Transmission & Bearing Corp.
A Division of Turbo Research Inc.

Technical Notes by Dr. Mel

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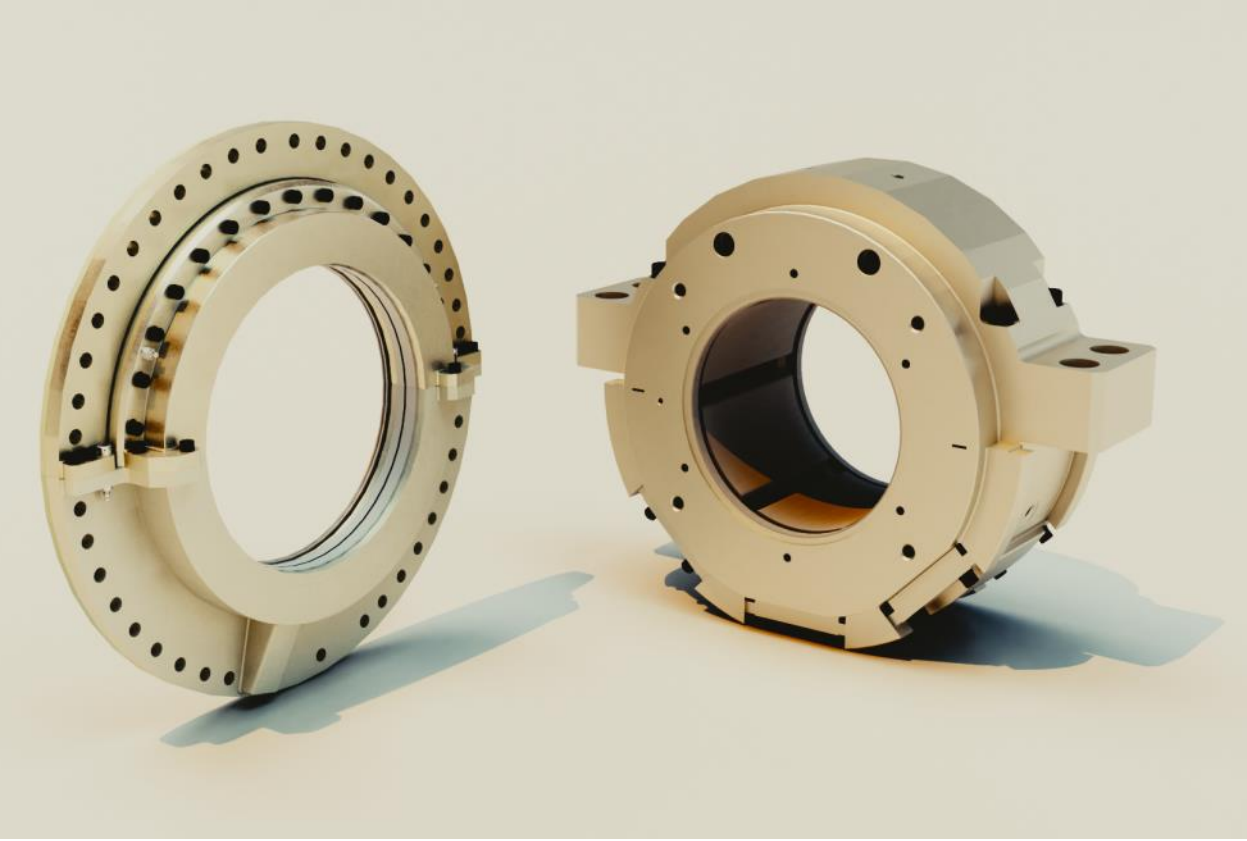
HYDROGEN SEALS AND TILT PAD BEARING UPGRADES

How to improve aging GE Large Steam Turbine-Generators



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Many large steam turbine-generators still in operation today have equipment that was designed over 50 years ago. Having stood the test of time is a testament to the quality of these designs, but that does not mean improvements aren't available.

