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**V**ibration **I**ndustrial **B**alancing & **E**quipment **S**ervices, Corporation

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# Learn About Vibration

## Volume 1: Basic Understanding of Machinery Vibration

Revised as of 2022

This article about industrial vibration technology was produced for technical and mechanical minded people that have not had any training and/or for others that work in the rotating machinery service industry but have not been properly trained. In a simplistic format it helps the reader through the basics and up to the beginning of more advanced stage of vibration analysis. You will learn about the basics of vibration measurements, trending, troubleshooting, fault detection, acceptability, preventative maintenance and the international standards vibration tolerance graph. Machinery photos at the end were taken from various VIBES Corp job sites.

Written by: Garrett Sandwell, MET, CVA, ASNT 3  
CEO

Revised as of 2022



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# Introduction to VIBES Corp®

## Why work with us? Serving Canadian Industry for over 50 Years.

VIBES Corp's reputation was built and established on thousands of promises fulfilled over 50 years in business across Canada. Superior quality service, sales and training courses provided on the intelligent specialist level has been the standard and always will be since our vibration and balancing business was formed in Calgary, AB, in 1982. (Formerly Industrial Balancing Ltd. Est. 1967) In the final real-time analysis VIBES Corp will deliver more value and peace of mind.

## What do we do? Expert technical services and preventative maintenance programs using advanced instruments and tools to solve various vibration, balance and mechanical noise related problems.

Factory trained and repair specialists on HVAC, fans, blowers, cooling towers, pumps, motors, industrial rotors. FlaktWoods Varofoils and Aerofoils, Sheldons Axico, Aerovent, Novenco, New York Blower, Chicago Blower, Canadian/Buffalo Blower, CML Northern Blower, Joy Axivane, Twin City, Alphair, Allied Blower, Markhot Varivane, Loren Cook, BAC, Evapco, Marley, Hoffman, Spencer, Baldor, Reliance, Trane, Carrier, Eng.Air, Haakon, WEG, Leeson, GEC, GE, Emerson, Westinghouse, Toshiba, Siemens, US Electric, Delhi, PennBarry, Armstrong, Westcan, Bell & Gossett, and most types of rotating, diesel engines & reciprocating machinery.

## What do we sell, supply, install & service?

- WEG Electric Motors
- Canada Support - Symphony Industrial AI - Engineered Vibration Solutions & Client Training
- COOLBLUE - Inductive Absorbers & Chokes = VFD any motor shaft current bearing damage protection
- DRIVE SYSTEM PARTS: Fans, Bearings, Sheaves, Couplings, Belts, Shafts, Misc.
- VIBRATION CONTROL, Isolation & thrust spring mounts, monitoring, trending, alarm/trip switch 24/7 machine protection

The machinery under our professional health care program = **VIBES-GUARD PdM Program**® are treated as if our own. We use proven technologies and methodologies along with our multi-technical and electro-mechanical (VIV, ASD, VPM, CPM, VFD, EIBD, EDM, Shaft Currents, etc.) training, skills, and experiences for total overall analysis and evaluations. When the total analyzed facts about a machine, motor or engine are known we formulate an accurate condition report and recommend the best possible solutions. We work with clients to organize necessary actions in order of urgency or budgets.

## Where do we work? (Commercial Towers, Infrastructure Facilities, Industrial Plants, Lumber Processing & Marine Ports, etc.)

Our service area is mainly BC Lower Mainland and Vancouver Island. If requested we can service other areas.

## Who have we worked with?

VIBES Corp service capabilities have been used and accepted by high-ranking officials in:

- |                                |  |                              |                                |
|--------------------------------|--|------------------------------|--------------------------------|
| • other service companies      | • power plants and dams                | • commercial towers          | • saw mills                    |
| • manufacturing and processing | • sewage and water treatment plants    | • agricultural               | • pulp and paper               |
| • engineering firms            | • government infrastructure facilities | • mining                     | • research and development     |
| • universities                 | • oil and gas                          | • ski hills                  | • machining / fabrication      |
| • colleges                     | • biogas energy systems                | • marine-terminals and ships | • chemical plants              |
| • hospitals                    | • transportation and construction      | • asphalt and cement         | • restaurants                  |
| • cold storage                 |  |                              | • skytrain and railway tunnels |



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**We take due diligence to the highest level on all projects regardless of size or budget.**

## Learn About Articles

You can download educational articles from our home page at [www.vibescorp.ca](http://www.vibescorp.ca). Here are five:

1. Learn About Vibration Volume 1: Basic Understanding Of Machinery Vibration
2. Learn About Vibration Volume 2: Advanced Vibration Analysis
3. Learn About Electrically Induced Bearing Damage & Shaft Currents
4. Failure Prevention Of Variable Pitch in Motion Axial Fans and Controllable Pitch In Motion Axial Fans
5. Learn About Agricultural Machinery Vibration Solutions

The photos below show typical projects that we have completed.

Fig 1. The failure was due to defective bearing.

Fig 2. The stainless steel guard helps prevent moisture contamination in cooling tower fan bearings (a very common problem).

Fig 3. A new fan was installed due to a complete failure of the original.

Fig 4. Shows a 200HP motor and fan repair/replacement.



Fig. 1

**Solution to Fig. 1** Replaced both Fan Bearings & New Motor Required.

**Solution to Fig. 2** The Guard has prolonged the Life Span of the Fan Bearings from 3 years to over 14 years.



Fig. 2



Fig. 3

**Solution to Fig. 3** Installed Brand New Controllable Pitch Fan & Repaired Motor.

**Solution to Fig. 4** Replaced the Old Motor based on 20 years of running time and Completed Variable Pitch in Motion Fan Maintenance.



Fig. 4



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# Basic Understanding of Machinery Vibration

*For: Plant and Building Maintenance Operations. Revised as of 2022.*

*Article by: Garrett Sandwell, MET, CVA, ASNT 3, CEO VIBES Corp.*

This is an article regarding vibration analysis, monitoring theory, application and the benefits it offers to facilities and power plant engineers, operators, managers, and maintenance technicians.

## Common terminology used for machinery vibration

VELOCITY = Velocity of vibration is measured in peak units such as inches per second (ips) or millimetres per second (mm/s). Another way of looking at velocity is distance per time or how much is the machine moving every second in three important directions at all main bearing points (AXIAL, VERTICAL, HORIZONTAL). Velocity measurements and monitoring of vibration is the most common unit to identify various problems or acceptability such as: unbalance, misalignment, looseness (machinery structural, foundations, or bearings), harmonics, and many other issues in the machinery frequency range and many multiples of actual speed.

Velocity measurements (if using a single axis sensor/probe and hand-held meter) are recorded in three directions: axial, horizontal and vertical at all main bearing blocks or motor frame end bells [see pages 10 – 11].

The convenient thing about vibration velocity is that it is not related to speed. Advanced computers with tri-axial sensors can measure in all three planes from one location.

Overall or Broadband Vibration Severity using Velocity is applicable to all types of general rotating equipment (ISO/ANSI/API) operating at full load or speed condition. (Exceptions = Diesel Engines & Rock Crushers.)

ULTRA LEVELS = .05 ips / 1.3 mm/s or less at any speed. No action required.

EXCELLENT LEVELS = .1 ips / 2.5 mm/s or less at any speed. No action required.

GOOD LEVELS = .2 ips / 5.0 mm/s or less at any speed. No action required.

FAIR LEVELS = .3 ips / 7.5 mm/s or less at any speed. No action required, unless manufacturer's specifications state otherwise, and/or there has been a history of problems on a specific machine (Numerous repairs). The velocity .3 ips / 7.5 mm/s is typically the maximum BORDERLINE tolerance level in any direction Radial, Tangential or Axial. In many circumstances it may be too costly or not practical to try and reduce vibration velocity below .3 ips / 7.5 mm/s in all sensor directions due to a variety of issues with: Structural or Support Base Weaknesses, System Turbulence, Belt Tension Sensitivities, Poor or Grounding Isolation, Poor/Wrong/Worn Drives, Difficult to Balance Down Further, Very Hot Applications, Warped Parts, etc.etc.

ROUGH LEVELS = .4 ips / 10 mm/s or higher at any speed. (Take action soon.)

VERY ROUGH LEVELS = .6 ips / 15 mm/s or higher at any speed. (Take action now.)

DANGER LEVELS = .8 ips / 20 mm/s or higher at any speed. (Shutdown and Fix.)



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The relationship of the above vibration velocity levels is found on the Vibration Severity Graph [see page 13]. It is important to understand that vibration can be smooth in one or more directions but very rough in another so record velocity in three directions at each bearing location and preferably within a few hours of start up.

**ACCELERATION** = Acceleration data is very important for detection of faults with bearings, gear mesh or electrical issues. Acceleration is measured in units of G. Simplified = inches per second/second (ips/s) or millimetres per second/second (mm/s/s). Acceleration is very important bearing and gear fault data in the high frequency ranges. Acceleration is also a sudden change in velocity. Acceleration data are relevant in the rotational axis only. Some vibration meters have earphone output to allow the analyst to listen to the noise inside bearings while recording G. Listening to bearings using earphones such as an electronic stethoscope is very useful for defect identification. Ultra Sound Analysers can also be used for various tests.

Typical acceleration data related to all types of bearings in general rotating equipment. (Exceptions = Diesel Engines & Rock Crushers.)

**EXCELLENT LEVELS** = Usually .10 G or Less. No action required.

**GOOD LEVELS** = Usually .35 G or Less. No action required unless noisy.

**FAIR LEVELS** = Usually .50 G or Less. No action required unless noisy.

(If you have no records consider vibration spectrum analysis for all levels below.)

**ROUGH LEVELS** = Usually .75 G or More. Possible action required if noisy. Also check bearing temperatures.

**VERY ROUGH LEVELS** = Usually 1.0 G or More. Further analysis required. Also check bearing noise and temperatures.

**DANGER LEVELS** = Usually 1.5 G or More. Problem likely. Further analyze and check bearing noise and temperatures.

**BREAKDOWN LEVELS** = Usually 2.5 G or More. Shutdown and fix now! Dangerous!

Note: Actual G = 32ft/sec/sec. = 9.8 m/s/s. Vibration equipment converts these values.

As mentioned if unusual noise is present either audible or using electronic stethoscope the acceleration G levels are secondary. This means there could be an early warning of a bearing defect at .1 G level. Turn off machine and carefully listen to all bearings during coast down. If motor bearings are noisy, repeat this test with belts removed or coupling disconnected. Run motor to full speed then turn off and listen. While motor is locked off, and drive (belts or coupling is disconnected) check the rotor shaft for looseness by applying pressure in the vertical or axial directions to assess excessive play. Turn shaft by hand a few rotations and listen carefully for unusual noises in the bearings.

**DISPLACEMENT** = Displacement is measured in peak to peak units of mils (1 mil = .001") or mm (1 mm = .0025"). Displacement measurements are recorded in the same three directions as velocity = axial, horizontal and vertical. Displacement is not used or recommended for recording or monitoring because severity or acceptability is speed dependent. Displacement is also used to identify problems in the lower frequency ranges. Displacement can be used for measuring reference values = walls, floors, beams, pads, frames = very slow moving or stationary objects. A tapered aluminum probe can be used to measure shaft axial motions. A Fish Tail™ Shaft Stick can be used to measure bends or misalignment with the machine running.



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For example 1 mil at 1800 rpm = Excellent. But 1 mil at 30,000 rpm is Dangerous. Typically, rotor dynamic balancing tolerances are often specified in displacement (mils) because it has been an industry standard for 60 years or more. Other balance tolerances are gram/centimetres or tolerance grade tables. Typically, displacement is used in field and shop balancing procedures. For further information about balance tolerances/grades see: The practical application of ISO 1940/1.

**FREQUENCY** = Frequency is measured in units of cpm, Hz, Orders, i.e. 50 cpm – 750,000 cpm. Knowing the frequency of vibration peaks helps to pinpoint the potential sources. Frequency is used in advanced vibration analysis to identify all types of bearing fault frequencies, real time spectrums, and motor current signature analysis, etc.

**PHASE** = Phase is the angle of vibration issue. Phase is used to dynamic balance and identifies resonance (critical speed) problems. Phase is not used in everyday vibration measurements or monitoring. Phase of vibration is recorded using a stroboscope or infrared tachometer in conjunction with a vibration analyzer instrument. New technology and software is being used to add phase analysis to the final evaluation and diagnostics.

