INSTALLATION OF BEVEL GEARS

GENERAL INSTRUCTIONS

Any apparent or suspected damage sustained by equipment manufactured or furnished by Philadelphia Gear Corporation during transport from the factory to the user should be reported immediately to both Philadelphia Gear Corporation and the Carrier.

Upon delivery, all equipment furnished must be carefully inventoried against shipping papers to determine whether any shortages exist in delivered material. Any such shortages must be immediately reported to both Philadelphia Gear and the Carrier if a timely claim is to be made.

All unassembled gears furnished by Philadelphia Gear Corporation are coated with a film of Cosmoline. An inspection should be made of the gear sets upon receipt by the Buyer, and if any corrosion is detected, Philadelphia Gear Corporation must be notified immediately.

The installation of most power transmission equipment does not normally require the services of a factory engineer. These services are not included in the selling price of the equipment unless specifically agreed upon in writing between the Seller and the Purchaser. In applications requiring a more complex arrangement of components, consideration should be given to the use of a factory engineer for construction supervision or check-out of the installation. These services are available from Philadelphia Gear by contacting the Service Department.

The Purchaser must prevent the existence of any destructive external conditions which might typically include vibratory loads due to critical speeds, severe shock and loading, mechanical or thermal overloads, external vibration, or other conditions which may adversely affect the operation. The gears must be installed and maintained in accordance with instructions provided in this manual.

Adequate installation, maintenance and safety instructions must be given by the User to personnel directly responsible for the operation of the gears and accessory equipment. In addition, the procedures set forth in the operating instructions must be carefully followed.

The User is also responsible for furnishing and installing any guards or other safety equipment needed to protect operating personnel as required by Occupational Safety and Health Administration standards (OSHA) or other applicable safety regulations. This equipment normally is not furnished by Philadelphia Gear Corporation except when specified as part of the order. In all cases, however, the User has the responsibility of complying with all safety regulations when installing the equipment.

All unauthorized personnel must be required to remain a safe distance from gear sets.

The type and grade of oil specified must be applied to all Philadelphia Gear sets before start-up.

The Sellers warranty applies only to the manufacturing quality of the gear set.

In the event of malfunction within the warranty period, Philadelphia Gear Corporation must be notified promptly, within thirty (30) days, if it is intended that the warranty is to cover the incident.

INTRODUCTION

NOTE

All tolerance levels referred to in this manual are to be used only as a guide. To obtain the most desirable operating conditions, it may be necessary in manufacturing or assembly to either tighten or go beyond the tolerances shown.

The installation of any gear set requires familiarity with the requirements for successful operation. Bevel, spiral bevel, and hypoid gear sets have certain requirements which must be met to obtain optimum performance. This manual first reviews some of the basic terminology, the requirements of the bearing arrangements, and the mountings or housings. It then gives installation, adjustment and checking procedures and lubrication requirements.

WARNING

The safety precautions listed in this manual must be followed by all personnel working on or with the equipment to avoid serious injury.

All service personnel must be knowledgeable before performing any work.

GENERAL INFORMATION

GEAR TOOTH NOMENCLATURE:

The **TOE** of a bevel gear tooth is the portion of the tooth surface at the inner end.

The **HEEL** of a bevel gear tooth is the portion of the tooth surface at the outer end.

The **TOP** of a gear tooth is the upper or addendum portion of the tooth surface.

The **FLANK** of a gear tooth is the lower or dedendum portion of the tooth surface.

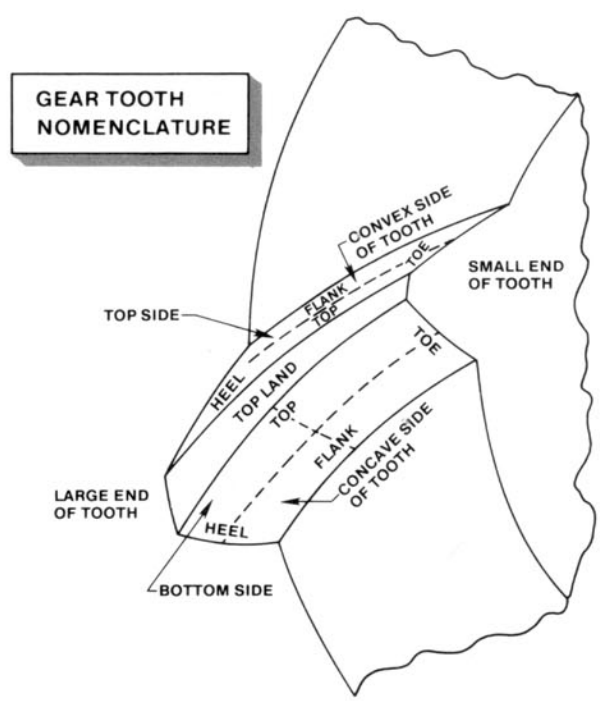
The **TOP LAND** of a gear tooth is the surface of the top of the tooth.

The **TOP SIDE** of a tooth

The **BOTTOM SIDE** of a tooth

The **CLEARANCE** is the distance from the bottom of a tooth space to the top of a mating tooth.

