



# Transmission & Bearing Corp.

## Technical Notes by Dr. Mel July 2009

### Gearbox Upgrades



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## TRI Upgraded Gearboxes for Power Trains: Gas Turbines, Exciters and Other Applications

### Gear Box Solutions:

- Upgrade Bearings
- Re-bore
- Balance
- Improved Oil Flow
- Improved Sealing
- New Instrumentation

### Experience:

TRI upgrades complete gearboxes and provides upgraded bearings and other components for many gearbox applications.

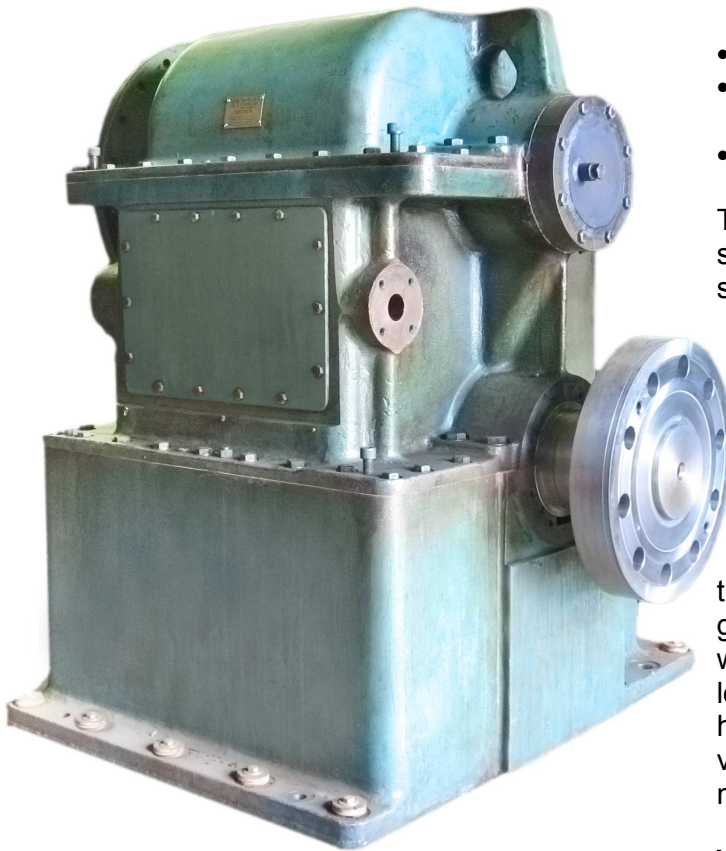
**Upgrade your gearbox  
Call 610-363-8570**

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TECHNICAL NOTE BY DR. MEL, JULY 2009

## GE Frame 5 Gas Turbine-Generator Gearbox:

TRI was approached by a customer that has approximately 20 identical Frame 5 GT - Generators originally rated at 19.6 MW. The customer had uprated the Gas Turbines so that on very cold days in winter, the GT - Gen set would produce close to 30 MW, and the original gearboxes were not capable of handling this load condition. The bearings of the gearboxes would wipe, permitting the gear centerlines to separate, and then both the bearings and the gear teeth would degrade rapidly.



After several attempts to have these problems dealt with by gear companies that made some of the original gearboxes for GE, and other independent companies that focus on gear boxes, the customer came to TRI for a complete Engineering Analysis of the situation. We used TRI's Proprietary Journal Bearing Simulation Computer Program to identify the principal factors involved and developed analytical solutions. Then, TRI Engineers designed and offered optional solutions.

### Align-A-Pad Journal Bearings

Heavy duty bearings for excellent vibration control



The set of solutions that were used included:

- inspection of the bearing bores and shaft centerlines relative to each other, and when not correct, the housing was re-bored to provide proper centerline distances.
- upgraded TRI bearings with a substantial increase in load carrying capacity,
- certain modifications to the gear shafts, then balanced in TRI's balance facility,
- housing modifications were made to improve lube oil flow to the bearings,
- housing modifications were implemented to control oil leaks through the horizontal joints due to high velocity oil thrown from the gears toward the internal housing surfaces,
- improved shaft seals, and
- bearing metal thermocouples located close to the load zones of the bearings
- using oil leak resistant thermocouple fittings.

