NEW DEPARTURE
HAND BOOK

VOL. II

TABLES – FORMULAE
BEARING PRINCIPLES
LOAD COMPUTATION
BEARING INSTALLATION

NEW DEPARTURE • • PIONEERS FOR OVER FIFTY YEARS

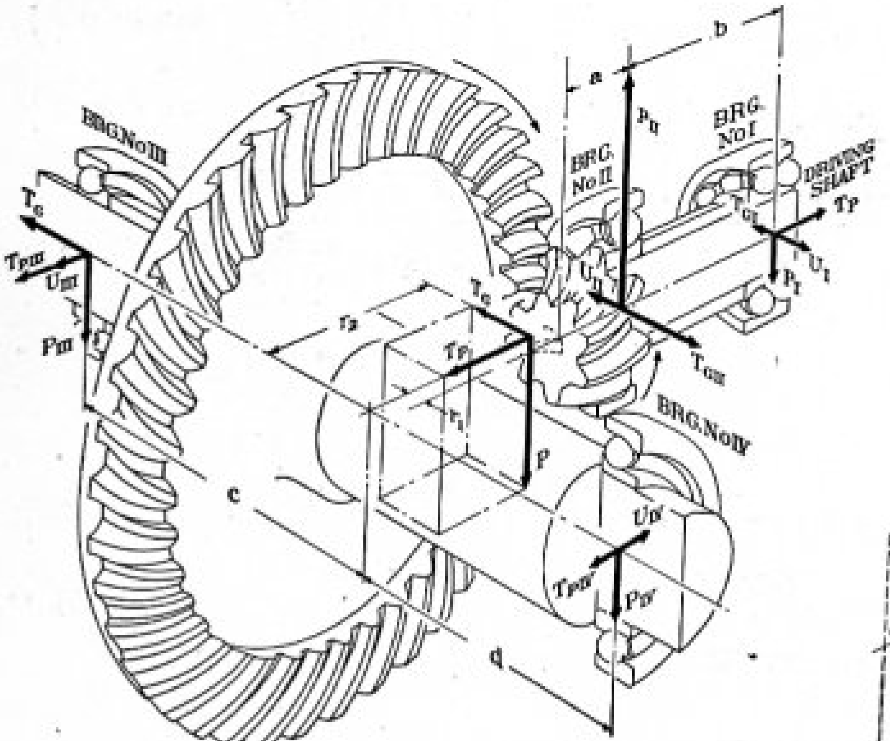
Bearing Loads Due to
SPIRAL BEVEL GEARING

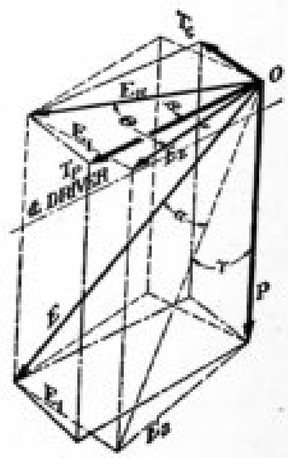
The pinion may rotate clockwise or counter-clockwise (viewed from power input end) and the gears may be cut with left-hand or right-hand spiral. The following combinations are therefore possible:

1. Pinion rotating clockwise with left-hand spiral.
2. Pinion rotating clockwise with right-hand spiral.
3. Pinion rotating counter-clockwise with left-hand spiral.
4. Pinion rotating counter-clockwise with right-hand spiral.

Condition 1 is commonly used, especially for the forward drive in automobile rear axles, in which case reverse drive gives condition 3. The diagram below illustrates condition 1.

Loads are imposed on the bearings by the three components of force E (normal to the driving tooth contact). The first, P, is directed vertically; the second, T_G, horizontally, both being in a plane at right angles to the pinion shaft. The third, T_P, is parallel to the pinion axis. For derivation of these components, see page 44.





Speed Change

$$\text{Gear r.p.m.} = N \times \frac{\text{Number of teeth in pinion}}{\text{Number of teeth in gear}}$$

SPIRAL BEVEL GEARING

$Q = \dfrac{\text{H.P.} \times 63025}{N}$ = TORQUE INPUT, lbs. inches, where H.P. = horsepower transmitted and N = revolutions per minute of pinion.

$P = \dfrac{Q}{r_1}$ = TANGENTIAL FORCE, where

r_1 = Mean pinion pitch radius in inches = ½ (pinion pitch diameter − tooth face x sin β), angle β being defined below.

