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Turbine-Generator Auxiliary Systems, Volume 6: Turning Gear Maintenance Guide

2010 TECHNICAL REPORT

Turbine-Generator Auxiliary Systems, Volume 6: Turning Gear Maintenance Guide

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REPORT SUMMARY

The Electric Power Research Institute's (EPRI's) Steam Turbine-Generators and Auxiliary Systems program (Program 65) produces a series of steam turbine and generator auxiliary system maintenance guides covering best practices for preventive, predictive, and routine maintenance and troubleshooting. This volume is devoted to the maintenance of steam turbine turning gear systems and is Volume 6 in the series. The volume addresses turning gear assemblies of the major original equipment manufacturers (OEMs), as found in fossil and nuclear power plants.

Background

Large steam turbines are equipped with a turning gear assembly to slowly rotate the turbine and generator rotors during periods of cooling down after a shutdown, while warming during startup, and during periods when the unit is off-line and on standby. In this document the reader should be made aware that the major turbine-generator component affected by thermal stresses is the steam turbine. The components, especially rotors, can be damaged as a result of thermal stresses when uneven cooling or heating is allowed to take place. Rotation of the turbine rotors helps even out the internal temperature distribution within the turbine shells and internal components with respect to the rotor. This helps reduce chances of thermal stress damage, such as rotor bowing and subsequently steam seal damage. By slowly rotating, the turbine rotors stay in a substantially straight and balanced condition during cooling, warming, and standby.

The turning gear assembly typically consists of an electric motor connected to a set of reduction gears that mesh with a corresponding bull gear attached to the turbine rotor. The electric motor torque is converted to slow-speed rotation of the turbine rotor through a series of gear reductions. The turning gear assembly is typically mounted separately from the turbine near the coupling between the steam turbine and generator. The turbine generator coupling will have a bull gear attached to the coupling via bolting or a shrink fit for meshing and engaging the turning gear assembly connection gear.

With the aging of the worldwide power plant fleet, utilities are increasing their focus on providing timely and cost-effective maintenance of their existing equipment, including turning gears. As operating conditions change along with dispatch modes in many current units, past facility turning gear maintenance and inspection practices need to be reevaluated and updated. The increase of units dispatched in a cycling mode has meant heavier use of their turning gears, which they were not designed for, increasing wear. Focus should be placed on potentially more frequent maintenance activities than in the past. In particular, components such as electric drive motors, chain drives, belt drives, oil flow nozzles, and instrumentation should be inspected on a routine basis. Heavier use of the turning gear will warrant more frequent internal visual inspections and could lead to more frequent rebuilds.

Objective

- To publish a guide summarizing best practices and procedures for the troubleshooting and maintenance of the turning gear systems commonly used by fossil and nuclear utilities in the operation of steam turbine-generator systems

Approach

A technical advisory group (TAG) composed of fossil and nuclear plant representatives from EPRI-member utilities provided input and review of this guide. As part of the underlying development, a survey was sent to selected members of EPRI Program 65 to collect information on current power plant operation and maintenance issues and practices. Additionally, a survey of existing EPRI literature and a search of manufacturer, vendor, and industry databases were conducted to review the latest information available.

Results

The guide addresses activities such as the following:

- General turning gear operations and configurations
- Troubleshooting, including mechanical, electrical, and digital control system data
- Periodic, preventive, and predictive maintenance techniques
- Routine inspection and maintenance criteria
- Jacking, barring, and lift oil systems
- Mechanical and electrical control systems

An appendix to the guide contains a set of data sheets for the recording of measurements and conditions of the turning gear.

EPRI Perspective

EPRI's Steam Turbine-Generators and Auxiliary Systems program develops technologies and guidelines that help plant operators optimize steam turbine and generator equipment life cycles to increase availability, shorten scheduled maintenance outages, and improve steam turbine performance. Research and technical support activities enable power plants to reduce operation and maintenance costs, maximize plant performance, and more effectively implement plant upgrades and asset management strategies.

Keywords

Steam turbine-generator
Maintenance
Turning gear
Barring gear
Clash gear
Bull gear

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1 INTRODUCTION

1.1 Background

The Electric Power Research Institute's (EPRI's) Steam Turbine-Generators and Auxiliary Systems program (Program 65) produces a series of auxiliary system maintenance guides that cover best practices for preventive, predictive, and routine maintenance and troubleshooting. The present guide, devoted to the maintenance of steam turbine turning gear systems, is Volume 6 in the series. It addresses turning gear assemblies of the major original equipment manufacturers (OEMs), as found in fossil and nuclear power plants.

1.2 Approach

A technical advisory group (TAG) composed of fossil and nuclear plant representatives from EPRI-member utilities provided input and review of this guide. As part of the underlying development, a survey was sent to selected members of EPRI Program 65 to collect information on current power plant operation and maintenance issues and practices. Additionally, a survey of existing EPRI literature and a search of manufacturer, vendor, and industry databases were conducted to review the latest information available. The database search included results from the GE Turbine Generator Users Group (GETURBGEN), a technical group hosted by Yahoo on the Internet.

1.3 EPRI Survey Summary

The survey asked members a series of questions concerning their turning gear maintenance practices. Responses were received from nuclear, fossil, and gas steam turbine combined-cycle sites. Information on General Electric, Westinghouse, Alstom, Siemens, Parsons, Toshiba, Rank, ABB, and Hitachi turning gear assemblies was received. Overall, the survey results show that most utilities have relatively few major problems with their turning gear assemblies and generally perform maintenance only when problems occur. Most of the utilities perform maintenance activities on their equipment based on their own problem history. Utilities perform internal inspections of their turning gear assemblies during planned major outages and rebuild or repair the equipment as problems are found.

1.3.1 Survey Results: List of Turning Gear Problems and Issues

Past problems and issues reported by the survey participants included the following:

- Engagement circuit problems
- Solenoid valves
- Gear damage caused by running dry during outage alignment activities
- Motor breaker problems
- Index cam failure
- Engagement linkage out of adjustment
- Engagement clutch problem
- Overheating of drive motor
- Blockage of lubrication oil nozzles
- Broken worm gear thrust plate
- Wrong zero speed indication—attempt to engage at high rpm
- Input gear to reduction gear slipped on shaft
- Broken gear teeth—not manufactured to the right hardness
- Linkage not fully disengaging after startup
- Motor bearing failure
- Bent linkage arm
- Slack and/or broken drive chain
- Minor oil leaks
- Bad pressure switch
- Bad motor starter
- Worm reduction gear bearings and gear pinion shafts
- Need to use jacking oil to stay on gear
- Difficulty of finding spare parts for older units
- Improper backlash

1.3.2 Survey Results: Internal Inspection Practices

Most survey participants had a schedule for visual inspection and rebuild of the turning gear assemblies based on their planned major outage schedules. The nuclear site internal inspection intervals were typically based on the refueling outage (RO) schedules and low-pressure (LP) turbine inspection frequencies. Fossil site intervals were typically based on the site major turbine inspection schedules. Survey responses show that turning gear assemblies are typically rebuilt on an "as needed" basis, as indicated by the results of planned internal inspections.

Table 1-1 summarizes the turning gear internal inspection frequency results from the EPRI survey.

Table 1-1
Turning Gear Survey Results: Internal Inspections Frequency

OEM	Plant Type	Reported Frequency (Number of Responses)				
		1–4 Years (1–2 RO)	5–8 Years (3–5 RO)	9–12 Years (6–8 RO)	13–16 Years (9–10 RO)	Never
General Electric	Nuclear	1	4	1		
	Fossil	2	8	6	2	1
Westinghouse	Nuclear		3	1		
	Fossil		4	3		
Alstom	Nuclear	2		1		
	Fossil		1	1		
Siemens	Nuclear	2				
Others (ABB, Parsons, Toshiba, Hitachi, Rank)	Fossil		3	3		

Note: Refueling outage (RO) interval = approximately 1.5 years

Two of the utilities that responded have turning gear inspection and rebuild procedures. Most utilities rely on the OEM or third-party contractors for both inspection and rebuild activities. Some utilities perform the inspections and rebuilds using internal personnel.

Table 1-2 summarizes survey responses regarding who typically performs turning gear internal inspections and rebuilds at the utility sites that responded to the survey.

Table 1-2
Turning Gear Survey Results: Internal Inspections and Rebuilds

Type of Work	Number of Responses		
	Performed by Internal Group	Performed by Third-Party Contractor	Performed by OEM
Inspections	17	9	17
Rebuilds	13	14	18

1.3.3 Survey Results: Preventive and Predictive Maintenance Activities

Most sites in the survey responded with "as needed" or "none" regarding the frequency of preventive and predictive maintenance activities performed on their turning gear assemblies outside of the inspections performed during planned outages. Several sites reported that they perform preventive maintenance on the motor breakers because of problems they have seen in the past. Several sites reported daily inspection of the turning gears during operator rounds, for oil leaks or unusual noises. Table 1-3 presents survey results regarding preventive and predictive maintenance activities based on the tasks performed.

Table 1-3
Turning Gear Survey Results: Maintenance Practices Frequency

Maintenance Activity	Reported Frequency (Number of Responses)			
	None or As Needed	1–4 Years (1–2 RO)	5–8 Years (3–5 RO)	9–12 Years (6–8 RO)
Electrical Testing	21	6	7	4
Motor Current Testing	26	9	2	2
Mechanical Testing	31	3	2	3
Motor Cleaning	26	6	4	4
Vibration Testing	31	9		
Lubrication	32	6	2	

2
TECHNICAL DESCRIPTION

2.1 General Discussion of Turning Gears

Large steam turbines are equipped with a turning gear assembly to slowly rotate the turbine rotors during periods of cooling down after a shutdown, while warming during startup, and during shutdown periods. Turbine components, especially rotors, can be damaged due to thermal stresses when uneven cooling or heating is allowed to take place. Rotation of the turbine rotor helps even out the internal temperature distribution within the turbine shells and internal components with respect to the rotor and helps reduce chances of thermal stress damage, such as bowing. By slowly rotating, the turbine rotor stays in a substantially straight and balanced condition during cooling and warming.

Turbine rotors are typically long, thin, heavy, and subject to temporary bowing when not rotated during periods of cooling or warming, as mentioned. Slow rotation of the rotor allows it to maintain a uniform temperature circumferentially as the turbine cools down, maintaining straightness and clearances with respect to internal turbine components. Allowing the rotor to stop rotation while cooling can cause excessive temporary bowing that must be dealt with by allowing the turbine to completely cool down, which can take several days. Temporary bowing of the turbine rotor is typically indicated by the eccentricity instrumentation on the unit. Excessive temporary bowing of the rotor can cause the rotor to become locked, at which point it can no longer be rotated by the turning gear assembly. When this occurs, the turning gear assembly should not be operated until the entire turbine is allowed to cool sufficiently for the rotor bowing to lessen sufficiently so the rotor can be turned. At this point, the turning gear can be put in service to help straighten out the turbine rotor in preparation for a future startup.

Caution: Never attempt to use steam to rotate a locked rotor, because extensive damage can occur to the turbine rotor or internal components.

