A Brief Tutorial on Misalignment

The function of a coupling is to connect driving and driven equipment. In addition, a coupling serves to protect costly equipment from the effects of misalignment, shock loads, vibration and shaft end float. Of these factors, the most common is misalignment and end float (also known as axial misalignment).

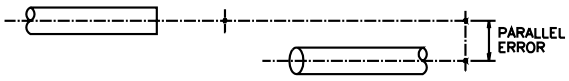
Misalignment is a condition created by two shafts whose axes are not in the same straight line. There are three forms of misalignment: parallel, angular, or the combination of the two. End float is the relative motion of two shaft ends.

Parallel misalignment occurs when the axes of the connected shafts are parallel, but not in the same straight line (fig. 1). Angular misalignment occurs when the axes of the shafts intersect at the center point of the coupling (fig. 2). End float occurs when one shaft moves along it's axis relative to the other shaft. (fig. 3)

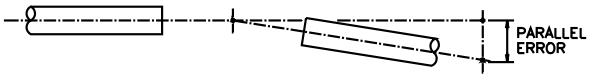
Misalignment can result from a combination of manufacturing tolerances, poor installation practices, thermal growth or shrinkage, foundation movement, and/or component wear. The combination of angular and parallel misalignment within a system may be more detrimental to the coupling and equipment than either of the individual misalignment. Axial misalignment- result of either thrust loads, reaction loads, or heat generated movement - compounds the problem. Understanding the amount of misalignment that the coupling must handle or installing a coupling where it exceeds a maximum rated misalignment can result in premature coupling failure and/or significant equipment damage.

Misalignment and Coupling Failure

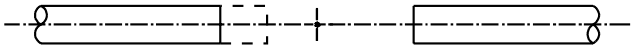
The life expectancy of a coupling is affected by the degree of misalignment. The larger the misalignment, the shorter the life of the coupling as shown in fig.5. Misalignment may causes heat generation, fatigue, and an increase in wear in bearings of the drive and driven components.



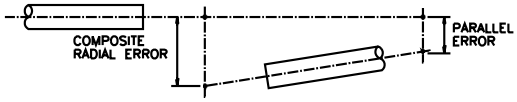
PARALLEL MISALIGNMENT
FIGURE 1



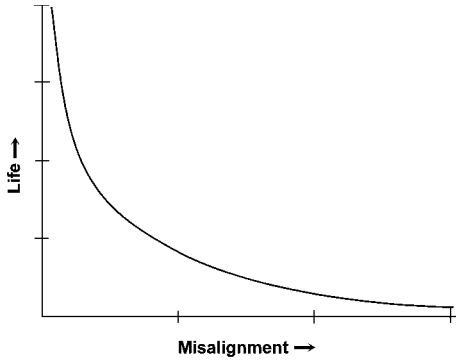
ANGULAR MISALIGNMENT
FIGURE 2



AXIAL MISALIGNMENT
FIGURE 3



COMPOSITE RADIAL MISALIGNMENT
FIGURE 4



LIFE VERSUS MISALIGNMENT
FIGURE 5

⚠ WARNING

You must refer to page iv for Important Safety Instructions and Precautions for the selection and use of these products. Failure to follow the instructions and precautions can result in severe injury or death.

When Misalignment Can Not be Measured

When it is not possible to measure the misalignment of a system, or in designing a new system, the following method can be used to estimate angular, parallel and combined misalignment. Each type of misalignment is first calculated and then the results are combined.

To calculate the maximum angular misalignment, the distance (L) and angle (α) must be known or estimated (see example below). First, calculate the angular misalignment noting the critical plane or midpoint of the shaft ends. Second, using the maximum parallel misalignment, be sure to consider both horizontal and vertical directions (Fig.3). Maximum parallel misalignment occurs when the shafts are diagonally opposed. Third, combine the results.

Worked example

Calculate the worst possible composite alignment misalignment when:

α_1 max = ±0.4°

α_2 max = ±0.4°

L max = 3 in.	L max = 75 mm (LH and RH shafts)
P_1 max = 0.008 in.	P_1 max = 0.2 mm
P_2 max = 0.008 in.	P_2 max = 0.2 mm

1. Worst possible angular misalignment (Fig. 1) = $\alpha_1 + \alpha_2$
   = 0.4° +0.4°
   = 0.8°
2. Maximum radial misalignment (Fig. 2) = $R_1 + R_2$
   Since α_1 and α_2 are equal, $R_1 = R_2$

Calculate for $2(R_1)$	= 2 (tan α_1 x L)
= 2 (tan α_1 x L)	= 2 (tan 0.4 x 75)
= 2 (tan 0.4 x 3)	= 2 (0.007 x 75)
= 2 (0.007 x 3)	= 1.05 mm
= 0.042 in.	

3. Maximum parallel misalignment P_3 (Fig. 3)= $\sqrt{P_1^2 + P_2^2}$

= $\sqrt{0.008^2 + 0.008^2}$	= $\sqrt{0.2^2 + 0.2^2}$
= 0.0113 inches	= 0.28 mm

4. Worst possible misalignment (Fig. 4) $R_C = R_1 + R_2 + P_3$

= 0.042 + 0.0113	= 1.05 + 0.28
= 0.0533 in.	= 1.33 mm

Note: How relatively minor angular misalignments can produce disproportionate radial misalignments. In this example, they account for approximately 80% of the worst possible composite misalignment.

Summary

Worst possible angular misalignment	= $\alpha_1 + \alpha_2$ (Fig. 1)
Maximum radial misalignment	= $R_1 + R_2$ (Fig. 2)
Maximum parallel misalignment $\sqrt{(P_1^2 + P_2^2)}$	= P_3 (Fig. 3)
Worst possible composite radial misalignment	$R_C = R_1 + R_2 + P_3$ (Fig. 4)

Figures 1 through 4 represent that $\alpha_1 = \alpha_2$ and $P_1 = P_2$, and that L is the same for LH and RH shafts.

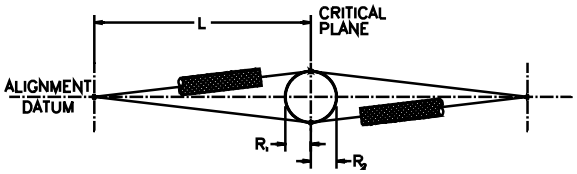


FIGURE 1

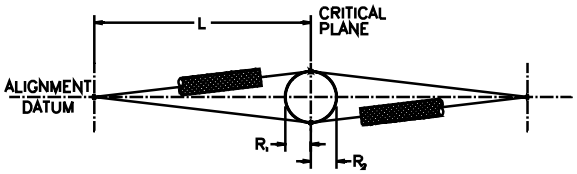


FIGURE 2

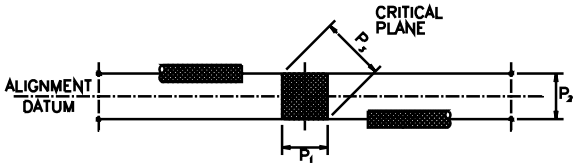


FIGURE 3

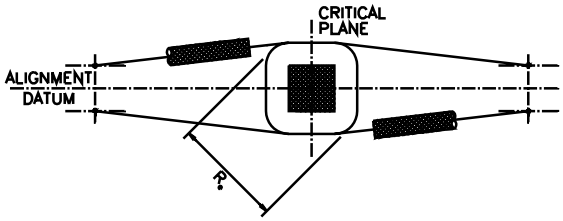


FIGURE 4

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Formulas and Equations

Horsepower

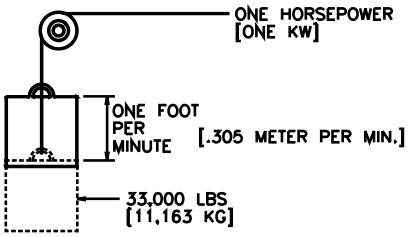
One HP is the rate of work required to raise 33,000 pounds one foot in one minute.

$$HP = \frac{\text{Force x FPM}}{33{,}000} \qquad HP = \frac{\text{Torque (in pound-inches) x RPM}}{63{,}025}$$

$$HP = \frac{\text{Torque (in pound-feet) x RPM}}{5{,}252}$$

FPM = Feet per minute

RPM = Revolutions per minute



Horsepower per Hundred RPM

When the HP is given and the RPM, N, is known, HP/C is:

$$HP/C = \frac{HP \times 100}{N}$$

Once HP/C is known, HP @ *N* RPM is found by HP=HP/C x N

Example:

15 HP @ 1750 RPM is:

$$HP/C = \frac{15 \times 100}{1750} = .85 \text{ HP per 100 RPM (HP/C)}$$

Using .85 HP/C, the HP rating @ 800 RPM is:

$$\frac{.85}{100} \times 800 = .85 \times 8 = 6.8 \text{ HP}$$

Kilowatts

One KW is the rate of work required to raise 11,163 kg 0.305 meter in one minute.

$$KW = \frac{Nm \times RPM}{9{,}550}$$

Torque

The twisting or turning effort around a shaft tending to cause rotation. Torque is determined by multiplying the applied force by the distance from the point where force is applied to the shaft center.

TQ = F (force) x R (radius)

Inch example:

20 HP at 100 RPM = 12,605 pound-inches Torque

$$\text{Torque (in-lb)} = \frac{63{,}025 \times HP}{RPM}$$

= Force x Lever Arm (in inches)

$$\text{Torque (ft-lb)} = \frac{5{,}252 \times HP}{RPM}$$

= Force x Lever Arm (in feet)

Force = Working load in pounds

Lever Arm = Distance from the force to the center of rotation in inches or feet.

Metric example:

10 KW at 100 RPM = 955 Nm:

$$\text{Torque (Nm)} = \frac{KW \times 9{,}550}{RPM}$$

Force = Working load in Newtons

Lever Arm = Distance from the Force to the center of rotation in millimeters.

Conversions

KW x 1.341 = HP
HP x 0.7457 = KW
Nm x 0.737562 = ft-lb
Nm x 8.85 = in-lb
ft-lb x 1.356 = Nm
in-lb x 0.113 = Nm
HP x 550 = ft-lb/sec

Formulas and Equations

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. These values should be compared with the load actually imposed by the connected drive.

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

F =
- 1.00 for single chain drives
- 1.10 for timing belt drives
- 1.25 for spur or helical gear or double chain drives
- 1.50 for V-belt drives
- 2.50 for flat belt drives

Inch 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 in.; service factor is 1.3.

