pouring.

Seal the socket base with fire clay or putty but make certain the material does not penetrate into the socket base. Should this occur, it could prevent the zinc from penetrating the full length of the socket basket thereby creating a void that would collect moisture after the socket is placed in service.

3.5.7 Pour the Zinc

The zinc used should meet ASTM Specification designation B6-49, Grade (1) Prime Western or better. Pour the zinc at a temperature between 925°F and 975°F. A word of caution: Do not heat zinc above 1000°F. Overheating of zinc may affect its bonding properties. The zinc temperature may be measured with a portable pyrometer or thermocouple. Remove all dross from the top of the zinc pool before pouring. Pour the zinc in one continuous stream until it reaches the top of the basket and all wire ends are covered. There should be no "capping" of the socket, unless the customer requires a smooth surface with no shrinkage on the top of the basket. The use of a pinhole in the basket may be employed to allow air and gases to escape. This helps prevent entrapment of air and voids within the zinc.

3.5.8 Remove Serving

After the zinc and socket have cooled, remove the fire clay or putty and the serving band from the socket base, and check to make certain that the zinc has penetrated to the socket base.

3.5.9 Lubricate the Rope

Apply wire rope lubricant to the rope at the base of the socket and on any rope section where the original lubricant may have been removed.

3.6 SOCKETING (RESIN POURED)

Before proceeding with a resin socketing procedure, check the resin manufacturer's instructions carefully. Each resin system has specific procedures and steps, which must be followed in the order specified for the system to give the desired results. Since any resin system depends upon a chemical reaction, the procedure becomes critically important. Give particular attention to selecting sockets designed for resin socketing. Sockets with "rings" should not be used, or if the sockets do have "rings", they should be filled prior to pouring the resin. Also, do not use oversize sockets with resin socketing. The following steps give a general outline to follow for resin socketing. They should not be used as a substitute for detailed instructions supplied by the resin manufacturer.

3.6.1 Measure the Rope Ends to be Socketed

The rope end should be of sufficient length so the ends of the unlaid wires (from the strands) will be at the top of the socket basket (See 4.2).

3.6.2 Apply Serving at Base of Socket

Apply a tight serving band—length of two rope diameters—at the point where the socket base will be to eliminate any distortion below the band of the wires and strands.

3.6.3 Broom Out Strand Wires

Unlay and straighten the individual rope strands and spread them evenly so that they form an included angle of approximately 60 degrees. Unlay the wires of 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. Unlay the wires of the independent wire rope core (IWRC) in the same manner. A fiber core should be cut out and removed as close to the serving band as possible.

3.6.4 Clean the Broomed-out Ends

A cleaning solvent recommended by a solvent supplier for the type of lubrication on the wire rope should be chosen. If there are questions about the type of lubrication on the wire rope, contact the supplier of the wire rope. Follow the solvent supplier's recommendations for cleaning the broomed end. Make certain that all grease and dirt is removed from the wires to the very bottom of the broom up to the serving band. After cleaning, place the broomed-out end pointing downward, allowing it to remain until all solvent has evaporated and the wires are dry. Solvent should never be permitted to remain on the rope or on the serving band since it will run down the wires when the rope is turned upright. The use of acid to etch the wires before resin socketing is not recommended. Also, the use of flux on the wires before pouring resin should be avoided since this adversely affects resin bonding to the steel wires.

3.6.5 Close Rope Ends and Place Socket

Place rope in a vertical position with the broom end up. Close and compact the broom to permit insertion of the broomed end into the base of the socketing. Slip the socket on, removing any temporary banding or seizing as required. Make certain the broomed wires are uniformly spaced in the basket, with the wire ends slightly below the top edge of the basket, and the axis of the rope and the fitting are aligned. Seal the annular space between the base of the socket and the rope to prevent leakage of the resin from the basket. In addition to normal sealing materials, non-hardening butyl rubber-base sealant or latex glazing compounds are satisfactory for this purpose. Make sure the sealant does not enter the base of the socket so the resin will be able to fill the complete depth of the socket basket.

