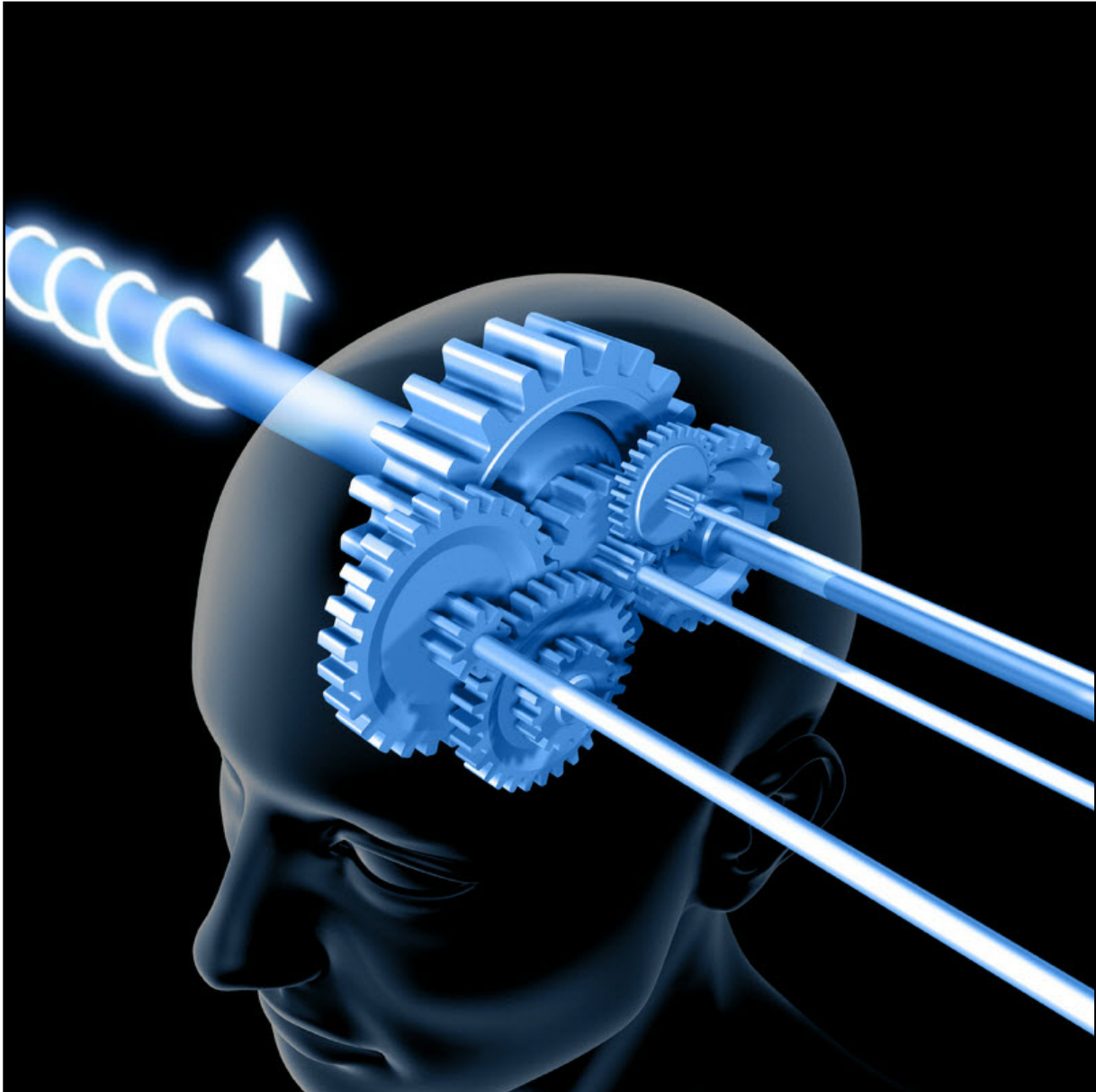




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## SPUR GEARS GEAR NOMENCLATURE

**ADDENDUM (a)** is the height by which a tooth projects beyond the pitch circle or pitch line.

**BASE DIAMETER ( $D_b$ )** is the diameter of the base cylinder from which the involute portion of a tooth profile is generated.

**BACKLASH (B)** is the amount by which the width of a tooth space exceeds the thickness of the engaging tooth on the pitch circles. As actually indicated by measuring devices, backlash may be determined variously in the transverse, normal, or axial-planes, and either in the direction of the pitch circles or on the line of action. Such measurements should be corrected to corresponding values on transverse pitch circles for general comparisons.

**BORE LENGTH** is the total length through a gear, sprocket, or coupling bore.

**CIRCULAR PITCH (p)** is the distance along the pitch circle or pitch line between corresponding profiles of adjacent teeth.

**CIRCULAR THICKNESS (t)** is the length of arc between the two sides of a gear tooth on the pitch circle, unless otherwise specified.

**CLEARANCE-OPERATING (c)** is the amount by which the dedendum in a given gear exceeds the addendum of its mating gear.

**CONTACT RATIO ( $m_c$ )** in general, the number of angular pitches through which a tooth surface rotates from the beginning to the end of contact.

**DEDENDUM (b)** is the depth of a tooth space below the pitch line. It is normally greater than the addendum of the mating gear to provide clearance.

**DIAMETRAL PITCH (P)** is the ratio of the number of teeth to the pitch diameter.

**FACE WIDTH (F)** is the length of the teeth in an axial plane.

**FILLET RADIUS ( $r_f$ )** is the radius of the fillet curve at the base of the gear tooth.

**FULL DEPTH TEETH** are those in which the working depth equals 2.000 divided by the normal diametral pitch.

**GEAR** is a machine part with gear teeth. When two gears run together, the one with the larger number of teeth is called the gear.

**HUB DIAMETER** is outside diameter of a gear, sprocket or coupling hub.

**HUB PROJECTION** is the distance the hub extends beyond the gear face.

**INVOLUTE TEETH** of spur gears, helical gears and worms are those in which the active portion of the profile in the transverse plane is the involute of a circle.

**LONG- AND SHORT-ADDENDUM TEETH** are those of engaging gears (on a standard designed center distance) one of which has a long addendum and the other has a short addendum.

**KEYWAY** is the machined groove running the length of the bore. A similar groove is machined in the shaft and a key fits into this opening.

**NORMAL DIAMETRAL PITCH ( $P_n$ )** is the value of the diametral pitch as calculated in the normal plane of a helical gear or worm.

**NORMAL PLANE** is the plane normal to the tooth surface at a pitch point and perpendicular to the pitch plane. For a helical gear this plane can be normal to one tooth at a point laying in the plane surface. At such point, the normal plane contains the line normal to the tooth surface and this is normal to the pitch circle.

**NORMAL PRESSURE ANGLE ( $\phi_n$ )** in a normal plane of helical tooth.

**OUTSIDE DIAMETER ( $D_o$ )** is the diameter of the addendum (outside) circle.

## SPUR GEARS GEAR NOMENCLATURE (Continued)

**PITCH CIRCLE** is the circle derived from a number of teeth and a specified diametral or circular pitch. Circle on which spacing or tooth profiles is established and from which the tooth proportions are constructed.

**PITCH CYLINDER** is the cylinder of diameter equal to the pitch circle.

**PINION** is a machine part with gear teeth. When two gears run together, the one with the smaller number of teeth is called the pinion.

**PITCH DIAMETER (D)** is the diameter of the pitch circle. In parallel shaft gears, the pitch diameters can be determined directly from the center distance and the number of teeth.

**PRESSURE ANGLE ( $\phi$ )** is the angle at a pitch point between the line of pressure which is normal to the tooth surface, and the plane tangent to the pitch surface. In involute teeth, pressure angle is often described also as the angle between the line of action and the line tangent to the pitch circle. Standard pressure angles are established in connection with standard gear-tooth proportions.

**ROOT DIAMETER (D<sub>r</sub>)** is the diameter at the base of the tooth space.

**PRESSURE ANGLE—OPERATING ( $\phi_r$ )** is determined by the center distance at which the gears operate. It is the pressure angle at the operating pitch diameter.

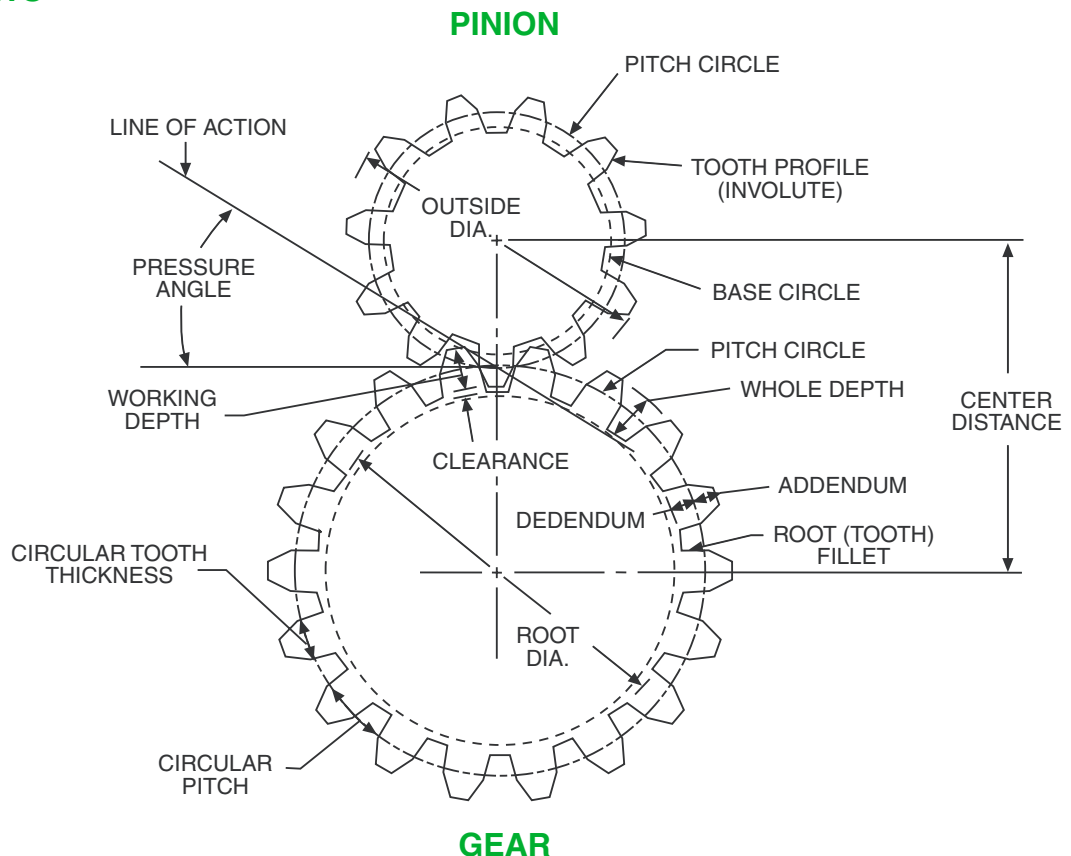
**TIP RELIEF** is an arbitrary modification of a tooth profile whereby a small amount of material is removed near the tip of the gear tooth.

