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Gas Seal Failures Caused by Axial Vibrations

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Presenter/Author bios

James M. Byrne is a Machinery Consultant at BRG Machinery Consulting, LLC. BRG performs research and analysis in the fields of fluid film bearings, magnetic bearings, and rotor dynamics. He began his career designing integrally geared centrifugal compressors for Carrier in Syracuse, NY. Mr. Byrne continued his career at Pratt and Whitney aircraft engines and became a technical leader for rotor dynamics. Later he became a program manager for Pratt and Whitney Power Systems managing the development of new gas turbine products. From 2001 to 2007, he was president of Rotating Machinery Technology, a manufacturer of tilting pad bearings.

He holds a BSME degree from Syracuse University, an MSME degree from the University of Virginia, and an MBA from Carnegie Mellon University. He is a member of the API 613 and 617 task forces.

Patrick Potter is Director of Sales at Cincinnati Gearing Systems (CGS). CGS is a full service design and manufacturing company, providing integrally geared and stand alone high speed gear drives to major OEMs as well as redesign, retrofit, and upgrade support to end users. Patrick started his career as a gearbox design engineer at the Cincinnati Gear Company, completing the clean sheet design of a high speed microturbine gearbox. He then continued working as an application engineer for BHS Getriebe GmbH while specializing in the specification and design of integrally geared compressor and expander drives. From 2008-2014 he served as engineering manager for high speed gearboxes at Voith Turbo prior to joining CGS in his current role.

Patrick holds a BSME degree from the University of Cincinnati, and an MSME degree from Purdue University. He is a member of the API 613, 617, and 677 task forces.

Jose Vazquez is a Machinery Consultant at BRG Machinery Consulting, LLC. Prior to joining BRG, he worked for 10 years at DuPont as a Mechanical Consultant, primarily solving machinery problems and developing advanced measurement techniques.

Dr. Vazquez received his B.S. (Mechanical Engineering, 1990) and MS (Specialization in Rotating Equipment, 1993) from the Universidad Simon Bolivar in Venezuela. He received his Ph.D. (Mechanical and Aerospace Eng., 1999) from the University of Virginia. He is a member of ASME.

Abstract

This case study describes the root cause investigation of 12 dry gas seal failures in three integrally geared centrifugal compressors over a period of 12 years. These compressors are in fuel gas booster service, supplying a 500 MW gas turbine combined cycle power plant.

The root cause investigation determined that the dry gas seal failures were the result of a design integration problem in which the rotor-bearing system exposed the dry gas seals to both excessive axial displacement and excessive axial vibrations.

These problems were resolved by redesigning the rotor-bearing system to incorporate thrust bearings on the pinion.

Introduction

- New York Power Authority's Astoria 500 MW Combined Cycle Power Plant
- Three integrally geared centrifugal compressors to boost the natural gas supply to the unit's two gas turbines.
- Installed in 2005
- 12 severe compressor failures
- Production loss, maintenance and repair costs exceeding $10MM.

