Cooling Technology Institute

CTI CODE TOWER
Standard Specifications

Gear Speed Reducers
for application on
Air Cooled Condensers

TABLE OF CONTENTS

Gear Speed Reducers for Application on Air Cooled Condensers

1.0 SCOPE

1.1 This Standard establishes the minimum recommended rating practice and operating considerations for gear speed reducers used with propeller type fans on air cooled condensers.

1.2 Where applicable, Standards published by the American Gear Manufacturers Association (hereinafter referred to as AGMA) are incorporated and made a part of this Standard by reference.

2.0 PURPOSE

The severe operating conditions encountered in air cooled condenser service make it desirable to establish minimum recommended design, installation, and operating practices for gear speed reducers to assure reliability, long service life and minimal maintenance.

3.0 DESIGN

3.1 The severe operating conditions in air cooled condensers require that the gear speed reducer be designed specifically for air cooled condenser service. "Multipurpose" gear speed reducers may have bearings that are not designed for external fan thrust, and may not have adequate thermal rating in the extreme operating environment of an air cooled condenser.

3.2 The mechanical power rating of the gear speed reducer shall be in accordance with applicable AGMA standards, except where otherwise specified in this standard. The mechanical power rating (i.e. k_0=1) of the helical gears shall be determined in accordance with ANSI/AGMA 2001-D04 "Fundamental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth" The mechanical power ratings of the gears are to be calculated for minimum 90% reliability at 100,000 hours life.

3.3 The manufacturer of the gear speed reducer shall insure that the thermal rating of the gear speed reducer is satisfactory for air cooled condenser applications. The thermal rating is dependent on the ambient temperature, air velocity, and fan power which is greater in cold temperatures due to the increase in air density. The thermal rating shall equal or exceed the motor nameplate power when calculated using the maximum expected ambient temperature. The thermal rating may be determined by actual testing of the gear speed reducer under operating conditions or by analytical methods. Both methods are outlined in AGMA ISO 14179-1, "Gear Reducers – Thermal Capacity Based on ISO/TR 14179-1". Service factors do not apply to the thermal ratings.

3.3.1 Thermal rating of the gear speed reducer is limited to a maximum oil sump temperature of 200°F (93°C). When the analytical method is used, an ambient air temperature and air velocity around the speed reducer of 100°F (38°C) and 250ft/min (1.2 m/s), respectfully, can be assumed if actual data is not available.

3.3.2 Higher oil sump temperature, up to 220°F (104°C), may be allowed when synthetic lubricants and special oil seals are used. Consult the gear speed reducer manufacturer for their guidelines. Synthetic oil and greases are preferred.

3.3.3 In an air cooled condenser application, fans on the input shaft of the gear speed reducer may have little effect on the oil sump temperature due to the primary airflow created by the main axial flow fan. For this reason, the gear speed reducer should preferably have adequate thermal rating without the use of an auxiliary cooling fan, unless field test data is provided.

3.4 Anti-friction bearings shall be used throughout the gear speed reducer. Journal bearings are not acceptable.

3.4.1 The bearing life shall be calculated on the motor nameplate power in accordance with ABMA STD 9 "Load Ratings and Fatigue Life for Ball Bearings", ABMA STD 11 "Load Ratings and Fatigue Life for Roller Bearings", IS0 281-2007 "Rolling Bearings -- Dynamic Load Ratings and Rating Life" or the bearing manufacturer's method.

3.4.2 Anti-friction bearings shall be selected to provide a minimum L_{10a} rated life of no less than 50,000 hours on the input and intermediate shafts. The output shaft anti-friction bearings life shall be calculated using the combined loading of the gear internal forces, the aerodynamic fan thrust, fan dynamic loading, (balance etc. as defined by the fan manufacturer) and fan weight. The output shaft bearings shall have L_{10a} rated life of no less than 100,000 hours. L_{10a} rating life is the life that 90% of a group of identical bearings will exceed before a fatigue spall develops, with adjustments for material, reliability, and operating conditions.

3.4.3 Wind effects on the inlet side of the air cooled condenser can create significant loading on fan blades that will reduce the fan shaft bearing life. Wind screens placed on an ACC may help to reduce these loads and help extend the life of the gear reducer and fan.

Greater distance between bearing centers in the gearbox

will help minimize the effect of wind loads on bearing life. Some gear speed reducer manufacturers may require an extended bearing housing to minimize this effect. Check with your gear speed reducer manufacturer if applicable.