Call TRI at (800) 363-8571 for more information about bearings.

What can be done to improve the H_2 sealing process?

Many GE Generators in service today use hydrogen seals that were developed in the 1930s. The seals consist of four 90° bronze segments that are held in place by garter springs. Pressurized seal oil pushes the two rings axially and in opposite directions making face seals with the housing. With this design, there were many areas where hydrogen leaks can develop:

(1) At the "butt" joints between the ring segments.

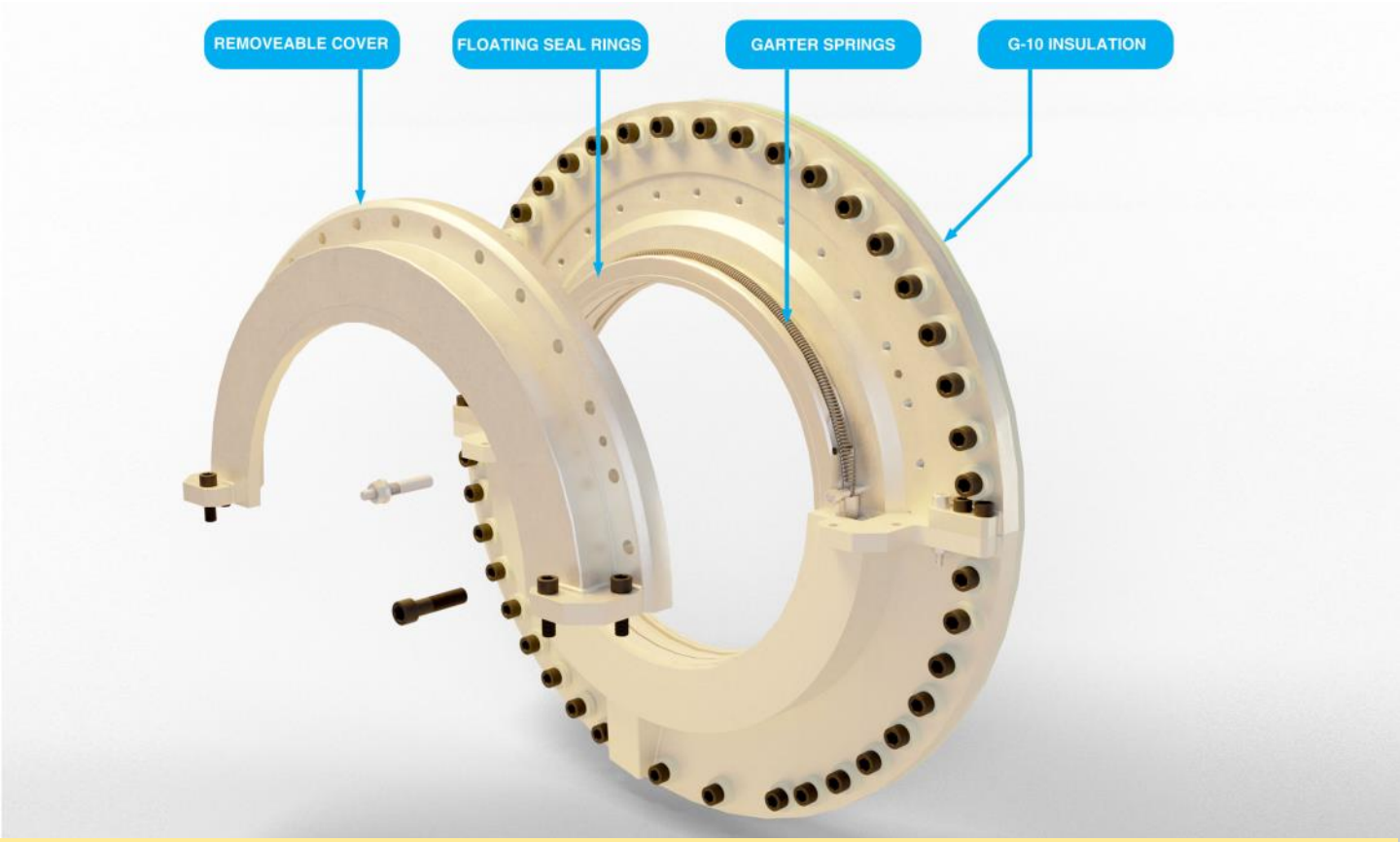
(2) Between the faces of the seal rings and the faces of the housings.

