Recommended Practice on Application, Care, and Use of Wire Rope for Oilfield Service

API RECOMMENDED PRACTICE 9B
TENTH EDITION, JUNE 1999

American
Petroleum
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Upstream Segment

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FOREWORD

This recommended practice is under the jurisdiction of the API Subcommittee on Standardization of Drilling and Servicing Equipment.

Detailed requirements applying to wire rope are given in API Spec 9A, *Specification for Wire Rope*, which also is under the jurisdiction of the API Subcommittee on Standardization of Drilling and Servicing Equipment.

Conversions of English units to International System (SI) metric units are provided throughout the text of Sections 1, 3 and 4 of this recommended practice in parentheses, e.g. 6 in. (152.4 mm). SI equivalents have also been included in all tables in Sections 1, 3 and 4. Sections 5, 6 and 7 are intentionally presented only in English units to preclude any ambiguity between formulas and tabulated and graphical values. English units are in all cases preferential and shall be standard in this recommended practice. The factors used for conversion of English units to SI units are listed below:

1 inch (in.)	=	25.4 millimeters (mm) exactly
1 foot (ft)	=	0.3048 meters (m) exactly
1 pound (lb) mass	=	0.4535924 kilograms (kg) (1000 kg = 1 tonne (t))
1 foot•pound force	=	1.355818 Newton•meters (ft•lbf) torque (N•m)
1 pound per in^2	=	0.006894757 Mega (psi) stress Pascals (MPa)
1 gallon (US gal)	=	3.785412 liters (L)

The following formula was used to convert degrees Fahrenheit (F) to degrees Celsius (C): $C = {}^{5}/_{9}\ (F - 32)$.

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Suggested revisions are invited and should be submitted to the general manager of the Upstream Segment, American Petroleum Institute, 1220 L Street, N.W., Washington, D.C. 20005.

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Recommended Practice on Application, Care, and Use of Wire Rope for Oilfield Service

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 oilfield 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.

3.2 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.

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.* Tension should be maintained on the wire rope as it leaves the reel by restricting the reel movement. A timber or plank provides satisfactory brake action. When winding the wire rope on the drum, sufficient tension should be kept on the rope to assure tight winding.

3.2.6 *Swivel-Type Stringing Grip.* When a worn rope is to be replaced with a new one, the use of a swivel-type stringing grip for attaching the new rope to the old rope is recommended. This will prevent transferring the twist from one piece of rope to the other. Care should be taken to see that the grip is properly applied. The new rope should not be welded to the old rope to pull it through the system.

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.

[1]American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959.

Table 1—Typical Sizes and Constructions of Wire Rope For Oilfield Service

1	2	3	4
Service and Well Depth	Wire Rope in.	Diameter mm	Wire Rope Description (Regular Lay)
Rod and Tubing Pull Lines			
Shallow	$^{1}/_{2}$ to $^{3}/_{4}$ incl.	13 to 19	
Intermediate	$^{3}/_{4}$, $^{7}/_{8}$	19, 22	6 × 25 FW or 6 × 26 WS or 6 × 31 WS or 18 × 7[a] or 19 × 7[a], PF, LL[a], IPS or EIPS, IWRC
Deep	$^{7}/_{8}$ to 1$^{1}/_{8}$ incl.	22 to 29	
Rod Hanger Lines	$^{1}/_{4}$	6.5	6 × 19, PF, RL, IPS, FC
Sand Lines			
Shallow	$^{1}/_{4}$ to $^{1}/_{2}$ incl.	6.5 to 13	
Intermediate	$^{1}/_{2}$, $^{9}/_{16}$	13, 14.5	6 × 7 Bright or Galv.[b], PF, RL, PS or IPS, FC
Deep	$^{9}/_{16}$, $^{5}/_{8}$	14.5, 16	
Drilling Lines—Cable Tool (Drilling and Cleanout)			
Shallow	$^{5}/_{8}$, $^{3}/_{4}$	16, 19	
Intermediate	$^{3}/_{4}$, $^{7}/_{8}$	19, 22	6 × 21 FW, PF or NPF, RL or LL, PS or IPS, FC
Deep	$^{7}/_{8}$, 1	22, 26	
Casing Lines—Cable Tool			
Shallow	$^{3}/_{4}$, $^{7}/_{8}$	19, 22	
Intermediate	$^{7}/_{8}$, 1	22, 26	6 × 25 FW or 6 × 26 WS, PF, RL, IPS or EIPS, FC or IWRC
Deep	1, 1$^{1}/_{8}$	26, 29	
Drilling Lines—Coring and Slim-Hole Rotary Rigs			
Shallow	$^{7}/_{8}$, 1	22, 26	6 × 26 WS, PF, RL, IPS or EIPS, IWRC
Intermediate	1, 1$^{1}/_{8}$	26, 29	6 × 19 S or 6 × 26 WS, PF, RL, IPS or EIPS, IWRC
Drilling Lines—Rotary Rigs			
Shallow	1, 1$^{1}/_{8}$	26, 29	
Intermediate	1$^{1}/_{8}$, 1$^{1}/_{4}$	29, 32	6 × 19 S or 6 × 21 S or 6 × 25 FW or FS, PF, RL, IPS or EIPS, IWRC
Deep	1$^{1}/_{4}$ to 1$^{3}/_{4}$ incl.	32, 45	
Winch Lines—Heavy Duty	$^{5}/_{8}$ to $^{7}/_{8}$ incl.	16 to 22	6 × 26 WS or 6x31 WS, PF, RL, IPS or EIPS, IWRC
	$^{7}/_{8}$ to 1$^{1}/_{8}$ incl.	22 to 29	6 × 36 WS, PF, RL, IPS or EIPS, IWRC
Horsehead Pumping-Unit Lines			
Shallow	$^{1}/_{2}$ to 1$^{1}/_{8}$ incl.[c]	13 to 29	6 × 19 Class or 6 × 37 Class or 19 × 7, PF, IPS, FC or IWRC
Intermediate	$^{5}/_{8}$ to 1$^{1}/_{8}$ incl.[d]	16 to 29	6 × 19 Class or 6 × 37 Class, PF, IPS, FC or IWRC
Offshore Anchorage Lines	$^{7}/_{8}$ to 2$^{3}/_{4}$ incl.	22 to 70	6 × 19 Class, Bright or Galv., PF, RL, IPS or EIPS, IWRC
	1$^{3}/_{8}$ to 4$^{3}/_{4}$ incl.	35 to 122	6 × 37 Class, Bright or Galv., PF, RL, IPS or EIPs, IWRC
	3$^{3}/_{4}$ to 4$^{3}/_{4}$ incl.	96 to 122	6 × 61 Class, Bright or Galv., PF, RL, IPS or EIPs, IWRC
Mast Raising Lines[e]	1$^{3}/_{8}$ and smaller	thru 35	6 × 19 Class, PF, RL, IPS or EIPS, IWRC
	1$^{1}/_{2}$ and larger	38 and up	6 × 37 Class, PF, RL, IPS or EIPS, IWRC
Guideline Tensioner Line	$^{3}/_{4}$	19	6 × 25 FW, PF, RL, IPS or EIPS, IWRC
			Wire Rope Description (Lang Lay)
Riser Tensioner Lines	1$^{1}/_{2}$, 2	38, 51	6 × 37 Class or PF, RL, IPS or EIPS, IWRC

Abbreviations:

EIPS	Extra improved plow steel	IWRC	Independent wire rope core	RL	Right lay
FC	Fiber core	LL	Left lay	S	Seale
FS	Flattened strand	NPF	Nonpreformed	WS	Warrington-Seale
FW	Filler-wire	PF	Preformed		
IPS	Improved plow steel	PS	Plow steel		

[a]Single line pulling of rods and tubing requires left lay construction or 18 × 7 or 19 × 7 construction. Either left lay or right lay may be used for multiple line pulling.

[b]Bright wire sand lines are regularly furnished: galvanized finish is sometimes required.

[c]Applies to pumping units having one piece of wire rope looped over an ear on the horsehead and both ends fastened to a polished-rod equalizer yoke.

[d]Applies to pumping units having two vertical lines (parallel) with sockets at both ends of each line.

[e]See API Spec 4F, *Specification for Drilling and Well Servicing Structures*.

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.

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.

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 IN SERVICE

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 *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 3.3.2.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
Cable-tool line	3
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	=	$1^3/_8$" (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 $1^3/_8$" (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.

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.

