WORLD-CLASS OUTSTANDING INTERNATIONAL

PROGRAM | EXHIBITION | NETWORKING

CASE STUDY:

BEARING FROSTING AND THE UNIQUE OCCURRENCE ON A GEARED CENTRIFUGAL COMPRESSOR

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Author Biographies

- Ed Czechowski – Fellow Engineer at FS-Elliott since 2011. Retired manager of New Product Development at Cameron Compression systems. MSIT and BMET from Buffalo State College. Advisory board member at both Buffalo State and the University of Buffalo.

- Chris Napoleon – Chris Napoleon is the President and Chief Engineer for Napoleon Engineering Services. He received a B.S. in mechanical engineering from the University of Pittsburgh and a M.S. in manufacturing management from Kettering University. 23 Years experience in bearing testing and development.

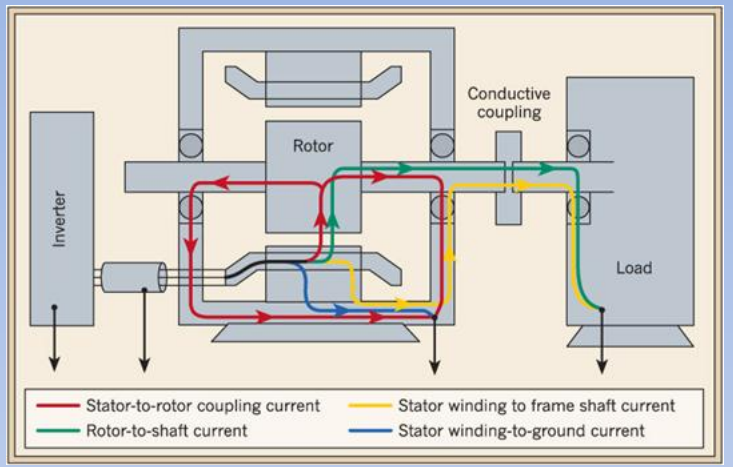
- Mike Tursky - Manager, Sustaining Engineering at FS-Elliott Company since 2003. Former Product Design Engineer at Elliott Turbomachinery Company. B.S. Aerospace Engineering from Penn State University.

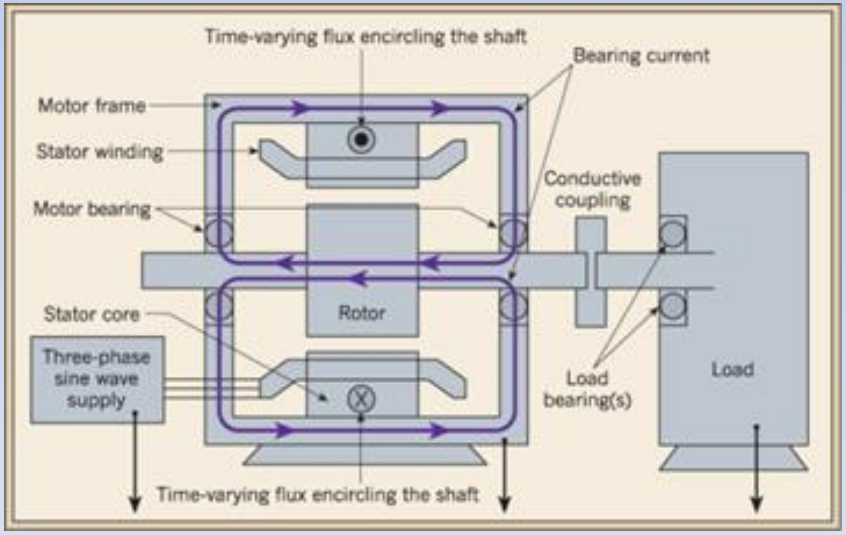
Background

- By definition, “Bearing Frosting” is term used to describe a physical defect to a bearing surface caused stray electrical currents.
- It is similar in nature to “EDM” (Electrical Discharge Machining) whereby bearing surfaces vaporize or soften as electrical current passes through them.
- It affects both conventional Babbitt style bearings as well as anti-friction bearings.
- Common to all types of drive/driven systems especially steam turbines and VFD (variable frequency drive) driven equipment.
- Results in either slow or rapid increases in pinion vibration and has a direct impact on machine reliability.