(3) Through the static joints of the top and bottom halves of the main seal housing.

Note that there is always some gas loss via absorption of H_2 into the seal oil that flows through and lubricates the seals rings.

Given that Hydrogen cooling is here to stay, the question is: What can be done to improve the H_2 sealing process? In an ideal world, the GE hydrogen seal design should work reasonably well. In practice, the quarter-segment seal rings do not stay seated at the "butt joints", particularly if there is significant rotor vibration or if the seal ring housing is not centered on the rotor.

The hydrogen seal ring design used by TRI has 360-degree steel and Babbitt rings with bolted joints. Access to the rings is achieved by removing only a small top half housing and the main housing stays in place. "Hook" fits on the seal rings are gone, so these seals can easily be removed and inspected or replaced if necessary. Improvements to the design, materials and manufacturing keep the TRI hydrogen seal bores round and the joint gaps closed.



The Hydrogen Seal Retrofit Process

1. Prepare a drawing with an estimated size of the existing Hydrogen seal assembly.
2. Prepare modifications to show the upper outer removable housing to be added.
3. Obtain materials for the housing for each end and for the mating seal rings.
4. Rough machine the new removable housings to "near shape".
5. Process the seal rings through the Babbitting process.
6. When the outage starts, receive the existing end shields. Finalize drawings.
7. Modify the main Hydrogen seal housing, both upper and lower halves.
8. Semi-finish machine the upper outer removable seal housing.
9. Complete the machining of the details such as dowel pins and the like, and then the seal housing assemblies, including inspection for flatness.
10. Complete machining of the seal rings to TRI's recommended seal bore diameters, with inspection for flatness.
11. Pack and ship to site.
12. The reinstallation process is so much simpler than disassembly that customers typically do not request Technical Direction from a TRI Representative, though such assistance is available.

TRI designs and manufactures complete hydrogen seal assemblies.

This permits the "Air Side" seals with slightly longer axial length to reduce seal oil flow out of the generator and permits higher pressures in the hydro-dynamic oil films which will minimize seal ring wear.

Tilt Pad Bearing Upgrades

The "classic" 6-pad tilting pad bearings of the GE Large Steam Turbines that were built between late 1950s through 2000 era (as well as other varied tilting pad bearings for Combined Cycle Gas Turbines including the D-11 Steam Turbines of more recent vintage) typically developed excessive wear patterns in the contact areas on the backs of the pads and on the mating surfaces of the housing bores. This applies to GE-style Tilting Pad Bearings with bores diameters from 8 inches to 24 inches.

If the contact surfaces are not refurbished, then even the best job of rebabbitting and remachining the bore is useless.

While the Babbitt surfaces may be fine, the wear patterns on the backs of the pads can be large enough to cause the pads to have limited ability to roll, tilt, or twist as required by the design. The consequence is that they do not permit rolling well enough to be able to suppress sub-synchronous rotor vibration, including steam-whirl, one of the most damaging forms of sub-synch rotor vibration.