## **Most common causes for bearing deterioration or complete machinery breakdowns - based on 40 years of experience**

- 1) Improper installation. Bearings must be properly installed and aligned in three directions using machinist levels and other precision tools to maximize the lifespan and control vibrations. In electric motors the bell housing and shaft fit is critical. Bearings must be locked correctly to the shaft (concentric lock collars or locking adaptor nuts/rings). Shafts must also be within tolerances (not under or oversized) and no damage where the bearing is located. New bearings should never be installed into old/worn blocks. Always replace the entire kit. **There is an industry saying = .0005" / .0125 mm under size can kill the bearing lifespan. In motor applications both bearing inner races must be heated to exactly 110C to expand and then shrink fit to shaft journal for perfect hold.** Make sure to clean the motor shaft bearing journals or shoulders of any burrs with a fine file and use emery cloth to smooth surface of all roughness before installation of the heated bearing.
- 2) Misalignment of drives. Accurate alignment is very important to reduce vibration and prolong good condition **of various parts. Check coupling manufacturer's specifications and comply using** double dial gauges or laser alignment. Remove belt guards during belt tensioning and check with level, straight edge or laser to insure pulleys are within tolerances at all times.
- 3) Belts too tight and/or too loose. Proper tension should be maintained at all times. Defective belts should be replaced as soon as possible. Retrofit to better drive system if necessary. Check for serious wear inside pulley grooves. Belt issues have been found to be a source of resonance.
- 4) Improper lubrication. Too much or not enough grease. Most good quality grease EP 1.5 – EP 2 on the market are acceptable but synthetics are the best. Lubrication charts are available for machines from the manufacturer. If mixing greases, lab test for compatibility. NOTE: On heavy duty machinery such as large HP hammermills or rock crushers you should contact the manufacturers for best grease to use.
- 5) Unbalance of the rotor. As this problem should be obvious it is usually resolved at start up. If vibration occurs suddenly on a machine, check for wear, debris build up, broken or cracked parts on the rotor. Unbalance



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in a variable speed machine usually shows up as a gradual increase in vibration as speed increases and highest at full speed. VIBES Corp specializes in rotating parts dynamic balancing.

6) Bad vibration for a long time. Sometimes rough vibrations may be overlooked because the machine has always run that way i.e. harmonics, beats, resonance, transient vibration, flexing supports, aerodynamic turbulence, pump cavitation, misc. In axial fans check for "Stall" or on pumps check for cavitations. Axial fan "Stall" is due to increased resistance on the inlet or outlet and can be caused from damper problems, dirty filters or coils, fan blade modulation defects and other system issues. Note: Axial fan "stall" will always cause loud noise. "Surge" is the same as "Stall" only it refers to centrifugal fans. During "Fan Surge" usually near or at full speed there may be an issue with dampers not opening or plugged filters on the inlet or plugged outlet screens. That resistance can cause "Surge" and you may notice extreme axial vibrations or erratic bouncing of the inertia pad.

7) Motor is operating beyond the full load amperage caused by over speed on the driven. Check the pulley ratios, use amp probe, tachometer or stroboscope to confirm driven speed is an issue or to confirm the machine is operating within or beyond design specifications.

8) Poor or no isolation. Check springs for grounding, too much deflection, or wrong selection. Axial vibrations on fans often can be reduced with thrust springs. Pump or piping vibration transmissions can be reduced with isolation expansion joints, flexible hose or spring hangers.

9) Bearing lubrication contamination. Driven machinery bearings that are in harsh environments such as vertical shaft cooling towers, weather exposed, gaseous/moisture mix, or very dirty areas can become contaminated if not protected by special seals, cooling discs, or shaft assembly guards. Careful not to over grease motors. Motors should also be protected with silicone around bell faces and wire boxes if exposed to high moisture areas. Alternatively consider motors with sealed bearings.

10) Poor or wrong bearing selection. Sometimes when bearings are replaced the new bearings are not the same load rated as the original. Bearings should always be the same rating as the original and if consistently failing consider upgrading to higher dynamic load rated bearings. Large HP motors on belt drives should have roller bearings in the drive end and fixed ball bearing in the opposite end.

11) Electrically Induced Bearing Damage (EIBD) aka Shaft Currents, aka Electrical Discharge Machining (EDM). Motors that are operating on 460V & 575V with VFD can often develop this problem which is caused by voltage build up in the rotor and the milliamps discharge (micro-arcing) through the bearings back to the stator. The result is LOUD bearing noises from pitting, glazing, fluting, micro-cracks and craters of the rolling elements and raceways along with burned/contaminated grease. There're various solutions to avoid or combat EIBD problems depending on the circumstances and budget such as:

- a) Sealed DE/ODE motor bearings packed with electroconductive grease (Kluber BE-44-152)
- b) Rotor grounding seal/ring (AEGIS / InproSeal)
- c) Sine wave filter (MIRUS INTERNATIONAL)
- d) Ceramic sleeves (SKF, FAG)
- e) Insulated bearings (SKF, FAG)
- f) Load side VFD electrical inductive absorbers (CoolBlue™)
- g) Magnetic Adjustable Speed Drives ASD (FLUXDRIVE)



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A more detailed article has been written and is available on our website: see [Learn About Shaft Currents / EIBD](#) at [www.vibescorp.ca](http://www.vibescorp.ca). Also see vibration acceleration spectrum showing serious EIBD issue on page 19.

12) Resonance is when the rotating speed and natural frequency are near or exactly the same. You'll notice a sudden and significant vibration increase at resonance. When converting a constant speed machine to variable frequency drive (VFD) or adjustable speed drive (ASD) you should run the machine up slowly to identify any resonance throughout the speed range. If you notice resonance you can try these four steps to control or eliminate it as follows:

- a) On VFD or ASD program the electronic signals to avoid that speed/frequency. Resonance can be present through a 1 Hz change in speed range usually above 45 Hz.
- b) Add parts to stiffen the machine. More tests required.
- c) Add mass to the machine. More tests required.
- d) Change the driven speed ratio by -10% -15% if it's a constant speed machine.

13) Soft Foot - Soft foot has been found to cause major increases in vibration usually on the motor. This problem should have been identified and corrected during alignment. To find soft foot problems try these two steps:

- a) Using (LIVE) display on your laser alignment instrument (soft foot) feature or on your vibration analyzer (Live) display loosen one motor foot at a time and observe changes. Tighten each foot bolt/nut before undoing the next one and so on.
- b) Same test as above but using a dial gauge to record all four foot data (while machine is on/off).

Fact = Soft foot was found on a motor to change vibration overall from rough to good levels with a minor lift of only +.002".

Soft foot can also be the source of high vibration spike at electrical frequency or 7200 CPM but much lower peak at 1x RPM. The reason is stress on the stator frame when there is uneven contact at all four motor feet.

The above a) and b) tests will confirm if it's soft foot.

Important: Vibration data should be recorded at the same spot sensor direction and location when the machine or motor is operating at the same load/speed each time or the trending may become useless or confusing. If full speed is not possible record at the same lower speed each time.

Typically 80% speed or fan blade angles are satisfactory for vibration monitoring and trending (100% speed or maximum load condition is best for monitoring and evaluation).

## **Vibration spectrum analysis – advanced software and data collection**

It is very important to have a record of the machine vibration baseline history after a few hours running time on the date of start up. Examples of several motor vibration spectrum using velocity, displacement, acceleration versus frequency are included [see pages 16 – 19]. The original motor peaks are shown for one location before



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with defects and after defects were resolved on several visits. The data is referred to as Waterfall Spectrum Plots. A software program such as Azima DLI ExpertAlert™ can identify many faults. After several sets of data (5 sets) are available the Waterfall reports become very accurate for trending, PM planning and failure prevention. In the machinery baseline vibration spectra we have everything we need to know about that equipment in the database history. As mentioned when several sets of data are recorded the ExpertAlert™ engineered software produces accurate detailed diagnostic reports that are rule based. The EA software screens for specific fault frequencies on 9500 bearings for all types of machines or engines and compares the recorded data to good data. See another more detailed article on our website: [Learn About Vibration, Volume 2: Advanced Vibration Analysis](#) at [www.vibescorp.ca](http://www.vibescorp.ca). You can also contact Azima DLI for product information. Note: Vibration articles and training materials are constantly changing so search for updates at various sites.

## Q&A

Q1) How often should I have vibration monitoring or analysis done on my machines?

A1) HVAC equipment should be checked once or twice per year. Industrial machinery should be checked more often. Some important machines are monitored 24/7. Example: gas plants, power plants, wind turbines, etc.

Q2) How much does vibration monitoring or analysis cost?

A2) VIBES Corp would be pleased to quote vibration analysis, PdM monitoring program, dynamic balancing and alignment projects at any time. Equipment can be (basic) monitored and inspected for as low as \$250-\$350 per machine or less. It always costs less based on volume per site. Complex machinery monitoring or analysis costs will be higher. Costs vary depending on Basic, Advanced, Inspection Requirements, Number of Machines at one location, Number of visits/year, and location of job sites. VIBES Corp will be pleased to assist with all your vibration, balancing and alignment requirements.

Q3) Should I consider mounting a permanent vibration switch or transmitter on my critical machines, engines or motors?

A3) Yes. As equipment gets older the chance of a sudden vibration-related breakdown increases. Vibration switches and transmitters are (4-20ma) low cost and gives you 24/7 protection, measuring, trending, alarm, trip settings, time delays and can operate via WIFI or installation of vibration transmitters from critical machines to control room panel meters up to 1000 ft away. Computer can be programmed to alarm if maximum pre-set limits are exceeded to alert you right away. Another lowest cost alternative is a simple motor shutdown switch such as a MURPHY vibration shock/shutdown switch.

## Don't wait for a machine or motor to fail!

Consider VIBES-GUARD PdM Program<sup>®</sup> for all your critical machines on a regular schedule and start saving unnecessary breakdowns and costs in the future. We can also supply vibration protection products and monitoring systems.

If you have other questions pertaining to any particular machinery vibration or noise issues, or require VIBES Corp services or free presentations, please email [info@vibescorp.ca](mailto:info@vibescorp.ca) (preferred) or call at any time: 604-619-9381 (24/7).



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**SERIOUS SERVICE®**  
Professional Machinery Health Care  
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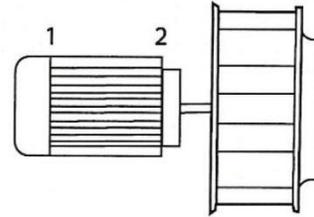
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**VIBRATION DIRECTION**

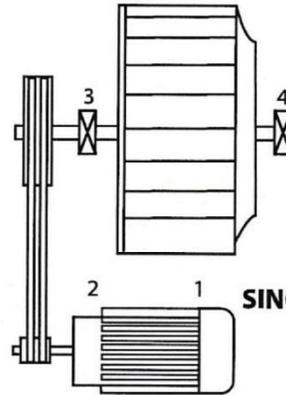
Vibrations in machinery can be measured in radial, axial, and tangential directions. The intent is to detect the direction of the largest signal. Generally, the strongest signals are in the Radial direction. Machine mountings can affect vibration readings. A machine mounted on isolators such as spring isolators may have strong vertical vibration signals. Bent shafts and loose bearings can sometimes cause large axial vibration signals. Therefore it is best to take vibration readings in all three directions when possible.

**MEASUREMENT POINTS**

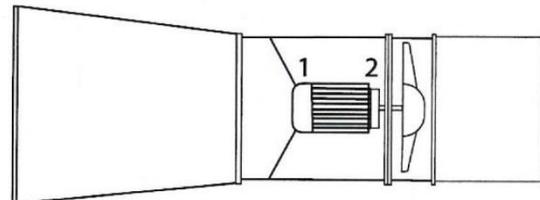
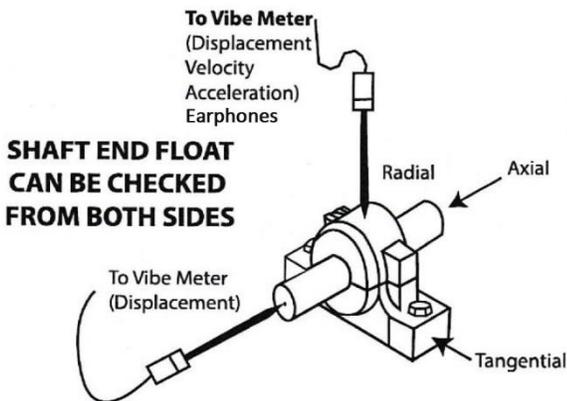
The following diagrams provide suggested vibration monitoring points. Generally, it is best to take readings on, or as close as possible to the bearings of the rotating machinery being tested. Vibration signals are strongest around bearings and tend to get weaker farther away from the bearings. Caution must be taken when working around rotating machinery, belts, pulleys and shafts.