The **WORKING AREA** is all that portion of the tooth surface above the clearance.



TYPES OF BEVEL GEARS

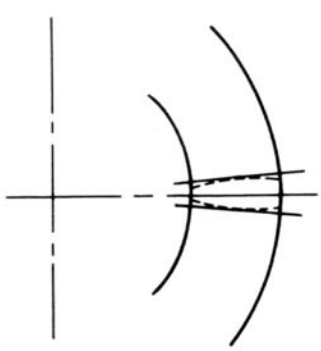
STRAIGHT BEVEL. A bevel gear with straight teeth which, if extended inward, would intersect at the axis. (See Figure A)

SPIRAL BEVEL. A bevel gear with either curved or skew teeth at an angle to the direction of a straight bevel tooth. They differ from the straight bevel in that if they were extended inward, they would not intersect at the axis. There are two different types of tooth forms—the "tapered depth tooth" where the tooth depth tapers from heel to toe, and the "uniform depth tooth" where the teeth are cut with a uniform depth (See Figures B and C)

ZEROL™. A spiral bevel gear of zero mean spiral angle having thrust characteristics similar to those of an equivalent straight bevel gear. (See Figure D)

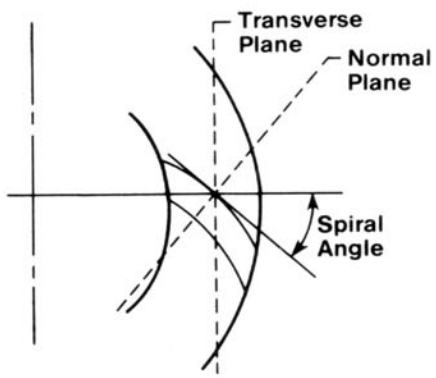
HYPOID. Hypoid gears are similar in appearance to spiral bevel gears but differ from spiral bevels in that the pinion axis and gear axis are not in the same plane but are offset from each other. (See Figure E)

FIGURE 1



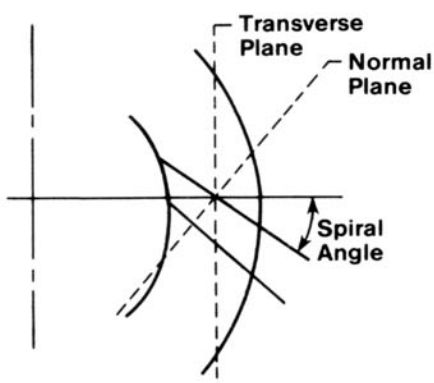
STRAIGHT BEVEL (Coniflex)

Figure A



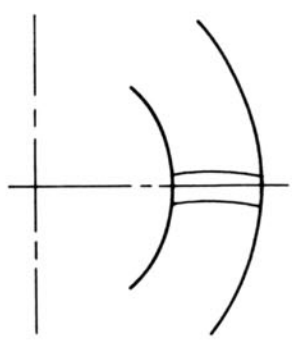
CURVED SPIRAL BEVEL

Figure B



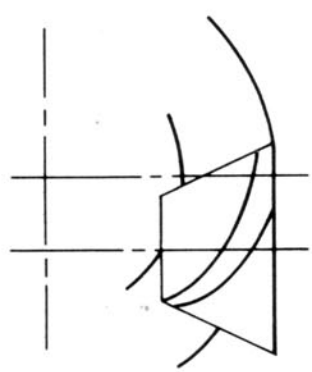
SKEW SPIRAL BEVEL

Figure C



ZEROL™

Figure D



HYPOID

Figure E

MOUNTINGS

It is important that the gear and pinion mountings be designed to give rigid support to the gears for all loads to which the gears may be subjected in service. It is equally important that the housing or mounting parts be machined within the recommended limits for alignment, squareness, fits and runout. While bevel and hypoid gears can accommodate reasonable displacements and misalignments without detriment to tooth action, excessive misalignment of the gears reduces their load capacity with consequent danger of surface failure and breakage in service.

In the mountings for all spiral bevel and hypoid gears, provision must be made for locking both gear and pinion against axial thrust in both directions. Provisions for locking against inward thrust on Zerol and straight bevel gears can be omitted provided conditions of operation are such that inward thrust will never occur.

Provision should also be made in the design of the mountings to adjust both gear and pinion to their respective mounting distances. It is also recommended that provision be made to permit inspection of the teeth of at least one member of the pair without disassembling the box. This is important for setting the gears in assembly and for periodic inspection in service.

When the tooth contact pattern calls for changes in gear positions other than adjustments along the axis of the gear or pinion, it is usually necessary to make changes in the housing or in the gears. It is desirable to correct the machine work on the housing rather than rework the gears to accommodate errors in the mounting. Reworking the gears to accommodate angle or offset errors in the housing is a critical process and should be undertaken only as a last resort. The results are usually not satisfactory.

Checking the housing for errors requires good equipment and great care. Inaccurate results complicate any investigation to locate trouble. While the shaft angle, offset and mounting distances are the usual items to check, the alignment of the bores and the squareness of the bearing seats are also important.