Solution:

$$\text{O.H.L} = \frac{(63{,}025)\ (7 \times 1.3)\ (1.25)}{(30)\ (5)} = 4{,}779.4 \text{ lbs.}$$

$$\text{O.H.L.} = \frac{63{,}025 \times \text{HP} \times F}{N \times R}$$

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

Metric example:

Find the overhung load imposed on a reducer by a double chain drive transmitting 10 KW @ 30 RPM. The pitch diameter of the sprocket is 254 mm; service factor is 1.3.

Solution:

$$\text{O.H.L} = \frac{(376)\ (10 \times 1.3)\ (1.25)}{(30)\ (1.27)} = 160 \text{ N}$$

$$\text{O.H.L.} = \frac{376 \times \text{KW} \times F}{N \times R}$$

KW = Transmitted KW x service factor
N = RPM of shaft
R = Radius of sprocket, pulley, etc. (mm)
F = Factor

Formulas and Equations

Horsepower/Speed/Torque Relationships

HP	Speed (RPM)	Torque
Constant —	Increases ↑	Decreases ↓
Constant —	Decreases ↓	Increases ↑
Increases ↑	Constant —	Increases ↑
Decreases ↓	Constant —	Decreases ↓
Increases ↑	Increases ↑	Constant —
Decreases ↓	Decreases ↓	Constant —

Electrical Formulas

To Find	Alternating Current		To Find	Alternating or Direct Current
	Single-phase	Three-phase		
Amperes when horsepower is known	$\frac{HP \times 746}{E \times Eff \times pf}$	$\frac{HP \times 746}{1.73 \times E \times Eff \times pf}$	Amperes when voltage and resistance are known	$\frac{E}{R}$
Amperes when kilowatts are known	$\frac{KW \times 1{,}000}{E \times pf}$	$\frac{KW \times 1{,}000}{1.73 \times E \times pf}$	Voltage when resistance and current are known	IR
Amperes when Kva are known	$\frac{Kva \times 1{,}000}{E}$	$\frac{Kva \times 1{,}000}{1.73 \times E}$	Resistance when voltage and current are known	$\frac{E}{I}$
Kilowatts	$\frac{I \times E \times pf}{1{,}000}$	$\frac{1.73 \times I \times E \times pf}{1{,}000}$	**General Information (Approximation)** ***(All values at 100% load)*** At 1,800 RPM, a motor develops 36 in-lb per HP. At 1,200 RPM, a motor develops 54 in-lb per HP. At 575 volts, a three-phase motor draws 1 amp per HP. At 460 volts, a three-phase motor draws 1.25 amp per HP. At 230 volts, a three-phase motor draws 2.5 amp per HP. At 230 volts, a single-phase motor draws 5 amp per HP. At 115 volts, a single-phase motor draws 10 amp per HP. **Temperature conversion** Deg. C = (Deg. F - 32) x $^5/_9$ Deg. F = (Deg. C x $^9/_5$) + 32	
Kva	$\frac{I \times E}{1{,}000}$	$\frac{1.73 \times I \times E}{1{,}000}$		
Horsepower = (Output)	$\frac{I \times E \times Eff \times pf}{746}$	$\frac{1.73 \times I \times E \times Eff \times pf}{746}$		
I = Amperes; E = Volts; Eff = Efficiency; pf = power factor; Kva = Kilovolt amperes; KW = Kilowatts; R = Ohms				

Motor Amps @ Full Load[1]

HP	Alt. Current Single-Phase	Alt. Current Three-Phase	DC	HP	Alt. Current Single-Phase	Alt. Current Three-Phase	DC	HP	Alt. Current Single-Phase	Alt. Current Three-Phase	DC	HP	Alt. Current Single-Phase	Alt. Current Three-Phase	DC
$^1/_2$	4.9	2.0	2.7	5	28	14.4	20	25	—	60	92	75	—	180	268
1	8.0	3.4	4.8	$7^1/_2$	40	21.0	29	30	—	75	110	100	—	240	355
$1^1/_2$	10.0	4.8	6.6	10	50	26.0	38	40	—	100	146	125	—	300	443
2	12.0	6.2	8.5	15	—	38.0	56	50	—	120	180	150	—	360	534
3	17.0	8.6	12.5	20	—	50.0	74	60	—	150	215	200	—	480	712

Note: **1.** *Values are for all speeds and frequencies @ 230 volts.*

Amperage other than 230 volts can be figured:

$$V = \frac{230 \times Amp\ from\ Table}{New\ Voltage}$$

Example:

For 60 HP, three-phase @ 550 volts: $\frac{(230 \times 150)}{550} = 62$ *amps*

Power factor estimated @ 80 percent for most motors. Efficiency is usually 80 to 90 percent.

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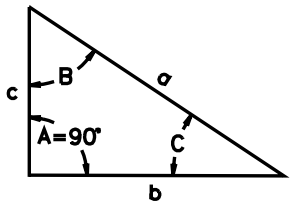
Trigonomic Formulas

Angles and sides of right angle triangles



To find angles

To find	Formulas
C	$\frac{c}{a}$ = Sine C
C	$\frac{b}{a}$ = Cosine C
C	$\frac{c}{b}$ = Tangent C
C	$\frac{b}{c}$ = Cotangent C
C	$\frac{a}{b}$ = Secant C
C	$\frac{a}{c}$ = Cosecant C
B	$\frac{b}{a}$ = Sine B
B	$\frac{c}{a}$ = Cosine B
B	$\frac{b}{c}$ = Tangent B
B	$\frac{c}{b}$ = Cotangent B
B	$\frac{a}{c}$ = Secant B
B	$\frac{a}{b}$ = Cosecant B

To find sides

To find	Formulas	
a	$\sqrt{b^2 + c^2}$	—
a	c x Cosecant C	$\frac{c}{\text{Sine C}}$
a	c x Secant B	$\frac{c}{\text{Cosine B}}$
a	b x Cosecant B	$\frac{b}{\text{Sine B}}$
a	b x Secant C	$\frac{b}{\text{Cosine C}}$
b	$\sqrt{a^2 - c^2}$	—
b	a x Sine B	$\frac{a}{\text{Cosecant B}}$
b	a x Cosine C	$\frac{a}{\text{Secant C}}$
b	c x Tangent B	$\frac{c}{\text{Cotangent B}}$
b	c x Cotangent C	$\frac{c}{\text{Tangent C}}$
c	$\sqrt{a^2 - b^2}$	—
c	a x Cosine B	$\frac{a}{\text{Secant B}}$
c	a x Sine C	$\frac{a}{\text{Cosecant C}}$
c	b x Cotangent B	$\frac{b}{\text{Tangent B}}$
c	b x Tangent C	$\frac{b}{\text{Cotangent C}}$

Formulas for finding functions of angles

$\frac{\text{Side opposite}}{\text{Hypotenuse}}$	= Sine
$\frac{\text{Side adjacent}}{\text{Hypotenuse}}$	= Cosine
$\frac{\text{Side opposite}}{\text{Side adjacent}}$	= Tangent
$\frac{\text{Side adjacent}}{\text{Side opposite}}$	= Cotangent
$\frac{\text{Hypotenuse}}{\text{Side adjacent}}$	= Secant
$\frac{\text{Hypotenuse}}{\text{Side opposite}}$	= Cosecant

Formulas for finding sides of right triangles with an angle and side known

To find length of opposite side	Hypotenuse x Sine Hypotenuse / Cosecant Side adjacent x Tangent Side adjacent / Cotangent
To find length of adjacent side	Hypotenuse x Cosine Hypotenuse / Secant Side opposite x Cotangent Side opposite / Tangent
To find length of hypotenuse	Side opposite x Cosecant Side opposite / Sine Side adjacent x Secant Side adjacent / cosine

Trigonomic Formulas

Triangle
Area = Base x $^1/_2$ perpendicular height

Sphere
Area of surface = Square of diameter x 3.1416
Volume = Cube of diameter x 0.5236

Cube
Area of surface = Square of side x 6
Volume = Cube of side
Diagonal = Side x 1.732

Cylinder
Area of curved surface = Diameter x length x 3.1416
Volume = Square of diameter x length x 0.7854

Cone
Area of curved surface = Base diameter x slant height x 1.5708
Volume = Base diameter squared x perpendicular height x 0.2618
(Or: Area of base x $^1/_3$ perpendicular height)

Circle
Area = Square of diameter x 0.7854 (Or: Square of radius x 3.1416)
Circumference = Diameter x 3.1416
Diameter = Circumference x 0.3183
Doubling diameter increases area four times; tripling diameter increases area nine times, etc.

Square
Area = Square of side
Diagonal = Side x 1.4142
Side = Diagonal x 0.7071

Square inscribed in circle
Side of square = Diameter of circle x 0.7071
(Or: Circumference of circle x 0.2251)
Diameter of circle = Side of square x 1.4142
Circumference of circle = Side of square x 4.4429

Square and circle with equal area
Side of square = Diameter of circle x 0.8862
Diameter of circle = Side of square x 1.128
Circumference of circle = Side of square x 3.545

Rectangle
Area = Length x width
Diagonal = Square root of width^2 + length^2

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Conversion Tables and Charts