3.6.6 Pouring the Resin

Mix and pour the resin in strict accordance with the resin manufacturer’s instructions.

3.6.7 Lubrication After Socket Attachment

After the resin has cured, re-lubricate the wire rope at the base of the socket to replace any lubricant that may have been removed during the cleaning operation.

3.6.8 Resin Properties

All properties and precautions of resins should be obtained from the resin manufacturers. Take special note of the “shelf life” of the resin being used.

3.7 ATTACHMENT OF CLIPS

3.7.1 Type and Strength

The clip method of making wire rope attachment is widely used. Dropforged 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.

3.7.2 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 2 and Table 3.

3.7.3 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.

3.7.4 Number and Attachment of Clips

Refer to Table 2 and Table 3 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.

3.7.4.1 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.

3.7.4.2 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.

3.7.4.3 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.

Table 2—Attachment of Clips
(See 3.7.2 and 3.7.4)

1		2	3		4	
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 × 37 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 inch 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.

Table 3—Attachment of Double Saddle Clips
(see 3.7.2 and 3.7.4)

1		2	3		4	
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 × 37 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. (45mm) 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 inch 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.

Figure 6—Correct Method of Attaching Clips to Wire Rope

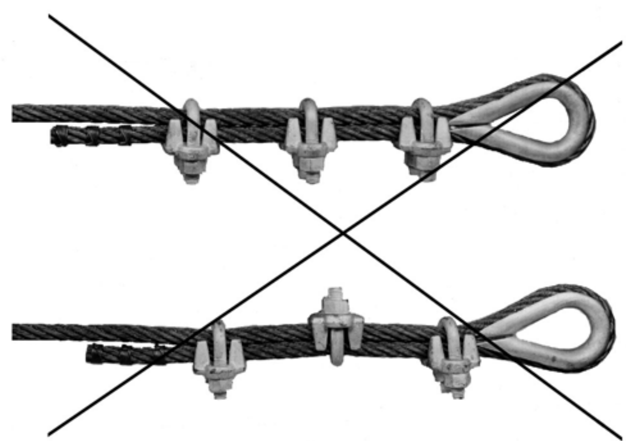


Figure 7—Incorrect Methods of Attaching Clips to Wire Rope

3.7.5 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.

3.7.6 Use of Half Hitch

A half hitch, either with or without clips, is not desirable as it damages and weakens wire rope.

3.8 CASING-LINE AND DRILLING-LINE REEVING PRACTICE

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 4 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 4. 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.