BEARINGS

The bearing manufacturer should be consulted regarding the selection of bearings suitable for the radial and thrust loading in order to maintain the alignment and position of the bearing and pinion.

The axial and radial movement of the bearings should not allow the load to substantially shift and the bearings should be stiff enough to prevent deflection in order to maintain proper contact. Deflection of the bearing shaft and the housing are all influenced by bearing contact.

All tolerance levels referred to in this manual are to be used only as a guide. To obtain the most desirable operating conditions, it may be necessary during manufacturing to either tighten or go beyond the tolerances shown.

MOUNTING DISTANCE

The axial position of a bevel gear and pinion in assembly is given by a dimension called the mounting distance (MD) as shown in Figure 2. This is the linear dimension from the axial locating surface of a given member to the crossing point * which is the point of intersection of the pinion and gear axes. Normally, the back of the pinion or gear is used to establish mounting distance; however, for convenience in assembling some gears, a front surface may be used. In all cases, the distance will be given to a flat surface square with the axis of the gear or pinion. The mounting distance is etched on the surface. (See Figure 4)

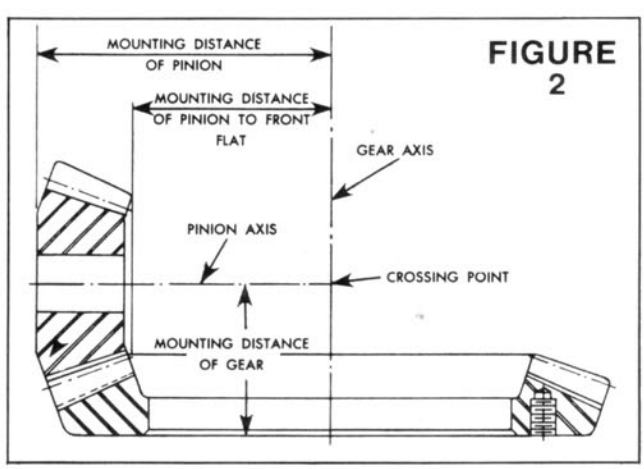


FIGURE 2

*Crossing point is the apparent point of intersection of the gear and pinion axis on a drawing showing the two axes. For bevel gears, it is the point of intersection of the two axes. For hypoids it is actually the projection of the common perpendicular to the gear and pinion axes to the plane of the drawing.

BACKLASH

Backlash is the difference in width of the gear tooth and the gear tooth space in the mating gear. (See Figure 3) It is measured at the tightest point of mesh.

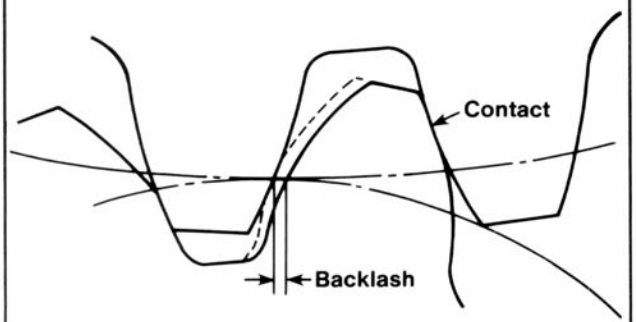


FIGURE 3

BACKLASH IN THE PLANE OF ROTATION

Backlash is necessary to achieve correct operation of the gears and varies with the size of the tooth and the operating conditions. Bevel gears are cut to have a definite amount of backlash when correctly assembled together. Excessive or insufficient backlash can result in noise, excessive wear, and damage. Backlash can be changed by changing the position of one or both members.

Setting the correct backlash is an important part of the installation procedure. Unless specified otherwise, the normal backlash is etched or stamped on one or both of the members. Table 1 shows recommended values but in many cases, manufacturing or operating conditions make it necessary to go outside these values. Values are given for normal backlash at the tightest point of mesh. Normal backlash is measured in a direction normal to the surface of the tooth. It can be checked by locking the pinion against rotation, placing a dial indicator against the gear tooth perpendicular to the tooth surface at the extreme heel of the tooth, and rotating the gear. To establish backlash in the plane of transverse rotation, the normal backlash must be divided by the cosine of the spiral angle and the cosine of the pressure angle of the gear teeth. Transverse rotation is approximately 30% higher than normal backlash.

The graph shown on page 8 illustrates the amount of axial movement necessary for either the pinion or gear member to obtain a change in backlash.

