

## Mounted Bearings Life Adjustment Factor

**1.1 GENERAL.** For certain applications, it is desirable to specify life for reliability other than 90%. In such cases a life adjustment factor for reliability may be applied to the RATING LIFE. Section 1.2 discusses life adjustment factors for reliability.

Some bearing steels; e.g., vacuum-melted steels, and improved processing techniques, permit manufacture of bearings which offer endurance greater than that calculated by the RATING LIFE formula. Section 1.3 recommends methods to incorporate life adjustment factors for bearing materials into the life formula.

Bearing life calculated according to the RATING LIFE formula assumes proper application conditions. If lubrication is not adequate, loading unusual, or temperatures extreme, the ability of the bearing to attain or exceed the RATING LIFE is seriously impaired. Section 1.4 contains some basic recommendations concerning the effect of unusual application conditions on bearing life.

**1.2 LIFE ADJUSTMENT FACTOR FOR RELIABILITY.** Bearing life estimated in accordance with this standard is RATING LIFE; i.e., the life associated With 90% reliability or the life which 90% of a group of apparently identical bearings in a given application under similar conditions of load and speed will complete or exceed. While RATING LIFE has proven useful over a period of years as a criterion of performance, some applications require definition of life at reliabilities greater than 90%.

To determine bearing life with reliabilities other than 90% (as previously calculated from the Selection Procedure) the  $L_{10}$  must be adjusted by a factor  $a_1$ , such that  $L_n = a_1 \times L_{10}$ .

The life adjustment factors for reliability of Table 11 are recommended.

**Table 11: Life Adjustment Factors For Reliability**

Reliability %	$L_n$	Life Adjustment Factor for Reliability $a_1$
90	$L_{10}$	1
95	$L_5$	0.62
96	$L_4$	(Rating Life)
97	$L_3$	
98	$L_2$	
99	$L_1$	0.21

**1.3 LIFE ADJUSTMENT FACTOR FOR MATERIAL.** For bearings, which incorporate improved materials and processing, the  $L_{10}$  (as previously calculated in Selection Procedure) must be adjusted by a factor  $a_2$ . Factor  $a_2$  depends upon steel analysis, metallurgical processing, forming methods, heat treatment and manufacturing methods in general.

Bearings fabricated from consumable vacuum remelted steels and certain other special analysis steels have demonstrated extraordinarily long endurance. These steels are of exceptionally high quality, and bearings fabricated from these are usually considered special manufacture. As such,  $a_2$  values will not be specified for such steels in this discussion. Generally,  $a_2$  values for such steels can be obtained from the bearing manufacturer.

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**1.4 LIFE ADJUSTMENT FACTOR FOR APPLICATION CONDITIONS.** Application conditions which affect bearing life include:

1. Lubrication.
  2. Load distribution (including effects of clearance, misalignment, housing, and shaft stiffness, type of loading and thermal gradients).
  3. Temperature.
- Consideration of (1.2) and (1.3) above requires analytical and experimental techniques beyond the scope of this discussion, therefore, the user should consult the bearing manufacturer for evaluations and recommendations.

In most bearing applications, lubrication serves to separate the rolling surfaces; i.e., rolling elements and raceways; to reduce retainer-rolling elements and retainer-land friction and sometimes to act as a coolant to remove frictional heat generated by the bearing.

If all limitations and qualifications specified by this discussion are observed, then the life adjustment application factor for bearings which are adequately lubricated is 1; i.e.,  $a_3=1$ .

Operating conditions where  $a_3$  might be less than 1 include:

- a. exceptionally low values of Ndm (rpm times bore diameter in mm); e.g., Ndm 1000.
  - b. Lubricant viscosity less than 20.4 centistokes (100 SSU) at operating temperature.
  - c. Excessively high operating temperatures.
- When  $a_3$  is less than 1, it may not be assumed that the deficiency in lubrication can be overcome by using an improved steel.

\* C = Basic Load Rating computed in accordance with ABMA-ANSI Standards.  
C90 = C x.259

**1.5 FACTOR COMBINATIONS.** A fatigue life formula embodying the foregoing life adjustment factors is:

For Ball Bearings:

$$L_n = a_1 \times a_2 \times a_3 \left( \frac{C^*}{P} \right)^3 \times \frac{(16,667)}{\text{RPM}}$$

For Tapered Roller Bearings:

$$L_n = a_1 \times a_2 \times a_3 \left( \frac{C90^*}{P} \right)^{10/3} \times \frac{(1,5000,000)}{\text{RPM}}$$

For Spherical Roller Bearings:

$$L_n = a_1 \times a_2 \times a_3 \left( \frac{C^*}{P} \right)^{10/3} \times \frac{(16,667)}{\text{RPM}}$$

Indiscriminate application of the life adjustment factors in this formula may lead to serious over-estimation of bearing endurance, since fatigue life is only one criterion for bearing selection.

Care must be exercised to select bearings which are of sufficient size for the application. Undersizing of shaft and housing structures by using bearings which appear adequate from a life standpoint could lead to misalignment and fitting problems which could invalidate the formulas in this discussion.

## V-Belt Drive Formulas

**V-belt tensioning** In cases where tensioning of a drive effects belt pull and bearing loads, the following formulas may be used.

$$T_1 - T_2 = 33,000 \left( \frac{HP}{V} \right)$$

where:  $T_1$  = tight side tension, pounds  
 $T_2$  = slack side tension, pounds  
 HP = design horsepower  
 $V$  = belt speed, feet per minute

$$T_1 + T_2 = 33,000 (2.5-G) \left( \frac{HP}{GV} \right)$$

where:  $T_1$  = tight side tension, pounds  
 $T_2$  = slack side tension, pounds  
 HP = design horsepower  
 $V$  = belt speed, feet per minute\*  
 $G$  = arc of contact correction factor\*

$$T_1/T_2 = \frac{1}{1-0.8G} \quad (\text{Also } T_1/T_2 = e^{K\theta})$$

where:  $T_1$  = tight side tension, pounds  
 $T_2$  = slack side tension, pounds  
 $G$  = arc of contact correction factor\*  
 $e$  = base of natural logarithms  
 $K$  = .51230, a constant for V-belt drive design  
 $\theta$  = arc of contact in radians

$$T_1 = 41,250 \left( \frac{HP}{GV} \right)$$

where:  $T_1$  = tight side tension, pounds  
 HP = design horsepower  
 $V$  = "belt speed, feet per minute  
 $G$  = arc of contact correction factor

$$T_2 = 33,000 (1.25-G) \left( \frac{HP}{GV} \right)$$

where:  $T_2$  = slack side tension, pounds  
 HP = design horsepower  
 $V$  = belt speed, feet per minute  
 $G$  = arc of contact correction factor

### Belt Speed

$$V = \frac{(PD)(rpm)}{3.82} = (PD)(rpm) (.262)$$

where:  $V$  = belt speed, feet per minute  
 PD = pitch diameter of sheave or pulley  
 rpm = revolutions per minute of the same sheave or pulley

\* See Table 12 at left

**Table 12: Arc of Contact Correction Factors G and R**

$\frac{D-d}{C}$	Small Sheave Arc of Contact	Factor G	Factor R	$\frac{D-d}{C}$	Small Sheave Arc of Contact	Factor G	Factor R
.00	180°	1.00	1.000	.80	133°	.87	.917
.10	174°	.99	.999	.90	127°	.85	.893
.20	169°	.97	.995	1.00	120°	.82	.866
.30	163°	.96	.989	1.10	130°	.80	.835
.40	157°	.94	.980	1.20	106°	.77	.800
.50	151°	.93	.968	1.30	99°	.73	.760
.60	145°	.91	.954	1.40	91°	.70	.714
.70	139°	.89	.937	1.50	83°	.65	.661

D = Diam. of large sheave. d = Diam. of small sheave  
 C = Center distance

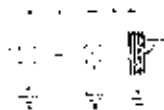
**Table 13: Allowable Sheave Rim Speed**

Sheave Material	Rim Speed in Feet per Minute
Cast Iron	6,500
Ductile Iron	8,000
Steel	10,000

**Note:** Above rim speed values are maximum for normal considerations. In some cases these values may be exceeded. Consult factory and include complete details of proposed application.

## Bearing Load Calculations

To find actual bearing loads it is necessary to know machine component weights and values of all other forces contributing to the load. Sometimes it becomes desirable to know the bearing load

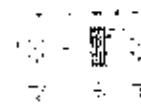


**Overhung Sheave**

$$\text{Load at B, lbs.} = \frac{\text{Shaft Load} \times (a + b)}{a}$$

$$\text{Load at A, lbs} = \text{Shaft Load} \times \frac{b}{a}$$

Where: a and b = Spacing, inches



**Sheave Between Bearings**

$$\text{Load at D, lbs.} = \frac{\text{Shaft Load} \times c}{c + d}$$

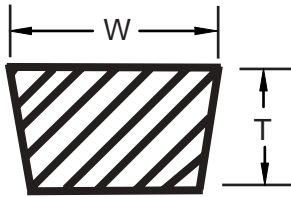
$$\text{Load at C, lbs} = \frac{\text{Shaft Load} \times d}{c + d}$$

Where: c and d = Spacing, inches

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## Nominal V-Belt Cross Sections

**Table 14: Nominal V-Belt Cross Sections**



Belt Section	Industry Standard Description	Width W, in Inches	Thickness T, in Inches
3L	FHP, Single	3/8	7/32
4L		1/2	5/16
5L		21/32	3/8
3V	Narrow	3/8	5/16
5V		5/8	17/32
8V		1	29/32
A	Classical Multiple	1/2	5/16
B		21/32	13/32
C		7/8	17/32
D		1-1/4	3/4

## Conveyor Belt FPM to RPM

Pulley Dia. Inches	FPM												
	100	150	200	250	300	350	400	500	600	700	800	900	1000
6	64	95	127	159	191	223	254	318	382	445	509	573	636
8	48	72	95	119	143	167	191	239	286	334	382	429	477
10	38	57	76	95	115	134	153	191	229	267	305	344	382
12	32	48	64	80	95	111	127	159	191	223	254	286	318
14	27	41	55	68	82	95	109	136	164	191	218	245	273
16	24	36	48	60	72	83	95	119	143	167	191	215	239
18	21	32	42	53	64	74	85	106	127	148	170	191	212
20	19	29	38	48	57	67	76	95	115	134	153	172	191
24	16	24	32	40	48	56	64	80	95	111	127	143	159
30	13	19	25	32	38	45	51	64	76	89	102	115	127
36	11	16	21	27	32	37	42	53	64	74	85	95	106
42	9	14	18	23	27	32	36	45	55	64	73	82	91
48	8	12	16	20	24	28	32	40	48	56	64	72	80
54	7	11	14	18	21	25	28	35	42	49	57	64	71
60	6	10	13	16	19	22	25	32	38	45	51	57	64

For values not shown use formula below:

$$SFM = .2618 \times D \times RPM$$

SFM = Surface feet Per Minute

D = Pulley Diameter, Inches

RPM = Revolutions per Minute

**Table 15: Material Characteristics**

MATERIAL	DENSITY (LB/FT <sup>3</sup> )	ANGLE OF REPOSE (DEG)	RECOM-MENDED MAXIMUM INCLINATION (DEG)	MATERIAL	DENSITY (LB/FT <sup>3</sup> )	ANGLE OF REPOSE (DEG)	RECOM-MENDED MAXIMUM INCLINATION (DEG)
Alfalfa, Ground	16	45°		Corn, Shelled	45	25°	10
Alum, Lumpy	50 - 60	35°		Corn Sugar	30	35°	
Alum, Pulverized	45 - 50	35°		Corn Grits	40 - 45	35°	
Alumina	60	30°	10-12	Cornmeal	32- 40	35°	22
Aluminum Oxide	70 - 120	30°		Cottonseed, Dry, De-Linted	35	35°	16
Ammonium Sulphate	45 - 60	45°		Cottonseed, Dry, Not De-Linted	18- 25	45°	19
Asbestos, Shredded	20 - 25	45°		Cottonseed, Cake, Lumpy	40- 45	35°	
Ashes, Dry	35 - 40	45°		Cottonseed, Hulls	12	45°	
Ashes, Wet	45 - 50	45°		Cottonseed, Meal	35- 40	35°	22
Ashes, Soft Coal	35 - 45	40°		Cottonseed, Meats	40	35°	
Asphalt, Crushed	45	35°		Cryolite	90-110	35°	
Bagasse	7.50	45°		Cullet	80-120	35°	20
Bakelite, Powder	30 - 40	45°		Diatomaceous Earth	11- 14	35°	
Baking Powder	40 - 50	35°		Dolomite, Lumpy	90-100	35°	22
Bark, Wood Refuse	10 - 20	45°	27	Dolomite, Pulverized	46	40°	
Barley	38	25°	10-15	Earth, Dry*	70- 80	35°	20
Basalt	80 - 120	25°		Earth, Moist	75-110	40°	23
Bauxite, Crushed	75 - 85	35°	20	Earth, Fullers Dry	30- 35	23°	20
Beans, Castor, Whole	30 - 45	25°	8-10	Emery	225	25°	
Beans, Cocoa	30 - 45	35°		Epsom Salt	40- 50	35°	
Beans, Navy	50	25°		Feldspar, Lumps	70-100	35°	17
Beans, Whole	45	45°		Feldspar, Dust	80-100	40°	
Bentonite, Crude	35 - 40	45°		Fish, Meal	35- 40	40°	
Bentonite, Fine	50 - 60	45°		Fish, Scrap	40- 50	0°	
Bones, Pulverized	50 - 60	45°		Flaxseed, Whole	45	25°	12
Borax, Fine	50 - 55	35°		Flaxseed, Meal	25	35°	
Borax Coarse	60 - 70	35°		Flour, Wheat	35- 40	45°	21
Bran	16	35°		Flue Dust, Dry	30- 40	20°	
Brewers Grain, Dry	25 - 35	45°		Fluorspar, Dust	85- 95	45°	
Brewers Grain, Wet	55 - 60	45°		Fluorspar, Lumps	80-110	45°	
Buck Wheat	40	25°	11-13	Foundry, Refuse	60- 80	35°	
Calcium, Carbide	70 - 80	35°		Foundry Sand, Loose	80- 90	35°	
Carbon Black, Pellets	25	25°		Foundry Sand, Rammed	100-110	0°	
Carbon Black, Powder	5	35°		Galena	250	35°	
Cast Iron Chips	100 -120	45°		Garbage, Average	30	25°	
Cement, Clinker	75 - 90	35°		Glass, Batch Fiber	45 - 55	10°	
Cement, Portland	80 -100	35°	20-23	Glass, Batch Wool	80-100	35°	20-22
Chalk, Fine	65 - 75	45°		Glass, Broken	80-100	10°	
Chalk, Lumpy	80 - 95	45°		Glue, Animal, Flaked	35	25°	
Charcoal, Wood	15 - 30	35°	20-25	Glue, Vegetable, Powdered	40	35°	
Chromium Ore	125 - 140	35°		Gluten, Meal	39	35°	
Cinders, Coal	40	35°	20	Granite, Lumps	150 -170	25°	
Clay, Dry, Fine	100 - 120	35°	20-22	Graphite, Flakes	40	35°	
Clay, Dry, Lumpy	60 - 75	35°	18-20	Graphite, Powder	30	25°	
Coal, Anthracite, Coarse	60 - 70	35°	18	Graphite, Ore	65 - 75	35°	
Coal, Anthracite, Loose	50 - 60	30°	16	Grass Seed	10	35°	
Coal, Bituminous, Coarse	50 - 60	35°	18	Gravel, Dry	90-100	35°	15-17
Coal, Bituminous, Loose	45 - 50	35°	16	Gravel, Wet	100-120	35°	
Cocoa Nibs	35 - 40	35°		Gypsum, Lumps	90-100	35°	15
Coconut, Shredded	20 - 25	45°		Gypsum, Ground	75- 80	35°	21
Coffee, Fresh Beans	30 - 40	35°	10-15	Hay, Loose	5	0°	
Coffee, Roasted Beans	22 - 30	25°		Hay, Pressed	25	0°	
Coke, Loose	23 - 32	35°	18	Hominy	35- 50	35°	
Coke Pulverized	25 - 35	45°	20-22	Hops, Spent, Dry	25- 35	45°	
Coke, Petroleum Calcinated	35 - 45	35°	20	Hops, Spent, Wet	55- 60	45°	
Concrete, Cinder	112	0°	12-30	Ice, Crushed	35- 40	20°	
Concrete, Gravel & Sand	150	0°		Ilmenite Ore	140-160	35°	
Copper Ore	120 - 150	35°	20	Iron Ore	120-180	35°	18-20
Copper Sulfate	75 - 85	30°	17	Iron Ore, Pellets	120-140	35°	13-15
Cork, Ground	5 - 15	45°		Iron Sulphate	50- 75	35°	
Corn, On Cob	45	0°		Iron Sulfide	120-140	35°	