The turning gear assembly typically consists of an electric motor connected to a set of reduction gears that mesh with a corresponding bull gear attached to the turbine rotor. The electric motor torque is converted to slow-speed rotation of the turbine rotor through a series of gear reductions. The turning gear assembly is typically mounted separately from the turbine near the coupling between the steam turbine and generator. The turbine-generator coupling will have a bull gear attached to the coupling via bolting or a shrink fit for meshing and engaging the turning gear assembly connection gear.

The turning gear assembly can typically be engaged to the turbine bull gear either manually at the assembly physical location or remotely via an electropneumatic control system. The remote electropneumatic system may be located and activated at a local turbine control panel or through the site's distributed control system (DCS). The control system is typically configured to automatically engage the turning gear system when the turbine rotor speed becomes zero during a shutdown; conversely, the system disengages when the turbine rotor speed reaches a prescribed speed during a startup.

Some turning gear assemblies have the capability to operate the turning gear at two different speeds, with some having a single two-speed motor and others having a separate motor for each speed. Because of its higher starting torque, the low-speed motor is typically used when starting the turbine rotor from rest, with the higher-speed motor taking over to maintain the OEM-recommended turning gear speed. Some utilities operate the motor only at the slower speed, whereas others operate it only at the higher speed. Some heavier rotors may require the higher-speed operation to maintain the lube oil wedge in the bearings during turning gear operation. Utilities should follow OEM recommendations regarding operating speeds.

Some turning gear applications may have provisions for an emergency means to provide the rotation torque in the case of a turning gear electric motor failure. These emergency drives are often permanently mounted pneumatic barring systems or manual barring systems.

Pneumatic barring systems can consist of a means to attach an air drive system to replace the electric motor for providing the reduction gear input torque. A pneumatic system can also be used to drive a barring jack that can mesh with the turbine bull gear on some units if the bull gear is readily accessible.

A toothed wheel mounted by shrinking onto the rear end of the rotor permits connection with a mechanical barring gear for slow turning of the rotor by hand in order to prevent warping. Manual barring systems can have different forms, depending on the configuration of the turning gear assembly. Manual barring may consist of a pawl and ratchet system used to rotate the turbine slowly by hand in an emergency.

Typically, the emergency means of rotation involve adaptations to the electric motor shaft or the reduction gear input shaft, by which a mechanical device can be used by an individual to rotate the turning gear reduction gear input shaft, simulating the driving mechanism.

In very-small-capacity units (on the order of about 500 kW and below), the mechanism may be hand-operated to frequently change the shaft position by 180 degrees. This is done using a bar temporarily attached to the shaft (hence the term *barring*.)

2.2 Turning Gear Operation

Turning gear operation takes place any time the turning gear assembly is used to rotate the turbine rotor inside the turbine shell. Typically, turning gear operation is used to help cool down the turbine internal components during shutdown periods, for rotation of the turbine rotor during extended shutdowns to minimize rotor bowing and sagging, for rotation of the turbine rotor for outage inspections, and for rotation of the turbine rotor to help prewarm the turbine internal components during startup periods.

2.2.1 Operation During Shutdown

When a steam turbine is shut down for an outage or an emergency trip, the rotor should be put on turning gear once the rotor has coasted down to a stopped or very near stopped condition. As mentioned previously, slow rotation of the rotor allows it to maintain a uniform temperature circumferentially as the turbine cools down, and to maintain its straightness and clearances with respect to internal turbine components. Time to cool the entire turbine will vary depending on the size, type, local environment, and operating conditions of the unit but can take many hours, or as much as several days.

Another advantage of putting the turbine on turning gear during a shutdown cooling period is that the turbine can readily go into a startup mode, if needed. If the turbine rotor is allowed to stand still while the turbine is cooling, temporary bowing of the rotor will take place and likely cause the rotor to become locked and unable to rotate. Then, startup of the unit cannot take place until the entire turbine is cooled to the OEM-recommended low temperature and can be put on turning gear for a minimum period of time before prewarming and restarting.

The turning gear is typically operated until the turbine is cooled to below the OEM-recommended temperature, at which point the turning gear is removed from service. It should not be operated continuously for extended periods of time after the turbine has cooled sufficiently, because continued operation can cause unnecessary wear to the turbine and generator rotating and stationary components such as coils, seals, and bearings and can potentially lead to forced outages. During long outage periods, the turbine should typically be rotated on turning gear continuously for about 5 hours each week.

2.2.2 Operation During Startup

The turning gear assembly is also used during startup to rotate the rotor while the turbine is prewarmed, which prevents temporary rotor bowing. For units with steam seals, the turbine should be placed on turning gear before admission of seal steam. Temporary rotor bowing during startup can cause packing rubs, seal damage, and vibration problems, and can potentially delay the unit coming on-line. The length of time required for the rotor to be rotated during turbine warming will vary for each specific unit. For the units of most major OEMs, the time on turning gear operation before startup is a minimum of 4 hours. The OEM startup instructions and turning gear operation time for each specific unit should be followed. During startup, the turning gear will be operated until steam flow is established. The turning gear assembly has an overspeed rotation protection device for disengaging when the rotor speed reaches the OEM's specifications. When the speed of the turbine increases sufficiently to drive the turning gear, the torque exerted by the turbine rotor bull gear on the turning gear clash gear causes the clash gear to disengage.

2.2.3 Operation During Outages

Another use of the turning gear assembly is rotating and positioning of the rotor during outage and shutdown for performing activities such as inspections, coupling alignments, and placement of balance weights. Temporary electrical jog switches may be installed on the turning gear electrical controls to aid in starting and stopping the electrical drive motor during positioning of the rotor. There are temporary turning gear drives available commercially to replace the turning gear during outages for a more controlled positioning of the rotor during maintenance activities. Vendors for temporary turning gears can be readily found through an Internet search.

Caution: Careful planning is required for operating the turning gear during an outage when performing inspection and maintenance activities. Care must be taken to comply with the site's lockout/tagout program. Removing and reinstalling the lockout/tagout system on the turning gear can be a time-consuming endeavor. A turning gear auxiliary drive, such as an emergency compressed air system, may also need to be included in the lockout/tagout process.

2.3 Lubrication Requirements

Lubrication oil for the turning gear assembly is supplied from the main turbine oil system. The oil supply is furnished via one of the main oil tank pumps. The turbine lubrication system must be in service when the turning gear assembly is in operation to provide oil to the bearings and to the turning gear reduction gear assembly. For some turning gear installations, lubricating oil is continuously supplied to the turning gear assembly; for other installations, the lubricating oil supply to the turning gear must be started manually by opening a valve. Oil pressure sensing instrumentation is included in the turning gear starting logic controls to ensure that lubricating oil is available before the turning gear can be started. During shutdown and cooling periods, the turbine lubrication oil temperature should be reduced to approximately 85–90°F (29–32°C) to increase the oil viscosity for the slow-speed operation and cooling of the turbine bearings. The higher oil viscosity is needed for proper full-film lubrication of the bearings at the slower rotation speed. The turning gear assembly requires oil to lubricate the reduction gear bearings and gear wheel teeth. It is important to establish oil flow to the turning gear assembly before putting it in operation.

Jacking lift pumps may be used on some larger units while the unit is on turning gear to assist the lubrication system with a full-film oil supply to each bearing. Use of the jacking lift pumps helps reduce the amounts of torque load on the turning gear motor and reduces gear tooth stresses.

EPRI report 1010191, *Turbine-Generator Auxiliary Systems, Volume 1: Turbine-Generator Lubrication System Maintenance Guide*, gives a good description of the turbine lubrication system while on turning gear, for a number of OEMs [1].

2.4 Design Criteria

The turning gear assembly for most units is designed and specified by the steam turbine generator OEM. Major design factors to consider include the following:

- Torque requirements for starting the rotor rotation from a stationary position and maintaining rotation once started
- Minimum rotor rotational speed
- Minimum full-film oil requirements at turning gear startup and at operating speed

The proper amount of torque for starting and maintaining the turbine rotor rotation is a function of the bearing sizes and types along with the turbine rotor physical weight and inertia characteristics.

The speed of rotor rotation is determined by the OEM for each specific unit. There is a designed calculated minimum rotor rotation speed requirement and a minimum oil film requirement for each bearing to prevent damage to turbine components during turning gear operation. For most steam turbines, the rotor rotation speed while on turning gear is a minimum of 2 rpm and a maximum of 10 rpm. Very slow (typically < 2 rpm) turbine rotor rotation speed can result in bearing damage, vibration, and blade stick-slip situations.

A more thorough discussion of the relationship between turning gear speed, lubrication oil temperatures, and bearing loading can be found in EPRI report CS-4555, *Guidelines for Maintaining Steam Turbine Lubrication Systems* [2].

Any major replacement or upgrade to the turning gear system components should be discussed with the OEM for their recommendations before implementation.

2.5 Turning Gear Replacements or Redesigns

In some situations, there may be a need for replacement or upgrading of the turning gear assembly in conjunction with rotor replacements, or replacement may be prompted by damage to the existing turning gear assembly. A turning gear assembly can potentially be made by non-OEM suppliers if it is properly designed and fabricated. Reduction gear vendors can supply detailed specification requirements for their specific units.

Major inputs required for specifications to upgrade, redesign, or replace the turning gear assembly include the following parameters:

- The type and size of turbine bearings used.
- The weight of the turbine generator rotors to be rotated.
- The output torque requirement—this is the torque required by the turning gear to start up and continuously rotate the steam turbine generator rotors.
- The turbine rotor rotation speed—this is the speed at which the turbine rotor is expected to rotate. Typically, the current rotation speed would be used. This speed will help determine the number of gear reductions required from the electric motor speed.
- The output gear teeth configuration—this includes the turning gear connecting gear configuration required to mesh with the turbine-generator bull gear. American Gear Manufacturer Association standards should be used for metallurgical and geometry specifications.
- The gear assembly alignment—this includes the existing base plate and pedestal dimensions for mounting the turning gear assembly. Also included is the mounting position of the electrical drive motor.
- The motor voltage—this is the voltage to be supplied for the electrical motor.

2.6 Blade Stick-Slip

Stick-slip is a phenomenon whereby the rotor climbs or “sticks” in the bearings as it is rotating at low speeds and creates an ongoing torsional vibration. During low-speed rotation, when gravity on the rotor overcomes friction in the bearing, the rotor “slips” and falls back to the bottom of the bearing as it is rotated. Repeat of sticking and slipping of the rotor in the bearing and corresponding torsional vibration oscillation has a fatigue damaging effect on the L-0 blades. Often, the torsional vibration of the L-0 blades is an audible chatter. This phenomenon typically occurs when the turbine rotor is starting on turning gear and the bearing does not have sufficient oil film to reduce the friction in the bearing. Larger-size turbines, which typically have longer and flexible rotors, have been especially suspect for blade stick-slip when operating on turning gear. Increasing the speed of the turbine rotor rotation while on turning gear has been effective in reducing the torsional vibration.

The following actions have been effective in eliminating or reducing blade stick-slip in most units:

- Increasing the turbine bearing oil film with an increase of the lubrication oil viscosity. It is important to make sure the lubricating oil feed temperature is at the OEM-recommended lower temperature when the unit is shut down.
- Increasing the turbine bearing oil film with use of jacking lift pumps at startup of the turning gear.
- Increasing the turning gear rotation speed to help reduce the torsional vibration.