Given	Multiply by	To find	Given	Multiply by	To find
Acres	43,560	Square feet	Cubic meter	1,000	Liter
Acres	4,046.8564	Square meters	Cubic yards	27	Cubic feet
Acres	1.562×10^{-3}	Square miles	Cubic yards	0.7645548	Cubic meter
Atmospheres	76	Cm of mercury	Cubic yards	201.974	Gallons (U.S.)
Atmospheres	33.89854	Feet of water	Cubic yards/minutes	0.45	Cubic feet/second
Atmospheres	29.92	Inches of mercury	Cubic yards/minutes	3.366234	Gallons (U.S.)/sec.
Atmospheres	14.69595	Pounds/square inch	Degree	0.017453	Radian
BTU	251.996	Calorie	Degree/second	0.166667	Revolution/minute
BTU	778.169	Foot-pounds-force	Fathom	6	Feet
BTU	3.9302×10^{-4}	Horsepower-hours	Feet of water	0.0295	Atmospheres
BTU	0.252	Kilogram-calories	Feet of water	0.8826	Inches of mercury
BTU	107.586	Kilogram-meters	Feet of water	304.8	Kilograms/sq. meter
BTU	2.9307×10^{-4}	Kilowatt-hours	Feet of water	62.43	Pounds/square foot
BTU	1,055.056	Joule	Feet of water	0.4335	Pounds/square inch
BTU / minutes	12.96	Foot-pounds/second	Feet/minute	0.508	Centimeter/second
BTU / minutes	0.0235809	Horsepower	Feet/minute	0.01667	Feet/second
BTU / minutes	0.0175843	Kilowatts	Feet/minute	0.01829	Kilometers/hour
BTU / minutes	17.5769	Watts	Feet/minute	0.3048	Meters/minute
Centimeters	0.3937008	Inches	Feet/minute	0.01136	Miles/hour
Centimeters	0.01	Meters	Feet/second	30.48	Centimeters/second
Centimeters	10	Millimeters	Feet/second	1.097	Kilometers/hour
Cm of mercury	0.01316	Atmospheres	Feet/second	0.5921	Knots
Cm of mercury	0.4461	Feet of water	Feet/second	18.29	Meters/minute
Cm of mercury	136	Kg/square meter	Feet/second	0.6818	Miles/hour
Cm of mercury	27.85	Pounds/square foot	Feet/second	0.01136	Miles/minute
Cm of mercury	0.1934	Pounds/square inch	Ferkin (U.S.)	9	Gallons (U.S.)
Coulomb	1	Ampere-second	Foot	30.48	Centimeter
Cubic centimeter	0.06102	Cubic inches	Foot	12	Inch
Cubic centimeter	0.001	Liter	Foot	0.3048	Meter
Cubic centimeter	1000	Cubic millimeter	Foot-pounds	1.356	NewtoNmeter
Cubic centimeter	0.0353	Cubic feet	Foot-pounds-force	1.286×10^{-3}	BTU
Cubic feet	1,728	Cubic inches	Foot-pounds-force	5.050×10^{-7}	Horsepower-hours
Cubic feet	0.0283168	Cubic meters	Foot-pounds-force	1.35582	Joules
Cubic feet	0.037037	Cubic yard	Foot-pounds-force	0.1383	Kilogram-meters
Cubic feet	6.228835	Gallons (British)	Foot-pounds-force	0.766×10^{-5}	Kilowatt-hours
Cubic feet	7.480519	Gallons (U.S.)	Foot-pounds/minute	1.286×10^{-3}	BTU/minute
Cubic feet	28.316847	Liters	Foot-pounds/minute	0.01667	Foot-pounds/second
Cubic feet	25.71405	Quarts (U.S. dry)	Foot-pounds/minute	3.03×10^{-4}	Horsepower
Cubic feet/hour	7.865791	Cubic cm/second	Foot-pounds/minute	2.26×10^{-5}	Kilowatts
Cubic feet/hour	0.4719474	Liter/minute	Foot-pounds/second	7.717×10^{-2}	BTU/minute
Cubic feet/minute	0.1246753	Gallons (U.S.)/sec.	Foot-pounds/second	1.818×10^{-3}	Horsepower
Cubic feet/pound	0.0624279	Cubic meter/kilogram	Foot-pounds/second	1.355818	Watts
Cubic meter	35.31467	Cubic feet	Gallon (British)	9.632619	Cubic feet/hour
Cubic meter	1.307951	Cubic yards	Gallon (British)	0.2727654	Cubic meter/hour
Cubic meter	264.1721	Gallons (U.S.)	Gallons (U.S.)/minute	8.020834	Cubic feet/hour

Conversion Tables and Charts

Given	Multiply by	To find	Given	Multiply by	To find
Gallons (U.S.)/minute	0.2271247	Cubic meter/hour	Inches of mercury	0.4912	Pounds/square inch
Gallon (dry)	268.8025	Cubic inch	Inches of water	0.002458	Atmospheres
Gallons (liquid)	3,785.412	Cubic centimeters	Inches of water	0.07355	Inches of mercury
Gallons (liquid)	0.1336805	Cubic feet	Inches of water	25.4	Kilograms/sq. meter
Gallons (liquid)	231	Cubic inches	Inches of water	0.5781	Ounces/square inch
Gallons (liquid)	4.951×10^{-3}	Cubic yards	Inches of water	5.202	Pounds/square foot
Gallons (liquid)	0.8326742	Gallons (British)	Inches of water	0.03613	Pounds/square inch
Gallons (liquid)	3.785412	Liters	Inch-pounds	0.11298	NewtoNmeters
Gallons (liquid)	8	Pints (liquid)	Joule	0.000948	BTU
Gallons (liquid)	4	Quarts (liquid)	Kilograms	9.81	Newtons
Gallons water	8.3453	Pounds of water	Kilograms	2.2046226	Pounds
Gallons water/minute	6.0086	Tons of water/24 hrs.	Kilograms	1.102×10^{-3}	Tons (short)
Gallons—Imperial	1.20095	Gallons—U.S.	Kilograms	10^{3}	Grams
Gallons—U.S.	0.83267	Gallons—Imperial	Kilograms-calories	3.968	BTU
Gallons (U.S.)/minute	2.228×10^{-3}	Cubic feet/second	Kilograms-calories	3086	Foot-pounds
Gallons (U.S.)/minute	8.020834	Cubic feet/hour	Kilograms-calories	1.558×10^{-3}	Horsepower-hours
Gallons (U.S.)/minute	0.06308	Liters/second	Kilograms-calories	1.162×10^{-3}	Kilowatt-hours
Grams	10^{-3}	Kilograms	Kilometers	3,280.84	Feet
Grams	0.0352739	Ounces	Kilometers	10^{3}	Meters
Grams	0.03215	Ounces (troy)	Kilometers	0.6213712	Miles
Grams	2.205×10^{-3}	Pounds	Kilometers	1,094	Yards
Grams (troy)	2.0833×10^{-3}	Ounces (troy)	Kilometers/hour	54.68	Feet/minute
Grams/centimeter	5.6×10^{-3}	Pounds/inch	Kilometers/hour	0.9113	Feet/second
Grams/cubic cm	62.43	Pounds/cubic foot	Kilometers/hour	0.53996	Knots
Grams/cubic cm	0.03613	Pounds/cubic inch	Kilometers/hour	16.67	Meters/minute
Grams/liter	8.345	Pounds/1,000 gallons	Kilometers/hour	0.6214	Miles/hour
Grams/liter	0.062427	Pounds/cubic foot	Killowatt-hours	3,415	BTU
Grams/liter	1,000	Parts/million	Killowatt-hours	2.655×10^{6}	Foot-pounds
Horsepower	42.4072	BTU/minute	Killowatt-hours	1.341	Horsepower-hours
Horsepower	33,000	Foot-pounds/minute	Killowatt-hours	3.6×10^{6}	Joule
Horsepower	550	Foot-pounds/second	Killowatt-hours	860.5	Kilogram-calories
Horsepower	1.014	Horsepower (metric)	Killowatt-hours	3.67×10^{5}	Kilogram-meters
Horsepower	0.7457	Kilowatts	Kilowatts	56.869	BTU/minute
Horsepower	745.7	Watts	Kilowatts	44,253.7	Foot-pounds/minute
Horsepower (boiler)	33,479	BTU/hour	Kilowatts	737.6	Foot-pounds/second
Horsepower (boiler)	9.8095	Kilowatt	Kilowatts	1.34102	Horsepower
Horsepower-hours	2,547	BTU	Kilowatts	14.3308	Kg-calories/minute
Horsepower-hours	1.98×10^{6}	Foot-pounds	Kilowatts	10^{3}	Watts
Horsepower-hours	2.737×10^{5}	Kilogram-meters	Knots	1.150779	Miles (statute)/hour
Horsepower-hours	0.7457	Kilowatt-hours	League (statute)	3	Miles (statute)
Inch	25.4	Millimeters	Light year	5.8785×10^{12}	Miles
Inches of mercury	0.03342	Atmospheres	Liters	10^{3}	Cubic centimeters
Inches of mercury	1.133	Feet of water	Liters	0.03531	Cubic feet
Inches of mercury	345.3	Kilograms/sq. meter	Liters	61.02	Cubic inches
Inches of mercury	70.73	Pounds/square foot	Liters	10^{-3}	Cubic meters

Conversion Tables and Charts

Given	Multiply by	To find
Liters	1.308×10^{-3}	Cubic yards
Liters	0.2642	Gallons
Liters	2.113	Pints (liquid)
Liters	0.908	Quarts (dry)
Liters	1.0567	Quarts (liquid)
Liters/minute	5.886×10^{-4}	Cubic feet/second
Liters/minute	13.19815	Gallons (British)/hour
Liters/minute	4.403×10^{-3}	Gallons/second
Liters/second	2.11888	Cubic feet/minute
Meters	100	Centimeters
Meters	3.2808399	Feet
Meters	39.37	Inches
Meters	10^{-3}	Kilometers
Meters	10^{3}	Millimeters
Meters	1.093613	Yards
Meters/minute	1.667	Centimeters/second
Meters/minute	3.281	Feet/minute
Meters/minute	0.05468	Feet/second
Meters/minute	0.06	Kilometers/hour
Meters/minute	0.03728	Miles/hour
Meters/second	3.281	Feet/second
Meters/second	3.6	Kilometers/hour
Meters/second	0.06	Kilometers/minute
Meters/second	2.236936	Miles/hour
Mil	0.001	Inch
Mil	0.0254	Millimeter
Miles	5,280	Feet
Miles	1.609	Kilometers
Miles	1,760	Yards
Miles/hour	44.7	Centimeters/second
Miles/hour	88	Feet/minute
Miles/hour	1.467	Feet/second
Miles/hour	0.86898	Knots
Miles/hour	26.82	Meters/minute
Miles/minute	2,682	Centimeters/second
Miles/minute	88	Feet/second
Miles/minute	1.609	Kilometers/minute
Milligrams	10^{-3}	Grams
Milligrams/liter	1	Parts/million
Milliliters	0.0610237	Cubic inch
Milliliters	0.0338142	Fluid ounces
Milliliters	10^{-3}	Liters
Millimeters	0.1	Cenitmeters
Millimeters	0.03937	Inches
Minutes (angle)	2.909×10^{-4}	Radians
NewtoNmeter	0.737562	Foot-pound-force
NewtoNmeter	8.85	Inch-pound-force
Newtons	0.22481	Pounds
Ounces	0.0625	Pounds
Ounces	28.349527	Grams
Ounces	0.9115	Ounces (troy)
Ounces	2.79×10^{-5}	Tons (long)
Ounces	2.835×10^{-5}	Tons (metric)
Ounces (fluid)	1.805	Cubic inches
Ounces (fluid)	0.02957	Liters
Ounces (fluid)	30	Milliliters
Ounces (fluid)	1.040843	Ounces (British fluid)
Ounces (troy)	0.08333	Pounds (troy)
Ounces (troy)	31.103481	Grams
Ounces (troy)	1.09714	Ounces (avoir)
Ounces/square inch	0.0625	Pounds/square inch
Parts/million	0.0584	Grains/U.S. gallon
Parts/million	0.07016	Grains/Imperial gal.
Parts/million	8.345	Pounds/million gal.
Pascal	0.0208854	Pounds-force/sq. ft.
Pounds	16	Ounces
Pounds	0.0005	Tons (short)
Pounds	453.5924	Grams
Pounds	1.21528	Pounds (troy)
Pounds	14.5833	Ounces (troy)
Pounds	4.45	Newtons
Pounds of water	0.01602	Cubic feet
Pounds of water	27.68	Cubic inches
Pounds of water	0.1198	Gallons
Pounds of water/min.	2.67×10^{-4}	Cubic feet/second
Pounds (troy)	12	Ounces (troy)
Pounds (troy)	373.24177	Grams
Pounds (troy)	0.822857	Pounds (avoir)
Pounds (troy)	13.1657	Ounces (avoir)
Pounds (troy)	3.6735×10^{-4}	Tons (long)
Pounds (troy)	4.1143×10^{-4}	Tons (short)
Pounds (troy)	4.1667×10^{-3}	Tons (metric)
Pounds/cubic foot	0.01602	Grams/cubic cm
Pounds/cubic foot	16.02	Kgs/cubic meter
Pounds/cubic foot	5.787×10^{-4}	Pounds/cubic inch
Pounds/cubic inch	27.68	Grams/cubic cm
Pounds/cubic inch	2.768×10^{4}	Kgs./cubic meter
Pounds/cubic inch	1,728	Pounds/cubic foot
Pounds/foot	1.488	Kilograms/meter
Pounds/inch	178.6	Grams/centimeter

