Vibration
What's Wrong with My Turbine?!

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Independent Turbine Consulting, LLC

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ITC Services

Turbine Services - Technical

- **Turbine Field Engineers (Steam, Gas, Generator)**
- **Outage Client Representation (Owner's Engineer)**
- Outage Planning/Scheduling
- Vibration Data Acquisition and Analysis
- Borescope Engineering Review
- Turbine Maintenance Training (ITC/HPC)
- Troubleshooting and Root Cause Analysis (RCA)

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Topics Covered

1. Introduction - Understanding Gas Turbine Vibration
2. Rotor Vibration Data – Reading the Tea Leaves
3. Diagnosis By Frequency Analysis
   - Sub-Synchronous
   - ½ Per Rev
   - 1 Per Rev
   - 2 Per Rev
4. Other Vibration Signatures
   - Rotor Position in Bearing
5. Vibration from Misalignment, Bearings, and Other Causes
   - Soft Feet
   - Alignment
   - Bearings
6. Diagnosing Gas Turbine Vibration Problems
   - Turbine Field Engineers
   - Vibration Specialists
   - Common Vibration Causes
7. Summary
8. The List…

Don't Do This to My Gas Turbine!

The List…

Don't Do This to My Gas Turbine!

1. Don't perform an outage to solve a vibration issue without performing a vibration analysis before shutdown.
2. Don't low speed balance a turbine or generator rotor to remove imbalance. This can remove the "high-speed" balance weights and be an extremely costly mistake to correct (may require unit disassembly, high-speed balance pits to correct, etc.)
3. Don't use a hand-held pump balancer to diagnose the complex, multi-bearing, supercritical rotor dynamics of turbine generator rotor vibration.
4. Beware of past balance weights that cover up an old issue – correcting the issue could put the unit out of balance.
5. Don't forget to check for soft feet.

1. Introduction

Understanding Gas Turbine Vibration

1. This presentation is aimed at demonstrating the nature of turbine vibration, how turbine components behave, and how to read vital signals to diagnose causes.
2. Demonstrate the importance of looking beyond amplitude and phase angle, specifically at frequency, centerlines, orbits, thermal vectors, trending, component behavior, and “the full picture.”
3. Amplitude and phase angle signals mainly detect rotor weight unbalance where as most vibration issues are caused by other issues.
4. This presentation is aimed at providing operation and maintenance details that will be actionable back in the plant.

2. Rotor Vibration Data

Reading the Tea Leaves

Most vibration issues are not easily diagnosed and fixed because the data is taken with limited installed instrumentation that focuses on bearing amplitude at low sample rates, and often without phase angle and frequency spectrum data.

To truly diagnose most issues requires:

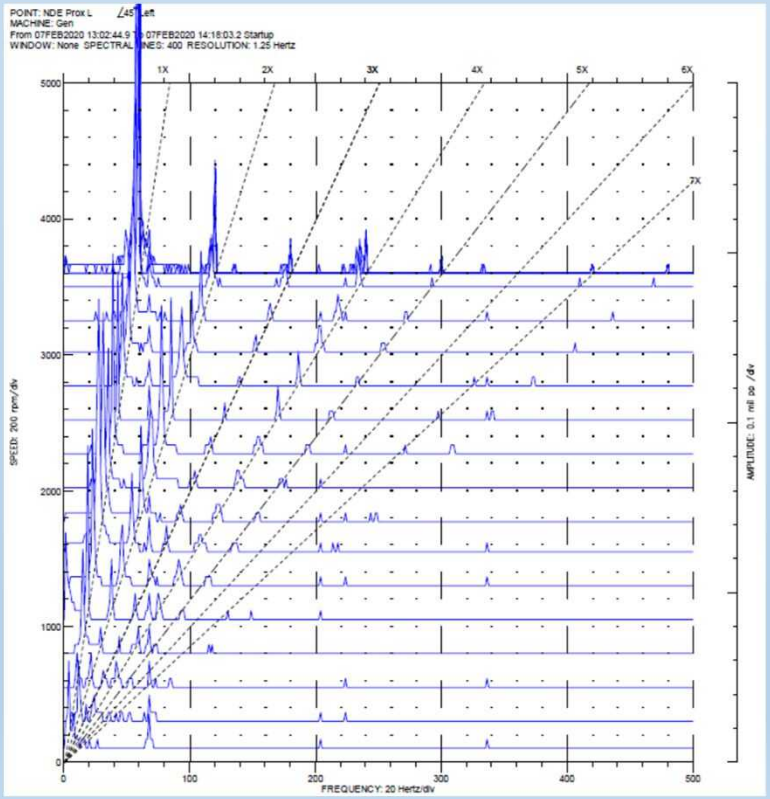
- High frequency data collection (ADRE or equivalent).
- Phase angle and amplitude with at least 2 planes.
- Frequency analysis.
- Trending vibration over time, startup/shutdown, centerline behavior, and events.
- Combination of Proximity probe and Seismic probe data.