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

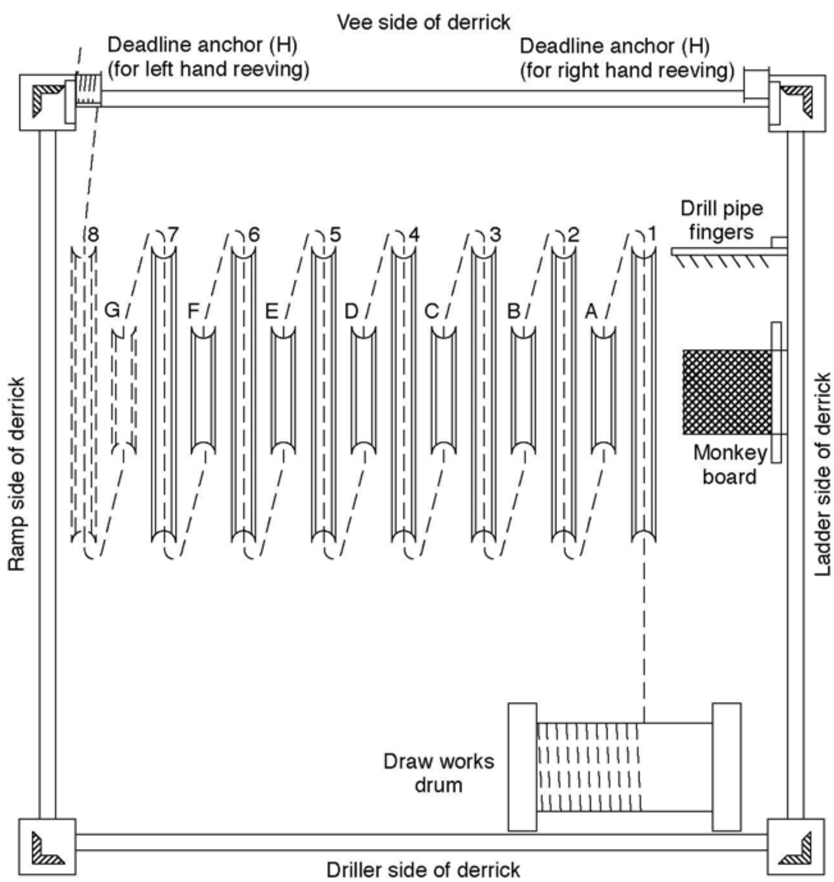


Figure 8—Typical Reeving Diagram for a 14-Line String-Up with 8-Sheave Crown Block and 7-Sheave Traveling Block: Left Hand Reeving (See Arrangement No. 1 in Table 4)

Table 4—Recommended 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 (Read From Left to Right Starting with Crown Block and Going Alternately From Crown to Traveling to Crown)															
	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					

4 Recommended Design Features

Note: See API Spec 8A and/or API Spec 8C for specifications on sheaves.

4.1 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.

4.2 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.

4.3 MATERIAL FOR SHEAVE GROOVES

Alloy or carbon steels, heat treated, will best serve for grooves in sheaves.

4.4 BEARINGS

Anti-friction bearings are recommended for all rotating sheaves.

4.5 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.

4.6 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 7.
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.

4.7 DIAMETER OF SHEAVES

4.7.1 Variations for Different Service Applications

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, 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 = tread diameter of sheave, inches (mm) (see Figure 10),
d = nominal rope diameter, inches (mm),
F = sheave-diameter factor, selected from Table 5.

a. 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.
b. 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.
c. 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 6. 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 6.

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.

Table 5—Sheave-diameter Factors

1	2	3	4
	Factor, *F*		
Rope Classification	Condition A	Condition B	Condition C
6 × 7	72	42	(See Figure 9 and Table 6)
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	—
18 × 7 and 19 × 7	51	36	—
Flattened Strand	51	45	Follow manufacturer's recommendations

Table 6—Relative Bending Life Factors for Various Construction[a]

1	2
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

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

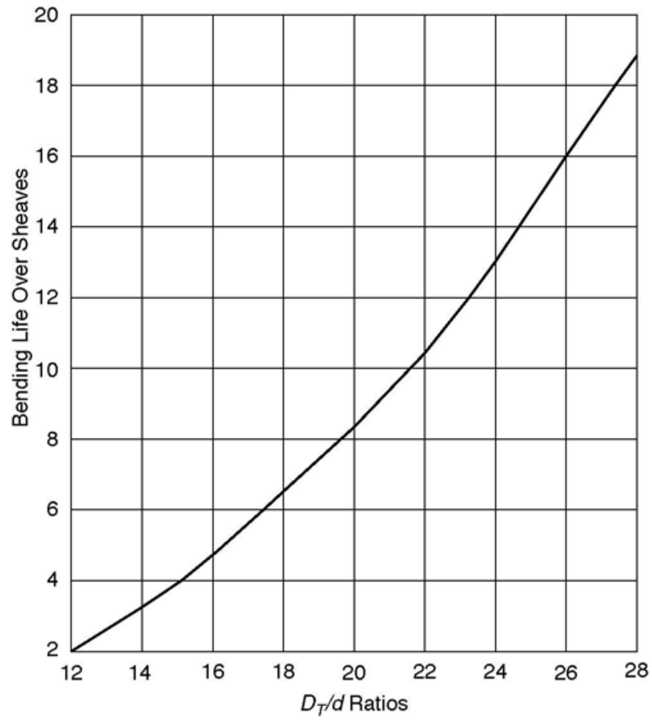


Figure 9—Relative Service for Various DT/d Ratios for Sheaves[a]

D_T = tread diameter of sheave, in. (mm) (see Figure 10).