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**SINGLE INLET CENTRIFUGAL FAN**



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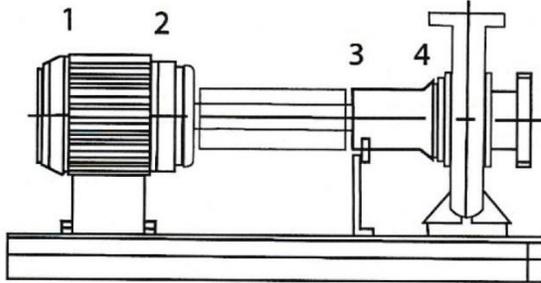
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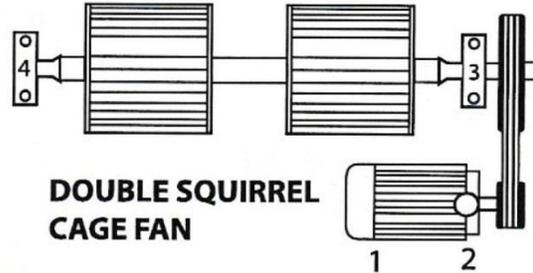
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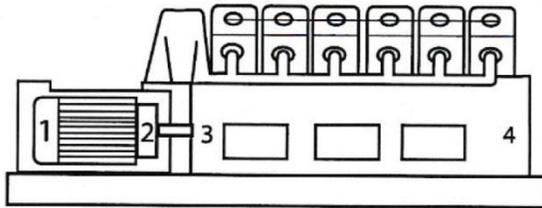
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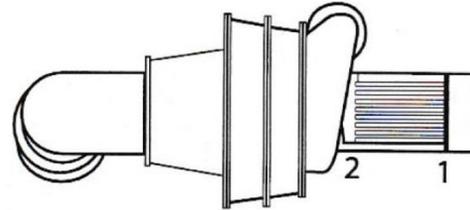
**DIRECT DRIVEN PUMP**



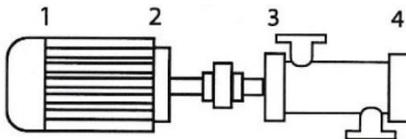
**DOUBLE SQUIRREL CAGE FAN**



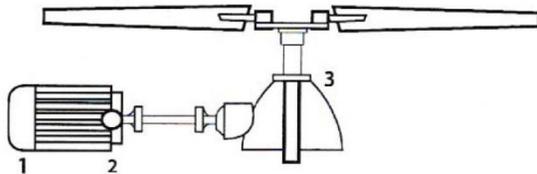
**DIESEL ENGINE / GENERATOR**



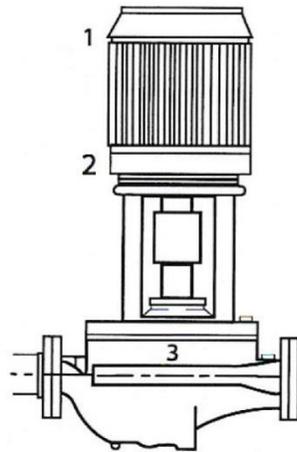
**CENTRIFUGAL CHILLER**



**DIRECT DRIVEN COMPRESSOR**



**MOTOR - DRIVE - SHAFT - GEARBOX  
INDUCED DRAFT - COOLING TOWER**



**DIRECT DRIVEN  
INLINE PUMP**



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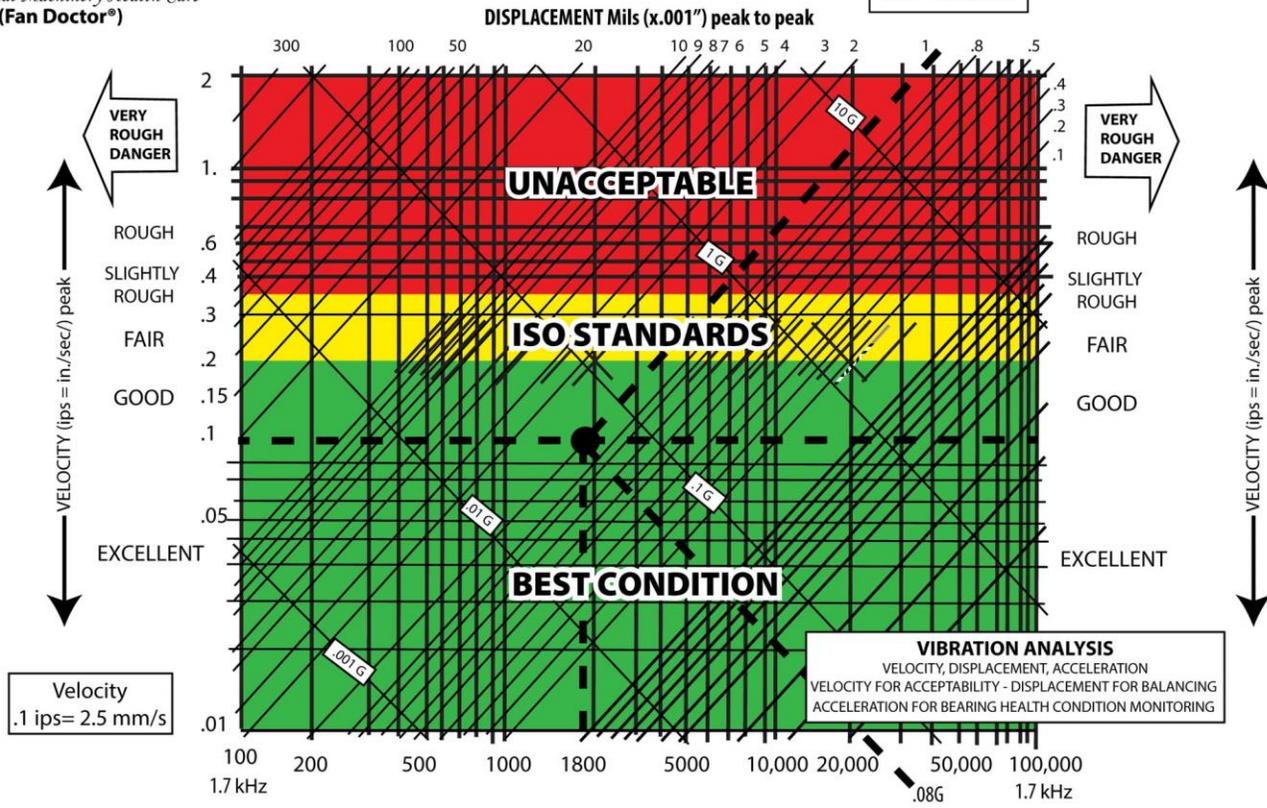
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**VIBRATION SEVERITY GRAPH FOR GENERAL ROTATING MACHINERY**

This Chart is based on ISO 10816-3



Displacement  
1 mil = 25 microns



**REFERENCE POINT ●** = 1800 rpm machine/ motor excellent condition

ACCELERATION or FORCE OF GRAVITY "G" (ips<sup>2</sup> = in./sec<sup>2</sup> for simplicity)  
ACTUAL G = 32 fps/s = 9.8 m/s/s

Note: the yellow area on chart represents issues that often can't be resolved due to time and cost.



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## Vibration Sources Identification Guide

CAUSE	FREQUENCY	AMPLITUDE	PHASE	COMMENTS
Unbalance	1 x RPM	Highest in Radial Direction- Proportional to Unbalance	Single Mark (Steady)	A common cause of vibration.
Defective Anti-Friction Bearings	Very High- Often From 10 to 100 x RPM	Use Velocity	Unstable	Velocity readings are highest at defective bearing. As failure approaches, the amplitude of the velocity signal will increase and its frequency will decrease. Cage frequency is approximately 0.6 x RPM x number elements.
Misalignment of Coupling or Bearing	1, 2 or 3 x RPM	High Axial Axial 50% or more of Radial	Often 2, Sometimes 1 or 3	Use phase analysis to determine relative movement of machine or bearings. Use a dial indicator if possible. Often diagnosed as a bent shaft. Can be caused by misalignment of V belts.
Sleeve Bearing	1 x RPM	Not Large Use Displacement Mode Up to 6000 CPM	Single Reference Mark	May appear to be unbalanced. Shaft and bearing amplitude should be taken. If shaft vibration is larger than the bearing, vibration amplitude indicates clearance.
Bent Shaft	1 or 2 x RPM	High Axial	1 or 2	Similar to misalignment. Use phase analysis.
Defective Gears	High No. Gear Teeth x RPM	Radial	Unsteady	Use velocity measurement. Often affected by misalignment. Generally accompanied by side band frequency. Pitting, scuffing and fractures are often caused by torsional vibrations. Frequency sometimes as high as 1 million CPM or more.
Mechanical Looseness	2 x RPM Sometimes 1 x RPM	Proportional to Looseness	1 or 2	Check movement of mounting bolts in relation to the machine base. Difference between base and machine indicates amount of looseness.
Defective Drive Belts	1 or 2 x Belt Speed	Erratic	Use Strobe to Freeze Belt in OSC Mode	Calculate the belt RPM using: $\text{Belt RPM} = \frac{\text{Pulley Diameter} \times 3.141}{\text{Belt Length}} \times \text{Pulley RPM}$ Look for cracks, hard spots, soft spots or lumps. Loose belt. Changes with belt tension.
Electrical	1 or 2 x Line Frequency (3600 or 7200 CPM for 60Hz Power) May appear at 1 x RPM	Usually Low	1 or 2 Marks Sometimes Slipping	Looks like mechanical unbalance until power is removed. Then drops dramatically.
Oil Whip	45 - 55% RPM	Radial Unsteady	Unstable	Caused by excessive clearance in sleeve bearings or by underloaded bearings. Will change with viscosity of oil (temperature).
Hydraulic- Aerodynamic	No. Blades or Vanes x RPM	Erratic	Unsteady	May excite resonance problems.
Beat Frequency	Near 1 x RPM	Variable at Beat Rate	Rotates at Beat Frequency	Caused by two machines, mounted on same base, running at close to same RPM.
Resonance	Specific Critical Speeds	High	Single Reference Mark	Phase will shift 180° going through resonance (90° at resonance). Amplitude will peak at resonance. Resonance in frame can be removed by changing rotor operating speed or by changing the stiffness of the structure.

There are several additional detailed articles that identify more complicated vibration sources at [www.vibescorp.ca](http://www.vibescorp.ca) titled:

- 1) LEARN ABOUT VIBRATION VOLUME 1: BASIC UNDERSTANDING OF MACHINERY VIBRATION
- 2) LEARN ABOUT VIBRATION VOLUME 2: ADVANCED VIBRATION ANALYSIS
- 3) LEARN ABOUT ELECTRICALLY INDUCED BEARING DAMAGE & SHAFT CURRENTS
- 4) FAILURE PREVENTION OF VARIABLE AND CONTROLLABLE PITCH IN MOTION AXIAL FANS



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# SAMPLE

## 250 HP NYB DUST FAN

MID: 292  
Report generated on: 9/14/2017 03:22 PM  
Acquired: 9/14/2017 03:22 PM 1xM = 1787 RPM 1xF = 1782 RPM

Maximum level: 0.32 in/s at 1.00x on 2T

### RECOMMENDATIONS:

MONITOR AND LOG FAN BEARING TEMPERATURES WITH IR OR LASER TOOL DAILY.  
REPEAT FAN SERVICE AND VIBRATION TEST EVERY SIX MONTHS.  
LUBRICATE FAN BEARINGS = 3 shots each per month.  
LUBRICATE MOTOR BEARINGS = 2 shots per month.  
TIGHTEN BELTS WHEN SLIPPING IS EXCESSIVE AT START UP OR WHILE RUNNING.