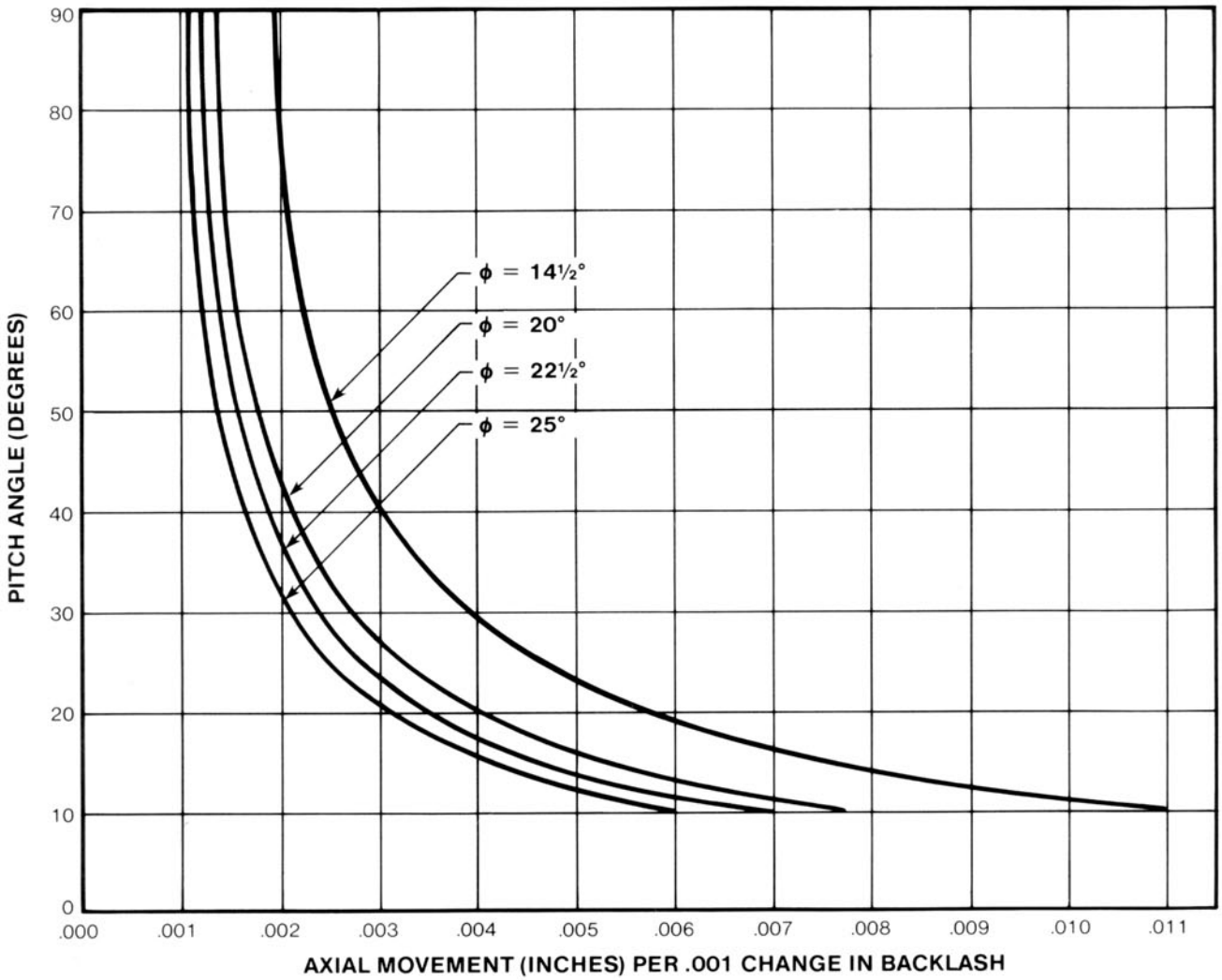
TABLE 1

Recommended Values of Normal Backlash at Tight Points of Mesh*

(All Values in Inches)

Diametral Pitch	Normal Backlash At Tight Points of Mesh
1.00 to 1.25	.020 — .030
1.25 to 1.50	.018 — .026
1.50 to 1.75	.016 — .022
1.75 to 2.00	.014 — .018
2.00 to 2.50	.012 — .016
2.50 to 3.00	.010 — .013
3.00 to 3.50	.008 — .011
3.50 to 4.00	.007 —.009
4.00 to 5.00	.006 — .008
5.00 to 6.00	.005 — .007
6.00 to 8.00	.004 — .006
8.00 to 10.00	.003 — .005
10.00 to 16.00	.002 — .004
16.00 to 20.00	.001 — .003

***The values shown in the above Table are for the recommended normal backlash for gears already assembled; however, all tolerance levels referred to in this manual are to be used only as a guide. To obtain the most desirable operating conditions, it may be necessary to either tighten or go beyond the tolerance shown.**



INSPECTION

Inspect the teeth to ensure there are no bumps or nicks which would injure the tooth surfaces of the mating member. All gears are inspected prior to shipment from Philadelphia Gear Corporation; however, damage to the teeth could occur in shipping or handling. Before installing a pair of bevel gears, note all markings and read tags which may be attached. The mounting distance is indicated as "MD", followed by the dimensions. Backlash is generally indicated by "LASH", followed by the amount. (See Figure 4) Gears which have been lapped have certain teeth marked "X".

Bevel gears are usually furnished in pairs and must be assembled with a mate having the proper identifying numbers and with marked teeth together as shown in Figure 4. Philadelphia Gear strongly recommends that if a gear member has to be replaced, it is in the best interest of the customer to replace both members.