D = nominal rope diameter, in. (mm).

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

4.7.2 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.

4.8 SHEAVE GROOVES

4.8.1 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.

4.8.2 Drilling and Casing Line Sheaves

(See API Spec 8A and/or Spec 8C.) Grooves for drilling and casing line sheaves shall be made for the rope size specified by the purchaser. The bottom of the groove shall have a radius R, Table 7, subtending an arc of 150°. The sides of the groove shall be tangent to the ends of the bottom arc. Total groove depth 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 7—Grove Radii for Sheaves
(See Figure 10)

Nominal Wirerope 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
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 on 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%

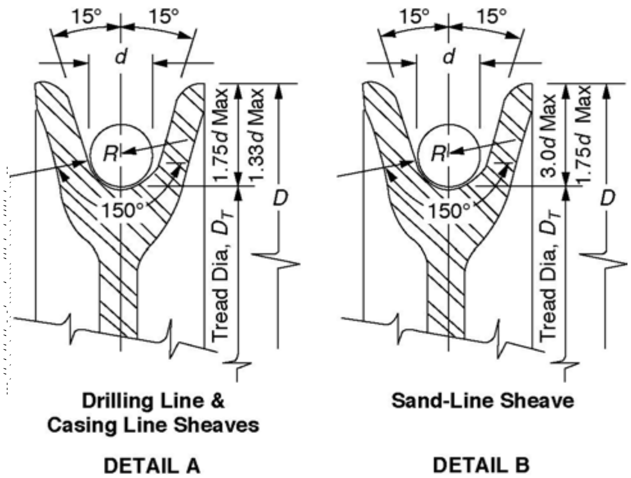


Figure 10—Sheave Groves

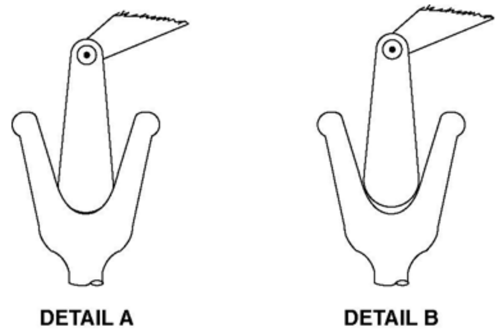


Figure 11—Use of Sheave Gage

4.8.3 Sand-Line Sheaves

(See API Spec 8A and/or Spec 8C.) Grooves for sand-line sheaves shall be made for the rope size specified by the purchaser. The bottom of the groove shall have a radius R, Table 7, subtending an arc of 150 degrees. The sides of the groove shall be tangent to the ends of the bottom arc. Total groove depth shall be a minimum of 1.75d and a maximum of 3d, where d is nominal rope diameter shown in Figure 10, Detail B.

4.8.4 Oil-Saver Rollers

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

4.8.5 Marking

(See API Spec 8A; Spec 8C.): The following requirements for marking of sheaves conforming to the foregoing recommendations are given:

Sheaves conforming to this specification (API Spec 8A and/or API Spec 8C) shall be marked with the manufacturer's name or mark, the sheave groove size, and the sheave OD. These markings shall be cast or stamped on the side of the outer rim of the sheave.

Example: A 36 in. sheave with $1^1/_8$ groove shall be marked (depending on which Spec is used):

AB CO $1^1/_8$ SPEC 8A 36

or

AB CO $1^1/_8$ SPEC 8C 36

or

AB CO 1.125 SPEC 8C 36

4.8.6 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 7.

4.8.7 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.

5 Evaluation of Rotary Drilling Line

5.1 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.

5.2 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:

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

where:

- T_r = ton-miles [weight in tons (2,000 lb) times distance moved in miles],
- D = depth of hole, ft.,
- L_s = length of drill-pipe stand, ft.,
- N = number of stands of drill-pipe,
- W_m = effective (buoyed) weight per foot of drill-pipe in drilling fluid, lb.
- M = total weight of traveling block-elevator assembly, lb.
- C = 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, lb.