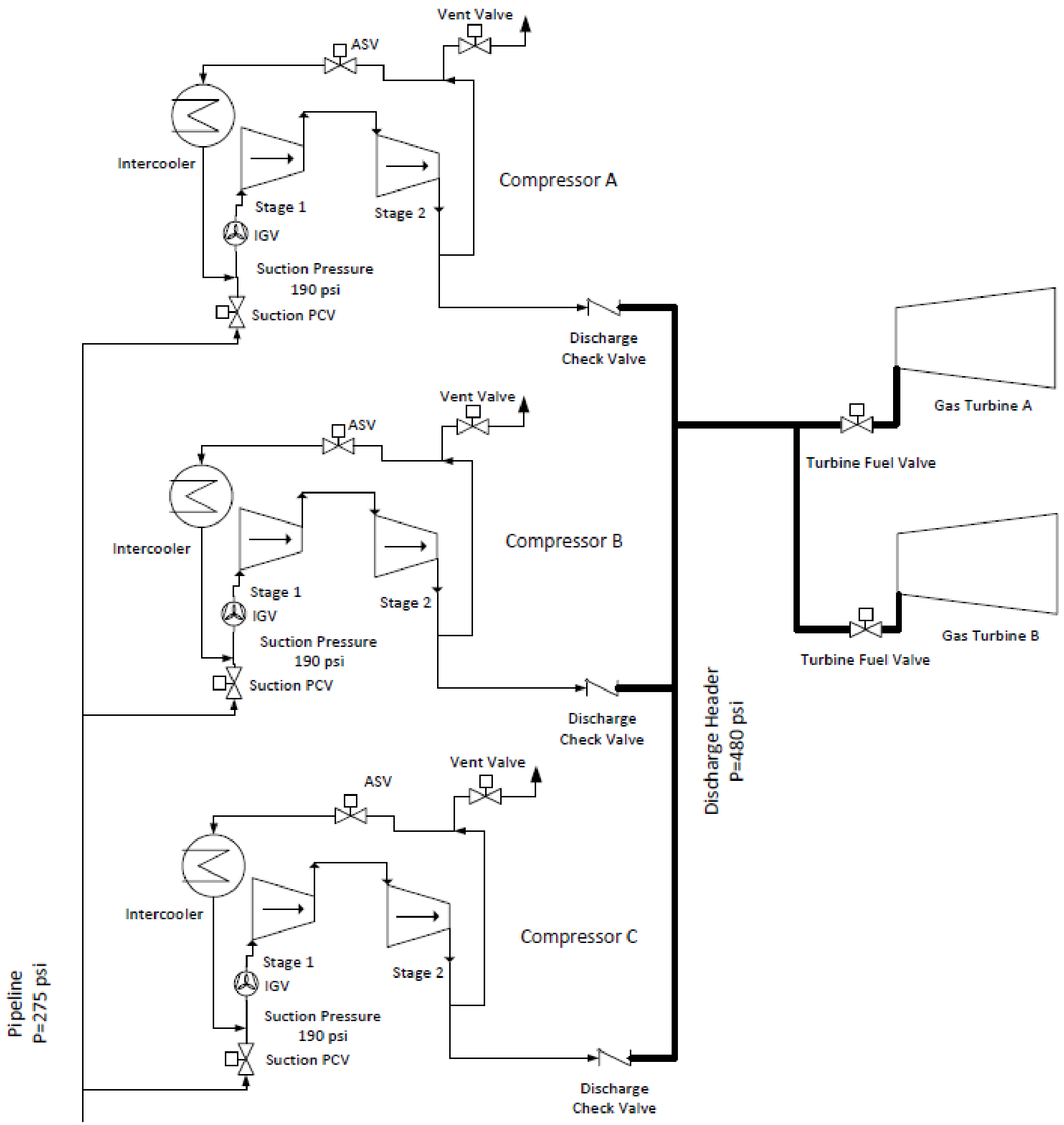
Failure pictures

Damaged parts include:
- Impellers
- Pinion
- Bearings
- Dry gas seals
- Gear
- Casing
- Laby Seals

Failure Analysis

- Damage analysis of failed parts
- Determined sequence of events from PI data
  - Pressures, flows, shaft vibration, shaft axial position, gas seal leakage, valve positions
- Review of operating procedures
- Review of assembly procedures
  - Rotor balancing
- Quality record review of spare parts

System Schematic



Key points:

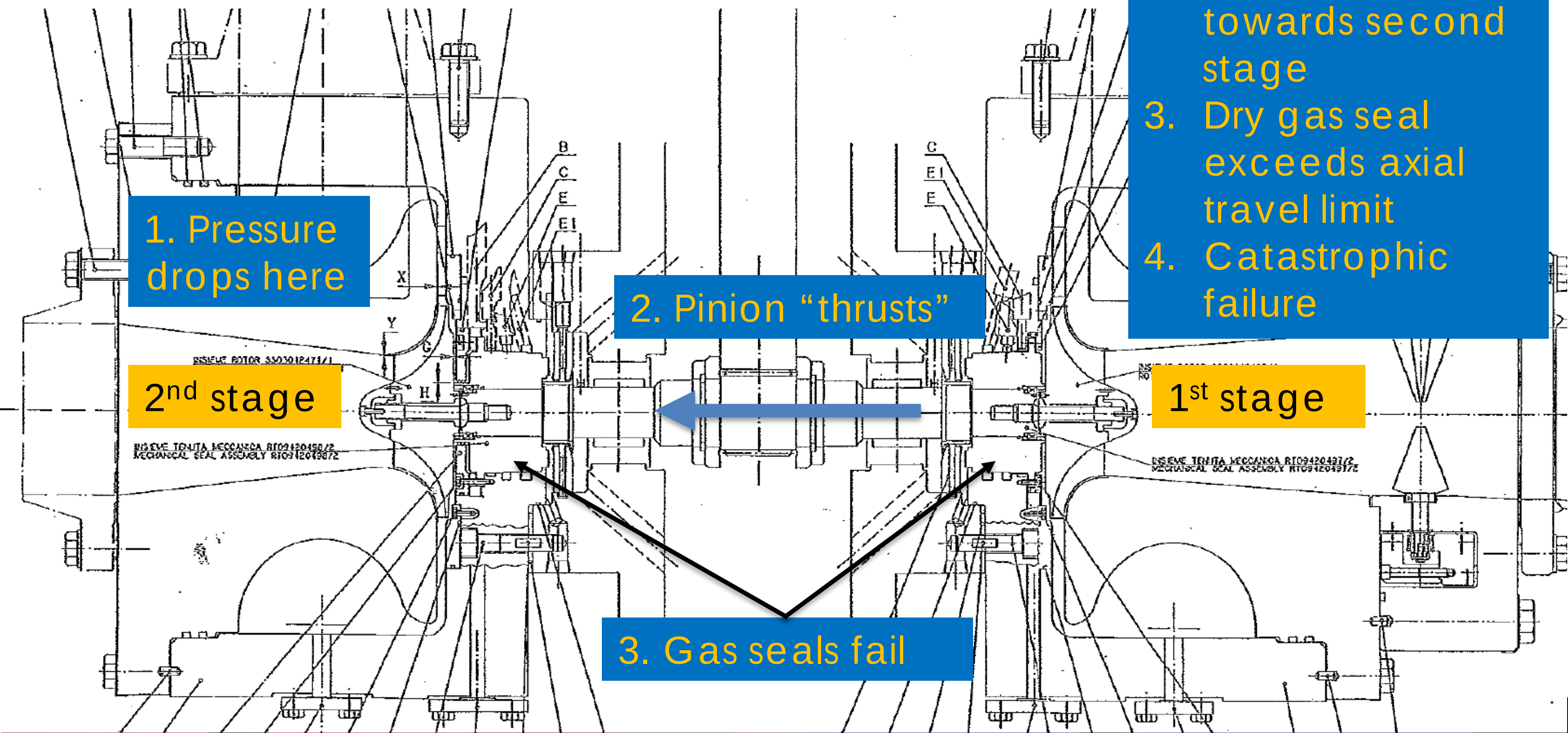
- System is typical of natural gas fired combined cycle power plants
- Two of three compressors operate at all times
- Turbines can also run on liquid fuel