Common Sources of Stray current

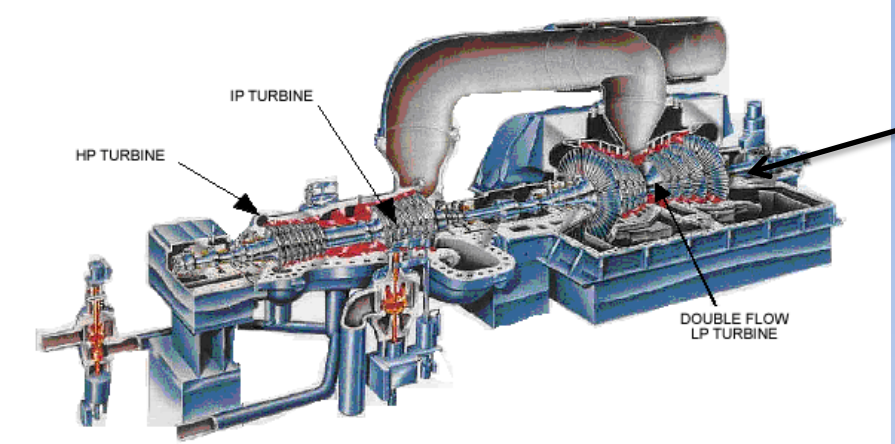
- Induction Motor Stray Currents – caused by time varying flux encircling the motor shaft from uneven symmetry in motor windings or from shipping damage.





- VFD harmonics – VFD's operate by rectifying AC voltage to DC voltage and subsequently inverting the voltage back to AC via high speed switching. This HS switching creates a current imbalance between the three phases and is often referred to as "common-mode voltage".

Common Sources of Stray current



VIEW OF THE INTERNALS OF A TYPICAL POWER STATION STEAM TURBINE

Static electricity on steam exit side bearings

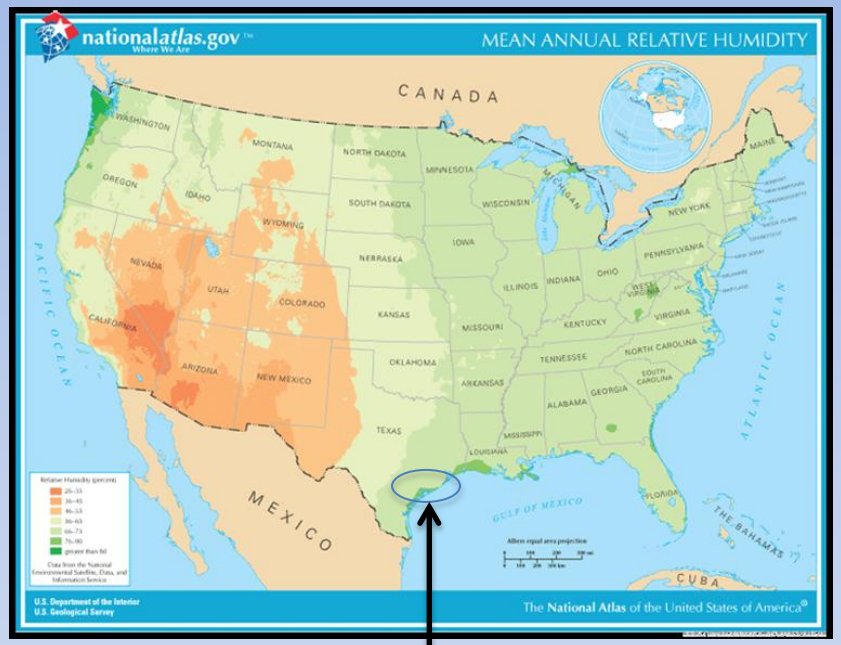
- Manufacturing processes – part holders, lathes
- Magnetic base inspection indicators
- Gear box Machining processes
- Magnetic Particle inspection
- Space heater failure
- Welding on frame
- Motor feed and drains
- Group III oils

How to Check for Stray Voltage

Carbon fiber shaft probe and portable oscilloscope

Electro-static charge detector with a charge plate adapter for use with a pipe probe

Unique factors affecting a group of Geared Centrifugals: Case study focus

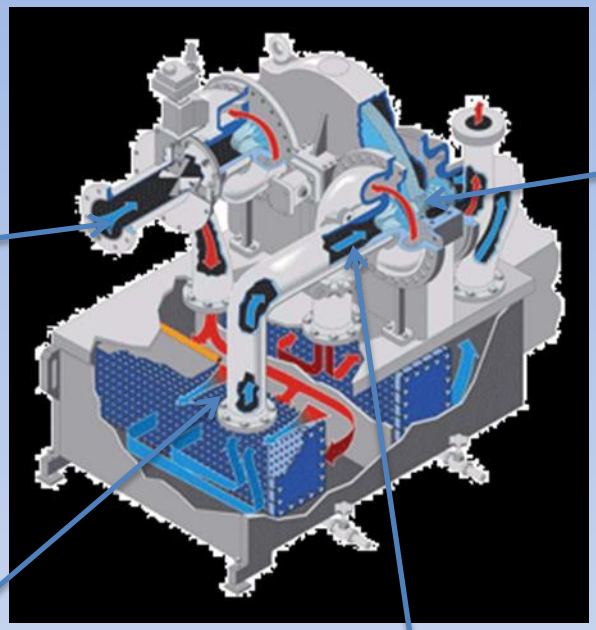


General location of frosted bearing compressors (highest annual humidity readings in the country)