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

$$\frac{4DM}{5{,}280 \times 2{,}000}\text{, in ton-miles} \quad (3)$$

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

$$\frac{1}{2}\,(W_m L_s + W_m L_s N)D\text{, or}$$

$$\frac{1}{2}\,(W_m Ls + W_m L_s D)D$$

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

$$\frac{DW_m(L_s + D)}{5{,}280 \times 2{,}000} \quad (4)$$

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

$$\frac{2 \times C \times D}{5{,}280 \times 2{,}000} \quad (5)$$

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

$$T_r = \frac{4DM}{5{,}280 \times 2{,}000} + \frac{DW_m(L_s + D)}{5{,}280 \times 2{,}000} + \frac{2CD}{5{,}280 \times 2{,}000} \qquad (6)$$

This can be rewritten as:

$$T_r = \frac{D(L_s + D)W_m}{5{,}280 \times 2{,}000} + \frac{4D\left(M + \frac{1}{2}C\right)}{5{,}280 \times 2{,}000}$$

or

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

5.3 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 1 and 2 is equal to one round trip; the sum of all operations 3 and 4 is equal to another round trip; the sum of all operations 7 is equal to one-half a round trip; and the sum of all operations 5, 6, and 8 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:

$$T_d = 3(T_2 - T_1) \qquad (8)$$

where:

T_d = ton-miles drilling,
T_1 = ton-miles for one round trip at depth D_1 (depth where drilling started after going in hole, ft.)
T_2 = ton-miles for one round trip at depth D_2 (depth where drilling stopped before coming out of hole, ft.).

If operations c and d are omitted, then formula 8 becomes:

$$T_d = 2(T_2 - T_1) \qquad (9)$$

If a top drive is used, formula 8 becomes:

$$T_d = T_2 - T_1 \qquad (10)$$

If reaming is done between connections with a top drive then formula 8 becomes:

$$T_d = 2(T_2 - T_1) \qquad (11)$$

5.4 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 1 and 2 is equal to one round trip; the sum of all operations 5 is equal to one-half a round trip; and the sum of all operations 3, 4, and 6 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 = ton-miles coring,
T_3 = ton-miles for one round trip at depth, D3 (depth where coring started after going in hole, ft),
T_4 = ton-miles for one round trip at depth D4 (depth where coring stopped before coming out of hole, ft).

Note: Extended coring operations are ordinarily not encountered.

5.5 SETTING CASING OPERATIONS

The calculation of the ton-miles for the operation of setting casing should be determined as in Section 5.2, 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:

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

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

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

where:

T_s = ton-miles setting casing,
L_{cs} = length of joint of casing, ft.,
W_{cm} = effective weight per foot of casing, lb, may be calculated as follows:
W_{cm} = $W_{ca}(1 - 0.015B)$

where:

W_{ca} = weight per foot of casing in air, lb,
B = weight of drilling fluid, lb/gal.

5.6 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} = ton-miles for short trip,
T_5 = ton-miles for one round trip at depth D5 (shallower depth),
T_6 = ton-miles for one round trip at depth D6 (deeper depth).

5.7 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.

5.8 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.

5.9 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

5.10 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.

Rotary Drilling Line Service Record

Sheet ________ of ________ Sheets

Company______________________ Well and No.______________________ Rig No.____________ Make and Type DWKS______________________

Drum Diam.____________ Plain or Groved Drum____________ Crown Block Sheave Diam.____________ Traveling Block Sheave Diam.____________ Wt. Of Traveling Block Assembly (Factor "M")____________ Size and Wt. Drill Pipe____________

Make of Line____________ Size and Length____________ Construction____________ Grade____________ Reel No.____________

Date Line Put Into Service____________ Date Line Retired from Service____________ No. Lines Strung________