Table 16: Material Characteristics

MATERIAL	DENSITY (LB/FT <sup>3</sup> )	ANGLE OF REPOSE (DEG)	RECOM-MENDED MAXIMUM INCLINATION (DEG)	MATERIAL	DENSITY (LB/FT <sup>3</sup> )	ANGLE OF REPOSE (DEG)	RECOM-MENDED MAXIMUM INCLINATION (DEG)
Kaolin, Clay	60	35°	19	Rubber, Pellets	50 - 55	35°	22
Lactose	30	35°		Rubber, Ground Scrap	25 - 35	45°	18
Lead Ore, Crushed	180 - 270	30°		Rye	42 - 45	25°	8
Lead Oxides	60 - 150	40°		Rye Meal	35 - 40	20°	
Lead Sulfate	170 - 190	45°		Salt Cake	80 - 95	30°	21
Lead Sulfide	240 - 260	35°		Salt, Coarse"	45 - 55	35°	18-22
Lignite, Air Dried	45 - 55	35°		Salt, Fine"	70 - 80	35°	11
Lime, Ground	60 - 65	40°	23	Sand, Wet	110 - 130	45°	20-22
Lime, Hydrated	40	40°	21	Sand, Dry	90 - 110	35°	16-18
Lime, Pebble	30 - 40	40°	17	Sand, Loose, Foundry	80 - 100	35°	22
Limestone, Loose	80 - 100	35°	20	Sand, Foundry, Rammed	100 - 110	0°	24
Limestone, Pulverized	85 - 90	45°	18	Sandstone	80 - 90	35°	
Linseed, Whole	45 - 50	25°		Sawdust	10 - 25	30°	22
Linseed, Meal	30 - 40	35°	20	Scale, Rolling Mill	125 - 160	45°	
Magnesium Chloride	30 - 35	40°		Sewage Sludge, Dry	45 - 55	35°	
Magnesium Sulfate	40 - 60	35°		Sewage Sludge, Wet	50 - 60	35°	
Malt, Dry	25 - 30	30°		Shale, Broken	90 - 100	25°	
Malt, Wet	60 - 65	45°		Shale, Crushed	85 - 90	40°	22
Malt, Meal	35 - 40	35°		Silica Gel, Dry	45	35°	
Manganese Ore	125 - 140	40°		Slag, Blast Furnace	80 - 90	25°	10
Manganese Oxide	120	35°		Slag, Granular, Dry	60 - 65	25°	13-16
Manganese Sulfate	70	35°		Slag, Granular, Wet	90 - 100	45°	20-22
Manure	25	0°		Slate, Ground	80 - 90	30°	15
Marble, Crushed	80 - 95	35°		Slate, Lumps	85 - 95	0°	
Marl	80	35°		Snow, Compacted	15 - 50	0°	
Mica, Flakes	20	20°		Soap	10 - 25	35°	
Mica, Ground	15	35°	23	Soda Ash, Briquettes	50	20°	7
Milk, Dried, Flaked	5	35°		Soda Ash, Heavy	55 - 65	30°	19
Milk, Malted	25 - 35	45°		Soda Ash, Light	20 - 35	35°	22
Milk, Powdered	20 - 30	40°		Sodium Aluminum, Ground	72	35°	
Milo Maize	55 - 60	35°		sodium Nitrate, Ground	70 - 80	24°	11
Molybdenum Ore	100 - 110	40°		Sodium Phosphate	50 - 65	35°	
Mortar, Wet	150	0°		soybeans, Cracked	30 - 40	35°	15-18
Niacin	35	35°		soybeans, Whole"	45 - 50	25°	12-16
Nickel-Cobalt Sulfate Ore	80 - 150	35°		starch, Powdered	25 - 45	25°	12
Oats	25 - 35	25°	10	steel, Chips	100 - 150	35°	18
Oats, Rolled	20	35°		steel, Turnings	60 - 120	45°	
Oil Cake	50	45°		sugar, Cane, Raw	55 - 65	45°	
Oxalic Acid Crystals	60	35°		sugar, Granulated, Dry	50 - 55	35°	
Oyster Shells, Ground	50 - 60	35°		sugar, Granulated, Wet	55 - 65	40°	
Oyster Shells, Whole	80	35°		Sugar Cane, Knifed	15 - 18	45°	
Paper Pulp Stock	40 - 60	20°		Sulphur, Lumps	80 - 85	35°	
Peanuts, Shelled	35 - 45	35°		Sulphur, Dust	50 - 70	35°	
Peanuts, Not Shelled	15 - 20	35°		Saonite, Pellets	120 - 140	35°	13-15
Peas, Dried	45 - 50	0°		Salc, Granulated	50 - 70	20°	
Phosphate, Fertilizer	50 - 60	35°	30	Titanium Dioxide	140	35°	
Phosphate, Rock, Crushed	60 - 100	35°	25	Titanium Sponge	60 - 70	45°	
Potash	70 - 80	30°		Tobacco, Leaves	14	45°	
Potassium Chloride	120 - 130	35°		Tobacco, Scraps	15 - 25	45°	
Potassium Nitrate	75 - 80	25°		Tobacco, Stems	15	45°	
Potassium Sulfate	45	45°		Traprock, Crushed	95 - 110	35°	
Potatoes, White"	48	0°		Traprock, Lumps	100 - 110	35°	
Pumice, Ground	40 - 45	45°		Turf	20 - 30	0°	
Pyrites, Lumps	135 - 145	25°		Walnut, Shells	35 - 45	35°	
Pyrites, Pellets	120 - 130	35°		Wheat	48	25°	12
Quartz, Lumps	95 - 100	25°		Wheat, Cracked	40 - 45	35°	
Quartz, Sand	70 - 80	25°		Wheat Germ, Dry	20 - 30	25°	27
Rice, Hulled	45 - 50	20°	8	Wood Chips	10 - 30	45°	22
Rice, Rough	35	35°		Zinc Ore, Granular	160	35°	
Rice, Grits	40 - 45	35°		Zinc Oxide	10 - 35	45°	
Rock, Crushed	100 - 150	30°					

## Shafting

**Table 17: Typical Commercial Shaft Tolerances**

Shaft Size	Plus	Minus
Up to 1-1/2"	.000	.002
Over 1-1/2 to 2-1/2"	.000	.003
Over 2-1/2 to 4"	.000	.004
Over 4 to 6"	.000	.005
Over 6 to 8"	.000	.006
Over 8 to 9"	.000	.007
Over 9"	.000	.008

**Table 18: Shaft Tolerances**

Shaft Size	Tolerance, Inches
Up to 1-1/2"	+ .0000 - .0005"
1-5/8 to 4"	+ .000 - .001"
4-7/16 to 6"	+ .000 - .0015"
6-7/16 to 8"	+ .000 - .002"

Table 18 lists the recommended tolerances for all set-screw locking, eccentric locking and D-LOK locking ball and roller bearings

**Table 19: Shaft Tolerances**

Shaft Size	Tolerance, Inches
Up to 1-1/2"	+ .000 - .002"
1-9/16 to 2-1/2"	+ .000 - .003"
2-5/8 to 4"	+ .000 - .004"
4-3/16 to 6"	+ .000 - .005"
6-7/16" and above	+ .000 - .006"

Table 19 list the recommended tolerances for all tapered adapter sleeve ball and roller bearings

## Selection of Shaft Diameters

Table 20 thru Table 23 inclusive can be used to find approximate shaft diameter for various service conditions For greater accuracy use chart under heading "Combined Torsion and Bending of Standard Shafts" (G6-19).

Tables and chart are based upon a safe shear stress of 6,000 pounds per square inch for standard keyseated shafting. Be generous in the selection of shaft diameters as

**Standard Shafting**-Table 17 indicates standard shafting is cold drawn in the smaller sizes and turned and polished in the larger diameters. It has a smooth surface, is commercially straight and is readily machinable; suitable and recommended for general power transmission and material handling service.

**Special Shafting**-While standard shafting is suitable for most installations, special shafting is sometimes required for certain chemical, temperature or physical requirements. Such materials as high carbon steel, alloy steel, stainless steel, brass, Monel metal, etc., can be furnished plain or heat treated. Stepped, flanged, hollow or other special forms are available.

Special shafting should be avoided in favor of standard shafting wherever possible because special shafting is usually considerably more expensive and requires a greater length of time to obtain, which is an especially important consideration should quick replacement ever become necessary.

**Ordering Shafting**-Standard shafting can be obtained from most supply houses and dealers who handle power transmission material.

**Turning Down Shaft Ends**-When necessary to turn down shaft ends, use as large a fillet as possible to keep the stress concentration to a minimum. The radius of this fillet should preferably be not less than the difference in the two diameters joined by the fillet. The fillet should be finished and polished as smoothly as possible to avoid scratches which might start cracks and failure of the shaft by fatigue.

liberal diameters not only reduce deflection and vibration but also generally increase bearing life.

When necessary to use other than standard shafting, find the required diameter for standard shafting as outlined above and multiply by proper factor shown in Table 24 , under heading "Factors for Shafting Other than Standard Shafting."(G6-18).

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## Selection of Shaft Diameters (Cont'd)

**Table 20: No Bending Moment** (Shafts without pulleys, sprockets or gears - Torsion only)

Shaft Size	Horse Power at Various Revolutions per Minute																		
	25	50	75	100	125	150	175	200	225	250	275	300	350	400	500	600	700	800	900
15/16	0.30	0.70	1.10	1.50	1.90	2.30	2.60	3	3.40	3.80	4.20	4.60	5.30	6.10	7.70	9.20	10.70	12.30	13.80
1-3/16	0.70	1.50	2.30	3.10	3.90	4.60	5.40	6.20	7	7.80	8.60	9.30	10.90	12.50	15.60	18.70	21.90	25	28.10
1-7/16	1.30	2.70	4.10	5.50	6.90	8.30	9.70	11.10	12.40	13.80	15.20	16.60	19.40	22.20	27.70	33.30	38.80	44.40	49.90
1-11/16	2.20	4.40	6.60	8.90	11.20	13.40	15.70	17.90	20.20	22.40	24.70	26.90	31.40	35.90	44.90	53.80	62.80	71.80	80.80
1-15/16	3.30	6.70	10.10	13.50	16.90	20.30	23.70	27.10	30.50	33.90	37.30	40.70	47.50	54.30	67.90	81.50	95.10	108	122
2-3/16	4.90	9.80	14.60	19.50	24.40	29.30	34.20	39.10	44	48.90	53.80	58.60	68.40	78.20	97.80	117	136	156	176
2-7/16	6.70	13.50	20.20	27	33.80	40.60	47.30	54.10	60.90	67.60	74.40	81.20	94.70	108	135	162	189	216	243
2-11/16	9	18.10	27.10	36.20	45.30	54.40	63.40	72.50	81.60	90.70	99.70	108	126	145	181	217	253	290	326
2-15/16	11.80	23.60	35.40	47.30	59.20	71	82.90	94.70	106	118	130	142	165	189	236	284	331	379	426
3-7/16	19	37.90	57	75.90	94.90	113	132	151	170	189	208	227	265	303	379	455	531	607	683
3-15/16	28.50	57	85.50	114	142	171	199	228	256	285	313	342	399	456	570	684	798	912	1026
4-7/16	40.80	81.60	122	163	204	245	286	327	367	408	449	490	572	653	816	980	1143	1306	1470

**Table 21: Limited Bending Moment** (Pulleys, sprockets or gears near bearings. Ordinary line shafts.)

Shaft Size	Horse Power at Various Revolutions per Minute																		
	25	50	75	100	125	150	175	200	225	250	275	300	350	400	500	600	700	800	900
15/16	0.20	0.50	0.70	1	1.20	1.50	1.70	2	2.30	2.50	2.80	3	3.50	4.10	5.10	6.10	7.10	8.20	9.20
1-3/16	0.50	1	1.50	2	2.60	3.10	3.60	4.10	4.70	5.20	5.70	6.20	7.30	8.30	10.40	12.50	14.60	16.70	18.80
1-7/16	0.90	1.80	2.70	3.70	4.60	5.50	6.40	7.40	8.30	9.20	10.10	11.10	12.90	14.80	18.50	22.20	25.90	29.60	33.30
1-11/16	1.40	2.90	4.30	5.90	7.40	8.90	10.40	11.90	13.40	14.90	16.40	17.90	20.90	23.90	29.90	35.90	41.90	47.90	53.90
1-15/16	2.20	4.50	6.70	9	11.30	13.60	15.80	18.10	20.40	22.60	24.90	27.20	31.70	36.20	45.30	54.40	63.40	72.50	81.60
2-3/16	3.20	6.50	9.70	13	16.30	19.50	22.80	26.10	29.30	32.60	35.80	39.10	45.60	52.20	65.20	78.30	91.30	104	117
2-7/16	4.50	9	13.50	18	22.50	27	31.60	36.10	40.60	45.10	49.60	54.10	63.20	72.20	90.20	108	126	144	162
2-11/16	6	12.10	18.10	24.20	30.20	36.30	42.30	48.40	54.40	60.50	66.50	72.60	84.70	96.80	121	145	169	193	217
2-15/16	7.90	15.80	23.70	31.60	39.50	47.40	55.30	63.20	71.10	79	86.90	94.80	110	126	158	189	221	252	284
3-7/16	12.60	25.30	37.90	50.60	63.30	75.90	88.60	101	113	126	139	151	177	202	253	303	354	405	455
3-15/16	19	38	57	76.10	94.10	114	133	152	171	190	209	228	266	304	380	456	532	608	685
4-7/16	27	54	81	108	136	163	190	217	245	272	299	326	381	435	544	653	762	871	980
4-15/16	37	75	112	150	187	225	262	300	337	375	412	450	525	600	750	900	1050	1200	1350
5-7/16	50	100	150	200	250	300	350	400	451	501	551	601	701	801	1002	1202	1403	1603	1804
5-15/16	65	130	195	261	326	391	456	522	587	652	717	783	913	1044	1305	1566	1827	2088	2349
6-1/2	85	171	256	342	427	513	598	684	769	855	940	1026	1197	1368	1710	2052	2394	2736	3078

## Selection of Shaft Diameters (Cont'd)

**Table 22: Heavy Bending Moment.** (Use for main or important shafts.)

Shaft Size	Horse Power at Various Revolutions per Minute																		
	25	50	75	100	125	150	175	200	225	250	275	300	350	400	500	600	700	800	900
1-11/16	0.80	1.70	2.50	3.50	4.40	5.30	6.20	7.10	8	8.90	9.80	10.70	12.50	14.30	17.90	21.50	25.10	28.70	32.30
1-15/16	1.30	2.70	4	5.40	6.70	8.10	9.50	10.80	12.20	13.50	14.90	16.30	19	21.70	27.10	32.60	38	43.50	48.90
2-3/16	1.90	3.90	5.80	7.80	9.70	11.70	13.70	15.60	17.60	19.50	21.50	23.40	27.40	31.30	39.10	46.90	54.80	62.60	70.40
2-7/16	2.70	5.40	8.10	10.80	13.50	16.20	18.90	21.60	24.30	27	29.70	32.40	37.90	43.30	54.10	64.90	75.80	86.60	97.40
2-11/16	3.60	7.20	10.80	14.50	18.10	21.70	25.40	29	32.60	36.20	39.90	43.50	50.80	58	72.50	87.10	101	116	130
2-15/16	4.70	9.40	14.10	18.90	23.60	28.40	33.10	37.90	42.60	47.30	52.10	56.80	66.30	75.80	94.70	113	132	151	170
3-7/16	7.50	15.10	22.60	30.30	37.90	45.50	53.10	60.70	68.30	75.90	83.50	91.10	106	121	151	182	212	243	273
3-15/16	11.40	22.80	34.20	45.60	57	68.40	79.90	91.30	102	114	125	136	159	182	228	273	319	365	410
4-7/16	16.30	32.60	48.90	65.30	81.60	98	114	130	147	163	179	196	228	261	326	392	457	522	588
4-15/16	22.50	45	67.50	90	112	135	157	180	202	225	247	270	315	360	450	540	630	720	810
5-7/16	30	60	90	120	150	180	210	240	270	300	330	360	420	480	601	721	841	961	1082
5-15/16	39	78	117	156	195	234	273	313	352	391	430	469	547	626	782	939	1095	1252	1409
6-1/2	51	102	153	205	256	308	359	410	462	513	564	616	718	821	1027	1232	1437	1643	1848
7	64	128	192	256	320	384	448	513	577	641	705	769	897	1026	1282	1539	1795	2052	2308
7-1/2	78.50	157	235	315	394	473	552	631	709	788	867	946	1104	1262	1577	1893	2208	2524	2839
8	95.50	191	286	382	478	574	670	765	861	957	1053	1148	1340	1531	1914	2297	2680	3063	3446
8-1/2	114	229	343	459	574	688	803	918	1033	1148	1263	1377	1607	1837	2296	2755	3215	3674	4133
9	136	272	408	545	681	817	954	1090	1226	1363	1499	1635	1908	2181	2726	3271	3816	4362	4907
9-1/2	160	320	480	641	801	961	1122	1282	1442	1603	1763	1923	2244	2565	3206	3847	4488	5130	5771
10	186	373	559	747	934	1121	1308	1495	1682	1869	2056	2243	2617	2991	3739	4487	5235	5983	6731

**Table 23: Severe Conditions** (Heavy shock loads. Excessively tight belts. long clutch sleeves.)

Shaft Size	Horse Power at Various Revolutions per Minute																		
	25	50	75	100	125	150	175	200	225	250	275	300	350	400	500	600	700	800	900
1-11/16	0.4	0.8	1.2	1.7	2.2	2.6	3.1	3.5	4	4.4	4.9	5.3	6.2	7.1	8.9	10.7	12.5	14.3	16.10
1-15/16	0.6	1.3	2	2.7	3.3	4	4.7	5.4	6.1	6.7	7.4	8.1	9.5	10.8	13.5	16.3	19	21.7	24.40
2-3/16	0.90	1.90	2.90	3.90	4.80	5.80	6.80	7.80	8.80	9.70	10.70	11.70	13.70	15.60	19.50	23.40	27.40	31.30	35.20
2-7/16	1.30	2.70	4	5.40	6.70	8.10	9.40	10.80	12.10	13.50	14.80	16.20	18.90	21.60	27	32.40	37.90	43.30	48.70
2-11/16	1.80	3.60	5.40	7.20	9	10.80	12.70	14.50	16.30	18.10	19.90	21.70	25.40	29	36.20	43.50	50.50	58	65
2-15/16	2.30	4.70	7	9.40	11.80	14.20	16.50	18.90	21.30	23.60	26	28.40	33.10	37.90	47.30	56.50	66	75.50	85
3-7/16	3.70	7.50	11.30	15.1	18.90	22.70	26.50	30.30	34.10	37.90	41.70	45.50	53	60.50	75.50	91	106	121	136
3-15/16	5.70	11.40	17.10	22.8	28.50	34.20	39.90	45.60	51	57	62.50	68	79.50	91	114	136	159	182	205
4-7/16	8.10	16.30	24.40	32.6	40.80	49	57	65	73.50	81.50	89.50	98	114	130	163	196	228	261	294
4-15/16	11.20	22.50	33.70	45	56	67.50	78.50	90	101	112	123	135	157	180	225	270	315	360	405
5-7/16	15	30	45	60	75	90	105	120	135	150	165	180	210	240	300	360	420	480	541
5-15/16	19.50	39	58.50	78	97.10	117	136	156	171	195	215	234	273	313	391	469	547	626	704
6-1/2	25.50	51	76.50	102.5	128	154	179	205	231	256	282	308	359	410	513	616	718	821	924
7	32	64.90	96	128	160	192	224	256	288	320	352	384	448	513	641	769	897	1026	1154
7-1/2	39.20	78.50	117	157	197	236	276	315	354	394	433	473	552	631	788	946	1104	1262	1419
8	47.70	95.50	143	191	239	287	335	382	430	478	526	574	670	765	957	1148	1340	1531	1723
8-1/2	57	114	171	229	287	344	401	459	516	574	631	688	803	918	1148	1377	1607	1837	2066
9	68	136	204	272	340	408	477	545	613	681	749	817	954	1090	1363	1635	1908	2181	2453
9-1/2	80	160	240	320	400	480	561	641	721	801	881	961	1122	1282	1603	1923	2244	2565	2885
10	93	186	279	373	467	560	654	747	841	934	1028	1121	1308	1495	1869	2243	2617	2991	3365

**Caution** - Be generous in the selection of shaft diameters as liberal diameters not only reduce deflection and vibration but also generally increase bearing life. See notes on next page.

## Selection of Shaft Diameters (Cont'd)

**Shaft Stiffness, Shaft Deflection**-Standard shafting of adequate strength usually has a sufficiently large diameter to prevent excessive deflection in ordinary installations. It is wise to select shafting of generous diameter, as the greater the diameter, the greater the stiffness. A high tensile strength alloy shaft, although stronger, is no stiffer than a standard shaft of the same diameter.