Conversion Tables and Charts

Given	Multiply by	To find	Given	Multiply by	To find
Pounds/square foot	0.01602	Feet of water	Square meters	1.196	Square yards
Pounds/square foot	4.883	Kgs/square meter	Square miles	27.88×10^{6}	Square feet
Pounds/square foot	6.945×10^{-3}	Pounds/square inch	Square miles	2.59	Square kilometers
Pounds/square inch	0.068046	Atmospheres	Square miles	3.098×10^{6}	Square yards
Pounds/square inch	2.307	Feet of water	Square millimeters	0.01	Square centimeters
Pounds/square inch	2.03602	Inches of mercury	Square millimeters	1.55×10^{-3}	Square inches
Pounds/square inch	703.1	Kgs/square meter	Square yards	9	Square feet
Psi	1	Pound-force/sq. inch	Square yards	0.8361	Square meters
Quarts (dry)	67.200625	Cubic inches	Square yards	3.228×10^{-7}	Square miles
Quarts (dry)	1.101	Liters	Temp. (ºC+17.78)	1.8	Temperature (ºF)
Quarts (liquid)	57.75	Cubic inches	Temp. (ºF-32)	0.55556 ($^{5}/_{9}$)	Temperature (ºC)
Quarts (liquid)	0.9463	Liter	Therm	100,000	BTU
Quarts (liquid)	0.8326742	Quart (British)	Tons (long)	1,016.0469	Kilograms
Quarts (liquid)	0.859367	Quart (dry)	Tons (long)	1.016047	Tons (metric)
Radians	57.29578	Degrees	Tons (long)	2,240	Pounds
Radians	3,437.747	Minutes	Tons (long)	1.12	Tons (short)
Radians/second	57.3	Degrees/second	Tons (metric)	10^{3}	Kilograms
Radians/second	0.1592	Revolutions/second	Tons (metric)	2,205	Pounds
Radians/second	9.549297	Revolutions/minute	Tons (short)	2,000	Pounds
Revolutions	360	Degrees	Tons (short)	32,000	Ounces
Revolutions	6.283	Radians	Tons (short)	907.18486	Kilograms
Revolutions/minute	6	Degrees/second	Tons (short)	2,430.56	Pounds (troy)
Revolutions/minute	0.1047	Radians/second	Tons (short)	0.89287	Tons (long)
Revolutions/minute	0.01667	Revolutions/second	Tons (short)	29,166	Ounces (troy)
Revolutions/second	360	Degrees/second	Tons (short)	0.90718	Tons (metric)
Revolutions/second	6.283	Radians/second	Watts	0.05692	BTU/minutes
Revolutions/second	60	Revolutions/minute	Watts	44.26	Foot-pounds/minute
Square centimeters	10^{-4}	Square meters	Watts	0.7376	Foot-pounds/second
Square feet	144	Square inches	Watts	1.341×10^{-3}	Horsepower
Square feet	0.0929	Square meters	Watts	0.01434	Kg-calories/minute
Square feet	3.587×10^{-3}	Square miles	Watts	10^{-3}	Kilowatts
Square feet	0.11111 ($^{1}/_{9}$)	Square yards	Watts-hours	3.41214	BTU
Square inches	6.452	Square centimeters	Watts-hours	2,655	Foot-pounds-force
Square inches	6.944×10^{-3}	Square feet	Watts-hours	1.341×10^{-3}	Horsepower-hours
Square inches	645.2	Square millimeters	Watts-hours	3,600	Joules
Square kilometers	10.76×10^{6}	Square feet	Watts-hours	0.8605	Kilogram-calories
Square kilometers	10^{6}	Square meters	Watts-hours	367.1	Kilogram-meters
Square kilometers	0.3861	Square miles	Watts-hours	10^{-3}	Kilowatt-hours
Square kilometers	1.196×10^{6}	Square yards	Yards	36	Inches
Square meters	10.76	Square feet	Yards	0.9144	Meters
Square meters	3.861×10^{-7}	Square miles			

Conversion Tables and Charts

Inch-Millimeter Equivalents

Inches			Inches			Inches		
Fraction	Decimal	mm	Fraction	Decimal	mm	Fraction	Decimal	mm
	.00004	.001		.11811	3		.550	13.970
	.00039	.01	1/8	.1250	3.175		.55118	14
	.00079	.02		.13780	3.5	9/16	.56250	14.2875
	.001	.025	9/64	.14063	3.5719		.57087	14.5
	.00118	.03		.150	3.810	37/64	.57813	14.6844
	.00157	.04	5/32	.15625	3.9688		.59055	15
	.00197	.05		.15748	4	19/32	.59375	15.0812
	.002	.051	11/64	.17188	4.3656		.600	15.24
	.00236	.06		.1750	4.445	39/64	.60938	15.4781
	.00276	.07		.17717	4.5		.61024	15.5
	.003	.0762	3/16	.18750	4.7625	5/8	.6250	15.875
	.00315	.08		.19685	5		.62992	16
	.00354	.09		.20	5.08	41/64	.64063	16.2719
	.00394	.1	13/64	.20313	5.1594		.64961	16.5
	.004	.1016		.21654	5.5		.650	16.51
	.005	.1270	7/32	.21875	5.5562	21/32	.65625	16.6688
	.006	.1524		.2250	5.715		.66929	17
	.007	.1778	15/64	.23438	5.9531	43/64	.67188	17.0656
	.00787	.2		.23622	6	11/16	.68750	17.4625
	.008	.2032	1/4	.250	6.35		.68898	17.5
	.009	.2286					.700	17.78
	.00984	.25		.25591	6.5	45/64	.70313	17.8594
	.01	.254	17/64	.26563	6.7469		.70866	18
	.01181	.3		.275	6.985	23/32	.71875	18.2562
1/64	.01563	.3969		.27559	7		.72835	18.5
	.01575	.4	9/32	.28125	7.1438	47/64	.73438	18.6531
	.01969	.5		.29528	7.5		.74803	19
	.02	.508	19/64	.29688	7.5406	3/4	.750	19.050
	.02362	.6		.30	7.62			
	.025	.635	5/16	.3125	7.9375	49/64	.76563	19.4469
	.02756	.7		.31496	8		.76772	19.5
	.0295	.75	21/64	.32813	8.3344	25/32	.78125	19.8438
	.03	.762		.33465	8.5		.78740	20
1/32	.03125	.7938	11/32	.34375	8.7312	51/64	.79688	20.2406
	.0315	.8		.350	8.89		.800	20.320
	.03543	.9		.35433	9		.80709	20.5
	.03937	1	23/64	.35938	9.1281	13/16	.81250	20.6375
	.04	1.016		.37402	9.5		.82677	21
3/64	.04687	1.191	3/8	.375	9.525	53/64	.82813	21.0344
	.04724	1.2	25/64	.39063	9.9219	27/32	.84375	21.4312
	.05	1.27		.39370	10		.84646	21.5
	.05512	1.4		.400	10.16		.850	21.590
	.05906	1.5	13/32	.40625	10.3188	55/64	.85938	21.8281
	.06	1.524		.41339	10.5		.86614	22
1/16	.06250	1.5875	27/64	.42188	10.7156	7/8	.875	22.225
	.06299	1.6		.43307	11		.88583	22.5
	.06693	1.7	7/16	.43750	11.1125	57/64	.89063	22.6219
	.07	1.778		.450	11.430		.900	22.860
	.07087	1.8		.45276	11.5		.90551	23
	.075	1.905	29/64	.45313	11.5094	29/32	.90625	23.0188
5/64	.07813	1.9844	15/32	.46875	11.9062	59/64	.92188	23.4165
	.07874	2		.47244	12		.92520	23.5
	.08	2.032	31/64	.48438	12.3031	15/16	.93750	23.8125
	.08661	2.2		.49213	12.5		.94488	24
	.09	2.286	1/2	.50	12.7		.950	24.130
	.09055	2.3				61/64	.95313	24.2094
3/32	.09375	2.3812		.51181	13		.96457	24.5
	.09843	2.5	33/64	.51563	13.0969	31/32	.96875	24.6062
	.1	2.54	17/32	.53125	13.4938		.98425	25
	.10236	2.6		.53150	13.5	63/64	.98438	25.0031
7/64	.10937	2.7781	35/64	.54688	13.8906	1	1.00000	25.4

ED

Sleeve and Flexible Element Chemical Resistance Chart

Legend: A = Fluid has little or no effect; B = Fluid has minor to moderate effect; C = Fluid has severe effect; — = No data available

