A BRIEF HISTORY OF THE WALKER PROCESS EQUIPMENT INTERNAL SPUR GEAR DRIVE

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In 1957, Walker Process Equipment was producing its initial pier supported internal spur gear drives. The turntable bearing employed in the original design was the replaceable raceway insert type that was then and is currently used by the major water and wastewater collector drive manufacturers. The expiration of several key US Patents covering the bearing system's features placed this design within the public domain.

The original Walker internal spur gear drives did have some noticeable differences to their later counterparts. One such change of course is the development of more in depth and accurate rating methods over time based on the on going refinement of American Gear Manufacturers Association standards and their incorporation in the American National Standards Institute standards. Likewise similar developments have occurred in the overseas standards such as the German DIN and European ISO standards.

Some areas of design evolution are not obvious, such as the change from a 20-degree pressure angle, two diametral pitch stub tooth form to a 25-degree, two diametral pitch full depth profile adjusted tooth form with generated trochoidal root fillets. Some areas of this evolution are not only not obvious but are often overlooked or misunderstood. Among these the shift from a solid ring internal spur gear to the two-piece split internal gear that is well established in the market today. Another greatly misunderstood and misapplied design feature is the ratio of the height of the tooth face to the pinion pitch diameter. This ratio is the Aspect Ratio and should be as small as practical to ensure proper load distribution over the pinion and spur gear teeth while in mesh. Through out the design process over all the years, Walker Process has maintained Aspect Ratios below 1.0 by having the tooth face always less than the pinion pitch diameter. Some manufacturers have equated larger faced gear teeth with higher torque ratings. While this is seemingly true at first glance, a close look at the entire rating equation shows that excessive tooth face height actually can be quite detrimental to the life of the gear set as well as lowering the torque rating of the drive. The misalignment and uneven distribution of load over the tooth face resulting from high Aspect Ratios causes high-localized loading of the tooth faces, which exceed the surface durability of the tooth. This results in pitting that will progress to failure. The material resulting from this pitting becomes a contaminant in the lubricant causing abrasive wear as well. The pitting and abrasive wear create new points of localized loading in a destructive spiral.

Walker Process' first internal spur gears were continuous or solid rings. These gears were installed in housings with a removable cover plate. Once the gear was positioned on the turntable bearing balls, the cover plate was bolted to the top of the housing. The intermediate drive was then bolted to the cover plate. The ring had the advantage of an easily poured casting. The circular shape allowed for equalized stresses during solidification of the molten metal, resulting in little or no distortion of a properly designed and produced casting.

Early on, several significant disadvantages were identified with this solid gear design. The location of the intermediate drive directly effects the alignment of the pinion and spur gear teeth in mesh. The intermediate drive location was dependent not only on the tolerance of the rabbet in the cover plate, but also on the bolt hole locations in the cover plate and the tapped hole locations in the housing.

The tolerance stack up in this assemblage can cause misalignment in the intermediate and final spur gear drives, reducing any benefits otherwise obtained from profile correction of the pinion and gear teeth, or obtained from appropriately chosen tooth face heights to provide a low aspect ratio.

Another and perhaps greater disadvantage of the solid ring gear in this application is the necessity of removing the access bridge and any platform structure that rests on or supported by the gear housing in order to expose the internal spur gear ring and turntable bearing for inspection, repair, or replacement. In many cases removal of the bridge structure leaves nothing for the maintenance personnel to stand on while working on the gear or bearing. This usually results in the complete removal of the drive from the top of the center pier and relocation to a safer working environment, which greatly extends the duration of the clarifier outage.

Once the work on the drive has been completed, the drive must be reset on the pier, the cage and collector arms reattached, and the drive releveled from scratch. After the drive has been leveled, the bridge and other superstructure can be replaced.

By 1958, WPE had recognized these problems and eliminated them by employing the two-piece split ring gear. A typical internal spur gear drive of the period consisted of an ASTM A48 Class 40 cast iron housing, an ASTM A48 Class 50 cast iron split spur gear, a through hardened alloy steel pinion, and turntable bearing. The turntable bearing consisted of four replaceable raceways and 1 ½ inch diameter AFBMA Grade 50, OK gauge, ball bearings. The gears and bearings ran in an oil bath. The tooth form was the original 20-degree pressure angle 2 diametral pitch stub tooth form. Each internal spur gear split joint was pinned in two locations and held with four bolts.

The split gear segments presented some new challenges to Walker Process engineers. The spur gear semicircular segment requires careful planning to prevent casting stresses developing and causing the ends of the segments to spring either apart or toward each other when the tie bar between the segment ends is cut away. The tie bar acts as a channel for molten metal during the pouring process and as a stiffener to restrain the segment ends during heat treatment. If correctly designed for the material, the casting geometry, and the heat treatment process, the gear segment will be undistorted and readily machined and jointed to a second segment. Inadequate design and knowledge of the material, geometry and heat treatment and the segment will be anything but the semicircular segment required. Fortunately, patience and hard work prevailed.