While it is sometimes possible to use an alloy shaft of less diameter than a standard shaft of equal strength, this practice is usually inadvisable, as the deflection is increased.

Shafts carrying medium or long clutch sleeves should be especially generous.

**High Speed Shafts**-High speed sometimes causes shaft whipping or vibration. Making the shaft diameter generous and the distance between bearing centers short usually prevents this trouble.

Location of the bearings close to wheels and couplings is advisable whether the shaft is transmitting heavy or light loads.

The use of high tensile strength alloy shafting instead of standard shafting is of no help in preventing vibration as this will not improve the stiffness and deflection characteristics of the shaft.

**Stepped Shafts**- For a heavily loaded wheel, a shaft with a boss or enlarged section under the wheel and turned to a smaller diameter at the bearings often provides the most economical installation. The two different diameters should be joined by a very generous fillet, as otherwise a

dangerous concentration of stress will occur at the fillet. See heading-"Turning Down Shaft Ends." (G6-15).

**Shaft Keyseats**-Plain keyseats are preferable to round end keyseats in respect to causing the least concentration of stress. However, round end keyseats are often used because of design and assembly requirements. Ends left by the milling cutter should not project into babbitted or bronze bushed bearing, but may project under the sleeve of any Dodge anti-friction bearings.

Shaft diameters obtained from the tables or chart allow for the use of keyseats.

**Shaft Bearings**-On ordinary line shafting, bearings are commonly spaced about eight feet centers. On large diameter shafts, the spacing may be somewhat greater.

Wheels and clutches should be located near bearings to avoid dangerous bending, deflection and vibration.

Bearings should be mounted on adequate supports so that accurate alignment may be maintained. Shafting misalignment may cause shaft or bearing failure.

**Shaft Couplings**-Where a rigid coupling is used, it is preferable to have a bearing fairly close. Where a cutoff coupling or a flexible coupling is used, locate bearings close to each end of the coupling.

**Expansion of Shafting**-Where changes in the length of the shaft due to changes in temperature are to be expected and the bearings are mounted on supporting structures other than steel, consideration must be given to expansion. For more detailed information see G6-20, headed: "Expansion of Shafting."

### Factors for Shafting Other Than Standard Shafting

When it is necessary to use other than standard shafting, multiply required diameter for standard shafting as found in the tables or chart by proper factor from Table 24 below.

Standard keyseated shafting, using a safe shear stress of 6,000 PSI is the basis of shafting tables and chart. For safe shear stress of other materials, use 1/10 of nominal ultimate tensile strength. For example, use 8,000 for C1045 and 10,000 for 4140 keyseated shafting. When definite physical specifications are known the least of 13.5% of minimum ultimate tensile strength and 22.5% of minimum

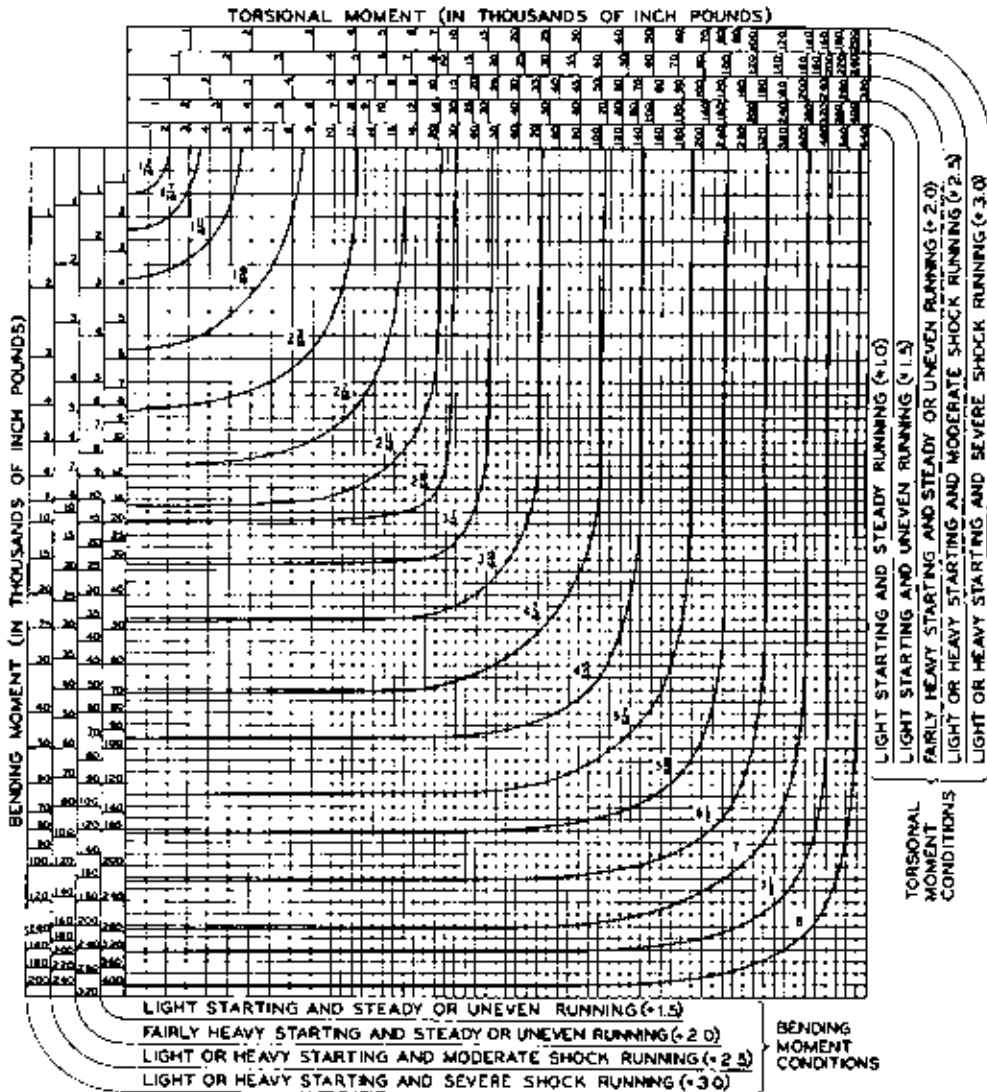
elastic limit in tension may be used for keyseated shafting; 18% and 30% respectively if not keyseated.

**Caution**-As the deflection of steel shafting depends upon the diameter and not upon the analysis of the steel, care should be exercised in the use of alloy shafting not to reduce the diameter unduly. Deflection should not be excessive and bearing capacities should be adequate. It is usually best to use standard shafting instead of a smaller diameter alloy shaft. The smaller alloy shaft may safely transmit the torque but often is undesirable in respect to deflection, vibration and bearing life.

**Table 24: Shear Stress Factors**

Safe Shear Stress	Factor	Safe Shear Stress	Factor	Safe Shear Stress	Factor	Safe Shear Stress	Factor	Safe Shear Stress	Factor
500	2.289	3,000	1.260	5,500	1.029	9,000	.874	14,000	.754
1,000	1.817	3,500	1.197	6,000	1.000	10,000	.843	15,000	.737
1,500	1.587	4,000	1.145	6,500	.974	11,000	.817	16,000	.721
2,000	1.442	4,500	1.101	7,000	.950	12,000	.794	17,000	.707
2,500	1.339	5,000	1.063	8,000	.909	13,000	.773	18,000	.693

## Combined Torsion and Bending of Standard Shafts (Based on a Safe Shear Stress of 6,000 PS for Keyseated Shafting)



**Example:** Engine extension shaft driving single cylinder compressor, 15,000 pound-inches torsional moment, 14,000 pound-inches bending moment. Because of the heavy shock running load conditions use scales designated "Light or Heavy Starting and Severe Shock Running". Project a line down from 15,000 torsional moment. Project a line to the right from 14,000 bending

moment. The two lines intersect between 3-7/16 and 3-15/16 curves. Use 3-15/16 standard shafting.

**Note:** The above chart is based on ASME approved standard ASA-B17C-1927 withdrawn in 1954. If the latest shaft selection analysis is required refer to ANSI/ASME B106.1M-1985.

**Note:** If considering use of other shafting material refer to "Selection of Shaft Diameters" on page G6-18.

## Expansion of Shafting

Provision should be made to permit the free movement of shafting endwise due to temperature changes. One bearing should serve as an anchor bearing to locate the shaft endwise. All other bearings should permit the shaft to move freely endwise.

The anchor bearing is often located near an important wheel. On long shafts it should preferably be located near the center of the shaft to keep the expansion of the two ends to a minimum. If the anchor bearing is babbitted it should be fitted with collars. If it is an anti-friction bearing it should be of the non-expansion type, which is the designation of Dodge roller and ball bearings for use as anchor bearings.

All bearings on the shafting other than the anchor bearing should permit the shaft to move freely endwise. If babbitted there should be no thrust collars. If anti-friction these bearings should be of the expansion type.

Several shafts firmly fastened together expand as if one continuous shaft. An example of this is line shafting with flange couplings. If the expansion is considered excessive a long line shaft may be split into two or more sections, the sections being connected with expansion couplings.

### Amount of Expansion to be provided for-

The amount of shafting expansion is given in Table 25 below. For example, with a 1005 temperature rise on a 150 ft. line shaft with the anchor bearing located 70 ft. from one end and 80 ft. from the other end the ends will move .529" and .605" respectively away from the anchor bearing. The

structure supporting the bearings may also expand but usually not as rapidly and as much as does the shafting. Several cases follow:

Case 1-Bearings supported on steel structures, where the shaft and structure are exposed to the same temperatures, will expand at the same rate. Expansion allowance is usually not required. If the shaft is exposed to a higher temperature than the support, allowances should be made. For example, if the shaft temperature is expected to change 80°, and the temperature of the structure 60°, the resulting movement between shafting and support ends will be equivalent to a 20° change.

Case 2-For bearings supported on wood, brick, or concrete walls, or on piers with foundations in the ground, the amount of expansion is usually considered negligible. Therefore, the full amount of shafting expansion as calculated in Table 25 below, may be accommodated.

Case 3-Certain structural designs have built-in flexibility. Where this is the case, expansion type bearings are not necessary.

Case 4-Short shafts with only two bearings are usually designed without compensation for expansion, if temperature variations are not excessive.

### Advice on Expansion Problems-

Dodge power transmission engineers will gladly make recommendations concerning shafting expansion problems and the use of suitable bearings.

**Table 25: Linear Expansion of Steel Shafting**

Base on Expansion In Inches = 0.0000063 x 12 x Length in Feet x Temp. Increase in Degrees Fahrenheit

Length (Feet)	Temperature Increase-Degrees F.					Length (Feet)	Temperature Increase-Degrees F.				
	20°	40°	60°	80°	100°		20°	40°	60°	80°	100°
1	.0015	.0030	.0045	.0060	.0075	40	.060	.121	.181	.242	.302
2	.0030	.0060	.0091	.0121	.0151	45	.068	.136	.204	.272	.340
3	.0045	.0091	.0136	.0181	.0227	50	.076	.151	.227	.302	.378
4	.0060	.0121	.0181	.0242	.0302	55	.083	.166	.249	.333	.416
5	.0076	.0151	.0227	.0302	.0378	60	.091	.181	.272	.363	.454
6	.0091	.0181	.0272	.0363	.0454	65	.098	.197	.295	.393	.491
7	.0106	.0212	.0318	.0423	.0529	70	.106	.212	.317	.423	.529
8	.0121	.0242	.0363	.0484	.0605	75	.113	.227	.340	.454	.567
9	.0136	.0272	.0408	.0544	.0680	80	.121	.242	.363	.484	.605
10	.0151	.0302	.0454	.0605	.0756	85	.129	.257	.386	.514	.643
12	.0181	.0363	.0544	.0726	.0907	90	.136	.272	.408	.544	.680
14	.0212	.0423	.0635	.0847	.1058	95	.144	.287	.431	.575	.718
16	.024	.048	.073	.097	.121	100	.151	.302	.454	.605	.756
18	.027	.054	.082	.109	.136	110	.166	.333	.499	.665	.832
20	.030	.060	.091	.121	.151	120	.181	.363	.544	.726	.907
25	.038	.076	.113	.151	.189	130	.197	.393	.590	.786	.983
30	.045	.091	.136	.181	.227	140	.212	.423	.635	.847	1.058
35	.053	.106	.158	.212	.265	150	.227	.454	.680	.907	1.134

## Weights and Properties of Steel Shafting

**Table 26: Weight of Round Steel Shafting**

Shaft Size	Weight of Shafting for Various Lengths in feet																Weight Per Inc.	
	1	2	3	4	5	6	7	8	9	10	12	14	16	18	20	22		24
3/4	1.5	3.0	4.5	6.0	7.5	9.0	10.5	12.0	13.5	15	18	21	24	27	30	33	36	.125
7/8	2.0	4.0	6.1	8.1	10.2	12.2	14.3	16.3	18.4	20	25	29	33	37	41	45	49	.170
*15/16	2.3	4.7	7.0	9.4	11.7	14.1	16.5	18.8	21.2	23	28	33	38	42	47	52	56	.195
1	2.7	5.3	8.0	10.6	13.3	16.0	18.6	21.3	24.0	27	32	37	43	48	53	59	64	.223
1-1/8	3.4	6.8	10.0	13.4	16.7	20.1	23.4	26.7	30.1	34	41	47	54	61	68	74	81	.281
*1-3/16	3.8	7.6	11.3	15.1	18.9	22.6	26.4	30.1	34.0	38	45	53	60	68	75	83	90	.314
1-1/4	4.2	8.3	12.5	16.7	20.8	25.0	29.2	33.3	37.5	42	50	58	67	75	83	92	100	.348
1-3/8	5.0	10.1	15.3	20.2	25.3	30.3	35.4	40.4	45.4	50	60	71	81	91	101	111	121	.420
*1-7/16	5.5	11	17	22	28	33	39	44	50	55	66	77	88	99	110	121	133	.460
1-1/2	6.0	12	18	24	30	36	42	48	54	60	72	84	96	108	120	132	144	.500
*1-11/16	7.6	15	23	30	38	46	53	61	68	76	91	107	122	137	152	167	183	.634
*1-15/16	10.0	20	30	40	50	60	70	80	90	100	120	140	161	181	201	221	241	.835
2	10.7	21	32	43	53	64	75	85	96	107	128	150	171	192	214	235	256	.890
*2-3/16	12.8	26	38	51	64	77	90	102	115	128	153	179	205	230	256	281	307	1.06
*2-7/16	15.9	32	48	63	79	95	111	127	143	159	190	222	254	286	317	349	381	1.32
2-1/2	16.7	34	50	67	83	100	117	134	150	167	200	234	267	301	334	367	401	1.39
*2-11/16	19.3	39	58	77	97	116	135	154	174	193	232	270	309	348	386	425	463	1.61
*2-15/16	23.0	46	69	92	115	138	161	184	208	231	277	323	369	415	461	507	553	1.92
*3-7/16	31.6	63	95	126	158	189	221	253	284	316	379	442	505	568	631	695	758	2.63
*3-15/16	41.4	83	124	166	207	248	290	331	373	414	497	580	662	745	828	911	994	3.45
*4-7/16	52.6	105	158	210	263	315	368	421	473	526	631	736	841	946	1052	1157	1262	4.38
*4-15/16	65.1	130	195	260	326	391	456	521	586	651	781	911	1041	1172	1302	1432	1562	5.42
*5-7/16	79.0	158	237	316	395	474	553	632	711	790	947	1105	1263	1421	1579	1737	1894	6.58
*6	96	192	288	384	481	577	673	769	865	961	1154	1346	1538	1730	1923	2115	2307	8.01

\* Recommended Diameters These shaft diameters are recommended for use whenever possible as various transmission items such as couplings, collars, clutches, pulleys, etc., are carried in stock in these sizes, at least up to 3-15/16", in the principal cities throughout the United States.