Observation 1

- Some failure events followed system upsets:
  - Turbine trip causes immediate, step change reduction in flow required – gas valves slam shut
  - Compressor suction pressure control valve must close – but is too slow
  - Anti- surge valve must open – but is too slow
  - Vent valve opens to maintain suction pressure
  - System is unstable, 4 valves opening and closing
- Side note: plant trips, swap to liquid fuel common at this plant
  - Redesign of compressor control scheme
    - Dynamic simulation
    - Feed forward control system

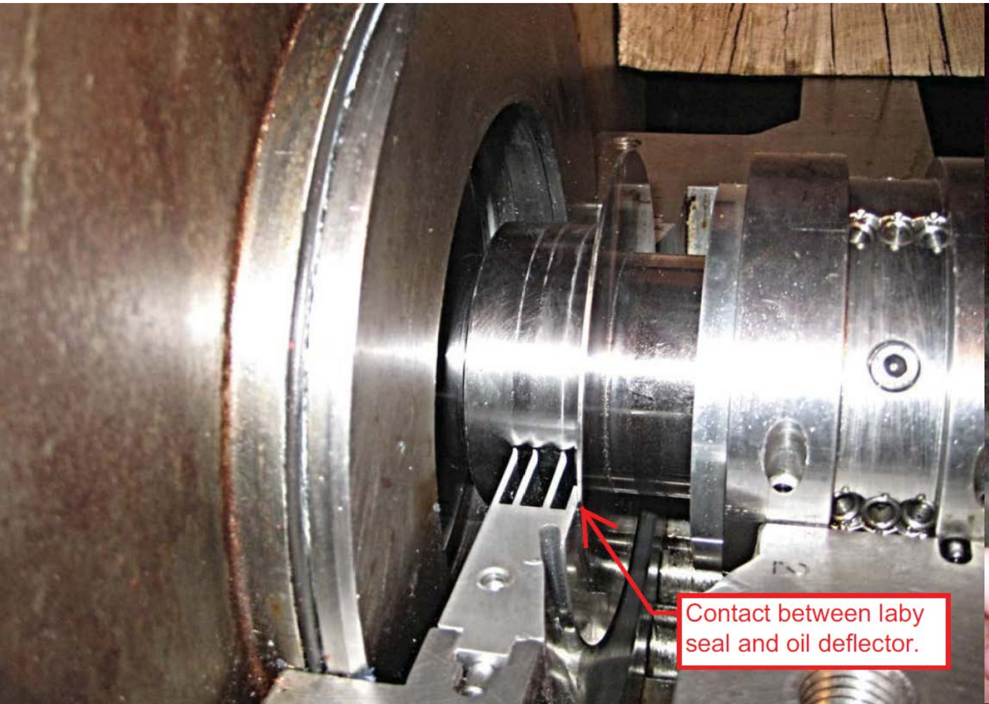
Excessive axial displacement failures - description

Sequence:
1. Vent causes 2nd stage pressure to drop faster
2. Pinion “Thrusts” towards second stage
3. Dry gas seal exceeds axial travel limit
4. Catastrophic failure