### DIAGNOSTICS:

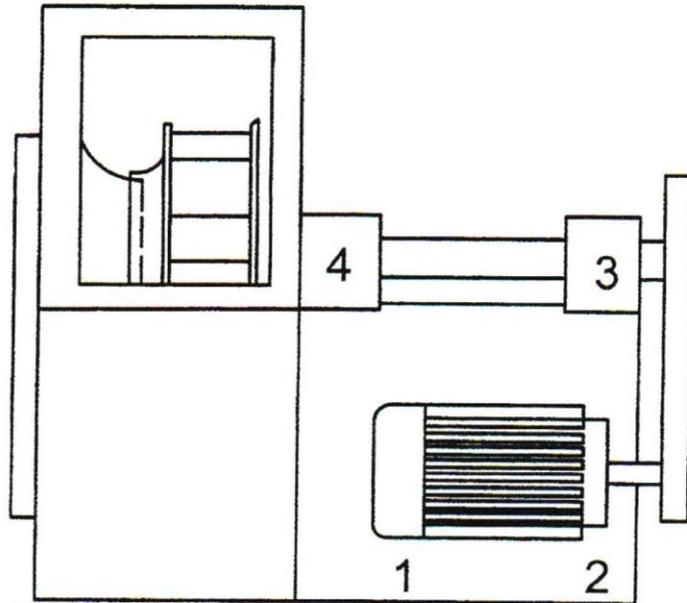
NO FAULTS HAVE BEEN DETECTED IN THE VIBRATION DATA

#### POSITION LEGEND:

- POSITION 1 IS: MOTOR ODE
- POSITION 2 IS: MOTOR DE
- POSITION 3 IS: FAN DE
- POSITION 4 IS: FAN ODE

### OVERALL LEVEL READINGS

OK: 0.18 in/s at 1A Alarm level: 0.40 in/s  
OK: 0.16 in/s at 1R Alarm level: 0.40 in/s  
OK: 0.16 in/s at 1T Alarm level: 0.40 in/s  
OK: 0.21 in/s at 2A Alarm level: 0.40 in/s  
OK: 0.21 in/s at 2R Alarm level: 0.40 in/s  
OK: 0.27 in/s at 2T Alarm level: 0.40 in/s  
OK: 0.31 in/s at 3A Alarm level: 0.40 in/s  
OK: 0.21 in/s at 3R Alarm level: 0.40 in/s  
OK: 0.20 in/s at 3T Alarm level: 0.40 in/s  
OK: 0.23 in/s at 4A Alarm level: 0.40 in/s  
OK: 0.12 in/s at 4R Alarm level: 0.40 in/s  
OK: 0.23 in/s at 4T Alarm level: 0.40 in/s



Vibration data recorded using AzimaDLI DCX RT - Software ExpertAlert 3.10 (2013-2016)



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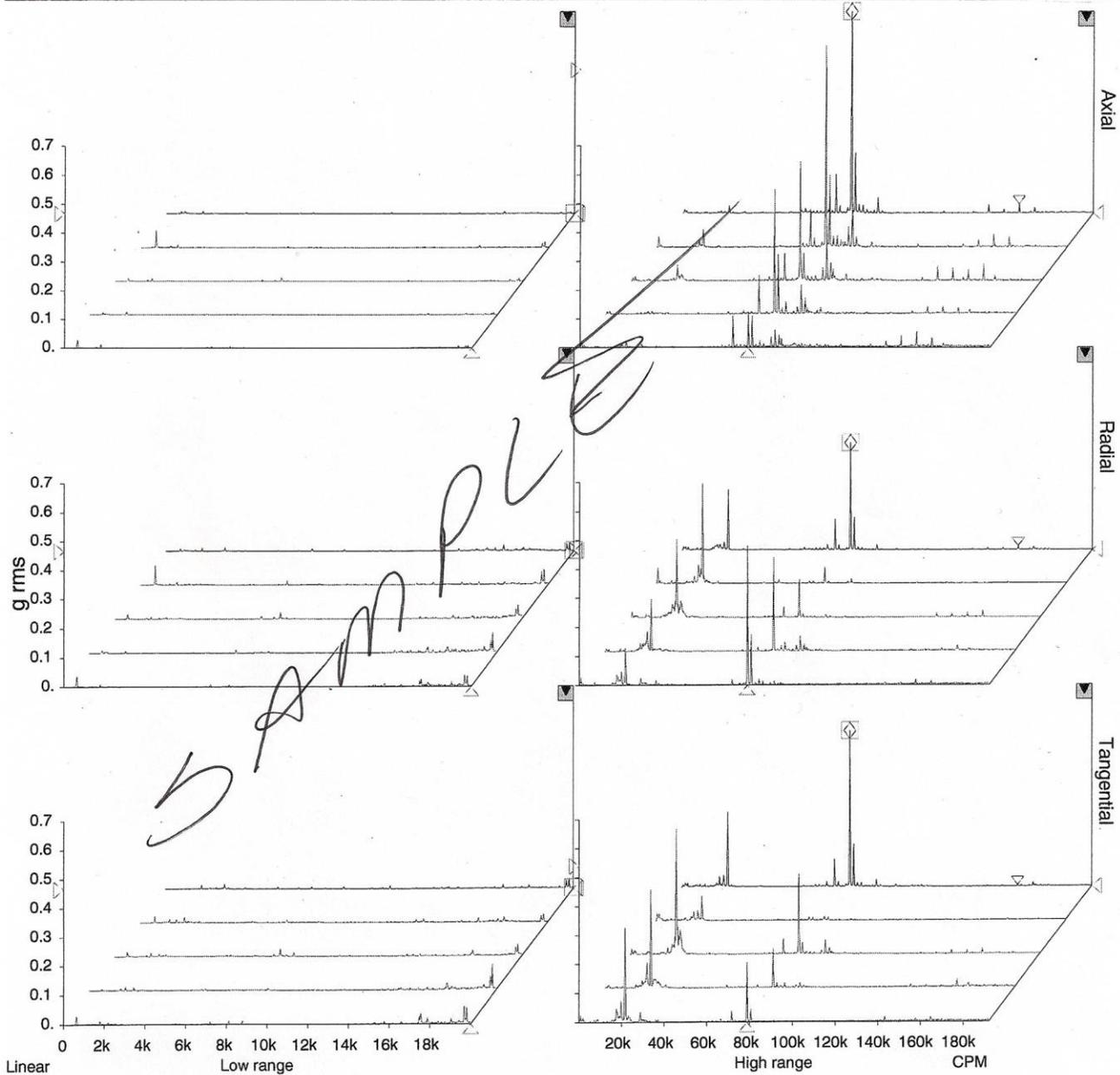
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# VIBRATION SPECTRUM DATA

## 60 HP 1800 RPM MOTOR (ACCELERATION)



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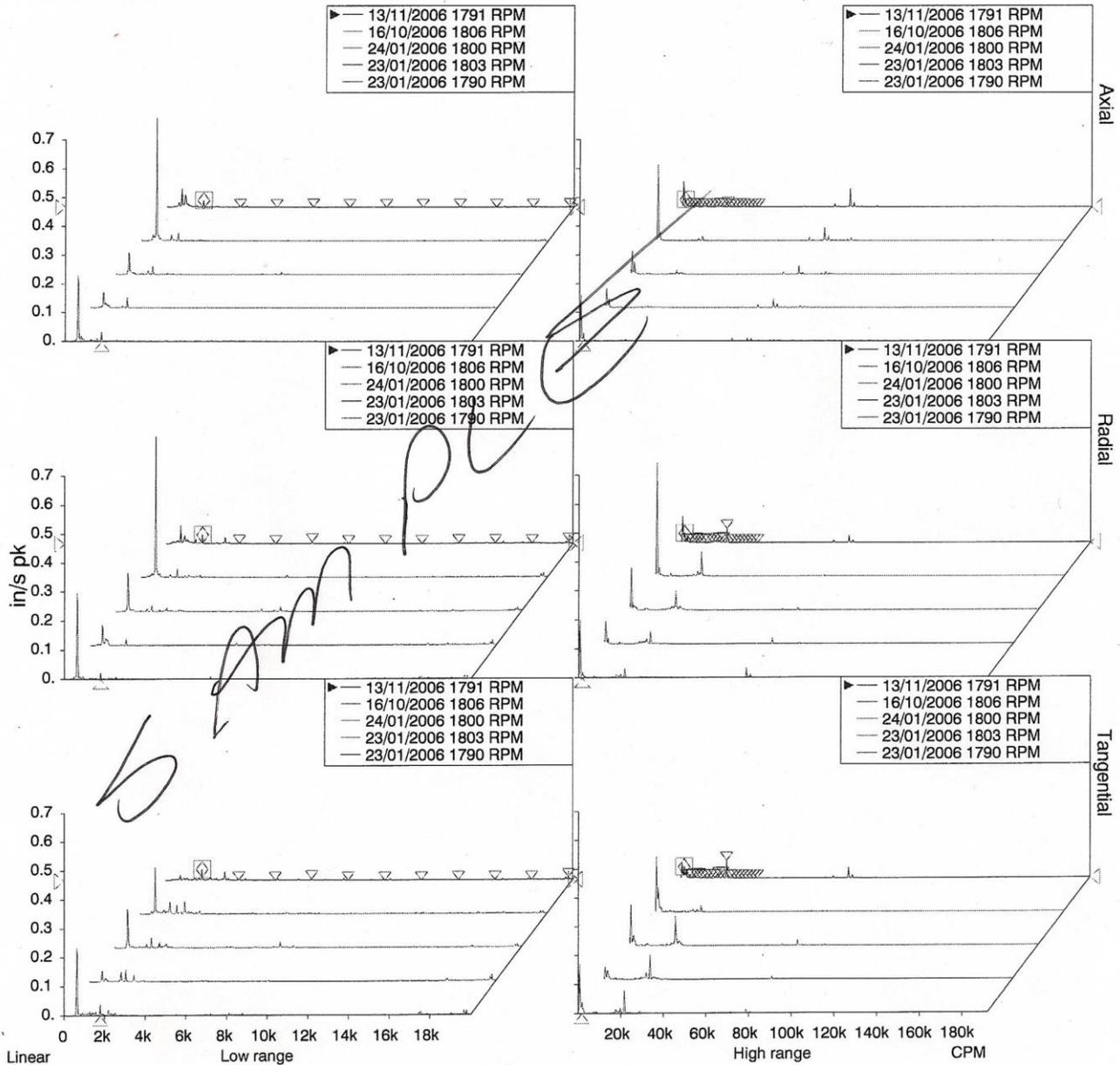
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# VIBRATION SPECTRUM DATA 60 HP 1800 RPM MOTOR (VELOCITY)



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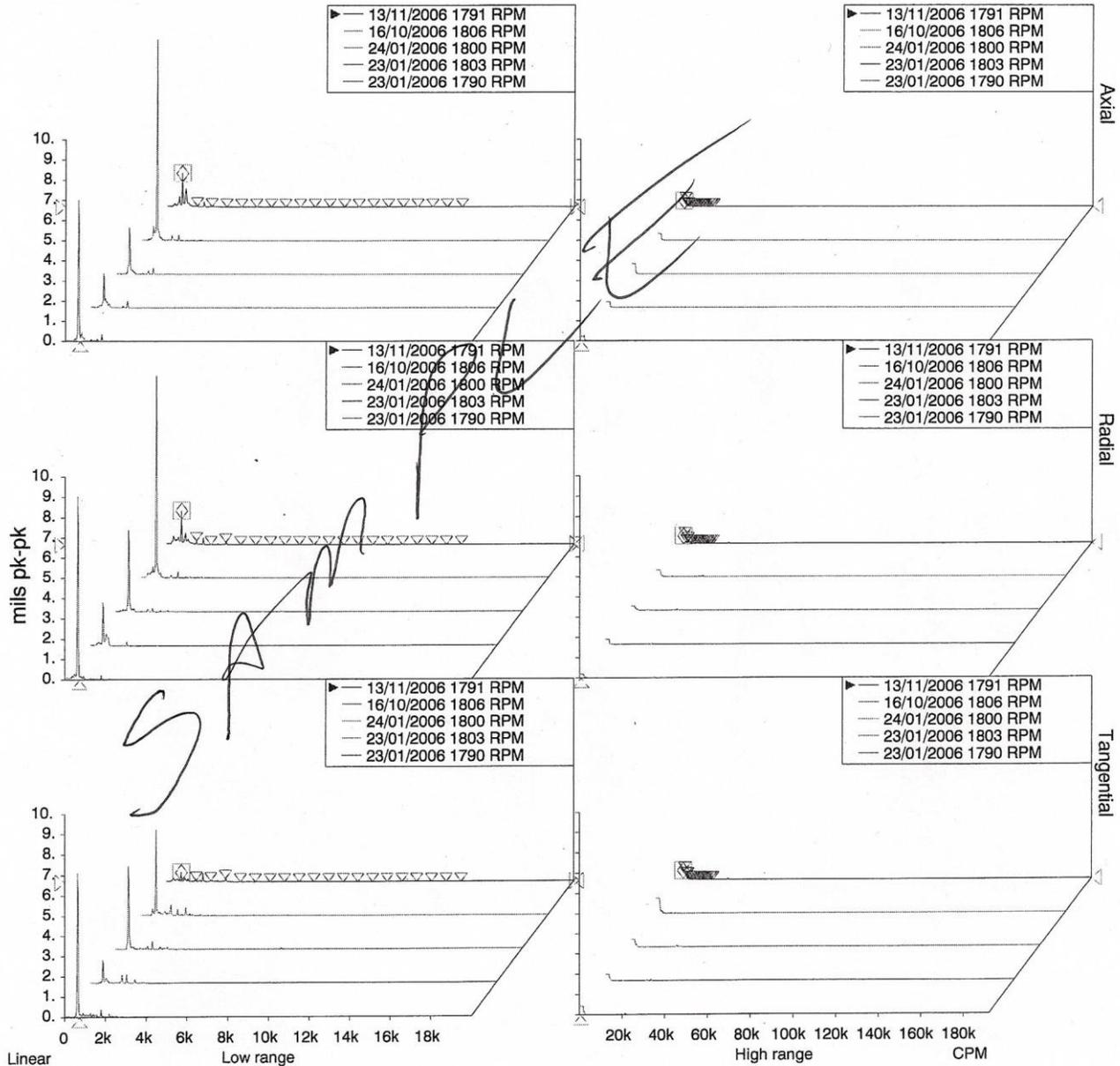
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# VIBRATION SPECTRUM DATA 60 HP 1800 RPM MOTOR (DISPLACEMENT)