**Table 27: Weight and Properties of Round Steel Shafting**

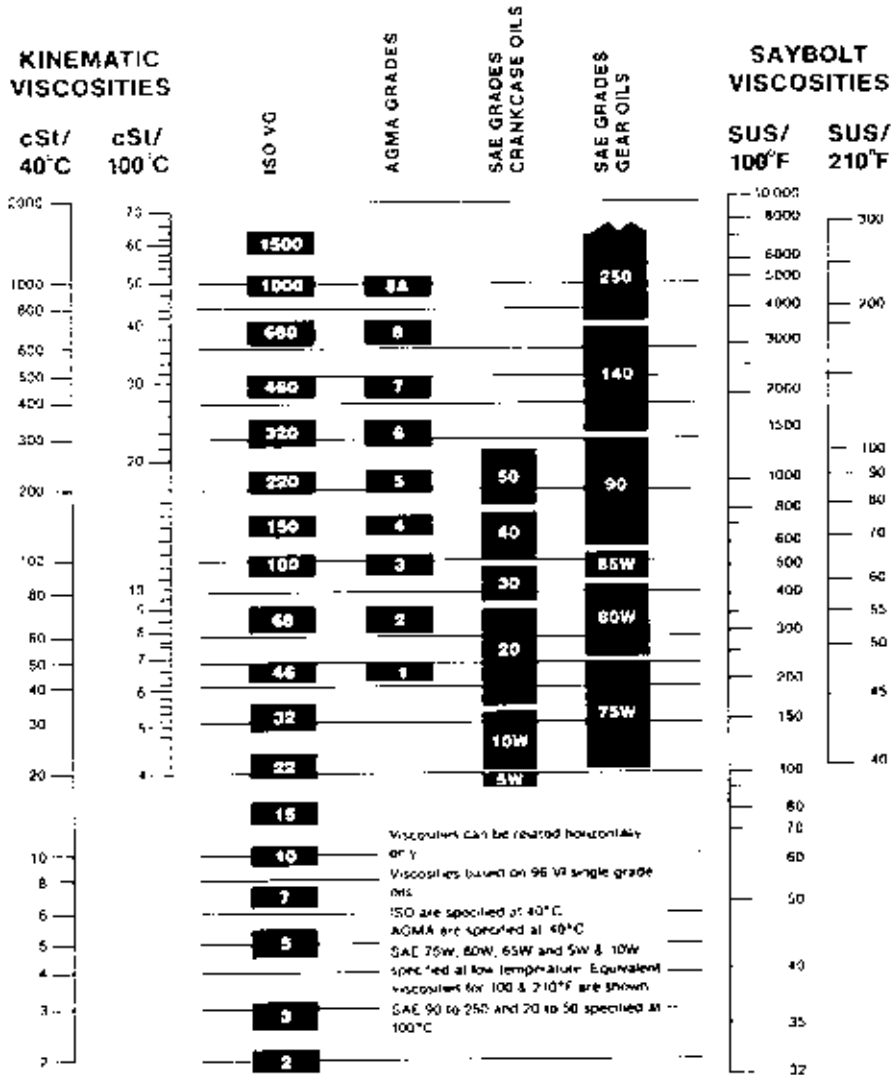
Shaft Size	Weight per Inch	Section Modulus		Moment of Inertia		Shaft Size	Weight per Inch	Section Modulus		Moment of Inertia	
		Bending	Torsion	Bending	Torsion			Bending	Torsion	Bending	Torsion
1/16	.00087	.000024	.000048	.000001	.000002	2-7/16	1.32	1.422	2.844	1.733	3.466
1/8	.0035	.000192	.000383	.000012	.000024	2-1/2	1.39	1.534	3.068	1.918	3.835
3/16	.0078	.000647	.001294	.000061	.000121	2-9/16	1.46	1.652	3.304	2.117	4.233
1/4	.0139	.001534	.003068	.000192	.000383	2-5/8	1.53	1.776	3.552	2.331	4.661
5/16	.0217	.002966	.005932	.000468	.000936	2-11/16	1.61	1.906	3.811	2.561	5.122
3/8	.0313	.005177	.010354	.000971	.001941	2-3/4	1.68	2.042	4.084	2.807	5.615
7/16	.0425	.008221	.016442	.001798	.003597	2-13/16	1.76	2.184	4.368	3.071	6.143
1/2	.0556	.0123	.0245	.0031	.0061	2-7/8	1.84	2.333	4.666	3.354	6.707
9/16	.0703	.0175	.0349	.0049	.0098	2-15/16	1.92	2.489	4.977	3.655	7.310
5/8	.0868	.0240	.0479	.0075	.0150	3	2.00	2.651	5.301	3.976	7.952
11/16	.1051	.0319	.0638	.0110	.0219	3-1/16	2.08	2.820	5.640	4.318	8.636
3/4	.125	.0414	.0828	.0155	.0311	3-1/8	2.17	2.996	5.992	4.681	9.363
13/16	.1467	.0527	.1053	.0214	.0428	3-3/16	2.26	3.179	6.359	5.067	10.13
7/8	.1701	.0658	.1315	.0288	.0575	3-1/4	2.35	3.370	6.740	5.477	10.95
15/16	.1954	.0809	.1618	.0379	.0758	3-5/16	2.44	3.568	7.137	5.910	11.82
1	.22	.0982	.1963	.0491	.0982	3-3/8	2.53	3.774	7.548	6.369	12.74
1-1/16	.25	.1178	.2355	.0626	.1251	3-7/16	2.63	3.988	7.976	6.854	13.71
1-1/8	.28	.1398	.2796	.0786	.1573	3-1/2	2.72	4.209	8.419	7.366	14.73
1-3/16	.31	.1644	.3288	.0976	.1952	3-9/16	2.82	4.439	8.878	7.907	15.81
1-1/4	.35	.1917	.3835	.1198	.2397	3-5/8	2.92	4.677	9.353	8.476	16.95
1-5/16	.38	.2220	.4439	.1457	.2913	3-11/16	3.02	4.923	9.845	9.076	18.15
1-3/8	.42	.2552	.5104	.1755	.3509	3-3/4	3.13	5.177	10.35	9.707	19.41
1-7/16	.46	.2916	.5832	.2096	.4192	3-13/16	3.23	5.440	10.88	10.37	20.74
1-1/2	.50	.3313	.6627	.2485	.4970	3-7/8	3.34	5.712	11.42	11.07	22.14
1-9/16	.54	.3745	.7490	.2926	.5852	3-15/16	3.45	5.993	11.99	11.80	23.60
1-5/8	.59	.4213	.8425	.3423	.6846	4	3.56	6.283	12.57	12.57	25.13
1-11/16	.63	.4718	.9435	.3981	.7961	4-1/16	3.67	6.582	13.16	13.16	26.74
1-3/4	.68	.5262	1.052	.4604	.9208	4-1/8	3.78	6.891	13.78	14.21	28.42
1-13/16	.73	.5846	1.169	.5298	1.060	4-3/16	3.90	7.209	14.42	15.09	30.19
1-7/8	.78	.6471	1.294	.6067	1.213	4-1/4	4.01	7.536	15.07	16.01	32.03
1-15/16	.83	.7140	1.428	.6917	1.384	4-5/16	4.13	7.874	15.75	16.98	33.96
2	.89	.7854	1.571	.7854	1.571	4-3/8	4.25	8.221	16.44	17.98	35.97
2-1/16	.94	.8614	1.723	.8883	1.777	4-7/16	4.38	8.579	17.16	19.03	38.07
2-1/8	1.00	.9421	1.884	1.001	2.002	4-1/2	4.50	8.946	17.89	20.13	40.26
2-3/16	1.06	1.028	2.055	1.124	2.248	4-9/16	4.63	9.324	18.65	21.27	42.54
2-1/4	1.13	1.118	2.237	1.258	2.516	4-5/8	4.75	9.713	19.43	22.46	44.92
2-5/16	1.19	1.214	2.428	1.404	2.808	4-11/16	4.88	10.11	20.22	23.70	47.40
2-3/8	1.25	1.315	2.630	1.562	3.124	4-3/4	5.01	10.52	21.04	24.99	49.98



**Table 27: Weight and Properties of Round Steel Shafting**

Shaft Size	Weight per Inch	Section Modulus		Moment of Inertia		Shaft Size	Weight per Inch	Section Modulus		Moment of Inertia	
		Bending	Torsion	Bending	Torsion			Bending	Torsion	Bending	Torsion
4-13/16	5.15	10.94	21.88	26.33	52.66	13-1/2	40.50	241.50	483.10	1630	3261
4-7/8	5.28	11.37	22.75	27.72	55.45	13-3/4	42.00	255.20	510.40	1755	3509
4-15/16	5.42	11.82	23.63	29.17	58.35	14	43.60	269.40	538.80	1886	3771
5	5.56	12.27	24.54	30.68	61.36	14-1/4	45.10	284.10	568.20	2024	4048
5-1/16	5.70	12.74	25.48	32.24	64.49	14-1/2	46.70	299.30	598.60	2170	4340
5-1/8	5.84	13.22	26.43	33.86	67.73	14-3/4	48.40	315.00	630.10	2324	4647
5-3/16	5.98	13.70	27.41	35.55	71.09	15	50.00	331.30	662.70	2485	4970
5-1/4	6.13	14.21	28.41	37.29	74.58	15-1/4	51.70	348.20	696.40	2655	5310
5-5/16	6.27	14.72	29.44	39.10	78.20	15-1/2	53.40	365.60	731.20	2833	5667
5-3/8	6.42	15.25	30.49	40.97	81.94	15-3/4	55.10	383.60	767.10	3021	6041
5-7/16	6.58	15.78	31.57	42.91	85.82	16	56.90	402.10	804.20	3217	6434
5-1/2	6.72	16.33	32.67	44.92	89.84	16-1/4	58.70	421.30	842.50	3422	6846
5-9/16	6.88	16.90	33.79	46.99	93.99	16-1/2	60.50	441.00	882.00	3638	7277
5-5/8	7.03	17.47	34.95	49.14	98.29	16-3/4	62.40	461.40	922.70	3864	7728
5-11/16	7.19	18.06	36.12	51.36	102.70	17	64.20	482.30	964.70	4100	8200
5-3/4	7.35	18.66	37.33	53.66	107.30	17-1/4	66.10	503.90	1008	4346	8693
5-13/16	7.51	19.28	38.56	56.03	112.10	17-1/2	68.10	526.20	1052	4604	9208
5-7/8	7.67	19.91	39.82	58.48	117.00	17-3/4	70.00	549.10	1098	4873	9745
5-15/16	7.84	20.55	41.10	61.01	122.00	18	72.00	572.60	1145	5153	10306
6	8.00	21.21	42.41	63.62	127.20	18-1/4	74.00	596.70	1193	5445	10891
6-1/16	8.17	21.88	43.75	66.31	132.60	18-1/2	76.10	621.60	1243	5750	11500
6-1/8	8.34	22.56	45.12	69.09	138.20	18-3/4	78.10	647.10	1294	6067	12134
6-3/16	8.51	23.26	46.51	71.95	143.90	19	80.20	673.40	1347	6397	12794
6-1/4	8.68	23.97	47.94	74.90	149.80	19-1/4	82.40	700.30	1401	6741	13481
6-5/16	8.86	24.69	49.39	77.94	155.90	19-1/2	84.50	728.00	1456	7098	14195
6-3/8	9.03	25.44	50.87	81.08	162.20	19-3/4	86.70	756.30	1513	7469	14937
6-7/16	9.21	26.19	52.38	84.30	168.60	20	88.90	785.40	1571	7854	15708
6-1/2	9.39	26.96	53.92	87.62	175.20	20-1/4	91.10	815.20	1630	8254	16508
6-5/8	9.76	28.55	57.09	94.56	189.10	20-1/2	93.40	845.80	1692	8669	17339
6-3/4	10.10	30.19	60.39	101.90	203.80	20-3/4	95.70	877.10	1754	9100	18200
6-7/8	10.50	31.90	63.80	109.70	219.30	21	98.00	909.20	1818	9547	19093
7	10.90	33.67	67.35	117.90	235.70	21-1/4	100.40	942.10	1884	10009	20019
7-1/8	11.30	35.51	71.02	126.50	253.00	21-1/2	102.70	975.70	1951	10489	20978
7-1/4	11.70	37.41	74.82	135.60	271.20	21-3/4	105.10	1010	2020	10985	21970
7-3/8	12.10	39.38	78.76	145.20	290.40	22	107.60	1045	2091	11499	22998
7-1/2	12.50	41.42	82.84	155.30	310.60	22-1/4	110.00	1081	2163	12031	24061
7-5/8	12.90	43.52	87.05	165.90	331.90	22-1/2	112.50	1118	2237	12581	25161
7-3/4	13.30	45.70	91.40	177.10	354.20	22-3/4	115.00	1156	2312	13149	26298
7-7/8	13.80	47.95	95.89	188.80	377.60	23	117.60	1194	2389	13737	27473
8	14.30	50.27	100.50	201.10	402.10	23-1/4	120.10	1234	2468	14344	28687
8-1/8	14.70	52.66	105.30	213.90	427.90	23-1/2	122.70	1274	2548	14971	29941
8-1/4	15.10	55.13	110.30	227.40	454.80	23-3/4	125.40	1315	2630	15618	31236
8-3/8	15.60	57.67	115.30	241.50	483.00	24	128.00	1357	2714	16286	32572
8-1/2	16.10	60.29	120.60	256.20	512.50	24-1/4	130.70	1400	2800	16975	33951
8-5/8	16.50	62.99	126.00	271.60	543.30	24-1/2	133.40	1444	2888	17686	35372
8-3/4	17.00	65.77	131.60	287.70	575.50	24-3/4	136.20	1488	2977	18419	36838
8-7/8	17.50	68.63	137.30	304.50	609.10	25	138.90	1534	3068	19175	38350
9	18.00	71.57	143.10	322.10	644.10	25-1/4	141.70	1580	3161	19954	39907
9-1/8	18.50	74.59	149.20	340.30	680.70	25-1/2	144.50	1628	3256	20755	41511
9-1/4	19.00	77.70	155.40	359.40	718.70	25-3/4	147.40	1676	3352	21581	43163
9-3/8	19.50	80.89	161.80	379.20	758.40	26	150.30	1726	3451	22432	44864
9-1/2	20.10	84.17	168.30	399.80	799.60	26-1/4	153.20	1776	3552	23307	46614
9-5/8	20.60	87.54	175.10	421.30	842.60	26-1/2	156.10	1827	3654	24208	48415
9-3/4	21.10	90.99	182.00	443.60	887.20	26-3/4	159.00	1879	3758	25134	50268
9-7/8	21.70	94.54	189.10	466.80	933.60	27	162.00	1932	3865	26087	52174
10	22.20	98.17	196.30	490.90	981.70	27-1/2	168.10	2042	4083	28074	56148
10-1/4	23.40	105.72	211.40	541.80	1084	28	174.30	2155	4310	30172	60344
10-1/2	24.50	113.65	227.30	596.70	1193	28-1/2	180.50	2273	4545	32385	64771
10-3/4	25.70	121.96	243.90	655.50	1311	29	186.90	2394	4789	34719	69437
11	26.90	130.67	261.30	718.70	1437	29-1/2	193.40	2520	5041	37176	74351
11-1/4	28.10	139.78	279.60	786.30	1573	30	200.00	2651	5301	39761	79522
11-1/2	29.40	149.31	298.60	858.50	1717	30-1/2	206.80	2785	5571	42479	84957
11-3/4	30.70	159.26	318.50	935.70	1871	31	213.60	2925	5849	45333	90666
12	32.00	169.65	339.30	1018	2036	31-1/2	220.50	3069	6137	48329	96659
12-1/4	33.40	180.47	360.90	1105	2211	32	227.60	3217	6434	51472	102944
12-1/2	34.70	191.75	383.50	1198	2397	32-1/2	234.80	3370	6740	54765	109530
12-3/4	36.10	203.48	407.00	1297	2594	33	242.10	3528	7056	58214	116428
13	37.60	215.69	431.40	1402	2804	34	256.90	3859	7717	65597	131194
13-1/4	39.00	228.37	456.70	1513	3026	35	272.30	4209	8418	73662	147324

## Viscosity Classification Equivalents



### ISO VISCOSITY CLASSIFICATION SYSTEM

All industrial oils are graded according to the ISO Viscosity Classification System, approved by the International Standards Organizations (ISO). Each ISO viscosity grade number corresponds to the mid-point of viscosity range expressed in centistokes (cSt) at 40°C. For example, a lubricant with an ISO grade of 32 has a viscosity within the range of 28.80-35.2, the midpoint of which is 32.

**Rule-of-Thumb:** The comparable ISO grade of a competitive product whose viscosity in SUS at 100°F is known can be determined by using the following conversion formula:

$$\text{SUS @ 100°F} \div 5 = \text{cSt @ 40°C}$$

# ENGINEERING/TECHNICAL



## English Standard Measures

### Long Measure

- 1 mile = 1760 yards = 5280 feet.
- 1 yard = 3 feet = 36 inches.
- 1 foot = 12 inches.

### Surveyor's Measure

- 1 mile = 8 furlongs = 80 chains.
- 1 furlong = 10 chains = 220 yards.
- 1 chain = 4 rods = 22 yards = 66 feet = 100 links.
- 1 link = 7.92 inches.

### Square Measure

- 1 square mile = 640 acres = 6400 square chains.
- 1 acre = 10 square chains = 4840 square yards = 43,560 square feet.
- 1 square chain = 16 square rods = 484 square yards = 4356 square feet.
- 1 square rod = 30.25 square yards = 272.25 square feet = 625 square links.
- 1 square yard = 9 square feet.
- 1 square foot = 144 square inches.
- An acre is equal to a square, the side of which is 208.7 feet.

### Dry Measure

- 1 bushel (U.S. or Winchester struck bushel) = 1.2445 cubic foot = 2150.42 cubic inches.
- 1 bushel = 4 pecks = 32 quarts = 64 pints.
- 1 peck = 8 quarts = 16 pints.
- 1 quart = 2 pints.
- 1 heaped bushel = 1 1/4 struck bushel.
- 1 cubic foot = 0.8036 struck bushel.
- 1 British Imperial bushel = 8 Imperial gallons = 1.2837 cubic foot = 2218.19 cubic inches.

### Liquid Measure

- 1 U.S. gallon = 0.1337 cubic foot = 231 cubic inches = 4 quarts = 8 pints.
- 1 quart = 2 pints = 8 gills.
- 1 pint = 4 gills.
- 1 British Imperial gallon = 1.2003 U.S. gallon = 277.27 cubic inches.
- 1 cubic foot = 7.48 U.S. gallons.

### Circular and Angular Measure

- 60 seconds (") = 1 minute (')
- 60 minutes = 1 degree (°)
- 360 degrees = 1 circumference (C)
- 57.3 degrees = 1 radian
- 2 π radians = 1 circumference (C)

### Specific Gravity

- The specific gravity of a substance is its weight as compared with the weight of an equal bulk of pure water.
- For making specific gravity determinations the temperature of the water is usually taken at 62° F. when 1 cubic foot of water weighs 62.355 lbs. Water is at its greatest density at 39.20° F. or 4° Centigrade.

### Temperature

The following equation will be found convenient for transforming temperature from one system to another:

Let F = degrees Fahrenheit; C = degrees Centigrade; R = degrees Reamur.

$$F - 32 = \frac{C}{100} = \frac{R}{80}$$

### Avoirdupois or Commercial Weight

- 1 gross or long ton = 2240 pounds.
- 1 net or short ton = 2000 pounds.
- 1 pound = 16 ounces = 7000 grains.
- 1 ounce = 16 drams = 437.5 grains.

### Measures of Pressure

- 1 pound per square inch = 144 pounds per square foot = 0.068 atmosphere = 2.042 inches of mercury at 62 degrees F. = 27.7 inches of water at 62 degrees F. = 2.31 feet of water at 62 degrees F.
- 1 atmosphere = 30 inches of mercury at 62 degrees F. = 14.7 pounds per square inch = 2116.3 pounds per square foot = 33.95 feet of water at 62 degrees F.
- 1 foot of water at 62 degrees F. = 62.355 pounds per square foot = 0.433 pound per square inch.
- 1 inch of mercury at 62 degrees F. = 1.132 foot of water = 13.58 inches of water = 0.491 pound per square inch.
- Column of water 12 in. high, 1 in. dia. = .341 lbs.

### Cubic Measure

- 1 cubic yard = 27 cubic feet.
- 1 cubic foot = 1728 cubic inches.
- The following measures are also used for wood and masonry: 1 cord of wood = 4 X 4 X 8 feet = 128 cubic feet.
- 1 perch of masonry = 16-1/2 X 1-1/2 X 1 foot = 24-3/4 cubic feet.

### Shipping Measure

For measuring entire internal capacity of a vessel: 1 register ton = 100 cubic feet.

For measurement of cargo:

- 1 U.S. shipping ton = 40 cubic feet = 32.143 U.S. bushels = 31.16 Imperial bushels.
- British shipping ton = 42 cubic feet = 33.75 U.S. bushels = 32.72 Imperial bushels.

### Troy Weight, Used for Weighing Gold and Silver

- 1 pound = 12 ounces = 5760 grains.
- 1 ounce = 20 pennyweights = 480 grains.
- 1 pennyweight = 24 grains.
- 1 carat (used in weighing diamonds) = 3.086 grains.
- 1 grain Troy = 1 grain avoirdupois = 1 grain apothecaries' weight.

### Measure Used for Diameters and Areas of Electric Wires

- 1 circular inch = area of circle 1 inch in diameter = 0.7854 square inch.
- 1 circular inch = 1,000,000 circular mils.
- 1 square inch = 1.2732 circular inch = 1,273,239 circular mils.
- A circular mil is the area of a circle 0.001 inch in diameter.