3.5 Bearings in the gear speed reducer should be oil lubricated, to the greatest extent possible. Oil lubricated bearings avoid common problems associated with grease lubrication such as overfilling, under filling, improper grease selection, and difficulty in determining grease condition.

3.6 Shafts and other components shall be designed using the mechanical power rating (service factor = 1.0) of the gear speed reducer and shall meet the requirements contained in ANSI/AGMA 6013-A06 "Standard for Industrial Enclosed Gear Drives"

3.7 The gear housings shall be of sufficient rigidity and strength to insure the proper alignment of all gears and bearings when the gear speed reducer is operating at rated speed and load (both internal & external). Gear housings may be of split casing design or mono-block design. Split casing designs are generally easier to disassemble in the event that repairs are necessary.

3.8 The gear speed reducer must be equipped with a support for mounting the motor that assures alignment, within the coupling manufacturer's tolerances, between the motor shaft and gear speed reducer input shaft.

3.8.1 The motor support must be of sufficient rigidity to maintain alignment during continuous operation and motor starts.

3.8.2 The motor support must have a guard to prevent inadvertent contact with the rotating shafts and coupling, contain debris from a coupling failure, and provide an opening for visual inspection of the coupling, shafts, and seals.

3.9 The gear speed reducer shall be designed to prevent the intrusion of water and other contaminants from all external sources.

3.10 Many types of shaft seals are wear items that require periodic replacement. A shaft seal above the axial flow fan requires expensive and time consuming removal of the fan for replacement. For this reason, it is advantageous for the gear speed reducer to be designed to contain the lubricant within the gear case using a non-wearable seal on the fan shaft.

3.11 A drain shall be provided at the lowest part of the oil reservoir to permit draining of accumulated moisture at periodic intervals. The drain plug should be magnetic. If kidney loop filtration is used, it is beneficial to have a port in each end of the gear speed reducer to assure complete filtration of the oil.

3.12 The exterior of the gear speed reducer shall be coated with paint over a properly prepared surface to provide corrosion protection.

3.13 If reverse rotation of the fan is not required; the gear speed reducer may be equipped with a device that prevents reverse rotation. This type of device reduces shock load that occurs when the motor is started with the fan freewheeling in the reverse direction. The backstop devices should be rated for at least 50% of the motor full load torque. An alternate method for preventing unwanted reverse rotation is to control the motor using a VSD.

3.14 To facilitate vibration measurements, the gear speed reducer should have spot-faced threaded holes for attaching vibration transducers. There should be a location for one bearing on each shaft and the locations should be as close to the bearing housing as possible to provide accurate measurements. Vibration measuring devices should be located in an area accessible to operators from the fan bridge.

4.0 SERVICE FACTOR AND POWER RATING

When a gear speed reducer is to be selected for a specific application, the service power rating shall be determined by dividing the appropriate service factor into the mechanical power rating of the gear speed reducer.

4.1 The gear speed reducer shall be rated in accordance with ANSI/AGMA 6013-B16 "Standard for Industrial Enclosed Gear Drives", and have a minimum service factor of 2.0 based on the electric motor nameplate power.

4.2 The maximum momentary or starting load may not exceed 200% of the mechanical power rating of the speed reducer (service factor of 1.0) for a maximum of 10,000 cycles. For applications exceeding these load conditions, the service factor of the gear speed reducer should be increased until the maximum load and cycle requirements are satisfied. It is preferable to provide the gear speed reducer manufacture with the actual motor torque curve for proper selection.

4.3 For selection of a gear speed reducer for an application using a driver other than an electric motor, consult the gear speed reducer manufacturer for the appropriate service factor.

5.0 LUBRICATION

5.1 The type and grade of lubricant used should always conform to the recommendations of the gear speed reducer manufacturer. These recommendations are based on the type of gearing and the climatic conditions at the installation.

5.2 It is recommended that the lubricating oil be changed every six months or 2500 hours, whichever comes first, or in accordance with the gear speed reducer manufacturer's recommendation. Many manufacturers allow periodic oil condition analysis to determine oil

change frequency. This coupled with oil filtration can greatly extend the life of the lubricating oil and reduce maintenance and operating costs.

5.3 The gear speed reducer should be equipped with an oil level dipstick, and oil level should be checked at least once per week. Normally, units must be stopped for several minutes before this check is made to accurately determine the static oil level.