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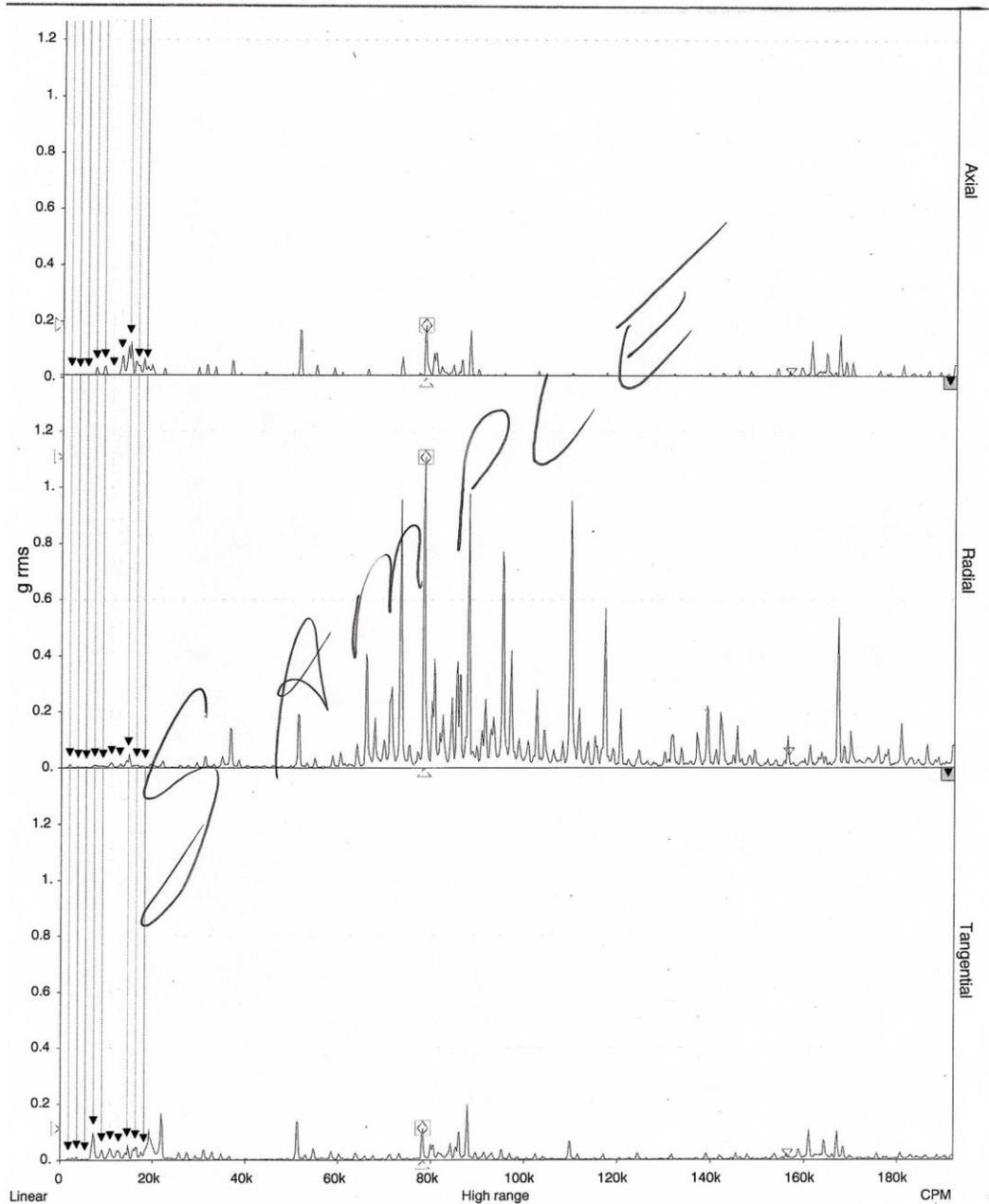
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**VIBRATION SPECTRUM DATA SHOWING VFD 600V  
MOTOR BEARING DEFECT = ELECTRICALLY  
INDUCED BEARING DAMAGE (EIBD) ACCELERATION**



Vibration data recorded using AzimaDLI DCX RT - Software ExpertAlert 3.10 (2013-2016)



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**This is the equipment Vibes Corp has been using for 15 years with good results**



**TRIO®**

Machine Data Acquisition

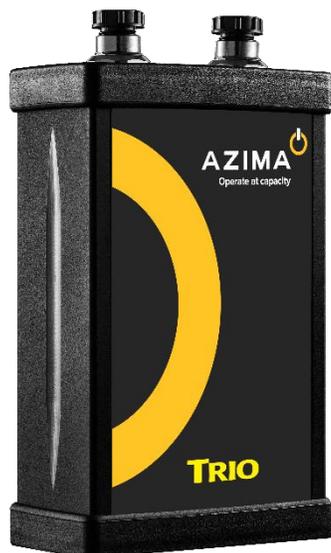
Powerful vibration data collectors, controllers, sensors, and field analyzers



Vendor Compliant for Property Owners, Management Firms of Commercial Buildings, Hospitals, Industrial Sites, & Infra-Structure Facilities



# POWERFUL, ERGONOMIC, AND SAFE MACHINE DATA ACQUISITION WITH THE TRIO® BRAND FIELD ANALYZERS



## TRIO C-Series

### COMMERCIAL INDUSTRIAL VIBRATION DATA COLLECTOR / FIELD ANALYZER

- ✓ Modular system with rugged IP-65 rated Windows 10 tablet PC
- ✓ 8" and 10" screen size options available
- ✓ Full-day, hot-swappable battery, standard-life or extended-life

## TRIO H-Series

### HAZLOC-RATED VIBRATION DATA COLLECTOR / FIELD ANALYZER

- ✓ Modular system with Class 1, Division 2 HAZLOC approvals
- ✓ 9", Ultra-rugged Windows 10 tablet PC
- ✓ Extra-long battery life, optional Snap-back battery packs

### TRIO Feature Highlights

- ✓ Modular, Bluetooth® connectivity, separates tablet from instrumentation
- ✓ 4 simultaneous channels of data plus dedicated tachometer channel
- ✓ Capacitive touchscreen, sunlight readable, brilliant screen resolution
- ✓ Safest vibration device on the market

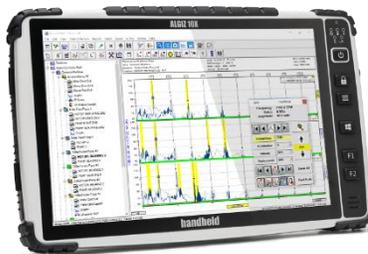
### TRIO Model Options

- ✓ ExpertALERT™ / Collector X applications for full automated diagnostic functions
- ✓ ViewALERT™ / Collector application for simple in field data collection
- ✓ ALERT RTA™ - Real-time Analyzer application for advanced troubleshooting
- ✓ ALERT™ Multi-plane Balance application for multi-plane, multi-speed balance

### CHOOSE THE PERFECT **HARDWARE DESIGN** SUITED FOR YOU



TRIO C8-Series



TRIO C10-Series



TRIO H8-Series



# TOTAL TRIO<sup>®</sup>

## BRAUN, BRAINS AND BEAUTY

### TOTAL TRIO IS A COMPLETE PACKAGE INCLUSION

Total TRIO ensures your equipment is operational, hardware and software is up-to-date, and technical and analytical support is there if needed.

With Total TRIO, the TRIO Controller is renewed every 3 years which keeps the technology always fresh.

Analysts have access to AzimaAI's domain experts to get second opinions on tough recommendations

Support will give you head-of-line for repairs and provide loaners if repair will take longer than 2 weeks.



# TRIO EMBRACES THE INDUSTRIAL INTERNET OF THINGS

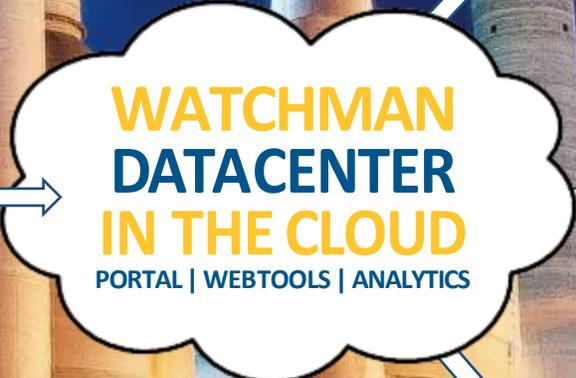
Total TRIO includes the WATCHMAN Data Center for database management and security. No IT capital expenses are required.

An included use license of ExpertALERT-Cloud is provided to work through AzimaAI's cloud application.

Key decision makers and program contributors can all gain insights into your PdM program through the included WATCHMAN Reliability Portal™.



**TRIO  
MACHINE DATA  
ACQUISITION**



**EXPERT  
ASSISTANCE**



**BIG DATA  
ANALYTICS**



**PLANT OWNERS,  
OPERATORS,  
MANAGERS,  
CUSTOMERS**

# HOW COULD TRIO<sup>®</sup> BE SO MUCH BETTER, YOU ASK?

## Powerful User Interface



The TRIO<sup>®</sup> line of data acquisition products includes the powerful, Windows OS industrial tablet computers. TRIO uses a robust Bluetooth<sup>®</sup> connection and includes a solid state hard drive, bright sunlight readable touch screen and Wi-Fi access allowing TRIO to communicate

with your desktop or networked PCs and servers. TRIO's user interface provides you more capabilities, better ease of use, and allows you to bring your other Windows PDM and Office productivity applications into the field

## Lower Cost and Flexibility of Ownership

TRIO<sup>®</sup> recognizes that computer technology is rapidly changing. Its distributed system configuration allows the tablet PC component to be replaced or upgraded for a small fraction of the cost of replacing a traditional vibration data collector.

## Improved Ergonomics and Safety



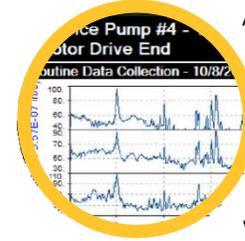
There is no safer vibration data collector on the market. TRIO's ergonomic design allows more efficient and safer use of the data collector around dangerous and difficult to access machinery. Machines can be tested from safe and secure distances from rotating machine locations using the

integral Bluetooth<sup>®</sup> communication. Its modular design helps keep technicians hands-free and untethered from the machine for improved safety.