Do not attempt to assemble a pair of bevel gears without complete information regarding mounting distances and backlash.

FIGURE 4

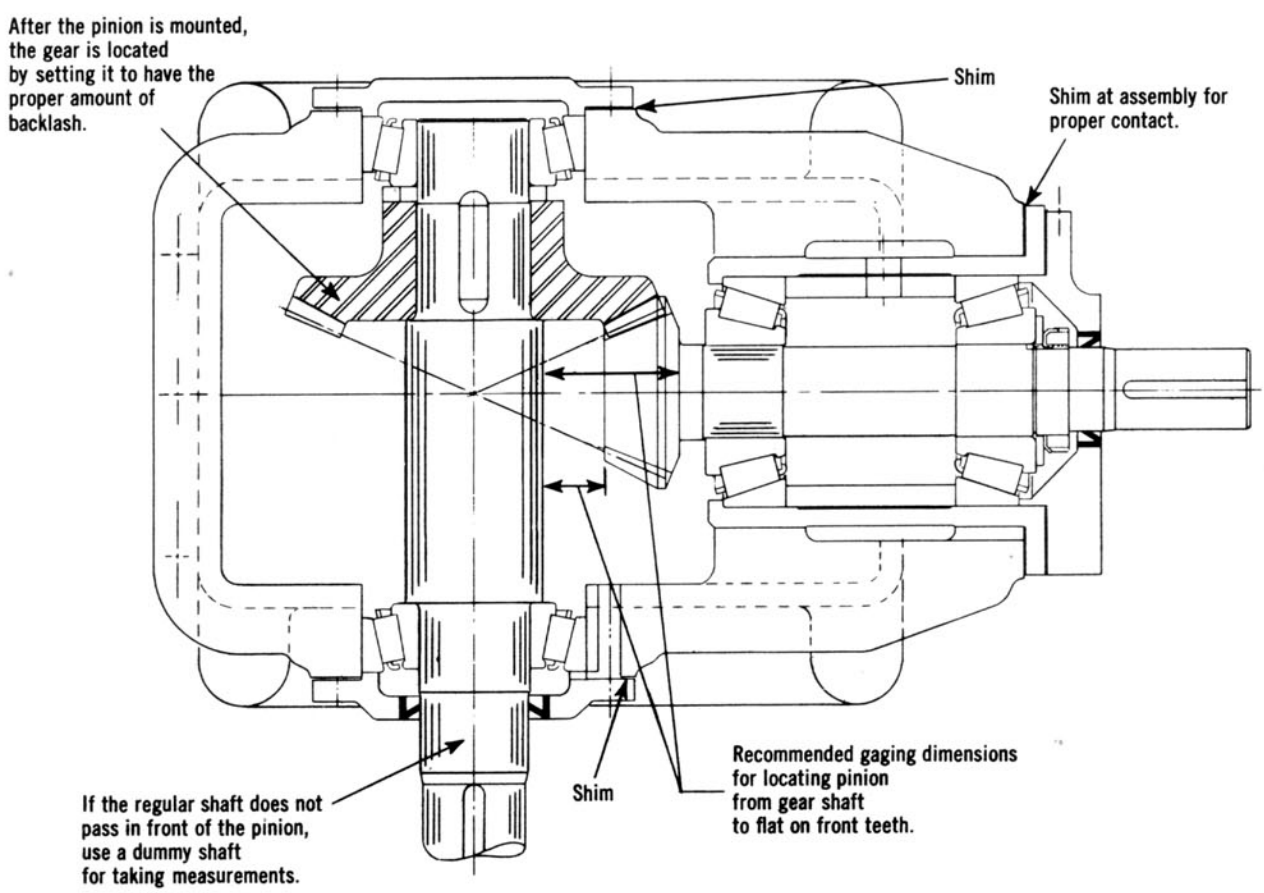
***TYPICAL BEVEL GEAR MARKINGS**

***Mounting distance and backlash markings can vary according to the gear and pinion configuration.**

INSTALLATION OF BEVEL PINIONS AND GEARS

Pinion and gear shaft bearings must be set to specified clearances before measuring mounting distances or backlash. The pinion should be positioned to its proper mounting distance, then the gear member should be set to its mounting distance and the specified backlash. These positions must be proven by checking the tooth contact pattern. A more detailed procedure for positioning the members follows.

FIGURE 5
REFERENCE POINTS



POSITIONING THE PINION IN BEVEL GEAR DRIVES

The pinion shaft assembly, including bearings, is usually contained in a cylindrical cartridge. Pinion mounting distance is set by adjusting thickness of shims between cartridge flange and gear drive housing. It is recommended that a gauge be used to set the pinion member to its proper mounting distance. When a gauge is not available, the pinion may be located axially by measuring from the locating surface to the axis of the mating gear. This measurement may be made by means of a micrometer, gauge blocks, or a special gauge manufactured for this purpose. Reference points for measuring are shown in Figure 5.