2.7 Copper Dusting

Copper dusting is a generic problem in generator rotor windings that have turns assembled from two or more strips of copper instead of a single piece. Operating a steam turbine-generator for extended periods of time after the unit has cooled sufficiently has been shown to be a major contributor to copper dusting.

As described in EPRI report 1013458, *Main Generator Rotor Maintenance* [3]:

> During turning gear operation, there is insignificant centrifugal force on the rotor. Still, the rotor's middle will flex as it turns, due to gravity. Certain rotor components, without centrifugal force securing them, can rub, thereby creating fretting and fatigue. Insulation wear and copper dusting are examples of the degradation that can occur mostly while on turning gear. Copper dusting, if excessive enough, can lead to field winding grounds and interturn shorts. Certain field winding designs incorporate two-part conductors. These two-part conductors are copper bars with C-shaped or E-shaped cross-sectional areas, that when installed face-to-face form one or two cooling passages through them. One other two-part conductor design consists of two flat pieces of copper that do not form cooling passages. Regardless of the shape of the two parts making up a conductor, relative movement between the copper parts can cause them to rub and abrade each other. This abrasion wears off some of the copper, forming a copper dust. Relative movement of the copper conductor parts may be due to thermal expansion and slight rotor flexing experienced during startup, operation, and cooldown of the generator. Being on turning gear for a period of time may cause significant copper dusting.
>
> While on turning gear, the windings can be freer to move than when in operation, not having centrifugal force or thermal expansion holding the conductors tightly in position. With each rotation while on turning gear, the individual conductor parts complete a cycle of relative movement, with possible wear against each other.
>
> Many generator rotors with two-part conductors do not necessarily have problems with copper dusting. In these machines the conductors are sufficiently braced to prevent relative movement, or at least make any movement insignificant. With some designs, the conductor parts are brazed together in spots along their length to more effectively hold them in relative position.
>
> Because some units may be on turning gear for extended periods of time—possibly spending more time on turning gear than in operation—significant wear can occur. Plants with generators known to be prone to significant wear while at low speeds, including when on turning gear, should avoid extended periods of time on turning gear as much as possible.

Another description of copper dusting, with illustrations (reproduced here as Figures 2-1 and 2-2), appears in Section 4.3 of EPRI report 1004951, *Optimized Maintenance of Rotors* [4]:

> Copper dusting is a condition that can occur with copper windings that have a double-layer design, where the two layers of copper are in direct contact. It occurs when the rotor is on turning gear at slow speed. During turning gear operation, the copper winding is loose in the slot because the centrifugal loading is not enough to lock the copper against

the winding slot wedge. Generally this speed is anywhere from 3 to 40 rpm, depending on the manufacturer. Thus, the layers rub together in the transverse direction and create copper particles [see figures]. These particles have a tendency to migrate from between the layers where they are created. They tend to work their way out of the slot, and this can cause shorts between adjacent turns. Sometimes grounds are created to the wedges and forging if the particle migration is significant enough.

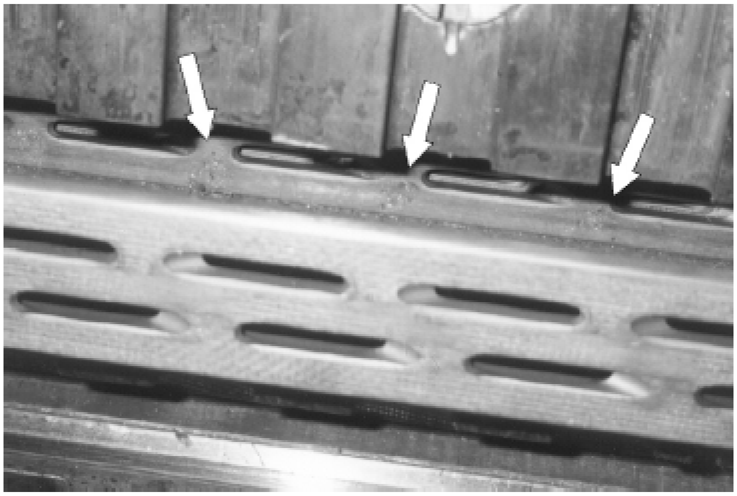

Figure 2-1
Copper Dusting Particles Due to Relative Motion Between Two Layers of One Turn of the Copper Winding

Figure 2-2
Copper Erosion Marks in the Transverse Direction Due to Relative Motion Between Two Layers of One Turn

2.8 Jacking Pumps or Lift Pumps

Because of the enormous weight of the many steam turbine-generator rotors, a jacking and/or lift pump system is used to float the rotor by using oil under high pressure during startup and operation of the turning gear system. Jacking pumps or lift pumps are used to decrease the amount of torque required to break the turbine rotor away from rest during turning gear startup and to decrease the amount of torque required for maintaining the rotor rotation while on turning gear. The jacking pump system provides an oil wedge between the bearing and turbine rotor to help lower the turning gear motor torque and ampere loads during turning gear startup and operation, to help prevent rotor vibration while in rotation, and to provide an oil wedge to protect the turbine bearings.

The use of shaft lift pumps can depend as much on the OEM as it does on unit size. For most large rotor turbine-generators, often 1000 MW or more, lift pumps are employed to improve oil film conditions at the bearings and provide an initial lift of the turbine-generator shaft off the bearings and allow oil wedge development as the shaft begins to turn. However, ALSTOM and their affiliated predecessor companies frequently employ shaft lift pumps (or jacking oil pumps) on steam turbines above approximately 100 MW. When supplied, lift pumps are generally started automatically during unit coast-down at a predetermined speed (for example, 600 rpm) and must be operating any time the turbine is on the turning (or jacking) gear while shut down.

Not all turbine-generator systems are supplied with lift pumps, and for those that are, the number and location of the pumps vary. Some OEMs provide one lift pump per low-pressure turbine shaft bearing and mount single pump assemblies on the low-pressure turbine bearing pedestal near the related bearing. Other OEMs provide lift pumps grouped in a skid-type arrangement in a more central location.

2.9 Turning Gear Configurations

Turning gear configurations can vary by OEM for each individual steam turbine application. Factors determining the turning gear drive configuration include the age of the unit, size of the unit, OEM preference, and available space for the turning gear and location. For most steam turbines within the utility industry, electric motor-driven turning gear configurations are most widely used. The electric motors for supplying the input torque for the turning gear assembly are mounted vertically in the case of a worm drive input unit or mounted horizontally in the case of a chain or belt drive input unit. Additionally, for some applications a hydraulic turning gear using a hydromatic gear motor that utilizes the lubricating oil pressure to rotate the turbine rotor is being applied within the industry.

2.9.1 Vertical Electric Motor Assemblies

The turning gear assemblies with vertically mounted electric motors are typically coupled directly to the reduction gear assembly, with the reduction gear input through a worm gear or bevel gear arrangement. The reduction gear assemblies have horizontal shaft-mounted gear trains. Figure 2-3 shows an example of a vertical Westinghouse worm gear arrangement.

The turning gear assemblies with vertically mounted electric motors are typically coupled directly to the reduction gear assembly, with the reduction gear input through a worm gear or bevel gear arrangement. The reduction gear assemblies have horizontal shaft-mounted gear trains. Figure 2-3 shows an example of a vertical Westinghouse worm gear arrangement.

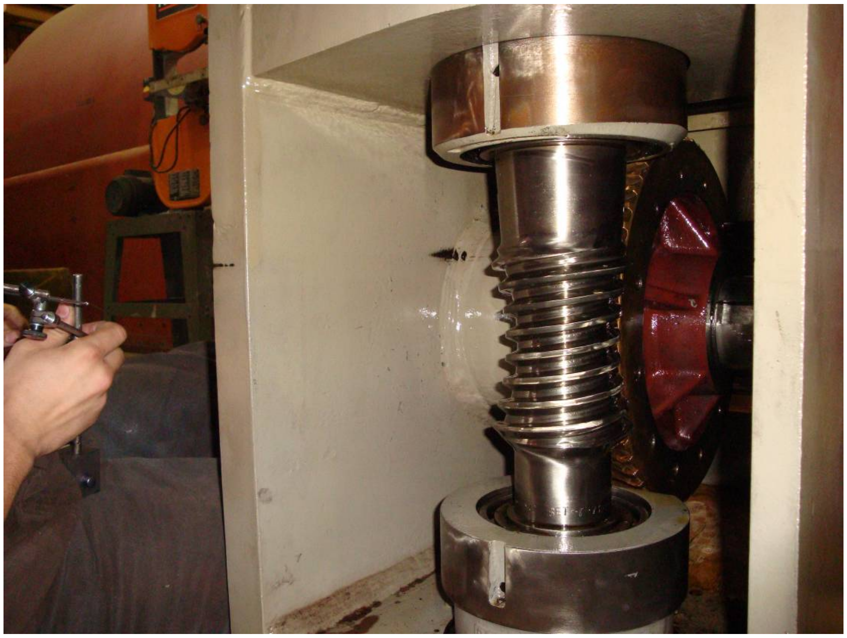

Figure 2-3
Westinghouse Turning Gear Worm Gear Arrangement

2.9.2 Horizontal Electric Motor Assemblies

Turning gear assemblies with horizontally mounted electric motors are typically connected to the reduction gear through a chain or belt drive assembly or may be directly coupled to the input shaft. The connection to the input shaft of the reduction gear assembly is typically through a belt or chain drive arrangement. Figure 2-4 shows an example of a horizontally mounted motor drive turning gear.

Figure 2-4
Horizontal Turning Gear Example

2.9.3 Hydraulic Turning Gear System

Siemens has a turning gear oil-driven system featuring a nozzle and impulse wheel. The impulse wheel is shrunk onto the high-pressure turbine at the first bearing pedestal. The turning gear speed can be controlled through a range of between 20 and 150 rpm by regulation of the turning gear oil supply valve to the hydromatic drive.

3
TURNING GEAR ASSEMBLY MAINTENANCE

3.1 General Discussion

Maintenance on the turning gear assembly should occur at routine intervals based on the amount of operating service and the conditions. Daily external inspection of the turning gear assembly should be included in the operator shift rounds. It should include a visual inspection of the external controls and components for cleanliness and a check for any looseness of control mechanisms, strange or unusual noises, and evidence of oil leaks. Any abnormal conditions should be investigated and addressed as soon as possible. The turning gear assembly should be free of dirt, dust, oil, and grease.

The worldwide fleet of power plants is aging, and utilities are increasing their focus on providing timely and cost-effective maintenance of their existing equipment, including turning gears. As operating conditions change along with dispatch modes in many current units, past facility turning gear maintenance and inspection practices need to be reevaluated. In the past, for many units traditionally dispatched in a baseload mode, the use of the turning gear did not occur very often. This meant that there was little wear and tear on the turning gear components, and few failures, so a heavy focus on maintenance activities was not needed. The increase of units dispatched in a cycling mode has meant heavier use of their turning gears, increased wear, and a focus on potentially more frequent maintenance activities than in the past. Components such as electric drive motors, chain drives, belt drives, oil flow nozzles, and instrumentation should be inspected on a routine basis. As a general rule, if the turning gear has been operating properly and no signs of heavy wear or damage are found during an outage internal visual inspection, then the turning gear reduction gear assembly should not be completely disassembled on a routine basis. Heavier use of the turning gear will warrant more frequent internal visual inspections and could lead to more frequent rebuilds.