It also requires a Vibration Engineer familiar with:

- Knowledge of the turbine generator internal components to narrow down to a "short-list" of potential causes.
- High-Speed data acquisition and analysis equipment (ADRE or equivalent).
- **Experience.**

3. Diagnosis By Frequency Analysis

- Vibration frequency analysis is necessary and the most important tool in diagnosing and fixing vibration problems.
- Most types of internal turbine issues have a vibration signature that can help determine what is going on inside a machine.
- Bearing vibration is a “Symptom”. The real question is what is the “Cause”.
  - Most often the cause is not visible or accessible.
  - Measuring and interpreting vibration data is often the cheapest solution to identify the root cause, assess severity, and determine repairs needed.



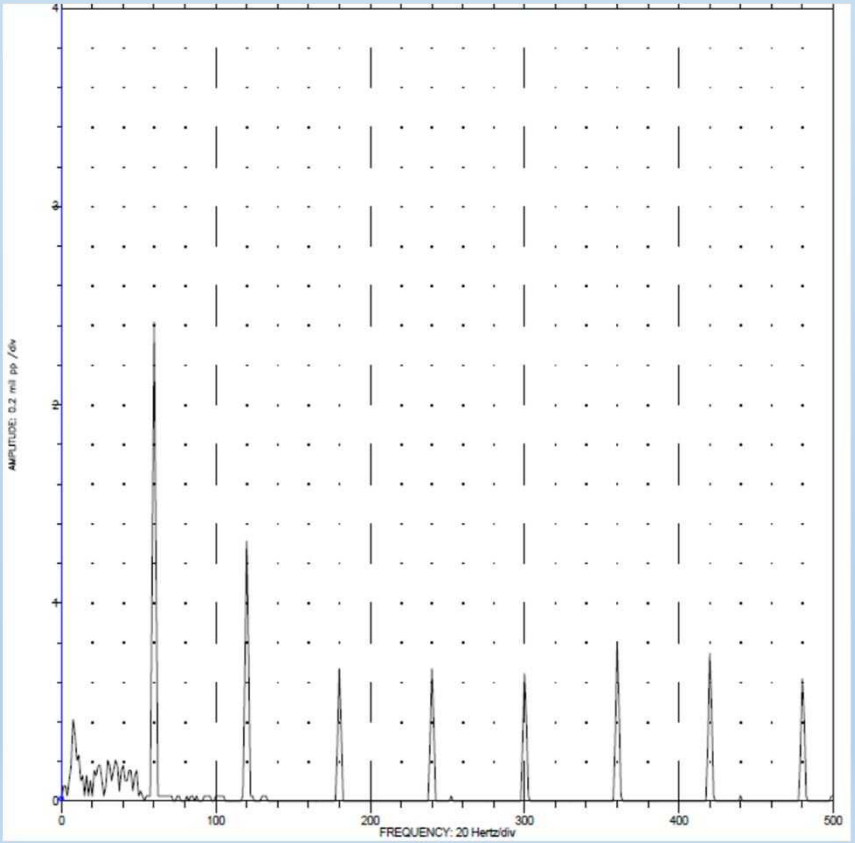
3. Diagnosis By Frequency Analysis

Sub-Synchronous

- Improper bearing support (Soft Feet, Structural Looseness, Foundation, Bearing Pinch, etc.)

½ Per Rev Frequency

- Bearing instability from under loading (incorrect bearing elevations or loading).
- Oil whirl / Oil-film stability problems (0.3 – 0.5x).
- Also caused by excess bearing clearances, or misapplied bearing design.