In the case of large bevel gears where direct measurement of mounting distance is difficult, a flat is hand ground on the back cone surfaces (back angles) of the gear and pinion when in proper position on the testing machine. When the gears are assembled, they must be positioned so that the hand ground flats on the back cone surfaces are flush. These surfaces are marked "X" and must be assembled in a manner similar to that used for lapped gears as shown in Figure 6.

This method may not be used on hypoid pairs as the back cone surfaces are not tangent. The hypoid pinions are set by a gauge generally shorter than the gauging distance to allow for space when using feeler gauges. (See Figure 7)

FIGURE 6

Large spiral bevel gears are marked "X". Hand ground back cone surfaces are mounted flush.

POSITIONING THE GEAR MEMBER IN BEVEL GEAR DRIVES

It is best to first obtain correct bearing adjustment on the gear shaft before checking gear position and then moving gear by switching shims as described below. The gear member may be positioned by either of two methods. After the pinion is in position, the proper position of the gear may be determined by measuring the backlash. If the backlash does not conform to specifications, the gear member must be repositioned axially.

Remove caps on housing at shaft ends. Remove shims from one end of shaft as needed, and add same thickness to opposite end. Replace caps. This procedure allows repositioning of gear/shaft assembly while maintaining bearing clearances.

The gear member may also be located by a gauge or by measurement as described for the pinion member. When the required backlash is not obtained for ratios other than 1:1, the gear member must be adjusted axially. Ratios of 1:1 require equal movement of both members.

If extensive corrective changes from the gauged or measured mounting distances are required, it is recommended that the gear drive be checked by a qualified serviceman.

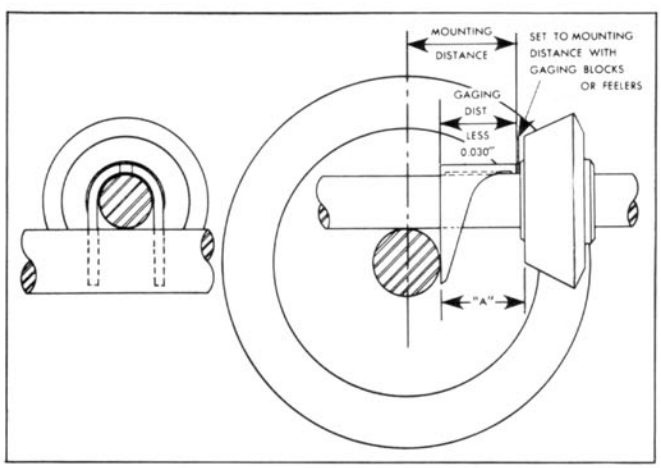


FIGURE 7

NOTE

When the front surface of the pinion is large enough in diameter to reach the center line of the cross shaft, measurements "A" may be made for positioning the pinion as shown in Figure 7.

INSTALLATION CHECKING PROCEDURE

After installation, the following precautions should be taken before checking the tooth pattern and operating the gears:

1. The gear and pinion must be securely locked in place.
2. Inner and outer races of the locating bearings should be securely clamped against axial movement.

TOOTH PATTERN

The backlash setting must be confirmed by checking the tooth pattern. Bevel gears with tapered depth teeth are usually cut with tooth contact slightly nearer the inner end of the tooth (toe) since the tooth contact generally spreads out and shifts toward the outer end of the tooth (heel) under heavy load and outward pinion thrust. This contact is known as "central toe tooth contact". See pages 14 through 26.

Bevel gears with uniform depth teeth have a tooth contact in the center of the tooth which is known as "central tooth contact". See pages 14 through 26 for examples of tooth contact patterns.

CAUTION

The mixture of the marking compound and spindle oil is suitable for lubricating the gears for light loads and slow speeds only. Extreme caution must be used and the gears checked constantly for evidence of scoring.

The tooth pattern may be checked by painting the gear teeth with a gear marking compound and then running the gears at slow speed under a very light load for a short period of time. The contact should be the same as the recommended tooth bearing for normal mounting shown in the examples.

DEFLECTIONS IN MOUNTING

Because of this complex nature of the forces generated by transmitting power through bevel gears, it is impossible to fully predict the behavior of gears under full load. Two or three of the gear teeth should be painted with steel marking ink and the gears run for a few minutes under full load with regular lubricant. The pattern should then be checked. The pattern should have spread out to utilize most of the tooth face and should not show heavy concentration at the ends or tops of teeth. Deviations will indicate possible future problems.

If the profile contact pattern is unsatisfactory under operating conditions but satisfactory under a light load, recheck the assembly before readjusting the gears. Both the gears and bearings should be clamped securely in their mountings. The backlash should also be checked for possible readjustment.