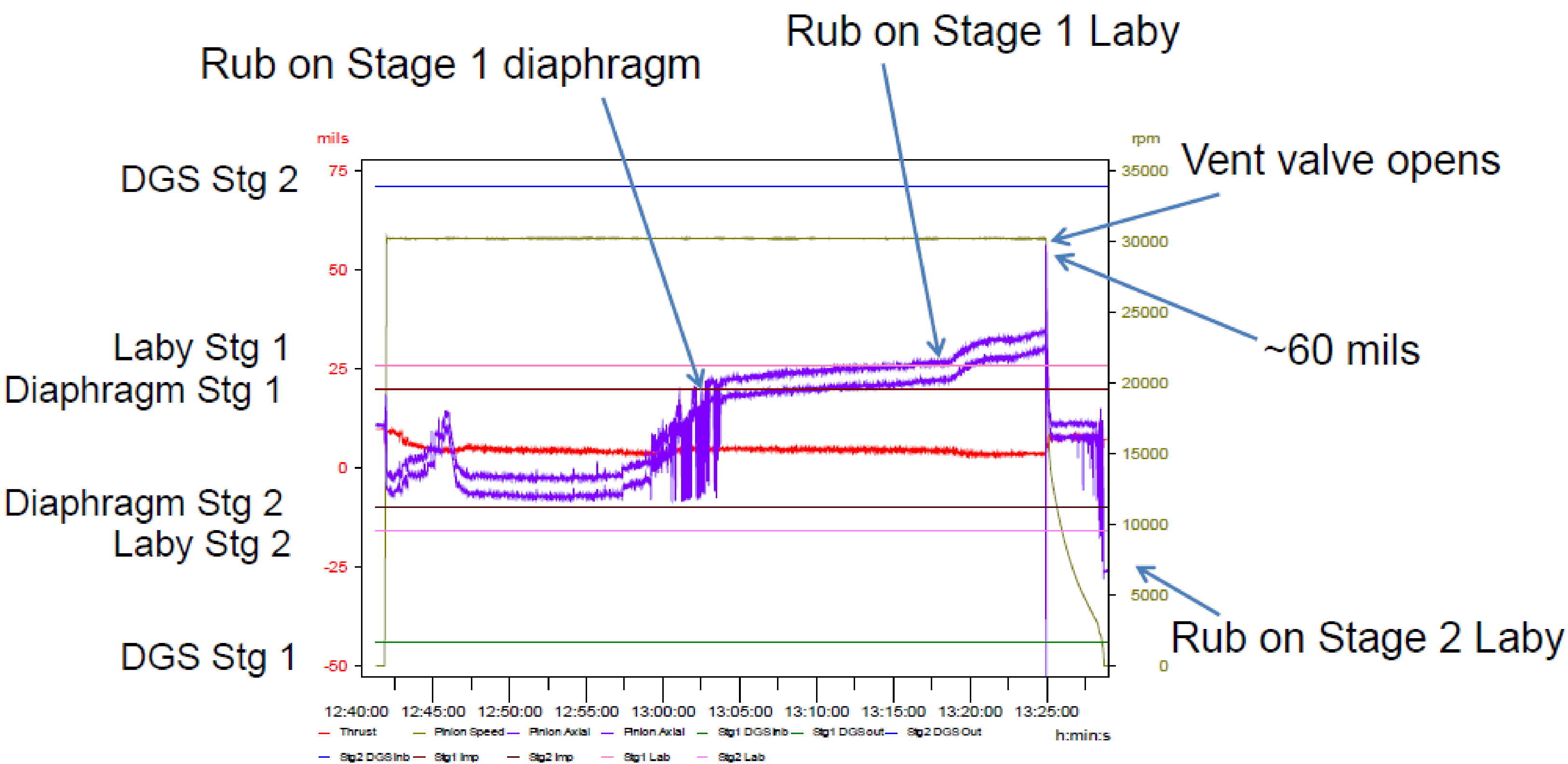
Excessive axial displacement failures - evidence