Type of location: Virtually all the major bearing failures have occurred in Petrochemical plants that produce ethylene based products

High Humidity / Plastics Plant = Static Charge Influence

High Humidity air is mixed with charged particles



Pinions can become charged and the combined effect of the tribo-electrification of oil and charge potential allow EDM to take place.

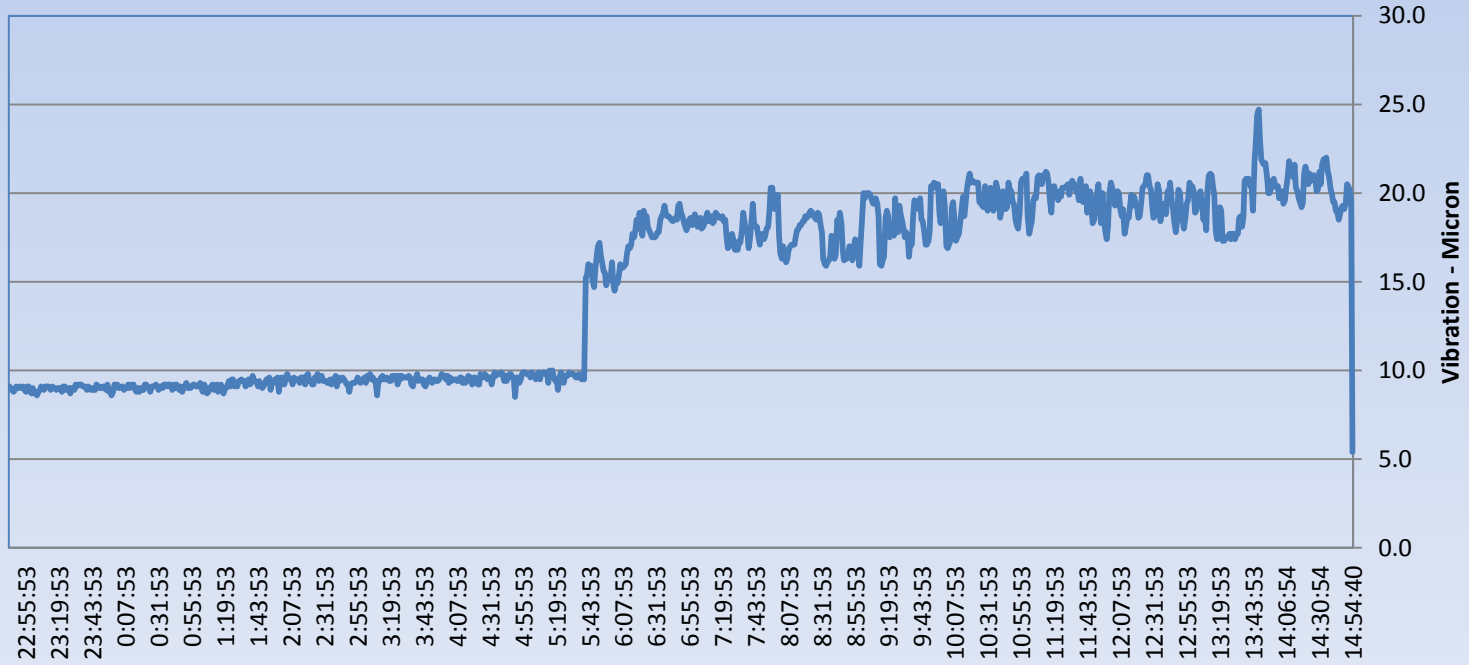
100% saturated high velocity air into the next stage of compression

Charges can develop due to base material location on the Triboelectric series – metal is neutral, polystyrene has strong negative charge.
Note: Human hands have the highest positive charge

Case Study Example – two compressors one with a bull gear shaft grounding ring and one without.