### Board Measure

- One foot board measure is a piece of wood 12 inches square by 1 inch thick, or 144 cubic inches. 1 cubic foot therefore equals 12 feet board measure.

**Table 28: Decimal and Millimeter Equivalents of Fractions**

Inches			Milli- meters	Inches			Milli-meters	Inches			Milli-meters
Fractions	Decimals			Fractions	Decimals			Fractions	Decimals		
1/64		.015625	.397		11/32	.34375	8.7319		11/16	.6875	17.463
	1/32	.03125	.794	23/64		.359375	9.128	45/64		.703125	17.859
3/64		.046875	1.191		3/8	.375	9.525		23/32	.71875	18.256
	1/16	.0625	1.588	25/64		.390625	9.922	47/64		.734375	18.653
5/64		.078125	1.984		13/32	.40625	10.319		3/4	.750	19.050
	3/32	.09375	2.381	27/64		.421875	10.716	49/64		.765625	19.447
7/64		.109375	2.778		7/16	.4375	11.113		25/32	.78125	19.844
	1/8	.125	3.175	29/64		.453125	11.509	51/64		.796875	20.241
9/64		.140625	3.582		15/32	.46875	11.906		13/16	.8125	20.638
	5/32	.15625	3.969	31/64		.48376	12.303	53/64		.828125	21.034
11/64		.171875	4.366		1/2	.500	12.700		27/32	.84375	21.431
	3/16	.1875	4.763	33/64		.515625	13.097	55/64		.859375	21.828
13/64		.203125	5.159		17/32	.53125	13.494		7/8	.875	22.225
	7/32	.21875	5.556	35/64		.546875	13.891	57/64		.890625	22.622
15/64		.234375	5.953		9/16	.5625	14.288		29/32	.90524	23.019
	1/4	.250	6.350	37/64		.578125	14.684	59/64		.921875	23.416
7/64		.265625	6.747		19/32	.59375	14.081		15/16	.9375	23.813
	9/32	.28125	7.144	39/64		.609375	15.478	61/64		.953125	24.209
19/64		.296875	7.541		5/8	.625	15.875		31/32	.96875	24.606
	5/16	.3125	7.938	41/64		.640625	16.272	63/64		.984375	25.003
21/64		.328125	8.334		21/32	.65625	16.669		1	1.000	25.400
				43/64		.671875	17.066				

**Table 29: Millimeter-Inch Equivalents: 1" = 25.4mm (.03937" = 1mm)**

Milli-meter	Decimal	Milli-meter	Decimal	Milli-meter	Decimal	Milli-meter	Decimal	Milli-meter	Decimal
1	.03937	52	2.04724	103	4.05511	154	6.06299	205	8.07086
2	.07874	53	2.08661	104	4.09448	155	6.10236	206	8.11023
3	.11811	54	2.12598	105	4.13385	156	6.14173	207	8.14960
4	.15748	55	2.16535	106	4.17322	157	6.18110	208	8.18897
5	.19685	56	2.20472	107	4.21259	158	6.22047	209	8.22834
6	.23622	57	2.24409	108	4.25196	159	6.25984	210	8.26771
7	.27559	58	2.28346	109	4.29133	160	6.29921	211	8.30708
8	.31496	59	2.32283	110	4.33070	161	6.33858	212	8.34645
9	.35433	60	2.36220	111	4.37007	162	6.37795	213	8.38582
10	.39370	61	2.40157	112	4.40944	163	6.41732	214	8.42519
11	.43307	62	2.44094	113	4.44881	164	6.45669	215	8.46456
12	.47244	63	2.48031	114	4.48818	165	6.49606	216	8.50393
13	.51181	64	2.51968	115	4.52755	166	6.53543	217	8.54330
14	.55118	65	2.55905	116	4.56692	167	6.57480	218	8.58267
15	.59055	66	2.59842	117	4.60629	168	6.61417	219	8.62204
16	.62992	67	2.63779	118	4.64566	169	6.65354	220	8.66141
17	.66929	68	2.67716	119	4.68503	170	6.69291	221	8.70078
18	.70866	69	2.71653	120	4.72440	171	6.73228	222	8.74015
19	.74803	70	2.75590	121	4.76378	172	6.77165	223	8.77952
20	.78740	71	2.79527	122	4.80315	173	6.81102	224	8.81889
21	.82677	72	2.83464	123	4.84252	174	6.85039	225	8.85826
22	.86614	73	2.87401	124	4.88189	175	6.88976	226	8.89763
23	.90551	74	2.91338	125	4.92126	176	6.92913	227	8.93700
24	.94488	75	2.95275	126	4.96063	177	6.96850	228	8.97637
25	.98425	76	2.99212	127	5.00000	178	7.00787	229	9.01574
26	1.02362	77	3.03149	128	5.03937	179	7.04724	230	9.05511
27	1.06299	78	3.07086	129	5.07875	180	7.08661	231	9.09448
28	1.10236	79	3.11023	130	5.11811	181	7.12598	232	9.13385
29	1.14173	80	3.14960	131	5.15749	182	7.16535	233	9.17322
30	1.18110	81	3.18897	132	5.19685	183	7.20472	234	9.21259
31	1.22047	82	3.22834	133	5.23622	184	7.24409	235	9.25196
32	1.25984	83	3.26771	134	5.27559	185	7.28346	236	9.29133
33	1.29921	84	3.30708	135	5.31496	186	7.32283	237	9.33070
34	1.33858	85	3.34645	136	5.35433	187	7.36220	238	9.37007
35	1.37795	86	3.38582	137	5.39370	188	7.40157	239	9.40944
36	1.41732	87	3.42519	138	5.43307	189	7.44094	240	9.44881
37	1.45669	88	3.46456	139	5.47244	190	7.48031	241	9.48818
38	1.49606	89	3.50393	140	5.51181	191	7.51968	242	9.52755
39	1.53543	90	3.54330	141	5.55118	192	7.55905	243	9.56692
40	1.57480	91	3.58267	142	5.59055	193	7.59842	244	9.60629
41	1.61417	92	3.62204	143	5.62992	194	7.63779	245	9.64566
42	1.65354	93	3.66141	144	5.66929	195	7.67716	246	9.68503
43	1.69291	94	3.70078	145	5.70866	196	7.71653	247	9.72440
44	1.73228	95	3.74015	146	5.74804	197	7.75590	248	9.76378
45	1.77165	96	3.77952	147	5.78740	198	7.79527	249	9.80315
46	1.81102	97	3.81889	148	5.82677	199	7.83464	250	9.84252
47	1.85039	98	3.85826	149	5.86614	200	7.87401	251	9.88189
48	1.88976	99	3.89763	150	5.90551	201	7.91338	252	9.92126
49	1.92913	100	3.93710	151	5.94488	202	7.95275	253	9.96063
50	1.96850	101	3.97637	152	5.98425	203	7.99221	254	10.00000
51	2.00787	102	4.01574	153	6.02362	204	8.03149	-	-

# ENGINEERING/TECHNICAL



## Metric System of Measurements

### Measures of Length

10	millimeters (mm.)	=	1 centimeter (cm.)
10	centimeters	=	1 decimeter (dm.)
10	decimeters	=	1 meter (m.)
1000	meter	=	1 kilometer (km.)

### Measure of Weight

10	milligrams (mg.)	=	1 centigram (cg.)
10	centigrams	=	1 decigram (dg.)
10	decigrams	=	1 gram (g.)
10	grams	=	1 decagram (Dg.)
10	decagrams	=	1 hectogram (Hg.)
10	hectograms	=	1 Kilogram (Kg.)
1000	kilograms	=	1 (metric) ton (T.)

### Surveyor's Square Measure

100	square meters (m. <sup>2</sup> )	=	1 are (ar.)
100	acres	=	1 hectare (har.)
100	hectares	=	1 sq. kilometer (Km. <sup>2</sup> )

Millimeters X.039370 = inches.  
Meters x 39.370 = inches.  
Meters X 3.2808 = feet.  
Meters X 1.09361 = yards.  
Kilometers X 3,280.8 = feet.  
Kilometers X.62137 = Statute Miles.  
Kilometers x.53959 = Nautical Miles.

Grams X 981 = dynes.  
Grams X 15.432 = grains.  
Grams X.03527 = ounces (Avd.).  
Grams x.033818 = fluid ounces (water).  
Kilograms X 35.27 = ounces (Avd.).  
Kilograms X 2.20462 = pounds (Avd.).  
Metric Tons (1000 Kg.) X 1.10231 = Net Ton (2000 lbs.).  
Metric Tons (1000 Kg.) X.98421 = Gross Ton (2240 lbs.).

Square Millimeters X.00155 = square inches.  
Square centimeters X.155 = square inches.  
Square Meters X 10.76387 = square feet.  
Square Meters X 1.19599 = square yards.  
Hectares X 2.47104 = acres.  
Square Kilometers X 247.104 = acres.  
Square Kilometers X.3861 = square miles.

Cubic centimeters X.033818 = fluid ounces.  
Cubic centimeters X.061023 = cubic inches.  
Cubic centimeters X.271 = fluid drams.  
Liters X 61.023 = cubic inches.  
Liters X 1.05668 = quarts.  
Liters X .26417 = gallons.  
Liters X.035317 = cubic feet.  
Hectoliters X 26.417 = gallons.  
Hectoliters X 3.5317 = cubic feet.  
Hectoliters X 2.83794 = bushel (2150.42 cu. in.).  
Hectoliters X.1308 = cubic yards.  
Cubic Meters x 264.17 = gallons.  
Cubic Meters x 35.317 = cubic feet.  
Cubic Meters X 1.308 = cubic yards.

Calorie x 0.003968 = B. T.U.  
Joules X.7373 = pound-feet.  
Newton-Meters X 8.851 = pound-inches  
Cheval Vapeur X.9863 = Horsepower.  
Kilowatts X 1.34 = Horsepower.  
Kilowatt Hours X 3415 = B.T.U.  
(Degrees Cent. X 1.8) + 32 = degrees Fahr.  
(Degrees Reamur X 2.25) + 32 = degrees Fahr.

### Square Measure

100	sq. millimeters (mm. <sup>2</sup> )	=	1 sq. centimeter (cm. <sup>2</sup> )
100	sq. centimeters	=	1 sq. decimeter (dm. <sup>2</sup> )
100	sq. decimeters	=	1 sq. meter (m. <sup>2</sup> )

### Cubic Measure

1000	cu. millimeters (mm. <sup>3</sup> )	=	1 cu. centimeter (cm. <sup>3</sup> )
1000	cu. centimeters	=	1 cu. decimeter (dm. <sup>3</sup> )
1000	cu. decimeters	=	1 cu. meter (m. <sup>3</sup> )

### Dry and Liquid Measure

10	milliliters (ml.)	=	1 centiliter (cl.)
10	centiliters	=	1 deciliter (dl.)
10	deciliters	=	1 liter (l.)
100	liters	=	1 hectoliter (Hl.)

1 liter = 1 cubic decimeter = the volume of 1 kilogram of pure water at a temperature of 39.2 degrees F.

### Length Conversion Constants for Metric and U.S. Units

Inches X 25.4001 = millimeters.  
Inches X.0254 = meters.  
Feet x.30480 = meters.  
Yards X.91440 = meters.  
Feet x.0003048 = kilometers.  
Statute Miles X 1.60935 = kilometers.  
Nautical Miles x 1.85325 = kilometers.

### Weight Conversion Constants for Metric and U.S. Units

Dynes X.0010193 = grams.  
Grains X.0648 = grams.  
Ounces (Avd.) X 28.35 = grams.  
Fluid Ounces (Water) X 29.57 = grams.  
Ounces (Avd.) X.02835 = kilograms.  
Pounds (Avd.) X.45359 = kilograms.  
Net Ton (2000 lbs.) X.90719 = Metric Tons (1000 Kg.).  
Gross Ton (2240 lbs.) X 1.01605 = Metric Tons (1000 Kg.).

### Area Conversion Constants for Metric and U.S. Units

Square Inches X 645.163 = square millimeters.  
Square Inches x 6.45163 = square centimeters.  
Square Feet x.0929 = square meters.  
Square Yards X.83613 = square meters.  
Acres X.40469 = hectares.  
Acres X.0040469 = square kilometers.  
Square Miles X 2.5899 = square kilometers.

### Volume Conversion Constants for Metric and U.S. Units

Fluid Ounces X 29.57 = cubic centimeters.  
Cubic Inches X 16.387 = cubic centimeters.  
Fluid Drams x 3.69 = cubic centimeters.  
Cubic Inches X.016387 = liters.  
Quarts x.94636 = liters.  
Gallons x 3.78543 = liters.  
Cubic Feet x 28.316 = liters.  
Gallons x.0378543 = hectoliters.  
Cubic Feet x.28316 = hectoliters.  
Bushels (2150.42 cu. in.) X.352379 = hectoliters.  
Cubic Yards x 7.645 = hectoliters.  
Gallons x.00378543 = cubic meters.  
Cubic Feet x.028316 = cubic meters.  
Cubic Yards x.7645 = cubic meters.

### Power and Heat Conversion Constants for Metric and U.S. Units

B.T.U. X 252 = calories.  
Pound-Foot X 1.3563 = joules.  
Pound-inches X.11298 = Newton-meters.  
Horsepower X 1.014 = Cheval Vapeur.  
Horsepower X.746 = kilowatts.  
B.T.U. X.00029282 = kilowatt hours.  
(Degrees Fahr. - 32) x.555 = degrees Cent.  
(Degrees Fahr. - 32) x.444 = degrees Reamur.

## COMMON CONVERSION FACTORS USEFUL IN MECHANICAL POWER TRANSMISSION

### Symbols and Abbreviations Used in Conversion Factors

Symbols and abbreviations found in this section are those currently used in many texts and product publications. Considerable effort is underway to standardize on abbreviations for metric and English units of measurement. Recently, ASTM (American Society for Testing and Materials) and IEEE (Institute of Electrical and Electronic Engineers) published a standard practice on the metric system. † This publication consolidates a great deal of the current thinking and provides a system of abbreviations and symbols that differ somewhat from those used here.

This Handbook has retained use of familiar abbreviations consistent with existing product and trade literature rather than the abbreviations found in current publications of technical and scientific societies.

### Prefixes Used in the Metric System

Common prefixes and symbols used in the metric system are listed below. An example of use is 1000 meters is equivalent to 1 kilometer, and 1/1000 of one meter is equivalent to 1 millimeter.

Prefix	Symbol	Multiplication Factor-Decimal and Power of 10
giga	G	1,000,000,000 or $10^9$ or one billion
mega	M	1,000,000 or $10^6$ or one million
kilo	k	1,000 or $10^3$ or one thousand
*hecto	h	100 or $10^2$ or one hundred
*deka	da	10 or $10^1$ or ten
**deci	d	0.1 or $10^{-1}$ or one tenth
**centi	c	0.01 or $10^{-2}$ or one hundredth
mill	m	0.001 or $10^{-3}$ or one thousandth
micro	$\mu$	0.000,001 or $10^{-6}$ or one millionth
nano	n	0.000,000,001 or $10^{-9}$ or one billionth

\* Not commonly used.

\*\* Not commonly used except for special situations.

The centimeter as a unit of length is in common use.

The decibel is a unit in both electrical and acoustical work.

†ASTM/IEEE Standard Metric Practice, ASTM E 380-75, IEEE Std. 268-1976.

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# ENGINEERING/TECHNICAL



Symbol or Abbreviation	Term
atm	atmosphere
avdp	avoirdupois
bbl	barrels
bu	bushels
C	degrees Centigrade or Celsius
cc	cubic centimeters
cfm	cubic feet per minute
cfs	cubic feet per second
cm	centimeter
cu	cubic
deg	degrees
F	degrees Fahrenheit
fps	feet per second
ft	feet
ft-lb	foot-pounds (work or energy)
ft per sec	feet per second (alternate)
ft per sec <sup>2</sup>	feet per second per second
g	acceleration due to gravity
g	grams
gal	gallons
gpm	gallons per minute
hp	horsepower
hr	hour
in	inches
in-lb	inch-pounds (work or energy)
K	degrees Kelvin
kg	kilograms
km	kilometers
kn	knots
KW	kilowatts

Symbol or Abbreviation	Term
l	liters
lb	pounds
lb-ft	pound-feet (torque)
m	meters
m per sec <sup>2</sup>	meters per second per second
mi	miles
mm	millimeters
mph	miles per hour
MGD	millions of gallons per day
N	Newtons
oz	ounces
oz-in	ounce-inches (torque)
Pa	Pascals
psi	pounds per square inch
psia or psig	pounds per square inch "absolute" or gauge
pt	pint
qt	quart
R	degrees Rankine (Fahrenheit, absolute)
rad	radians
rev	revolutions
rpm	revolutions per minute
sec	seconds
sq	square
std	standard
temp	temperature
wt	weight
yd	yard
yr	year

## Rounding of Numbers

A minimum of four significant figures are used in conversion factors presented here. Where the conversion factor is exact (for example, 1 foot contains 12 inches), decimal fractions are not necessary. Also, where large whole numbers are used (for example, 1 square kilometer contains 1195990 square yards), decimal fractions are not used unless justified by the accuracy of ordinary computations.