- Heavy axial rubs
  - Slinger laby seal
  - Impeller shroud

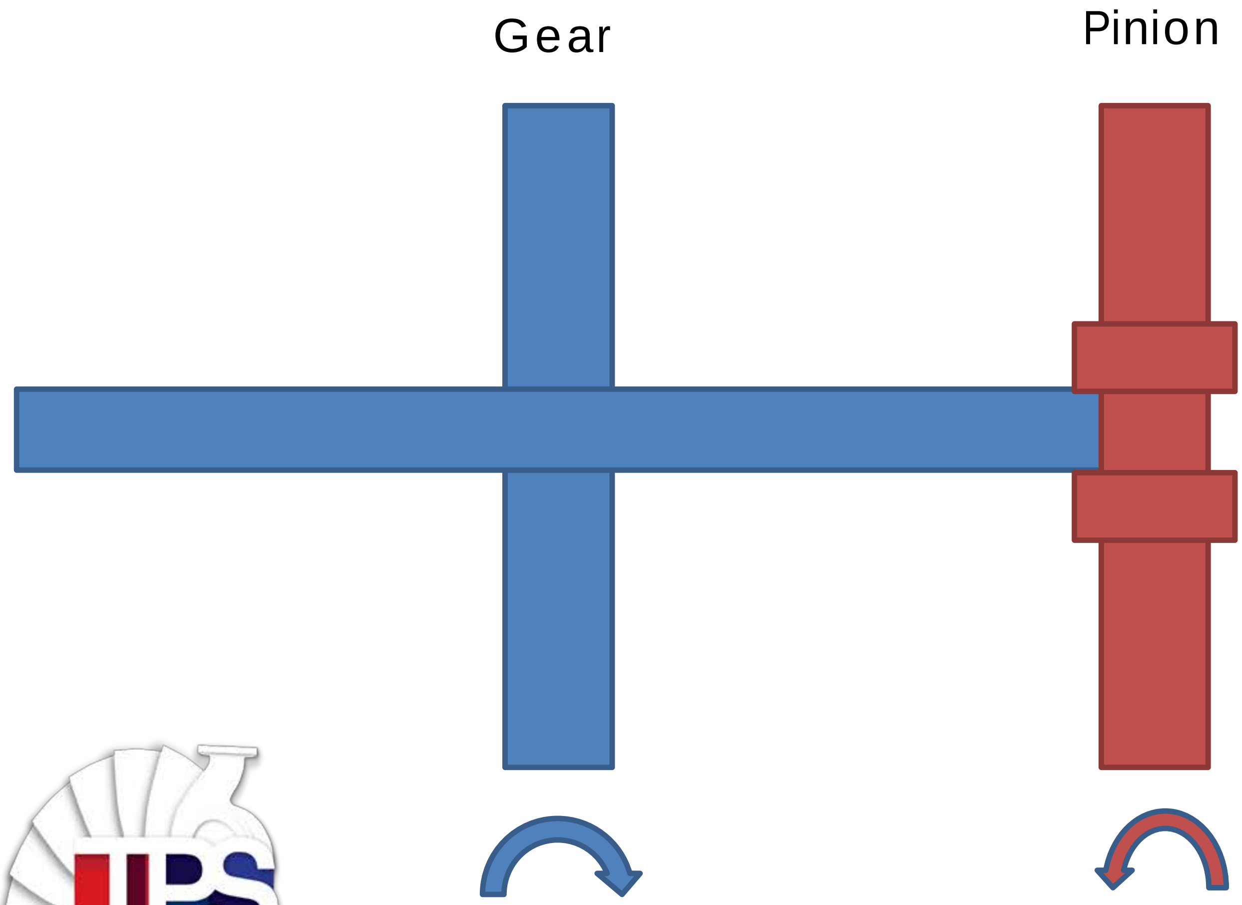


Excessive axial displacement failures - evidence

- Pinion axial displacement “measured” using bull gear displacement (proximity) probes