Initial Data from one of the Failed Units

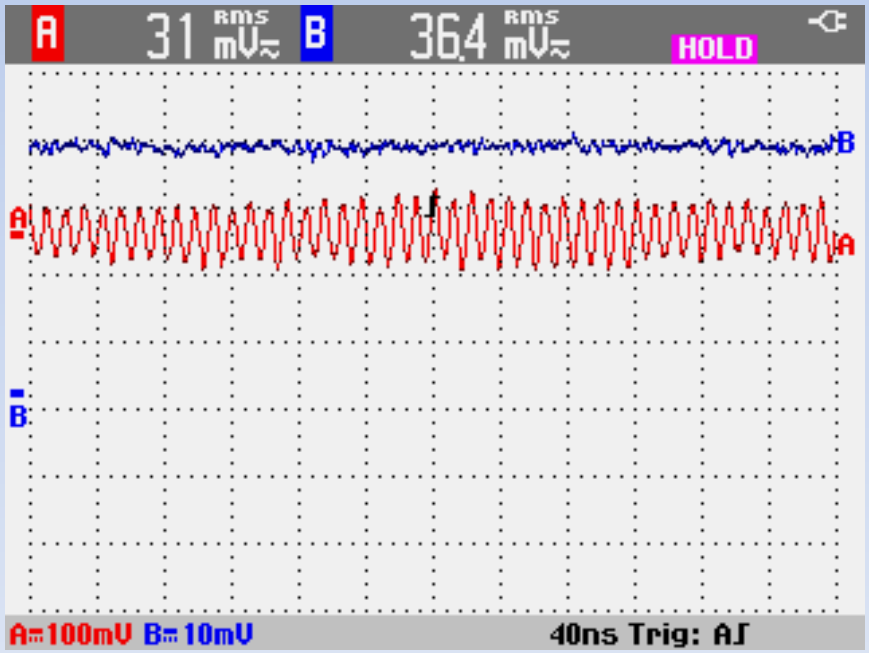
- The compressors in this case study all experienced alarm and trip levels of vibration before being shut down for bearing replacement. One unit exhibited a sudden shift in vibration just hours after start up…an oversize pinion bore caused by bearing frosting ended up being the problem.



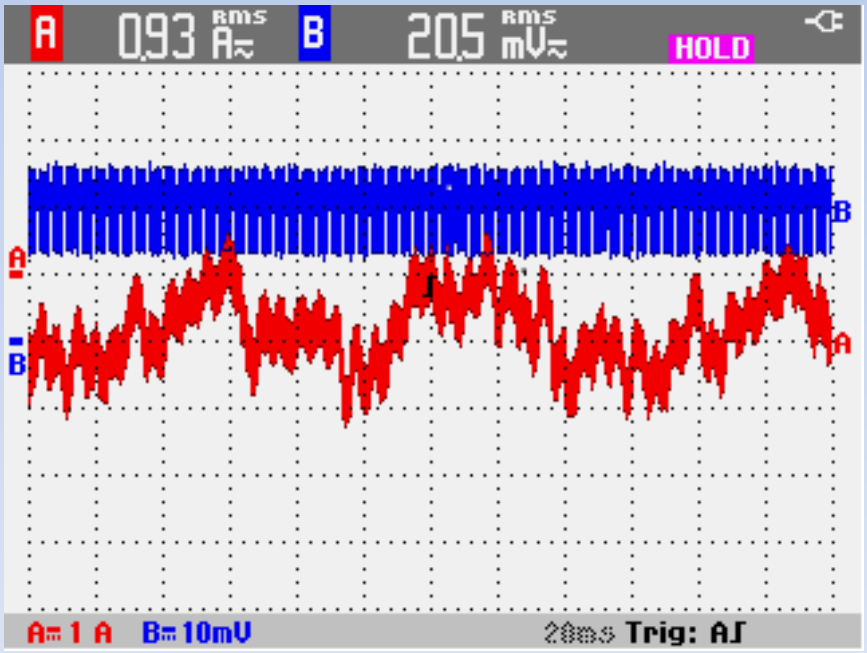
Data Collected from Repaired Units

Unit	Shaft Voltage	Shaft Current	Static Charge	Comments
W/ Ground ring	31 mV rms	26 mA rms	170 - 515 V	Static decayed over time
W/O GR	1.029 V rms	.93- 1.02 A rms	50 – 360 V	Cycled every eight minutes