**UNDERCUT** is a condition in generated gear teeth when any part of the fillet curve lies inside a line drawn tangent to the working profile at its point of juncture with the fillet.

**WHOLE DEPTH (h<sub>t</sub>)** is the total depth of a tooth space, equal to addendum plus dedendum, equal to the working depth plus variance.

**WORKING DEPTH (h<sub>k</sub>)** is the depth of engagement of two gears; that is, the sum of their addendums.

## TOOTH PARTS

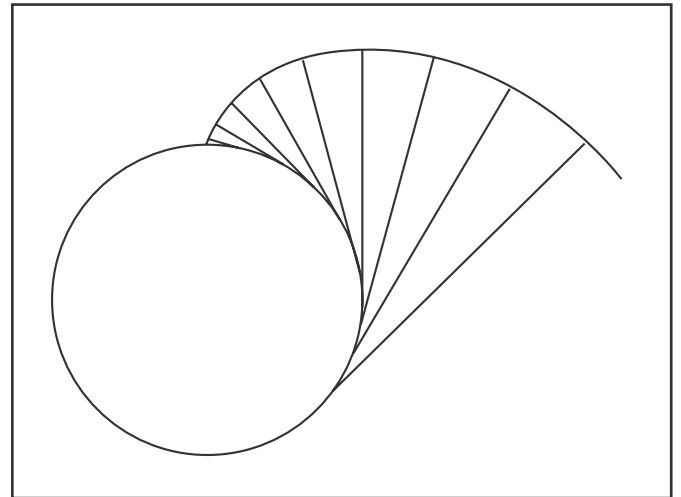
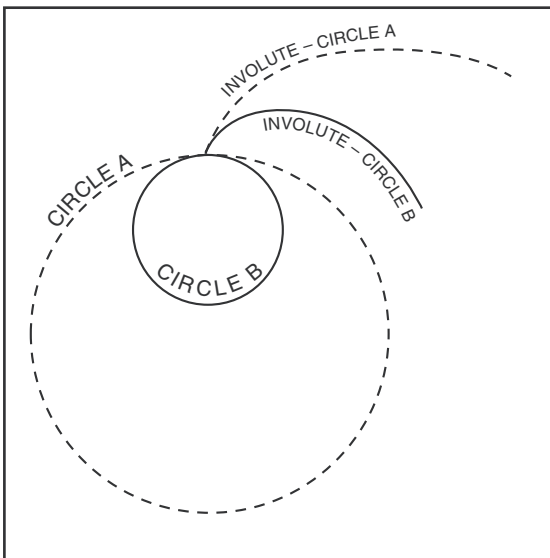


## SPUR GEARS INVOLUTE FORM

Gear teeth could be manufactured with a wide variety of shapes and profiles. The involute profile is the most commonly used system for gearing today, and all Beard and Fitch spur and helical gears are of involute form.

An involute is a curve that is traced by a point on a taut cord unwinding from a circle, which is called a **BASE CIRCLE**. The involute is a form of spiral, the curvature of which becomes straighter as it is drawn from a base circle and eventually would become a straight line if drawn far enough.

An involute drawn from a larger base circle will be less curved (straighter) than one drawn from a smaller base circle. Similarly, the involute tooth profile of smaller gears is considerably curved, on larger gears is less curved (straighter), and is straight on a rack, which is essentially an infinitely large gear.



Involute gear tooth forms and standard tooth proportions are specified in terms of a basic rack which has straight-sided teeth, for involute systems.



# SPUR GEARS

## DIAMETRAL PITCH SYSTEM

The diametral pitch of a gear is the number of teeth in the gear for each inch of pitch diameter. Therefore, the diametral pitch determines the size of the gear tooth.

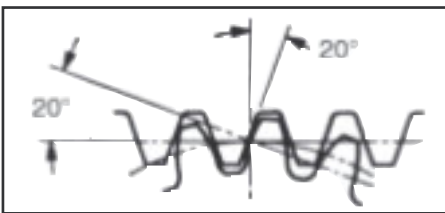
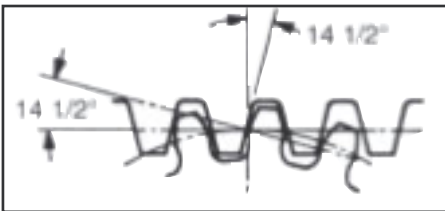
## MODULE PITCH SYSTEM

The module (Metric) pitch represents the amount of pitch diameter per tooth.

## PRESSURE ANGLE

Pressure angle is the angle at a pitch point between the line of pressure which is normal to the tooth surface, and the plane tangent to the pitch surface. The pressure angle, as defined in this document, refers to the angle when the gears are mounted on their standard centre distances.

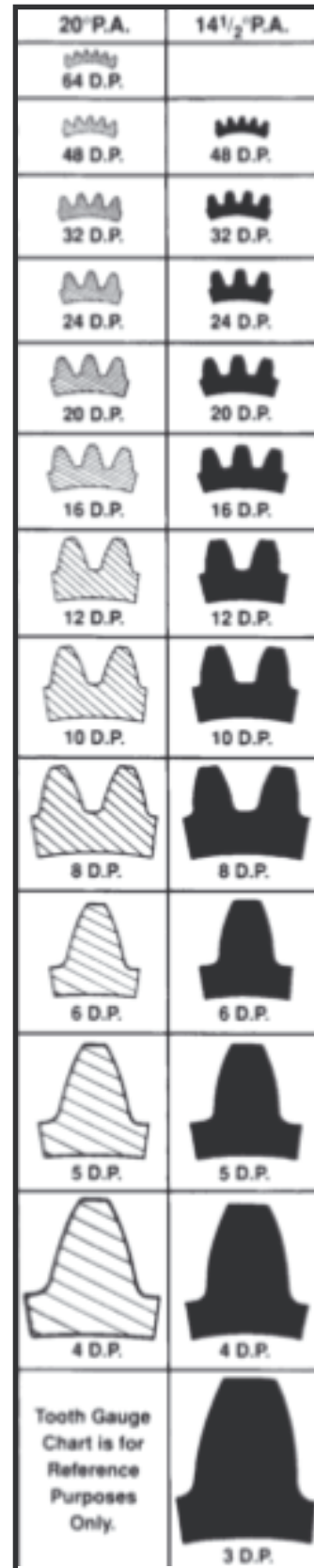
Beard and Fitch manufacture both 14-1/2° and 20° PA, involute, full depth system gears as well as other involute forms defined by our customers design needs. While 20°PA and greater are generally recognised as having higher load carrying capacity, 14-1/2°PA gears have extensive use. The lower pressure angle results in less change in backlash due to centre distance variation and concentricity errors. It also provides a higher contact ratio and consequent smoother, quieter operation provided that undercut of teeth is not present.



## TOOTH DIMENSIONS

For convenience, Tooth Proportions of various standard diametral pitches of Spur Gears are given below.

| Diametral Pitch | Circular Pitch (Inches) | Thickness of Tooth on Pitch Line (Inches) | Depth to be Cut in Gear (Inches) (Hobbed Gears) | Addendum (Inches) |
|-----------------|-------------------------|-------------------------------------------|-------------------------------------------------|-------------------|
| 3               | 1.0472                  | .5236                                     | .7190                                           | .3333             |
| 4               | .7854                   | .3927                                     | .5393                                           | .2500             |
| 5               | .6283                   | .3142                                     | .4314                                           | .2000             |
| 6               | .5236                   | .2618                                     | .3565                                           | .1667             |
| 8               | .3927                   | .1963                                     | .2696                                           | .1250             |
| 10              | .3142                   | .1571                                     | .2157                                           | .1000             |
| 12              | .2618                   | .1309                                     | .1798                                           | .0833             |
| 16              | .1963                   | .0982                                     | .1348                                           | .0625             |
| 20              | .1571                   | .0785                                     | .1120                                           | .0500             |
| 24              | .1309                   | .0654                                     | .0937                                           | .0417             |
| 32              | .0982                   | .0491                                     | .0708                                           | .0312             |
| 48              | .0654                   | .0327                                     | .0478                                           | .0208             |
| 64              | .0491                   | .0245                                     | .0364                                           | .0156             |



# SPUR GEARS

## BACKLASH

Spur gears that cut to operate at standard centre distances. The standard centre distance being defined by:

$$\text{Standard Centre Distance} = \frac{\text{Pinion PD} + \text{Gear PD}}{2}$$

When mounted at this centre distance, machine cut spur gears will have the following average backlash:

| Diametral Pitch | Backlash (Inches) | Diametral Pitch | Backlash (Inches) |
|-----------------|-------------------|-----------------|-------------------|
| 3               | .013              | 8-9             | .005              |
| 4               | .010              | 10-13           | .004              |
| 5               | .008              | 14-32           | .003              |
| 6               | .007              | 33-64           | .0025             |
| 7               | .006              |                 |                   |

An increase or decrease in centre distance will cause an increase or decrease in backlash.

