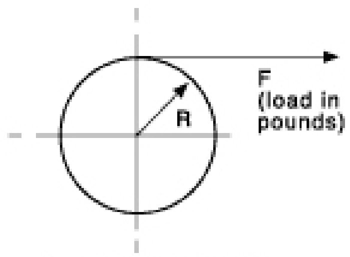
MECHANICAL ENGINEERING FORMULAE

Power & Torque Imperial Standards

Horsepower (HP)

Common unit of mechanical power, one HP is the rate of work required to raise 33,000 pounds one foot in one minute.



R = Radius (inches)
RPM = Rotational Speed
(revolutions per minute)

$$HP = \frac{F \times \pi \times 2R \times RPM}{33000 \times 12}$$

or

$$HP = \frac{F \times R \times RPM}{63025}$$

or

$$HP = \frac{torque \times RPM}{63025}$$

One Imperial Horsepower Equals:

33,000 foot pounds per minute
36 inch pounds torque at 1750 RPM
.746 Kilowatts
1.014 Metric Horsepower (PS)
42.4 BTU per Minute

Torque (T)

Torque is a twisting force. Torque causes rotation of a shaft, or it will set up a twist in a stationary shaft. It is generally expressed in foot pounds or in inch pounds. Torque is measured by the load or pull and by the distance of the pull from the center of a shaft.

$$T = F \times R$$

or

$$T = \frac{HP \times 63025}{RPM}$$

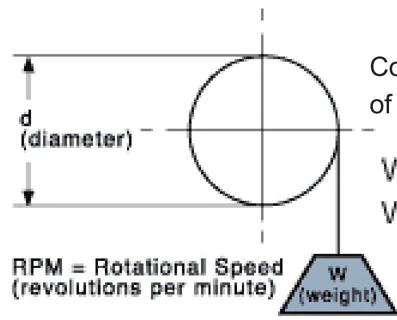
Calculation Examples

A cable wrapped around a 6” dia. drum must lift a 2500 pound weight. The drum rotates at 30 RPM.

Metric (SI) Standards

Power (P)

The basic unit power measurement in the metric (SI) system is the Watt. 1000 Watts = 1 Kilowatt (kW)



Constant g = acceleration of free fall 9.81 m/s^2

V = velocity in meters/sec.

$$V = \frac{\pi d \bullet RPM}{60}$$

Torque (M)

Torque is a twisting force. Torque causes rotation of a shaft, or it will set up a twist in a stationary shaft. It is generally expressed in Newton-Meters.

$$M = \frac{9550 \bullet P}{RPM}$$

SI Symbols

M = Torque P = Power in Kilowatts
N = Newton Kfgm = Kilogram force meter
m = Meter N-m = Torque in Newton-Meters
x = Multiplication Symbol

Calculation Examples

A cable wrapped around a .5 meter dia. drum must lift 5000 kilograms of weight. The drum rotates 50 RPM.

MECHANICAL ENGINEERING FORMULAE

To Calculate HP:

$$HP = \frac{F \times R \times RPM}{63025}$$
$$HP = \frac{2500 \times 3 \times 30}{63025}$$
$$HP = 3.57$$

To Calculate P:
Power in Kilowatts

$$P = \frac{W \bullet g \bullet V}{1000}$$
$$P = \frac{5000 \bullet 9.81 \bullet \frac{\pi . 5 \bullet 50}{60}}{1000}$$
$$P = 64.2 \text{ kilowatts}$$

To Calculate T:

$$T = F \times R$$
$$T = 2500 \times 3''$$
$$T = 7500 \text{ inch pounds}$$

To Calculate M:
Torque in Newton-Meters

$$M = \frac{9550 \bullet 64.2}{50}$$
$$M = 12262 \text{ Nm}$$

Conversion Factors				
1 Kilowatt =	**1 N-m =**	**1 kgfm =**	**1 lb ft =**	**1 lb in =**
1.341	.10197	9.807 N-m	1.356 N-m	.1129 N-m
Imperial	.73756 lb ft	7.233 lb ft	.1883 kgfm	.0115 kgfm
Horsepower	8.8507 lb in	86.796 lb in	12 lb in	.083 lb ft