With the split gear ring design, the collector must still be drained and the collector mechanism disconnected from the spur gear as with the solid ring gear. Also, in most cases, it is necessary to erect a scaffold or platform for workmen to stand on while working on the gear. The great difference is that the removal of a gear from the spur gear housing can be accomplished without removing the bridge or other superstructure, and this is substantially safer and more easily done than complete removal of the gear from the pier.

Another benefit is the time and effort saved by the elimination of the need to relevel the gear and mechanism. These advantages make the efforts in split gear design worthwhile.

As the AGMA standards evolved to AGMA 210(1) and AGMA 220(2), WPE began to use ASTM A536 grade 80-60-03 ductile cast iron as a gear ring material. This material change increased both the strength and durability of the internal spur gear set, thus increasing the torque rating of the drive within the original dimensional envelop.

In the late 1970's, the tooth form was changed to full depth and the pressure angle was increased to 25 degrees from the earlier 20 degrees pressure angle stub tooth design. The pressure angle change brought increased bending strength to the teeth as recognized by AGMA 218(3). In the early 1980's, additional heat treatment also increased the torque rating of the spur gear drive by increasing both the bending strength and surface durability of the internal spur gear teeth.

In the mid 1980's, WPE added a cast steel internal spur gear to its product line. This gear was later discontinued due to the greater corrosion resistance of ductile cast iron that produced identical torque ratings.

During this period, WPE engaged the assistance of consultants and experts in the field of gearing and turntable bearings to ensure the WPE spur gear design would continue to evolve and remain a leader in the market. One of these was Raymond J. Drago, Associate Member of AGMA and noted author of <u>Fundamentals of Gear Design</u>, and the <u>Helical Gears</u> section of the <u>Standard Handbook of Machine Design</u>, edited by Joseph E Shigley and Charles R. Mischke.

In the early 1990's, AGMA 218 was replaced by ANSI/AGMA 2001(4). WPE as always took the lead in the industry and brought out spur gear rings of quenched and tempered ASTM A536 Grade 120-90-02 ductile cast iron. This material has the best gear properties of the ductile iron grades listed by ANSI/AGMA 2001 and 2004(5), and is superior to cast or forged steel rings in the water and wastewater drive application.

As part of the on going program to keep Walker Process drives ahead, WPE has and continues to enlist the aid and council of AGMA Associate Members, among these is Mr. George Olson of Olson Engineering Services, Inc. Mr. Olson serves on several of the AGMA Standards Committees and is a well known expert in the field of gear design and manufacture. Mr. Olson evaluated the WPE split gear joint to ensure the joint strength equals or exceeds the strength of the spur gear ring.

Today, the design evolution continues, a process that has brought WPE from solid gray cast iron internal gears with numerous disadvantages to a split gear ring with teeth cut to AGMA Quality 6 minimum in accordance with ANSI/AGMA 2000(6), the structural integrity of a solid ring, and maximum material properties of the highest grade of ductile cast iron recognized by ANSI/AGMA Standards.

We are justifiably proud of the WPE spur gear drive of today. The only drive better than the WPE drive of today is the WPE drives of tomorrow, and we are working on it today.

1) AGMA 210.02, JAN., 1965, TENTATIVE AGMA STANDARD for Surface Durability (Pitting) of Spur Gear Teeth, superseded by AGMA 218.01, Dec. 1982, AGMA STANDARD: For Rating the Pitting Resistance and Bending Strength of Spur and helical Involute Gear Teeth

2) AGMA 220.02, AUG., 1966, AGMA STANDARD for Rating the Strength of Spur Gear Teeth, superseded by AGMA 218.01, Dec. 1982, AGMA STANDARD: For Rating the Pitting Resistance and Bending Strength of Spur and helical Involute Gear Teeth

3) AGMA 218.01, Dec. 1982, AGMA STANDARD: For Rating the Pitting Resistance and Bending Strength of Spur and helical Involute Gear Teeth, superseded by ANSI/AGMA 2001-B88, AMERICAN NATIONAL STANDARD: Fundemental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth

4) ANSI/AGMA 2001-B88, AMERICAN NATIONAL STANDARD: Fundemental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth, superseded by ANSI/AGMA 2001-C95, AMERICAN NATIONAL STANDARD: Fundemental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth

5) ANSI/AGMA 2004-B89, AMERICAN NATIONAL STANDARD: Gear Materials and Heat Treatment Manual

6) ANSI/AGMA 2000-A88, AMERICAN NATIONAL STANDARD: Gear Classification And Inspection Handbook - Tolerances And Measuring Methods For Unassembled Spur And Helical Gears (Including Metric Equivalents)