## Collection Automation

TRIO automatically queues multiple frequency ranges of FFT, time, overall and demodulated vibration tests for a single machine location and collects X, Y and Z axis data simultaneously with a single command. You will collect more quality data in less time with TRIO.

## Automated Diagnostics



ALERT provides critical machinery health information in addition to vibration data, by rapidly screening vibration measurements and applying over 6000 unique rules to identify over 1200 individual faults in a wide variety of machine types.

## Variety of Configurations



TRIO offers several ergonomic-designed, in-field carrying options, including the convenient utility belt, shoulder-worn soft case and the shoulder strap/belt configurations. Depending on your specific use model, you can wear it, carry it or sling it over your shoulder.

## TRIO<sup>®</sup> and WATCHMAN<sup>™</sup> Reliability Services

Our combination of TRIO and WATCHMAN Reliability Services offer a new level of efficiency and capability to the predictive maintenance market. WATCHMAN provides business level and enterprise performance metrics for transparent visibility. Advanced dashboards ensure managers and executives are informed on maintenance decisions, risks to production and readiness of operations

## Proof Comes from the Field Experts



AzimaAI's WATCHMAN users prefer using the TRIO systems. They have found that route-based data collection is easier and more productive. Also, whether your predictive maintenance program is implemented in-house, outsourced or hybrid in-between, TRIO can be integrated with online and other service programs for flexibility and sustainability.

# Machine Data Acquisition

## TECHNICAL SPECIFICATIONS

### Overview

- Triaxial vibration data collector system
- Industrial Windows 10CSTabletPC Controllers
- Wireless, Bluetooth®, IP-65 rated Data Processing Unit (TRIO DP)
- Optional HAZLOC-rated North American Class 1, Division 2
- Portal-enabled connectivity to the hosted WATCHMAN Data Center
- Handheld laser tachometer for speed and phase measurement optional
- Flexible carrying options including utility belt, should straps, courier bags, hard transit case
- Sybase 12 SQL database onboard allows full PdM database to be mobile on unit
- Database synchronization for collaboration with multiple TRIOs or analysts
- Ergonomic designs allow more efficient and safer use
- 4-plane balancing and advanced real-time analysis software options
- HX- or CX-Series includes embedded ExpertALERT onboard analysis software (no host software required)
- HA- or CA-Series includes embedded ViewALERT onboard software (Requires host system: ExpertALERT (desktop, embedded, cloud- subscription) or StandardALERT)

### ALERT™ Capabilities

- Intuitive graphical user interface that is simple to learn and operate
- Setup wizards reduce set up time and increase configuration accuracy
- Enhanced management and visualization of dynamic data
- Automated vibration data screening using narrow-band vibration techniques for early faults detection
- Automated bearing fault identification without requiring bearing make and model number
- Multi-level fault severity and prioritized repair recommendations improve repair planning
- Advanced reporting tools produce professional reports
- Included 75,000 bearing asset library and 15,000 motor asset library
- Better machine performance determination through ALERT's calculated process points feature
- Integration of multiple PdM technologies, reports, documents, spreadsheets, inspections, and data
- Online monitoring, walk-around vibration collection and operating log collection in one system
- Close loop reporting with ALERT's Event Tracker

### Graphical Capabilities

- Amplitude Alarm Triggering
  - Impact Demod Spectra and Waveform
  - Overall Values
  - Spectrum
  - Waveform
- Automated Peak Locator
  - Harmonics
  - Order Normalization
  - Sidebands
- Average Baseline Comparison
  - Synthesized Average
  - Average plus sigma
- Bode Plot
- Bump Test
  - Equipment ON
  - Equipment OFF
- Customized Real-time Setup
- Graphical Remote Control Window
- Hotkeys & Hotspots
- Integration & Differentiation
- Long-time Data Capture
- Markers
  - Reference Cursor Delta
  - Harmonics
  - Sidebands
  - Fault Frequencies
- Nyquist Plot
- Order Tracking
- Peak Analysis and Identification Functions
- Phase Analysis
  - Cross Channel
  - Polar Phase Plot
- Run-up/Coast-down plotting
  - Spectral Waterfall
  - Bode-Peak & Phase
  - Peak Hold
- Spectrum
  - Single Axis
  - Triaxial
  - Double-Triaxial
  - Demodulation
  - Waterfall
  - Native, Integrate, Double integrated, Decibel
- Time Synchronous Averaging
- Waveform
  - Autocorrelation
  - Single Axis
  - Triaxial
  - Double-Triaxial
  - Orbit, Filtered Orbit
  - Poincare Map
  - Single Circular Graph
  - Triaxial Circular Graph
  - Waterfall with Correlation Factor
  - Native, Integrated, Double-integrated
- Long time Data Capture
- Cross Channel Phase Analysis

## TRIO Data Acquisition / Processor (DP-2, DP-2H)

### Inputs

- 4 simultaneous sampled, fully phase matched, ICP programmable
- Other Coupling: AC (for proximity probe connections)
- AC Input Voltage Range: +/- 10V
- AC Bandwidth: 0.5Hz to 40 kHz
- DC Bias/Gap Measurement: +/- 25V range for ICP bias voltage check and proximity probe gap measurement
- Measurements: Acceleration, velocity (by hw integration), bearing demodulation (accelerometers), and displacement (proximity probes)
- Gain Ranges: Gain steps 1, 2, 4, 10, 20, and 50
- Digital trigger input: External trigger, tachometer speed, ordered data (by phase-lock-loop)

### Processing

#### AC MEASUREMENTS

- ADC: 24-bit sigma-delta, simultaneous on four AC channel inputs, better than 104 dB dynamic range
- Sampling Rates: 64Hz to 102.4kHz
- Bandwidth Ranges: 0.5Hz-25Hz, 0.5Hz-40kHz, protected by anti-alias filters
- Data Block Lengths: 64 to 400,000 samples
- Spectral Lines: Up to 25,600
- Noise Floor: Less than 0.2 micro-volts per root Hz from 0.5 to 1000kHz

#### DC MEASUREMENTS

- ADC: 16-bit multiplexed for bias voltage, process, and probe gap measurements, 0-10kHz Bandwidth

### Analysis Capabilities

- Dynamic Analysis: Overall, Spectra, Waveform, Phase and Speed
- Cross-channel: Cross-power, Transform Function, Coherence, Phase and Magnitude
- Demodulation Function: Digital amplitude demodulator and Impact Demodulation for low speed detection
- Averaging: RMS, Exponential, Peak Hold, Order Tracking, Synchronous Time, and Negative Averaging
- Number of averages: 1 – 1000
- FFT Window Function: Hanning, Hamming, Rectangular, Flattop

#### Communications with Tablet Controller

- Wireless: Bluetooth v2.0 with EDR (1.5Mbps max)
- Wired: USB user port (includes data stream and remote power to DP)

### Power

- Charging rate: 0.5A from USB PC input (4 hrs), 1.0A from USB wall power adapter (2 hrs)
- Battery life: 8 hours, continued use

### Physical

- Dimensions: 6.18" x 3.62" x 1.81" (157 mm x 92 mm x 46 mm)
- Carrying options: Belt holster or courier bag
- Weight: 1.0 lb (0.45kg)
- Operating Temperature: -10C to +60C
- Humidity: MIL-STD-810G
- Drop: 4 feet per MIL-STD-810G
- Sealing: IP-65; polycarbonate and nylon
- Compliance: CE, ETL Listed
- IP65 rated; dust tight, protected from water jet





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P 781-938-0707

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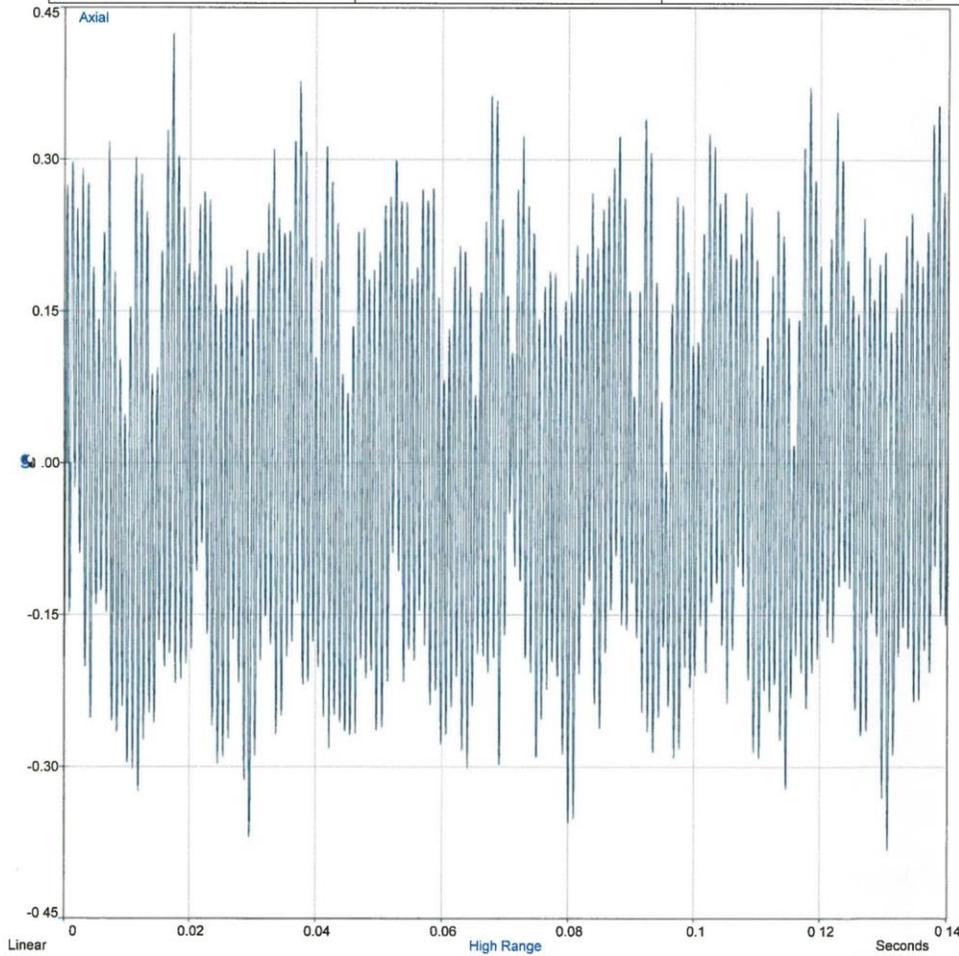
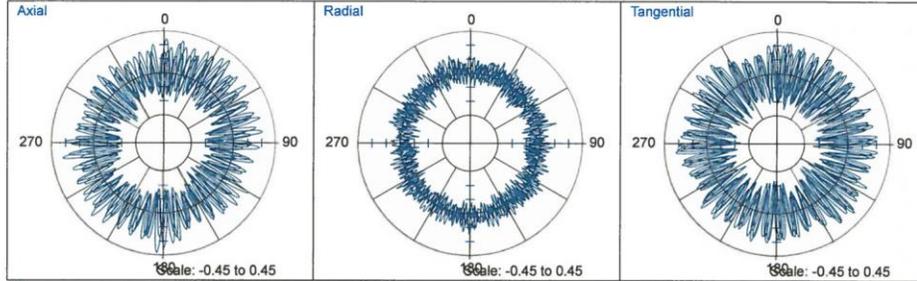
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Plant: Confidential	Axial 12/4/2018 12:35:40
Area: Compressor Room	MID Averages: 0 MID: 395
Machine: Rotary Screw Compressor	RPM = 1776 RPS = 29.60
Location: RS Comp End [1] - RAT	P-P = 0.806 g



Vibration data recorded using AzimaDLI CX 8 advanced data spectrum analyzer - Software ExpertAlert 4.0 (2019)