This multi-point solution was implemented on a spare gearbox and then sequentially on the succeeding gearbox as each GT / gearbox / gen sets came up for a maintenance outage.

In some cases, the gears were rebuilt with new shafts, keeping the old gears. In some cases, TRI created gear drawings and then purchased a matched pair of new gears to the original gear specs. These gears were made by a well-known American manufacturer of "open gearing" using the current gear grinding capabilities. For all of the gearboxes, TRI made upgraded Babbitted bearings with a number of features that (a) increased the load capacity sufficient to withstand the uprated high MW conditions, (b) suppressed sub-sync vibrations, and (c) provided satisfactory bearing metal temperatures.

## Westinghouse Shaft Driven Exciter Gearbox:

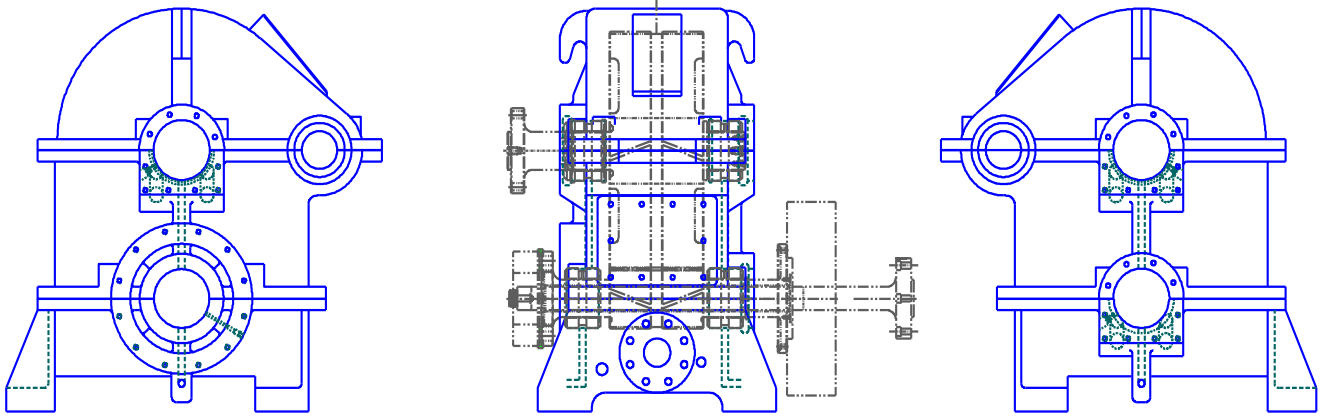
This customer has a series of 3 or 4 relatively similar Westinghouse 3600 rpm Large Steam Turbine-Generators that were built in the 1970s. Each unit has an exciter package that includes a shaft driven quill shaft, speed reducing gear box, and an exciter operating around 895 rpm. There was one spare gearbox available.

For years, these double helix gearboxes experienced high vibration, both transverse and axial, as well as wear of bearings and gear teeth.

### Heavy Duty Fluid Drives

Designed for long life and better performance





TRI Consulting Engineers were requested to participate in alignment of a replacement gearbox and then to disassemble, inspect in detail, make recommendations, and then to remanufacture the removed gearbox in a manner to bring the gearbox up to current vintage, within the capabilities of the gearbox.

Upon disassembly, the teeth on the gear and on the pinion were found to have different profiles and not to have the centerline to centerline distance of the bearing bores. The original gears were hobbled, and did not have a good contact pattern. The wear pattern showed that the gears had been shuttling axially from one end to the other, consistent with the measured high axial vibration pattern. The hub of the quill shaft did not have a mating surface that properly contacted the end of the generator shaft, so it was not possible for them to mate properly, introducing a bowed rotor condition.