Grounding Ring unit had better results

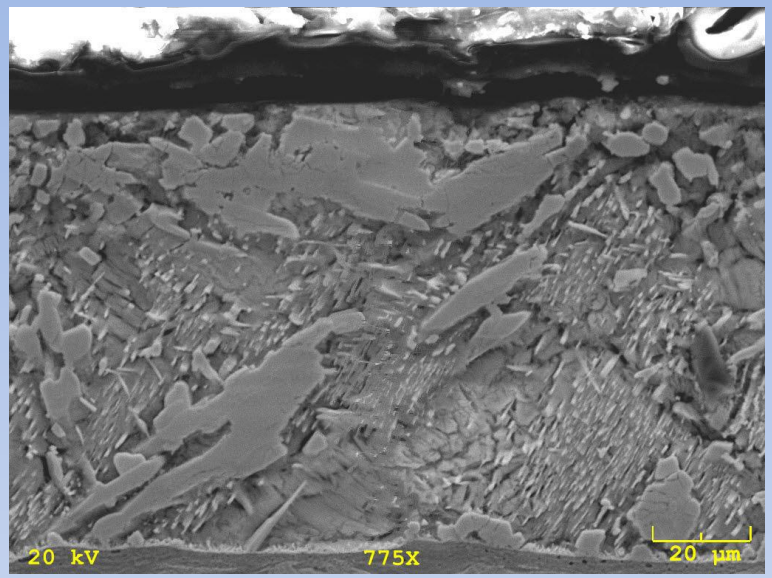


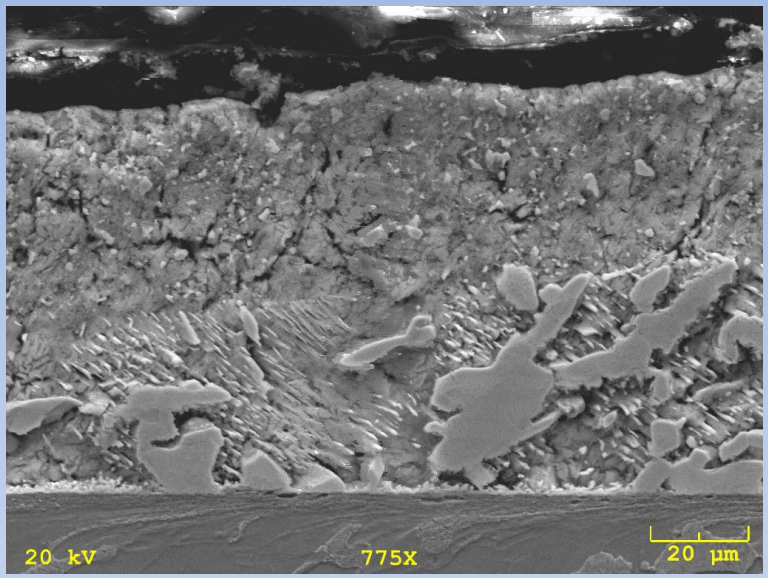
Unit w/ground ring

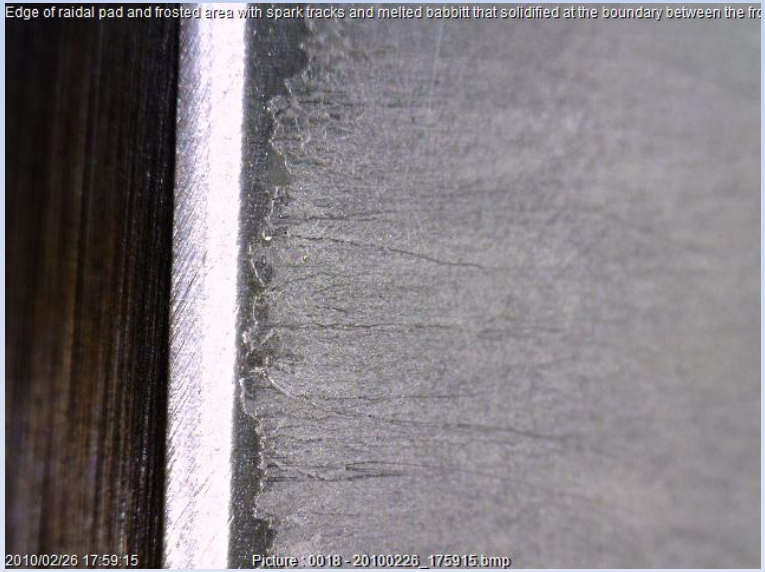


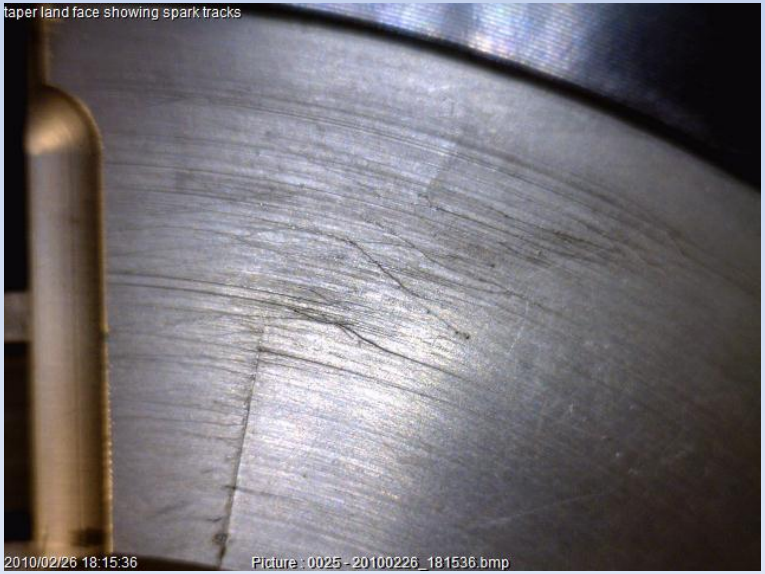
Unit w/o ground ring

Typical Sleeve and Thrust Bearing Damage

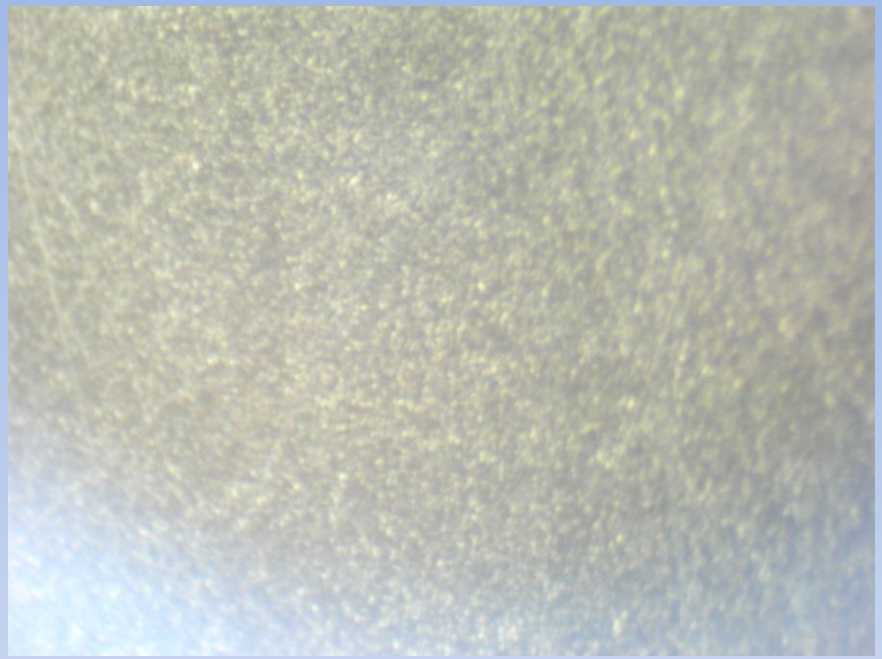






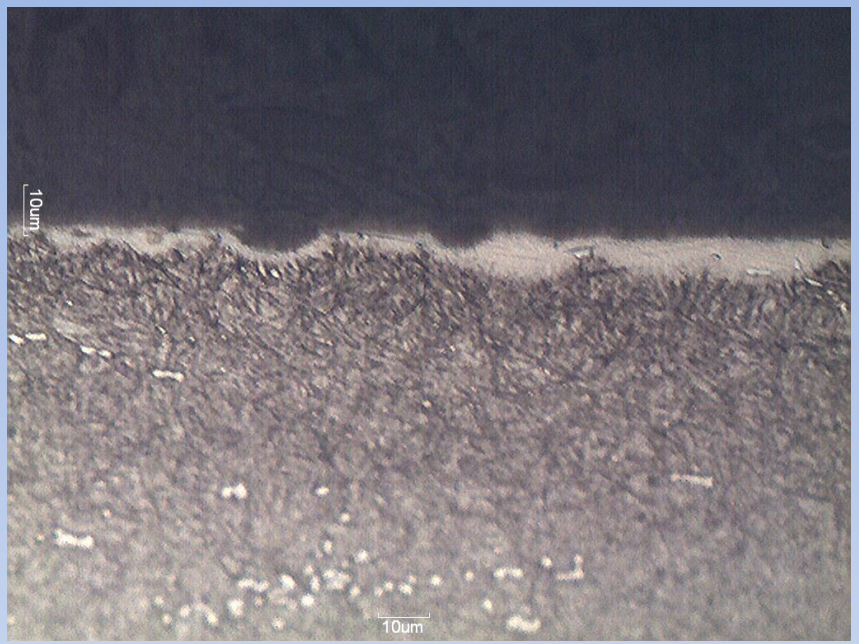


Rolling Element Bearing Damage



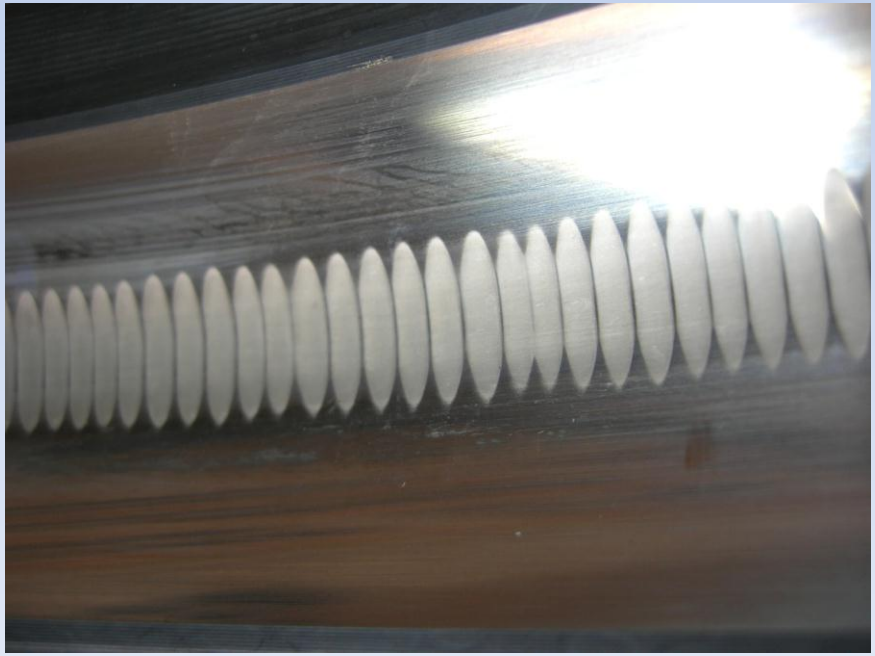
- Micro-cratering – damage surface appears dull, characterized by molten pit marks

Rolling Element Bearing Damage



- Localized heat from current passage creates re-hardened surface layer

- Fluting – resonance vibration pattern from over-rolling smaller micro-craters