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

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

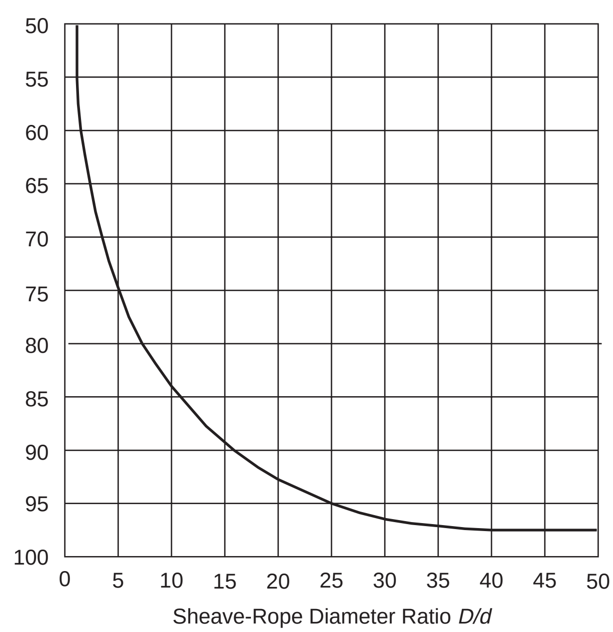
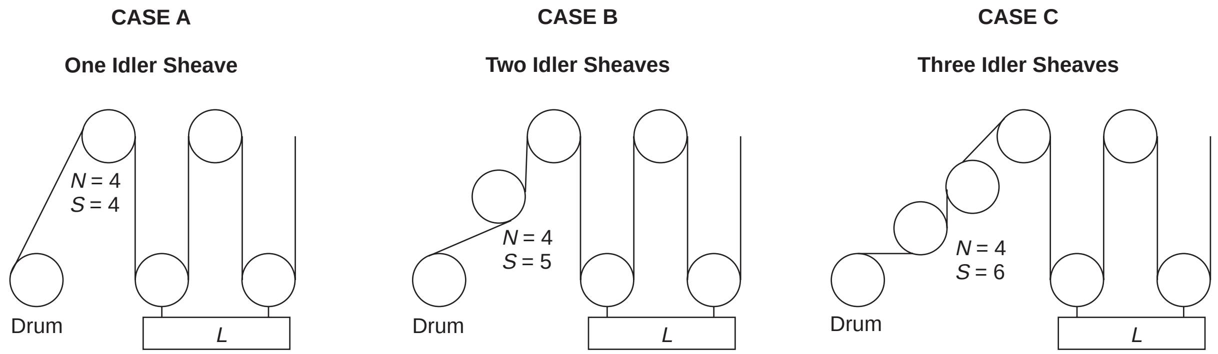


Figure 1—Efficiencies of Wire Ropes Bent Around Stationary Sheaves (Static Stresses Only)



L = Load
S = No. of sheaves
N = No. 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]					
	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	0.368	0.620	0.675	0.943	0.907	0.872	0.530	0.551	0.574
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	0.908	0.873	0.839	0.275	0.286	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	0.216	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	0.148	0.154	0.161
9	0.666	0.611	0.561	0.167	0.182	0.198	0.826	0.794	0.764	0.135	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	0.124
12	0.597	0.547	0.502	0.140	0.152	0.166	0.782	0.752	0.723	0.106	0.111	0.115
13	0.576	0.528	0.485	0.133	0.145	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	0.099	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

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

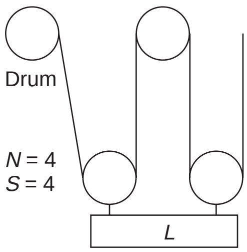
Note: The above cases apply also where the rope is dead ended at the lower or traveling block or derrick floor after passing over a dead sheave in the crown.

[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.)

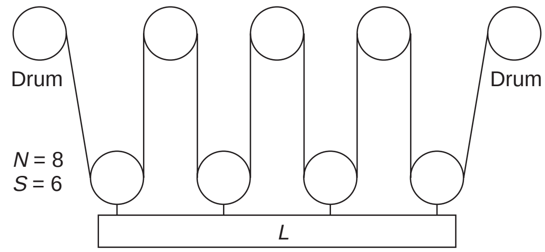
CASE D

Single Drum



CASE E

Double Drum With Equalizer



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	0.204	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	0.141	0.875	0.944	0.143	0.132
9	0.726	—	0.153	—	0.859	—	0.130	—
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	0.101	0.091
13	0.628	—	0.122	—	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	—

$$\text{Case D Efficiency} = \frac{(K^N - 1)}{K^S N(K - 1)}$$

$$\text{Case E Efficiency} = \frac{2(K_T^N - 1)}{K_T^S N(K - 1)}$$

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

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

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.)

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

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

3.3.7 *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.

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

3.3.9 *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.

3.3.10 *Premature Wire Breakage in Drilling Lines.* The following precautions should be observed to prevent premature wire breakage in drilling lines:

a. Cable-Tool Drilling Lines. Movement of wire rope against metallic parts can accelerate wear. This can also create sufficient heat to form martensite, causing embrittlement of wire and early wire rope removal. Such also can be formed by friction against the casing or hard rock formation.

b. Rotary 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.

Note: Martensite is a hard, nonductile microconstituent 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 an 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 × 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.

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

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

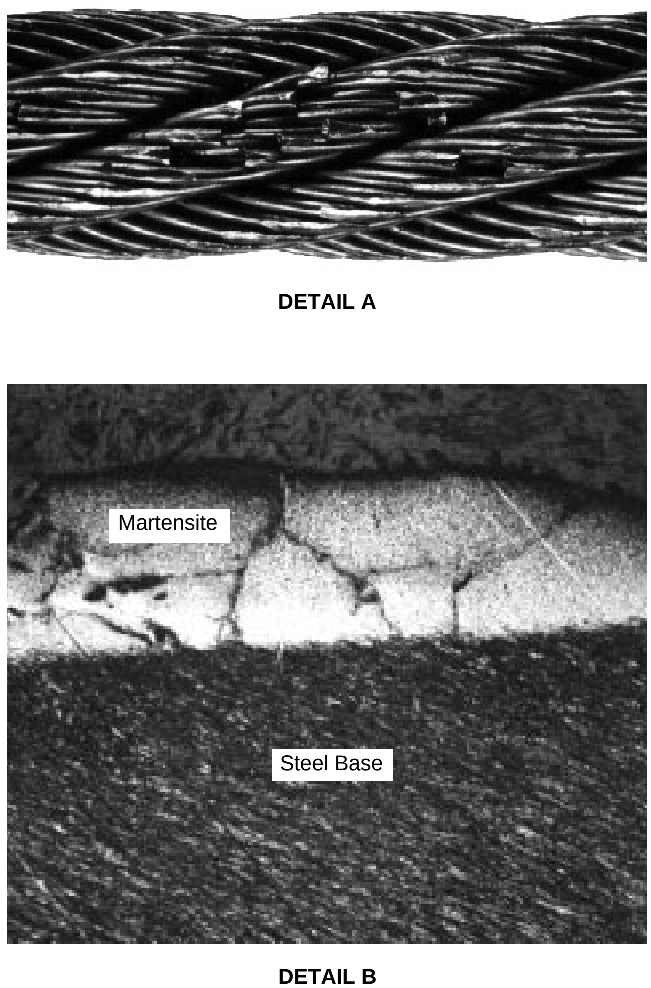


Figure 4—Fatigue Fractures in Outer Wires Caused by the Formation of Martensite
See 3.3.10

3.3.13 *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 6; 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 6. Each operator should establish the most economical point at which sheaves should be regrooved by considering the loss in rope life which will result from worn sheaves as compared to the cost involved in regrooving.

3.3.14 *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 3.3.13.

3.3.15 *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.

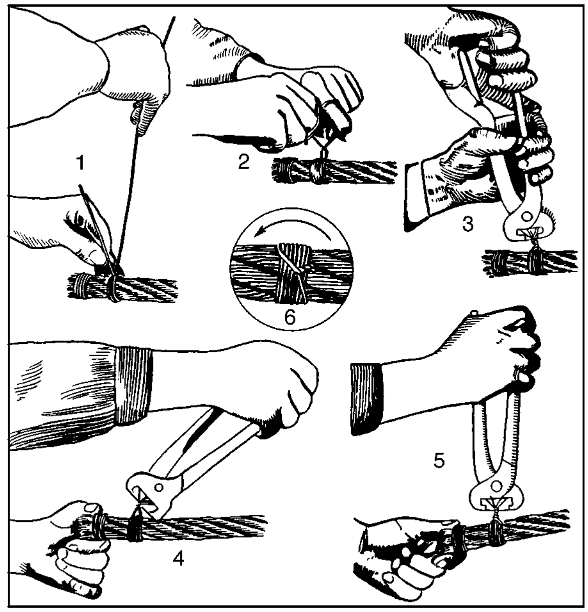


Figure 5—Putting a Seizing on a Wire Rope

3.5 SOCKETING (ZINC POURED OR SPELTER)

3.5.1 Wire Rope Preparation

3.5.1.1 Seizing. The wire rope should securely seized or clamped at the end prior to cutting. Measure from the end of the rope a length equal to approximately 90% of the length of the socket basket. Seize or clamp at this point. Use as many seizings as necessary to prevent the rope from unlaying.

3.5.1.2 Brooming. After the rope is cut, the end seizing should be removed. Partial straightening of the strands and/or wires may be necessary. The wires should then be separated and broomed out and the cores treated as follows:

a. Fiber Core—Cut back length of socket basket.

b. Steel Core—Separate and broom out.

c. Other—Follow manufacturer's recommendations.

3.5.2 Cleaning

The wires should be carefully cleaned for the distance they are inserted in the socket by one of the following methods.

3.5.2.1 Acid Cleaning

3.5.2.1.1 Improved Plow Steel and Extra Improved Plow Steel, Bright and Galvanized

Use a suitable solvent to remove lubricant. The wires then should be dipped in commercial muriatic acid until thoroughly cleaned. The depth of immersion in acid must not be more than the broomed length. The acid should be neutralized by rinsing in a bicarbonate of soda solution.

Note: Fresh acid should be prepared when satisfactory cleaning of the wires requires more than one minute. Prepare new solution—do not merely add new acid to old. Be sure acid surface is free of oil or scum.

The wires should be dried and then dipped in a hot solution of zinc-ammonium chloride flux. Use a concentration of one pound (454 g) of zinc-ammonium chloride in one gallon (3.8 L) of water and maintain the solution at a temperature of 180°F (82°C) to 200°F (93°C).

3.5.2.1.2 Stainless Steel

Use a suitable solvent to remove lubricant. The wires then should be dipped in a hot caustic solution such as oakite, then in a hot water rinse. They then should be dipped in one of the following solutions until thoroughly cleaned:

Commercial Muriatic Acid

1 part by weight of Cupric Chloride
20 parts by weight of concentrated Hydrochloric Acid

1 part by weight of Ferric Chloride
10 parts by weight of either concentrated Nitric or Hydrochloric Acid
20 parts by weight of water

Use the above solutions at room temperature.