Since, in practice, some deviation from the theoretical standard centre distance is inevitable and will alter the backlash, such deviation should be as small as possible. For most applications, it would be acceptable to limit the deviation to an increase over the nominal centre distance of one half the average backlash. Varying the centre distance may afford a practical means of varying the backlash to a limited extent.

The approximate relationship between centre distance and backlash change of 14-1/2° and 20° pressure angle gears is shown below:

For 14-1/2°—Change in Centre Distance = 1.933 x Change in Backlash  
 For 20° —Change in Centre Distance = 1.374 x Change in Backlash

From this, it is apparent that a given change in centre distance, 14-1/2° gears will have a smaller change in backlash than 20° gears. This fact should be considered in cases where backlash is critical.

## UNDERCUT

When the number of teeth in a gear is small, the tip of the mating gear tooth may interfere with the lower portion of the tooth profile. To prevent this, the generating process removes material at this point. This results in loss of a portion of the involute adjacent to the tooth base, reducing tooth contact and tooth strength.

On 14-1/2°PA gears undercutting occurs where a number of teeth is less than 32 and for 20°PA less than 18. Since this condition becomes more severe as tooth numbers decrease, it is recommended that the minimum number of teeth be 16 for 14-1/2°PA and 13 for 20°PA.

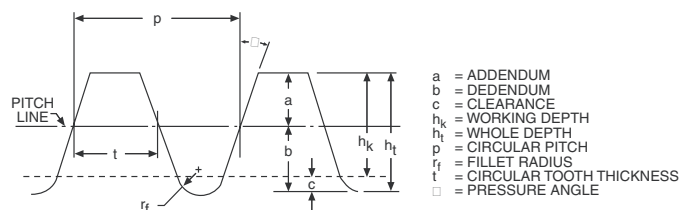
In a similar manner INTERNAL Spur Gear teeth may interfere when the pinion gear is too near the size of its mating internal gear. The following may be used as a guide to assure proper operation of the gear set. For 14-1/2°PA, the difference in tooth numbers between the gear and pinion should not be less than 15. For 20°PA the difference in tooth numbers should not be less than 12.

# SPUR GEAR FORMULAS

FOR FULL DEPTH INVOLUTE TEETH

| To Obtain                                        | Having                                                             | Formula                                                                                 |
|--------------------------------------------------|--------------------------------------------------------------------|-----------------------------------------------------------------------------------------|
| Diametral Pitch (P)                              | Circular Pitch (p)                                                 | $P = \frac{3.1416}{p}$                                                                  |
|                                                  | Number of Teeth (N) & Pitch Diameter (D)                           | $P = \frac{N}{D}$                                                                       |
|                                                  | Number of Teeth (N) & Outside Diameter (D <sub>o</sub> )           | $P = \frac{N+2}{D_o}$ (Approx.)                                                         |
| Circular Pitch (p)                               | Diametral Pitch (P)                                                | $p = \frac{3.1416}{P}$                                                                  |
| Pitch Diameter (D)                               | Number of Teeth (N) & Diametral Pitch (P)                          | $D = \frac{N}{P}$                                                                       |
|                                                  | Outside Diameter (D <sub>o</sub> ) & Diametral Pitch (P)           | $D = D_o - \frac{2}{P}$                                                                 |
| Base Diameter (D <sub>b</sub> )                  | Pitch Diameter (D) and Pressure Angle (φ)                          | $D_b = D \cos \phi$                                                                     |
| Number of Teeth (N)                              | Diametral Pitch (P) & Pitch Diameter (D)                           | $N = P \times D$                                                                        |
| Tooth Thickness (t) @ Pitch Diameter (D)         | Diametral Pitch (P)                                                | $t = \frac{1.5708}{P}$                                                                  |
| Addendum (a)                                     | Diametral Pitch (P)                                                | $a = \frac{1}{P}$                                                                       |
| Outside Diameter (D <sub>o</sub> )               | Pitch Diameter (D) & Addendum (a)                                  | $D_o = D + 2a$                                                                          |
| Whole Depth (h <sub>t</sub> ) (20P & Finer)      | Diametral Pitch (P)                                                | $h_t = \frac{2.2}{P} + .002$                                                            |
| Whole Depth (h <sub>t</sub> ) (Coarser than 20P) | Diametral Pitch (P)                                                | $h_t = \frac{2.157}{P}$                                                                 |
| Working Depth (h <sub>k</sub> )                  | Addendum (a)                                                       | $h_k = 2(a)$                                                                            |
| Clearance (c)                                    | Whole Depth (h <sub>t</sub> ) & Addendum (a)                       | $c = h_t - 2a$                                                                          |
| Deendum (b)                                      | Whole Depth (h <sub>t</sub> ) & Addendum (a)                       | $b = h_t - a$                                                                           |
| Contact Ratio (M <sub>c</sub> )                  | Outside Radii, Base Radii, Center Distance and Pressure Angle+C.P. | $M_c = \frac{\sqrt{R_o^2 - R_b^2} + \sqrt{r_o^2 - r_b^2} - C \sin \phi^*}{p \cos \phi}$ |
| Root Diameter (D <sub>r</sub> )                  | Pitch Diameter (D) and Deendum (b)                                 | $D_r = D - 2b$                                                                          |
| Center Distance (C)                              | Pitch Diameter (D) or No. of Teeth and Pitch                       | $C = \frac{D_1 + D_2}{2}$<br>or $\frac{N_1 + N_2}{2P}$                                  |

\*R<sub>o</sub> = Outside Radius, Gear  
 r<sub>o</sub> = Outside Radius, Pinion  
 R<sub>b</sub> = Base Circle Radius, Gear  
 r<sub>b</sub> = Base Circle Radius, Pinion



# SPUR GEARS

## LEWIS FORMULA (Barth Revision)

Gear failure can occur due to tooth breakage (tooth stress) or surface failure (surface durability) as a result of fatigue and wear. Strength is determined in terms of tooth-beam stresses for static and dynamic conditions, following well established formula and procedures. Satisfactory results may be obtained by the use of Barth's Revision to the Lewis Formula, which considers beam strength but not wear. The formula is satisfactory for commercial gears at Pitch Circle velocities of up to 1500 FPM.

### METALLIC SPUR GEARS

$$W = \frac{SFY}{P} \left( \frac{600}{600 + V} \right)$$

- W = Tooth Load, Lbs. (along the Pitch Line)
  - S = Safe Material Stress (static) Lbs. per Sq. In. (Table II)
  - F = Face Width, In.
  - Y = Tooth Form Factor (Table I)
  - P = Diametral Pitch
  - D = Pitch Diameter
  - V = Pitch Line Velocity, Ft. per Min. = .262 x D x RPM
- For NON-METALLIC GEARS, the modified Lewis Formula shown below may be used with (S) values of 6000 PSI for Phenolic Laminated material.

$$W = \frac{SFY}{P} \left( \frac{150}{200 + V} + .25 \right)$$

## TABLE II—VALUES OF SAFE STATIC STRESS (s)

| Material        | (s) Lb. per Sq. In.               |       |
|-----------------|-----------------------------------|-------|
| Plastic .....   | 5000                              |       |
| Bronze .....    | 10000                             |       |
| Cast Iron ..... | 12000                             |       |
| Steel {         | .20 Carbon (Untreated) .....      | 20000 |
|                 | .20 Carbon (Case-hardened) .....  | 25000 |
|                 | .40 Carbon (Untreated) .....      | 25000 |
|                 | .40 Carbon (Heat-treated) .....   | 30000 |
|                 | .40 C. Alloy (Heat-treated) ..... | 40000 |

Max. allowable torque (T) that should be imposed on a gear will be the safe tooth load (W) multiplied by  $\frac{D}{2}$  or  $T = \frac{W \times D}{2}$

The safe horsepower capacity of the gear (at a given RPM) can be calculated from  $HP = \frac{T \times RPM}{63,025}$  or directly from (W) and (V);

$$HP = \frac{WV}{33,000}$$

$$\text{For a known HP, } T = \frac{63025 \times HP}{RPM}$$

## TABLE I TOOTH FORM FACTOR (Y)

| Number of Teeth | 14-1/2° Full Depth Involute | 20° Full Depth Involute |
|-----------------|-----------------------------|-------------------------|
| 10              | 0.176                       | 0.201                   |
| 11              | 0.192                       | 0.226                   |
| 12              | 0.210                       | 0.245                   |
| 13              | 0.223                       | 0.264                   |
| 14              | 0.236                       | 0.276                   |
| 15              | 0.245                       | 0.289                   |
| 16              | 0.255                       | 0.295                   |
| 17              | 0.264                       | 0.302                   |
| 18              | 0.270                       | 0.308                   |
| 19              | 0.277                       | 0.314                   |
| 20              | 0.283                       | 0.320                   |
| 22              | 0.292                       | 0.330                   |
| 24              | 0.302                       | 0.337                   |
| 26              | 0.308                       | 0.344                   |
| 28              | 0.314                       | 0.352                   |
| 30              | 0.318                       | 0.358                   |
| 32              | 0.322                       | 0.364                   |
| 34              | 0.325                       | 0.370                   |
| 36              | 0.329                       | 0.377                   |
| 38              | 0.332                       | 0.383                   |
| 40              | 0.336                       | 0.389                   |
| 45              | 0.340                       | 0.399                   |
| 50              | 0.346                       | 0.408                   |
| 55              | 0.352                       | 0.415                   |
| 60              | 0.355                       | 0.421                   |
| 65              | 0.358                       | 0.425                   |
| 70              | 0.360                       | 0.429                   |
| 75              | 0.361                       | 0.433                   |
| 80              | 0.363                       | 0.436                   |
| 90              | 0.366                       | 0.442                   |
| 100             | 0.368                       | 0.446                   |
| 150             | 0.375                       | 0.458                   |
| 200             | 0.378                       | 0.463                   |
| 300             | 0.382                       | 0.471                   |
| Rack            | 0.390                       | 0.484                   |



# HELICAL GEARS

## HELIX ANGLE - —

### GEAR NOMENCLATURE

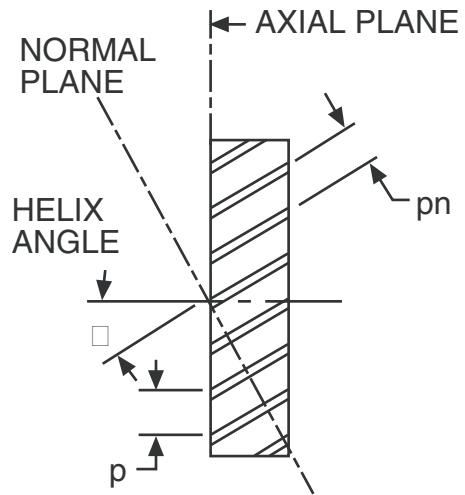
The information contained in the Spur Gear section is also pertinent to Helical Gears with the addition of the following:

**HELIX ANGLE ( $\phi$ )** is the angle between any helix and an element of its cylinder. In helical gears, it is at the pitch diameter unless otherwise specified.