Resistance to:	NBR ("SOX")	Urethane	Hytrel	EPDM	Neoprene
Acetone	C	C	B	A	B
Ammonia Anhydrous	—	—	—	A	A
Ammonium Hydroxide Solutions	C	C	A	A	A (158ºF)
ASTM oil No. 1	A	A	A	C	A
ASTM oil No. 3	A	B	A	C	B-C (158ºF)
ASTM reference fuel A	A	A	A	C	B
ASTM reference fuel B	A	B	A	C	C
ASTM reference fuel C	B	C	B	C	C
Benzene	C	C	B	C	C
Butane	A	A	A	C	A
Carbon Tetrachloride	C	C	C	C	C
Chlorobenzene	C	C	C	C	C
Chloroform	C	C	C	C	C
Chromic Acid 10-50%	C	C	—	C	C
Dowtherm A or E solvent	—	—	—	C	C
Ethyl Alcohol	C	C	A	A	A (158ºF)
Ethylene Glyco	A	B	A	A	A (158ºF)
Fuel Oil	A	C	—	C	A
Gasoline	A	B	A	C	B
Glycerine	A	C	A	A	A
Hydraulic Oils (Petroleum Based)	A	A	A	C	A-B
Hydrochloric Acid, 37% (cold)	C	C	C	A	A-B
Hydrogen Peroxide, 90%	C	—	—	C	C
Isopropyl Alcohol	B	C	A	A	A-B
Kerosene	A	B	A	C	B-C
Lacquer Solvents (MEK)	C	C	C	C	C
Lubricating Oils	B	—	A	C	B
Methyl Alcohol	C	C	A	A	A
Mineral Oil	A	A	A	C	B
Naphtha	C	C	A	C	C
Nitric Acid, 10%	C	C	B	B	B
Nitrobenzene	C	C	C	C	C
Phenol	C	C	B	C	C
Phosphoric Acid, 20%	C	A	—	A	B
Phosphate Esters	—	—	A	C	C
Pickling Solution (20% Nitric Acid, 4% HP)	C	C	C	C	C
Soap Solutions	A	A	A	A	A(158ºF)
Sodium Hydroxide, 20%	B	B	A	A	B
Stearic Acid	B	A	A	B	B (158ºF)
Sulfuric Acid, up to 50%	C	C	A	B	A-B (158ºF)
Sulfuric Acid, 50% to 80%	C	C	C	B	B-C
Tannic Acid, 10%	A	—	A	A	A-B
Toluene	C	C	A	C	C
Trichloroethylene	C	C	B	C	C
Turpentine	A	C	—	C	C
Water	A	—	B (158ºF)	A (158ºF)	A (212ºF)
Xylene	C	C	B	C	C

Metric Clearance-fit Bore and Keyway Standards

Bore Tolerances per DIN 7154, H7; Keyway Tolerances per DIN 6885, Js9

Bore	Keyway	Height	Bore		Keyway		T	
mm	mm	mm	Min.	Max.	Min.	Max.	Min.	Max.
8	2	1	8.000	8.015	1.9875	2.0125	9.000	9.100
9	3	1.4	9.000	9.015	2.9875	3.0125	10.400	10.500
10	3	1.4	10.000	10.015	2.9875	3.0125	11.400	11.500
11	4	1.8	11.000	11.018	3.9850	4.0150	12.800	12.900
12	4	1.8	12.000	12.018	3.9850	4.0150	13.800	13.900
14	5	2.3	14.000	14.018	4.9850	5.0150	16.300	16.400
15	5	2.3	15.000	15.018	4.9850	5.0150	17.300	17.400
16	5	2.3	16.000	16.018	4.9850	5.0150	18.300	18.400
17	5	2.3	17.000	17.018	4.9850	5.0150	19.300	19.400
19	6	2.8	19.000	19.021	5.9850	6.0150	21.800	21.900
20	6	2.8	20.000	20.021	5.9850	6.0150	22.800	22.900
22	6	2.8	22.000	22.021	5.9850	6.0150	24.800	24.900
24	8	3.3	24.000	24.021	7.9820	8.0180	27.300	27.500
25	8	3.3	25.000	25.021	7.9820	8.0180	28.300	28.500
28	8	3.3	28.000	28.021	7.9820	8.0180	31.300	31.500
30	8	3.3	30.000	30.021	7.9820	8.0180	33.300	33.500
32	10	3.3	32.000	32.025	9.9820	10.0180	35.300	35.500
35	10	3.3	35.000	35.025	9.9820	10.0180	38.300	38.500
38	10	3.3	38.000	38.025	9.9820	10.0180	41.300	41.500
40	12	3.3	40.000	40.025	11.9785	12.0215	43.300	43.500
42	12	3.3	42.000	42.025	11.9785	12.0215	45.300	45.500
45	14	3.8	45.000	45.025	13.9785	14.0215	48.800	49.000
48	14	3.8	48.000	48.025	13.9785	14.0215	51.800	52.000
50	14	3.8	50.000	50.025	13.9785	14.0215	53.800	54.000
52	16	4.3	52.000	52.030	15.9785	16.0215	56.300	56.500
55	16	4.3	55.000	55.030	15.9785	16.0215	59.300	59.500
58	16	4.3	58.000	58.030	15.9785	16.0215	62.300	62.500
60	18	4.4	60.000	60.030	17.9785	18.0215	64.400	64.600
62	18	4.4	62.000	62.030	17.9785	18.0215	66.400	66.600
65	18	4.4	65.000	65.030	17.9785	18.0215	69.400	69.600
68	20	4.9	68.000	68.030	19.9740	20.0260	72.900	73.100
72	20	4.9	72.000	72.030	19.9740	20.0260	76.900	77.100
75	20	4.9	75.000	75.030	19.9740	20.0260	79.900	80.100
78	22	5.4	78.000	78.030	21.9740	22.0260	83.400	83.600
80	22	5.4	80.000	80.030	21.9740	22.0260	85.400	85.600
82	22	5.4	82.000	82.035	21.9740	22.0260	87.400	87.600
85	22	5.4	85.000	85.035	21.9740	22.0260	90.400	90.600
88	25	5.4	88.000	88.035	24.9740	25.0260	93.400	93.600
90	25	5.4	90.000	90.035	24.9740	25.0260	95.400	95.600
92	25	5.4	92.000	92.035	24.9740	25.0260	97.400	97.600
95	25	5.4	95.000	95.035	24.9740	25.0260	100.400	100.600
98	28	6.4	98.000	98.035	27.9740	28.0260	104.400	104.600
100	28	6.4	100.000	100.035	27.9740	28.0260	106.400	106.600
102	28	6.4	102.000	102.035	27.9740	28.0260	108.400	108.600
105	28	6.4	105.000	105.035	27.9740	28.0260	111.400	111.600
108	28	6.4	108.000	108.035	27.9740	28.0260	114.400	114.600
110	28	6.4	110.000	110.035	27.9740	28.0260	116.400	116.600

Metric Interference-fit Bore and Keyway Standards

Bore Tolerances per ISO R286, P7; Keyway Tolerances per DIN 6885, JS9

Bore	Keyway	Height	Bore		Keyway		T	
mm	mm	mm	Min.	Max.	Min.	Max.	Min.	Max.
10	3	1.4	9.976	9.989	2.9875	3.0125	11.400	11.500
11	4	1.8	10.971	10.991	3.9850	4.0150	12.800	12.900
12	4	1.8	11.971	11.989	3.9850	4.0150	13.800	13.900
14	5	2.3	13.971	13.989	4.9850	5.0150	16.300	16.400
16	5	2.3	15.971	15.989	4.9850	5.0150	18.300	18.400
18	6	2.8	17.971	17.989	5.9850	6.0150	20.800	20.900
20	6	2.8	19.965	19.986	5.9850	6.0150	22.800	22.900
22	6	2.8	21.965	21.986	5.9850	6.0150	24.800	24.900
25	8	3.3	24.965	24.986	7.9820	8.0180	28.300	28.500
28	8	3.3	27.965	27.986	7.9820	8.0180	31.300	31.500
30	8	3.3	29.965	29.986	7.9820	8.0180	33.300	33.500
35	10	3.3	34.958	34.983	9.9820	10.0180	38.300	38.500
40	12	3.3	39.958	39.983	11.9785	12.0215	43.300	43.500
45	14	3.8	44.958	44.983	13.9785	14.0215	48.800	49.000
50	14	3.8	49.958	49.983	13.9785	14.0215	53.800	54.000
55	16	4.3	54.949	54.979	15.9785	16.0215	59.300	59.500
60	18	4.4	59.949	59.979	17.9785	18.0215	64.400	64.600
70	20	4.9	69.949	69.979	19.9740	20.0260	74.900	75.100
80	22	5.4	79.949	79.979	21.9740	22.0260	85.400	85.600
90	25	5.4	89.941	89.976	24.9740	25.0260	95.400	95.600
100	28	6.4	99.941	99.976	27.9740	28.0260	106.400	106.600
110	28	6.4	109.941	109.976	27.9740	28.0260	116.400	116.600
120	32	7.4	119.941	119.976	31.9690	32.0310	127.400	127.600
140	36	8.4	139.932	139.972	35.9690	36.0310	148.400	148.700
160	40	9.4	159.932	159.972	39.9690	40.0310	169.400	169.700
180	45	10.4	179.932	179.972	44.9690	45.0310	190.400	190.700
200	45	10.4	199.921	199.967	44.9690	45.0310	210.400	210.700
220	50	11.4	219.921	219.967	49.9690	50.0310	231.400	231.700
250	56	12.4	249.921	249.967	55.9630	56.0370	262.400	262.700
280	63	12.4	279.912	279.964	62.9630	63.0370	292.400	292.700
300	70	14.4	299.912	299.964	69.9630	70.0370	314.400	314.700
350	80	15.4	349.902	349.959	79.9630	80.0370	365.400	365.700
400	90	17.4	399.902	399.959	89.9565	90.0435	417.400	417.700
450	100	19.5	449.892	449.955	99.9565	100.0435	469.500	469.800
500	100	19.5	499.892	499.955	99.9585	100.0435	519.500	519.800

U.S. Customary Clearance-fit Bore and Keyway Standards — Core Products

Bore and Keyway Tolerances per AGMA 9002-A86. Bore Tolerances per AGMA -9002-A86; Keyway tolerances per ANSI B17.1