Note: Fresh solution should be prepared when satisfactory cleaning of the wires requires more than a reasonable time. Prepare new solutions—do not merely add new solution to old. Be sure solution surface is free of oil and scum.

The wires should then be dipped in clean hot water. A suitable flux may be used.

3.5.2.1.3 Phosphor Bronze

Use a suitable solvent to remove lubricant. The wires should then be dipped in commercial Muriatic Acid until thoroughly cleaned (See 3.5.2.1.1).

3.5.2.1.4 Monel Metal

Use a suitable solvent to remove lubricant. The wires then should be dipped in the following solution until thoroughly cleaned:

1 Part Glacial Acetic Acid
1 Part Concentrated Nitric Acid

This solution is used at room temperature. The broom should be immersed from 30 to 90 seconds. The depth of immersion in the solution must not be more than broomed length.

Note: Fresh solution should be prepared when satisfactory cleaning of the wires requires more than a reasonable time. Prepare new solution—do not merely add new solution to old. Be sure solution surface is free of oil and scum.

The wires should then be dipped in clean hot water.

3.5.2.2 Ultrasonic Cleaning (All Grades)

An ultrasonic cleaner suitable for cleaning wire rope is permitted in lieu of the acid cleaning methods described previously.

3.5.2.3 Other Cleaning Methods

Other cleaning methods of proven reliability are permitted.

3.5.3 Attaching Socket

3.5.3.1 Installing

Preheat the socket to approximately 200°F (93°C). Slip socket over ends of wire. Distribute all wires evenly in the basket and flush with top of basket. Be sure socket is in line with axis of rope.

3.5.3.2 Pouring

Use only zinc not lower in quality than *high grade* per ASTM Specification B-6. Heat zinc to a range allowing pouring at 950°F (510°C) to 975°F (524°C). Skim off any dross which may have accumulated on the surface of the zinc bath. Pour molten zinc into the socket basket in one continuous pour if possible. *Tap socket basket while pouring*.

3.5.4 Final Preparation

Remove all seizings. Apply lubricant to rope adjacent to socket to replace lubricant removed by socketing procedure. Socket is then ready for service.

3.5.5 Splicing

Splicing wire rope requires considerable skill. The instructions for splicing wire rope are too long to be given here. They will be found in the catalogues of most of the wire-rope manufacturers. The sequence of the operation is carefully described, and many clear illustrations show the progress of the work in the hands of experienced workmen. These illustrations give, in fact, most of the information that a person would receive by watching the making of a splice by skilled hands.

3.6 SOCKETING (THERMO-SET RESIN)

3.6.1 General

Before proceeding with thermo-set resin socketing, the manufacturer's instructions for using the product should be read carefully. Particular attention should be given to sockets that have been designed specifically for resin socketing. There are other thermo-set resins that can be used which may have specifications that differ from those shown in this section.

3.6.2 Seizing and Cutting the Rope

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

3.6.3 Opening and Brooming the Rope End

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

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

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

3.6.4 Cleaning the Wires and Fittings

Different types of resin with different characteristics require varying degrees of cleanliness. For some, the use of a soluble oil for cleaning wires has been found to be effective. The following cleaning procedure was used for one type of polyester resin with which over 800 tensile tests were made on ropes in sizes $^1/_4$" (6.5 mm) to $3^1/_2$" (90 mm) diameter without experiencing any failure in the resin socket attachment.

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

3.6.5 Placement of the Fitting

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

3.6.6 Pouring the Resin

Controlled heat-curing (no open flame) at a temperature range of 250°F to 300°F (121°C to 149°C) is recommended and is *required* if ambient temperatures are less than 60°F (16°C) (may vary with different resins). When controlled heat curing is not available and ambient temperatures are not less than 60°F (16°C), the attachment should not be disturbed and tension should not be applied to the socketed assembly for at least 24 hours.

3.6.7 Lubrication of Wire Rope after Socket Attachment

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

3.6.8 Description of the Resin

Resins vary considerably with the manufacturer and it is important to refer to manufacturer's instructions prior to using them as no general rules can be established. Properly formulated thermo-set resins are acceptable for socketing. These resin formulations, when mixed, form a pourable material which hardens at ambient temperatures or upon the applications of moderate heat. No open flame or molten metal hazards exist with resin socketing since heat curing, when necessary, requires a relatively low temperature, 250°F to 300°F (121° to 149°C), which can be supplied by electric resistance heating.

Tests have shown satisfactory wire rope socketing performance by resins having the following properties.

3.6.8.1 General Description

The resin shall be a liquid thermo-set material which hardens after mixing with the correct proportion of catalyst or curing agent.

3.6.8.2 Properties of Liquid (Uncured) Material

Resin and catalyst will normally be supplied in two separate containers, the complete contents of which, after thorough mixing, can be poured into the socket basket. Liquid resins and catalysts shall have the following properties:

a. Viscosity of Resin-Catalyst Mixture. 30,000–40,000 CPS at 75°F (24°C) immediately after mixing. Viscosity will increase at lower ambient temperatures, and resin may need warming prior to mixing in the catalyst if ambient temperatures drop below 40°F (4°C).

b. Flash Point. Both resin and catalyst shall have a minimum flash point of 100°F (38°C).

c. Shelf Life. Unmixed resin and catalyst shall have a 1-year minimum shelf life at 70°F (21°C).

d. Pot Life and Cure Time. After mixing, the resin-catalyst blend shall be pourable for a minimum of 8 minutes at 60°F (16°C) and shall harden in 15 minutes. Heating of the resin in the socket to a maximum temperature of 300°F (149°C) is permissible to obtain full cure.

3.6.8.3 Properties of Cured Resin

Cured resins shall have the following properties:

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

b. Compressive Strength. Minimum for fully cured resin is 12,000 psi (82.7 MPa).

c. Shrinkage. Maximum 2%. Use of an inert filler in the resin is permissible to control shrinkage, provided the viscosity requirements specified above for the liquid resin are met.

d. Hardness. A desired hardness of the resin is in the range of Barcol 40–55.

3.6.9 Resin Socketing Compositions

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

3.6.9.1 Performance of Cured Resin Sockets

Poured resin sockets may be moved when the resin has hardened. After ambient or elevated temperature cure recommended by the manufacturer, resin sockets should develop the nominal strength of the rope; and should also withstand, without cracking or breakage, shock loading sufficient to break the rope. Manufacturers of resin socketing material should be required to test to these criteria before resin materials are approved for this end use.

3.7 ATTACHMENT OF CLIPS

3.7.1 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.

3.7.2 Turn Back

When attaching clips, the length of rope to be turned back when making a loop is based on 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.

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 Attachment of First Clip

The first clip should be attached at a point about one base width from the last seizing on the dead end of the rope and tightened securely. The saddle of the clip should rest on the long or main rope and the U-bolt on the dead end. All clips should be attached in the same manner (see Figure 6).

3.7.5 Position of Short End of Rope

The short end of the rope should rest squarely on the main portion.

3.7.6 Number and Attachment of Remaining Clips

The second clip should be attached as near the loop as possible. The nuts for this clip should not be completely tightened when it is first installed. The recommended number of clips and the space between clips are given in Table 2. Additional clips should be attached with an equal spacing between clips. Prior to completely tightening the second and any of the additional clips, some stress should be placed on the rope to take up the slack and equalize the tension on both sides of the rope.

3.7.7 Correct and Incorrect Attachment

When the clips are attached correctly, the saddle should be in contact with the long end of the wire rope and the U-bolt in contact with the short end of the loop in the rope as shown in Figure 6. The incorrect application of clips is illustrated in Figure 7.

Table 2—Attachment of Clips
See 3.7.2 and 3.7.6

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

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" (38 mm) and smaller, 8 × 19 class, right regular lay, IPS, FC; and 1 3/4" (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.

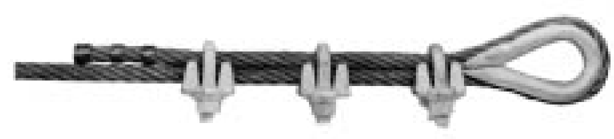


Figure 6—Correct Method of Attaching Clips to Wire Rope

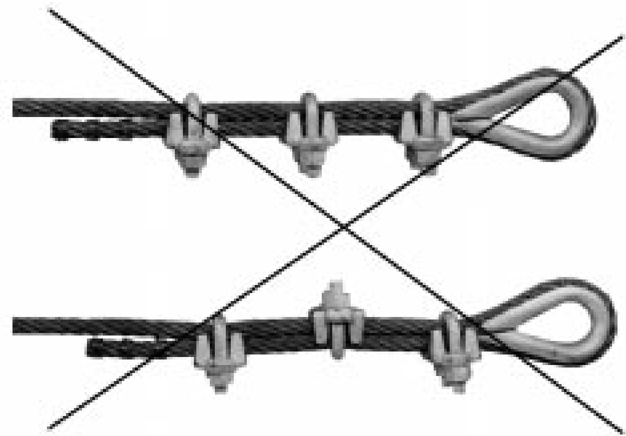


Figure 7—Incorrect Methods of Attaching Clips to Wire Rope

3.7.8 Tightening of Nuts During Installation

The nuts on the second and additional clips should be tightened uniformly, by giving alternately a few turns to one side and then the other. It will be found that the application of a little oil to the threads will allow the nuts to be drawn tighter.

3.7.9 Tightening Nuts After Use

After the rope has been in use a short time, the nuts on all clips should be retightened, as stress tends to stretch the rope, thereby reducing its diameter. The nuts should be tightened at all subsequent regular inspection periods.

3.7.10 Use of Half Hitch

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

3.7.11 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 3 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 a 8-sheave crown-block and 7-sheave traveling block illustrated in Figure 8 is given in Arrangement No. 1 of Table 3. 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 derrickman.
e. Location of deadline anchor, and its influence upon the maximum rated static hook load of derrick.