Thrust rider ring design

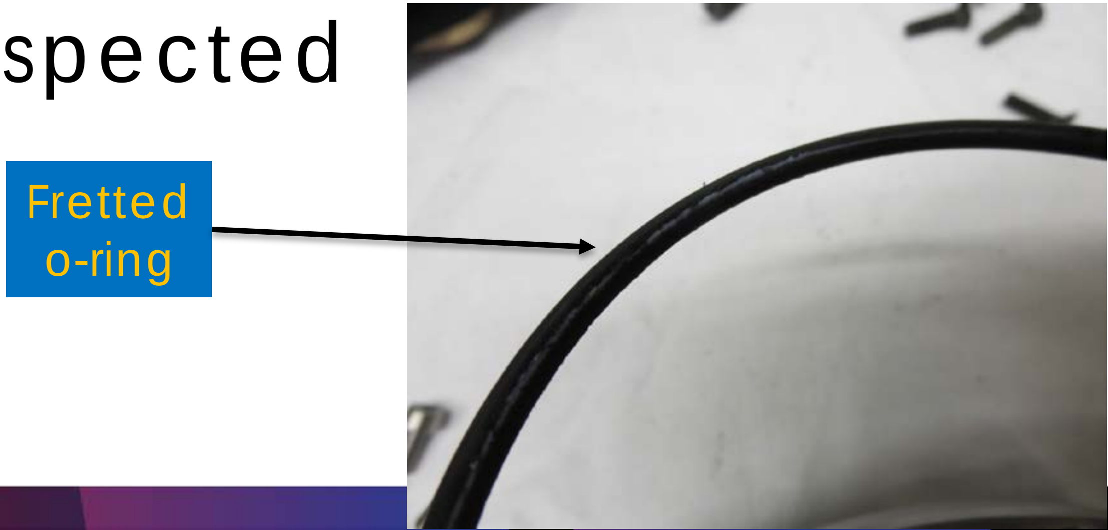


Description:

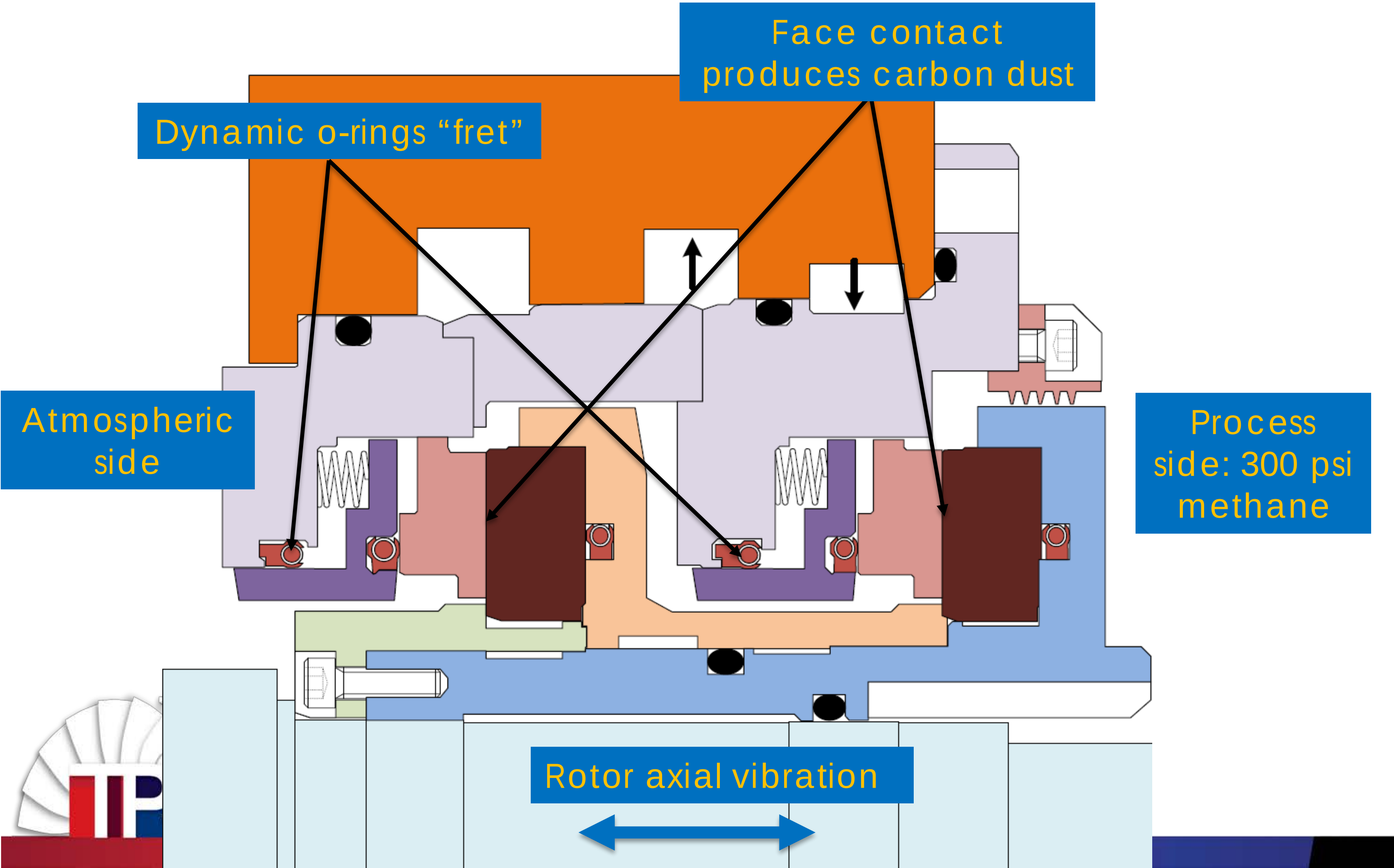
1. Thrust collars or "Rider rings" on pinion contact sides of bull gear
2. Axial forces on pinion reacted through the bull gear