1195990	(sq yd in a sq km)
4389.12	(cc in a cu ft)
448.86	(gpm in a liter per sec)
14.70	(psi in an atmosphere)
0.4331	(psi in a ft of water)
0.0625	(lb-in in an oz-in)

## VELOCITY

centimeters per second (cm per sec) . . . . .	feet per second (fps or ft per sec) . . . . .	0.3281
feet per second (fps) . . . . .	centimeters per second (cm per sec). . . . .	30.48
	meters per second (m per sec) . . . . .	0.3048
	kilometers per hour (km per hr) . . . . .	1.097
	miles per hour (mph) . . . . .	0.6818
kilometers per hour (km per hr). . . . .	knots (kn) . . . . .	0.5396
	feet per second (fps) . . . . .	1.467
	kilometers per hour (km per hr) . . . . .	1.609
	feet per minute (ft per min.) . . . . .	88
knots (kn) . . . . .	miles per hour (mph) . . . . .	1.152
	kilometers per hour (km per hr) . . . . .	1.853
radians per second (rad per sec) . . . . .	revolutions per minute (rpm) . . . . .	9.55
	degrees per minute (deg per min.) . . . . .	3437.7
revolutions per minute (rpm) . . . . .	radians per second (rad per sec) . . . . .	0.1047
	degrees per minute (deg per min.) . . . . .	360

## ACCELERATION

### COLUMN A

To Convert From...	To...	Multiply Col. A by
feet per second per second (ft per sec <sup>2</sup> )	meters per second per second (m per sec <sup>2</sup> ) . . . . .	0.3048
m per sec <sup>2</sup>	ft per sec <sup>2</sup> . . . . .	3.281
revolutions per minute per second (rpm per sec)	radians per second per second (rad per sec <sup>2</sup> ) . . . . .	0.1047
rad per sec <sup>2</sup>	rpm per sec . . . . .	9.55



# ENGINEERING/TECHNICAL

## VOLUMETRIC FLOW RATES

gallons per minute, US (gpm)	liters per second (l per sec)	0.008434
	cubic feet per minute (cfm)	0.1337
gallons per minute, UK or Canadian (gpm)	cubic feet per hour (cu ft per hr)	8.022
	liters per second (l per sec)	0.0101
	cubic feet per minute (cfm)	0.1606
cubic feet per second (cfs)	cubic feet per hour (cu ft per hr)	9.634
	gpm (UK or Canadian)	373.77
	gpm (US)	448.86
liters per second (l per sec)	liters per second (l per sec)	1699.2
	cubic feet per minute (cfm)	2.119
	gpm (UK or Canadian)	13.20
millions of gallons per day, US (MGD)	gpm (US)	15.85
	liters per second (l per sec)	43.81
	cubic feet per minute (cfm)	92.85
	gallons per minute, US (gpm)	694.44

## PRESSURE

pascals (Pa)	pounds per square inch (psi)	0.0001450
	pounds per square foot (lb per ft <sup>2</sup> )	0.02089
	newtons per square meter	1
pounds per square inch (psi)	atmospheres, std. (atm)	0.0680
	pounds per square foot (lb per ft <sup>2</sup> )	144
	pascals (Pa)	6894.8
	foot of water (ft of H <sub>2</sub> O) 60F	2.301
atmospheres (atm), standard	psi	14.70
	lb per ft <sup>2</sup>	2116.8
	Pa	101325
inch of water, 60F (in of H <sub>2</sub> O)	psi	0.03609
	lb per ft <sup>2</sup>	5.197
	Pa	248.84
foot of water, 60F (ft of H <sub>2</sub> O)	psi	0.4331
	lb per ft <sup>2</sup>	62.36
	Pa	2985.9

## WEIGHT, MASS, INERTIA

pounds (lb)*	kilograms (kg)	0.4536
	ounces (oz)	16
kilograms (kg)	pounds (lb)	2.205
	ounces (oz)	35.27

## WEIGHT, MASS, INERTIA, continued

### COLUMN A

Convert From...	To	Multiply To Col. A by
tons (short) . . . . .	metric tons . . . . .	0.9072
	kilograms (kg) . . . . .	907.2
	pounds (lb) . . . . .	2000
metric tons . . . . .	tons (short) . . . . .	1.102
	kilograms . . . . .	1000
	pounds . . . . .	2205
pounds, weight (lb) . . . . .	slugs, mass (lb-sec <sup>2</sup> per ft) . . . . .	0.03106
pound-foot <sup>2</sup> (lb-ft <sup>2</sup> ) . . . . .	kilogram-meters <sup>2</sup> (kg-m <sup>2</sup> ) . . . . .	0.04214

\*pounds and ounces are avoirdupois

### FORCE AND TORQUE

pounds (lb) . . . . .	newtons(N) . . . . .	4.448
newtons (N) . . . . .	pounds (lb) . . . . .	0.2248
newton-meters (N-m) . . . . .	pound-feet (lb-ft) . . . . .	0.7376
	pound-inches (lb-in) . . . . .	8.851
	ounce-inches (oz-in) . . . . .	141.60
ounce-inches (oz-in) . . . . .	lb-ft . . . . .	0.005208
	N-m . . . . .	0.007062
	lb-in . . . . .	0.0625
pound-inches (lb-in) . . . . .	lb-ft . . . . .	0.0833
	N-m . . . . .	0.1298
	oz-ln . . . . .	16
pound-feet (lb-ft) . . . . .	N-m . . . . .	1.356
	lb -in . . . . .	12
	oz-ln . . . . .	192

### POWER

horsepower (hp) . . . . .	kilowatts (kW) . . . . .	0.7457
	foot-pounds per second (ft-lb per sec) . . . . .	550
	foot-pounds per minute (ft-lb per min.) . . . . .	33000
kilowatts (kW) . . . . .	horsepower (hp) . . . . .	1.341

### TEMPERATURE

		Use This Relationship
degrees Fahrenheit (F) . . . . .	degrees Celsius (C) . . . . .	$C = 5/9 (F - 32)$
degrees Celsius (C) . . . . .	degrees Fahrenheit (F) . . . . .	$F = 9/5C + 32$
degrees Fahrenheit (F) . . . . .	degrees Rankine (R) . . . . .	$R = F + 459.69$
degrees Celsius (C) . . . . .	degrees Kelvin (K) . . . . .	$K = C + 273.16$

Examples:

- Convert 12F to C.  $C = 5/9 (F - 32) = 5/9 (12 - 32) = 5/9 (-20)$   
Answer = -11.1C
- Convert 40C to F.  $F = 9/5C + 32 = 9/5 (40) + 32 = 72 + 32$   
Answer = 104F



## GRAVITATIONAL CONSTANT

g = 32.174 feet per second per second (ft per sec<sup>2</sup>)  
 = 9.8067 meters per second per second (m per sec<sup>2</sup>)

## APPROXIMATE DENSITIES OF COMMON MATERIALS

### REPRESENTATIVE DENSITIES

Grams per cc                      lb per cu ft

#### GASES @ 68F, std atm

Air . . . . .	1.30 grams per liter . . . . .	0.07528
Oxygen . . . . .	1.45 grams per liter . . . . .	0.08305
Hydrogen . . . . .	0.09 grams per liter . . . . .	0.005234
Nitrogen . . . . .	1.25 grams per liter . . . . .	0.07274
	All Other Materials	
	grams per cc	

#### LIQUIDS

Water @ 4C . . . . .	1.000 grams per cc . . . . .	62.43
20C . . . . .	0.998 . . . . .	62.32
40C . . . . .	0.992 . . . . .	61.94
SeaWater . . . . .	1.02-1.03 . . . . .	64.00
Ethyl alcohol 100% . . . . .	0.789 . . . . .	49.2
Kerosene . . . . .	0.78-0.82 . . . . .	50
Gasoline . . . . .	0.70-0.75 . . . . .	45

#### METALS

Aluminum (95% Al) . . . . .	2.70 . . . . .	169
Bronze (90% Cu, 10% Zn) . . . . .	8.80 . . . . .	549
Copper (Annealed, ACS) . . . . .	8.89 . . . . .	555
Gold . . . . .	19.32 . . . . .	1206
Iron, gray cast . . . . .	7.10 . . . . .	443
Lead . . . . .	11.36 . . . . .	709
Magnesium . . . . .	1.74 . . . . .	109
Steel (0.4-0.5%Carbon) . . . . .	7.80 . . . . .	487
Steel, 410 stainless . . . . .	7.70 . . . . .	480

#### ENGINEERING PLASTICS

ABS, general purpose . . . . .	1.01-1.05 . . . . .	64
Acrylics, cast sheet . . . . .	1.19 . . . . .	74
Nylon 6/6 . . . . .	1.13-1.15 . . . . .	71
Phenolic, general purpose . . . . .	1.35-1.46 . . . . .	87
Polycarbonates, general purpose . . . . .	1.2 . . . . .	75
Polyesters, thermoplastic, unreinforced . . . . .	1.31 - 1.43 . . . . .	86
Polyethylene, medium density . . . . .	0.926-0.940 . . . . .	58
Polyvinyl Chloride . . . . .	1.30-1.58 . . . . .	89

## APPROXIMATE DENSITIES OF COMMON MATERIALS

	REPRESENTATIVE DENSITIES	
	Grams per cc	lb per cu ft
<b>OTHER MATERIALS</b>		
Concrete (stone and sand) . . . . .	2.2-2.4 . . . . .	144
Limestone . . . . .	1.5 . . . . .	94
Anthracite coal, not piled. . . . .	1.4-1.8 . . . . .	100
Bituminous coal, not piled. . . . .	1.2-1.5 . . . . .	83
Lignite coal, not piled . . . . .	1.1-1.4 . . . . .	78
Wood, air dried:		
Douglas fir. . . . .	0.48-0.55 . . . . .	32
White oak . . . . .	0.77 . . . . .	48
White maple . . . . .	0.53 . . . . .	33
Oregon pine . . . . .	0.51 . . . . .	32
Hickory . . . . .	0.74-0.80 . . . . .	48
Mahogany . . . . .	0.56-0.85 . . . . .	44
African teak. . . . .	0.99 . . . . .	62
Indian teak . . . . .	0.66-0.88 . . . . .	48

### Formulas and Constants

- 1 HP = 33,000 Foot-pounds of work per minute.
- 1 HP = .746 K.W. = K.W.P 1.341.
- 1 HP = 2547 B.T.U. per hour.
- 1 B.T.U. = Heat required to raise 1 lb. water 1°F.
- 1 B.T.U. = 777.6 Foot-pounds work.
- 1 Kilowatt Hour = 3415 B.T.U.
- Heat Value of Carbon = 14,600 B.T.U. per pound.
- Latent Heat of Fusion of Ice = 143.15 B.T.U. per pound.
- Latent Heat of Evaporation of Water at 212°F. = 970.4 B.T.U. per pound.
- Total Heat of Saturated Steam at atmospheric pressure = 1,150.4 B.T.U. per pound.
- 1 Ton of Refrigeration = 288,000 B.T.U. per 24 hours.
- g = Acceleration of Gravity (commonly taken as 32.16 feet per second per second).
- 1 Radian = 57.296 degrees.
- 1 Meter = 100 cm. = 39.37 inches.

- 1 Kilometer = .62137 miles.
- 1 Gallon = 231 cubic inches.
- 1 Barrel = 31.5 gallons.
- Atmospheric Pressure = 14.7 pounds per sq. in. = 29.92 inches mercury at 32°F.
- 1 Lb. per Sq. In. Pressure = 2.3095 feet fresh water at 62°F. = 2.0355 inches mercury at 32°F. = 2.0416 inches mercury at 62°F.
- Water Pressure (pounds per sq. in.) = .433 X height of water in feet (Fresh water at 62°F.).
- Weight of 1 cu. ft. fresh Water = 62.355 lbs. at 62°F. = 59.76 lbs. at 212°F.
- Weight of 1 cu. ft. Air at 14.7 lbs. per sq. in. Pressure = .07608 lbs. at 62°F. = .08073 lbs. at 32°F.
- † Also look in the General Index under Weights, Measures, or the subject material required.

## Flywheel Formulas

**Flywheels** are used on some machines, for example air compressors, to even out load pulsations. The following formulas are useful in designing entire flywheels and flywheel rims. A V-belt sheave may also be used as a flywheel eliminating the need for a separate flywheel in the system.

### Formulas for Entire Flywheel

Kinetic energy of rotation of a flywheel (foot pounds) = .0001705  $N_2(WR_2)^*$ .

Torque to uniformly accelerate or decelerate a flywheel

$$= \frac{.03908 (N_2 - N_1) (WR_2), * \text{ pound-inches}}{t}$$

where  $N_2$  = final R.P.M. and  $N_1$  = initial R.P.M.

Velocity at outside diameter (feet per minute) = 0.2618 ND.

W = weight (pounds).

R = radius of gyration (feet).

N = speed (R.P.M.)

t = time to change from  $N_1$  to  $N_2$  (seconds).

F = face of rim (inches).

D = outside diameter of rim (inches).

d = inside diameter of rim (inches).

K = weight per cubic inch of material (pounds).

\* $WR^2$  = flywheel effect (pounds X feet<sup>2</sup>). See table to the right for  $WR^2$  of rims. Ordinarily the  $WR^2$  of the rim only is considered. In unusual instances the relatively small  $WR^2$  values of the hub and arms or web can be added directly to the  $WR^2$  of the rim if desired. To find the  $WR^2$  of a hub or web use the  $WR^2$  formula for rims, substituting the hub or web outside diameter, inside diameter, and width for D, d

and F respectively. When arms are used instead of a web an approximate  $WR^2$  value of the arms is the total weight of the arms in pounds times the square of the radius in feet from the shaft center line to the mid point of the arms between hub and rim.

**Table 30: Formulas for Flywheel Rims**

Property	Cast Iron Rim (Based on .26 lbs. per cu. in.)	Steel Rim (Based on .283 lbs. per cu. in.)	Rim of any material weighing K pounds per cubic inch
Volume (Cubic Inches)	.7854F(D <sup>2</sup> -d <sup>2</sup> )	.7854F(D <sup>2</sup> -d <sup>2</sup> )	.7854F(D <sup>2</sup> -d <sup>2</sup> )
W Weight (Pounds)	.2042F(D <sup>2</sup> -d <sup>2</sup> )	.2223F(D <sup>2</sup> -d <sup>2</sup> )	.7854FK(D <sup>2</sup> -d <sup>2</sup> )
R Radius of Gyration (Feet)	$\sqrt{\frac{0.8681(D^2 + d^2)}{1000}}$	$\sqrt{\frac{0.8681(D^2 + d^2)}{1000}}$	$\sqrt{\frac{0.8681(D^2 + d^2)}{1000}}$
$WR^2$ Wt X Sq. of Radius of Gyration (Lbs. X Ft. <sup>2</sup> )	$\frac{.1773F(D^4-d^4)}{1000}$	$\frac{.1929F(D^4-d^4)}{1000}$	$\frac{.6818FK(D^4-d^4)}{1000}$
T ▲ Tensile Load in rim (Lbs.)	$\frac{.3078FN_2(D^3-d^3)}{1,000,000}$	$\frac{.3350FN_2(D^3-d^3)}{1,000,000}$	$\frac{1,184FKN_2(D^3-d^3)}{1,000,000}$

▲ Centrifugal force causes this tensile load at each and every section of the rim. Hence, on rims split into two or more sections the fastening at each joint should be designed to take the full load as calculated from the formula here given.

## Centrifugal Force

R = Distance from the axis of rotation to the center of gravity of the body (feet).

N = Revolutions per minute.

v = Velocity of the center of gravity of the body (feet per second).

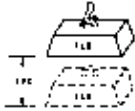
g = Acceleration due to gravity (32.16 commonly).

$$F = \frac{Wv^2}{gR} = \frac{WRN^2}{2933} = .000341 WRN^2$$

F = Centrifugal force tending to move the body outward from the axis of rotation (pounds).

W = Weight of body (pounds).

## Torque and Horsepower Equivalents



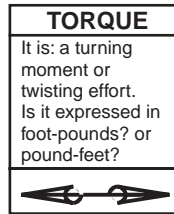
A foot-pound is the amount of energy expended in lifting a one-pound mass a distance of one foot against the pull of gravity

### FOOT-POUNDS INDICATE ENERGY

$$\begin{aligned} \text{Torque (in Pound-Inches)} &= \frac{63.025 \times \text{HP}}{\text{RPM}} \\ &= \text{Force} \times \text{Lever Arm (In Inches)} \\ \text{Torque (In Pound-Feet)} &= \frac{5.252 \times \text{HP}}{\text{RPM}} \\ &= \text{Force} \times \text{Lever Arm (In Feet)} \end{aligned}$$

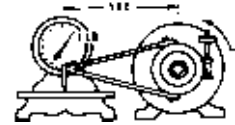
Force = Working Load in Pounds.  
 FPM = Feet Per Minute.  
 RPM = Revolutions Per Minute.  
 Lever Arm = Distance from the Force to the center of rotation in Inches or Feet.

HORSEPOWER
Common Unit of Mechanical power - (HP)
One HP is the rate of work required to raise 33,000 pounds one foot in one minute



### TORQUE

It is: a turning moment or twisting effort. Is it expressed in foot-pounds? or pound-feet?



A pound-foot is the moment created by a force of one pound applied to the end of a lever arm one

### POUND-FEET INDICATE TORQUE

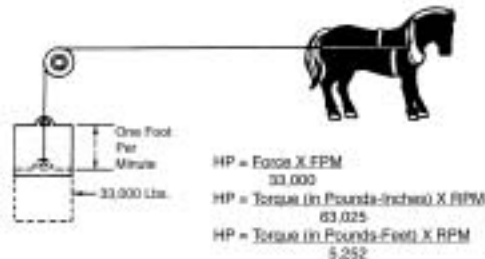
Example:-

$$\begin{aligned} 25 \text{ HP at } 150 \text{ RPM} &= 10504 \text{ Pound-Inches Torque} \\ 2.5 \text{ HP at } 150 \text{ RPM} &= 1050.4 \text{ Pound-Inches Torque} \end{aligned}$$

For other values of RPM move decimal point in RPM values to the left or right as desired, and in Torque values move to the right or left (opposite way) the same number of places.

Example:-

$$\begin{aligned} 25 \text{ HP at } 150 \text{ RPM} &= 10504 \text{ Pound-Inches Torque} \\ 25 \text{ HP at } 1.50 \text{ RPM} &= 1050400 \text{ Pound-Inches Torque} \\ 2.5 \text{ HP at } 1.50 \text{ RPM} &= 105040 \text{ Pound-Inches Torque} \end{aligned}$$



### Overhung Loads

An overhung load is a bending force imposed on a shaft due to the torque transmitted by V-drives, chain drives and other power transmission devices, other than flexible couplings.

Most motor and reducer manufacturers list the maximum values allowable for overhung loads. It is desirable that these figures be compared with the load actually imposed by the connected drive.

Overhung loads may be calculated as follows:

$$\text{O.H.L.} = \frac{63,000 \times \text{HP} \times \text{F}}{\text{N} \times \text{R}}$$

Where HP = Transmitted hp X service factor  
 N = RPM of shaft  
 R = Radius of sprocket, pulley, etc.  
 F = Factor

Weights of the drive components are usually negligible. The formula is based on the assumption that the load is applied at a point equal to one shaft diameter from the bearing face. Factor F depends on the type of drive used:

$$F = \begin{cases} 1.00 & \text{for single chain drives.} \\ 1.3 & \text{for TIMING Belt Drives and HTD belt Drives.} \\ 1.25 & \text{for spur or helical gear or double chain drives.} \\ 1.50 & \text{for V-belt drives. 2.50 for flat belt drives.} \\ 2.50 & \text{for flat belt drives.} \end{cases}$$

**Example:** Find the overhung load imposed on a reducer by a double chain drive transmitting 7 hp @ 30 RPM. The pitch diameter of the sprocket is 10"; service factor is 1.3.

**Solution:**

$$\text{O.H.L.} = \frac{(63,000) (7 \times 1.3) (1.25)}{(30) (5)} = 4,780 \text{ lbs.}$$

### Mathematical Equations

- To find circumference of a circle, multiply diameter by 3.1416.
- To find diameter of a circle, multiply circumference by .31831.
- To find area of a circle, multiply square of diameter by .7854.
- To find area of a rectangle, multiply length by breadth.
- To find area of a triangle, multiply base by 1/2 perpendicular height.
- To find area of ellipse, multiply product of both diameters by .7854.
- To find area of parallelogram, multiply base by altitude.
- To find side of an inscribed square, multiply diameter by 0.7071 or multiply circumference by 0.2251 or divide circumference by 4.4428.
- To find side of inscribed cube, multiply radius of sphere by 1.1547.