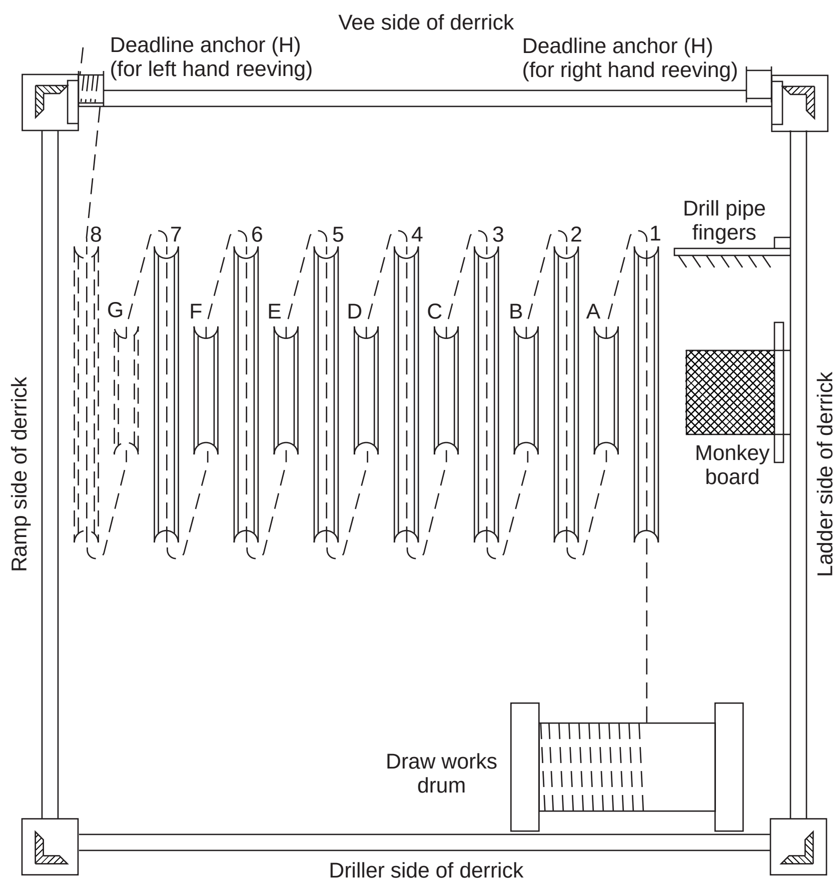


Figure 8—Typical Reeving Diagram for 14-Line String-Up With 8-Sheave Crown Block and 7-Sheave Traveling Block: Left Hand Reeving
(See Arrangement No. 1 in Table 3)

Table 3—Recommended Reeving Arrangements for 12, 10, 9, and 6-Line String-Ups Using 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						G	
12	6	5	Right Hand	8	Crown Block	6		5		4		3		2						
					Trav. Block		E		D		C		B						H	
13	6	5	Left Hand	6	Crown Block			2		3		4		5						
					Trav. Block				B		C		D						G	
14	6	5	Right Hand	6	Crown Block			5		4		3		2						
					Trav. Block				D		C		B						H	
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 with 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 center lines 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 6.

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 4.

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.

Table 4—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 5)
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

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 5. 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 5.

Table 5—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.

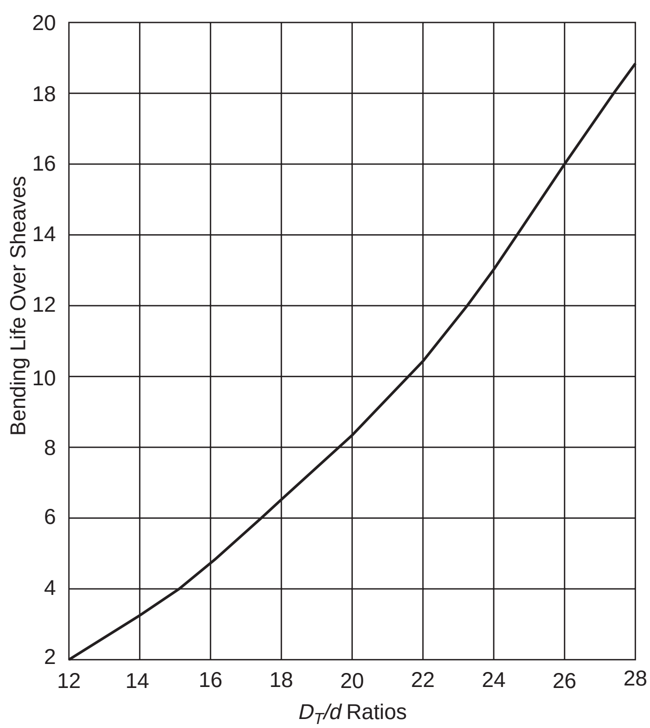


Figure 9—Relative Service for Various D_T/d Ratios for Sheaves[a]

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.

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.

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, Section 8.2 and/or API Spec 8C, 9.2.4) 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 6, 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 1.33*d* and a maximum of 1.75*d*, where *d* is the nominal rope diameter shown in Figure 10, Detail A.

Table 6—Groove Radii For Sheaves
See Figure 10

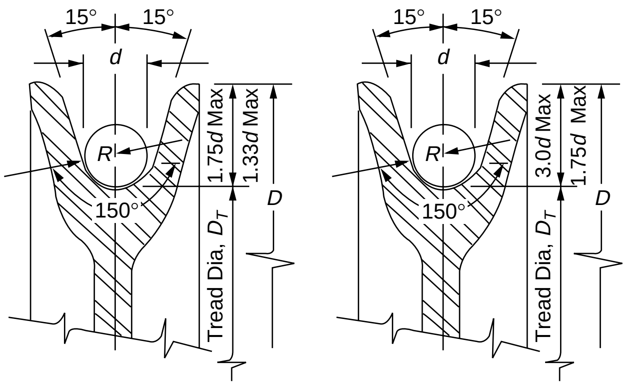
Nominal Wirerope Diameter		Groove Radius Minimum Worn		Groove Radius Minimum New		Groove Radius Maximum	
in.	mm	in.	mm	in.	mm	in.	mm
0.250	6.5	0.128	3.25	0.134	3.40	0.138	3.51
0.313	8.0	0.160	4.06	0.167	4.24	0.172	4.37
0.375	9.5	0.192	4.88	0.199	5.05	0.206	5.23
0.438	11.0	0.224	5.69	0.232	5.89	0.241	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%



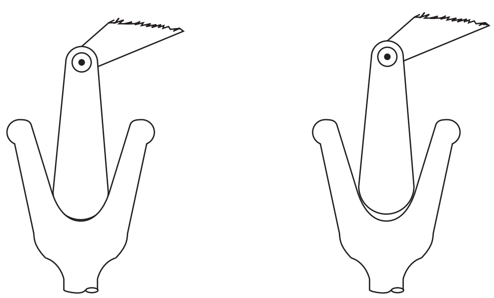
Drilling Line & Casing Line Sheaves

DETAIL A

Sand-Line Sheave

DETAIL B

Figure 10—Sheave Grooves



DETAIL A **DETAIL B**

Figure 11—Use of Sheave Gage

4.8.3 Sand-Line Sheaves

(See API Spec 8A, Section 8.3 and/or API Spec 8C, Section 9.2.5) 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 6, 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 1.75*d* and a maximum of 3*d*, 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, Section 8.4; API Spec 8C, Section 9.2.6): 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 decreases below the values shown in Table 6.

4.8.7 Sheave Gages

Use sheave gages as shown in Figure 11. Detail A shows a sheave with a minimum groove radius, and Detail B shows a sheave with a tight groove.

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:

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

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 weight per foot of drill-pipe, lb, from Figure 13,

M = total weight of traveling block-elevator assembly, lb,

C = effective weight of drill collar assembly from Figure 13, minus the effective weight of the same length of drill-pipe, lb, from Figure 13.

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

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

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

$$^1/_2\,(W_m L_s + W_m L_s N)D\text{, or}$$

$$^1/_2\,(W_m L_s + W_m L_s D)D$$

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 is equal to

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

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

$$\frac{2 \times C \times D}{5{,}280 \times 2{,}000} \tag{5}$$

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

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

This can be rewritten as:

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

or

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

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:

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

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 3 and 4 are omitted, then formula 8 becomes:

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

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:

$$T_c = 2(T_4 - T_3) \tag{10}$$

where

T_c = ton-miles coring,

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

T_4 = ton-miles for one round trip at depth D_4 (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:

$$T_s = \frac{D(L_{cs} + D)W_{cm}}{10{,}560{,}000} + \frac{D(M + \frac{1}{2}C)}{2{,}640{,}000} \times \frac{1}{2} \tag{11}$$

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

$$T_s = \frac{D(L_{cs} + D)W_{cm}}{10{,}560{,}000} + \frac{DM}{2{,}640{,}000} \times \frac{1}{2} \tag{12}$$

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 estimated from data given on Figure 13 for drill pipe, or 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, from Figure 13 or Figure 14.

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:

$$T_{ST} = T_6 - T_5 \tag{13}$$

where

T_{ST} = ton-miles for short trip,

T_5 = ton-miles for one round trip at depth D_5 (shallower depth),

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

5.7 EVALUATION OF SERVICE

For the comparative evaluation of service from rotary drilling lines, the grand total of ton miles of work performed will be the sum of the ton-miles for all round-trip operations (Formula 2), the ton-miles for all drilling operations (Formula 8), the ton-miles for all coring operations (Formula 10), the ton-miles for all casing setting operations (Formula 11), and the ton-miles for all short trip operations (Formula 13). By dividing the grand total ton-miles for all wells by the original length of line in feet, the evaluation of rotary drilling lines in ton-miles per foot of initial length may be determined.