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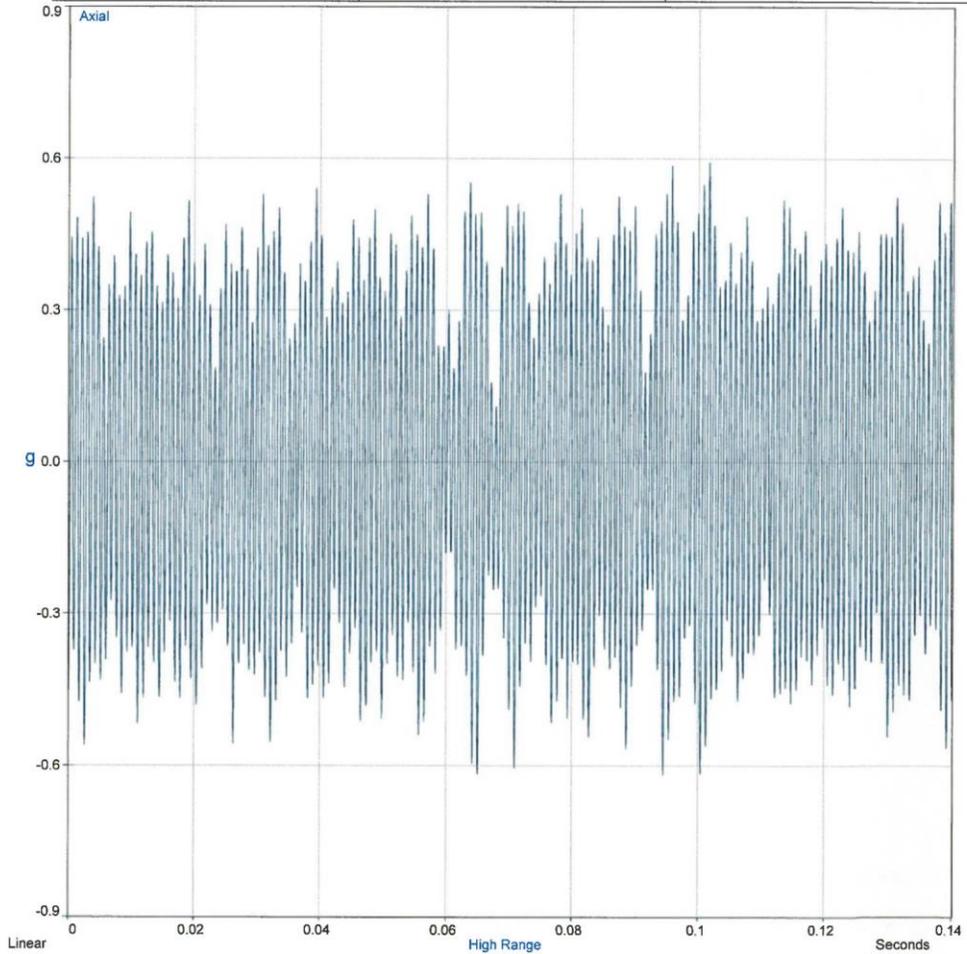
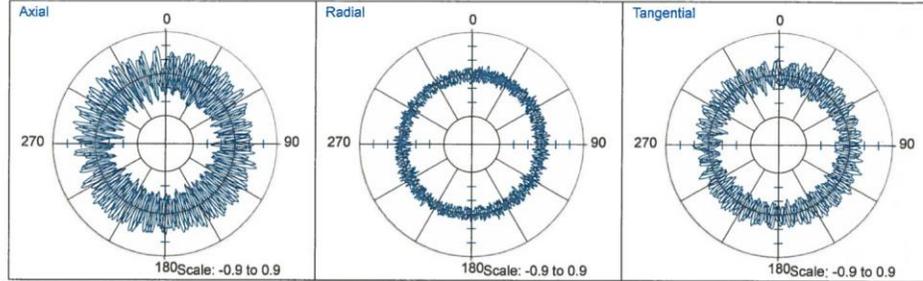
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Phone: 604 - 619 - 9381 (24/7)

Plant: Confidential	Axial 12/4/2018 12:37:30
Area: Compressor Room	MID Averages: 0 MID: 395
Machine: Rotary Screw Compressor	RPM = 1764 RPS = 29.39
Location: RS Gear End [2] - RAT	P-P = 1.211 g



Vibration data recorded using AzimaDLI CX 8 advanced data spectrum analyzer - Software ExpertAlert 4.0 (2019)



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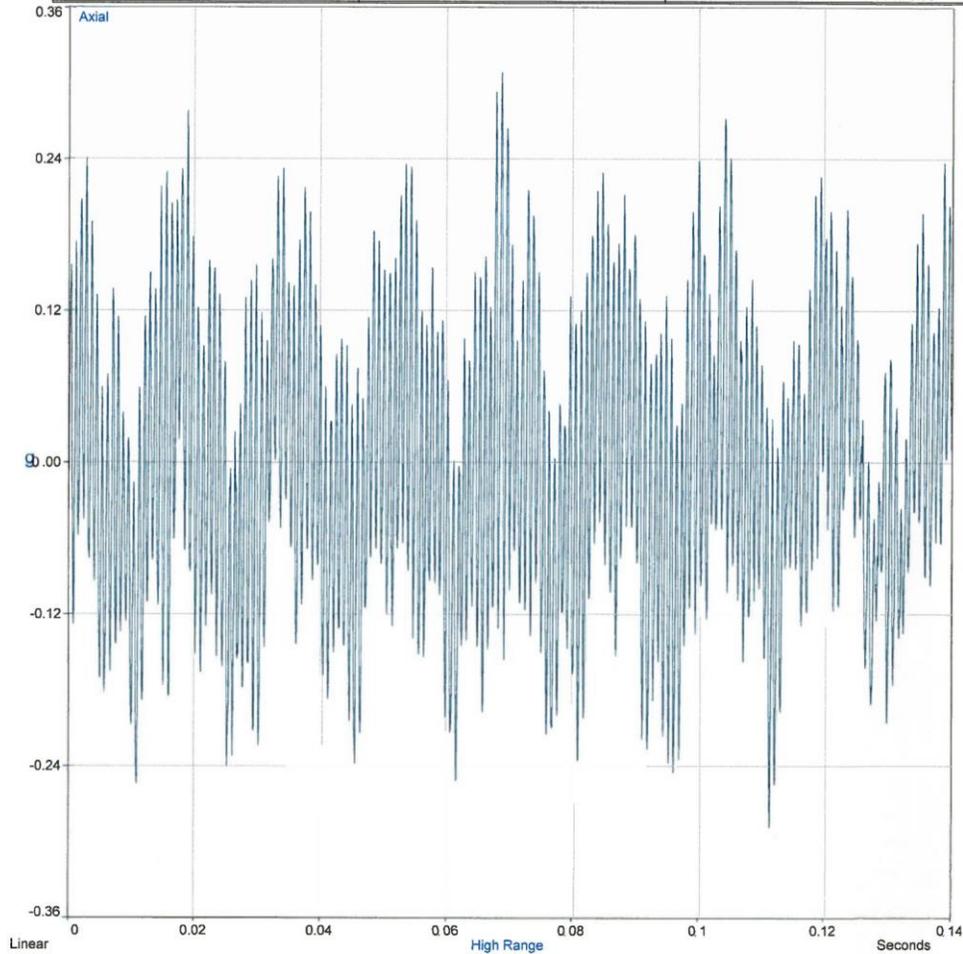
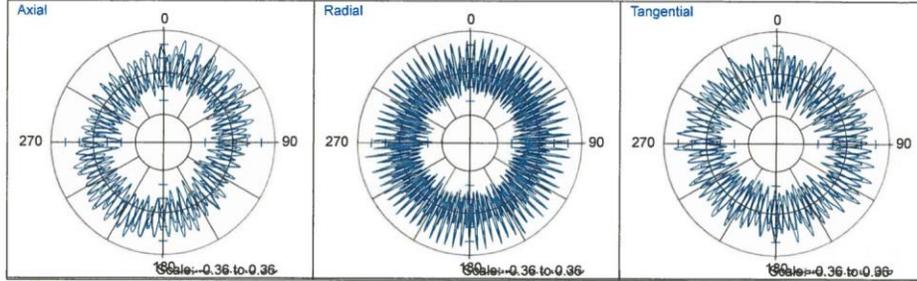
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Plant: Confidential	Axial 12/4/2018 12:19:03
Area: Compressor Room	MID Averages: 0 MID: 395
Machine: Rotary Screw Compressor	RPM = 1800 RPS = 30.00
Location: RS Comp End [1] - RAT	P-P = 0.596 g



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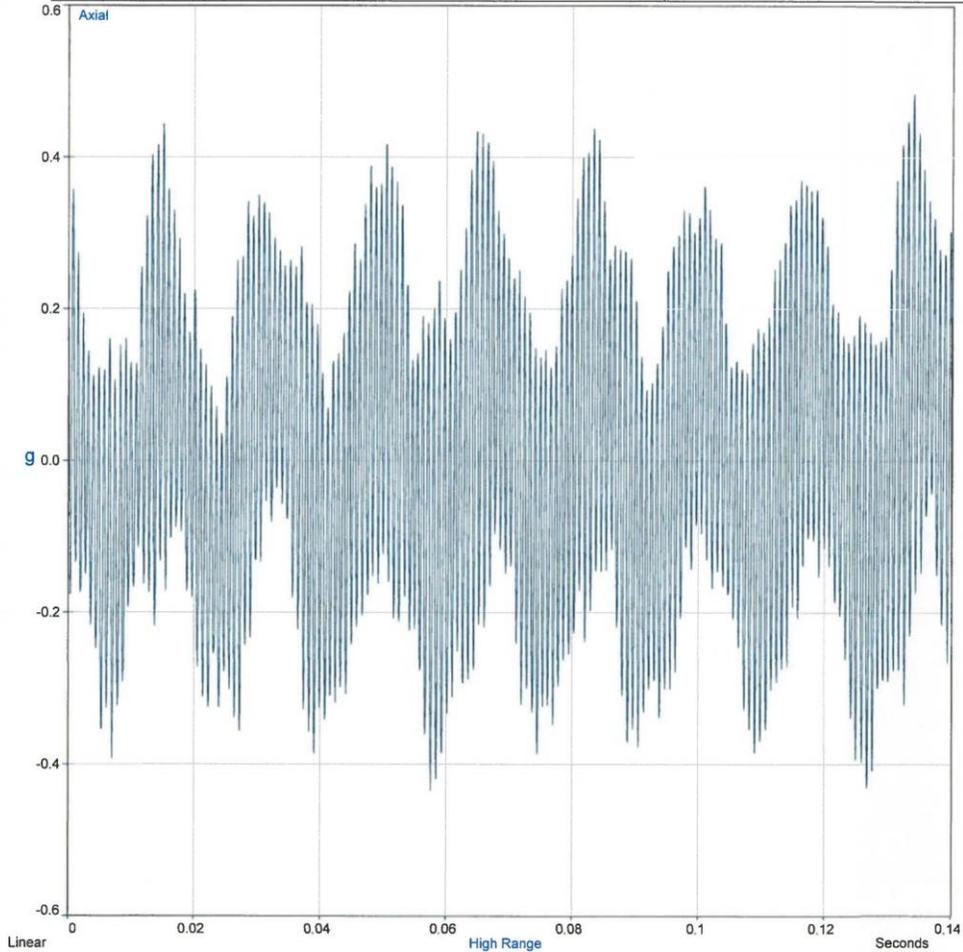
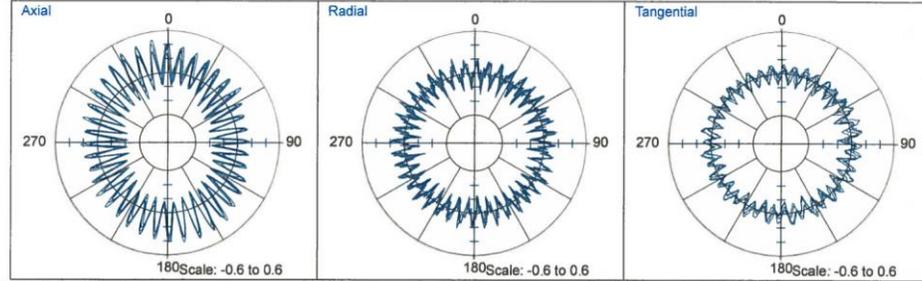
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Plant: Confidential	Axial 12/4/2018 12:20:29
Area: Compressor Room	MID Averages: 0 MID: 395
Machine: Rotary Screw Compressor	RPM = 1782 RPS = 29.70
Location: RS Gear End [2] - RAT	P-P = 0.918 g