TRI's recommended solution, approved by the customer, included:

- a new gear set made by a well-known American Manufacturer of "open gearing" using current gear grinding methods
- the remainder of the shaft profiles matched the original shaft profiles,
- new TRI Babbitted journal bearings with proper clearances,
- the thrust bearing surfaces were shaped to provide enhanced load carrying ability and oil flow control,
- the quill shaft was machined to provide an improved mating surface on the hub, and

improved surfaces for measuring alignment during assembly, and

- thermocouples were installed from the outside with leak-resistant fittings to measure the bearing metal temperatures in the load zones

#### **TRI Manufactured Products and Consulting Services for Trains that Include Gearboxes, Fluid Drives with Internal Gear Sets, and Related Equipment:**

TRI has these engineering, design, and manufacturing capabilities for manufacturing, upgrading, and remanufacturing a range of high powered gearboxes:

- Bearings to increase load carrying capability, and to suppress sub-synchronous rotor vibration (oil whip, oil whirl, and the like). TRI manufactures both solid bore bearings (circular bore, elliptical bore, pressure dam) as well as TRI Align-A-Pad<sup>®</sup> Tilting pad bearings, as is most suitable for the application.
- Remanufacture / repair gear box housings as necessary.
- Build complete gearbox housings to suit specific applications. This need may arise to replace a damaged gearbox, or to make a "one-off" gear box assembly for a custom application.
- Add instrumentation as desired: proximity probes, seismic probes, and thermocouples / RTDs.

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Heavy duty bearings for excellent vibration control



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### **TRI Rotor-dynamic and Journal Bearing Computer Simulation Programs and Services:**

TRI has a repertoire of rotor-dynamic simulation computer programs that were created by TRI personnel, are very mature, and have been eminently successful: They have been used by TRI since the 1970s to provide evaluations of a considerable amount of gas compression equipment in many oil and gas fields around the world, as well as for the heavy rotating equipment in electrical generating plants across the US. These computer programs can be used to perform complete rotor-dynamic analyses of all types of equipment including gearboxes and related power trains from very small to very large:

- journal bearing design analyses, almost all designs,
- lateral critical speeds and lateral synchronous vibratory responses to unbalance,
- lateral non-synchronous rotor stability analyses of multi-bearing trains, and
- torsional analyses of power trains.

TRI also provides field service with consulting engineers and field service technical personnel in order to evaluate problems, offer recommendations for improvements, upgrades, and/or repairs, and to install and align equipment trains.

**TRI will be pleased to review your application and offer recommendations and proposals to suit your situation.**

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TRI product & service information is available at [www.turboresearch.com](http://www.turboresearch.com)

We make "house calls" Emergency tel: 610-283-9077

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](mailto:info@turboresearch.com) or click visit the removal page on the TRI web site MFG 07/2009

### **Special TRI Gearbox for Operating a Disconnect Coupling as Part of a Synchronous Condenser Start-up Package:**

TRI has converted two 100 MW Turbine-Generators to Synchronous Condensers for a major utility in America. The design of the equipment train was based on US Patent 5,610,500 that was granted to TRI. Each start-up train consisted of a large induction motor, a variable speed fluid drive, a speed increasing gear-box, a disconnect coupling, and an extension shaft connected to the generator shaft coupling. Thrust and journal bearings supported the extension shaft.

The gear box had unique features permitting the high speed pinion to slide axially under hydraulic pressure when it was rotating or not rotating. When it was not rotating, the disconnect coupling could be engaged hydraulically to the Extension Shaft, and when it was rotating, it could be disengaged hydraulically from the Extension Shaft.

TRI designed and manufactured this unique gear box, though, again, TRI purchased the ground gear set as "open gearing" from a major US gear manufacturer and TRI made the rest of the arrangement, including all of the hydraulic features involved. A full complement of temperature and vibration sensors was installed. This train of equipment, including the gear box, performed very well.

### **Heavy Duty Fluid Drives**

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