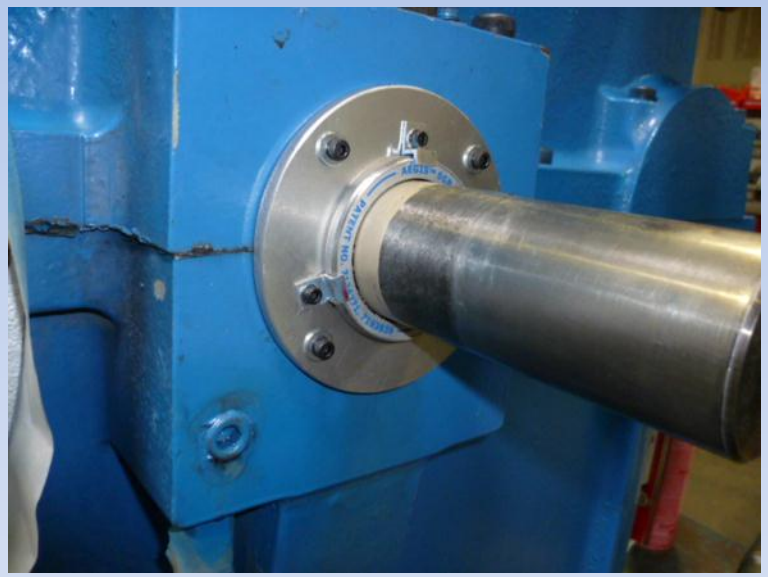
Common Solutions to prevent stray currents on turbo machinery - economics

- Drive motor with insulated rear bearing - $$
- Insulated drive coupling - $$
- Insulated forced feed lube and drains - $
- Grounding straps on drive motor - $
- Bull gear shaft grounding brushes - $
- No welding stickers - $
- Degaussing processes added - $$$
- Material changes to bearings i.e. ceramic or ceramic coatings - $$$
- Oil additives could be used to make the oil more conductive $$

* Actual $ depends on size of compressor frame involved

Common Solutions to prevent stray currents on turbo machinery

Grounding Strap on Motor.



Bull gear Shaft Grounding Brushes.

Common Solutions to prevent stray currents on turbo machinery

Insulated Drive Couplings

Insulated Bearings for Drive Motors

Common Solutions to prevent stray currents on turbo machinery

Place “No Welding” Stickers on Compressor Equipment.

Degaussing Equipment to remove Magnetism in Parts.

Case Study Findings

In this case we found that bull gear shaft stray currents were the major contributor to frosted bearings. However, static charges found at plastics plants showed a slow build up in charge potential followed by an immediate discharge leading us to believe that high speed pinions become electrified and that these charges also contribute to bearing damage.