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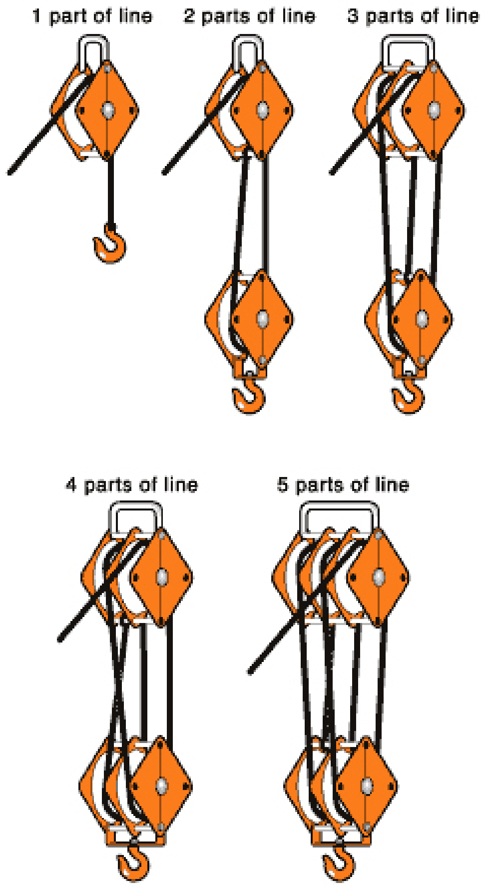
LIFTING WITH MULTI-PART LINE



$$\frac{\text{Total Load to be Pulled}}{\text{Single Line Pull in Pounds}} = \text{RATIO}$$

Example:
To find the *number of parts of line* needed when weight of load and single line pull is established.

Sample Problem:

$$\frac{\text{72 480 lbs. (load to be lifted)}}{\text{8 000 lbs. (single line pull)}} = \text{9.06 RATIO}$$

Refer to ratio 9.06 in table or number nearest to it, then check column under heading "Number of Parts of Line" ... 12 parts of line to be used for this load.

Example:
To find *single line pull* needed when weight of load and number of parts of line are established.

Sample Problem:

$$\frac{\text{68 000 lbs. (load to be lifted)}}{\text{6.60 (ratio of 8 part line)}} = \text{10 300 lbs. (single line pull)}$$

10 300 lbs. single line pull required to lift this load on 8 parts of line.

How To Calculate Line Parts

Number of Parts of Line	Ratio for Bronze Bushed Sheaves	Ratio for Anti-Friction Bearing Sheaves
1	.96	.98
2	1.87	1.94
3	2.75	2.88
4	3.59	3.81
5	4.39	4.71
6	5.16	5.60
7	5.90	6.47
8	6.60	7.32
9	7.27	8.16
10	7.91	8.98
11	8.52	9.79
12	9.11	10.6
13	9.68	11.4
14	10.2	12.1
15	10.7	12.9
16	11.2	13.6
17	11.7	14.3
18	12.2	15.0
19	12.6	15.7
20	13.0	16.4
21	13.4	17.0
22	13.8	17.7
23	14.2	18.3
24	14.5	18.9

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Winch Sizing

As a General Guide to Sizing the Right Winch for the Job, the Following Detail May Be of Help:

Load

Calculate the total weight of all the loaded railcars to be moved simultaneously. For example, if four loaded railcars, each weighing 85 tons are to be moved together, the total load will be four times 85 tons, for a combined weight of 340 tons.

Rolling Resistance Under Ideal Conditions

Resistance to rolling is influenced by the wheel journals, type of lubrication used and the ambient temperature. Assuming the railcars are to be moved along a straight, level and well-maintained track, select the running line pull for the lowest anticipated temperature, using Table 1.

Example: If the lowest anticipated temperature is 32&#176F, the required running line pull from Table 1 will be 15 lbs/ton. Multiply the total weight of the railcars 340 tons by 15 lbs/ton and the total running line pull becomes 5100 lbs.

Temperature	More Than 32° F	Less Than 32° F	More Than 0° F	Less Than -20° F
Running Line Pull (lbs/ton)	12	15	20	25

Track Gradient

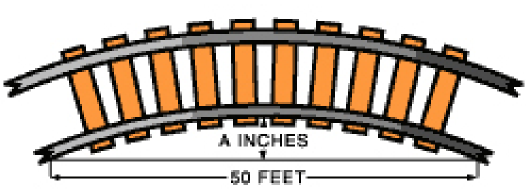
For each one percent gradient a rise of one foot for every 100 feet of track the running line pull must be increased by 20 lbs/ton.