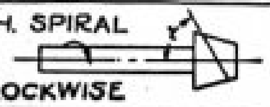
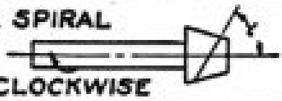
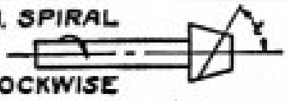
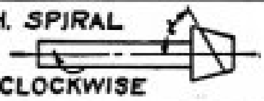
r_2 = Mean gear pitch radius = $r_1 \times \dfrac{\text{Number of teeth in gear}}{\text{Number of teeth in pinion}}$

α = TOOTH PRESSURE ANGLE.

β = ½ PINION PITCH CONE ANGLE = $\tan^{-1} \dfrac{\text{Number of teeth in pinion}}{\text{Number of teeth in gear}}$

γ = SPIRAL ANGLE.

The values of pinion thrust, T_P, and gear thrust, T_G, are derived from the above data for the four possible combinations as follows:

R.H. SPIRAL  CLOCKWISE	$T_P = P\left(\dfrac{\tan\alpha \sin\beta}{\cos\gamma} - \tan\gamma\cos\beta\right)$
L.H. SPIRAL  C. CLOCKWISE	$T_G = P\left(\dfrac{\tan\alpha \cos\beta}{\cos\gamma} + \tan\gamma\sin\beta\right)$
L.H. SPIRAL  CLOCKWISE	$T_P = P\left(\dfrac{\tan\alpha \sin\beta}{\cos\gamma} + \tan\gamma\cos\beta\right)$
R.H. SPIRAL  C. CLOCKWISE	$T_G = P\left(\dfrac{\tan\alpha \cos\beta}{\cos\gamma} - \tan\gamma\sin\beta\right)$

Note: Positive sign (+) indicates thrust direction away from center.
Negative sign (−) indicates thrust direction toward center.