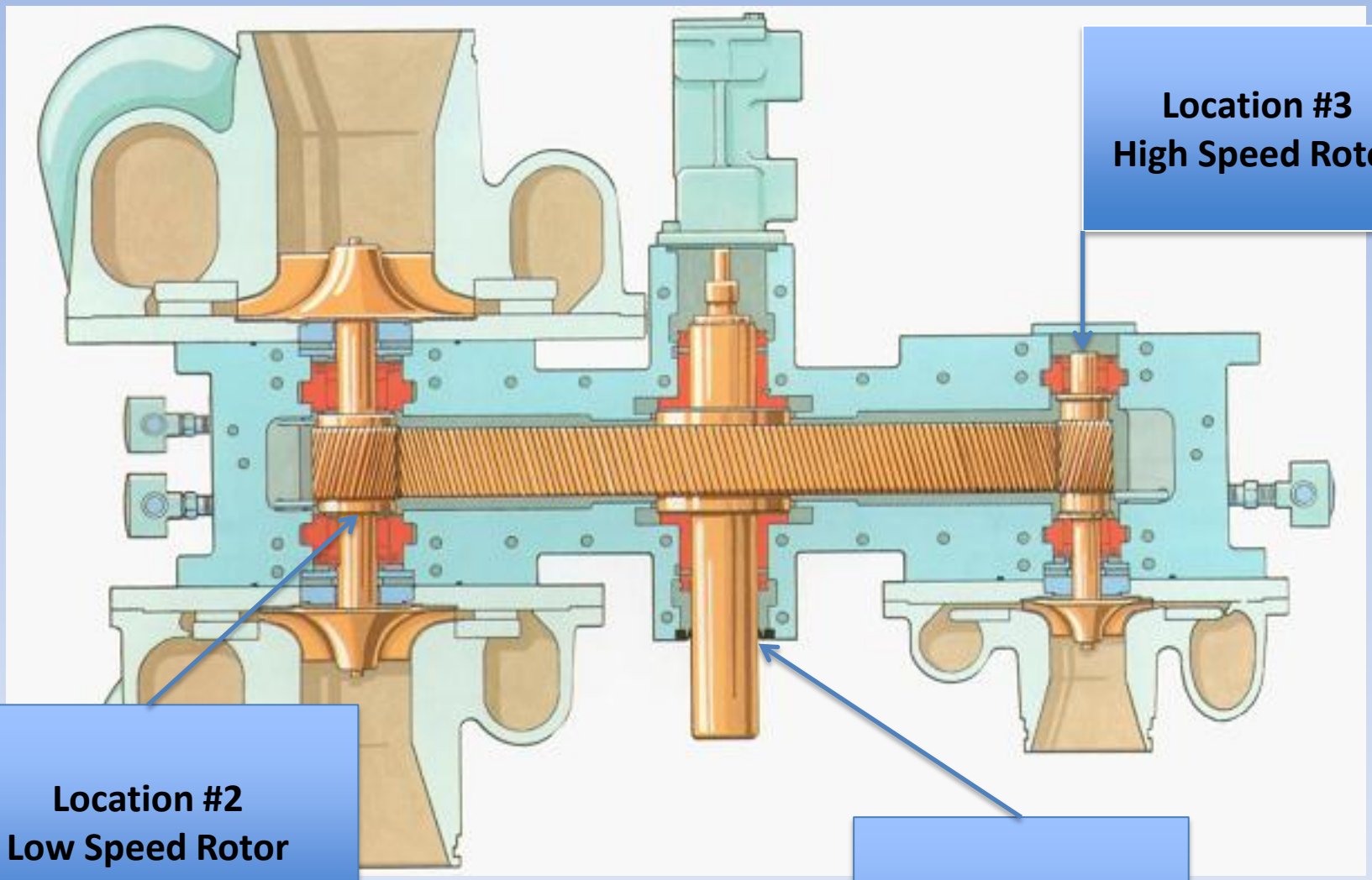
According to (Paschen's Law) electrostatic discharges can occur as low as 380 V.

* - refer to Summary

Summary

- There are multiple ways that stray electrical currents can develop in any given compressor.
  - Trying to stop each path could be very expensive and time consuming.
- There are two possible paths leading to the pinion bearings
  - Motor to bullgear
  - Static charged air to the impeller
- OK Fix – make the oil more conductive
- Good Fix - Although a bull gear shaft grounding system has proven to effectively reduce bearing frosting, air side charges must still cross the bull gear mesh in order to ground out. This could damage the gear teeth over time.
- Ultimate Solution – Direct grounding of both the bull gear shaft and HS pinions on a geared centrifugal.

Direct Pinion Grounding Recommendation



Future Topic – Static Charges in Hydraulic Systems?

- Questions?