**LEAD (L)** is the axial advance of a helix for one complete turn, as in the threads of cylindrical worms and teeth of helical gears.

**NORMAL DIAMETRAL PITCH ( $P_n$ )** is the Diametral Pitch as calculated in the normal plane.

**HAND** – Helical Gears of the same hand operate at right angles, see Fig. 1  
Helical Gears of opposite hands run on parallel shafts. Fig. 2



$p$  = AXIAL CIRCULAR PITCH  
 $p_n$  = NORMAL CIRCULAR PITCH

**INVOLUTE**—The Helical tooth form is involute in the plane of rotation and can be developed in a manner similar to that of the Spur Gear. However, unlike the Spur Gear, which may be viewed as two-dimensional, the Helical Gear must be viewed as three-dimensional to show change in axial features.

- Helical gears offer additional benefits relative to Spur Gears, those being:
- Improved tooth strength due to the elongated helical wrap-around.
  - Increased contact ratio due to the axial tooth overlap.
  - Helical Gears thus tend to have greater load carrying capacity than Spur Gears of similar size.
  - Due to the above, smoother operating characteristics are apparent.



TWO RIGHT-HAND HELICAL GEARS

TWO LEFT-HAND HELICAL GEARS

LEFT-HAND AND RIGHT-HAND HELICAL GEARS

Figure 1

Figure 2

LEFT HAND HELICAL GEAR

RIGHT HAND HELICAL GEAR



The teeth of a LEFT HAND Helical Gear lean to the left when the gear is placed flat on a horizontal surface.



The teeth of a RIGHT HAND Helical Gear lean to the right when the gear is placed flat on a horizontal surface.

# HELICAL GEARS

## HELICAL GEAR FORMULAS

| To Obtain                                  | Having                                                    | Formula                       |
|--------------------------------------------|-----------------------------------------------------------|-------------------------------|
| Transverse Diametral Pitch (P)             | Number of Teeth (N) & Pitch Diameter (D)                  | $P = \frac{N}{D}$             |
|                                            | Normal Diametral Pitch ( $P_N$ ) & Helix Angle ( $\phi$ ) | $P = P_N \cos \phi$           |
| Pitch Diameter (D)                         | Number of Teeth (N) & Transverse Diametral Pitch (P)      | $D = \frac{N}{P}$             |
| Normal Diametral Pitch ( $P_N$ )           | Transverse Diametral Pitch (P) & Helix Angle ( $\phi$ )   | $P_N = \frac{P}{\cos \phi}$   |
| Normal Circular Tooth Thickness ( $\phi$ ) | Normal Diametral Pitch ( $P_N$ )                          | $\phi = \frac{1.5708}{P_N}$   |
| Transverse Circular Pitch ( $p_t$ )        | Diametral Pitch (P) (Transverse)                          | $p_t = \frac{\phi}{P}$        |
| Normal Circular Pitch ( $p_n$ )            | Transverse Circular Pitch (p)                             | $p_n = p_t \cos \phi$         |
| Lead (L)                                   | Pitch Diameter and Pitch Helix Angle                      | $L = \frac{\pi D}{\tan \phi}$ |

## TRANSVERSE VS. NORMAL DIAMETRAL PITCH FOR 45° HELICAL GEARS

| P<br>Transverse<br>Diametral Pitch | $P_N$<br>Normal<br>Diametral Pitch |
|------------------------------------|------------------------------------|
| 24                                 | 33.94                              |
| 20                                 | 28.28                              |
| 16                                 | 22.63                              |
| 12                                 | 16.97                              |
| 10                                 | 14.14                              |
| 8                                  | 11.31                              |
| 6                                  | 8.48                               |

## HELICAL GEAR LEWIS FORMULA

The beam strength of Helical Gears operating on *parallel shafts* can be calculated with the Lewis Formula revised to compensate for the difference between Spur and Helical Gears, with modified Tooth Form Factors Y.

$$W = \frac{SFY}{P_N} \left( \frac{600}{600 + V} \right)$$

W = Tooth Load, Lbs. (along the Pitch Line)

S = Safe Material Stress (static) Lbs. per Sq. In. (Table III)

F = Face Width, Inches

Y = Tooth Form Factor (Table IV)

$P_N$  = Normal Diametral Pitch

(Refer to Conversion Chart)

D = Pitch Diameter

V = Pitch Line Velocity, Ft. Per Min. = .262 x D x RPM

## TABLE III—VALUES OF SAFE STATIC STRESS (S)

| Material  | (s) Lb. per Sq. In.         |       |
|-----------|-----------------------------|-------|
| Bronze    | 10000                       |       |
| Cast Iron | 12000                       |       |
| Steel     | .20 Carbon (Untreated)      | 20000 |
|           | .20 Carbon (Case-hardened)  | 25000 |
|           | .40 Carbon (Untreated)      | 25000 |
|           | .40 Carbon (Heat-treated)   | 30000 |
|           | .40 C. Alloy (Heat-treated) | 40000 |

## TABLE IV—VALUES OF TOOTH FORM FACTOR (Y)

| FOR 14-1/2° PA—45° HELIX ANGLE GEAR |          |              |          |
|-------------------------------------|----------|--------------|----------|
| No. of Teeth                        | Factor Y | No. of Teeth | Factor Y |
| 8                                   | .295     | 25           | .361     |
| 9                                   | .305     | 30           | .364     |
| 10                                  | .314     | 32           | .365     |
| 12                                  | .327     | 36           | .367     |
| 15                                  | .339     | 40           | .370     |
| 16                                  | .342     | 48           | .372     |
| 18                                  | .345     | 50           | .373     |
| 20                                  | .352     | 60           | .374     |
| 24                                  | .358     | 72           | .377     |

## HORSEPOWER AND TORQUE

Max. allowable torque (T) that should be imposed on a gear will be the safe tooth load (W) multiplied by  $\frac{D}{2}$  or  $T = \frac{W \times D}{2}$

The safe horsepower capacity of the gear (at a given RPM) can be calculated from  $HP = \frac{T \times RPM}{63,025}$  or directly from (W) and (V);

$$HP = \frac{WV}{33,000}$$

$$\text{For a known HP, } T = \frac{63025 \times HP}{RPM}$$

## HELICAL GEARS

When Helical gears are operated on other than Parallel shafts, the tooth load is concentrated at a point, with the result that very small loads produce very high pressures. The sliding velocity is usually quite high and, combined with the concentrated pressure, may cause galling or excessive wear, especially if the teeth are not well lubricated. For these reasons, the tooth load which may be applied to such drives is very limited and of uncertain value, and is perhaps best determined by trial under actual operating conditions. If one of the gears is made of bronze, the contact area and thereby the load carrying capacity, may be increased, by allowing the gears to "run in" in their operating position, under loads which gradually increase to the maximum expected.

## THRUST LOADS

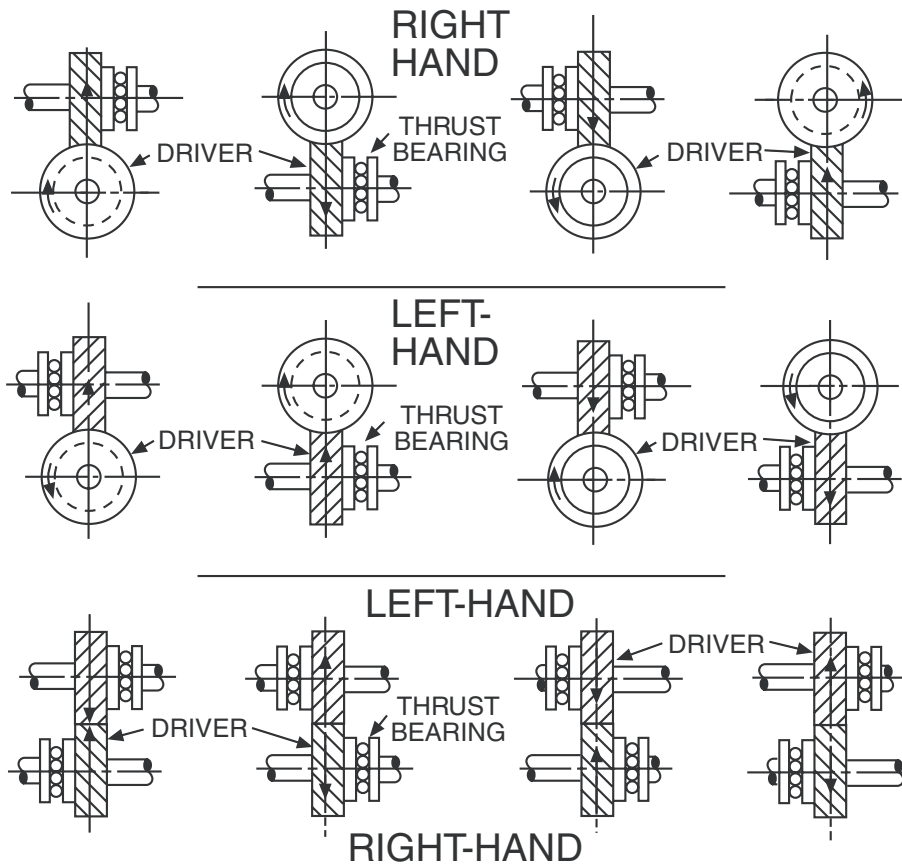
As a result of the design of the Helical Gear tooth, an axial or thrust load is developed. Bearings must be adequate to absorb this load. The thrust load direction is indicated below. The magnitude of the thrust load is based on calculated Horsepower.

$$\text{Axial Thrust Load} = \frac{126,050 \times \text{HP}}{\text{RPM} \times \text{Pitch Diameter}}$$

All 45° Helix Angle, producing a tangential force equal in magnitude to the axial thrust load. A separating force is also imposed on the gear set based on calculated Horsepower.

$$\text{Separating Load} = \text{Axial Thrust Load} \times .386$$

Above formulae based on 45° Helix Angle and 14-1/2° Normal Pressure Angle.