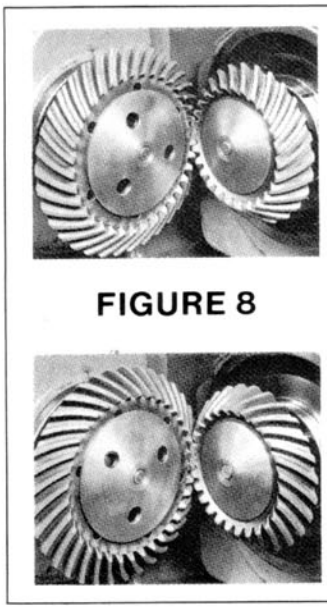


FIGURE 8

The "hand of the spiral" denotes the direction of the spiral angle. In the illustration at the left, the pinion member is left handed; the teeth incline away from the axis in counterclockwise direction. The gear member (always opposite from the pinion) is right handed. A pair is called by the hand of its pinion member.

LUBRICATION

Two types of lubrication generally used are splash or pressure (force feed) systems.

Splash lubrication is normally used for peripheral speeds up to 2000 feet per minute with the oil level set high enough to submerge the lowest member.

NOTE

Too high an oil level causes temperatures to rise from a resultant churning action; therefore, it is imperative that the level be checked periodically by the method provided—either a dipstick or a sight gauge.

For peripheral speeds greater than 2000 feet per minute, the gears are pressure lubricated via jet spray. The source of the spray should be positioned so that the spray is directed to cover the full length of the teeth at the meshing point. A good rule of thumb to determine the amount of oil required to lubricate a gear mesh would be approximately 0.3 gallon per minute per 100 horsepower transmitted. The jet spray should be directed to the entering side of the mesh. The same lubricating system may be used also to lubricate and cool the bearings. The direction of the jets and the amount of oil to the bearings should be as recommended by the bearing manufacturer. Ample drainage should be provided from both the gears and bearings so that the oil cannot back up and cause churning by either gears or bearings. Before filling the case with lubricant, the housing must be thoroughly cleaned of any contaminants. Use only the recommended lubricant and fill to the proper oil level. We recommend extreme pressure lubricants for heavily loaded spiral bevels and also for hypoid gears which are subject to scoring if not properly lubricated.

Check the lubrication level to ensure adequate coverage across the full face of the gear mesh and to ensure there is a sufficient supply to lubricate the bearings. Check for leakage and possible contamination by inspecting all closures.

If extreme variations in temperature are expected, we recommend the installation of breathers. Oil temperatures increase during operation; therefore, the oil selected must have the viscosity required at operating temperatures. Refer to the AGMA Oil Number Selection Chart on page 13.

OIL CHANGES

After the initial two (2) weeks of operation, the original oil must be changed. If desired, this oil may be strained and used again. Do not use a strainer finer than 25 micro-inches to avoid filtering out additives. Very often, due to the wearing-in process, small metal particles will appear in the oil; this is not abnormal.

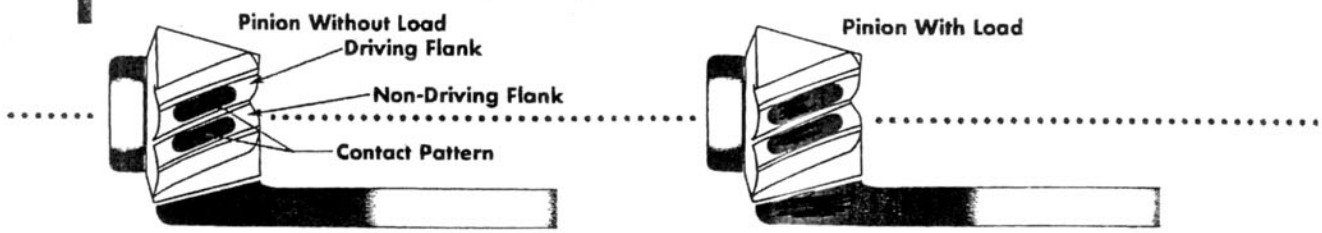
It is recommended that the gear housing be thoroughly flushed after the original oil has been drained. Fill the housing to the indicated level with SAE 10 straight mineral flushing oil which must not contain additives. Start gear drive and bring up to operating speed (preferably without load) and then stop. Drain flushing oil and fill with recommended operating lubricant to proper level. After the break-in period, it is recommended that the oil be changed after each subsequent 2500 hours of operation or six (6) months of normal operation, whichever occurs first.

Unusual environmental or load conditions may necessitate replacement of oil as frequently as one (1) to two (2) month intervals as determined by field inspection. Special attention must be given to the inspection of lubricants when following conditions exist:

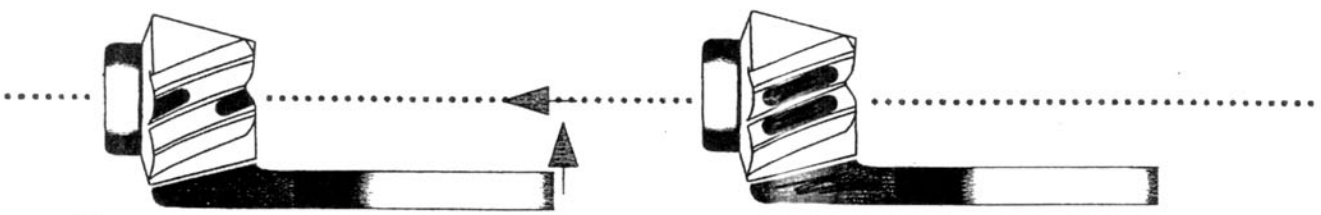
1. High operating temperatures resulting from heavy intermittent loads, causing the temperature of the gear housing to rise rapidly and then cool.
2. Ambient temperature conditions which may cause sweating on the inside walls of the gear housing, contaminating the oil and forming sludge.
3. Operating oil temperatures that remain constantly above 180°F.
4. When gears are exposed to an unusually moist atmosphere or vapors.