5.8 INSTRUCTIONS FOR USE OF ROTARY DRILLING LINE SERVICE-RECORD FORM

The following instructions apply to captions and column headings as shown in Figure 15, and are intended to assist in filling out the service-record form. Derivation of the formulas upon which the calculations and Figure 12 are based are explained in Sections 5.1–5.7.

5.8.1 Col. 1: Date

Enter the date operation was performed.

5.8.2 Col. 2: Trip Number

Enter the consecutive trip number.

5.8.3 Col. 3: Depth of Trip

Enter the well depth from or to which a trip is made, or at which drilling or coring is stopped, or at which casing is set, or at which side-wall coring or similar operations are started and stopped.

5.8.4 Col. 4: Operation to be Performed and Remarks

For calculating ton-miles of wire rope service, all operations may be considered as one of the following, and the appropriate entry should be made in Col. 4.

a. Round trip (or $^1/_2$ round trip).
b. Drilling.
c. Coring.
d. Setting casing.

Note: So that ton-miles for drilling, coring, or setting casing may readily be calculated, it is recommended that Col. 4 entries be as complete as possible. In deep wells, the ton-miles service for drilling and coring operations will be substantial and should be considered for slip and cutoff purposes.

5.8.5 Col. 5: Drilling Fluid Weight

Enter drilling fluid weight in pounds per gallon. When fluid weight is given in pounds per cubic foot, the conversion to pounds per gallon can be made by use of Figure 13 or Figure 14.

5.8.6 Col. 6: Effective Weight of Pipe

For trip operations, enter the effective weight of drill pipe, or of tubing used as drill pipe. This weight (W_m) should be determined from Figure 13. For setting casing, enter the effective weight of the casing. It will be necessary to either estimate this effective weight (W_{cm}) from data given on Figure 13, or calculate same as follows:

$$\text{Effective weight of casing } (W_{cm}) = W_{ca}\,(1 - 0.015B)$$

where

W_{ca} = weight of casing in air, lb/ft,

B = weight of drilling fluid, lb/gal.

5.8.7 Col. 7: OD and Bore of Drill Collars

Enter these dimensions in Col. 7.

5.8.8 Col. 8: Effective Weight of Drill Collars (E_c)

For trip operations, enter the effective weight of drill collars. This value should be determined from Figure 14. For collar sizes not shown on Figure 14 this weight may be estimated or may be calculated as follows:

$$E_c = C_a\,(1 - 0.015B)$$

where

C_a = weight of drill collars in air, lb/ft,

B = weight of drilling fluid, lb/gal.

5.8.9 Col. 9: Excess Weight

Excess weight is the difference in the effective weight per foot of drill collars and the effective weight per foot of drill pipe. It is obtained by subtracting the value in Col. 6 from the value in Col. 8.

5.8.10 Col. 10: Number of Feet

Enter the total number of feet of drill collars, plus the length of the bit assembly.

5.8.11 Col. 11: Factor C

Factor C is the excess weight entered in Col. 9, multiplied by the number of feet entered in Col. 10.

5.8.12 Col. 12: Factor ($M + {}^1/_2\ C$)

Factor *M* is the weight of the traveling block assembly (including the traveling block, hook, links and elevators), as entered in the form heading. If the actual weight of the traveling block assembly is not known, the following approximate values may be used.

Traveling Block Capacity, Tons	Assembly Weight, lb
100	6,000
150	9,000
250	12,000
350	19,000
500	28,000
650	35,000
750	48,000

From the value of *M*, and the *C* value entered in Col. 11, calculate the value of $M + {}^1/_2\ C$ and enter in Col. 12.

5.8.13 Col. 13: Ton-Miles Service this Operation

For trip and setting-casing operations, using the values recorded in Col. 3, 6, and 12, determine the number of ton-miles to be entered in Col. 13 by use of Figure 12. For setting casing the ton-miles of service equals one half the ton-miles for one round trip from the depth to which the casing is set.

For other operations the amount of work done is to be calculated in terms of round trips as follows:

a. Drilling. The ton-miles service in drilling usually equals three times the difference between the ton-miles for one round trip from the depth at which drilling stopped and the ton-miles for one round trip from the depth at which drilling started.

b. Coring. The ton-miles service in coring equals two times the difference in the ton-mile for one round trip from the depth at which coring stopped and the ton-miles for one round trip from the depth at which coring started.

c. Short Trips. The ton-miles service for a short trip equals the round trip ton-miles at the deeper depth, minus the round trip ton-miles at the shallower depth.

5.8.14 Col. 14: Cumulative Ton-Miles Since Last Slip

Enter in Col. 14 the running totals of entries in Col. 13 since last slip.

5.8.15 Col. 15: Length Line Slipped

Enter number of feet of line slipped.

5.8.16 Col. 16: Cumulative Ton-Miles Since Last Cut

Enter in Col. 16 the running totals of values entered in Col. 13 since last cut-off.

5.8.17 Col. 17: Length Line Cut-Off

Enter number of feet of line cut-off.

5.8.18 Col. 18: Length Line Remaining

Enter in Col. 18, the length of line remaining on the reel.

5.8.19 Entries at Bottom of Form

Entries at the bottom of the form are to be made when all the forms covering a particular line are completed, and the line discarded. These entries should show the total ton-miles of service for the different operations. If the ton-miles of service for drilling, coring, and setting casing are not itemized in the body of the form, these can be calculated from the drilling record.

5.9 EXAMPLES

The following examples illustrate the proper calculations and entries in the various columns of the service record form.

5.9.1 Example 1

Round trip operation from less than 6,000 ft.
Given conditions:

a. Drill pipe: $4^1/_2$ in. – 16.6 lb/ft.
b. Depth: 4,000 ft.
c. Drill collars: 200 ft, $5^1/_2$ in. × $4^1/_4$ in.
d. M = 10,720 lb.
e. Drilling fluid: 10.5 lb per gal.

Solution of entries to be made on service record form:

5.9.1.1 Col. 6: Effective Weight of Pipe

From Figure 13, the effective weight of $4^1/_2$ in., 16.6 lb drill pipe in 10.5 lb per gal fluid is 14.5 lb/ft.

5.9.1.2 Col. 8: Effective Weight of Drill Collars (E_c)

From Figure 14, the effective weight of $5^1/_2$ -in. × $2^1/_4$-in. drill collar in 10.5 lb per gal fluid is 56.8 lb/ft.

5.9.1.3 Col. 9: Excess Weight

Col. 8 minus Col. 6, 56.8 – 14.5 = 42.3 lb/ft

5.9.1.4 Col. 11: Factor C

Col. 9 × Col. 10, 42.3 × 200 = 8,640 ft

5.9.1.5 Col. 12: Factor ($M + \frac{1}{2} C$)

10,720 + 8,460/2 = 14,950

5.9.1.6 Col. 13: Ton-Miles Service

Refer to Figure 12, Chart A (0–6,000 ft depth) as follows:

a. Locate intersection of 4,000 ft depth (vertical line) with ($M + \frac{1}{2} C$) value of 14,950 (curved line).
b. Locate effective weight of drill pipe (14.5) on right vertical scale.
c. Project a line from 14.5 lb/ft on right vertical scale through point found in a, above to ton-miles per round trip on left vertical scale and read 45.5 ton-miles per round trip. Enter the value in Col. 13.

5.9.2 Example 2

Round trip operation from depth greater than 6,000 ft.
Given Conditions:

a. Drill Pipe: 3$\frac{1}{2}$ in. – 15.5 lb/ft.
b. Depth: 11,000 ft.
c. Drill collars: 500 ft, 5$\frac{1}{2}$ in. × 2$\frac{1}{4}$ in.
d. M = 24,450 lb.
e. Drilling fluid: 12.2 lb per gal.

For operations carried on below 6,000 ft proceed as in Example: 1 (see 5.9.1), but to obtain the ton-miles service use Chart B of Figure 12. Thus, the ton-miles per round trip (Col. 13 entry) at 11,000 ft should be 310 ton-miles.

5.9.3 Example 3

Ton-Miles Service, Drilling

Given Conditions:
Same as Example 2 (see 5.9.2), with the drilling starting at 11,000 ft and stopping at 11,500 ft.

Solution:
Ton-Miles service, drilling
= 3 (ton-miles for round trip from 11,500 ft ton-miles for round trip 11,000 ft),
= 3 (330 – 310),
= 60.

5.9.4 Example 4

Ton-Miles Service, Coring

Given Conditions:

Same as Example 3 (see 5.9.3), except coring between 11,000 ft and 11,500 ft instead of drilling.

Solution:
Ton-miles service, coring
= 2 (ton-miles for round trip from 11,500 ft ton-miles for round trip from 11,00 ft),
= 2 (330 – 310),
= 40.

5.9.5 Example 5

Setting Casing

Given Conditions:

a. Casing: 7 in., 29 lb/ft.
b. Depth: 11,500 ft.
c. M = 24,450.
d. Drilling fluid: 2.2 lb/gal.

Solution of entries to be made on service record form:

5.9.5.1 Col. 6: Effective Weight of Casing (See instructions)

$$\begin{aligned} W_{cm} &= W_{ca}(1 - 0.015B), \\ &= 29\,(1 - 0.015 \times 12.2), \\ &= 29 \times 0.817, \\ &= 23.69 \text{ lb/ft.} \end{aligned}$$

Since there are no drill collars involved in setting casing, no entries are required for Cols. 7, 8, 9, 10 and 11.