Nominal bore diameter	Bore +0.001/-0.000	Keyway width +0.002/-0.000	Keyway height Reference	"T"-DIM +0.010/-0.000
3/8	0.3750	0.0938	0.0469	0.421
7/16	0.4375	0.0938	0.0469	0.484
1/2	0.5000	0.1250	0.0625	0.560
9/16	0.5625	0.1250	0.0625	0.623
5/8	0.6250	0.1875	0.0938	0.709
11/16	0.6875	0.1875	0.0938	0.773
3/4	0.7500	0.1875	0.0938	0.837
13/16	0.8125	0.1875	0.0938	0.900
7/8	0.8750	0.1875	0.0938	0.964
15/16	0.9375	0.2500	0.1250	1.051
1	1.0000	0.2500	0.1250	1.114
1 1/16	1.0625	0.2500	0.1250	1.178
1 1/8	1.1250	0.2500	0.1250	1.241
1 3/16	1.1875	0.2500	0.1250	1.304
1 1/4	1.2500	0.2500	0.1250	1.367
1 5/16	1.3125	0.3125	0.1563	1.455
1 3/8	1.3750	0.3125	0.1563	1.518
1 7/16	1.4375	0.3750	0.1875	1.605
1 1/2	1.5000	0.3750	0.1875	1.669
1 9/16	1.5625	0.3750	0.1875	1.732
1 5/8	1.6250	0.3750	0.1875	1.796
1 11/16	1.6875	0.3750	0.1875	1.859
1 3/4	1.7500	0.3750	0.1875	1.922
1 13/16	1.8125	0.5000	0.2500	2.032
1 7/8	1.8750	0.5000	0.2500	2.096
1 15/16	1.9375	0.5000	0.2500	2.160
2	2.0000	0.5000	0.2500	2.223
Nominal bore diameter	**Bore +0.0015/-0.000**	**Keyway width +0.002/0.000**	**Keyway height Reference**	**"T"-DIM +0.010/0.000**
2 1/16	2.0625	0.5000	0.2500	2.287
2 1/8	2.1250	0.5000	0.2500	2.350
2 3/16	2.1875	0.5000	0.2500	2.414
2 1/4	2.2500	0.5000	0.2500	2.477
Nominal bore diameter	**Bore +0.0015/-0.000**	**Keyway width +0.003/-0.000**	**Keyway height Reference**	**"T"-DIM +0.010/-0.000**
2 5/16	2.3125	0.625	0.3125	2.587
2 3/8	2.3750	0.625	0.3125	2.651
2 7/16	2.4375	0.625	0.3125	2.714
2 1/2	2.5000	0.625	0.3125	2.778
2 9/16	2.5625	0.625	0.3125	2.841
2 5/8	2.6250	0.625	0.3125	2.905
2 11/16	2.6875	0.625	0.3125	2.968
2 3/4	2.7500	0.625	0.3125	3.032
2 13/16	2.8125	0.7500	0.3750	3.142
2 7/8	2.8750	0.7500	0.3750	3.205

Nominal bore diameter	Bore +0.0015/-0.000	Keyway width +0.003/-0.000	Keyway height Reference	"T"-DIM +0.010/-0.000
2 15/16	2.9375	0.7500	0.3750	3.269
3	3.0000	0.7500	0.3750	3.332
3 1/16	3.0625	0.7500	0.3750	3.396
3 1/8	3.1250	0.7500	0.3750	3.459
3 3/16	3.1875	0.7500	0.3750	3.523
3 1/4	3.2500	0.7500	0.3750	3.586
3 5/16	3.3125	0.8750	0.4375	3.696
3 3/8	3.3750	0.8750	0.4375	3.760
3 7/16	3.4375	0.8750	0.4375	3.823
3 1/2	3.5000	0.8750	0.4375	3.887
3 9/16	3.5625	0.8750	0.4375	3.950
3 5/8	3.6250	0.8750	0.4375	4.014
3 11/16	3.6875	0.8750	0.4375	4.077
3 3/4	3.7500	0.8750	0.4375	4.141
3 13/16	3.8125	1.0000	0.5000	4.251
3 7/8	3.8750	1.0000	0.5000	4.314
3 15/16	3.9375	1.0000	0.5000	4.378
4	4.0000	1.0000	0.5000	4.441
Nominal bore diameter	**Bore +0.002/-0.000**	**Keyway width +0.003/-0.000**	**Keyway height Reference**	**"T"-DIM +0.010/-0.000**
4 1/16	4.0625	1.0000	0.5000	4.505
4 1/8	4.1250	1.0000	0.5000	4.568
4 3/16	4.1875	1.0000	0.5000	4.632
4 1/4	4.2500	1.0000	0.5000	4.695
4 5/16	4.3125	1.0000	0.5000	4.759
4 3/8	4.3750	1.0000	0.5000	4.822
4 7/16	4.4375	1.0000	0.5000	4.885
4 1/2	4.5000	1.0000	0.5000	4.949
Nominal bore diameter	**Bore +0.002/-0.000**	**Keyway width +0.004/-0.000**	**Keyway height Reference**	**"T"-DIM +0.010/-0.000**
4 9/16	4.5625	1.2500	0.6250	5.105
4 5/8	4.6250	1.2500	0.6250	5.169
4 11/16	4.6875	1.2500	0.6250	5.233
4 3/4	4.7500	1.2500	0.6250	5.296
4 13/16	4.8125	1.2500	0.6250	5.360
4 7/8	4.8750	1.2500	0.6250	5.424
4 15/16	4.9375	1.2500	0.6250	5.487
5	5.0000	1.2500	0.6250	5.551
5 1/16	5.0625	1.2500	0.6250	5.614
5 1/8	5.1250	1.2500	0.6250	5.678
5 3/16	5.1875	1.2500	0.6250	5.741
5 1/4	5.2500	1.2500	0.6250	5.805
5 5/16	5.3125	1.2500	0.6250	5.868
5 3/8	5.3750	1.2500	0.6250	5.931
5 7/16	5.4375	1.2500	0.6250	5.995
5 1/2	5.5000	1.2500	0.6250	6.058

Note: Check the Lovejoy price list for bores and keyways normally stocked at factory or warehouse.

U.S. Customary Interference-fit Bore and Keyway Standards

BORE AND KEYWAY TOLERANCES PER AGMA 9002-A86

Bore		Keyway size			Bore		Keyway size		
Nominal bore diameter	Actual AGMA interference fit	Nominal	Decimal		Nominal bore diameter	Actual AGMA interference fit	Nominal	Decimal	
1/2	0.499/0.4995	1/8 x 1/16	0.1250	0.0625	3 1/8	3.122/3.1235	3/4 x 3/8	0.7500	0.3750
5/8	0.624/0.6245	3/16 x 3/32	0.1875	0.0938	3 1/4	3.247/3.2485	3/4 x 3/8	0.7500	0.3750
3/4	0.749/0.7495	3/16 x 3/32	0.1875	0.0938	3 3/8	3.372/3.3735	7/8 x 7/16	0.8750	0.4375
7/8	0.874/0.8745	3/16 x 3/32	0.1875	0.0938	3 1/2	3.497/3.4985	7/8 x 7/16	0.8750	0.4375
1	0.999/0.9995	1/4 x 1/8	0.2500	0.1250	3 5/8	3.622/3.6235	7/8 x 7/16	0.8750	0.4375
1 1/8	1.124/1.1245	1/4 x 1/8	0.2500	0.1250	3 3/4	3.747/3.7485	7/8 x 7/16	0.8750	0.4375
1 1/4	1.249/1.2495	1/4 x 1/8	0.2500	0.1250	3 7/8	3.872/3.8735	1 x 1/2	1.0000	0.5000
1 3/8	1.374/1.3745	5/16 x 5/32	0.3125	0.1563	4	3.997/3.9985	1 x 1/2	1.0000	0.5000
1 1/2	1.499/1.4995	3/8 x 3/16	0.3750	0.1875	4 1/4	4.2465/4.248	1 x 1/2	1.0000	0.5000
1 5/8	1.623/1.624	3/8 x 3/16	0.3750	0.1875	4 1/2	4.4965/4.498	1 x 1/2	1.0000	0.5000
1 3/4	1.748/1.749	3/8 x 3/16	0.3750	0.1875	4 3/4	4.7465/4.748	1 1/4 x 5/8	1.2500	0.6250
1 7/8	1.873/1.874	1/2 x 1/4	0.5000	0.2500	5	4.9965/4.998	1 1/4 x 5/8	1.2500	0.6250
2	1.998/1.999	1/2 x 1/4	0.5000	0.2500	5 1/4	5.246/5.2475	1 1/4 x 5/8	1.2500	0.6250
2 1/8	2.123/2.124	1/2 x 1/4	0.5000	0.2500	5 1/2	5.496/5.4975	1 1/4 x 5/8	1.2500	0.6250
2 1/4	2.248/2.249	1/2 x 1/4	0.5000	0.2500	5 3/4	5.746/5.7475	1 1/2 x 3/4	1.5000	0.7500
2 3/8	2.373/2.374	5/8 x 5/16	0.625	0.3125	6	5.996/5.9975	1 1/2 x 3/4	1.5000	0.7500
2 1/2	2.498/2.499	5/8 x 5/16	0.625	0.3125	6 1/4	6.246/6.2475	1 1/2 x 3/4	1.5000	0.7500
2 5/8	2.623/2.624	5/8 x 5/16	0.625	0.3125	6 1/2	6.496/6.4975	1 1/2 x 3/4	1.5000	0.7500
2 3/4	2.748/2.749	5/8 x 5/16	0.625	0.3125	6 3/4	6.746/6.7475	1 3/4 x 3/4	1.7500	0.7500
2 7/8	2.873/2.874	3/4 x 3/8	0.7500	0.3750	7	6.996/6.9975	1 3/4 x 3/4	1.7500	0.7500
3	2.998/2.999	3/4 x 3/8	0.7500	0.3750					

Note: For shaft sizes 1/2″ through 6 1/2″, square keyways are preferred. For shaft sizes over 6 1/2″, rectangular keyways are preferred.