5.4 Use of synthetic lubricants should be approved by the speed reducer manufacturer. The manufacturer will assure that the synthetic lubricant is compatible with the gear speed reducer, specifically with oil seals, gasket compounds, and paint. Generally, synthetic lubricants provide higher viscosity index, broader operating temperature range, reduced friction, and improved oxidation stability.

5.5 Lubricant contamination is a major cause of reduced service life of gear speed reducers. Extended oil change intervals should be supported by a lubrication analysis program that includes accurate water content, spectrochemical analysis, viscosity measurement, and total acid number (TAN). Oil samples should be taken from the active oil zone, and the sample should be collected using a procedure to minimize contamination from external sources. Oil samples should be analyzed quarterly or at an interval determined by the owner based on historical data. As a reference, a baseline oil sample should be analyzed when filling the gear speed reducer with fresh oil. The oil should be changed if any of the following limits are exceeded.

Water content (ppm)	400
Total Acid Number	2.0
Viscosity	5% change from previous sample or 10% change from original value

Spectrochemical analysis of oil to identify wear metal concentrations is an important tool to aid in assessing the gear speed reducer condition. Contact the gear speed reducer manufacturer or oil analysis laboratory for guidance on maximum concentrations of wear metals and trend analysis.

5.6 When operation in cold weather requires the gear speed reducer manufacturer may supply lube oil heaters and operating instructions. The heaters must be controlled by a thermostat and have a Watt density of less than 6 W/in^2 ($1W/cm^2$) to prevent "coking" (burning) of the oil.

5.7 Lubricants that contain "extreme pressure" (EP) additives may prevent certain types of non-reverse devices from working properly. Always check with the gear speed reducer manufacturer for specific recommendations concerning lubricant selection.

5.8 If components of the gear speed reducer or flexible coupling require grease lubrication, follow the manufacturer's recommendation on grease type, quantity, and interval. Note that low speed thrust bearings normally require high viscosity grease that must meet the manufacturer's specification to prevent premature bearing damage. **Warning:** The use of incorrect grease may lead to poor operation or premature speed reducer failure.

5.9 The gear speed reducer should be equipped with a positive displacement oil pump to distribute lubricant to the gears and non-submerged bearings. The oil pump should be designed to provide lubrication during both directions of rotation and during periods of low speed wind milling of the fan. To reduce potential leak points, external plumbing lines should be kept to a minimum. The lubrication system should allow for the addition of an oil filter to improve lubricant quality.

5.10 The gear speed reducer should be equipped with a flow switch or pressure switch to assure that the oil pump is working.

6.0 PROTECTION DURING SHUTDOWN

6.1 Shutdown periods make the gear speed reducer particularly vulnerable to corrosion. During such periods, internal parts are not protected by the circulation of the lubricant as occurs during operation. Precautions should be taken for protection of the unit during shutdown periods of a week or more. Always check with the gear speed reducer manufacturer for specific recommendations concerning protection during shutdown.

6.2 For long periods of time between installation and operation of the gear speed reducer, contact the manufacturer for specific recommendations.

6.3 During short term shut down periods (less than one year) the preferred procedure is to operate the gear speed reducer weekly for several minutes to recoat internal parts with lubricant. This will also help protect the electric motor by evaporating condensed moisture.

6.4 For long term shut downs (one year or more), it may be necessary to coat the gear speed reducer internals with a rust preventative or add a vapor phase rust inhibitor to the oil. Contact the manufacturer for specific recommendations.

6.5 Power washing of the ACC tube bundles uses a large volume of water and the gear speed reducer needs to be protected during this cleaning process.

6.5.1 Remove the breather and plug the opening. If using a hygroscopic breather, seal it in a waterproof bag and remove it from the area.

6.5.2 Make sure the dip stick is pressed tightly into the casting or tubing.

6.5.3 Cover the motor/gearbox assembly with a large waterproof protective cover during the power washing.

6.5.4 After washing is complete, uncover the assembly, re-install the breather, and take an oil sample to ensure that water did not get into the oil sump.

7.0 INSTALLATION

7.1 Since the motor support assures proper alignment of the gear speed reducer and the electric motor, manual alignment is not required.

7.2 Ensure that the gear speed reducer is located in the center of the fan shroud by checking the fan blade tip clearance. Move the gear reducer or the fan shroud until all fan blades meet the tip clearance specified by the fan manufacturer.

7.3 If the gear speed reducer is equipped with a non-reverse device, disconnect the motor from the gear speed reducer prior to verifying the direction of rotation of the electric motor.