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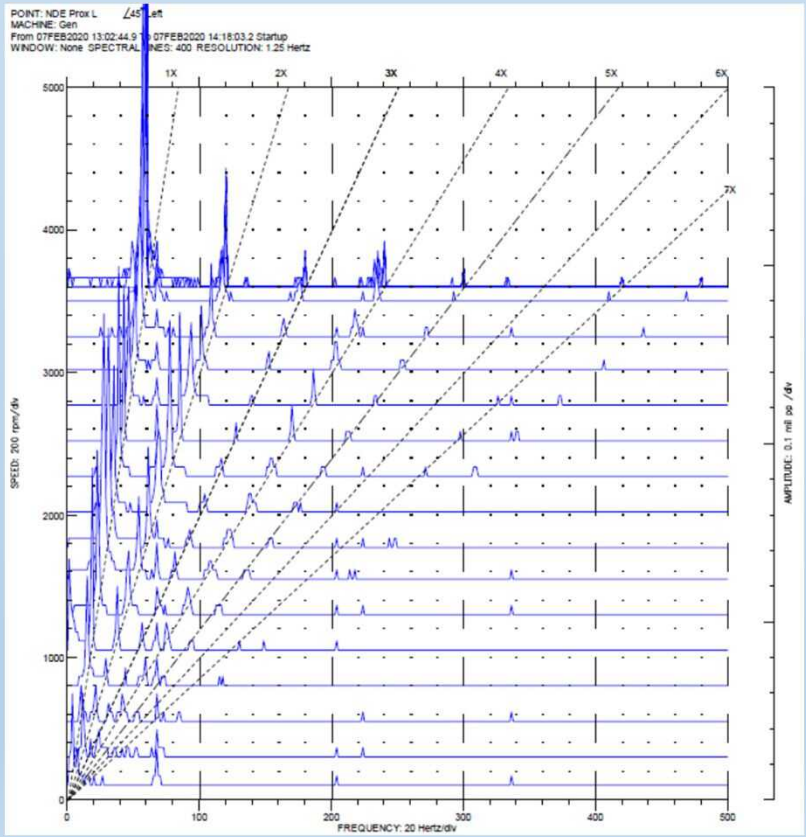
3. Diagnosis By Frequency Analysis

1 Per Rev Frequency

- Weight change / unbalance on rotor.
- Bowed rotors / rubs, etc.
- Angular misalignment - face (often with 2x and 3X present).

2 Per Rev Frequency

- Generator coupling face run-out – (rotor not straight).
- Parallel offset alignment (rim, often with 1x present).
- 3 bearing rotors – coupling sling check not performed – (adjacent rotors not straight, like tail wagging a dog).



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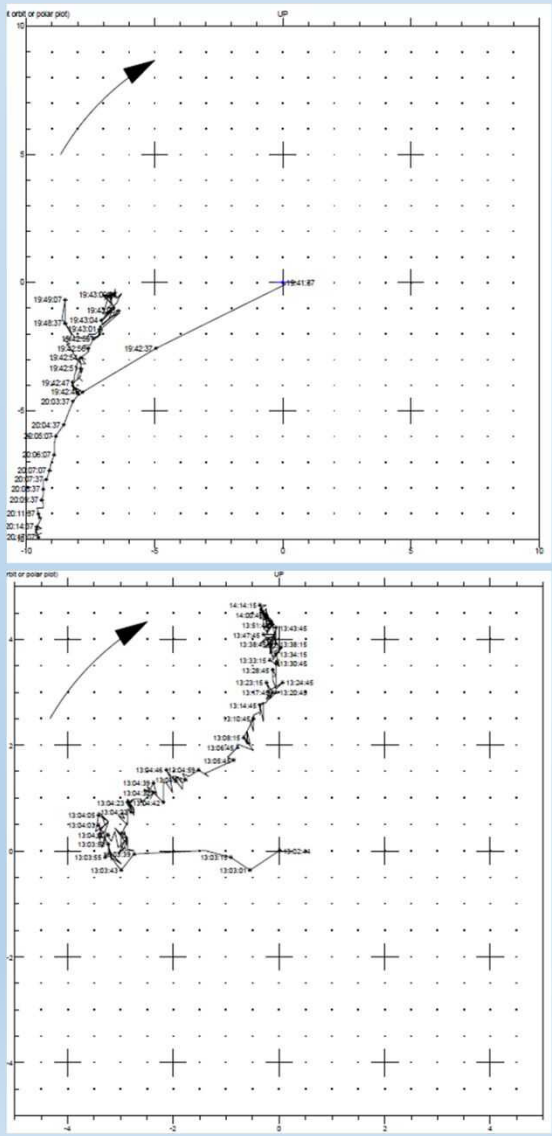
4. Other Vibration Signatures