Shaft Diameter (inches)		Bore Dimensions	
Over	Thru	Nominal shaft diameter less:	Bore Tolerance
—	1 1/2	.001	+.0005-.000
1 1/2	3	.002	+.0010-.000
3	4	.003	+.0015-.000
4	5	.0035	+.0015-.000
5	7	.004	+.0015-.000
7	8	.005	+.002-.000
8	9	.0055	+.002-.000
9	12	.006 to .008	+.002-.000
12	20	.009 to .012	+.0025-.000

2 3/16 inch bore example:
Nominal shaft = 2.1875
less .002 + .001 bore
total = 2.1855/2.1865

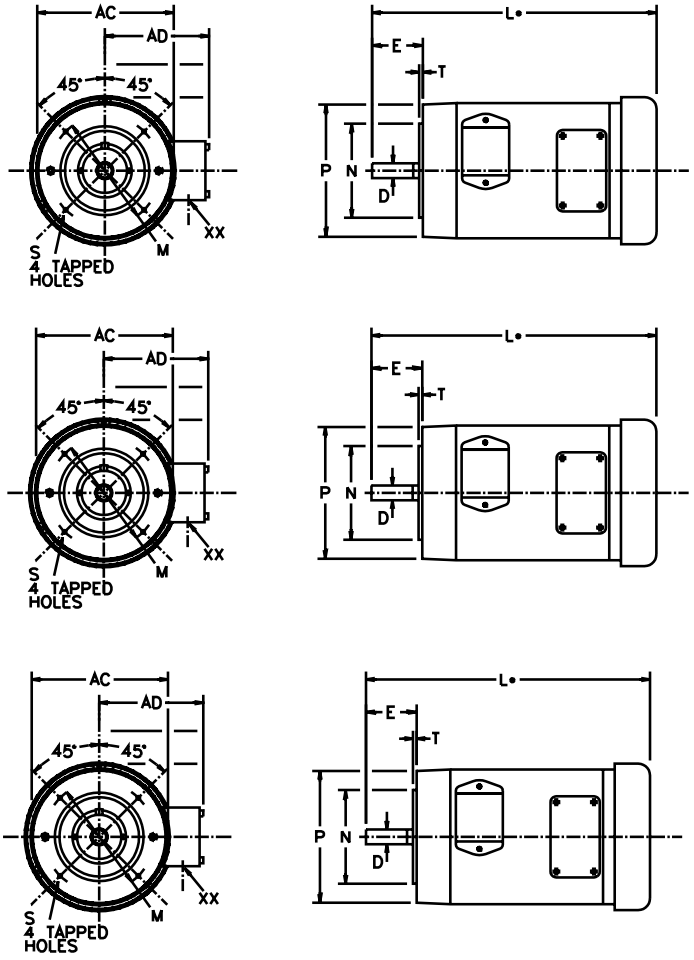
Notes: **1.** Consult Lovejoy when considering fits other than these.
2. Complies with AGMA 9002-A86 through 9-inch shaft diameter. There is no industry standard above that.

IEC Quick Reference Chart

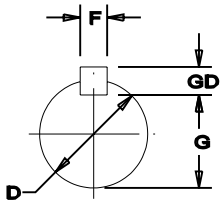
IEC Frame	Type	Foot Mounting				Shaft		B5 Flange						B14 Face					General					
			A	B	C	H		D	E	LA	M	N	P	S	T	M	N	P	S	T	L	AC	AD	HC	XX
63	300	**100** 3.937	**80** 3.150	**40** 1.570	**63** 2.480	**11** 0.433	**23** 0.906	**8** 0.313	**115** 4.528	**95** 3.740	**140** 5.512	**9** 0.354	**3** 0.118	**75** 2.953	**60** 2.362	**90** 3.540	M5	**2.5** 0.098	*	**119** 4.690	**102** 4 **116d** 4.567d	**121** 4.760 **136d** 5.375d	**13** 0.500 **22d** 0.880d
71	300 400	**112** 4.409	**90** 3.543	**45** 1.770	**71** 2.800	**14** 0.551	**30** 1.181	**8** 0.313	**130** 5.118	**110** 4.331	**160** 6.299	**10** 0.393	**3.5** 0.138	**85** 3.347	**70** 2.756	**105** 4.130	M6	**2.5** 0.098	*	**119** 4.690 **145d** 5.690d	**102** 4	**131** 5.140 **149d** 5.880d	**18** 0.690 **21d** 0.844d
80	400 500	**125** 4.921	**100** 3.937	**50** 1.969	**80** 3.150	**19** 0.748	**40** 1.575	**13** 0.500	**†165** 6.496	**130** 5.118	**200** 7.874	**11** 0.430	**3.5** 0.138	**100** 3.937	**80** 3.150	**120** 4.724	M6	**3** 0.118	*	**145** 5.690 **168d** 6.614d	**116** 4.510 **130** 5.120	**152** 6 **162d** 6.380d	**22** 0.880 **21d** 0.844d
90	S L	**140** 5.511	**100** 3.937 **125** 4.921	**56** 2.205	**90** 3.543	**24** 0.945	**50** 1.969	**13** 0.500	**165** 6.496	**130** 5.118	**200** 7.874	**12** 0.472	**3.5** 0.138	**115** 4.530	**95** 3.740	**140** 5.512	M8	**3** 0.118	*	**168** 6.614 **144d** 5.687d	**130** 5.120 **107d** 4.250d	**173** 6.810 **165d** 6.531d	**22** 0.880 **21d** 0.844d
100	S L	**160** 6.300	**112** 4.409 **140** 5.512	**63** 2.480	**100** 3.937	**28** 1.102	**60** 2.362	**14** 0.562	**215** 8.465	**180** 7.087	**250** 9.840	**14** 0.560	**4** 0.160	**130** 5.108	**110** 4.331	**160** 6.299	M8	**3.5** 0.138	*	**200** 7.875	**149** 5.875 **153d** 6.060d	**180** 7.906 **239d** 9.440d	**27** 1.062
112	S M	**190** 7.480	**114** 4.488 **140** 5.512	**70** 2.760	**112** 4.409	**28** 1.102	**60** 2.362	**14** 0.562	**215** 8.465	**180** 7.087	**250** 9.840	**14** 0.560	**4** 0.160	**130** 5.108	**110** 4.331	**160** 6.299	M8	**3.5** 0.138	*	**200** 7.875	**149** 5.875	**214** 8.437	**27** 1.062
132	S M	**216** 8.504	**140** 5.512 **178** 7.008	**89** 3.504	**132** 5.197	**38** 1.496	**80** 3.150	**14** 0.562	**265** 10.433	**230** 9.055	**300** 11.811	**14** 0.560	**4** 0.160	**165** 6.496	**130** 5.118	**200** 7.874	M8	**3.5** 0.138	*	**243** 9.562	**187** 7.375	**256** 10.062	**27** 1.062
160	M L	**254** 10	**210** 8.268 **254** 10	**108** 4.252	**160** 6.299	**42** 1.654	**110** 4.331	**20** 0.787	**300** 11.811	**250** 9.842	**350** 13.780	**19** 0.748	**5** 0.200	**215** 8.465	**180** 7.087	**250** 9.840	M12	**4** 0.160	*	**329** 12.940	**242** 9.510	**329** 12.940	**35** 1.375
180	M L	**279** 10.984	**241** 9.488 **279** 10.984	**121** 4.764	**180** 7.087	**48** 1.890	**110** 4.331	—	**300** 11.811	**250** 9.842	**350** 13.780	**19** 0.748	**5** 0.200	—	—	—	—	—	*	**395** 15.560	**333** 13.120	**372** 14.640	**51** 2.008
200	L M	**318** 12.520	**267** 10.512 **305** 12.008	**133** 5.236	**200** 7.874	**55** 2.165	**110** 4.331	—	**350** 13.780	**300** 11.811	**400** 15.748	**19** 0.748	—	—	—	—	—	—	*	**441** 17.375	**359** 14.125	**416** 16.375	**63** 2.500
225	S M	**356** 14.016	**286** 11.260 **311** 12.244	**149** 5.866	**225** 8.858	**60** 2.362	**140** 5.512	—	**400** 15.748	**350** 13.780	**450** 17.716	**19** 0.748	—	—	—	—	—	—	*	**495** 19.488	**383** 15.079	**483** 19.016	**63** 2.500
250	S M	**406** 15.984	**311** 12.244 **349** 13.740	**168** 6.614	**250** 9.843	**70** 2.756	**140** 5.512	—	—	—	—	—	—	—	—	—	—	—	*	**520** 20.472	**457** 17.992	**513** 20.197	**63** 2.500
280	S M	**457** 17.992	**368** 14.488 **419** 16.496	**190** 7.485	**280** 11.025	**80** 3.150	**170** 6.693	—	**LEGEND** **Metric dimensions (millimeters) in bold.** Inch dimensions in plain type. **d = DC Motors** **1 mm = 0.03937 inches** **1 inch = 25.40 mm**										*	**616** 24.252	**497** 19.567	**581** 22.874	**63** 2.500
315	S M	**508** 20	**406** 16 **457** 18	**216** 8.500	**315** 12.400	**85** 3.346	**170** 6.693	—											*	**759** 29.900	**683** 26.880	**682** 26.840	**102** 4
355	S L	**610** 24	**500** 19.690 **630** 24.800	**254** 10	**355** 13.980	**85** 3.346	**170** 6.693	—											*	**759** 29.900	**683** 26.880	**719** 28.320	**102** 4

Note: * indicates that this dimension varies depending upon manufacturer

IEC Motor Frame Dimensions



Key and Keyseat Dimensions				
Frame	D	G	F	GD
63	11	8.5	4	4
71	14	11	5	5
80	19	15.5	6	6
90	24	20	8	7
100	28	24	8	7
112	28	24	8	7
132	38	33	10	8
160	37	42	12	8
180	48	42.5	14	9
200	55	49	16	10
225	60	53	18	11
250	70	67.5	20	12
280	80	71	22	14
315	85	76	22	14
355	85	76	22	14



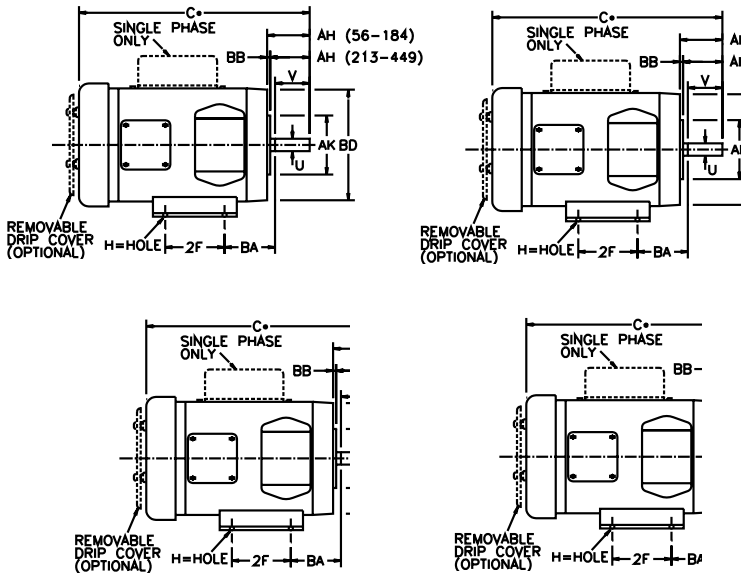
Note: Drawings represent standard TEFC general purpose motors. Dimensions are for reference only.