In the current economic environment, many utilities have reduced or limited their maintenance budgets and are using a more aggressive approach, performing economics-based risk analysis for evaluating maintenance of various power plant equipment and systems. Heavier usage of the turning gear equipment is warranting that more maintenance activities to be performed. The maintenance recommendations that follow are based on feedback from EPRI and industry member practices, OEM recommendations, and prudent industry standards. The recommendations are primarily for preventive and predictive maintenance techniques for identifying a turning gear problem before failure. Any economics-based risk evaluations for performing these or additional maintenance activities should be done specifically for each utility and unit as their conditions and situation warrant. Information on performing an economic analysis can be found in Section 4 of EPRI product 1006965, *Proceedings: Advances in Life Assessment and Optimization of Fossil Power Plants* [5].

3.2 Electric Drive Motor Maintenance

Routine inspection and preventive maintenance on the turning gear electric drive motor should be performed. Electric drive motors can be positioned either vertically or horizontally on the turning gear assembly. Connection to the reduction gear may be directly through a clutch or coupling, through a belt drive, or through a chain drive. The motors typically have factory-packed grease-lubricated bearings, with the thrust bearing(s) located on the drive end and the guide (float) bearing(s) on the other end. The motor manufacturer's instructions should be followed for the grease type, viscosity grade, and frequency for adding grease. Care should be taken to not overgrease electric motors. Because turning gear motor operation can vary greatly across different units and power plants, turning gear motor maintenance activities need to be tailored for each specific situation. EPRI report 1003095, *Electric Motor Tiered Maintenance Program,* provides detailed information on electric motor maintenance in power plants [6]. EPRI report NP-7502, *Electric Motor Predictive and Preventive Maintenance Guide,* provides detailed information on performing in-service testing of electric motors in power plants [7].

3.2.1 Daily Checks

On a daily basis the electric motor should be inspected for overall cleanliness and any signs of oil or grease leakage. The motor ventilation openings should be unobstructed and clear. If the motor is operating, a check should be made for any excessive vibration, higher than normal amperage readings, higher than normal bearing temperature readings, overheating of the motor casing, or any abnormal noises. Any abnormal conditions should be investigated and corrected as soon as possible.

3.2.2 Disassembly, Inspection, and Cleaning

Typically, the turning gear drive motor should be disassembled, inspected, and cleaned internally on the same outage schedule as when the turning gear reduction gear assembly is inspected. Site motor cleaning procedures should be followed, or the motor should be sent to a qualified electric motor shop. Worn or damaged bearings should be replaced with the same type of bearings if problems are found. Proper grease lubrication should be packed in the bearings as specified by the OEM before reassembly.

Caution: Be sure to properly install the thrust bearings in the same positions and orientations as found. Improper installation of thrust bearings can allow limited or excess thrust loading within the motor and potentially damage the motor or reduction gear during operation.

The motor windings, insulation, and housing should be cleaned using the site's motor cleaning procedures. Vacuum cleaning the windings and insulation is usually preferred to compressed air blowing for cleaning dust and dirt from the winding and insulation. Vacuum cleaning lessens the chance of water and other contaminants being forced into winding crevices and future potential damage to coils. Any cleaning solvents used for cleaning should be in accordance with the site's approved list and usage procedures.

3.2.3 Electric Motor Breakers and Starters

Turning gear motor breakers and starters should be cleaned, inspected, and tested on a routine basis as part of the site's preventive maintenance program. Inspection of the turning gear motor breaker and starter should be included in the turning gear inspection during major outages. Any motor trips should be investigated and corrected before the turning gear is operated.

3.3 Chain Drive Maintenance

Routine inspection and preventive maintenance on the turning gear chain drive should be performed. The connection of the electric motor to the reduction gear assembly is typically through a chain drive for horizontally mounted electric motors. Silent chain drives are most often used for turning gear applications because they can transmit higher torques in a more compact drive, have no slippage, are more tolerant to high temperatures, produce less vibration, produce less noise, and provide more precise operation than equivalent roller chain or belt drives.

A turning gear silent chain drive consists of a driving sprocket connected to the electric motor shaft, a drive chain, a chain guard enclosure, and the driven sprocket connected to the input shaft of the reduction gear assembly. Steam turbine turning gear applications typically use center-guided silent chain drives. Figure 3-1 shows an example of a driven sprocket. Figure 3-2 shows an example of a center-guided silent chain often used on turning gears.

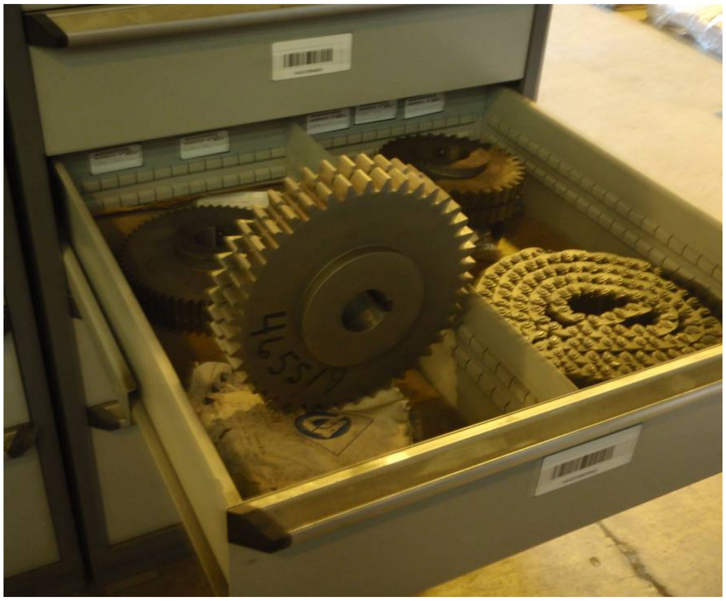

Figure 3-1
Example of a Turning Gear Chain Driven Sprocket

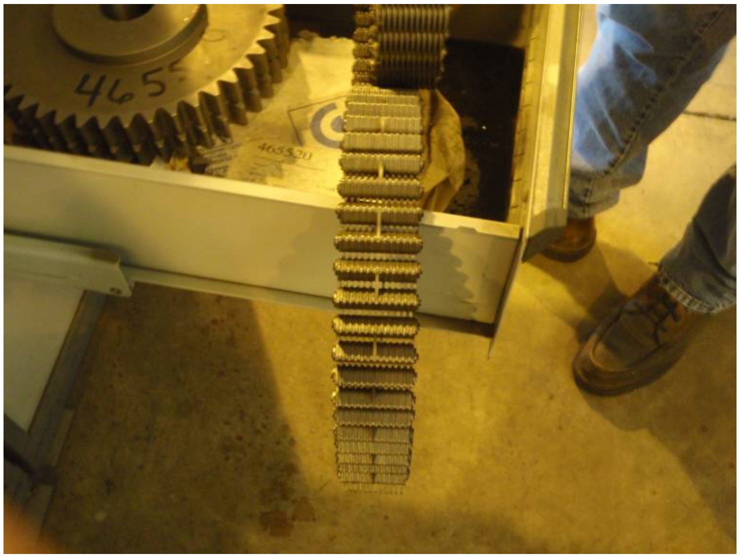

Figure 3-2
Example of a Turning Gear Chain Drive

3.3.1 Daily Checks

If the turning gear is operating, the chain drive should be checked for abnormal vibration or noise. Any findings should be investigated and repaired as soon as possible.

3.3.2 Disassembly and Inspection

All chain drive components should be visually inspected annually for looseness and excessive wear.

Caution: Ensure that proper site safety tagging procedures are followed for deenergizing the electric motor if performing an inspection outside of an outage.

3.3.2.1 During Outages

The chain should be inspected for alignment, looseness, wear, and elongation. The most likely wear is elongation of the chain due to wearing of the chain links and sprocket teeth contact surfaces over time. Excessive chain elongation or slack can lead to premature wear. The sprockets should be inspected for wear and replaced as needed because worn sprockets will increase the rate of chain wear. Sprockets should be dye-penetrant tested for cracks in the tooth faces or roots. Silent chains and sprockets can be manufactured by different vendors, and replacements must be made carefully with the same type chain, pitch, guide type, and width.

The sides of the chain guide links should be inspected for signs of wear and gouging, because this is often a sign of the sprockets being offset and misaligned. Ensure that the sprockets are properly aligned and keyed and that set screws are properly torqued per OEM specifications at reassembly.

Silent chain links by different manufacturers should not be mixed into the same strand. Chains of the same size, pitch, and type may be able to operate on the sprockets of different manufacturers without any problems. You will need to verify chain and sprocket compatibility for each specific application with the chain supplier or the OEM.

During reassembly, attention should be given to properly aligning the chain drive for smooth operation. The motor shaft and reduction gear input shafts should be horizontal and parallel, the sprockets aligned with no offset, and the chain tensioned in accordance with OEM specifications. Positioning of the shaft centers should be such that adjustment for tensioning can be made as the chain and sprocket wear. Tensioning of the silent chain drive should be done such that the chain length required is an even number of pitches. An odd number of chain pitches requires use of an offset section, which weakens the chain. Tensioning should be set in accordance with the OEM instructions and not be too loose or too tight. The proper tension will produce smooth operation. Excessive undertensioning may cause the chain to whip or surge and create shock loads that will shorten the chain life. Excessive overtensioning will also greatly increase chain wear, lead to chain elongation, and result in a shorter chain life. As a general rule, overtensioning is more harmful to a silent chain than undertensioning.

3.3.3 Chain Guard Enclosure and Chain Lubrication

The chain guard enclosure is used as a safety guard for the moving chain, to hold or contain the chain lubricant and to keep any debris from accumulating in the sprocket teeth. The enclosure should have seals located at the shaft penetrations for containing the lube oil. The seals should be replaced if leaks develop. There should be a daily check of the chain drive enclosure for leaks, with repairs made as the need is found.

Lubrication of the chain is required to slow down the wear of the chain pins, bushings, and links and provide lubricant for the chain's engagement with the drive and the driven sprockets. Chain lubricating oil may be provided via an oil bath or forced spray lubrication.

For turning gear chain drives lubricated by oil bath, the chain guard enclosure contains an oil level at the bottom for the chain to run through when in operation. The oil bath should be just enough for a short section of the chain to pass through. Having too much of an oil bath can cause the oil to foam and overheat. The enclosure should have an oil level indicator for visually checking the level on a daily basis. When the turning gear is in operation, the chain lubricating oil should be checked for foaming and overheating. Change the oil during the annual inspection of the chain drive.

For turning gear chain drives with a forced spray lubrication system, the oil is pumped to a nozzle, located near the bottom of the chain drive, that distributes the oil across the chain width. The oil supply should be provided from the same source as forced spray oil going to the reduction gear assembly. The oil is then drained through an orifice from the chain drive enclosure back to the reduction gear sump. During operation there should be a sight glass that shows oil flow to the chain drive. Inspect and clean the spray nozzle annually, and drain the orifice. Ensure that the spray nozzle is properly positioned to spray the chain.