Centerline Trends

- Rotor Position
  - Journal not at intended 27 Degree Position – (oil wedge instability)
- Rotor Movement In Bearing
  - Abnormal journal movements (orbit centerline over time)
  - Journal moving left and right – (rotor side loading over time – alignment, rotor coupling not straight, etc.)



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4. Other Vibration Signatures

(Continued)

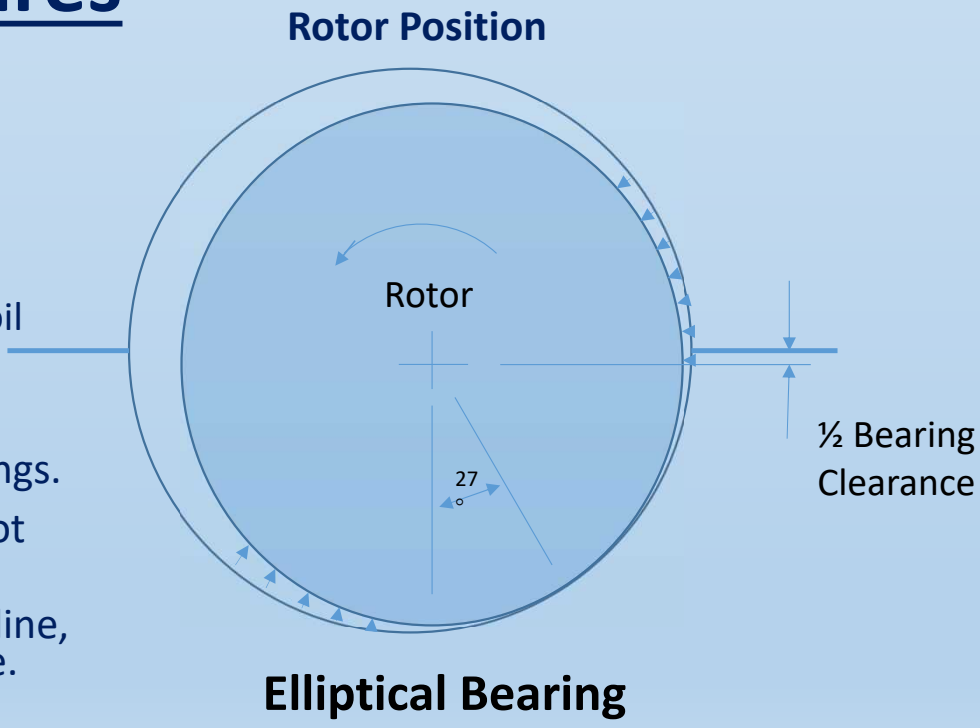
Rotor Position Within Bearing

Journal Analysis

- Ideal journal position is ~27 degrees from bottom.
  - Journal not at intended 27 Degree Position – (oil wedge instability).

Abnormal Journal Positions

- Rotor forced in other positions by adjacent bearings.
- Journal movement back and forth – rotor train not straight.
- Abnormal journal movements, frequency, centerline, and orbit within bearing indicates vibration cause.
  - (under/over loading, rubs, alignment, etc.)