Example: If the track has a 1.5% grade, the additional running line pull is 20, multiplied by 1.5, or 30 lbs/ton. The new running line pull is the original 15 lbs/ton plus the 30 lbs/ton adjustment for grade or 45 lbs/ton. The new running line pull is now calculated by multiplying 45 lbs/ton by the 350 tons of railcars for a total of 15,300 lbs.

Track Curvature

To overcome the effects of wheels binding against rails on curved sections of track, running line pull must be increased.

Track curvature is expressed in terms of radius or degree of curvature. When this information is not available, the chordal factor can be easily measured. Simply stretch a 50-foot tape along the inside of the curve and measure the distance 'A' in Diagram 1.



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RAILCAR PULLING DETAIL

Select the appropriate additional running line pull from Table 2 using either radius, degrees of curvature or chordal factor. (Interpolation for a measure of curvature is not shown.)

Radius (ft)	Degree of Curvature (degree)	Chordal Factor A (in)	Additional Running Line Pull (lbs/ton)
1146	5	3.50	3.75
573	10	6.50	7.50
383	15	9.75	11.25
288	20	13.00	15.00
231	25	16.50	18.75
193	30	20.00	22.50
166	35	23/50	26.25
146	40	27.00	30.00

Example: Chordal factor A was found to be 6.5 inches. The additional running line pull from Table 2 is 7.50 lbs/ton. Now the running line pull has increased from 45 lbs/ton to 52.5 lbs/ton. Again, multiplied by the 340 tons of railcars, the total running line pull is 17,850 lbs.

Track Conditions

If track conditions are substandard soft ballast, uneven or deteriorating ties or debris on the track additional running line pull will be needed. Since the condition of substandard track can vary considerably, Jeamar recommends that line pull be measured with a dynamometer.

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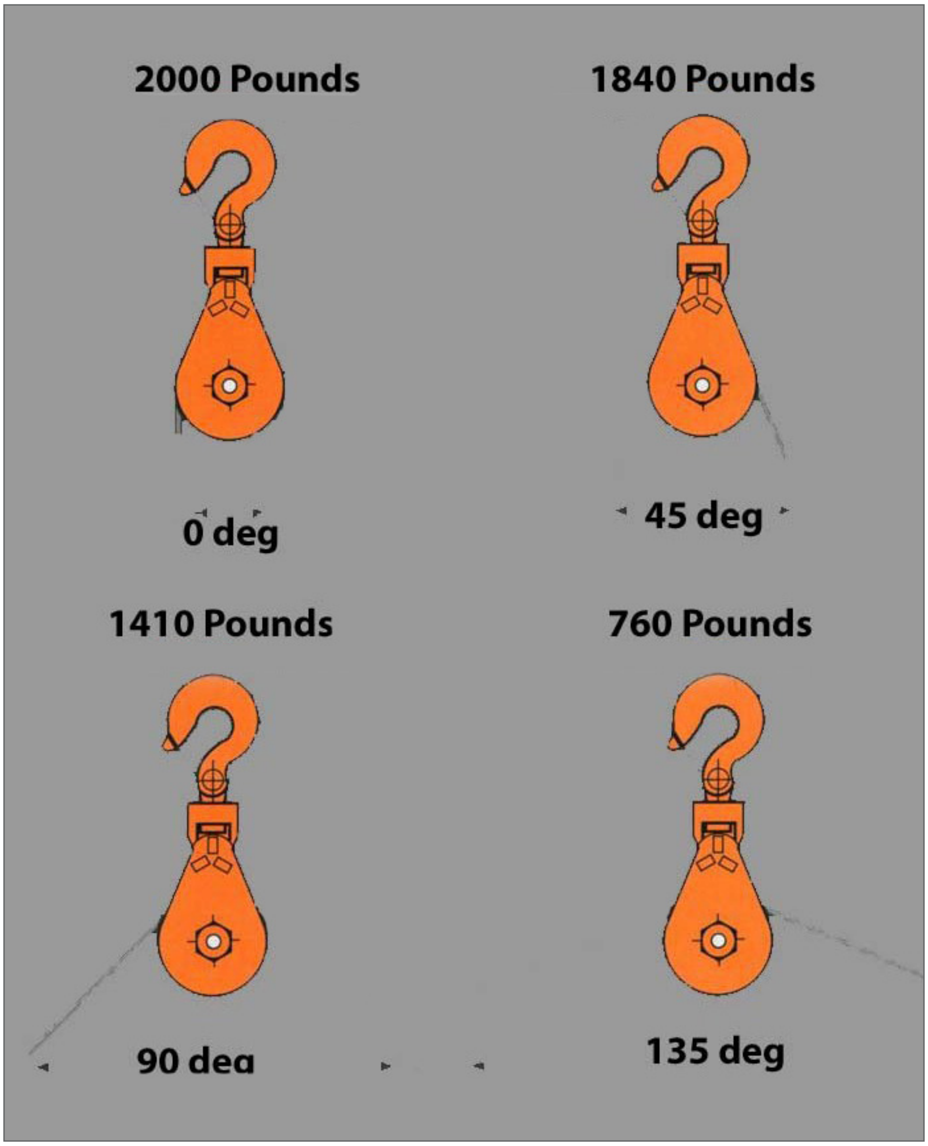
Determining The Stress On A Hook