If a turning gear drive chain develops rust, or shows any signs of rust, it is probably not receiving enough lubrication.

3.4 Belt Drive Maintenance

The connection of the electric motor to the reduction gear assembly can be through a belt drive for horizontally mounted electric motors. Timing belt drives are most often used for turning gear applications because they can transmit higher torques in a more compact drive configuration, have no slippage, are more tolerant to high temperatures, create less vibration, create less noise, and provide more precise operation than equivalent V-belt drives.

A turning gear timing belt drive consists of a driving sprocket connected to the electric motor shaft, the timing belt, a belt guard enclosure, and the driven sprocket connected to the input shaft of the reduction gear assembly.

3.4.1 Daily Checks

If the turning gear is operating, the belt drive should be checked for abnormal vibration or noise. Any findings should be investigated and repaired as soon as possible.

3.4.2 Disassembly and Inspection

On an annual basis all belt drive components should be visually inspected for excessive wear.

Caution: Ensure that proper site safety tagging procedures are followed for deenergizing the electric motor.

3.4.2.1 During Outages

The timing belt should be inspected for looseness, wear, and elongation. It is normally prudent to replace the belt during the inspection as a preventive measure. The most likely wear is cracking of the belt gear teeth or general wear of the belt over time due to exposure to the higher temperatures at the turbine. The sprockets should be inspected for wear, because worn sprockets will increase the rate of belt wear. Sprockets should be inspected for cracks in the tooth faces or roots. Timing belts and sprockets can be manufactured by different vendors, and replacements must be made carefully with the same type belt, pitch, guide type, and width. Belts and sprockets of different manufacturers can typically be used in the same drive without any problems.

During reassembly, attention should be given to proper alignment of the belt drive for smooth operation. The motor shaft and reduction gear input shafts should be horizontal and parallel, the sprockets aligned, and the timing belt tensioned in accordance with OEM specifications. Positioning of the shaft centers should be such that adjustment for tensioning can be made as the belt and sprockets wear.

3.4.3 Belt Guard Enclosure

The belt guard enclosure is used as a safety guard for the moving belt. Because no lubrication is needed for the belt drive, an advantage of a belt drive guard assembly is that it can be constructed of a metal mesh so that it is open for view during daily visual inspections. The drive can also be viewed while in operation to check for smooth operation.

3.5 Reduction Gear Assembly Maintenance

The turning gear reduction gear assembly receives the input torque of the electric motor and transmits it to the turbine rotor bull gear for rotation of the turbine rotor. The reduction gear assembly consists of a number of gear trains that reduce the electric motor speed to the necessary output speed for rotating the turbine rotor. A clash gear or engaging gear mechanism connects the turning gear reduction assembly to the turbine rotor bull gear.

Unless a problem is found during the internal visual, the reduction gear should not be completely disassembled as a general routine maintenance procedure.

Maintenance of the reduction gear should be focused on prevention and detection of gear train problems before any failure takes place. Most turning gear train failures are due to improper lubrication or component misalignment. Careful monitoring of these conditions is important.

It is important that the proper amount of lubricating oil be supplied to the turning gear reduction gear assembly at the proper pressure, when the gear assembly is in operation. Many reduction gear bearings and gear teeth are lubricated under oil pressure through housing machined passages and spray nozzles. In other cases, the bearings may be lubricated with grease. In some applications, the gears and bearings may operate in an oil bath. Proper oil bath levels must be maintained for these applications.

Alignment of the reduction gear assembly components is required to ensure that proper torque is converted from the electric motor to the turbine rotor bull gear. Gear train alignment and teeth engagements can only be checked when the unit is off line with the turning gear reduction assembly disassembled for inspection. Some turning gears have two machined surfaces that are used to align the turning gear to the rotor tight wire centerline and the rotor bull gear. Measurements from the machined surfaces and rotor centerline should be taken and documented after final alignment for future reference as needed.

3.5.1 Daily Checks

The reduction gear assembly should be visually inspected for oil leaks and evaluated for any unusual noises. If either situation is encountered, the unit should be stopped as soon as possible and the cause determined and corrected. The position of the turning gear lubricating oil supply valve should be checked on a daily basis. For turning gear systems with lubricating oil continuously supplied to the turning gear assembly, oil pressure and flow should be verified. For turning gear systems with lubricating oil supplied during startup, the position of the supply manual and solenoid shutoff valves that must be opened prior to starting the turning gear should be checked and verified.

If the turning gear is operating, the reduction gear should be checked for abnormal vibration or noise. Any findings should be investigated and repaired as soon as possible.

3.5.2 Outage Inspection

At a minimum, the turning gear reduction assembly should have the top cover removed and the interior components visually inspected and cleaned. Any damage to the bearings, gears, or seals should be repaired upon discovery. Gear backlash readings should be taken for all sets of gear trains. The gear train backlash may change over time as gear teeth wear. Adjustments should be made as needed to return the backlash measurements to within the OEM standard with the turning gear reduction gear realigned and redowelled. Any major changes in gear teeth backlash from the last inspection should be investigated for root cause and corrected during the inspection.

Major backlash changes are likely to warrant further disassembly of the reduction gear trains for determining the root cause and correction. If backlash readings compare favorably to past readings and there are no visual signs of bearing or shaft damage, then further disassembly of the reduction gear is usually not warranted. Bearings should not have any movement when the backlash measurements are taken.

Complete disassembly of the reduction gear assembly should not be considered a required routine maintenance practice if the turning gear assembly is installed correctly with proper clash gear alignment to the bull gear, adequate lubrication is provided, gear train backlash readings are within OEM specifications, and operation of the assembly has not identified any unusual noises or problems. However, on a routine basis the reduction gear assembly should be visually inspected internally for signs of wear and tear. Figure 3-3 shows a damaged bull gear. Figure 3-4 shows an example of a damaged clash gear. If a complete disassembly is warranted, more detailed instructions for performing this procedure along with rebuild maintenance can be found in EPRI report 1009831, *Gearbox and Gear Drive Maintenance Guide* [8].

Figure 3-3
Damaged Bull Gear

Figure 3-4
Damaged Clash Gear

It is a good practice to document any part numbers etched or stamped on any internal components when performing an internal reduction gear visual inspection. This practice may simplify the purchase of spare or replacement parts in case of major failure or damage of the reduction gear components. Also, for some reduction gear units there may be match marks, mounting distances, and set numbers etched on gears or pinions. These need to be recorded and documented when found during internal visual inspections.

A root cause analysis should be performed on any reduction gear assembly failures to determine the causes of failure and steps to be taken to prevent failures in the future. Some measures to consider for preventing future gear failures include potential upgrade of the failed gear material or performing different heat treatment of the gear. A qualified reduction gear repair contractor, the OEM, or a qualified metallurgist may be able to help.

On some units, the turning gear assembly can be inspected in place on the turbine pedestal by removing the motor and the top half of the turning gear housing. Other units require the turning gear assembly to be removed from the turbine pedestal for disassembly, with inspection conducted remotely.

Figure 3-5 shows an example of a removed GE bull gear.

Figure 3-5
General Electric Bull Gear

Figure 3-6 shows an example of an installed Westinghouse bull gear.

Figure 3-6
Westinghouse Bull Gear

3.5.2.1 Inspection On the Turbine Pedestal

Here are the major steps for inspecting the reduction gear assembly while leaving the reduction gear on the turbine pedestal:

1. Safety tag and disconnect the electric motor(s), compressed air connections, and lubricating oil lines. Tag each line to ensure that it is returned to its original position at reassembly.
2. Remove the turning gear top horizontal cover to expose the gear trains. Ensure that all dowel pins are removed.
3. Mark, measure, and document the distance the turning gear assembly is from the turbine rotor centerline at two places on the housing. This information will be needed as a reference when final alignments are made.
4. Clean and inspect all lubricating oil lines and orifices. Ensure that they are clean by blowing compressed air through all holes and drain lines. Clean the breather cap in solvent, inspect, and replace as needed.
5. Remove the top cover of the reduction gear, clean out the interior, and visually inspect for damage and for components needing repairs.
6. Measure and record backlash between all gear trains from the input pinion to the turbine bull gear. These should be in accordance with the OEM recommendations. Typically, backlash is measured using wire gauges or lead wire and turning the gear assembly by hand. The reduction gear assembly should be turnable by hand in both clockwise and counter-clockwise directions.
7. Visually inspect the gear tooth contacts and patterns for all gear trains. A good gear contact pattern will be even across each tooth, with the tooth surface shiny. Gear teeth should be smooth, without cracks, score marks, or pitting. Look for any cracks in gear tooth faces or roots. Perform a dye penetrant check, and file any burrs or sharp gear tooth edges. Generally, most minor damage to gear teeth, except in the case of bevel gears, can be repaired by filing or stoning until smooth. Bevel gears with damage need to be replaced, unless the damage is very minor.
8. Visually inspect all bearings for discoloration or signs of wear. Bearing replacements will require properly setting the shaft thrust and end float to OEM specifications.
9. Ensure that there is no movement in the bearings during the gear train backlash checks. Any bearing movements should be checked and corrected.
10. Realign the turning gear clash gear pinion to rotor bull gear to OEM specifications after each final turbine rotor alignment. Use the marks and measurements from the rotor centerline noted at removal. It is important to check clash gear end tooth backlash alignment with the bull gear. Too little backlash can overload the bearing, whereas excessive backlash can damage the gear teeth.
11. All housing and foundation bolts should be torqued to values specified by the OEM.

3.5.2.2 Inspection Off the Turbine Pedestal

For some turning gear assemblies, inspection must be done with the assembly removed from the turbine pedestal. If the turning gear assembly has underslung gears, care should be taken in rigging when removing so as not to damage these gears. Here are the major steps for inspecting the reduction gear assembly with it removed from the turbine pedestal:

1. Safety tag and disconnect the electric motor(s), compressed air connections, and lubricating oil lines. Tag each line to ensure that each is returned to its original position at reassembly. Make sure any orifices are reinstalled in their original positions.
2. Mark, measure, and document the distance the turning gear assembly is from the turbine rotor centerline at two places on the housing before removing the assembly from the turbine pedestal. When the reduction gear assembly is reinstalled on the turbine pedestal, it should be returned to this position. Be sure to remove and tag all dowel pins.
3. Safely rig and remove the entire turning gear assembly and relocate it to cribbing that maintains the assembly in its installed position.
4. Remove the electric motor and drive chain, if applicable.
5. Remove the top horizontal cover to expose the gear trains. Ensure that all dowel pins are removed.
6. Clean and inspect all lubricating oil lines and orifices. Ensure that they are clean by blowing compressed air through all holes and drain lines. Clean the breather cap in solvent, inspect, and replace as needed. Make sure any orifices found are reinstalled in their original positions.
7. Measure and record backlash between all gear trains from the input pinion to the turbine bull gear. These should be in accordance with the OEM recommendations. Typically, backlash is measured using wire gauges or lead wire and turning the gear assembly by hand. The reduction gear assembly should be turnable by hand in both clockwise and counter-clockwise directions.
8. Visually inspect the gear tooth contacts and patterns for all gear trains. A good gear contact pattern will be even across each tooth, with the tooth surface shiny. Gear teeth should be smooth, without cracks, score marks, or pitting. Look for any cracks in gear tooth faces or roots. Perform a dye penetrant check and file any burns or sharp gear tooth edges. Generally, most minor damage to gear teeth, except in the case of bevel gears, can be repaired by filing or stoning until smooth. Bevel gears with damage need to be replaced, unless the damage is very minor.
9. Visually inspect all bearings for discoloration or signs of wear. Bearing replacements will require properly setting the shaft thrust and end float to OEM specifications. If removed, tag all bearing shims for reinstallation in the correct positions.
10. Ensure that there is no movement in the bearings during the gear train backlash checks. Any bearing movements should be checked and corrected.