Observation 2

- Some gas seal failures occurred when seal faces "stuck" open
- Disassembly inspection identified:
  - "fretted" o-rings
  - Carbon dust resulting from face contact
- Axial vibrations suspected

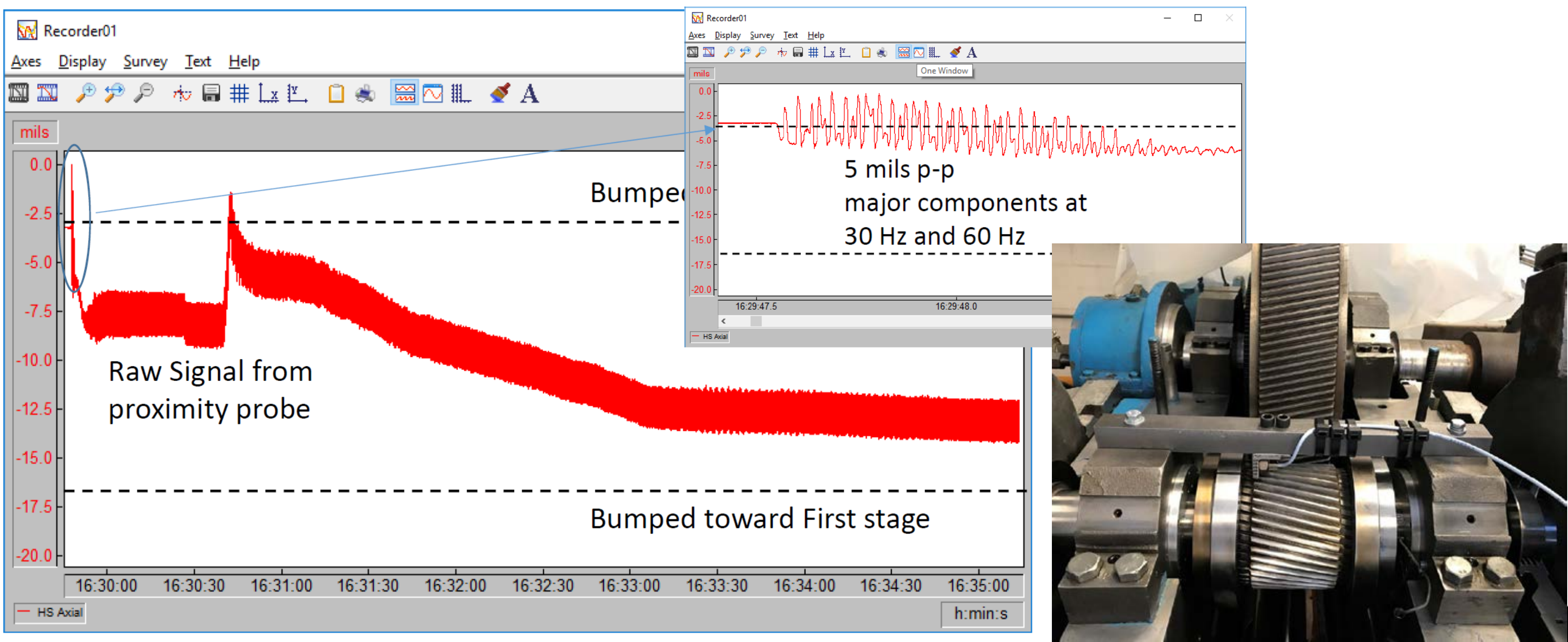


Axial vibration failures – DGS aspects



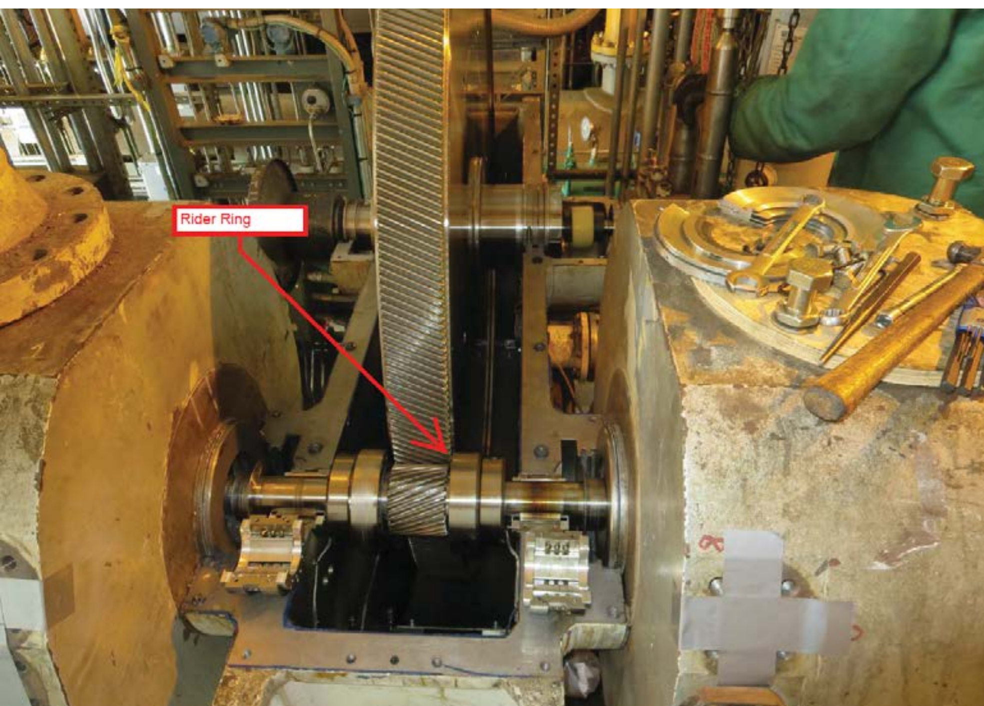
Axial vibration failure - measurements

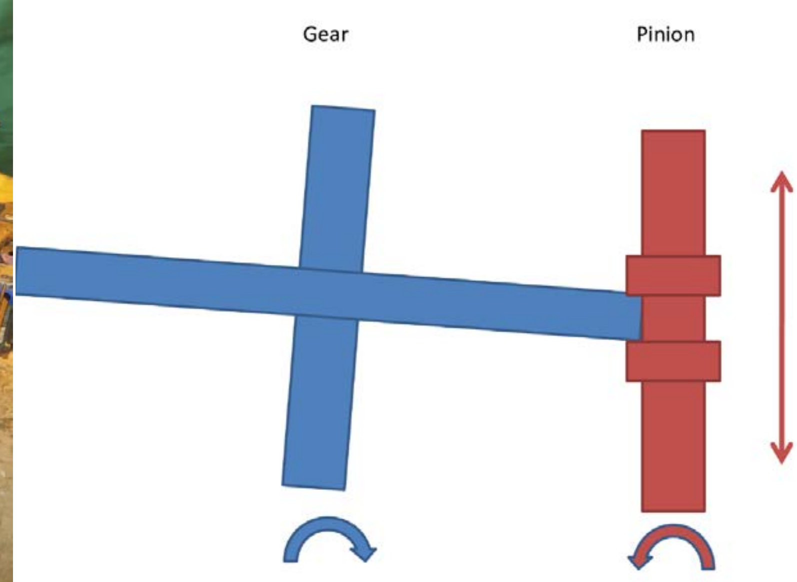
- Axial proximity probe installed to measure pinion axial vibes
- Axial vibes exceeded 5 mils p-p
- Axial vibe limit??? 1 mil p-p – ask seal mfg



Axial vibration failure - cause

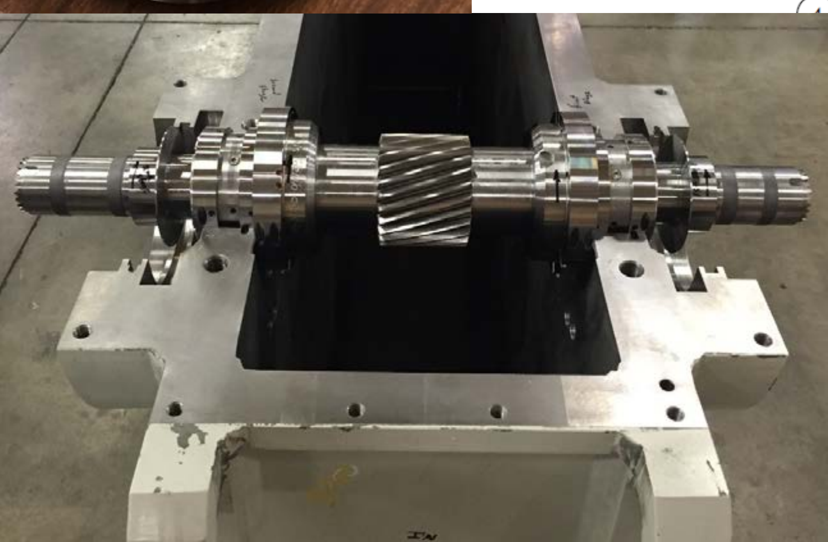
- Pinion axial position established by thrust "rider rings" to bull gear rim
- Bull gear axial runout and vibrations (wobble) ***cause*** pinion axial vibrations