- To find side of an equal square, multiply diameter by .8862.
- To find the surface of a sphere, square the diameter and multiply by 3.1416.
- To find the volume of a sphere, cube the diameter and multiply by .5236.
- A side of a square multiplied by 1.4142 equals diameter of its circumscribing circle.
- A side of a square multiplied by 4.443 equals circumference of its circumscribing circle.
- A side of a square multiplied by 1.128 equals diameter of an equal circle.
- A side of a square multiplied by 3.547 equals circumference of an equal circle.
- To find gallon capacity of tanks (given dimensions of a cylinder in inches): square the diameter of the cylinder, multiply by the length and by .0034.

# ENGINEERING/TECHNICAL



**Table 31: Strength and Physical Properties of Various Metals**

Metals and Alloys	Stress in Thousands of Pounds per Sq. Inch				Modulus of Elasticity Millions of PSI	Elongation%
	Tension Ultimate	Tension Yield Point	Compression Ultimate	Shear Ultimate		
Aluminum, Type 1100-0, Annealed	13	5	.....	9	10	45
Aluminum, Type 1100-H18, Hard	24	22	.....	13	10	15
Aluminum, Type 3003-0, Annealed	16	6	.....	11	10	40
Aluminum, Type 3003-H18, Hard	29	27	.....	16	10	10
Aluminum, Type 5052-0, Annealed	28	13	.....	18	10.20	30
Aluminum, Type 5052-H38, Hard	42	37	.....	24	10.20	8
Aluminum, Type 5056-0, Annealed	42	22	.....	26	10.30	35
Aluminum, Type 2014-0, Annealed	27	14	.....	18	10.60	18
Aluminum, Type 2014-T4, Heat Treated	62	42	.....	38	10.60	20
Aluminum, Type C4A, Casting, Solution Heat Treat	32	16	16▲	24	.....	8.50
Aluminum, Type S5C, As Die Cast	30	16	16▲	19	.....	9
Brass, Admiralty, Annealed	53	22	.....	.....	16	65
Brass, Aluminum, Annealed	60	27	.....	.....	16	55
Brass, Cartridge, 30% Zn, Annealed	44	11	.....	32	16	66
Brass, Cartridge, 30% Zn, Hard	76	63	.....	44	16	8
Brass, Naval, Annealed	57†	25†	.....	40 †	15	47†
Brass, Naval, Leaded, Annealed	57†	25†	.....	36 †	15	40†
Brass, Red, 15% Zn, Annealed	39	10	.....	31	17	48
Brass, Red, 15% Zn, Hard	70	57	.....	42	17	5
Brass, Red, Leaded, Cast, Grade 4A	33-46	17-24	10-12▲	.....	9.1-14.8	20-35
Brass, Red, Leaded, Cast, Grade 4B	30-38	12-17	11-12▲	.....	.....	15-27
Brass, Semi-Red, Leaded, Cast, Grade 5A	29-39	13-17	.....	.....	7.7-14.3	18-30
Brass, Semi-Red, Leaded, Cast, Grade 5B	30-40	12-16	8-10▲	.....	10-14	20-35
Brass, Yellow, 35% Zn, Annealed	46	14	.....	32	15	65
Brass, Yellow, 35% Zn, Hard	74	60	.....	43	15	8
Bronze, Aluminum, As Cast	67-95	27-45	.....	.....	15-18	5-35
Bronze, Commercial, 10% Zn, Annealed	37†	10†	.....	28 †	17	45†
Bronze, Manganese, Annealed	65†	30†	.....	42 †	15	33†
Bronze, Phosphor, Annealed	40-66	14-24	.....	.....	16-17	48-70
Bronze, Tin, High Leaded, Cast	23-38	11-22	12-16▲	.....	8.5-13	7-20
Bronze, Tin, Leaded, Cast	33-48	16-26	9-15s▲	.....	10.6-16	15-40
Copper, Beryllium, Annealed	60-80	25-35†	.....	50-60 †	19	35-50†
Copper, Electrolytic, Tough Pitch, Annealed	32†	10†	.....	22 †	17	45†
Inconel, Cast	65-90	.....	.....	.....	23	10-20
Inconel, S, Cast	90-120	80-100	.....	.....	25	1-3
Inconel, Shapes, Plate, Etc., Annealed	80-100†	30-45†	.....	.....	31	35-55†
Inconel, X, Shapes, Plate, Etc., Annealed	110-130†	45-65†	.....	.....	31	40-55†
Iron, Cast, Class 30	30-34	.....	115	44	15	.....
Iron, Cast, Class 35	35-40	.....	125	43	16	.....
Iron, Ingot, Hot Rolled	44	23	.....	.....	29.80	47
Iron, Malleable, Class 32510	50	33	90	46	25	10-18
Iron, Malleable, Class 35018	55	37	90	51	25	18-25
Iron, Nodular (Ductile) Class 60-45-10	60	45	120	.....	22-25	10-25
Iron, Nodular (Ductile) Class 80-60-3	80	60	160	.....	22-25	3-10
Iron, Pearlitic, Malleable	60-90	40-70	.....	.....	28	3-12
Iron, Wrought, Hot Rolled	34-47	23-24	.....	.....	29	7-35
Lead, Hard, Rolled	4.0-4.6	.....	.....	.....	.....	31-48
Magnesium Alloy, Extruded, ASTM M1A	26-28	23-28	10-13	16	6.50	8-11
Magnesium Alloy, Extruded, ASTM AZ61A-F	40-45	22-32	15-21	21	6.50	15-16
Magnesium Alloy, Cast, ASTM M1B	14	4.50	.....	11	6.50	5
Magnesium Alloy, Cast, ASTM AZ92A	24	14	.....	19	6.50	2
Magnesium Alloy, Cast, ASTM AZ91A	36	23	.....	20	6.50	4
Monel, Cast	65-90	32-45	.....	.....	23	20-50
Monel, S, Cast	120-145	80-130	.....	.....	24.20	1-4
Monel, Shapes, Plate, Etc., Annealed	70-85†	25-45†	.....	.....	26	35-50†
Monel, K, Shapes, Plate, Etc., Annealed	90-105†	40-65†	.....	26	25-45	35-55†
Muntz Metal, Cu 59.63%, Zn balance	54	21	.....	40	15	45
Nickel, Cast	50-65	15-30	.....	.....	21.50	15-30
Nickel, Silver, Annealed	49-63†	18-30†	.....	.....	17-18	35-60†
Steel, Cast Carbon, Class 70,000 Normalized	70	38	.....	.....	30	28
Steel, Cast Low Alloy, Class 100,000, Normalized and Tempered	100	68	.....	.....	29-30	20
Steel, Cast Low Alloy, Class 120,000, Quenched and Tempered	120	95	.....	.....	29-30	16
Steel, Cast Low Alloy, Class 200,000, Quenched and Tempered	200	170	.....	.....	29-30	5
Steel, Sheets	48	25	.....	.....	29-30	18-27
Steel, Stainless, Austenitic, Types 304, 316	85	35	.....	.....	28	55-60
Steel, Stainless, Martensitic, Type 416	75	40	.....	.....	29	30
Steel, Structural, Bridge and Building, ASTM A7	60-72	33	33▲	45-54	29-30	21
Steel, Structural, High Strength, Low Alloy, ASTM A242	63-70	42-50	42-50▲	47-53	29-30	18-24
Zinc, Die Cast Alloy XXIII	41	.....	60▲	31	.....	10

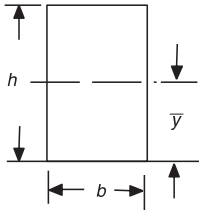
† When hardened, strength values are higher, elongation less

▲ Compression yield point

**Table 32: Properties of Sections**

$A$  = area  
 $I$  = moment of inertia  
 $J$  = polar moment of inertia

$Z$  = section modulus  $\pi$   
 $k$  = radius of gyration  
 $\bar{y}$  = centroidal distance

**Rectangle**


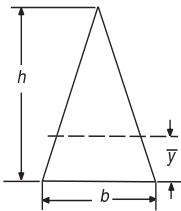
$$A = bh$$

$$k = 0.289h$$

$$I = \frac{bh^3}{12}$$

$$\bar{y} = \frac{h}{2}$$

$$Z = \frac{bh^2}{6}$$

**Triangle**


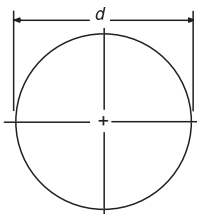
$$A = \frac{bh}{2}$$

$$k = 0.236h$$

$$I = \frac{bh^3}{36}$$

$$\bar{y} = \frac{h}{3}$$

$$Z = \frac{bh^2}{24}$$

**Circle**


$$A = \frac{\pi d^2}{4}$$

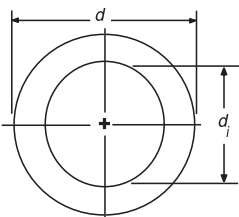
$$J = \frac{\pi d^4}{32}$$

$$I = \frac{\pi d^4}{64}$$

$$k = \frac{d}{4}$$

$$Z = \frac{\pi d^3}{32}$$

$$\bar{y} = \frac{d}{2}$$

**Hollow Circle**


$$A = \frac{\pi d}{4}(d^2 - d_i^2)$$

$$J = \frac{\pi d}{32}(d^4 - d_i^4)$$

$$I = \frac{\pi d}{64}(d^4 - d_i^4)$$

$$k = \frac{\sqrt{d^2 + d_i^2}}{16}$$

$$Z = \frac{\pi d}{32d}(d^4 - d_i^4)$$

$$\bar{y} = \frac{d}{2}$$

# ENGINEERING/TECHNICAL



**Table 33: Coefficients of Friction "f"**

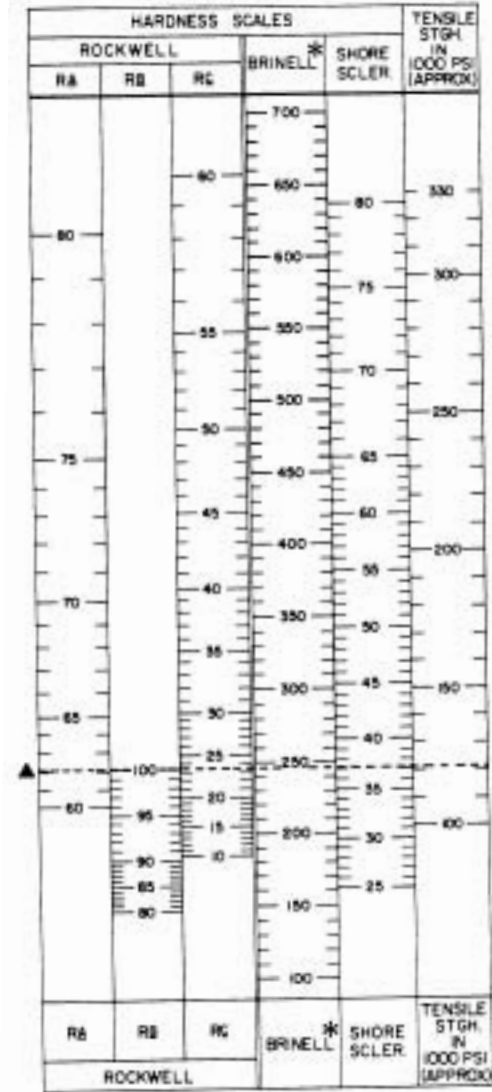
Material	Static		Sliding	
	Dry	Lubri-cated	Dry	Lubricated
Aluminum on aluminum	1.35	.....	.....	.....
Canvas belt on rubber lagging	0.30	.....	.....	.....
Canvas belt, stitched, on steel	.....	.....	0.20	0.10
Canvas belt, woven, on steel	.....	.....	0.22	0.10
Cast iron on asbestos, fabric brake material	.....	.....	0.35-0.40	.....
Cast iron on brass	.....	.....	0.30	.....
Cast iron on bronze	.....	.....	0.22	0.07-0.08
Cast iron on cast iron	1.10	.....	0.15	0.06-0.10
Cast iron on copper	1.05	.....	0.29	.....
Cast iron on lead	.....	.....	0.43	.....
Cast iron on leather	0.60	.....	.....	0.13-0.36
Cast iron on oak (parallel)	.....	.....	0.30-0.50	0.07-0.20
Cast iron on magnesium	.....	.....	0.25	.....
Cast iron on steel, mild	.....	0.18	0.23	1/000 3:11
Cast iron on tin	.....	.....	0.32	.....
Cast iron on zinc	0.85	.....	0.21	.....
Earth on earth	0.25-1.0	.....	.....	.....
Glass on glass	0.94	.....	0.40	.....
Hemp rope on wood	0.50-0.80	.....	0.40-0.70	.....
Nickel on nickel	1.10	.....	0.53	0.12
Oak on leather (parallel)	0.50-0.60	.....	0.30-0.50	.....
Oak on oak (parallel)	0.62	.....	0.48	0.16
Oak on oak (perpendicular)	0.54	.....	0.32	0.07
Rubber tire on pavement	0.8-0.9	0.6-0.7*	0.75-0.85	0.5-0.7*
Steel on ice	0.03	.....	0.01	.....
Steel, hard, on babbit	0.42-0.70	0.08-0.25	0.33-0.35	0.05-0.16
Steel, hard, on steel, hard	0.78	0.11-0.23	0.42	0.03-0.12
Steel, mild, on aluminum	0.61	.....	0.47	.....
Steel, mild, on brass	0.51	.....	0.44	.....
Steel, mild, on bronze	.....	.....	0.34	0.17
Steel, mild, on copper	0.53	.....	0.36	0.18
Steel, mild, on steel, mild	0.74	.....	0.57	0.09-0.19
Stone masonry on concrete	0.76	.....	.....	.....
Stone masonry on ground	0.65	.....	.....	.....
Wrought iron on bronze	0.19	0.07-0.08	0.18	.....
Wrought iron on wrought iron	.....	0.11	0.44	0.08-0.10

\* Wet pavement

**Table 34: U.S. Standard Sheet Metal Gages**

Gage No.	Thickness in Decimal Parts of an Inch	Gage No.	Thickness in Decimal Parts of an Inch
1	.2813	20	.0359
2	.2656	21	.0329
3	.2391	22	.0299
4	.2242	23	.0269
5	.2092	24	.0239
6	.1943	25	.0209
7	.1793	26	.0179
8	.1644	27	.0164
9	.1495	28	.0149
10	.1345	29	.0135
11	.1196	30	.0120
12	.1046	31	.0109
13	.0897	32	.0102
14	.0747	33	.0094
15	.0673	34	.0086
16	.0598	35	.0078
17	.0538	36	.0070
18	.0478	37	.0066
19	.0418	38	.0063

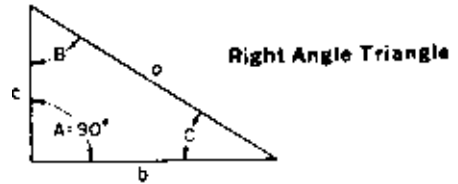
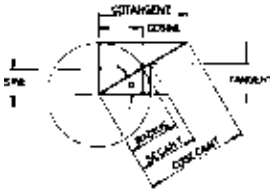
**Hardness Comparison Chart**



\* Shaded area indicates values may vary depending on type of ball used

▲ Example: A Brinell number of 245 is equal to 62 Rockwell "A", 100 Rockwell "B", 23 Rockwell "C", 37 Shore with a tensile of approximately 120,000 PSI.

## Trigonometric Formula



**Table 35: Formulas for Finding Functions of Angles**

Side opposite Hypotenuse	=	SINE
Side adjacent Hypotenuse	=	COSINE
Side opposite Side adjacent	=	TANGENT
Side adjacent Side opposite	=	COTANGENT
Hypotenuse Side adjacent	=	SECANT
Hypotenuse Side opposite	=	COSECANT

**Table 36: Formulas for Finding Sides of Right Angle Triangles with an Angle and Side Known**

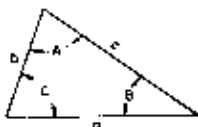
To find: Length of side opposite	$\left\{ \begin{array}{l} \text{Hypotenuse} \times \text{Sine} \\ \text{Hypotenuse} \div \text{Coscant} \\ \text{Side adjacent} \times \text{Tangent} \\ \text{Side adjacent} \div \text{Cotangent} \end{array} \right.$
To find: Length of side adjacent	
To find: Length of Hypotenuse	

**Table 37: To Find Angles and Sides of Right Angle Triangles**

To Find Angles			To Find Angles		
To Find:	Formulas	To Find:	Formulas	To Find:	Formulas
C	$\frac{c}{a}$	=	Sine C	a	$\sqrt{b^2 + c^2}$ ---
C	$\frac{b}{a}$	=	Cosine C	a	$c \times \text{Cosec. C}$ $\frac{c}{\text{Sine C}}$
C	$\frac{c}{b}$	=	Tan. C	a	$c \times \text{Secant B}$ $\frac{c}{\text{Cosine B}}$
C	$\frac{b}{c}$	=	Cotan C	a	$b \times \text{Cosec. B}$ $\frac{b}{\text{Sine B}}$
C	$\frac{a}{b}$	=	Secant C	a	$b \times \text{Secant C}$ $\frac{b}{\text{Cosine C}}$
C	$\frac{a}{c}$	=	Cosec. C	b	$\sqrt{a^2 - c^2}$ ---
B	$\frac{c}{a}$	=	Sine B	b	$a \times \text{Sine B}$ $\frac{a}{\text{Cosecant B}}$
B	$\frac{c}{a}$	=	Cosine B	b	$a \times \text{Cos. C}$ $\frac{a}{\text{Secant C}}$
B	$\frac{b}{c}$	=	Tan. B	b	$c \times \text{Tan. B}$ $\frac{c}{\text{Cotangent B}}$
B	$\frac{c}{d}$	=	Cotan. B	b	$c \times \text{Cot. C}$ $\frac{c}{\text{Tangent C}}$
B	$\frac{a}{c}$	=	Secant B	c	$\sqrt{a^2 - b^2}$ ---
B	$\frac{a}{b}$	=	Cosec. B	c	$a \times \text{Cos. B}$ $\frac{a}{\text{Secant B}}$
				c	$a \times \text{Sine C}$ $\frac{a}{\text{Cosecant C}}$
				c	$b \times \text{Cot. B}$ $\frac{b}{\text{Tangent B}}$
				c	$b \times \text{Tan. C}$ $\frac{b}{\text{Cotangent C}}$