Multiply the Pull on the Lead Line By a Suitable Factor From the Following Table. All Loads Shown Ignore Frictional Losses in the System.

Angle	Factor
0°	2.00
5°	1.998
10°	1.99
15°	1.98
20°	1.97
25°	1.95
30°	1.93
35°	1.90
40°	1.87
45°	1.84
50°	1.81
55°	1.77
60°	1.73
65°	1.69
70°	1.64
75°	1.58
80°	1.53
85°	1.47
90°	1.41
95°	1.35
100°	1.29
105°	1.22
110°	1.15
115°	1.07
120°	1.00
125°	0.92
130°	0.84
135°	0.76
140°	0.68
145°	0.60
150°	0.52
155°	0.43
160°	0.35
165°	0.26
170°	0.17
175°	0.08
180°	0.00

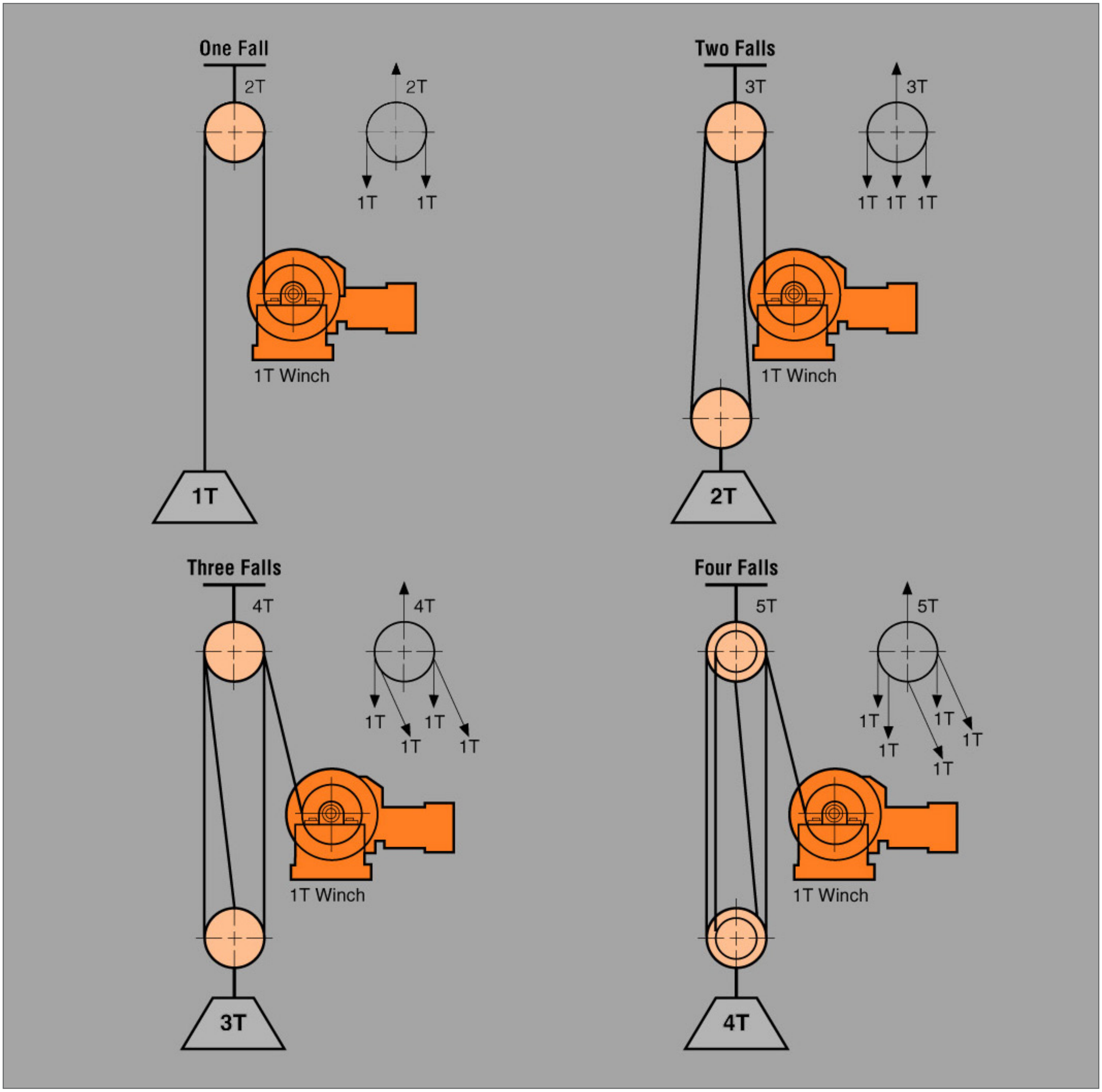
The stress on a sheave or block varies with the degree of angle between the lead and load lines. When the two lines are parallel, 1000 pounds on the lead line results in a load of 2000 pounds on the hook. As the angle between the lines increases, the stress on the hook is reduced as illustrated below.