Elliptical Bearing

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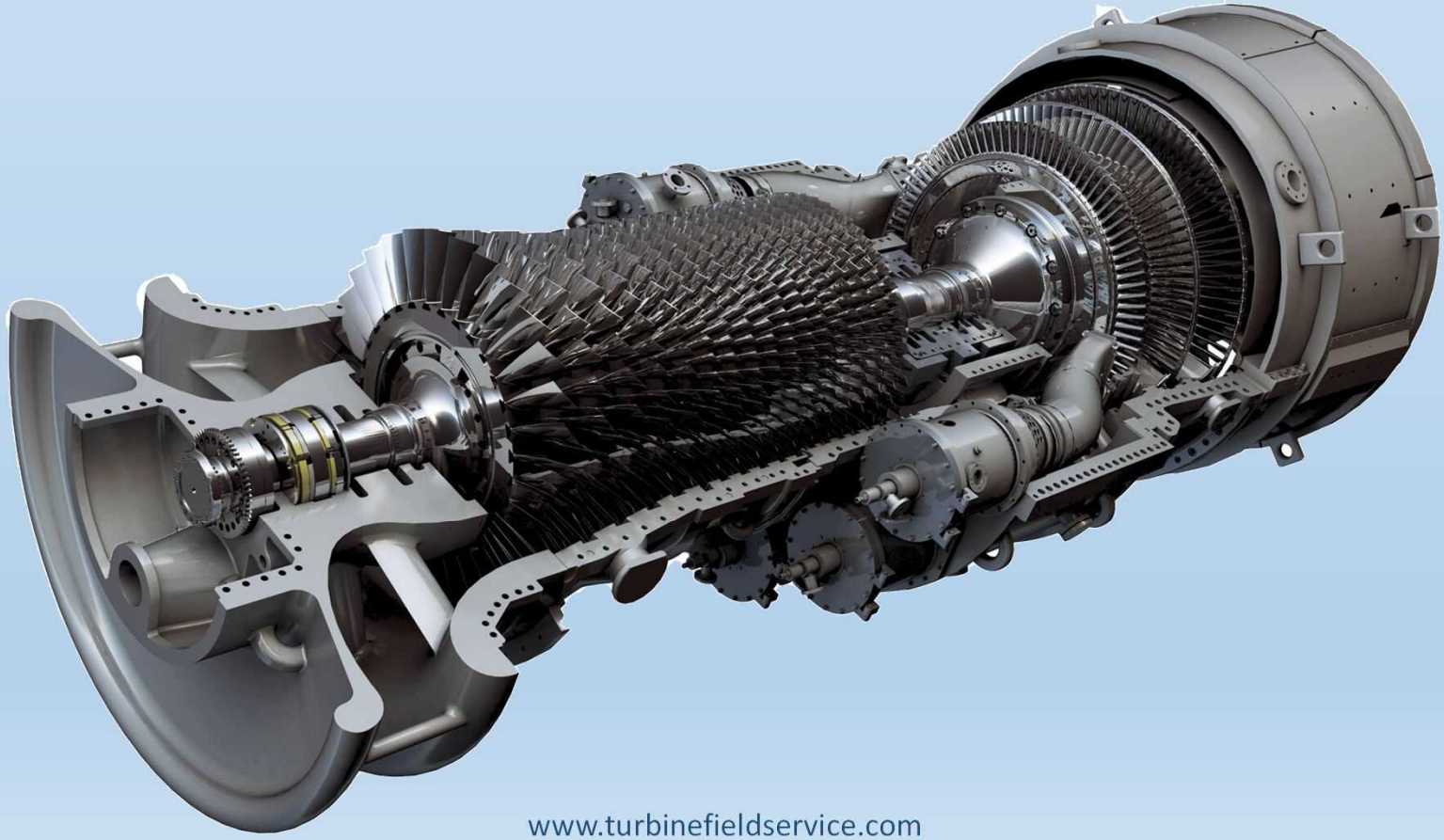
5. Vibration from Misalignment, Bearings, and Other Causes



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5. Turbine Vibration – Soft Feet

Always Check for Soft Feet

- Structural issues are often noted in casing Seismic sensors, often with sub-synchronous and higher resonant frequencies present.

Some Common Causes

- Improper fixator contact and foot loading.
- Improper foot shim contact.
- Foundation degradation.
- No soft foot check performed.