**Table 38: To Find Angles and Sides of Oblique Angle Triangle**

Oblique Angle Triangle



To find:	Known	Formulas	To Find:	Known	Formulas
C	A, B	$180^\circ - (A + B)$	A	B, C	$180^\circ - (B + C)$
b	a, B, A	$\frac{a \times \text{Sin. B}}{\text{Sin. A}}$	Cos. A	a, b, c	$\frac{b^2 + c^2 - a^2}{2bc}$
c	a, A, C	$\frac{a \times \text{Sin. C}}{\text{Sin. A}}$	Sin. C	c, A, a	$\frac{c \times \text{Sin. A}}{a}$
Tan. A	a, C, b	$\frac{a \times \text{Sin. C}}{b - (a \times \text{Cos. C})}$	Cot. B	a, C, b	$\frac{a \times \text{Cosec. C}}{b}$
B	A, C	$180^\circ - (A + C)$	c	b, C, B	$b \times \text{Sin. C} \times \text{Cosec. B}$
Sin. B	b, A, a	$\frac{b \times \text{Sin. A}}{a}$	---	---	-----

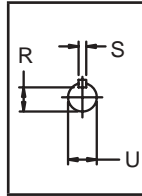
# ENGINEERING/TECHNICAL



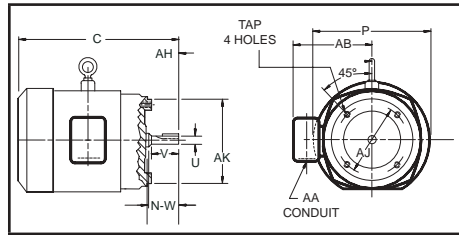
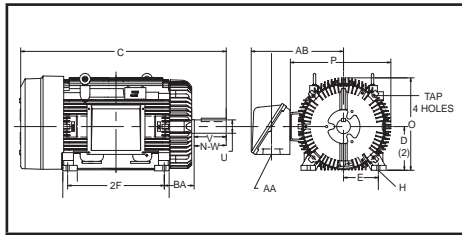
## NEMA QUICK REFERENCE CHART

- Dimensions are for reference only
- Drawings represent standard TEFC general purpose motors

Contact your local Rockwell Automation office or go to the Motor Information Cent at [222.reliance.com](http://222.reliance.com) for "C" dimensions



FRAME		NEMA SHAFT		KEYSEAT DIMENSIONS			FRAME		NEMA SHAFT		KEYSEAT DIMENSIONS		
		U	R	S				U	R	S			
48	48	1/2	29/64	FLAT	284T	286T	1-7/8	1-19/32	1/2				
56	56	5/8	33/64	3/16	324T	326T	2-1/8	1-27/32	1/2				
143T	145T	7/8	49/64	3/16	364T	365T	2-3/8	2-1/64	5/8				
182T	184T	1-1/8	63/64	1/4	404T	405T	2-7/8	2-29/64	3/4				
213T	215T	1-3/8	1-13/64	5/16	444T	445T	3-3/8	2-7/8	7/8				
254T	256T	1-5/8	1-13/32	3/8	447T	449T	3-3/8	2-7/8	7/8				

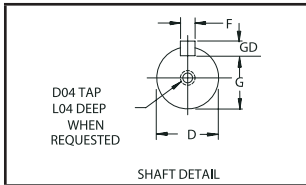
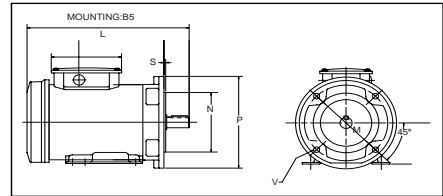
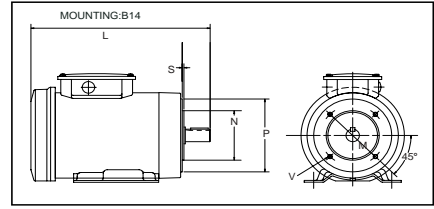
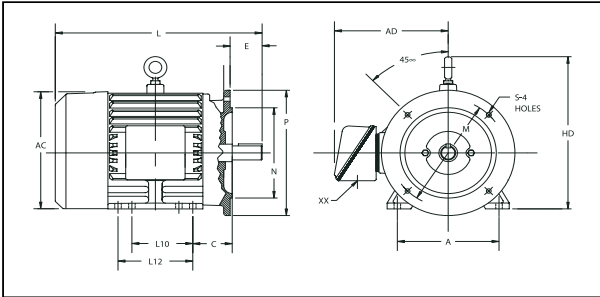


NEMA C-FACE	BA Dimensions
143TC - 145TC	2-3/4
182TC - 184 TC	3-1/2
213TC - 215TC	4-1/4
254TC-256TC	4-3/4

NEMA Frame	D	E	2F	H	N-W	O	P	U	Keyway	V	AA	AB	AH	AJ	AK	BA	Tap Size
48	3	2-1/8	2-3/4	11/32 SLOT	1-1/2	5-13/16	5-5/8	1/2		1-1/2	1/2	-	1-11/16	3-3/4	3	2-1/2	1/4-20
56	3-1/2	2-7/16	3	11/32	1-7/8	8-9/16	7-9/32	5/8	3/16x3/32	1-7/8	1/2	-	2-1/16	5-7/8	4-1/4	2-3/4	3/8-16
56H	3-1/2	2-7/16	5	SLOT	1-7/8	8-9/16	7-9/32	5/8	3/16x3/32	1-7/8	1/2	-	2-1/16	5-7/8	4-1/2	2-3/4	3/8-16
143T	3-1/2	2-7/16	4	11/32	2-1/4	8-9/16	7-9/32	7/8	3/16x3/32	2-1/4	3/4	-	2-1/8	5-7/8	4-1/2	2-1/4	3/8-16
145T	3-1/2	2-3/4	5	11/32	2-1/4	8-9/16	7-9/32	7/8	3/16x3/32	2-1/4	3/4	-	2-1/8	5-7/8	4-1/2	2-1/4	3/8-16
182	4-1/2	3-3/4	4-1/2	13/32	2-1/4	9-7/8	9-1/4	7/8	3/16x3/32	2-1/4	3/4	8-7/16	2-1/8	5-7/8	4-1/2	2-3/4	3/8-16
184	4-1/2	3-3/4	5-1/2	13/32	2-1/4	9-7/8	9-1/4	7/8	3/16x3/32	2-1/4	3/4	8-7/16	2-1/8	5-7/8	4-1/2	2-3/4	3/8-16
182T	4-1/2	3-3/4	4-1/2	13/32	2-3/4	9-7/8	9-1/4	1-1/8	1/4x1/8	2-3/4	3/4	7-13/16	2-5/8	7-1/4	8-1/2	2-3/4	1/2-13
184T	4-1/2	3-3/4	5-1/2	13/32	2-3/4	9-7/8	9-1/4	1-1/8	1/4x1/8	2-3/4	3/4	7-13/16	2-5/8	7-1/4	8-1/2	2-3/4	1/2-13
213	5-1/4	4-1/4	5-1/2	13/32	3	11-1/4	10-1/2	1-1/8	1/4x1/8	3	1	9-5/16	2-3/4	7-1/4	8-1/2	3-1/2	1/2-13
215	5-1/4	4-1/4	7	13/32	3	11-1/4	10-1/2	1-1/8	1/4x1/8	3	1	9-5/16	2-3/4	7-1/4	8-1/2	3-1/2	1/2-13
213T	5-1/4	4-1/4	5-1/2	13/32	3-3/8	11-1/4	10-1/2	1-3/8	5/16x5/32	3-3/8	1	8-11/16	3-1/8	7-1/4	8-1/2	3-1/2	1/2-13
215T	5-1/4	4-1/4	7	13/32	3-3/8	11-1/4	10-1/2	1-3/8	5/16x5/32	3-3/8	1	8-11/16	3-1/8	7-1/4	8-1/2	3-1/2	1/2-13
254U	6-1/4	5	8-1/4	17/32	3-3/4	13-1/4	13-1/4	1-3/8	5/16x5/32	3-3/4	1-1/4	10-13/16	3-1/2	7-1/4	8-1/2	4-1/4	1/2-13
256U	6-1/4	5	10	17/32	3-3/4	13-1/4	13-1/4	1-3/8	5/16x5/32	3-3/4	1-1/4	10-13/16	3-1/2	7-1/4	8-1/2	4-1/4	1/2-13
254T	6-1/4	5	8-1/4	17/32	4	13-1/4	13-1/4	1-5/8	3/8x3/16	4	1-1/4	10-3/4	3-3/4	7-1/4	8-1/2	4-1/4	1/2-13
256T	6-1/4	5	10	17/32	4	13-1/4	13-1/4	1-5/8	3/8x3/16	4	1-1/4	10-3/4	3-3/4	7-1/4	8-1/2	4-1/4	1/2-13
284U	7	5-1/2	9-1/2	17/32	4-7/8	14-3/4	14-7/8	1-5/8	3/8x3/16	4-7/8	1-1/2	12-5/8	4-5/8	9	10-1/2	4-3/4	1/2-13
286U	7	5-1/2	11	17/32	4-7/8	14-3/4	14-7/8	1-5/8	3/8x3/16	4-7/8	1-1/2	12-5/8	4-5/8	9	10-1/2	4-3/4	1/2-13
284T	7	5-1/2	9-1/2	17/32	4-5/8	14-3/4	14-7/8	1-7/8	1/2x1/4	4-5/8	1-1/2	12-3/4	4-3/8	9	10-1/2	4-3/4	1/2-13
286T	7	5-1/2	11	17/32	4-5/8	14-3/4	14-7/8	1-7/8	1/2x1/4	4-5/8	1-1/2	12-3/4	4-3/8	9	10-1/2	4-3/4	1/2-13
284TS	7	5-1/2	9-1/2	17/32	3-1/4	14-3/4	14-7/8	1-5/8	3/8x3/16	3-1/4	1-1/2	12-3/4	3	9	10-1/2	4-3/4	1/2-13
286TS	7	5-1/2	11	17/32	3-1/4	14-3/4	14-7/8	1-5/8	3/8x3/16	3-1/4	1-1/2	12-3/4	3	9	10-1/2	4-3/4	1/2-13
324U	8	6-1/4	10-1/2	21/32	5-5/8	16-11/16	17	1-7/8	1/2x1/4	5-5/8	2	15-7/16	5-3/8	11	12-1/2	5-1/4	5/8-11
326U	8	6-1/4	12	21/32	5-5/8	16-11/16	17	1-7/8	1/2x1/4	5-5/8	2	15-7/16	5-3/8	11	12-1/2	5-1/4	5/8-11
324T	8	6-1/4	10-1/2	21/32	5-1/4	16-11/16	17	2-1/8	1/2x1/4	5-1/4	2	15-3/16	5	11	12-1/2	5-1/4	5/8-11
326T	8	6-1/4	12	21/32	5-1/4	16-11/16	17	2-1/8	1/2x1/4	5-1/4	2	15-3/16	5	11	12-1/2	5-1/4	5/8-11
324TS	8	6-1/4	10-1/2	21/32	3-3/4	16-11/16	17	1-7/8	1/2x1/4	3-3/4	2	15-3/16	3-1/2	11	12-1/2	5-1/4	5/8-11
326TS	8	6-1/4	12	21/32	3-3/4	16-11/16	17	1-7/8	1/2x1/4	3-3/4	2	15-3/16	3-1/2	11	12-1/2	5-1/4	5/8-11
364U	9	7	11-1/4	21/32	6-3/8	18-1/2	19-1/2	2-1/8	1/2x1/4	6-3/8	2-1/2	18	6-1/8	11	12-1/2	5-7/8	5/8-11
365U	9	7	12-1/4	21/32	6-3/8	18-1/2	19-1/2	2-1/8	1/2x1/4	6-3/8	2-1/2	18	6-1/8	11	12-1/2	5-7/8	5/8-11
364T	9	7	11-1/4	21/32	5-7/8	18-1/2	19-1/2	2-3/8	5/8x5/16	5-7/8	2-1/2	18-1/16	5-5/8	11	12-1/2	5-7/8	5/8-11
365T	9	7	12-1/4	21/32	5-7/8	18-1/2	19-1/2	2-3/8	5/8x5/16	5-7/8	2-1/2	18-1/16	5-5/8	11	12-1/2	5-7/8	5/8-11
364TS	9	7	11-1/4	21/32	3-3/4	18-1/2	19-1/2	1-7/8	1/2x1/4	3-3/4	2-1/2	18-1/16	3-1/2	11	12-1/2	5-7/8	5/8-11
365TS	9	7	12-1/4	21/32	3-3/4	18-1/2	19-1/2	1-7/8	1/2x1/4	3-3/4	2-1/2	18-1/16	3-1/2	11	12-1/2	5-7/8	5/8-11
404U	10	8	12-1/4	13/16	7-1/8	21-5/16	22-1/2	2-3/8	5/8x5/16	7-1/8	3	19-1/4	6-7/8	11	12-1/2	6-5/8	5/8-11
405U	10	8	13-3/4	13/16	7-1/8	21-5/16	22-1/2	2-3/8	5/8x5/16	7-1/8	3	19-1/4	6-7/8	11	12-1/2	6-5/8	5/8-11
404T	10	8	12-1/4	13/16	7-1/4	21-5/16	22-1/2	2-7/8	3/4x3/8	7-1/4	3	19-5/16	7	11	12-1/2	6-5/8	5/8-11
405T	10	8	13-3/4	13/16	7-1/4	21-5/16	22-1/2	2-7/8	3/4x3/8	7-1/4	3	19-5/16	7	11	12-1/2	6-5/8	5/8-11
404TS	10	8	12-1/4	13/16	4-1/4	21-5/16	22-1/2	2-1/8	1/2x1/4	4-1/4	3	19-5/16	4	11	12-1/2	6-5/8	5/8-11
405TS	10	8	13-3/4	13/16	4-1/4	21-5/16	22-1/2	2-1/8	1/2x1/4	4-1/4	3	19-5/16	4	11	12-1/2	6-5/8	5/8-11
444U	11	9	14-1/2	13/16	8-5/8	23-3/8	25-1/4	2-7/8	3/4x3/8	8-5/8	3	22-3/16	8-3/8	14	16	7-1/2	5/8-11
445U	11	9	16-1/2	13/16	8-5/8	23-3/8	25-1/4	2-7/8	3/4x3/8	8-5/8	3	22-3/16	8-3/8	14	16	7-1/2	5/8-11
444T	11	9	14-1/2	13/16	8-1/2	23-3/8	25-1/4	3-3/8	7/8x7/16	8-1/2	3	23-3/8	8-1/4	14	16	7-1/2	5/8-11
445T	11	9	16-1/2	13/16	8-1/2	23-3/8	25-1/4	3-3/8	7/8x7/16	8-1/2	3	23-3/8	8-1/4	14	16	7-1/2	5/8-11
447T	11	9	20	13/16	8-1/2	23-5/8	26	3-3/8	7/8x7/16	8-1/2	3	23-7/8	8-1/4	14	16	7-1/2	5/8-11
449T	11	9	25	13/16	8-1/2	23-5/8	26	3-3/8	7/8x7/16	8-1/2	3	23-7/8	8-1/4	14	16	7-1/2	5/8-11
444TS	11	9	14-1/2	13/16	4-3/4	23-3/8	25-1/4	2-3/8	5/8x5/16	4-3/4	3	23-3/8	4-1/2	14	16	7-1/2	5/8-11
445TS	11	9	16-1/2	13/16	4-3/4	23-3/8	25-1/4	2-3/8	5/8x5/16	4-3/4	3	23-3/8	4-1/2	14	16	7-1/2	5/8-11
447TS	11	9	20	13/16	4-3/4	23-5/8	26	2-3/8	5/8x5/16	4-3/4	4 NPT	23-7/8	4-1/2	14	16	7-1/2	5/8-11
449TS	11	9	25	13/16	4-3/4	23-5/8	26	2-3/8	5/8x5/16	4-3/4	4 NPT	23-7/8	4-1/2	14	16	7-1/2	5/8-11

## IEC QUICK REFERENCE CHART

- Dimensins are for reference only
  - Drawings represent standard TEFC general purpose motors
- Contact your local Rockwell Automation office or go to the Motor Information Cent at [222.reliance.com](http://222.reliance.com) for "L" dimensions



KEY AND KEYSEAT DIMENSIONS										
FRAME	D	G	F	GD	FRAME	D	G	F	GD	
71	14	11	5	5	160	37	42	12	8	
80	19	15.5	6	6	180	48	42.5	14	9	
90	24	20	8	7	200	55	49	16	10	
100	28	24	8	7	225	60	53	18	11	
112	28	24	8	7	250	70	67.5	20	12	
132	38	33	10	8	280	80	71	22	14	

Frame	B3 RIGID BASE				SHAFT		B5 FLANGE					B14 FACE				GENERAL				
	A	L10	L12	HD	C	E	D	N	M	P	S	V	N	M	P	S	V	AC	AD	XX
71	-	-	-	-	-	-	-	110	130	160	"3,5"	"9,5"	70	85	105	2.5	M6	143	-	13
80	125	100	-	188	50	40	19	130	165	200	"3,5"	"11,5"	80	100	120	3	M6	143	-	13
90	140	100	125	208	56	50	24	130	165	200	"3,5"	"11,5"	95	115	140	3	M8	163	-	13
100	160	112	140	229	63	60	28	180	215	250	4	14	110	130	160	3.5	M8	175	-	19
112S	190	114	-	301.8	71.4	60	28	180	215	250	4	14	110	130	160	3.5	M8	243	210	32
112M	190	-	140	301.8	71.4	60	28	180	215	250	4	14	110	130	160	3.5	M8	243	210	32
132S	216	140	-	336.6	88.9	80	38	230	265	300	4	14	130	165	200	3.5	M8	286	243	32
132M	216	-	178	336.6	88.9	80	38	230	265	300	4	14	130	165	200	3.5	M8	286	243	32
160M	254	210	-	399	108	110	42	250	300	350	5	18	180	215	250	4	M12	324	320	40
160L	254	-	254	399	108	110	42	250	300	350	5	18	180	215	250	4	M12	324	320	40
180M	279	241	-	436	121	110	48	250	300	350	5	18	398	355	40			398	355	40
180L	279	-	279	436	121	110	48	250	300	350	5	18	398	355	40			398	355	40
200M	318	267	-	486	133	110	55	300	350	400	5	18	442	445	50			442	445	50
200L	318	-	305	486	133	110	55	300	350	400	5	18	442	445	50			442	445	50
225S	356	286	-	545	149	140	60	350	400	450	5	18	490	470	50			490	470	50
225M	356	-	311	545	149	140	60	350	400	450	5	18	490	470	50			490	470	50
250S	406	311	-	616	168	140	65											600	510	63
250M	406	-	349	616	168	140	65											600	535	63
280S	457	368	-	677	190	140	75											650	535	63
280M	457	-	419	677	190	140	75											650	535	63
280K	457	500	-	677	190	140	75											650	535	63
280H	457	630	-	677	190	140	75											650	535	63
L280H	457	635	-	677	202	205	75											650	535	63

# NOTES

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