CALCULATING HEAD LOADS

Note:

Note: Since the rope is continuous, from the winch drum to the attachment point, the load is always 1 ton, no matter where measured. The head load is the number of line attachments at the head sheave x 1 ton. All loads shown ignore frictional losses in the system.



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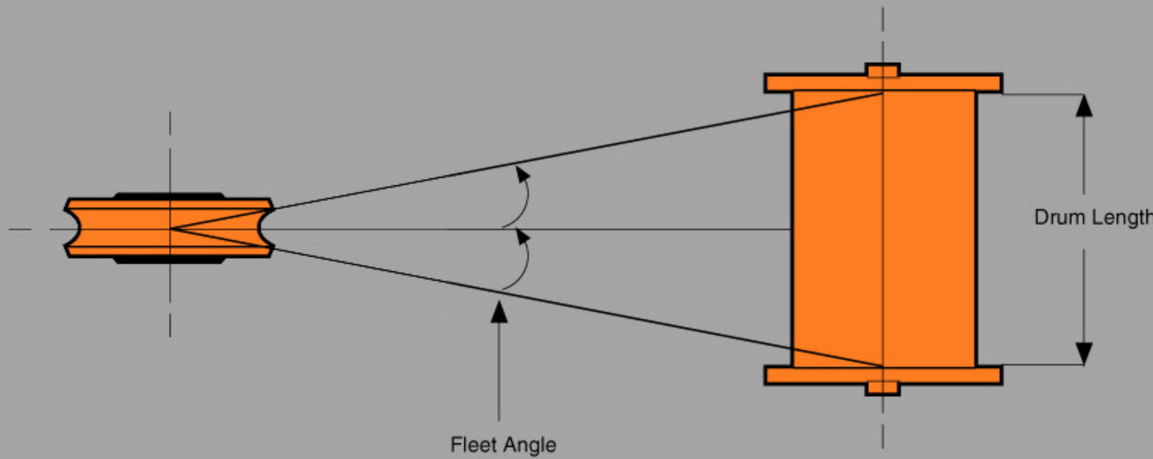
CALCULATING FLEET ANGLE



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REFERENCE CHARTS

Wire Rope Specifications

Preformed Galvanized Aircraft Cable 7x19		
Size Diameter (in)	Weight per 100’ (lbs)	Breaking Strength (lbs)
1/8”	2.9 lbs.	2,000 lbs.
3/16”	6.5 lbs.	4,200 lbs.
1/4”	11.0 lbs.	7,000 lbs.
5/16”	17.3 lbs.	9,800 lbs.
3/8”	24.3 lbs.	14,400 lbs.