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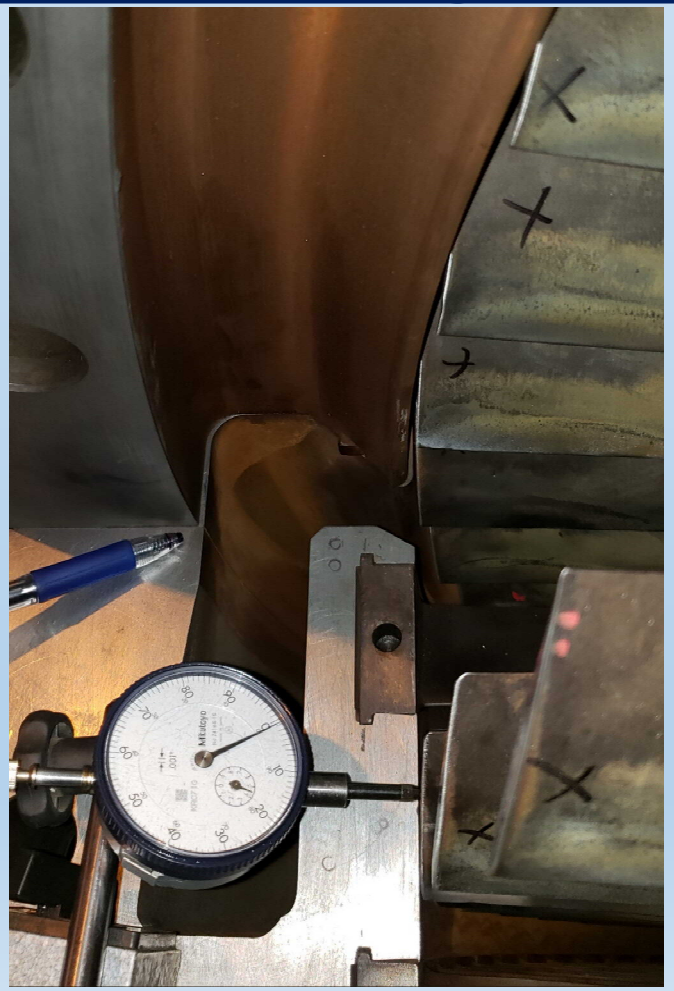
5. Turbine Vibration–Misalignment

Alignment Problems

- Bearing Overloading / Unloading – incorrect generator alignment.
- Internal Alignment Issues – casing warpage, 4-way joint ratcheting, broken supports, improper alignment methods.
- Casing Bore Misalignment – joint dowel yielding, improper assembly.
- Incorrect Coupling Alignment.



5. Turbine Vibration – Bearing Stability

Common Rotor Vibration Caused By Bearings

- Bearing Condition - babbett damage – cracks, electrolysis, wiped babbett, FOD, grooves, etc.)
- Excessive or Inadequate Clearances – (excessive wear, measurement errors, manufacturing and repair errors).
- Inadequate Bearing Pinch or support contact area.
- Incorrect Bearing Elevation, alignment, and offsets – (Incorrect Casing Alignment).
- Bearing Ring Bolt Tightening and Contact – (Incorrect Maintenance).
- Bearing Alignment (Incorrect Maintenance - Twist and Tilt incorrectly set, some designs not adjustable).
- Lift oil check valve failure

5. Turbine Vibration – Other Common Causes

Improper Maintenance

- Rubs and Clearance Issues
  - Compressor, deflector, and gas path rubs
  - Incorrect or inadequate assembly clearances
  - Joint steps
  - Improper rotor position – radial and axial
- Installation of unbalanced components
- Soft Feet

Startup

- Thermal transients within multipiece rotors during startup, including stuck vane platforms and wheels growing into running position.

6. Diagnosing and Solving Gas Turbine Vibration Problems

A Good Turbine Field Engineer

- This is your best defense against future turbine problems. The right person will have:
- Excellent knowledge level.
- OEM training and decades of experience performing the work.
- An understanding on how to do it right, and how folks get it wrong.
- Ability to diagnose issues and recommend corrective actions.

A Good Vibration Specialist

- Will know how to measure, diagnose, and solve vibration problems.
- Have equipment for high-speed data acquisition, analysis, diagnosis, and make knowledgeable, actionable recommendations to correct vibration.

7. Summary

Understanding Turbine Vibration / Successful Maintenance Involves:

- Understanding Turbine Designs And Component Behaviors
- Proper Maintenance Evaluation, Diagnosis, Technical Work Direction
- Proper OEM Maintenance Methodology and Non-OEM Alternatives
- Understanding the Physics and Practical Causes of Vibration

Technical Direction:

- Experience, Depth Of Knowledge
- Improper Maintenance – Responsible For Majority Of Turbine Problems

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Questions?

Thank You!

Please stop by the ITC exhibitor booth
and meet our speaker, chief engineer, and management team.