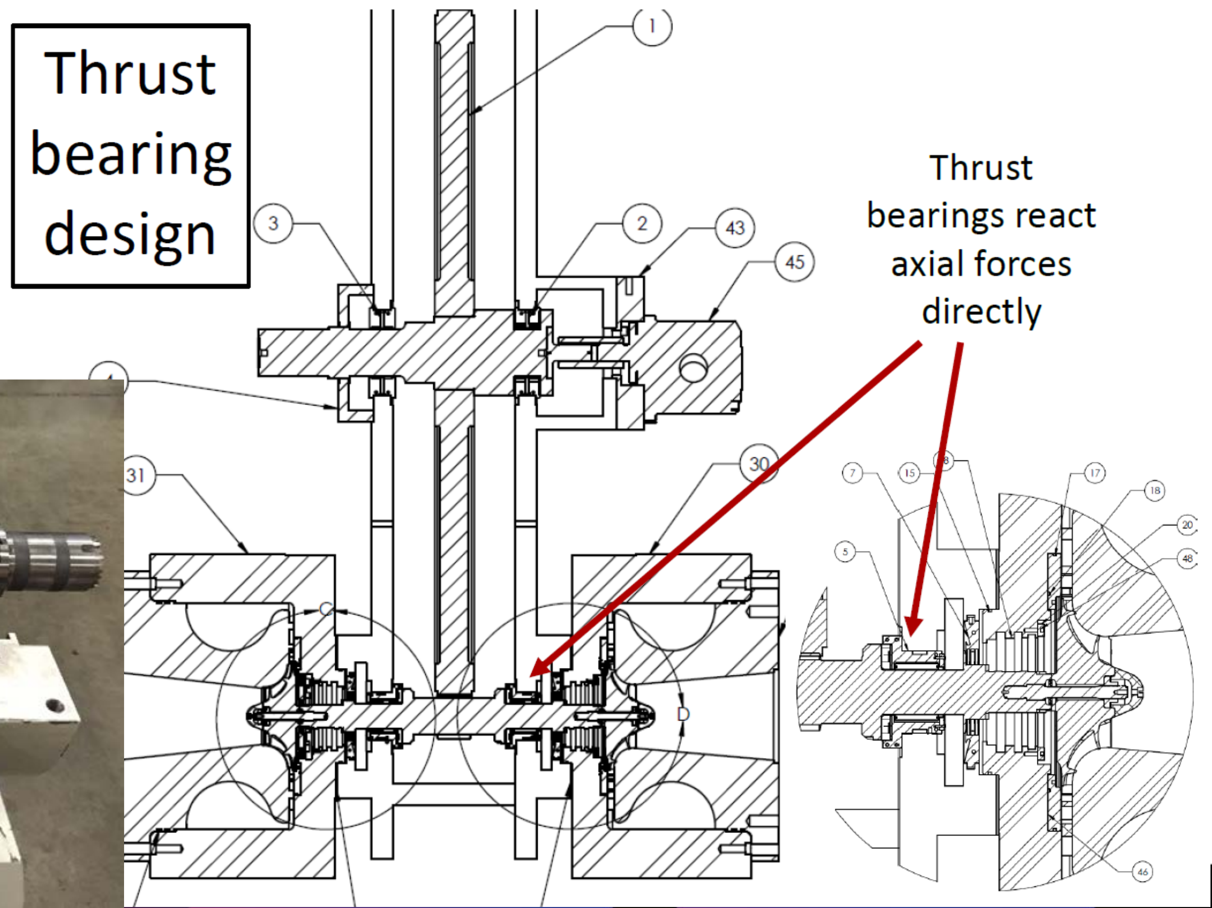




Excessive axial displacement and vibration - solution

- Replace thrust collar (rider ring) design with a dedicated pinion thrust bearing





Recommendations - 1

- Use data to correlate compressor failures to process conditions
- If compressors utilize thrust rider rings, be aware of:
  - Axial displacement issues
  - Axial vibration issues
- Install axial displacement/vibration monitoring equipment
  - Establish alarm and/or trip limits

Recommendations - 2

- Consider retrofitting to pinion thrust bearing design – maximum robustness
- Process controls can impact compressor reliability
  - Beware of venting!
  - Turbine trip halts forward flow immediately
  - Controls that respond to changes in pressure or flow are too slow
    - Take immediate action based on turbine trip
      - Suction pressure control
      - Anti-surge valve
      - Inlet guide vanes

Recommendations - 3

- For new equipment:
  - Require pinion thrust bearings
  - Require axial displacement/vibration monitoring on all pinions
  - Establish alarm and/or trip limits

Recommendations - 4

- Gas seal reliability:
  - Consider upgrade to modern design
    - Unidirectional
    - Materials: faces, o-rings
    - Tandem seal with intermediate laby or single seal?
  - Ensure clean, dry gas – coalescing filters, heaters
  - Backpressure to ensure adequate secondary seal pressure differential
  - Startup gas
  - High speed integrally geared compressors challenging application
  - Secondary seal is often the problem