5.9.5.2 Col. 12: Factor (M + $\frac{1}{2}$ C)

Since there are no drill collars,

$$M + \tfrac{1}{2} C = 24{,}450 + 0 = 24{,}450 \text{ lb}$$

5.9.5.3 Col. 13: Ton-Miles Service

Applying the above information and results to Figure 12, Chart B, ton-mile per round trip is 424.
Ton-miles for setting casing = $\frac{1}{2}$ ton-miles for round trip
= $\frac{1}{2} \times 424$
= 212

5.9.6 Example 6

Ton-Miles Service, Short Trip.

Given Conditions
Same as Example 4 (see 5.9.4), except a short trip between 11,500 ft and 11,000 ft instead of coring.

Solution:
= ton-miles for round trip from 11,500 ft – ton-miles for round trip from 11,000 ft,
= 330 – 310,
= 20.

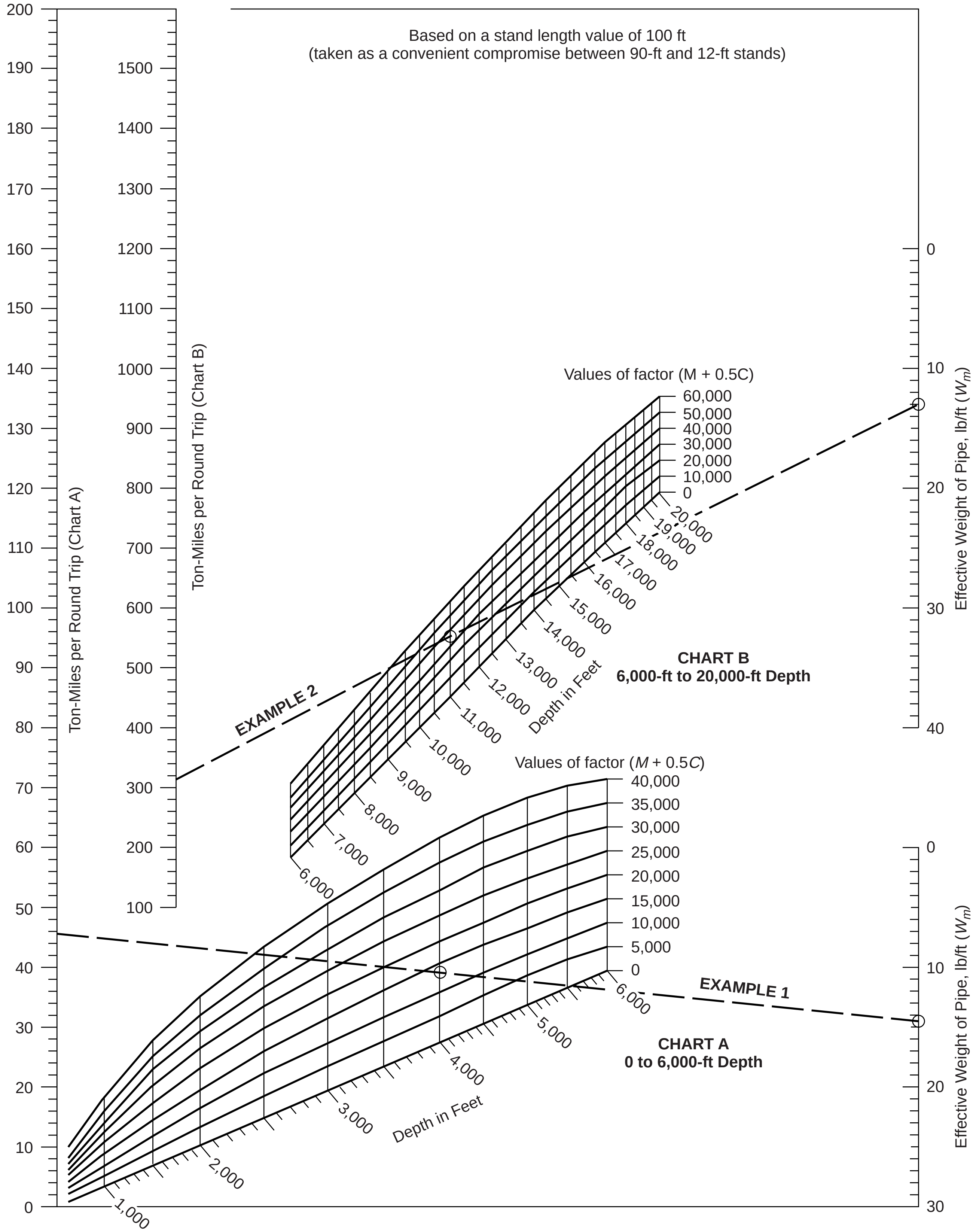


Figure 12—Rotary-Drilling Ton-Mile Charts

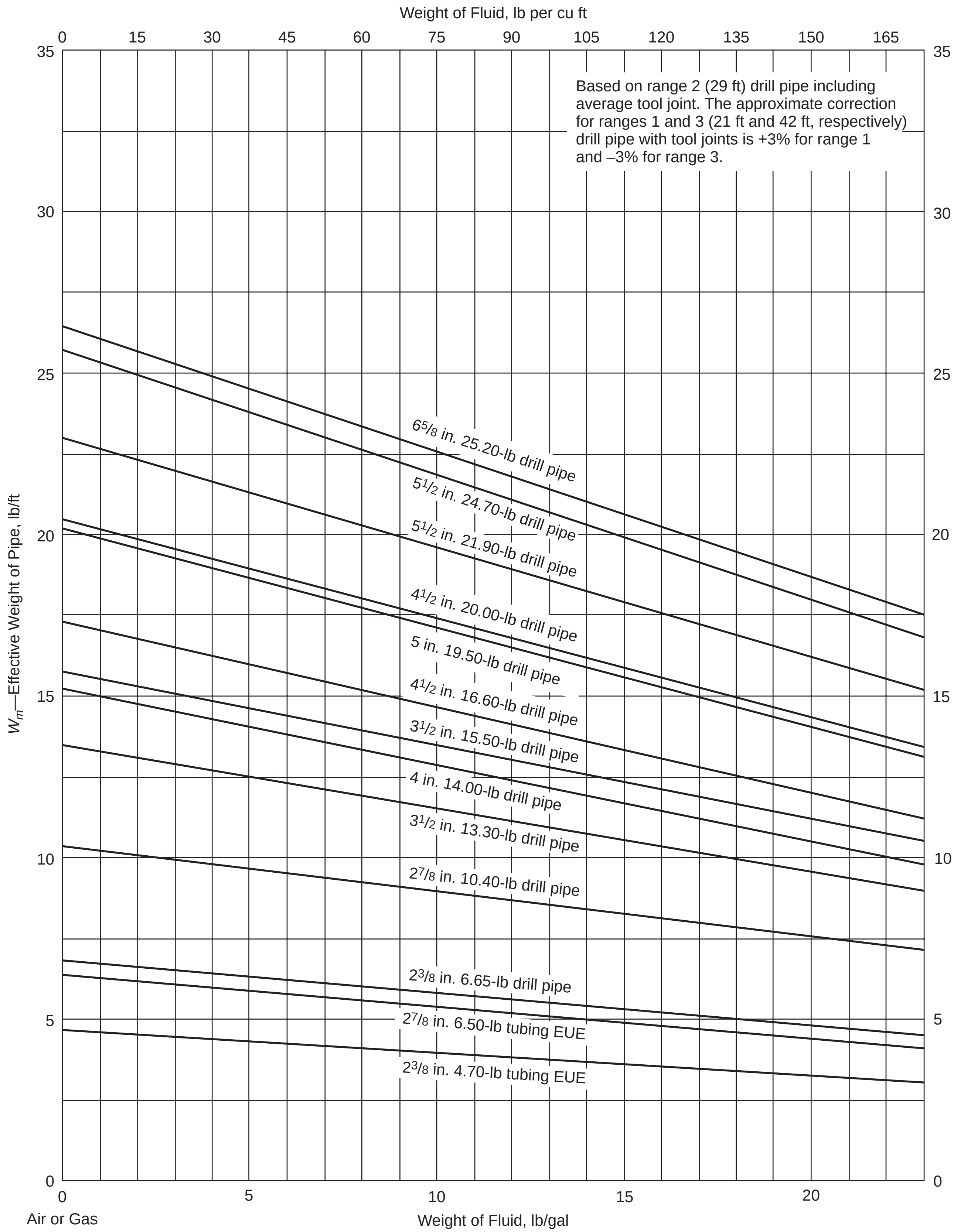


Figure 13—Effective Weight of Pipe in Drilling Fluid

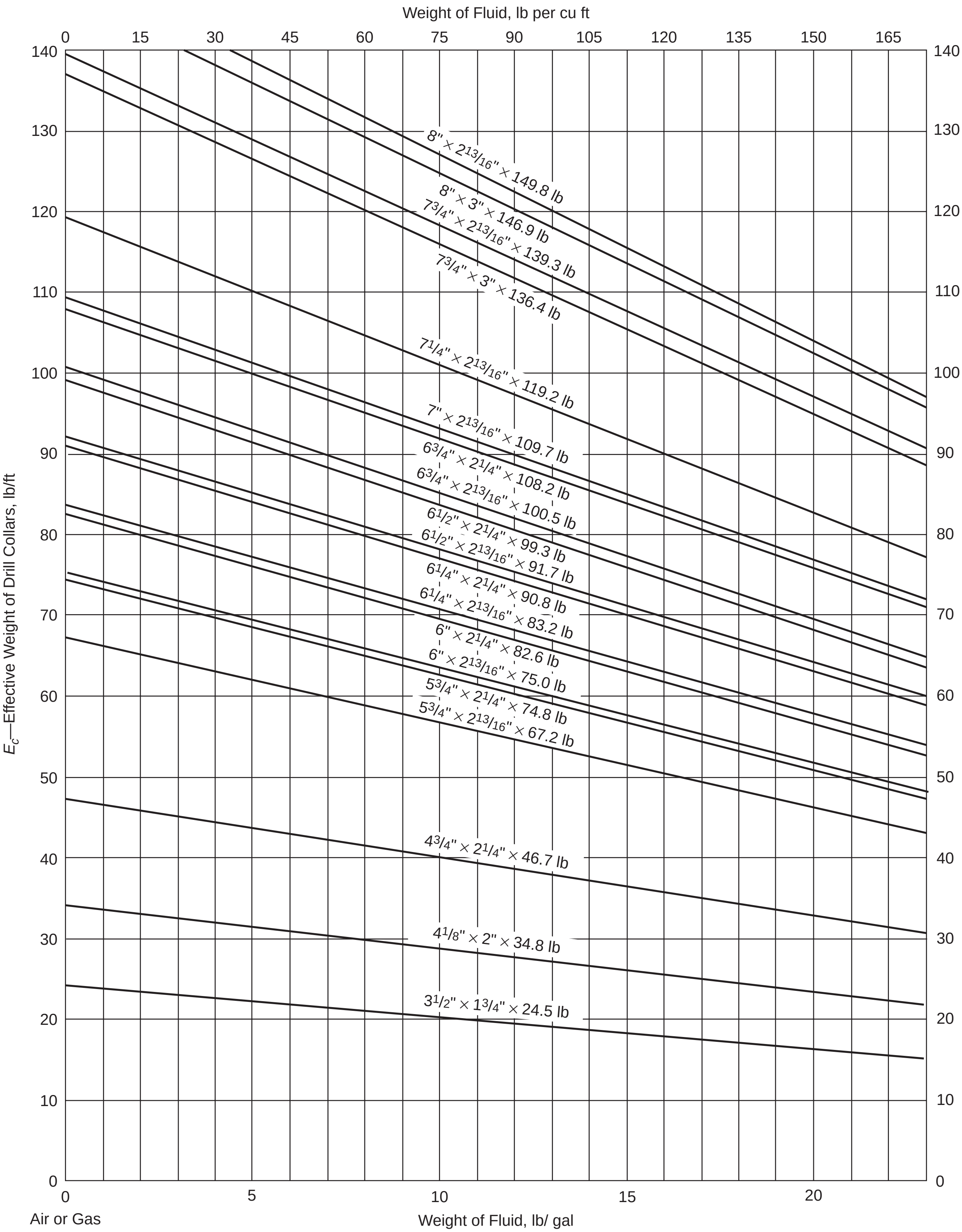


Figure 14—Effective Weight of Drill Collars in Drilling Fluid

Rotary Drilling Line Service Record

Sheet ________ of ________ Sheets

Company ______________________ Well and No. ______________________ Rig No. __________ Make and Type DWKS ______________________

Drum Diam. ____________ Plain or Grooved 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 No.	Depth of Trip	Orientation to be Performed & Remarks	Mud Weight lb/gal	Effective Wt. of Pipe Fig. 13	O.D. and Bore	Effective Wt., E_c Fig. 14	Excess Wt. (Col.8 Minus Col. 6)	No. of Feet	Factor C (Col. 9 × Col. 10)	Factor $M + {}^{1}/_{2}C$	Ton-Miles Service This Operation Fig. 12	Cumulative Ton-Miles Since Last Slip	Length of Line Slipped, ft	Cumulative Ton-Miles Since Last Cutoff	Length Line Cutoff ft	Length Line Remaining ft

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—All Wells ____________ Ton-Miles per ft of Initial Length ____________

Directions for filling out this form, including use of charts, are given in the instruction sheets included with each pad, and are also given in API RP 9B, *Recommended Practices on Application, Care and use of Wire Rope for Oilfield Service.*

Figure 15—Facsimile of Rotary Drilling Line Service Record Form

6 Slipping and 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 16. Possible savings by the use of a longer line may be offset by an increased cost of handling for a longer line.

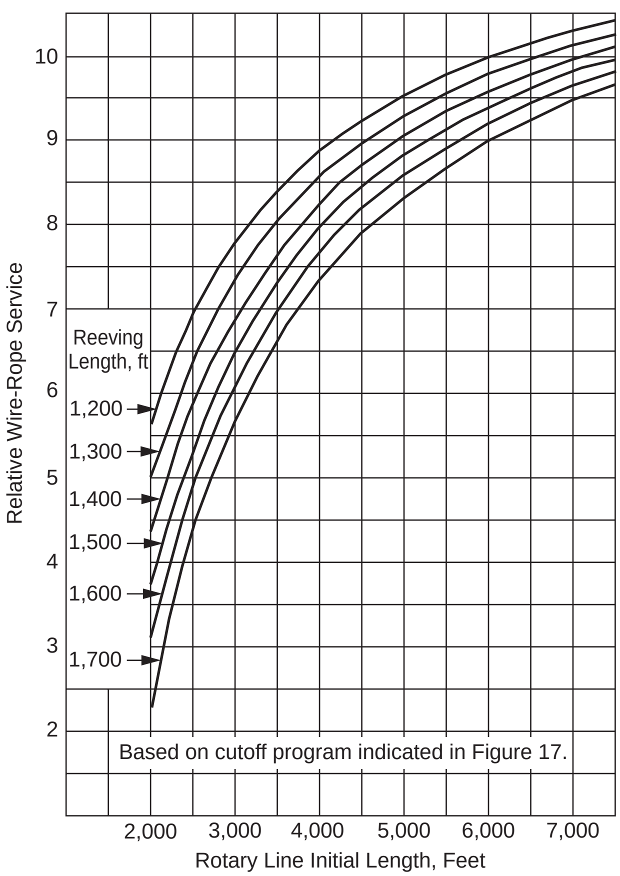


Figure 16—Relationship Between Rotary-Line Initial Length and Service Life[a]

[a]Empirical curves developed from general field experience.

6.3 SERVICE GOAL

A goal for line service in terms of ton-miles between cutoffs should be selected. This value can initially be determined from Figures 17 and 18 and later adjusted in accordance with experience. Figure 19 shows a graphical method of determining optimum cut-off frequency.

6.4 VARIATIONS IN LINE SERVICES

Ton-miles of service will vary with the type and condition of equipment used, drilling conditions encountered, and the skill used in the operation. A program should be “tailored” to the individual rig. The condition of the line as moved through the reeving system and the condition of the cutoff portions will indicate whether the proper goal was selected. In all cases, visual inspection of the wire rope by the operator should take precedence over any predetermined procedures. (See Figure 19 for a graphical comparison of rope service.)