Initial	1st Change	2nd Change

Well Depth When String-Up Increased______

1st Change	2nd Change

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
						Drill Collars											
Date	Trip	Depth	Orientation to be	Mud	Effective	O.D.	Effective	Excess	No. of	Factor C	Factor	Ton-Miles	Cumulative	Length	Cumulative	Length	Length

Ton-miles Service Previous Wells____________ Ton-miles Service on Trips—This Well____________ Ton-miles Service Drilling—This Well____________ Ton-miles Service Coring—This Well____________ Ton-miles Service Setting Casing—This Well____________

Total Ton-miles Service—Air Wells____________ Ton-miles per ft of Initial Length____________

See API RP 9B, *Recommended Practice on Application, Care and use of Wire Rope for Oilfield Service*

Figure 12—Facsimile of Rotary Drilling Line Service Record Form

6 Cutoff Practice for Rotary Drilling Lines

6.1 SERVICE LIFE

The service life of drilling lines can be greatly increased by the use of a planned program of slipping and cutoff based on increments of service. The sole dependence on visual inspection to determine when to slip and cut results in uneven wear, trouble with spooling (line "cutting in" on the drum), and long cutoffs, thus decreasing the service life. The general procedure in any program should be to supply an excess of drilling line over that required to string up and to slip this excess through the system at such a rate that it is evenly worn and that the line removed by cutoff at the drum end has just reached the end of its useful life.

6.2 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.

6.3 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 8 gives an initial goal for different size drill lines based on drum diameter. The diameter of the sheaves may be taken into considerations to slightly adjust the goal.

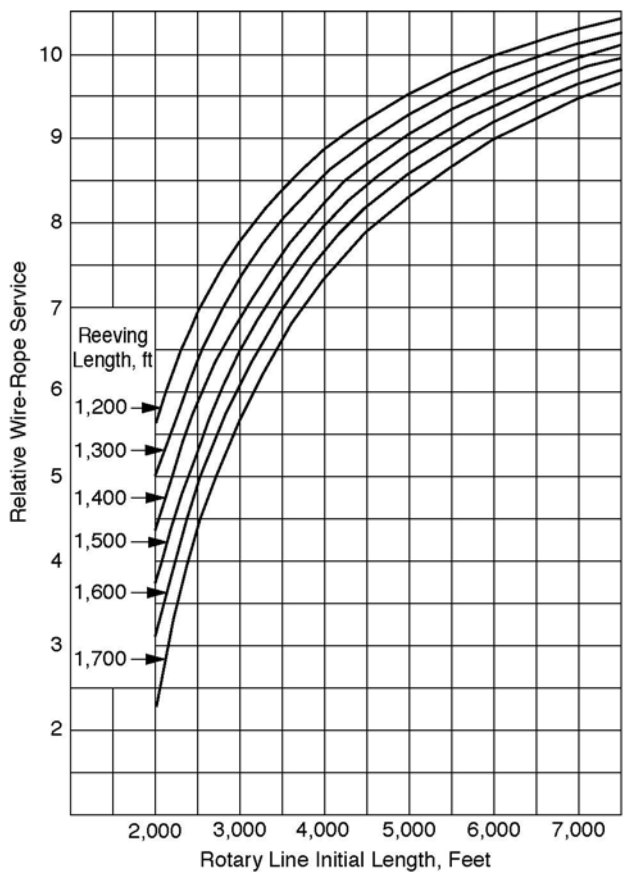


Figure 13—Relationship Between Rotary-line Initial Length and Service Life[a]