11. Realign the turning gear clash gear pinion to rotor bull gear to OEM specifications after each final turbine rotor alignment. Use the marks and measurements from the rotor centerline noted at removal. It is important to check clash gear end tooth backlash alignment with the bull gear. Too little backlash can overload the bearings, whereas excessive backlash can damage the gear teeth.
12. All housing and foundation bolts should be torqued to values specified by the OEM.

3.6 Rotor Bull Gear

Visual inspection of the rotor bull gear should take place during an outage. The bull gear teeth should show contact only on the drive side of the teeth. If contact is shown on the opposite side of the teeth, then the backlash between the clash gear and bull gear is not set properly. Minor damage less than 0.003 inch (0.076 mm) deep on the bull gear teeth can typically be repaired by filing or stoning until smooth. For more extensive bull gear teeth damage, the OEM should be contacted for evaluation and recommendations.

Backlash between the clash gear and the bull gear can be measured in the following manner on many turning gear assemblies. With the turning gear operated manually or from an auxiliary drive with the clash gear and bull gear fully engaged and rotating, place a sheet of lead into the clash gear and bull gear mesh. Once the lead sheet has completely passed through the clash gear and bull gear mesh, the turning gear should be stopped and the lead sheet recovered. The lead sheet should be shaped like a gear tooth, with the contact thicknesses formed on both the leading side and the lagging side of the lead sheet tooth. The contact thicknesses are measured at the middle of the contact tooth pattern sides with their sum being the total gear backlash measurement as shown in Figure 3-7. The A and B measurements should be consistent across the contact area.

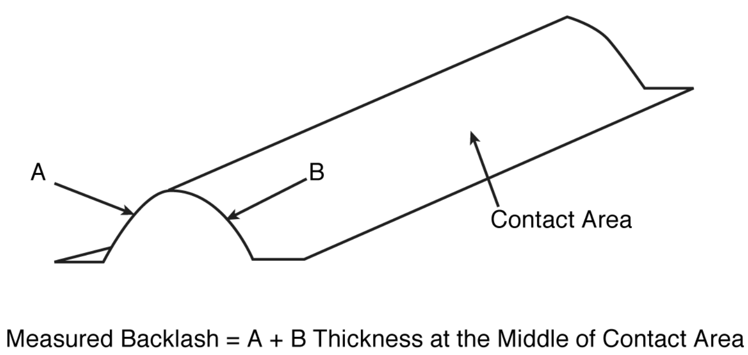

Figure 3-7
Backlash Measurement Diagram

3.7 Controls and Instrumentation

The turning gear can usually be engaged manually at the turbine pedestal or remotely through a control system. The control system is typically an electropneumatic system that can either be initiated manually from a local turbine panel or from the site's digital control system. Some turning gear systems can be started automatically through the control system. The automatic instrument control system can vary for each site and will have various logic schemes specific to the individual site or unit configuration. Typical logic schemes involve zero- or low-speed turbine rotor rotation switches or instrumentation; lubrication oil pressure and flow instrumentation; compressed air pressure instrumentation; turning gear motor electrical operation; and other DCS logic specific to a site. There can also be control logic that stops or locks out the turning gear if the turbine rotor speed reaches or goes above a predetermined speed, to keep the turning gear from automatic engagement.

There should be turbine speed rotation per minute instrumentation in the unit's control room with an audible alarm set at the "zero speed" indication. Also, there should be turning gear motor amperage instrumentation in the unit's control room with an audible alarm set at appropriate set points.

The turning gear engagement linkages, solenoids, air cylinders, pressure switches, and other instrumentation should be visually inspected for any signs of damage on a daily basis as part of the operator rounds.

During an outage inspection, the control linkages should be checked for free, smooth movement and evidence of worn or damaged parts. Attention should be given to mechanical wear of pins, bushings, pivots, springs, pivot bearings, and keys. Ensure that all set screws and locknut connections are tight, with thread locking compound applied as needed. Test the air cylinder for leakage and full travel and return stroke.

Inspection and calibration of turbine turning gear instrumentation controls for electrical, pressure, speed, and flow permissive and limit indication switches should take place during each scheduled major turbine outage.

4
MAINTENANCE CONSIDERATIONS

4.1 Troubleshooting

Table 4-1 provides assistance in determining possible causes and potential corrective actions for some of the most common operating problems identified with turning gears, as indicated by survey results. When troubleshooting a turning gear problem, it is prudent to first ensure that conditions are correct for the turning gear to be operating and to verify that the controls and permissive instrumentation are producing the correct signals for initiating and maintaining turning gear operation.

Table 4-1
Turning Gear Troubleshooting Table

Component	Observation	Potential Cause	Potential Correction
Electric drive motor	Noisy operation	Misalignment/mechanical Looseness	• Check foundation base bolting for tightness • Check for mechanical looseness • Check coupling alignment
		Chain or belt drive alignment	• Check alignment to chain or belt drive • Adjust chain or belt tension • Ensure lubricating oil bath is in chain guard enclosure
		Bad bearings	• Inspect bearings • Take and analyze vibration readings
	Excessive vibration	Electrical voltage	• Ensure correct voltage to motor • Check for proper motor rotation direction • Check for high motor amperage readings
		Mechanical looseness	• Check for loose mounting bolts • Check motor alignment to reduction gear • Inspect bearings
		Lubrication	• Ensure lubricating oil temperature is at OEM recommended value • Ensure motor is properly greased
		Coupling	• Check coupling for damage • Check coupling for misalignment

Table 4-1 (continued)
Turning Gear Troubleshooting Table

Component	Observation	Potential Cause	Potential Correction
Electric drive motor (continued)	Excessive motor temperature	Dirty motor filters or windings	• Clean motor filters • Clean air flow openings to windings
	Excessive electrical current usage	Check motor windings for degradation	• Operate electric motor uncoupled and verify amperage readings • Bench test electric motor • Replace electric motor with spare
		Turning gear mechanical Problem	• Run turning gear assembly disengaged from the bull gear • Check turbine rotor for excessive eccentricity • Verify jacking oil
	Motor will not start	Electrical power supply	• Verify electrical power supply to starter • Verify starting permissive values and inputs • Verify DCS controls
Reduction gear assembly	Noisy operation	Misalignment	• Check foundation bolting for tightness • Inspect clash gear
		Lubrication problems	• Check oil pressure and flow • Check oil levels; add or drain oil as needed • Inspect oil sprays and nozzles for proper flow • Ensure oil temperature is at OEM recommended value • Verify turning gear speed • Check for clash gear to bull gear chatter
		Gears misaligned/worn	• Check turning gear clash gear alignment to turbine bull gear • Visually inspect gears for broken teeth and tooth wear pattern • Check gear train backlash settings
		Bad or improper installed bearings	• Visually inspect bearings for wear or failure • Inspect shaft end seals for leakage or excessive wear • Inspect bearing thrust and alignment settings

Table 4-1 (continued)
Turning Gear Troubleshooting Table

Component	Observation	Potential Cause	Potential Correction
Reduction gear assembly (continued)	Oil leakage	Improper oil pressure and flow	• Ensure oil temperature is at OEM recommended value • Clean breather cap; check for worn seals • Ensure proper oil pressure and flow
		Main oil tank vacuum low	• Verify vapor extractor is operating
	Blade slip-stick noise	Improper turbine bearing lubrication.	• Ensure jacking pumps used as needed • Oil viscosity too low; ensure lubrication oil temperature is at OEM recommended value
		Turning gear speed too slow	• Ensure turning gear speed is at OEM recommended value • Ensure clash gear fully engaged
	Overheating	Improper lubricating oil flow to reduction gear	• Oil viscosity too low; ensure lubrication oil temperature is at OEM recommended value • Ensure flow to all gears and bearings; clean spray nozzles
		Breather cap clogged	• Clean breather cap • Replace breather cap
		Dirt and dust on outside of unit	• Clean outside of unit • Repair oil leaks • Replace seals and gaskets as needed
Control mechanism	Won't engage	Permissive indicators not available	• Check speed, limit, and pressure switches • Manually engage turning gear • Verify control switch position
		No compressed air	• Check solenoid valves • Manually engage turning gear
		No oil pressure	• Ensure lubrication oil pumps are operating • Verify oil flow to turbine bearings at discharge sight glasses
		Electric motor not operating	• Ensure power supply to motor
		Automatic start does not take place	• Ensure turning gear control switch set to automatic • Manually start turning gear

Table 4-1 (continued)
Turning Gear Troubleshooting Table

Component	Observation	Potential Cause	Potential Correction
Control mechanism (continued)	Excessive rolloff	Steam flow and pressure to the steam turbine inlet	• Identify and repair leaking steam extraction valve(s) • Ensure bull gear to clash gear backlash is set properly • Ensure proper steam flow and pressure for rotor prewarming
		Improper rotor rotation speed indication	• Ensure rotor speed indication instrumentation correct
		Too much jacking oil	• Ensure jacking oil alignment is correct

4.2 Preventive and Predictive Maintenance

The turning gear's primary function is to prevent bowing of the turbine shaft during shutdown and startup periods. Turning gear criticality for predictive and preventive maintenance (PM) can depend upon the plant's operating philosophy and actual operating conditions. Operating conditions and times for turning gears can vary widely for utility units, and each site should design/develop a turning gear PM program to complement its own situation. At a minimum the turning gear assembly should be visually checked on a daily basis and verified to be in alignment mechanically and electrically, in a condition for operation as needed. Data Sheet 1 in Appendix A provides a listing of daily recommended checks. The turning gear and engagement controls should be cleaned and visually inspected at each scheduled outage. The electric drive motor PM tasks and frequencies should be included and specified in accordance with the existing site's motor inspection and maintenance program. Controls and instrumentation for engaging and monitoring the turning gear should be inspected and calibrated in accordance with the site's instrumentation PM program.

When the turning gear motor is in operation, amperage readings should be documented on a periodic basis and trended to identify any changes over time that might identify a potential problem. Changes in motor amperage readings should be investigated when found.

During operation, vibration readings on the electric motor should be documented, evaluated, and trended over time. Vibration readings on the reduction gear can be taken and trended if access is available. Permanent collection will need to be installed to ensure that readings are taken at the same places for effective trending purposes. A qualified vibration contractor can help identify reading points and trend tracking criteria for each reduction gear configuration.

Table 4-2 shows recommended preventive maintenance activities for the steam turbine generator turning gear assembly based on the survey results and information reviewed for this report.