## WORMS AND WORM GEARS

Worms and Worm Gears are used for the transmission of motion and/or power between non-intersecting shafts at right angles (90°). Worm Gear drives are considered the smoothest and quietest form of gearing when properly applied and maintained. They should be considered for the following requirements:

HIGH RATIO SPEED REDUCTION  
LIMITED SPACE  
RIGHT ANGLE (NON-INTERSECTING) SHAFTS  
GOOD RESISTANCE TO BACK DRIVING

General nomenclature having been applied to Spur and Helical gear types, may also be applied to Worm Gearing with the addition of Worm Lead and Lead Angle, Number of Threads (starts) and Worm Gear Throat diameter.

### HOW TO TELL A LEFT-HAND OR RIGHT-HAND WORM OR WORM GEAR



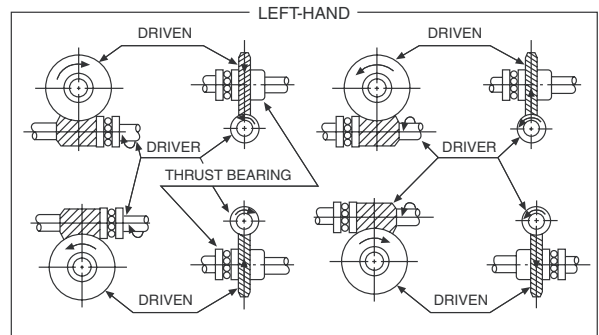
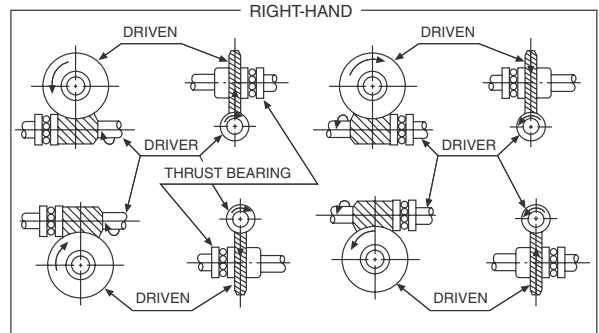
Threads of LEFT-HAND lean to the Left when standing on either end:



Threads of RIGHT-HAND lean to the Right when standing on either end:

### THRUST LOADS

As is true with Helical and Bevel gearing, Worm gearing, when operating, produces Thrust loading. The Chart below indicates the direction of thrust of Worms and Worm Gears when they are rotated as shown. To absorb this thrust loading, bearings should be located as indicated.



### EFFICIENCY

The efficiency of a worm gear drive depends on the lead angle of the worm. The angle decreases with increasing ratio and worm pitch diameter. For maximum efficiency the ratio should be kept low.

Due to the sliding action which occurs at the mesh of the Worm and Gear, the efficiency is dependent on the Lead Angle and the Coefficient of the contacting surface. A common formula for estimating efficiency of a given Worm Gear reduction is:

$$\text{EFFICIENCY} = E = \frac{\tan \lambda (1 - f \tan \lambda)}{f + \tan \lambda}$$

where  $\lambda$  = Worm Lead Angle  
 $f$  = Coefficient of Friction

For a Bronze Worm Gear and hardened Steel Worm, a Coefficient of Friction in the range of .03/.05 may be assumed for estimated value only.

# WORMS AND WORM GEARS

## WORM AND WORM GEAR FORMULAS

| To Obtain                                     | Having                                                       | Formula                                                |
|-----------------------------------------------|--------------------------------------------------------------|--------------------------------------------------------|
| Circular Pitch (p)                            | Diametral Pitch (P)                                          | $p = \frac{3.1416}{P}$                                 |
| Diametral Pitch (P)                           | Circular Pitch (p)                                           | $P = \frac{3.1416}{p}$                                 |
| Lead (of Worm) (L)                            | Number of Threads in Worm & Circular Pitch (p)               | $L = p(\text{No. of Threads})$                         |
| Addendum (a)                                  | Diametral Pitch (P)                                          | $a = \frac{1}{P}$                                      |
| Pitch Diameter (D) of Worm ( $D_w$ )          | Outside Diameter ( $d_o$ ) & Addendum (a)                    | $D_w = d_o - 2a$                                       |
| Pitch Diameter of Worm Gear ( $D_g$ )         | Circular Pitch (p) & Number of Teeth (N)                     | $D_g = \frac{N_g p}{3.1416}$                           |
| Center Distance Between Worm & Worm Gear (CD) | Pitch Diameter of Worm ( $d_w$ ) & Worm Gear ( $D_g$ )       | $CD = \frac{d_w + D_g}{2}$                             |
| Whole Depth of Teeth ( $h_T$ )                | Circular Pitch (p)                                           | $h_T = .6866 p$                                        |
|                                               | Diametral Pitch (P)                                          | $h_T = \frac{2.157}{P}$                                |
| Bottom Diameter of Worm ( $D_r$ )             | Whole Depth ( $h_T$ ) & Outside Diameter ( $d_o$ )           | $d_r = d_o - 2h_T$                                     |
| Throat Diameter of Worm Gear ( $D_T$ )        | Pitch Diameter of Worm Gear (D) & Addendum (a)               | $D_T = D_g + 2a$                                       |
| Lead Angle of Worm ( $\lambda$ )              | Pitch Diameter of Worm (D) & The Lead (L)                    | $\lambda = \tan^{-1} \left( \frac{L}{3.1416d} \right)$ |
| Ratio                                         | No. of Teeth on Gear ( $N_g$ ) and Number of Threads on Worm | $\text{Ratio} = \frac{N_g}{\text{No. of Threads}}$     |
| Gear O.D. ( $D_o$ )                           | Throat Dia. ( $D_T$ ) and Addendum (a)                       | $D_o = D_T + .6a$                                      |

## SELF-LOCKING ABILITY

There is often some confusion as to the self-locking ability of a worm and gear set. Worm gear sets, under no condition should be considered to hold a load when at rest. The statement is made to cover the broad spectrum of variables effecting self locking characteristics of a particular gear set in a specific application. Theoretically, a worm gear will not back drive if the friction angle is greater than the worm lead angle. However, the actual surface finish and lubrication may reduce this significantly. More important, vibration may cause motion at the point of mesh with further reduction in the friction angle.

Generally speaking, if the worm lead angle is less than 5°, there is reasonable expectation of self-locking. Again, no guarantee should be made and customer should be advised. If safety is involved, a positive brake should be used.

## WORM GEAR BACK-DRIVING

This is the converse of self-locking and refers to the ability of the worm gear to drive the worm. The same variables exist, making it difficult to predict. However, our experience indicates that for a hardened worm and bronze gear properly manufactured, mounted and lubricated, back-driving capability may be expected, if the lead angle is greater than 11°. Again, no guarantee is made and the customer should be so advised.

## RATING

The high rate of sliding friction that takes place at the mesh of the Worm and Gear results in a more complex method of rating these Gears as opposed to the other Gear types. Material factors, friction factors and velocity factors must all be considered and applied to reflect a realistic durability rating.

# GENERAL

## MOUNTING

### SPUR & HELICAL

For proper functioning gears, gears must be accurately aligned and supported by a shaft and bearing system which maintains alignment under load. Deflection should not exceed .001 inch at the tooth mesh for general applications. The tolerance on Centre Distance normally should be positive to avoid possibility of gear teeth binding. Tolerance value is dependent on acceptable system backlash. As a guide for average application, this tolerance might vary from .002 for fine pitch gears to .005 for the coarsest pitch.

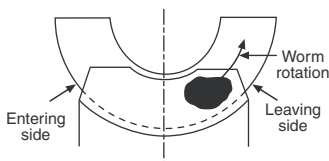
### WORMS AND WORM GEAR

It is important that the mounting assures the central plane of the Worm gear passes essentially through the axis of the Worm. This can be accomplished by adjusting the Worm Gear axially. Boston Worm Gears are cut to close tolerancing of the Centre Line of the Gear tooth to the flush side of the Gear. When properly mounted Worm Gears will become more efficient after initial break-in period.

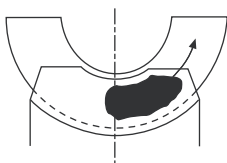
### HOW WORM GEARS “ADJUST” THEMSELVES

The gear in a worm gear reducer is made of a soft bronze material. Therefore, it can cold-work and wear-in to accommodate slight errors in misalignment.