[a]Empirical curves developed from general field experience

Table 8—Ton-Mile Goal per Foot of Rope*

	Rope Diameter							
Drum Diameter	1 in.	1-1/8 in.	1-1/4 in.	1-3/8 in.	1-1/2 in.	1-5/8 in.	1-3/4 in.	2 in.
18 in.	6.0	9.0						
19 in.	6.0	9.0						
20 in.	7.0	9.0						
21 in.	7.0	10.0						
22 in.	7.0	10.0						
23 in.	8.0	10.0	13.0					
24 in.	8.0	10.0	13.0	17.0				
25 in.	8.0	10.0	14.0	17.0				
26 in.	9.0	11.0	14.0	17.0				
27 in.	9.0	12.0	15.0	18.0				
28 in.		12.0	15.0	18.0				
29 in.		12.0	15.0	18.0				
30 in.		13.0	16.0	19.0	20.0			
31 in.			16.0	19.0	21.0			
32 in.			17.0	20.0	22.0			
33 in.			17.0	20.0	23.0			
34 in.			18.0	21.0	24.0			
35 in.				21.0	25.0			
36 in.				22.0	25.0	28	30	
42 in.								32
48 in.								
60 in.								

*Premium ropes such as plastic impregnated can provide additional service.

6.4 VARIATIONS IN LINE SERVICES

The goals in Table 8 are for normal operations when the drill line is operated around a design factor of 5. Continued operations 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.

6.5 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 make cuts that are multiples of the distance between sheave pick-up points.

7 Field Troubles and Their Causes

7.1 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. The following field troubles and their causes give 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.

a. Rope broken (all strands).
Possible Cause: Overload resulting from severe impact, kinking, damage, localized wear, weakening of one or more strands, or rust-bound condition and loss of elasticity. Loss of metallic area due to broken wires caused by severe bending.
b. One or more whole strands parted.
Possible Cause: 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.

c. Excessive corrosion.
Possible Cause: Lack of lubrication. Exposure to salt spray, corrosive gases, alkaline water, acid water, mud, or dirt. Period of inactivity without adequate protection.

d. Rope damage by careless handling in hauling to the well or location.
Possible Cause: Rolling reel over obstruction or dropping from car, truck, or platform. The use of chains for lashing, or the use of lever against rope instead of flange. Nailing through rope to flange.

e. Damage by improper socketing.
Possible Cause: 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.

f. Kinks, doglegs, and other distorted places.
Possible Cause: Kinking the rope and pulling out the loops such as in improper coiling or unreeling. 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 drum diameter. Stressing while rope is over small sheave or obstacle.

g. Damage or failure on a fishing job.
Possible Cause: Rope improperly used on a fishing job, resulting in damage or failure as a result of the nature of the work.

h. Lengthening of lay and reduction of diameter.
Possible Cause: Frequently produced by some type of overloading, such as an overload resulting in a collapse of the fiber core in swabbing lines.

i. Premature breakage of wires.
Possible Cause: Caused by frictional heat developed by pressure and slippage, regardless of drilling depth.

j. Excessive wear in spots.
Possible Cause: 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.

k. Spliced rope.
Possible Cause: A splice is never as good as a continuous piece of rope, and slack is liable to work back and cause irregular wear.

l. Abrasion and broken wires in a straight line. Drawn or loosened strands. Rapid fatigue breaks.
Possible Cause: Injury due to slipping rope through clamps.

m. Reduction in tensile strength or damage to rope.
Possible Cause: Excessive heat due to careless exposure to fire or torch.

n. Distortion of wire rope.
Possible Cause: Damage due to improperly attached clamps or wire-rope clips.

o. High strands.
Possible Cause: Slipping through clamps, improper seizing, improper socketing or splicing kinks, doglegs, and core popping.

p. Wear by abrasion.
Possible Cause: Lack of lubrication. Slipping clamp unduly. Sandy or gritty working conditions. Rubbing against stationary object or abrasive surface. Faulty alignment. Undersized grooves in sheaves.

q. Fatigue breaks in wires.
Possible Cause: 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.

r. Spiraling or curling.
Probable Cause: 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.

s. Excessive flattening or crushing.
Probable Cause: Heavy overload, loose winding on drum, or cross winding.

t. Bird-caging or core popping.
Probable Cause: 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.

u. Whipping off of rope.
Probable Cause: Running too loose.

v. Cutting in on drum.
Probable Cause: Loose winding on drum. Improper cutoff and moving program for rotary drilling lines. Improper or worn drum grooving or line turnback plate.

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