NEMA Quick Reference Chart—Inch

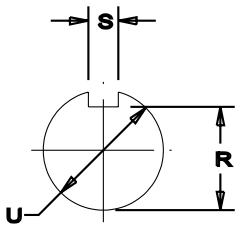
NEMA Frame	D	E	2F	H	N	O	P	U	V	AA	AB	AH	AJ	AK	BA	BB	BD	XO	TAP
42	2 5/8	1 3/4	1 11/16	9/32*	1 1/2	5	4 11/16	3/8	1 1/8	3/8	4 1/32	1 5/16	3 3/4	3	2 1/16	1/8	4 5/8	1 9/16	1/4-20
48	3	2 1/8	2 3/4	11/32*	1 7/8	5 7/8	5 11/16	1/2	1 1/2	1/2	4 3/8	1 11/16	3 3/4	3	2 1/2	1/8	5 5/8	2 1/4	1/4-20
56 56H	3 1/2	2 7/16	3 5	11/32*	2 7/16 2 1/8	6 7/8	6 5/8	5/8	1 7/8	1/2	5	2 1/16	5 7/8	4 1/2	2 3/4	1/8	6 1/2	2 1/4	3/8-16
143T 145T	3 1/2	2 3/4	4 5	11/32	2 1/2	6 7/8	6 5/8	7/8	2 1/4	3/4	5 1/4	2 1/8	5 7/8	4 1/2	2 1/4	1/8	6 1/2	2 1/4	3/8-16
182 184 182T 184T	4 1/2	3 3/4	4 1/2 5 1/2 4 1/2 5 1/2	13/32	2 11/16 2 11/16 3 9/16 3 9/16	8 11/16	7 7/8	7/8 7/8 1 1/8 1 1/8	2 1/4 2 1/4 2 3/4 2 3/4	3/4	5 7/8	2 1/8 2 1/8 2 5/8 2 5/8	5 7/8 5 7/8 7 1/4 7 1/4	4 1/2 4 1/2 8 1/2 8 1/2	2 3/4	1/8 1/8 1/4 1/4	6 1/2 6 1/2 9 9	2 3/8	3/8-16 3/8-16 1/2-13 1/2-13
213 215 213T 215T	5 1/4	4 1/4	5 1/2 7 5 1/2 7	13/32	3 1/2 3 1/2 3 7/8 3 7/8	10 1/4	9 9/16	1 1/8 1 1/8 1 3/8 1 3/8	3 3 3 3/8 3 3/8	3/4	7 3/8	2 3/4 2 3/4 3 1/8 3 1/8	8 1/2	8 1/2	3 1/2	1/4	9	2 3/4	1/2-13
254U 256U 254T 256T	6 1/4	5	5 1/8 10 8 1/8 10	17/32	4 1/16 4 1/16 4 5/16 4 5/16	12 7/8	12 15/16	1 3/8 1 3/8 1 5/8 1 5/8	3 3/4 3 3/4 4 4	1	9 5/8	3 1/2 3 1/2 3 3/4 3 3/4	7 1/4	8 1/2	4 1/4	1/4	10	—	1/2-13
284U 286U 284T 286T 284TS 286TS	7	5 1/2	9 1/2 11 9 1/2 11 9 1/2 11	17/32	5 1/8 5 1/8 4 7/8 4 7/8 3 3/8 3 3/8	14 5/8	14 5/8	1 5/8 1 5/8 1 7/8 1 7/8 1 5/8 1 5/8	4 7/8 4 7/8 4 5/8 4 5/8 3 1/4 3 1/4	1 1/2	13 1/8	4 5/8 4 5/8 4 3/8 4 3/8 3 3	9	10 1/2	4 3/4	1/4	11 1/4	—	1/2-13
324U 326U 324T 326T 324TS 326TS	8	6 1/4	10 1/2 12 10 1/2 12 10 1/2 12	21/32	5 7/8 5 7/8 5 1/2 5 1/2 3 15/16 3 15/16	16 1/2	16 1/2	1 7/8 1 7/8 2 1/8 2 1/8 1 7/8 1 7/8	5 5/8 5 5/8 5 1/4 5 1/4 3 3/4 3 3/4	2	14 1/8	5 3/8 5 3/8 5 5 3 1/2 3 1/2	11	12 1/2	5 1/4	1/4	13 3/8	—	5/8-11
364U 365U 364T 365T 364TS 365TS	9	7	11 1/4 12 1/4 11 1/4 12 1/4 11 1/4 12 1/4	21/32	6 3/4 6 3/4 6 1/4 6 1/4 4 4	18 1/2	18 1/4	2 1/8 2 1/8 2 3/8 2 3/8 1 7/8 1 7/8	6 3/8 6 3/8 5 7/8 5 7/8 3 3/4 3 3/4	2 1/2	15 1/16	6 1/8 6 1/8 5 5/8 5 5/8 3 1/2 3 1/2	11	12 1/2	5 7/8	1/4	13 3/8	—	5/8-11
404U 405U 404T 405T 404TS 405TS	10	8	12 1/4 13 3/4 12 1/4 13 3/4 12 1/4 13 3/4	13/16	7 3/16 7 3/16 7 5/16 7 5/16 4 1/2 4 1/2	20 5/16	20 1/8 22 3/8 22 3/8	2 3/8 2 3/8 2 7/8 2 7/8 2 1/8 2 1/8	7 1/8 7 1/8 7 1/4 7 1/4 4 1/4 4 1/4	3	18	6 7/8 6 7/8 7 7 4 4	11	12 1/2	6 5/8	1/4	13 7/8	—	5/8-11
444U 445U 444T 445T 447T 449T 444TS 445TS 447TS 449TS	11	9	14 1/2 16 1/2 14 1/2 16 1/2 20 25 14 1/2 16 1/2 20 25	13/16	8 5/8 8 5/8 8 1/2 8 1/2 8 15/16 8 15/16 5 3/16 5 3/16 4 15/16 4 15/16	22 7/8 22 7/8 22 7/8 22 7/8 22 15/16 22 15/16 22 7/8 22 7/8 22 15/16 22 15/16	22 3/8 22 3/8 23 3/8 23 3/8 22 3/8 22 3/8 23 3/4 23 3/4	2 7/8 2 7/8 3 3/8 3 3/8 3 3/8 3 3/8 2 3/8 2 3/8 2 3/8 2 3/8	8 5/8 8 5/8 8 1/2 8 1/2 8 1/2 8 1/2 4 3/4 4 3/4 4 3/4 4 3/4	3 4NPT 4NPT	19 9/16 19 9/16 19 9/16 19 9/16 21 11/16 21 11/16 19 9/16 19 9/16 21 11/16 21 11/16	8 3/8 8 3/8 8 1/4 8 1/4 8 1/4 8 1/4 4 1/2 4 1/2 4 1/2 4 1/2	14	16	7 1/2	1/4	16 3/4	—	5/8-11

Note: * indicates Slot

NEMA Motor Frame Dimensions



NEMA Shaft	Keyseat Dimensions	
U	R	S
3/8	21/64	FLAT
1/2	29/64	FLAT
5/8	33/64	3/16
7/8	49/64	3/16
1 1/8	63/64	1/4
1 3/8	1 13/64	5/16
1 5/8	1 13/32	3/8
1 7/8	1 19/32	1/2
2 1/8	1 27/32	1/2
2 3/8	2 1/64	5/8
2 1/2	2 3/16	5/8
2 7/8	2 29/64	3/4
3 3/8	2 7/8	7/8
3 7/8	3 5/16	1



NEMA C-Face	BA Dimensions
143-5TC	2 3/4
182-4TC	3 1/2
213-5TC	4 1/4
254-6TC	4 3/4

Note: Drawings represent standard TEFC general purpose motors. Dimensions are for reference only.

5000 Frame	D	E	2F	H	O	P	U	V	AA	AB	BA
5007S	12 1/2	10	22	15/16	26 27/32	30	2 1/2	6 1/2	4-NPT	26 7/8	8 1/2
5007L	12 1/2	10	22	15/16	26 27/32	30	3 7/8	11 1/8	4-NPT	26 7/8	8 1/2
5009S	12 1/2	10	28	15/16	26 27/32	30	2 1/2	6 1/2	4-NPT	26 7/8	8 1/2
5009L	12 1/2	10	28	15/16	26 27/32	30	3 7/8	11 1/8	4-NPT	26 7/8	8 1/2
5011S	12 1/2	10	36	15/16	26 27/32	30	2 1/2	6 1/2	4-NPT	26 7/8	8 1/2
5011L	12 1/2	10	36	15/16	26 27/32	30	3 7/8	11 1/8	4-NPT	26 7/8	8 1/2

Frames Prior to 1963

Frame	D	E	F	N	U	V	BA
66	4 1/8	2 15/16	2 1/2	2 1/4	3/4	2 1/4	3 1/8
203 204	5	4	2 3/4 3 1/4	2 7/16	3/4	2	3 1/8
224 225	5 1/2	4 1/2	3 3/8 3 3/4	3 1/4	1	3	3 1/2
254	6 1/4	5	4 1/8	3 7/16	1 1/8	3 3/8	4 1/4
284	7	5 1/2	4 3/4	4 1/4	1 1/4	3 3/4	4 3/4
324 326	8	6 1/4	5 1/4 6	5 3/8	1 5/8	4 7/8	5 1/4
364 365	9	7	5 5/8 6 1/8	5 5/8	1 78/83	5 3/8	5 7/8
404 405	10	8	6 1/8 6 7/8	6 3/8	2 1/8	6 1/8	6 5/8
444 445	11	9	7 1/4 8 1/4	7 1/8	2 3/8	6 7/8	7 1/2
504 505	12 1/2	10	8 9	8 5/8	2 7/8	8 3/8	8 1/2