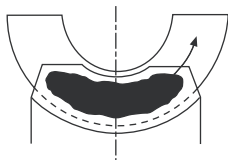
### Evolution of Contact in a Worm Gear



*Initially, contact is concentrated on the leaving side of the worm.*



*After several hours or running under load, gear has cold-worked to spread area of contact.*



*After many hours of operation, contact has spread to cover the entire working area of the tooth.*

## LUBRICATION

The use of a straight mineral oil is recommended for most worm gear applications. This type of oil is applicable to gears of all materials, including non-metallic materials.

Mild E.P. (Extreme Pressure) lubricants may be used with Iron and Steel Gears. E.P. lubricants normally should be selected of the same viscosity as straight mineral oil, E.P. lubricants are not recommended for use with brass or bronze gears.

SAE80 or 90 gear oil should be satisfactory for splash lubricated gears. Where extremely high or low speed conditions are encountered, consult a lubricant manufacturer. Oil temperature of 150°F should not be exceeded for continuous duty applications. Temperatures up to 200°F can be safely tolerated for short periods of time.

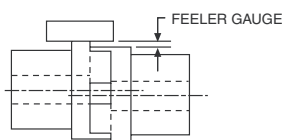
Many specialty lubricants have been recently developed to meet the application demands of today's markets, including synthetics and both high and low temperature oils and greases. In those instances where Bath or Drip Feed is not practical, a Moly-Disulphide grease may be used successfully, for low speed applications.

## COUPLINGS

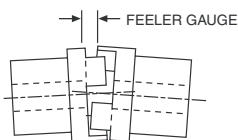
### ALIGNMENT

Alignment of couplings should be performed by the following steps to meet lateral and angular misalignment specifications below.

1. Align shafts and supports to give minimum lateral and angular misalignment.
2. Assemble coupling halves to shaft.
3. Slide couplings together and check lateral misalignment using straight edge and feeler gauge over coupling outside diameter (On BF Series couplings, spider must be removed.) This should be within specifications below.
4. Lock couplings on shaft and check distance using feeler gauges between drive lug on one half and space between on other coupling half. Rotate coupling and check gap at a minimum of 3 other coupling positions. The difference between any two readings should be within specifications below.



LATERAL MISALIGNMENT



ANGULAR MISALIGNMENT

### MISALIGNMENT TOLERANCES

| Coupling Series    | Lateral | Angular         |
|--------------------|---------|-----------------|
| FC—Bronze Insert   | .001    | See Chart below |
| FC—Urethane Insert | .002    |                 |
| FC—Rubber Insert   | .002    |                 |
| BF                 | .002    | 1-1/2°          |
| BG (Shear Type)    | 1/32    | 2°              |
| FA                 | .002    | 2°              |
| FCP (Plastic)      | .003    | 3°              |

### FC SERIES ANGULAR MISALIGNMENT

Chart reflects maximum angular misalignment of 1-1/2° for rubber, 1° for urethane and 1/2° for bronze.

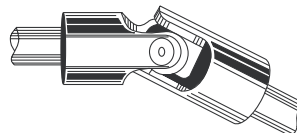
### MAXIMUM READING DIFFERENTIAL

| Size | Rubber | Insert<br>Urethane | Bronze |
|------|--------|--------------------|--------|
| FC12 | .033   | .022               | .011   |
| FC15 | .039   | .026               | .013   |
| FC20 | .053   | .035               | .018   |
| FC25 | .066   | .044               | .022   |
| FC30 | .078   | .052               | .026   |
| FC38 | .097   | .065               | .032   |
| FC45 | .117   | .078               | .039   |

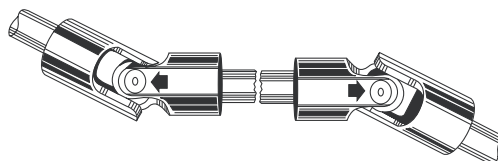
## UNIVERSAL JOINTS

### MOUNTING

A single universal joint (rotating at uniform speed) operating at an angle will introduce periodic variations of angular velocity to the driven shaft. These cyclic speed fluctuations (two per revolution) cause vibration, higher shaft stresses and bearing loads which will be more severe with larger angles of operation.



The detrimental effects of these rotational deviations can be reduced, and uniform speed restored by using two joints (and an intermediate shaft) to connect shafts at an angle or misaligned in a parallel direction.



For connecting shafts in the same plane the joints should be arranged to operate at equal angles and with the bearing pins of the yokes on the intermediate shaft in line with each other.

### LUBRICATION

#### PIN and BLOCK TYPE

**These universal joints are not lubricated when shipped.**

Many applications are considered severe when in harsh environments and when a combination of speed, dirt contamination and inaccessible locations make it impractical to maintain proper lubrication.

It is in these instances when the Boot Kits become a desirable alternative. For satisfactory performance, all booted joints should be used with a LITH-EP-000 grease for an ambient temperature range of 40° to 225°F.

### VOLUME OF LUBRICATION FOR BOOTED JOINTS

| Size | Volume (Ozs.) | Size | Volume (Ozs.) | Size | Volume (Ozs.) |
|------|---------------|------|---------------|------|---------------|
| 37   | .4            | 100  | 2.0           | 250  | 25.0          |
| 50   | .5            | 125  | 3.5           | 300  | 30.0          |
| 62   | .75           | 150  | 4.5           | 400  | 50.1          |
| 75   | 1.0           | 175  | 7.0           |      |               |
| 87   | 1.5           | 200  | 15.0          |      |               |

Note: Joints should be initially lubricated with a 90 weight oil before being packed with grease.

### FORGED AND CAST TYPE

**Universal Joints are not lubricated when shipped.**

Lubricate these joints with a Lith EP-2 grease or equivalent. The centre cross of these joints holds a generous supply of lubricant which is fed to the bearings by centrifugal action. Light-duty, low-angle operation may require only occasional lubrication. For high-angle, high-speed operation or in extreme dirt or moist conditions, daily re-greasing may be required.

# HOW TO FIGURE HORSEPOWER AND TORQUE

| TO OBTAIN                                             | HAVING                                                                          | FORMULA                                         |
|-------------------------------------------------------|---------------------------------------------------------------------------------|-------------------------------------------------|
| Velocity (V)<br>Feet Per Minute                       | Pitch Diameter (D) of<br>Gear or Sprocket – Inches<br>& Rev. Per Min. (RPM)     | $V = .2618 \times D \times \text{RPM}$          |
| Rev. Per Min. (RPM)                                   | Velocity (V) Ft. Per Min.<br>& Pitch Diameter (D) of<br>Gear or Sprocket—Inches | $\text{RPM} = \frac{V}{.2618 \times D}$         |
| Pitch Diameter (D)<br>of Gear or Sprocket<br>— Inches | Velocity (V) Ft. Per<br>Min. & Rev. Per Min.<br>(RPM)                           | $D = \frac{V}{.2618 \times \text{RPM}}$         |
| Torque (T) In. Lbs.                                   | Force (W) Lbs. &<br>Radius (R) Inches                                           | $T = W \times R$                                |
| Horsepower (HP)                                       | Force (W) Lbs. &<br>Velocity (V) Ft. Per Min.                                   | $\text{HP} = \frac{W \times V}{33000}$          |
| Horsepower (HP)                                       | Torque (T) In. Lbs. &<br>Rev. Per Min. (RPM)                                    | $\text{HP} = \frac{T \times \text{RPM}}{63025}$ |
| Torque (T) In. Lbs.                                   | Horsepower (HP)<br>& Rev. Per Min. (RPM)                                        | $T = \frac{63025 \times \text{HP}}{\text{RPM}}$ |
| Force (W) Lbs.                                        | Horsepower (HP) &<br>Velocity (V) Ft. Per Min.                                  | $W = \frac{33000 \times \text{HP}}{V}$          |
| Rev. Per Min. (RPM)                                   | Horsepower (HP) &<br>Torque (T) In. Lbs.                                        | $\text{RPM} = \frac{63025 \times \text{HP}}{T}$ |

**POWER** is the rate of doing work.

**WORK** is the exerting of a FORCE through a DISTANCE. ONE FOOT POUND is a unit of WORK. It is the WORK done in exerting a FORCE OF ONE POUND through a DISTANCE of ONE FOOT.

**THE AMOUNT OF WORK** done (Foot Pounds) is the FORCE (Pounds) exerted multiplied by the DISTANCE (Feet) through which the FORCE acts.

**THE AMOUNT OF POWER** used (Foot Pounds per Minute) is the WORK (Foot Pounds) done divided by the TIME (Minutes) required.

$$\text{POWER (Foot Pounds per Minute)} = \frac{\text{WORK (Ft. Lbs.)}}{\text{TIME (Minutes)}}$$

**POWER** is usually expressed in terms of HORSEPOWER.

**HORSEPOWER** is POWER (Foot Pounds per Minute) divided by 33000.

$$\begin{aligned} \text{HORSEPOWER (HP)} &= \frac{\text{POWER (Ft. Lbs. per Minute)}}{33000} \\ &= \frac{\text{WORK (Ft. Pounds)}}{33000 \times \text{TIME (Min.)}} \\ &= \frac{\text{FORCE (Lbs.)} \times \text{DISTANCE (Feet)}}{33000 \times \text{TIME (Min.)}} \\ &= \frac{\text{FORCE (Lbs.)} \times \text{DISTANCE (Feet)}}{33000 \times \text{TIME (Min.)}} \end{aligned}$$

## APPLICATION FORMULAS

1 hp = 36 lb-in. @ 1750 rpm  
1 hp = 3 lb-ft. @ 1750 rpm

$$\text{hp} = \frac{\text{Torque (lb.-in.)} \times \text{rpm}}{63,025}$$

$$\text{hp} = \frac{\text{Force (lb.)} \times \text{Velocity (ft/min.)}}{33,000}$$

Velocity (ft/min.) = 0.262 x Dia. (in.) x rpm  
Torque (lb.-in.) = Force (lb.) x Radius (in.)

$$\text{Torque (lb.-in.)} = \frac{\text{hp} \times 63,025}{\text{rpm}}$$

$$\text{Mechanical Efficiency} = \frac{\text{Output hp}}{\text{Input hp}} \times 100\%$$

$$\text{Output hp} = \frac{\text{OT (lb.-in.)} \times \text{Output rpm}}{63,025}$$

$$\text{OT} = \text{Input Torque} \times \text{Ratio} \times \text{Efficiency}$$

OT = Output Torque

$$\text{Output rpm} = \frac{\text{Input rpm}}{\text{Ratio}}$$

$$\text{OHL} = \frac{2 \text{ TK}}{D}$$

OHL = Overhung Load (lb)

T = Shaft Torque (lb-in.)