Table 4-2
Recommended Preventive Maintenance Frequencies

Maintenance Activity	Frequency				
	Never or As Needed	Per Site PM Program	1–4 Years (1–2 RO)	5–8 Years (3–5 RO)	9–12 Years (6–8 RO)
Clean and visually inspect engagement linkages and controls			X		
Clean electric motor		X			
Calibrate instrumentation		X			
Inspect electric motor starter		X			
Inspect chain/belt drive				X	
Change chain drive lubrication/clean spray nozzles				X	
Perform internal inspection of reduction gear assembly					X
Inspect turbine rotor bull gear					X
Clean and inspect reduction gear lubrication spray nozzles			X		
Perform complete reduction gear disassembly and rebuild	X				

As a general rule, the turning gear should not undergo a complete disassembly unless problems are found during visual internal inspections and gear train backlash measurements or unless required by the OEM for warranty or performance reasons.

4.3 Recommended Spare Parts and Tooling

Having turning gear inventory spare parts is a matter of specific site inventory philosophy and station experience with past inspections or problems with individual turning gear assemblies. Table 4-3 contains recommendations for items to have on hand for the turning gear assembly before starting an internal inspection. Off-the-shelf spare parts for older turning gears may be hard to find, especially if the OEM is no longer in business. However, most needed parts for a turning gear assembly can be purchased from the OEM or qualified vendors (in some cases the parts may need to be made). This recommended list does not address instrumentation, control, or monitoring devices.

All spare parts and components should be kept in a clean, dry environment free of vibration and temperature fluctuations.

Table 4-3
Recommended Spare Parts

Description	Recommended for Warehouse Inventory Spare Parts	Recommended for Purchase as Needed and Not Stored as Inventory
Electric drive motor	1 each	
Drive chain/belt	1 each	
Drive sprockets	1 set	
Reduction gear assembly bearings		X
Reduction assembly gears/shafts		X
Rotor bull gear		X
Clash gear		X
Control linkages, springs, bushings, tie rods, and so on		X
Electrical motor breaker and starter fuses/contacts	1 set	

A tool list for removing, inspecting, and reassembling the steam turbine turning gear assembly may vary by location and specific turning gear configuration and assembly. Table 4-4 lists the most common items typically needed for removal, disassembly, and internal inspection for a turning gear assembly.

Table 4-4
Inspection Equipment, Tools, and Expendable Items List

Calibrated torque wrench(es) capable for up to 1500 ft-lb (2034 N-m)
Straightedges, up to 3 foot (2.74 m)
Anti-seize, nickel special, nuclear grade
Chain falls rated for lift requirements
Slings and nylon straps rated for lift requirements
Honing stones (various grit)
Micrometer, inside, set 0–24 inch (0–60 cm)
Micrometer, outside, set 0–6 inch (0–15 cm)
Micrometers, outside, set 6–12 inch (15–30 cm)
Micrometers, outside, set 12–18 inch (30–45 cm)

Table 4-4 (continued)
Inspection Equipment, Tools, and Expendable Items List

3M emery cloth, fine grit
Dial indicator set
Prussian Blue gear marking compound
Scotch-Brite pads
1/2 inch (13 mm) socket set, U.S. (customary) and International System (SI) sizes
3/4 inch (19 mm) socket set, U.S. and SI sizes
Impact socket set and drive for large bolting
Cleaning solvent
General hand tools set, U.S. and SI sizes: wrenches, pliers, screw drivers, punches, and so on
Alignment shim set
Lead sheet, for backlash measurements
Gasket sealant
Tubing wrench set, U.S. and SI sizes
Scaffolding, as required
Eyebolt, various sizes
Feeler gage set, long standard
Cloths, lint free
Tap and die set for various threads
Gasket and seal material
Sandblaster with approved blast grit material
Blanking fixtures and adapters for leak/pressure testing
Alcohol for washing lubrication tubing fittings before opening

4.4 Industrial Safety Considerations

It is a good personnel safety practice for a power plant to develop procedures that outline the site-specific safety requirements when troubleshooting, inspecting, repairing, or operating the turbine turning gear assemblies.

Some site-specific safety considerations follow.

4.4.1 Pre-Job Safety Discussion and Planning

Planning increases the likelihood of achieving desired results when a task is performed. Planning begins with anticipating and identifying potential safety hazards in a job task and evaluating the subsequent risks of those hazards. For example, when inspecting and rebuilding steam turbine turning gear assemblies, personnel should be fully aware of other turbine work being performed during the outage and potential movement of the turbine rotor. Schedule integration should be a priority. Also, personnel should ensure proper safety tagging of the electric drive motor and the turbine lubrication oil system.

4.4.2 Personal Protective Equipment Requirements

During the planning process, attention should be paid to identification of the site-specific requirements for proper use and selection of equipment to adequately protect the personnel performing activities for inspecting and rebuilding of steam turbine turning gear assemblies. Site-specific procedures should be followed.

4.4.3 Lockout/Tagout Requirements

The purpose of lockout/tagout requirements is to eliminate the unexpected energizing/startup of machinery or equipment, or the release of stored energy from machinery or equipment that could cause injury to employees. Site-specific lockout/tagout procedures should be followed.

4.4.4 Electrical Safety Requirements

The purpose of electrical safety requirements is to provide safe work practices to be used when working on, near, or with electrical conductors and related equipment. Site-specific electrical safety procedures should be used for isolating and removing electrical hazards when work is being performed on steam turbine turning gear assemblies.

4.4.5 Scaffolding and Fall Protection Requirements

Depending on the configuration, steam turbine turning gear assemblies may require scaffolding or fall protection in order for personnel to inspect or perform maintenance on them. Site-specific procedures for scaffolding erection, inspections, and personnel fall protection should be used.

4.4.6 Rigging Requirements

Removal and installation of steam turbine turning gear assemblies typically require some type of rigging and lifting with mechanical means, such as choker straps, cranes, and/or chain falls. Site-specific procedures for maintenance and inspection of rigging equipment and for the training of personnel on its use should be followed.

4.4.7 Proper Handling of Lubrication System Oils

Personnel who may be exposed to the petroleum-based and synthetic fluids typically used in steam turbine lubrication systems should understand the hazards associated with these fluids. Site-specific procedures for handling and disposing of the lubrication oils used in the systems should be followed when performing work on turning gear assemblies. Skin contact with the lubrication oil should be prevented through the use of protective clothing such as neoprene gloves. Eye contact with the fluid/oil should be prevented through the use of chemical safety goggles and/or a face shield. The applicable Material Safety Data Sheet (MSDS) should be available for review for the specific lubrication used. Used turbine lubrication oil may be considered environmentally hazardous substances at some locations.

4.5 Best Practices Summary

The following list summarizes best practices for turning gear maintenance:

- Inspect all bearings, bushings, gears, gear backlash, shafts, motor, and engaging mechanism on a routine basis. The inspection frequency should be based on the specific turning gear assembly operation and maintenance history. Return all components to OEM specifications as needed. Major changes in gear tooth backlash readings should be investigated for cause and corrected as found.
- As a general rule, complete disassembly and rebuild of the turning gear reduction gear should be done only on an as-needed basis.
- Be sure to match-mark all linkages and gear train components for reassembly in the correct position.
- Check lubricating oil spray nozzles and positions on internal reduction gears during each major outage.
- Verify lubricating oil flow to all spray nozzles during each turning gear inspection.
- Make sure any orifices are properly identified and reinstalled in their original positions.
- Realign the turning gear clash gear pinion to the rotor bull gear to OEM specifications after each final turbine rotor alignments.
- Check the turning gear input drive chain or belt for looseness, wear, and alignment during each major outage.
- Visually inspect the turning gear for any oil leaks when in operation, and repair as found.
- Calibrate lubrication permissive limit and pressure switches annually.
- Check automatic remote engaging mechanism air valves and solenoids annually for proper operation. Rebuild or replace as found.
- Measure and record initial electric motor amperes after reassembly and before returning the unit to service.
- Measure and record electric motor amperes on a routine basis when turning gear is operated.

- Listen for and investigate any excessive noises or vibrations to the assembly when the turning gear is in operation.
- Disassemble and clean electric motor windings during each major turbine inspection outage.
- Clean and test the turning gear electrical motor and starter breaker on a routine basis.
- Make sure the oil deflectors at the turning gear are set at the proper clearances after each outage.
- Check and clean the breather cap during each outage.
- Avoid putting an excessive amount of sealant on reduction gear covers and joints, because it can plug internal oil passages.
- Document part numbers, dimensions, and any other identifying details seen on the reduction gear internal parts during the inspection. If damage occurs later, this information can be crucial for obtaining replacement parts.

Data sheets to support specific aspects of turning gear maintenance are found in Appendix A.

5
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For compiled descriptions of many of the reports produced by EPRI’s Steam Turbine-Generators and Auxiliary Systems program, see EPRI report 1021425, *Descriptions of Past Research: EPRI Fossil and Nuclear Steam Turbines and Generators – 2010.*

A
TURNING GEAR MAINTENANCE DATA SHEETS

This appendix contains the following data sheets to support specific aspects of turning gear maintenance:

- Data Sheet 1: Daily Turning Gear Checks
- Data Sheet 2: Turning Gear Control and Linkage Checks
- Data Sheet 3: Turning Gear Drive Chain Inspection Checklist
- Data Sheet 4: Turning Gear Reduction Gear Outage Inspection Checklist
- Data Sheet 5-1: Rotor Bull Gear Checklist
- Data Sheet 5-2: Bull Gear Inspection Sheet Example

Data Sheet 1 Daily Turning Gear Checks

Plant ______________________________

Unit ______________________________

Location ______________________________

Readings Taken By ______________________________ Date ____________

Reviewed By Supervisor __________________________ Date ____________

Time of Day			
Electric Motor/Drive Device			
Turning Gear Is in Operation (Y/N)			
Turbine Rotor RPM			
Motor Amperage Readings			
Expected Amperage Reading (____ amps)			
Excessive Vibration Present (Y/N)			
Vibration Readings Taken			
Bearing Temperature Readings Taken			
Expected Temp. Range (____ °F to ____ °F)			
Abnormal Noises Present (Y/N)			
Ventilation Openings Clear (Y/N)			
Lubrication Level Correct (Y/N)			
Lubrication Leaks Present (Y/N)			
General Cleanliness (Y/N)			
Jacking Oil System in Operation (Y/N)			
Chain/Belt Drive			
Lubrication Level Correct (Y/N)			
Lubrication Leaks Present (Y/N)			
Abnormal Vibration or Noise Present (Y/N)			
Reduction Gear Assembly			
Lubrication Supply Valve Properly Positioned (Y/N)			
Oil Pressure Reading			
Expected Oil Pressure Reading (___psi)			
Oil Flow Visually Observed (Y/N)			
Lubrication Level Correct (Y/N)			
Lubrication Leaks Present (Y/N)			
Lubrication Oil Temperature Reading			
Expected Temp. Range (____ °F to ____ °F)			
Abnormal Vibration or Noise Present (Y/N)			
Controls/Instrumentation			
Solenoid Valves Properly Aligned (Y/N)			
Linkages Properly Aligned (Y/N)			
Compressed Air Leaks Present (Y/N)			
Permissive Switches Properly Aligned (Y/N)			