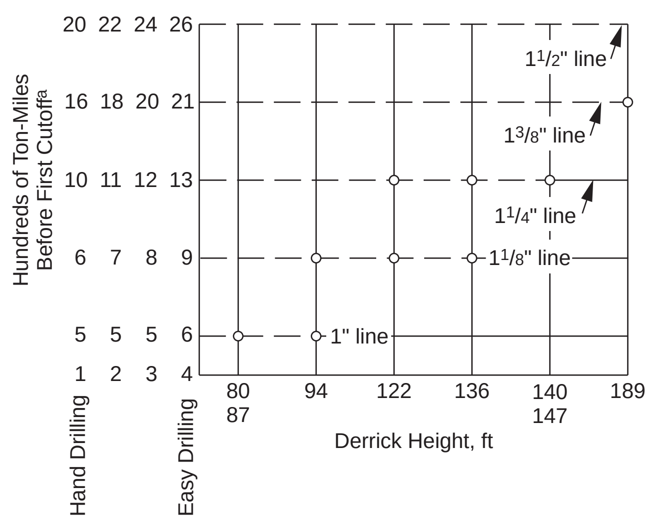


Figure 17—Ton-Mile, Derrick-Height, and Line-Size Relationships[a]

Explanation: To determine (approximately) the desirable ton-miles before the first cutoff on a new line, draw a vertical line from the derrick height to the wireline size used. Project this line horizontally to the ton-mile figure given for the type of drilling encountered in the area. Subsequent cutoffs should be made at 100 ton-miles less than those indicated for $1^1/_8$-in. and smaller lines, and at 200 ton-miles less than $1^1/_4$-in. and $1^3/_8$-in. lines.

[a]The values for ton-miles before cutoff, as given in Figure 17 were calculated for improved blow steel with an independent wire-rope core and operating at a design factor of 5. When a design factor other than 5 is used, these values should be modified in accordance with Figure 18. The values given in Figure 17 are intended to serve as a guide for the selection of initial ton-mile values as explained in Section 6.3. These values are conservative, and are applicable to all typical constructions of wire rope as recommended for the rotary drilling line shown in Table 1.

6.5 CUTOFF LENGTH

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

a. The excess length of line which can conveniently be carried on the drum.
b. Load pickup points from reeving diagram.
c. Drum diameter and crossover points on the drum.

Care should be taken to see that crossover and pickup points do not repeat. This is done by avoiding cutoff lengths which are multiples of either drum circumference, or lengths between pickup points. Successful programs have been based on cutoff lengths ranging from 30 to 150 ft. Table 7 shows a recommended length of cutoff (number of drum laps) for each height derrick and drum diameter.

6.6 SLIPPING PROGRAM

The number of slips between cutoffs can vary considerably based on drilling conditions and on the length and frequency of cutoffs. This frequency can vary from one or two slips to as much as seven slips between cutoffs. Slips should be increased if the digging is rough, if jarring jobs occur, etc. Slipping in such a manner that too much line piles up on the drum before cutoff should be avoided. Slipping that causes an extra layer on the drum should particularly be avoided. In slipping the line, the rope should be slipped an amount such that no part of the rope will be located for a second time in a position of severe wear. The positions of severe wear are the point of crossover on the drum and the sections in contact with the traveling- and crown-block sheaves at the pickup position. The cumulative number of feet slipped between cutoffs should be equal to the recommended number of feet for ton-mile cutoff. For example, if cutting off 80 ft every 800 ton-miles, 20 ft should be slipped every 200 ton-miles and the line cut off on the fourth slip.