D = PD of Sprocket, Pinion or Pulley (in.)

K = Overhung Load Factor

Overhung Load Factors:

Sprocket or Timing Belt ..... 1.00

Pinion & Gear Drive ..... 1.25

Pulley & V-Belt Drive ..... 1.50

Pulley & Flat Belt Drive ..... 2.50

Variable Pitch Pulley ..... 3.50

$$\text{kW} = \text{hp} \times 0.7457$$

in. = mm/25.4

Temp. °C = (°F - 32) x 0.556

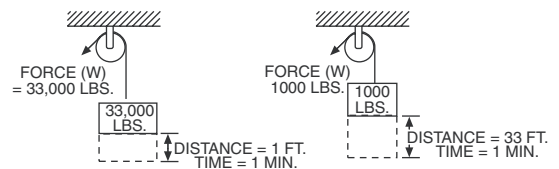
Temp. °F = (°C x 1.8) + 32

Torque (lb-in.) = 86.6 x kg\*m

Torque (lb-in.) = 8.85 x N\*m

Torque (lb-in.) = 88.5 x daNm

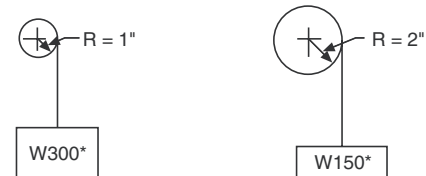
## ILLUSTRATION OF HORSEPOWER



$$\text{HP} = \frac{33,000 \times 1}{33,000 \times 1} = 1 \text{ HP}$$

$$\text{HP} = \frac{1000 \times 33}{33,000 \times 1} = 1 \text{ HP}$$

**TORQUE (T)** is the product of a FORCE (W) in pounds, times a RADIUS (R) in inches from the center of shaft (Lever Arm) and is expressed in Inch Pounds.



$$T = WR = 300 \times 1 = 300 \text{ In. Lbs.} \quad T = WR = 150 \times 2 = 300 \text{ In. Lbs.}$$

If the shaft is revolved, the FORCE (W) is moved through a distance, and WORK is done.

$$\text{WORK (Ft. Pounds)} = W \times \frac{2 \times R}{12} \times \text{No. of Rev. of Shaft.}$$

When this WORK is done in a specified TIME, POWER is used.

$$\text{POWER (Ft. Pounds per Min.)} = W \times \frac{2 \times R}{12} \times \text{RPM}$$

Since (1) HORSEPOWER = 33,000 Foot Pounds per Minute

$$\text{HORSEPOWER (HP)} = W \times \frac{2 \times R}{12} \times \frac{\text{RPM}}{33,000} = \frac{W \times R \times \text{RPM}}{63,025}$$

but TORQUE (Inch Pounds) = FORCE (W) X RADIUS (R)

$$\text{Therefore HORSEPOWER (HP)} = \frac{\text{TORQUE (T)} \times \text{RPM}}{63,025}$$

## APPLICATION CLASSIFICATION FOR VARIOUS LOADS

| Type of Machine To Be Driven                  | Chart I For All Drives           |                               |                           |
|-----------------------------------------------|----------------------------------|-------------------------------|---------------------------|
|                                               | Service Factor Loading           |                               |                           |
|                                               | Not More Than 15 Mins. in 2 Hrs. | Not More Than 10 Hrs. per Day | More Than 10 Hrs. Per Day |
| <b>AGITATORS</b>                              |                                  |                               |                           |
| Pure Liquid                                   | 0.80                             | 1.00                          | 1.25                      |
| Semi-Liquids, Variable Density                | 1.00                             | 1.25                          | 1.50                      |
| <b>BLOWERS</b>                                |                                  |                               |                           |
| Centrifugal and Vane                          | 0.80                             | 1.00                          | 1.25                      |
| Lobe                                          | 1.00                             | 1.25                          | 1.50                      |
| <b>BREWING AND DISTILLING</b>                 |                                  |                               |                           |
| Bottling Machinery                            | 0.80                             | 1.00                          | 1.25                      |
| Brew Kettles—Continuous Duty                  | —                                | —                             | 1.25                      |
| Cookers – Continuous Duty                     | —                                | —                             | 1.25                      |
| Mash Tubs – Continuous Duty                   | —                                | —                             | 1.25                      |
| Scale Hopper – Frequent Starts                | —                                | 1.25                          | 1.50                      |
| <b>CAN FILLING MACHINES</b>                   |                                  |                               |                           |
|                                               | —                                | 1.00                          | —                         |
| <b>CANE KNIVES</b>                            |                                  |                               |                           |
|                                               | —                                | 1.50                          | —                         |
| <b>CAR DUMPERS</b>                            |                                  |                               |                           |
|                                               | —                                | 1.75                          | —                         |
| <b>CAR PULLERS</b>                            |                                  |                               |                           |
|                                               | —                                | 1.25                          | —                         |
| <b>CLARIFIERS</b>                             |                                  |                               |                           |
|                                               | —                                | 1.00                          | 1.25                      |
| <b>CLASSIFIERS</b>                            |                                  |                               |                           |
|                                               | —                                | 1.25                          | 1.50                      |
| <b>CLAY WORKING MACHINERY</b>                 |                                  |                               |                           |
| Brick Press & Briquette Machine               | —                                | 1.75                          | 2.00                      |
| Extruders and Mixers                          | 1.00                             | 1.25                          | 1.50                      |
| <b>COMPRESSORS</b>                            |                                  |                               |                           |
| Centrifugal                                   | —                                | 1.00                          | 1.25                      |
| Lobe—Reciprocating, Multi-Cycle               | —                                | 1.25                          | 1.50                      |
| Reciprocating – Single Cycle                  | —                                | 1.75                          | 2.00                      |
| <b>CONVEYORS—</b>                             |                                  |                               |                           |
| <b>UNIFORMLY LOADED &amp; FED</b>             |                                  |                               |                           |
| Apron                                         | —                                | 1.00                          | 1.25                      |
| Assembly-Belt – Bucket or Pan                 | —                                | 1.00                          | 1.25                      |
| Chain – Flight                                | —                                | 1.00                          | 1.25                      |
| Oven – Live Roll – Screw                      | —                                | 1.00                          | 1.25                      |
| <b>CONVEYORS—HEAVY DUTY NOT UNIFORMLY FED</b> |                                  |                               |                           |
| Apron                                         | —                                | 1.25                          | 1.50                      |
| Assembly-Belt – Bucket or Pan                 | —                                | 1.25                          | 1.50                      |
| Chain – Flight                                | —                                | 1.25                          | 1.50                      |
| Live Roll                                     | —                                | —                             | —                         |
| Oven – Screw                                  | —                                | 1.25                          | 1.50                      |
| Reciprocating – Shaker                        | —                                | 1.75                          | 2.00                      |
| <b>CRANES AND HOISTS</b>                      |                                  |                               |                           |
| Main Hoists                                   |                                  |                               |                           |
| Bridge and Trolley Drive                      | *                                | 1.00                          | 1.25                      |
| <b>CRUSHER</b>                                |                                  |                               |                           |
| Ore, Stone                                    | —                                | 1.75                          | 2.00                      |
| Sugar                                         | —                                | 1.50                          | 1.50                      |

| Type of Machine To Be Driven           | Chart I For All Drives           |                               |                           |
|----------------------------------------|----------------------------------|-------------------------------|---------------------------|
|                                        | Service Factor Loading           |                               |                           |
|                                        | Not More Than 15 Mins. in 2 Hrs. | Not More Than 10 Hrs. per Day | More Than 10 Hrs. Per Day |
| <b>ELEVATORS</b>                       |                                  |                               |                           |
| Bucket – Uniform Load                  | —                                | 1.00                          | 1.25                      |
| Bucket – Heavy Load                    | —                                | 1.25                          | 1.50                      |
| Centrifugal Discharge                  | —                                | 1.25                          | 1.50                      |
| Freight                                | —                                | 1.25                          | 1.50                      |
| Gravity Discharge                      | —                                | 1.00                          | 1.25                      |
| <b>FANS</b>                            |                                  |                               |                           |
| Centrifugal – Light (Small Diam.)      | —                                | 1.00                          | 1.25                      |
| Large Industrial                       | —                                | 1.25                          | 1.50                      |
| <b>FEEDERS</b>                         |                                  |                               |                           |
| Apron – Belt – Screw                   | —                                | 1.25                          | 1.50                      |
| Disc                                   | —                                | 1.00                          | 1.25                      |
| Reciprocating                          | —                                | 1.75                          | 2.00                      |
| <b>FOOD INDUSTRY</b>                   |                                  |                               |                           |
| Beet Slicer                            | —                                | 1.25                          | 1.50                      |
| Cereal Cooker                          | —                                | 1.00                          | 1.25                      |
| Dough Mixer – Meat Grinder             | —                                | 1.25                          | 1.50                      |
| <b>GENERATORS (NOT WELDING)</b>        | —                                | 1.00                          | 1.25                      |
| <b>HAMMER MILLS</b>                    |                                  |                               |                           |
|                                        | —                                | 1.75                          | 2.00                      |
| <b>HOISTS</b>                          |                                  |                               |                           |
| Heavy Duty                             | —                                | 1.75                          | 2.00                      |
| Medium Duty and Skip Type              | —                                | 1.25                          | 1.50                      |
| <b>LAUNDRY TUMBLERS</b>                |                                  |                               |                           |
|                                        | —                                | 1.25                          | 1.50                      |
| <b>LINE SHAFTS</b>                     |                                  |                               |                           |
| Uniform Load                           | —                                | 1.00                          | 1.25                      |
| Heavy Load                             | —                                | 1.25                          | 1.50                      |
| <b>MACHINE TOOLS</b>                   |                                  |                               |                           |
| Auxiliary Drive                        | —                                | 1.00                          | 1.25                      |
| Main Drive – Uniform Load              | —                                | 1.25                          | 1.50                      |
| Main Drive – Heavy Duty                | —                                | 1.75                          | 2.00                      |
| <b>METAL MILLS</b>                     |                                  |                               |                           |
| Draw Bench Carriers & Main Drive       | —                                | 1.25                          | 1.50                      |
| <b>SLITTERS</b>                        |                                  |                               |                           |
|                                        | —                                | 1.25                          | 1.50                      |
| <b>TABLE CONVEYORS — NON REVERSING</b> |                                  |                               |                           |
| Group Drives                           | —                                | 1.25                          | 1.50                      |
| Individual Drives                      | —                                | 1.75                          | 2.00                      |
| Wiring Drawing, Flattening or Winding  | —                                | 1.25                          | 1.50                      |
| <b>MILLS ROTARY TYPE</b>               |                                  |                               |                           |
| <b>BALL AND ROD</b>                    |                                  |                               |                           |
| Spur Ring Gear and Direct Connected    | —                                | —                             | 2.00                      |
| Cement Kilns, Pebble                   | —                                | —                             | 1.50                      |
| Dryers and Coolers                     | —                                | —                             | 1.50                      |
| Plain and Wedge Bar                    | —                                | —                             | 1.50                      |
| Tumbling Barrels                       | —                                | —                             | 2.00                      |