Comments/Actions Taken:

Data Sheet 2 Turning Gear Control and Linkage Checks

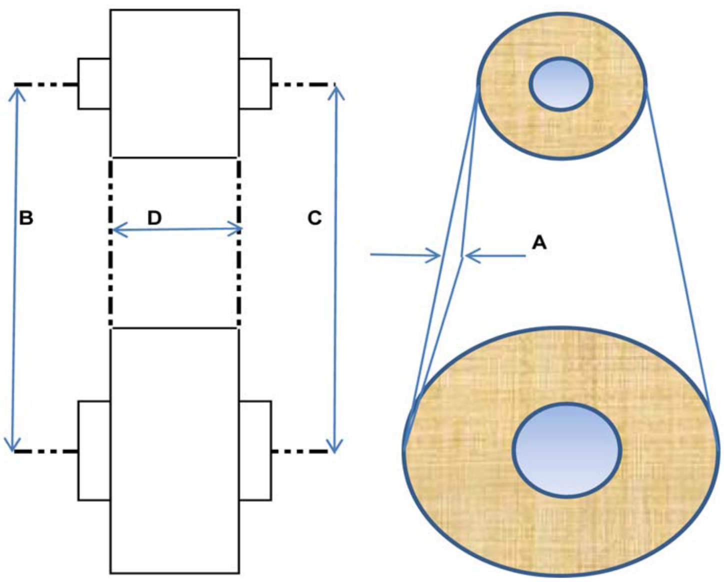
Plant ____________________	Readings Taken By ______________________	Date ______________
Unit _____________________	Reviewed by Foreman ____________________	Date ______________
Outage No. _______________	Outage Supervisor ______________________	Date ______________
	Reviewed By OEM _______________________	Date ______________
	Outage Engineer _________________________	Date ______________

Maintenance Activity	As Found	As Assembled	Comments
Check linkages for free movement			
Check all set screws and locknuts for tightness			
Test air cylinder for full travel and air leakage			
Check turbine rotor RPM indicator			
Check turbine rotor zero speed alarm			
Check instrument air lines for damage or leakage			
Check lubrication lines for damage or leakage			
Clean reduction gear lubrication oil lines, spray nozzles, and orifices			
Blow air through reduction gear lubrication lines to ensure cleanliness			
Perform functional test of pemissive pressure switches			
Perform functional test of permissive limit switches			
Ensure instrument air valve position alignments per OEM instructions			
Ensure lubrication oil valve position alignments per OEM instructions			
Ensure control linkage adjustments and alignments per OEM instructions			

Data Sheet 3 Turning Gear Drive Chain Inspection Checklist

Plant ____________________	Readings Taken By _____________________	Date _____________
Unit ______________________	Reviewed by Foreman ___________________	Date _____________
Outage No. ______________	Outage Supervisor ____________________	Date _____________
	Reviewed By OEM _____________________	Date _____________
	Outage Engineer _______________________	Date _____________

Maintenance Activity	As Found	As Assembled	Comments
Inspect chain for looseness and wear			
Inspect chain for signs of rust			
Measure chain tension (A) and set per OEM specification			
Check motor shaft is parallel to reduction gear shaft (B = C)			
Check sprockets for offset (D) and set per OEM specifications			
Perform dye penetrant test of sprockets for cracks in face and root areas			
Inspect seals on chain guard enclosure			



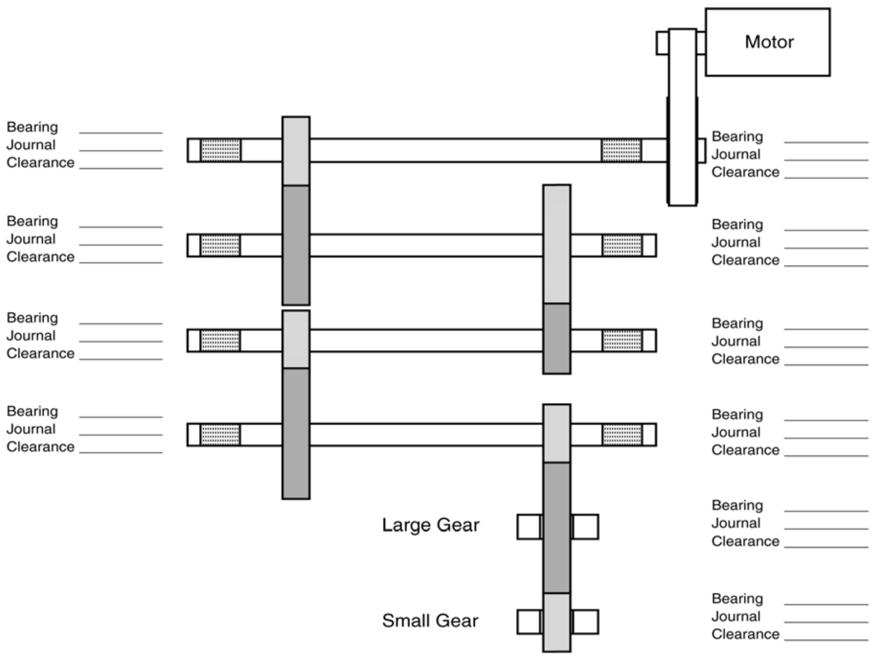
Data Sheet 4 Turning Gear Reduction Gear Outage Inspection Checklist
Sheet 1 of 3

Plant ____________________	Readings Taken By ____________________	Date ______________
Unit ____________________	Reviewed by Foreman ____________________	Date ______________
Outage No. ______________	Outage Supervisor ____________________	Date ______________
	Reviewed By OEM ____________________	Date ______________
	Outage Engineer ____________________	Date ______________

Maintenance Activity	As Found	As Assembled	Comments
Clean and blow instrument air through all oil line connections and orifices—ensure all spray nozzles are open and properly positioned			
Check backlash between input gear set and compare to past measurements			
Check backlash between intermediate gear set #1 and compare to past measurements			
Check backlash between intermediate gear set #2 and compare to past measurements			
Check backlash between intermediate gear set #3 and compare to past measurements			
Visually inspect all gear teeth for uniform full face wear patterns, sharp edges, or rough spots			
Perform dye penetrant testing of all gear teeth for cracks in face and root areas			
Visually inspect all bearings for signs of wear or heat damage—bearings should have no movement during gear train backlash measurements			
Visually inspect all seals for lubrication leakage and replace as required			
Check backlash of clash gear to bull gear and set per OEM specifications			
Clean and inspect oil breather cap			
Record part numbers etched on all components as possible			

Data Sheet 4 Turning Gear Reduction Gear Outage Inspection Checklist
Sheet 2 of 3

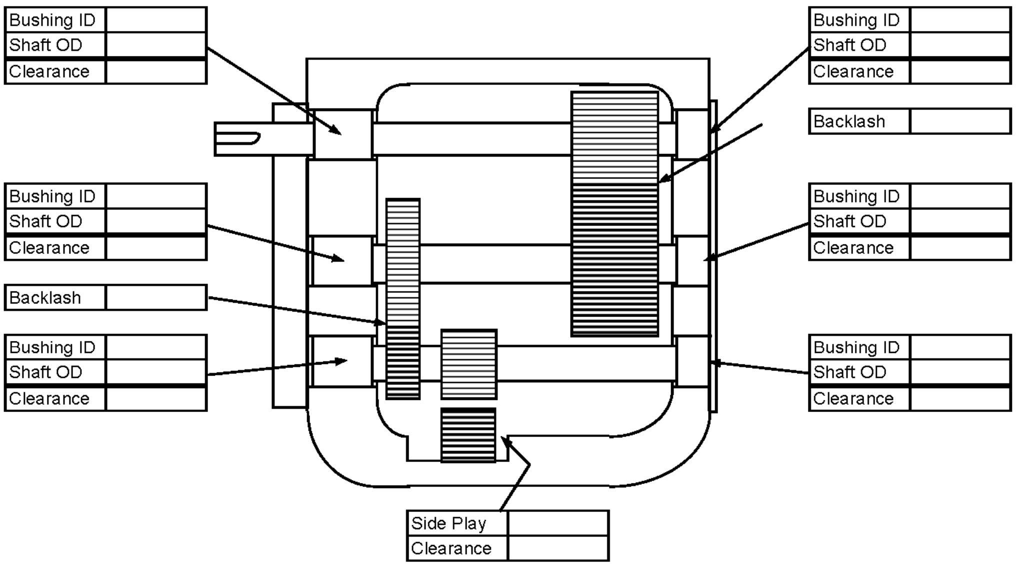
Plant ____________________	Readings Taken By ____________________	Date ____________
Unit ____________________	Reviewed by Foreman ____________________	Date ____________
Outage No. ______________	Outage Supervisor ____________________	Date ____________
As Found ______________	Reviewed By OEM ____________________	Date ____________
As Assembled ____________	Outage Engineer ______________________	Date ____________



Comments:

Data Sheet 4 Turning Gear Reduction Gear Outage Inspection Checklist
Sheet 3 of 3

Plant ____________	Readings Taken By ____________	Date ________
Unit ____________	Reviewed by Foreman ____________	Date ________
Outage No. ____________	Outage Supervisor ____________	Date ________
	Reviewed By OEM ____________	Date ________
	Outage Engineer ____________	Date ________



Comments:

Data Sheet 5-1 Rotor Bull Gear Checklist

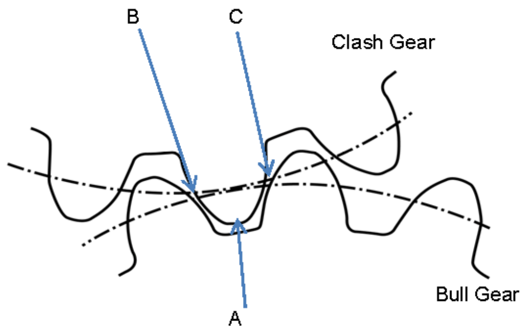
Plant ____________________	Readings Taken By ______________________	Date ______________
Unit _____________________	Reviewed by Foreman ____________________	Date ______________
Outage No. _______________	Outage Supervisor _______________________	Date ______________
	Reviewed By OEM _______________________	Date ______________
	Outage Engineer _________________________	Date ______________

Maintenance Activity	As Found	As Assembled	Comments
Visually inspect all gear teeth for uniform full face wear patterns, sharp edges, or rough spots			
Repair any minor gear teeth damage by filing or stoning until smooth			
Perform dye penetrant testing of all gear teeth for cracks in face and root areas			
Check that bull gear teeth show contact on drive side only			
Check backlash of clash gear to bull gear and set per OEM specifications			
Check clash gear tooth tip clearance to bull gear and set per OEM specifications			

Data Sheet 5-2 Bull Gear Inspection Sheet Example

Plant ____________________	Readings Taken By ____________________	Date ____________
Unit ____________________	Reviewed by Foreman ____________________	Date ____________
Outage No. ______________	Outage Supervisor ____________________	Date ____________
	Reviewed By OEM ____________________	Date ____________
	Outage Engineer ____________________	Date ____________

Tooth Tip Clearance (A)	
Backlash Driving Side (B)	
Backlash Lagging Side (C)	
Total Backlash (B+C)	



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