Precautions must be taken to prevent any foreign matter from entering the gear housing. Dust, dirt, moisture and chemical fumes form sludge which is the biggest detriment to proper and adequate lubrication.

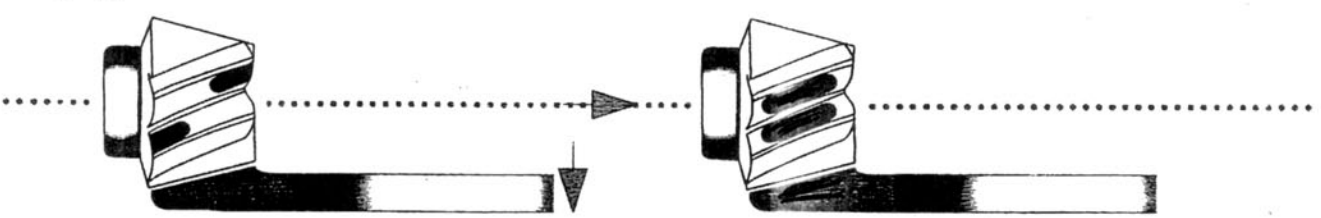
1 Correct Contact Pattern For Bevel Gears:

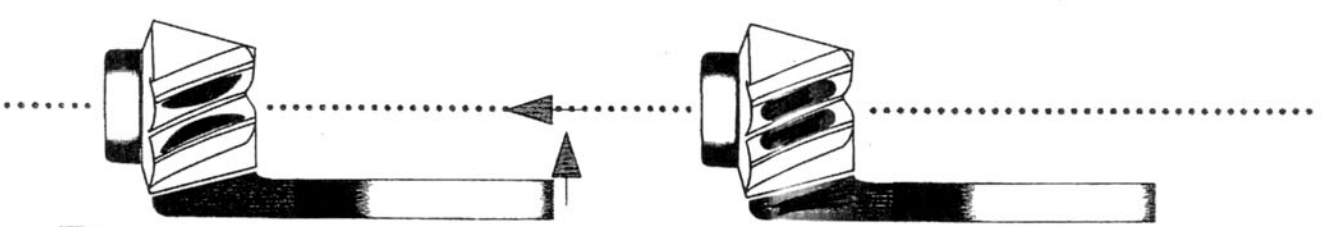


Figures A and B show an incorrect contact pattern on the left. The arrows in the center indicate the direction of movment needed to the wheel and pinion to achieve a correct contact pattern, shown on the right



A





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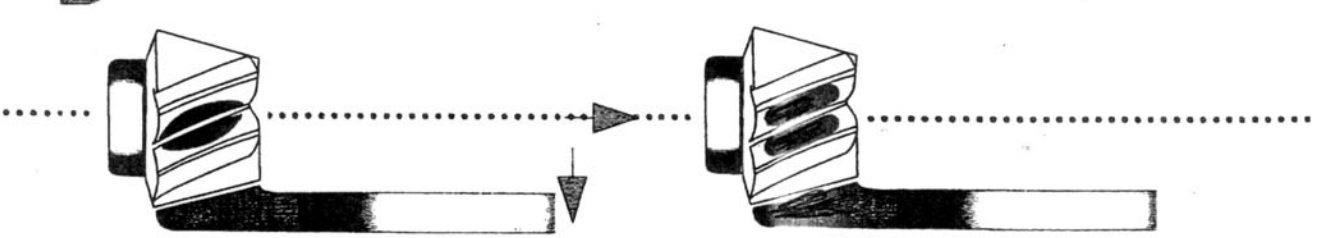

SUMMARY

Of Recommended Procedure for Installing Bevel Gears

1. Thoroughly clean all housings and parts.
2. Follow bearing manufacturer's instructions in handling anti-friction bearings.
3. Keep matched or lapped gears in their original sets or pairs.
4. Replace both members of a pair.
5. Assemble lapped gears of even ratio with the teeth marked "X" in proper mesh.
6. Check radial and axial mounting surfaces for runout.
7. The fits on radial mounting surfaces should be consistent with the application (never loose).
8. Set pinion member to the correct mounting distance.
9. Set gear for recommended backlash.
10. Check to be sure that locknuts, bolts, etc., are tight. In the case of spiral bevel and hypoid gears, be sure that both pinion and gear are locked against thrust in both directions.
11. Check for correct tooth bearing pattern.
12. Recheck backlash if correction is necessary.
13. Before operating under power, check to ensure that there is an adequate supply of specified lubricant to the mesh point of the gears and to the bearings.