## APPLICATION CLASSIFICATION FOR VARIOUS LOADS

| TYPE OF MACHINE<br>TO BE DRIVEN | NON-MOTOR<br>REDUCER<br>(SERVICE<br>FACTORS) |            | MOTORIZED<br>REDUCER<br>(CLASS OF<br>SERVICE) |            | TYPE OF MACHINE<br>TO BE DRIVEN      | NON-MOTOR<br>REDUCER<br>(SERVICE<br>FACTORS) |            | MOTORIZED<br>REDUCER<br>(CLASS OF<br>SERVICE) |            |
|---------------------------------|----------------------------------------------|------------|-----------------------------------------------|------------|--------------------------------------|----------------------------------------------|------------|-----------------------------------------------|------------|
|                                 | HRS. PER DAY                                 |            | HRS. PER DAY                                  |            |                                      | HRS. PER DAY                                 |            | HRS. PER DAY                                  |            |
|                                 | 3<br>TO<br>10                                | OVER<br>10 | 3<br>TO<br>10                                 | OVER<br>10 |                                      | 3<br>TO<br>10                                | OVER<br>10 | 3<br>TO<br>10                                 | OVER<br>10 |
| <b>PAPER MILLS (Cont.)</b>      |                                              |            |                                               |            | <b>RUBBER INDUSTRY (Cont.)</b>       |                                              |            |                                               |            |
| Chipper                         | ---                                          | 2.00       | ---                                           | III        | Extruders - Continuous               | ---                                          | 1.50       | ---                                           | ---        |
| Chip Feeder                     | 1.25                                         | 1.50       | ---                                           | ---        | Extruders - Intermittent             | ---                                          | 1.75       | ---                                           | ---        |
| Coating Rolls - Couch Rolls     | 1.00                                         | 1.25       | ---                                           | ---        | Tire Building Machines               | ---                                          | ---        | II                                            | II         |
| Conveyors - Chips - Bark        |                                              |            |                                               |            | Tire and Tube Press Operators        | ---                                          | ---        | I                                             | I          |
| - Chemical                      | 1.00                                         | 1.25       | ---                                           | ---        | <b>SEWAGE DISPOSAL<br/>EQUIPMENT</b> |                                              |            |                                               |            |
| Conveyors - Log and Slab        | ---                                          | 2.00       | ---                                           | ---        | Bar Screens                          | 1.00                                         | 1.25       | I                                             | II         |
| Cutter                          | ---                                          | 2.00       | ---                                           | ---        | Chemical Feeders                     | 1.00                                         | 1.25       | I                                             | II         |
| Cylinder Molds, Dryers          |                                              |            |                                               |            | Collectors                           | 1.00                                         | 1.25       | I                                             | II         |
| - Anti-Friction                 | ---                                          | 1.25       | ---                                           | ---        | Dewatering Screws                    | 1.25                                         | 1.50       | II                                            | II         |
| Felt Stretcher                  | 1.25                                         | 1.50       | ---                                           | II         | Scum Breakers                        | 1.25                                         | 1.50       | II                                            | II         |
| Screens - Chip and Rotary       | 1.25                                         | 1.50       | ---                                           | ---        | Slow or Rapid Mixers                 | 1.25                                         | 1.50       | II                                            | II         |
| Thickener (AC)                  | 1.25                                         | 1.50       | ---                                           | ---        | Thickeners                           | 1.25                                         | 1.50       | II                                            | II         |
| Washer (AC)                     | 1.25                                         | 1.50       | ---                                           | ---        | Vacuum Filters                       | 1.25                                         | 1.50       | II                                            | II         |
| Winder - Surface Type           | ---                                          | 1.25       | ---                                           | II         | <b>SCREENS</b>                       |                                              |            |                                               |            |
| <b>PLASTICS INDUSTRY</b>        |                                              |            |                                               |            | Air Washing                          | 1.00                                         | 1.25       | I                                             | II         |
| Intensive Internal Mixers       |                                              |            |                                               |            | Rotary - Stone or Gravel             | 1.25                                         | 1.50       | II                                            | II         |
| Batch Type                      | ---                                          | 1.75       | ---                                           | ---        | Traveling Water Intake               | 1.00                                         | 1.25       | I                                             | II         |
| Continuous Type                 | ---                                          | 1.50       | ---                                           | ---        | Skip Hoists                          | ---                                          | ---        | II                                            | ---        |
| Batch Drop Mill - 2 Rolls       | ---                                          | 1.25       | ---                                           | ---        | Slab Pushers                         | 1.25                                         | 1.50       | ---                                           | ---        |
| Compounding Mills               | ---                                          | 1.25       | ---                                           | ---        | Stokers                              | ---                                          | 1.25       | ---                                           | II         |
| Calendars                       | ---                                          | 1.50       | ---                                           | ---        | <b>TEXTILE INDUSTRY</b>              |                                              |            |                                               |            |
| Extruder - Variable Speed       | ---                                          | 1.50       | ---                                           | ---        | Batchers or Calendars                | 1.25                                         | 1.50       | II                                            | II         |
| Extruder - Fixed Speed          | ---                                          | 1.75       | ---                                           | ---        | Cards                                | 1.25                                         | 1.50       | I                                             | II         |
| <b>PULLERS</b>                  |                                              |            |                                               |            | Card Machines                        | 1.75                                         | 2.00       | III                                           | III        |
| Barge Haul                      | ---                                          | 2.00       | ---                                           | ---        | Dry Cans and Dryers                  | 1.25                                         | 1.50       | II                                            | II         |
| <b>PUMPS</b>                    |                                              |            |                                               |            | Dyeing Machines                      | 1.25                                         | 1.50       | II                                            | II         |
| Centrifugal                     | ---                                          | 1.25       | ---                                           | ---        | Looms                                | 1.25                                         | 1.50       | *                                             | *          |
| Proportioning                   | ---                                          | 1.50       | *                                             | *          | Mangles, Nappers and Pads            | 1.25                                         | 1.50       | II                                            | II         |
| Reciprocating                   |                                              |            |                                               |            | Soapers, Tenner Frames               | 1.25                                         | 1.50       | II                                            | II         |
| Single Acting, 3 or More Cycles | 1.25                                         | 1.50       | II                                            | III        | Spinners, Washers, Winders           | 1.25                                         | 1.50       | II                                            | II         |
| Double Acting, 2 or More Cycles | 1.25                                         | 1.50       | II                                            | III        |                                      |                                              |            |                                               |            |
| Rotary - Gear or Lube           | 1.00                                         | 1.25       | I                                             | II         |                                      |                                              |            |                                               |            |
| <b>RUBBER INDUSTRY</b>          |                                              |            |                                               |            |                                      |                                              |            |                                               |            |
| Batch Mixers                    | ---                                          | 1.75       | ---                                           | ---        |                                      |                                              |            |                                               |            |
| Continuous Mixers               | ---                                          | 1.50       | ---                                           | ---        |                                      |                                              |            |                                               |            |
| Calendars                       | ---                                          | 1.50       | ---                                           | ---        |                                      |                                              |            |                                               |            |

\*Consult Manufacturer.

This list is not all-inclusive and each application should be checked to determine if any unusual operating conditions will be encountered.

### SERVICE FACTOR CHART

| AGMA<br>CLASS OF<br>SERVICE | SERVICE<br>FACTOR | OPERATING CONDITIONS                                                                                    |
|-----------------------------|-------------------|---------------------------------------------------------------------------------------------------------|
| I                           | 1.00              | Moderate Shock - not more than 15 minutes in 2 hours.<br>Uniform Load - not more than 10 hours per day. |
| II                          | 1.25              | Moderate Shock - not more than 10 hours per day.<br>Uniform Load - more than 10 hours per day.          |
|                             | 1.50              | Heavy Shock - not more than 15 minutes in 2 hours.<br>Moderate Shock - more than 10 hours per day.      |
| III                         | 1.75              | Heavy Shock - not more than 10 hours per day.                                                           |
|                             | 2.00              | Heavy Shock - more than 10 hours per day.                                                               |