TRI has demonstrated the Engineering Skills to evaluate each tilting pad bearing situation, as well as to have a shop with the skilled manpower and specialized tooling necessary to refurbish the various bearing designs in an expeditious manner. Critical worksteps of these refurbishment processes are to bore out the housing and to machine a double radius curvature on the backs of the pads. The double radius curvature is critical because it allows the pads to roll, tilt, and twist correctly. Each pad must be able to move properly in order for the oil film to suppress the "cross-coupled" stiffness and damping characteristics that leads to sub-synchronous rotor vibration. If the contact surfaces are not refurbished, then even the best job of rebabbitting and remachining the bore is useless. If the pads cannot move properly, then the pads act as if they are a fixed bore bearing and this can lead to sub-synchronous rotor vibration. If in doubt, turn over the pads and look at the back side.

The 6-pad "classical" design

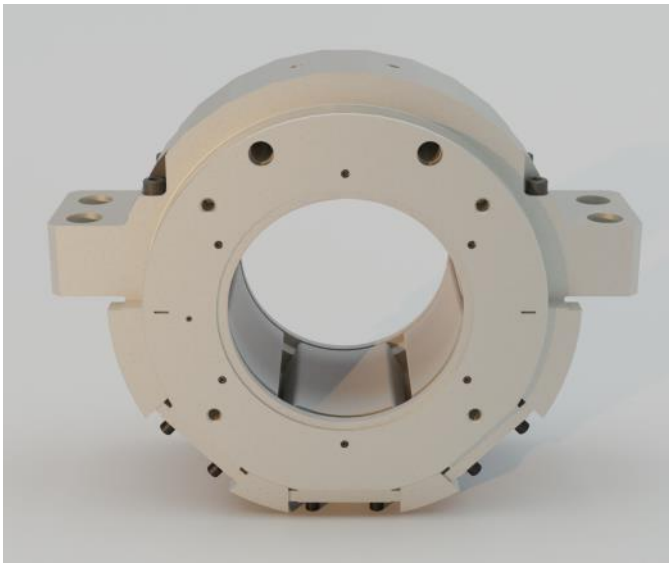
In many cases, the pad backs have worn a pocket into the bore of the housing. The pads and housings are made of very soft steel, and inserts have been made to fit into the back of the pads, not particularly the bottom pads. The top pads usually have a bar of soft steel across each pad to be used to adjust clearance.

In other cases, the bottom three pads have had bars installed that resemble the bars on the top pads, and these have been hand rounded so that they have a double curvature, but not a curvature that is sufficiently correct to produce the desired rolling function.

A problem with bottom pads that have had a slot cut for a bar is that this greatly reduces the bending stiffness and strength of the pad for supporting the oil film with a heavy load. TRI can offer other viable options, if time to obtain other materials exists.

Limited Options:

Preferred options include making pad rings of heat-treated alloy steel and installing round inserts



of similar steel in the top pads for clearance adjustments. Another variation is to install round inserts of heat-treated steel at all pad locations to resist wear.

In some cases, it appears that GE has made some new "classic" bearings with the latter insert feature for some of the high MW Steam Turbines.

In any of these cases, the preferred choice is to machine the backs of the pads with a proper double radius shape.

Exposure to GE Gas Turbine and D-11 Steam Turbine Bearings

During recent exposures to refurbishing bearings for GE Gas and Steam Turbines, generally associated with combined cycle plants, it appears that the tilting pad bearings have been produced with only initial cost in mind. Maintenance, operational considerations and reliability have unfortunately not been in primary focus as was the case years ago.

In any event, TRI clearly can refurbish these bearings, whether four or six pads, load on pivot, or load between pivots. An over-riding issue is that by using soft steel in contact zones and not using alignment pads on the outside of the bearings, any refurbishment job simply cannot produce a significantly improved product. All TRI can do in these cases is to return refurbished bearings in conditions that match the original bearings.