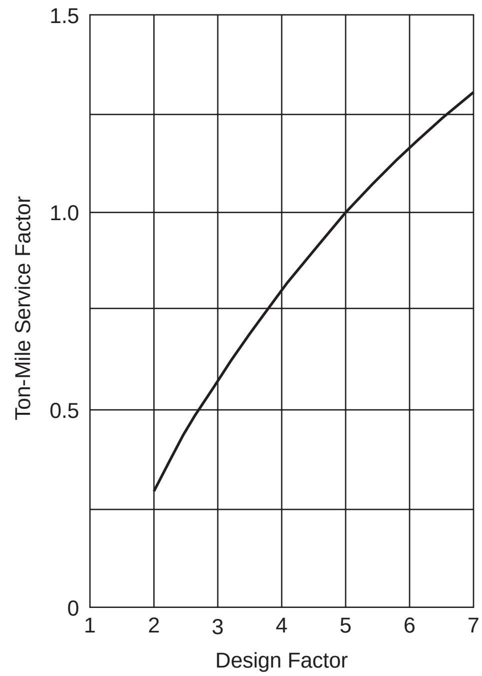


Figure 18—Relationship Between Design Factors and Ton-Mile Service Factors[a]

Note: Light loads can cause rope to wear out from fatigue prior to accumulation of anticipated ton-miles.
[a]Based on laboratory tests of bending over sheaves.

Table 7—Recommended Cutoff Lengths in Terms of Drum Laps[a]
See Par. 6.5

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Derrick or Mast Height, ft	Drum Diameter, in.													
	11	13	14	16	18	20	22	24	26	28	30	32	34	36
	Number of Drum Laps per Cutoff													
151 Up										$15\frac{1}{2}$	$14\frac{1}{2}$	$13\frac{1}{2}$	$12\frac{1}{2}$	$11\frac{1}{2}$
141 to 150								$13\frac{1}{2}$	$12\frac{1}{2}$	$11\frac{1}{2}$	$11\frac{1}{2}$	$10\frac{1}{2}$		
133 to 140						$15\frac{1}{2}$	$14\frac{1}{2}$	$12\frac{1}{2}$	$11\frac{1}{2}$	$11\frac{1}{2}$	$10\frac{1}{2}$	$9\frac{1}{2}$		
120 to 132				$17\frac{1}{2}$	$15\frac{1}{2}$	$14\frac{1}{2}$	$12\frac{1}{2}$	$12\frac{1}{2}$	$11\frac{1}{2}$	$10\frac{1}{2}$	$9\frac{1}{2}$	$9\frac{1}{2}$		
91 to 119		$19\frac{1}{2}$	$17\frac{1}{2}$	$14\frac{1}{2}$	$12\frac{1}{2}$	$11\frac{1}{2}$	$10\frac{1}{2}$	$9\frac{1}{2}$	$9\frac{1}{2}$	$8\frac{1}{2}$				
73 to 90		$17\frac{1}{2}$	$14\frac{1}{2}$	$12\frac{1}{2}$	$11\frac{1}{2}$									
Up through 72	$12\frac{1}{2}$	$11\frac{1}{2}$												

[a]To insure a change of the point of crossover on the drum, where wear and crushing are most severe, the laps to be cut off are given in multiples of one-half lap or one quarter lap based on the type of drum grooving.

6.7 EXAMPLE

Assumed conditions:

a. Derrick height: 138 ft.
b. Wire-line size: $1^1/_4$ in.
c. Type Drilling: #3.
d. Drum diameter: 28 in.
e. Design Factor: 3.

Solution:

1. From Figure 17 determine that (for a line with a design factor of 5) the first cutoff would be made after 1,200 ton-miles and additional cut-off after each successive 1,000 ton-miles.

2. Since a design factor of 3 applies, Figure 18 indicates that these values should be multiplied by a factor of 0.58. Hence the first cutoff should be made after 696 ton-miles and additional cutoff after each successive 580 ton-miles.

3. From Table 7 determine that $11^1/_2$ drum laps (84 ft) should be removed at each cutoff.

4. Slip 21 ft every 174 ton-miles for four times and cut off after the fourth slip. Thereafter, slip 21 ft every 145 ton-miles and cut off on the fourth slip.

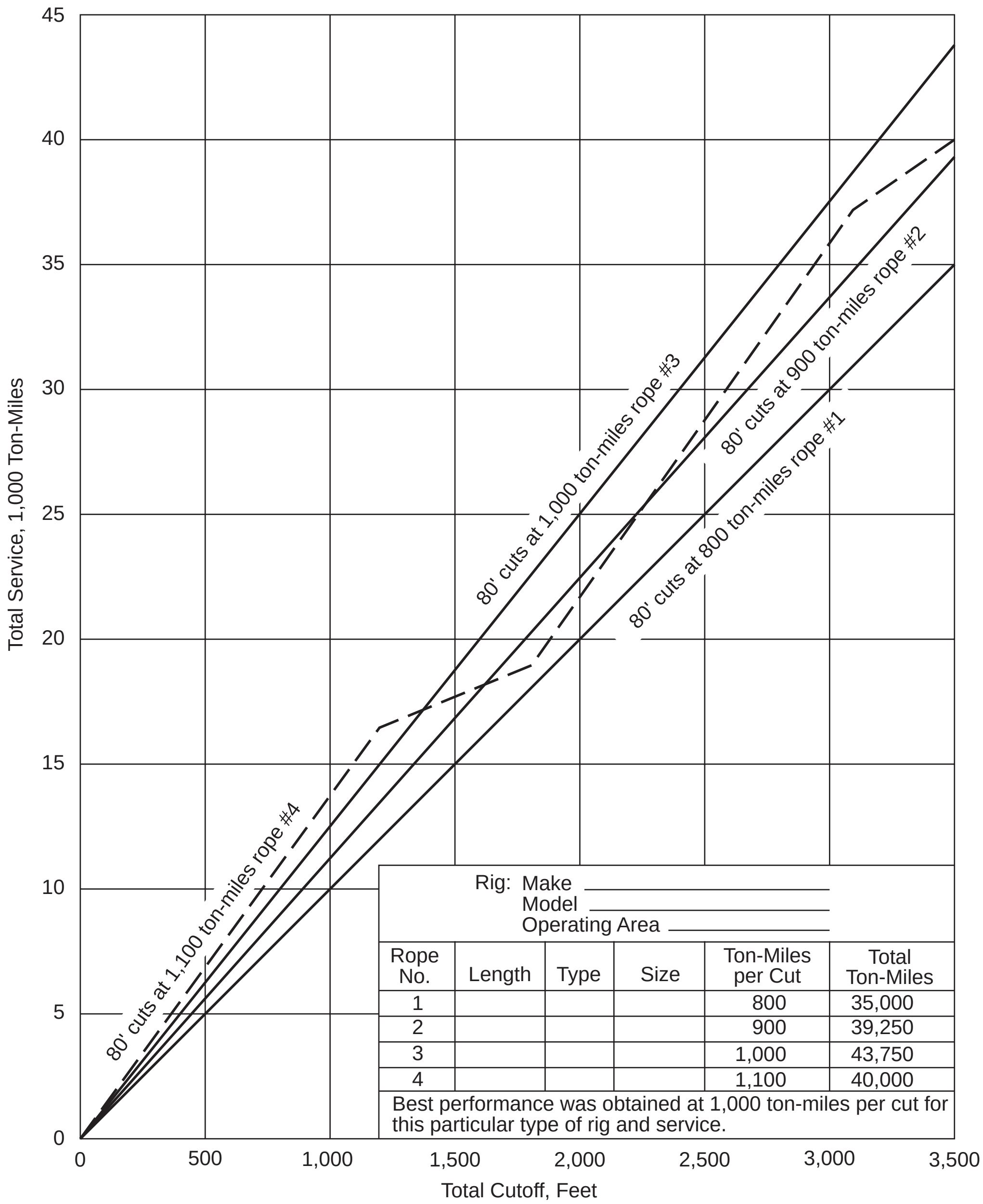


Figure 19—Graphic Method of Determining Optimum Frequency of Cutoff to Give Maximum Total Ton-Miles for a Particular Rig Operating Under Certain Drilling Conditions

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 tiedown. Open-drum reels having longitudinal spokes too widely spaced. Divider interference. The addition of improperly spaced cleats to increase the drum diameter. Stressing while rope is over small sheave or obstacle.

g. Damage by hooking back slack too tightly to girt.
Possible Cause: Operation of walking beam causing a bending action on wires at clamp and resulting in fatigue and cracking of wires, frequently before rope goes down into hole.

h. 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.

i. 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. This may also occur in cable-tool lines as a result of concentrated pulsating or surging forces which may contribute to fiber-core collapse.

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

k. 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.

l. 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.

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

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

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

p. High strands.
Possible Cause: Slipping through clamps, improper seizing, improper socketing or splicing kinks, dog legs, and core popping.

q. 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 and sheaves.

r. Fatigue breaks in wires.
Possible Cause: Excessive vibration due to poor drilling conditions, i.e., high speed, rope slipping, concentration of vibration as dead sheave or dead-end anchor, undersized grooves and sheaves, and improper selection of rope construction. Prolonged bending action over spudder sheaves, such as that due to hard drilling.

s. 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.

t. Excessive flattening or crushing.
Probable Cause: Heavy overload, loose winding on drum, or cross winding. Too infrequent cutoffs on working end of cable-tool lines. Improper cutoff and moving program for cable-tool lines.

u. 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.

v. Whipping off of rope.

Probable Cause: Running too loose.

w. 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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