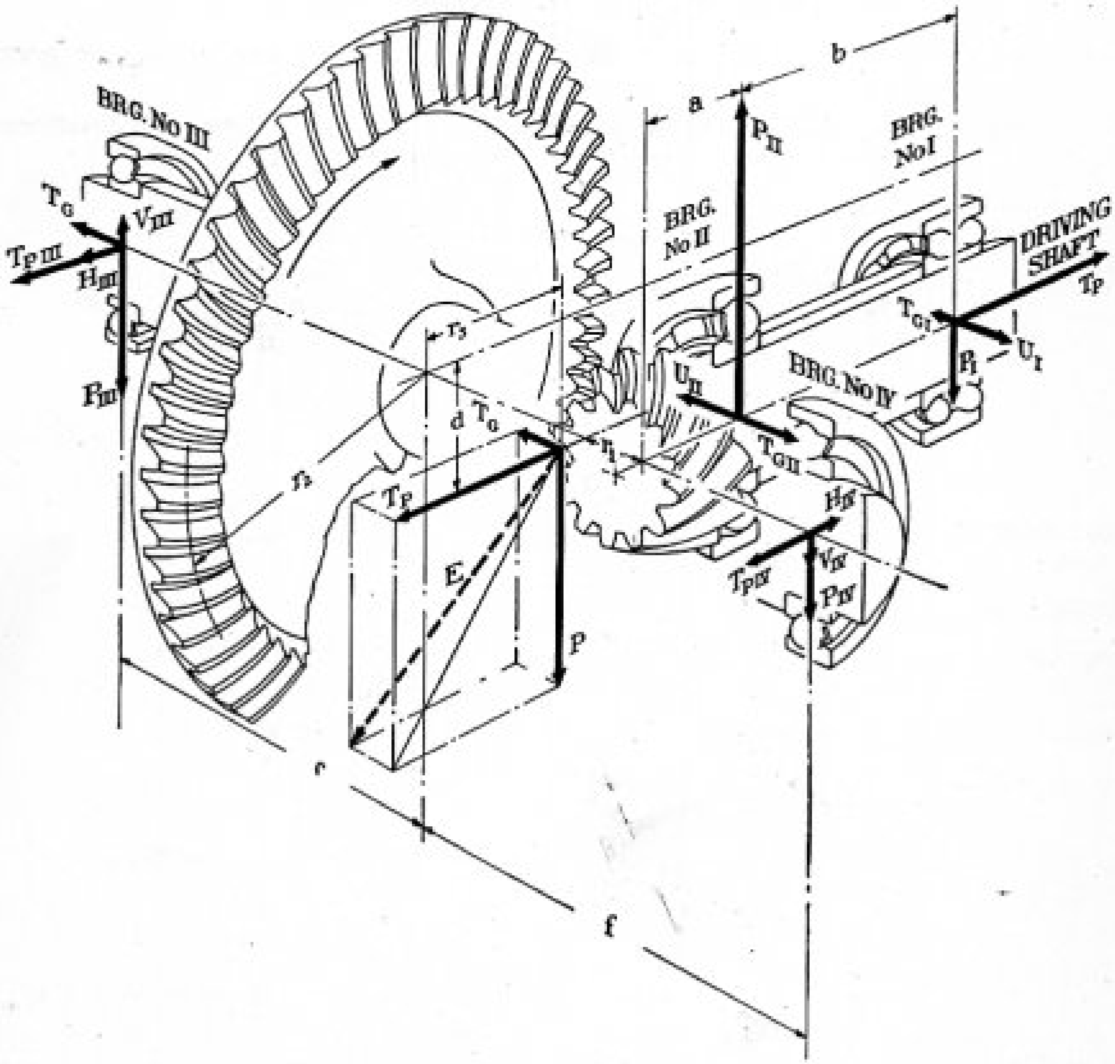
BEARING LOADS

Due to	on Brg. I	on Brg. II
P	$P\dfrac{a}{b} = P_I$	$P\dfrac{a+b}{b} = P_{II}$
T_G	$T_G\dfrac{a}{b} = T_{GI}$	$T_G\dfrac{a+b}{b} = T_{GII}$
T_P	$T_P\dfrac{r_1}{b} = U_I$	$T_P\dfrac{r_1}{b} = U_{II} = U_I$
Total Rad. Load	$\sqrt{P_I^2 + (T_{GI} - U_I)^2} = R_I$	$\sqrt{P_{II}^2 + (T_{GII} - U_{II})^2}$
Thrust Load	T_P	
Total Load	$\sqrt{T_P^2 + R_I^2}$	$\sqrt{P_{II}^2 + (T_{GII} - U_{II})^2}$
Due to	**on Brg. III**	**on Brg. IV**
P	$P\dfrac{d}{c+d} = P_{III}$	$P\dfrac{c}{c+d} = P_{IV}$
T_G	$T_G\dfrac{r_2}{c+d} = U_{III}$	$T_G\dfrac{r_2}{c+d} = U_{IV} = U_{III}$
T_P	$T_P\dfrac{d}{c+d} = T_{PIII}$	$T_P\dfrac{c}{c+d} = T_{PIV}$
Total Rad. Load	$\sqrt{P_{III}^2 + (U_{III} + T_{PIII})^2} = R_{III}$	$\sqrt{P_{IV}^2 + (U_{IV} - T_{PIV})^2}$
Thrust Load	T_G	
Total Load	$\sqrt{T_G^2 + R_{III}^2}$	$\sqrt{P_{IV}^2 + (U_{IV} - T_{PIV})^2}$

Bearing Loads Due to
HYPOID GEARING

In appearance, hypoid gears are similar to spiral bevel gears; the distinction lies in the fact that while the pinion is being generated by the gear form, it is held in an off-set position, so that the axes of gear and pinion do not intersect. The direction of the off-set determines the hand of the spiral. In the diagram and the calculations based thereon, the left-hand spiral pinion, as commonly applied to automotive rear axles, is selected, with the pinion axis dropped from 1½ to 3½ inches from the horizontal axis of the ring gear.

The tooth action of hypoid gears combines the rolling action of spiral bevel gears with a percentage of endwise sliding. The three actions of the pinion tooth may be derived by the same method as used in ordinary spiral bevel gears.



Speed Change

$$\text{Gear r.p.m.} = N \times \frac{\text{Number of teeth in pinion}}{\text{Number of teeth in gear}}$$

HYPOID GEARING

$Q = \frac{H.P. \times 63025}{N}$ = TORQUE INPUT, lbs. inches, where H.P. = horsepower transmitted and N = revolutions per minute.