There is another very viable option

Retrofit TRI Align-A-Pad ™ tilting pad journal bearings for GE Turbines and Generators make good products better. TRI can design and manufacture bearings with improved features:

- 6-pad design with spherical dome on flat plate to provide the best contact demonstrated for rolling, tilting, and twisting to suppress sub-synchronous rotor vibration.
- Alloy steel pads and support pad support disks that resist wear.
- Superior Babbitt that permits particulate matter to embed, and still has the yield strength at bearing metal temperatures approaching 230 deg F on a continuous basis to function without Babbitt degradation.
- Pads that are easy to maintain (rebabbitt, machine to specs, and to install in the housing).
- Floating seal rings made from alloy steel with Babbitt lining that are used at both ends of the bearing housing to minimize oil flow exiting along the shaft.
- Typical TRI Align-A-Pad™ bearings have heat treated alloy steel "saddle blocks" for "vector" alignment adjustments using both radial and tangential shim packs.

TRI Align-A-Pad™ bearings perform for 100,000 hrs between turbine inspections and overhaul

In summary

Regarding GE Hydrogen seal assemblies, TRI is in an excellent position to modify, upgrade, or refurbish, these seals up to or in excess of 30-inch journals. TRI will refurbish existing seal assemblies or upgrade them as desired.

Regarding Tilting Pad Journal Bearings for the "classic" or more recent tilting pad journal bearings now in GE Gas Turbines, or D-11 Steam Turbines, TRI has demonstrated the skills to handle the wide range of designs that GE now uses.

While not discussed in this document, TRI has the engineering and shop skills to refurbish, modify, or upgrade any fixed bore bearing in any turbine or generator built by GE or other manufacturer.

On the Web

Dr. Mel Giberson gave a presentation to the EPRI Users in August of 2018. He discussed hydrogen seals in greater detail. That presentation has been made into a 10 minute video and is available on YouTube...http://www.turboresearch.com/gallery/videos.

Tech Note Archive

Tech Note July 2018: Fluid Drive Upgrades; Getting 100,000 hours between overhauls

Tech Note March 2018: Dr. Mel asks, "Why don't you fix it?"

Tech Note May 2017: Improved Competitiveness for Conventional Coal & Gas-fired Power Plants

Tech Note January 2017: Solving a Sub-Synchronous Rotor Vibration for a Critical Steam Turbine in a Seemingly Small, but Actually, a Large Application

Tech Note June 2016: Pressure Dam & Elliptical Bore Bearings

Tech Note Febuary 2015: Improving a Critical Component of a Fluid Drive: The Scoop Tube

Tech Note September 2014: Emergency Lube Oil Pump System based on AC/UPS/VFD Technology

Tech Note February 2013: Improved Journal Bearings for Nuclear Powered Turbine-Generators

Tech Note May 2010: Cracked Bearing Cases; 3 case studies

Tech Note July 2009: Gearbox Upgrades

Tech Note April 2009: The cause and solutions to many problems with ring-oiled bearings

Tech Note November 2007: How changes to condenser back pressure and condensate temperature can effect LP Turbine rotor vibrations.

Tech Note November 2006: Manufactured Components for a New Co -Gen Facility

Tech Note March 2005: Solutions for Problematic MHC Full Arc Controls of GE Steam Turbine-Generators

Tech Note March 2005: Solutions For Common Problems of Extension Shafts, Oil Pumps and Steady Rest Bearings For Westinghouse Large Steam Turbine Generators

Tech Note October 2003: Emergency Lube Oil Systems

Tech Note June 2003: Solutions for over-heating and vibration: two common problems of existing fluid drives.

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This Technical Note was written by Dr. Melbourne F. Giberson, P.E., President of TRI Transmission & Bearing Corp., Turbo Research, Inc. The objectives of Technical Notes are to disseminate information and experience on understanding problems and how to solve them. We attempt to send this Technical Note only to those people for whom the information might be useful. Over the years, many people have asked to be added to the distribution list (see our website). Occasionally, a few individuals inform us that they do not wish to receive the information. Should you desire not to receive future Technical Notes, please advise TRI by info@turboresearch.com or click visit the removal page on the TRI web site MFG 06/2019