Steel I.W.R.C. 6x37		
Size Diameter (in)	Weight per 100’ (lbs)	Breaking Strength (lbs)
7/16”	33 lbs.	20,400 lbs.
1/2”	43 lbs.	26,600 lbs
9/16”	54 lbs.	33,600 lbs.
5/8”	67 lbs.	41,200 lbs.
3/4”	96 lbs.	58,800 lbs.
7/8”	131 lbs.	79,600 lbs.
1”	170 lbs.	103,400 lbs.
1-1/8”	216 lbs.	130,000 lbs.
1-1/4”	266 lbs.	159,800 lbs.
1-3/8”	322 lbs.	192,000 lbs.
1-1/2”	384 lbs.	228,000 lbs
1-5/8”	450 lbs.	264,000 lbs.
1-3/4”	522 lbs.	306,000 lbs.
1-7/8”	600 lbs.	384,000 lbs.
2”	682 lbs.	396,000 lbs.

Grades - Slope & Grade Resistance

Grade (% per 100 Horizontal ft)	Slope (Degrees & Minutes per 100 Horizontal ft	Grade Resistance (lbs. Pull per Ton to Overcome Grade Resistance)
1	0-34	20
2	1-9	40
3	1-43	60
4	2-17	80
5	2-52	100
6	3-26	120
7	4-0	140
8	4-34	160
9	5-9	180
10	5-43	199
11	6-17	219
12	6-51	238
13	7-24	258
14	7-58	277
15	8-32	296
16	9-39	315
17	9-5	334
18	10-12	353
19	10-45	373
20	11-19	392
25	14-2	485
30	15-17	575
35	16-42	660
40	21-48	743
45	24-14	822
50	26-34	895
55	28-49	965
60	30-58	1025
65	33-1	1085
70	34-59	1145
75	36-52	1196
80	38-40	1248
85	40-22	1295
90	41-59	1338
95	43-32	1376
100	45-0	1402

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Equivalent of Common Fractions of an Inch

Fraction	Dec.	mm	Fraction	Dec.	mm
1/64	.015625	0.397	33/64	.515625	13.097
1/32	.03125	0.794	17/32	.53125	13.494
3/64	.046875	1.191	35/64	.546875	13.891
1/16	.0625	1.588	9/16	.5625	14.288
5/64	.078125	1.984	37/64	.578125	14.684
3/32	.09375	2.381	19/32	.59375	15.081
7/64	.109375	2.778	39/64	.609375	15.478
1/8	.1250	3.175	5/8	.6250	15.875
9/64	.140625	3.572	41/64	.640625	16.272
5/32	.15625	3.969	21/32	.65625	16.669
11/64	.171875	4.366	43/64	.671875	17.066
3/16	.1875	4.762	11/16	.6875	17.462
13/64	.203125	5.159	45/64	.703125	17.859
7/32	.21875	5.556	23/32	.71875	18.256
15/64	.234375	5.953	47/64	.734375	18.653
1/4	.2500	6.350	3/4	.7500	19.050
17/64	.265625	6.747	49/64	.765625	19.447
9/32	.28125	7.144	25/32	.78125	19.844
19/64	.296875	7.541	51/64	.796875	20.241
5/16	.3125	7.938	13/16	.8125	20.638
21/64	.328125	8.334	53/64	.828125	21.034
11/32	.34375	8.731	27/32	.84375	21.431
23/64	.359375	9.128	55/64	.859375	21.828
3/8	.3750	9.525	7/8	.8750	22.225
25/64	.390625	9.922	57/64	.890625	22.622
13/32	.40625	10.319	29/32	.90625	23.019
27/64	.421875	10.716	59/64	.921875	23.416
7/16	.4375	11.112	15/16	.9375	23.812
29/64	.453125	11.509	61/64	.953125	24.209
15/32	.46875	11.906	31/32	.96875	24.606
31/64	.484375	12.303	63/64	.984375	25.003
1/2	.5000	12.700	1	1.000	25.400

1 mm = .03937" **1" = 25.4 mm**