7.4 Foundation bolting shall be securely tightened, to the torque given by the gearbox supplier, to prevent the gear speed reducer from shifting under the reaction of the maximum fan torque which normally occurs at motor start-up. Confirm the correct bolt size with the gear speed reducer manufacture. Ensure that all surfaces are clean and free of debris before installing and tightening bolts. As a general guideline, the bolt diameter should not be less than 1/8" smaller than the bolt hole diameter.

7.5 Shimming may be required to ensure the speed reducer is level and to prevent "soft foot" that may distort the gear case, causing misalignment in gearing and bearings. When installing the gear speed reducer, gaps between the mounting feet and structural support should be filled with shims prior to tightening the bolts. Soft foot may be checked and corrected with or without the electric motor installed. "Soft foot" can be checked after all hold down bolting has been properly torqued by releasing the bolt torque one at a time and measuring deflection with a dial indicator. If there is deflection, use proper shim thicknesses to eliminate the deflection. Always make sure that shims are clean and free of debris. Once complete with the first hold down bolt, re-torque and move to the next hold down bolt. Proceed until all hold down bolting has been properly verified to have no deflection. Recheck gear reducer/assembly level after soft foot adjustments.

7.6 Gear speed reducers may be shipped "dry" and should be filled with the type and amount of lubricant or volatile preservative recommended by the manufacturer. Verify that the lubricant level is correct prior to operation. Reducers should be shipped in 'operating position' if required to be stored in operating position. The gear speed reducer manufacturer will provide specific storage recommendations and packaging.

7.7 If equipped, remove the protective plugs or caps and install the hygroscopic breather on the gearbox prior to operation and replace when indicated by the color change of the breather media.

8.0 OPERATION

8.1 Torsional fluctuations whether induced by the motor, the motor controller, or the fan can cause low cycle fatigue of the gear speed reducer and must be avoided.

Examples:

1. Operation at or near a torsional resonant frequency.
2. Use of a variable speed drive (VSD) that is not properly selected or tuned for the system.
3. When more than 33% of the fan blades are over an obstruction to the air flow (beams and walkways) at the same time.

8.2 Operation within 10% of any natural frequency in the power train system must be avoided. Operating frequencies that coincide with structural natural frequencies should be avoided and field corrections made when excessive vibration is encountered. ISO 14694:2003 "Industrial fans -- Specifications for balance quality and vibration levels", table 5 and fan class "BV-3" may be used to determine acceptable levels of vibration. When a VSD system is used, all natural frequencies within the operating speed range shall be determined by the ACC designer and locked-out to prevent continuous operation at or near those natural frequencies.

8.3 When two speed motors are used, a time delay shall be incorporated in the starter to prevent damage to the power train when the speeds are changed. When changing from high to low speeds, the time delay shall always be greater than the normal deceleration time of the fan when the motor is de-energized. When changing from low to high speed, the time delay shall be of sufficient time to allow the flux around the low speed winding to decay before energizing the high speed winding. (See CTI Paper TP97-10 "Mechanical Damage Caused by EMF Generated from Fast Bus Reclosure")

8.4 For variable speed drive systems (VSD) the deceleration time shall be set greater than the natural coast down time of the fan when the motor is de-energized.

8.4.1 The gear speed reducer should never be operated above its name plate speed without the permission of the manufacturer.

NOTE: The power required by the fan varies with the cube of its speed and the power rating of the gear speed reducer varies directly with its speed. A 10% increase of the fan speed (above its rated speed) will result in a 33% increase in the power required by the fan.

8.4.2 The minimum speed of the gear speed reducer and

the electric motor should always be confirmed by the respective manufacturer to insure that they will operate properly at reduced speeds.

8.5 Reverse Operation: Prior to running the gear speed reducer in reverse direction, make sure the gear speed reducer will lubricate properly, verify no non-reverse device is in use, and contact the manufacturer for specific recommendations. When reversing the direction of rotation, allow the fan to come to a complete stop before restarting the motor. If the fan cannot be stopped because it naturally rotates in the forward direction, this rotation can be stopped using a brake or VSD control on the motor.

8.6 **Sound pressure levels:** Due to the mechanical equipment being installed inside of the ACC, the reflective surfaces may cause sound levels to exceed 85 dB(A) on the fan bridge under some operating conditions. If the sound pressure level exceeds this limit, follow OSHA guidelines for hearing protection.

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