$P = \frac{Q}{r_1}$ = TANGENTIAL FORCE, where

r_1 = Mean pinion pitch radius in inches = ½ (pinion pitch diameter − tooth face x sin β), angle β being defined below.

r_2 = Mean gear pitch radius.

$= r_1 \times \frac{\text{Number of teeth in gear}}{\text{Number of teeth in pinion}} \times \frac{\cos(\text{pinion spiral angle})}{\cos(\text{gear spiral angle})}$

For derivation of this value, see page 48.

α = TOOTH PRESSURE ANGLE on drive side.

β = ½ PINION PITCH CONE ANGLE. *(See detail diagram, page 42.)*

γ = PINION SPIRAL ANGLE.

$T_P = P\left(\frac{\tan\alpha \sin\beta}{\cos\gamma} + \tan\gamma\cos\beta\right)$ = PINION THRUST.

$T_G = P\left(\frac{\tan\alpha \cos\beta}{\cos\gamma} - \tan\gamma\sin\beta\right)$ = GEAR THRUST.

d = PINION DROP in inches = Distance pinion center line lies below gear center line.

$r_3 = \sqrt{r_2^2 - d^2}$ = EFFECTIVE GEAR RADIUS, or horizontal projection of mean gear radius r_2 defined above.

BEARING LOADS

Due to	on Brg. I	on Brg. II
P	$P\frac{a}{b} = P_I$	$P\frac{a+b}{b} = P_{II}$
T_P	$T_P\frac{r_1}{b} = U_I$	$T_P\frac{r_1}{b} = U_{II} = U_I$
T_G	$T_G\frac{a}{b} = T_{GI}$	$T_G\frac{a+b}{b} = T_{GII}$
Total Rad. Load	$\sqrt{P_I^2 + (U_I - T_{GI})^2} = R_I$	$\sqrt{P_{II}^2 + (U_{II} - T_{GII})^2}$
Thrust Load	T_P	
Total Load	$\sqrt{R_I^2 + T_P^2}$	$\sqrt{P_{II}^2 + (U_{II} - T_{GII})^2}$

Due to	on Brg. III	on Brg. IV
P	$P\frac{f}{c+f} = P_{III}$	$P\frac{c}{c+f} = P_{IV}$
T_P	$T_P\frac{f}{c+f} = T_{PIII}$	$T_P\frac{c}{c+f} = T_{PIV}$
T_G	$T_G\frac{d}{c+f} = V_{III}$	$T_G\frac{d}{c+f} = V_{IV}$
	$T_G\frac{r_3}{c+f} = H_{III}$	$T_G\frac{r_3}{c+f} = H_{IV} = H_{III}$
Total Rad. Load	$\sqrt{(P_{III}-V_{III})^2+(T_{PIII}+H_{III})^2} = R_{III}$	$\sqrt{(P_{IV}+V_{IV})^2+(T_{PIV}-H_{IV})^2}$
Thrust Load	T_G	
Total Load	$\sqrt{T_G^2 + R_{III}^2}$	$\sqrt{(P_{IV}+V_{IV})^2+(T_{PIV}-H_{IV})^2}$

HYPOID GEARING

Derivation of Mean Radii Relation

r_1 = Mean pinion pitch radius.

γ = Pinion spiral angle.

n = Number of teeth in pinion.

Q = Pinion torque.

α = Tooth pressure angle.

E = Normal tooth force (see diagram).

r_2 = Mean gear pitch radius.

γ_2 = Gear spiral angle.

n_2 = Number of teeth in gear.

Q_2 = Gear torque.

$$\frac{\text{Pinion Torque}}{\text{Gear Torque}} = \frac{Q}{Q_2} = \frac{n}{n_2}$$

Normal Force $E = \frac{P}{\cos\gamma\cos\alpha} = \frac{Q}{r_1\cos\gamma\cos\alpha}$

Also, $E = \frac{P}{\cos\gamma_2\cos\alpha} = \frac{Q_2}{r_2\cos\gamma_2\cos\alpha}$

Therefore, $\frac{Q}{Q_2} = \frac{r_1\cos\gamma}{r_2\cos\gamma_2}$, equating and simplifying

or $\frac{n}{n_2} = \frac{r_1\cos\gamma}{r_2\cos\gamma_2}$, substituting

From which $r_2 = r_1\frac{n_2\cos\gamma}{n\cos\gamma_2}$, or $r_1 = r_2\frac{n\cos\gamma_2}{n_2\cos\gamma}$