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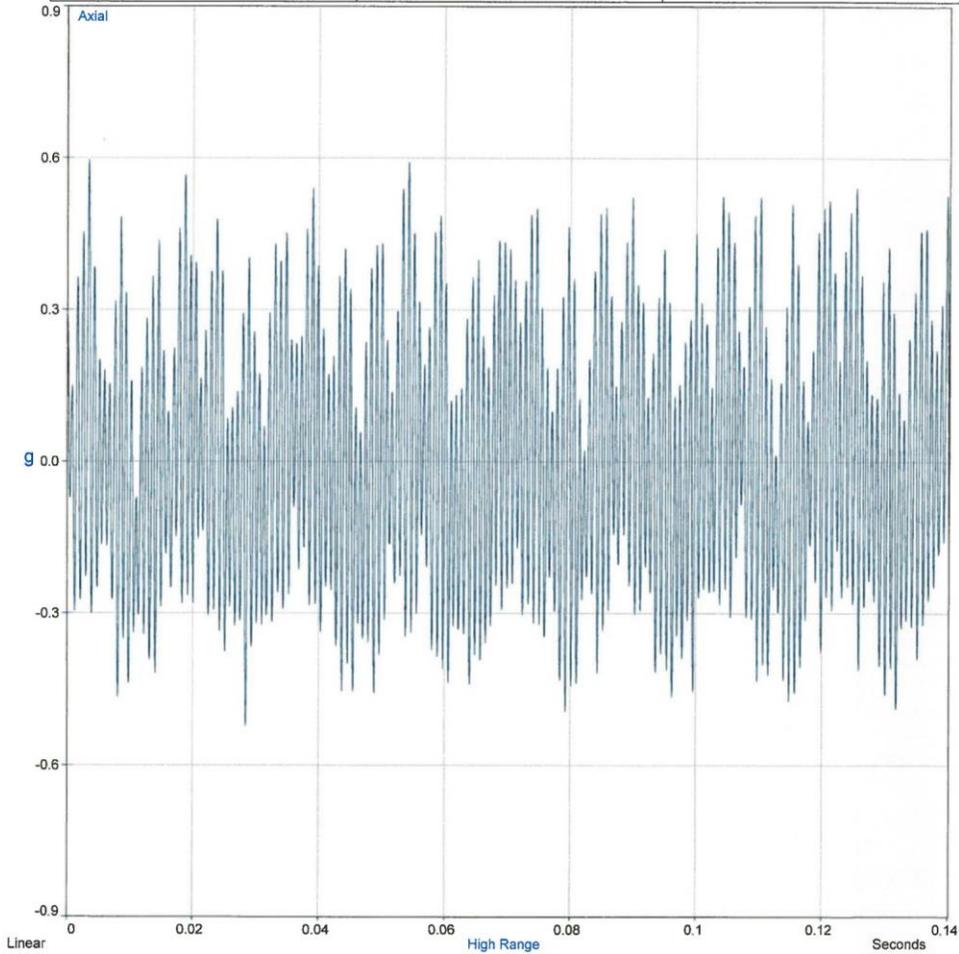
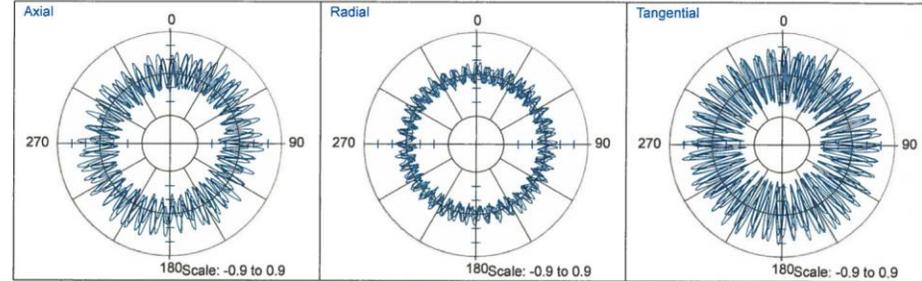
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Plant: Confidential	Axial 12/4/2018 12:15:47
Area: Compressor Room	MID Averages: 0 MID: 395
Machine: Rotary Screw Compressor	RPM = 1778 RPS = 29.63
Location: RS Gear End [2] - RAT	P-P = 1.119 g



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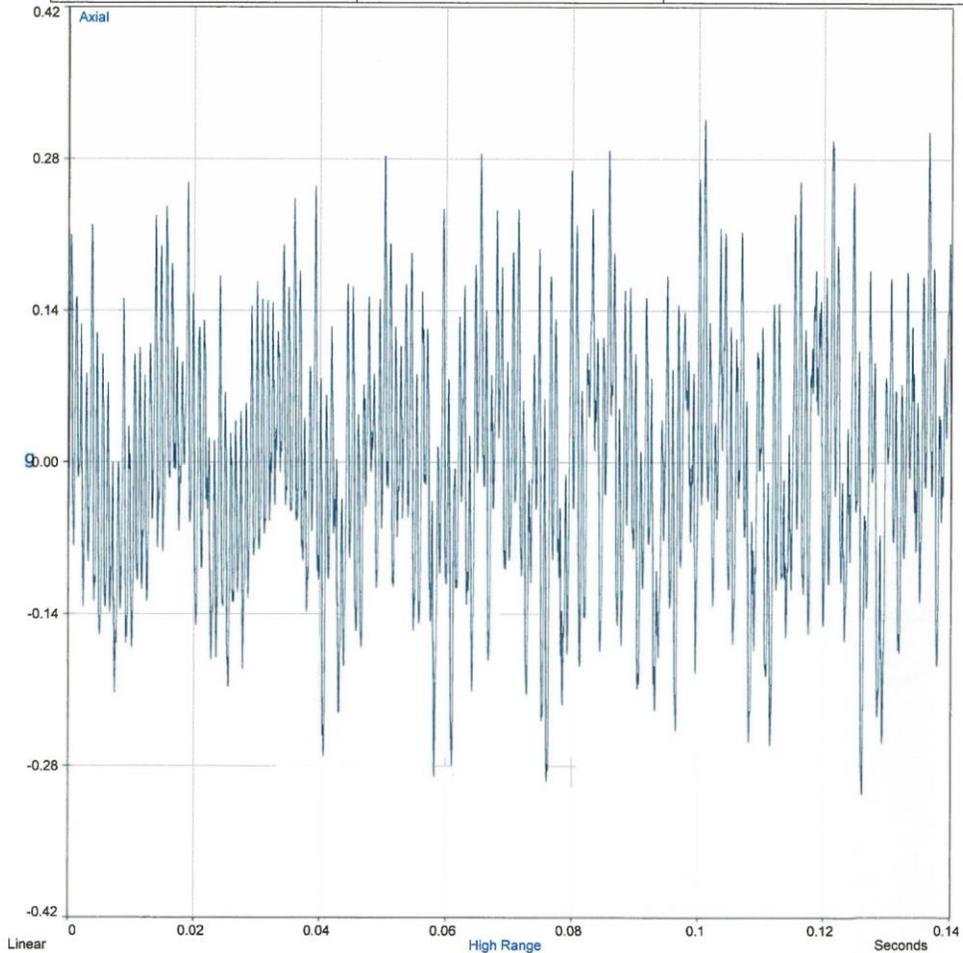
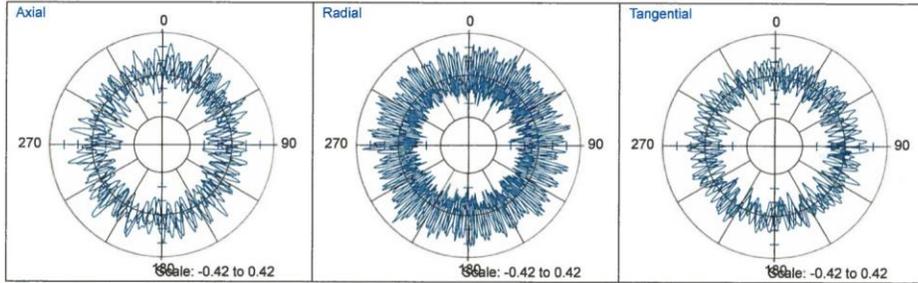
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Plant: Confidential	Axial 12/4/2018 12:17:11
Area: Compressor Room	MID Averages: 0 MID: 395
Machine: Rotary Screw Compressor	RPM = 1793 RPS = 29.88
Location: RS Gear End [2] - RAT	P-P = 0.622 g



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# MACHINERY AND BEARING FAULTS AND FAILURES

**ROTATING MECHANICAL PARTS BREAKDOWNS CAN LEAD TO VARIOUS PROBLEMS SUCH AS: PEOPLE SAFETY, HVAC/R OR PRODUCTION SYSTEMS DOWNTIME AND MAJOR COSTS.**

**MANY PROBLEMS CAN BE AVOIDED OR FOUND IN ADVANCE IF A DEDICATED PREVENTATIVE MAINTENANCE PROGRAM IS IMPLEMENTED INCLUDING:**

- ACCURATE MECHANICAL INSPECTIONS AND PREVENTATIVE MAINTENANCE**
- BEARING NOISE AND ACCELERATION**
- VIBRATION SPECTRUM ANALYSIS**
- OIL SAMPLE ANALYSIS**
- BEARING ACCELERATION, TEMPERATURE, NOISE MEASUREMENTS AND TRENDING**



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## Electrically Induced Bearing Damage (EIBD) on a Bearing Race

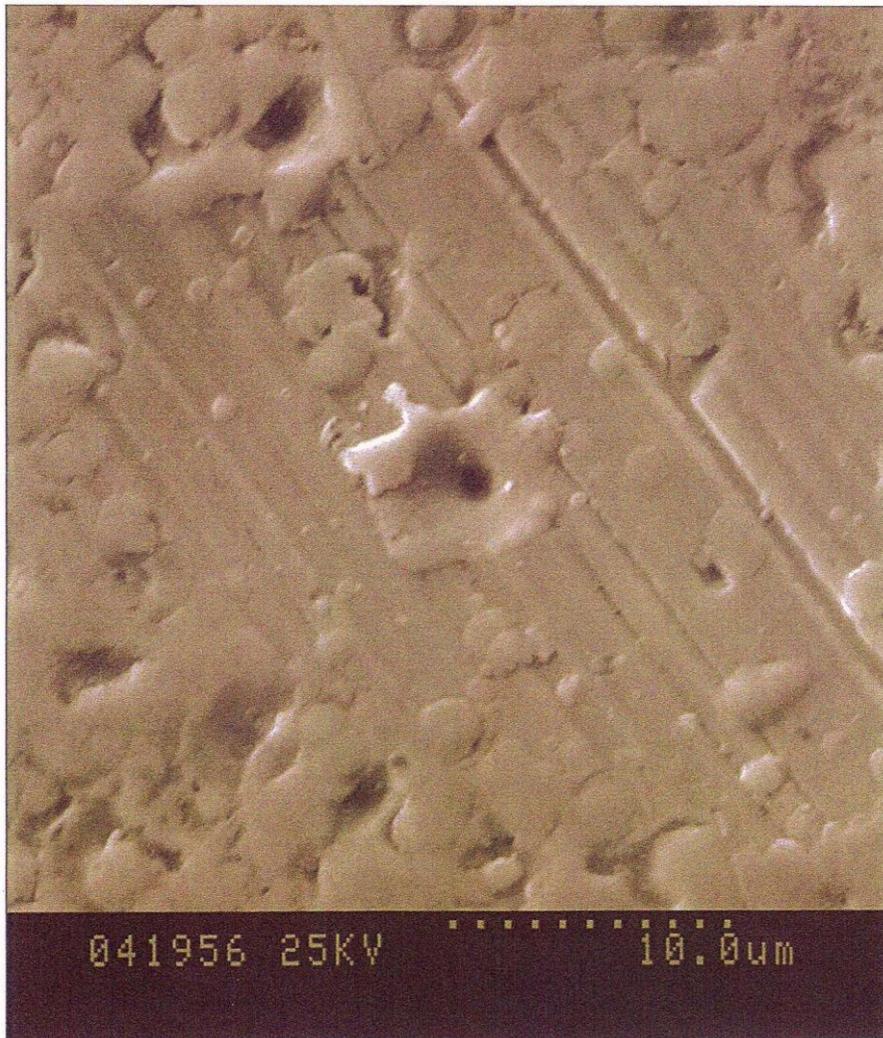


*The bearing race shown in this photo was found in the advanced stage of fluting. See scanning electron microscope (SEM) images for the above bearing race on pages 28 and 29.*

EIBD/Shaft Currents is directly related to 460V (USA) and 600V (Canada) motor VFD applications. A thorough [EIBD article](#) is available at [vibescorp.ca](http://vibescorp.ca).

## Electrically Induced Bearing Damage (EIBD) on a Bearing Race

This SEM image is from page 27 bearing race

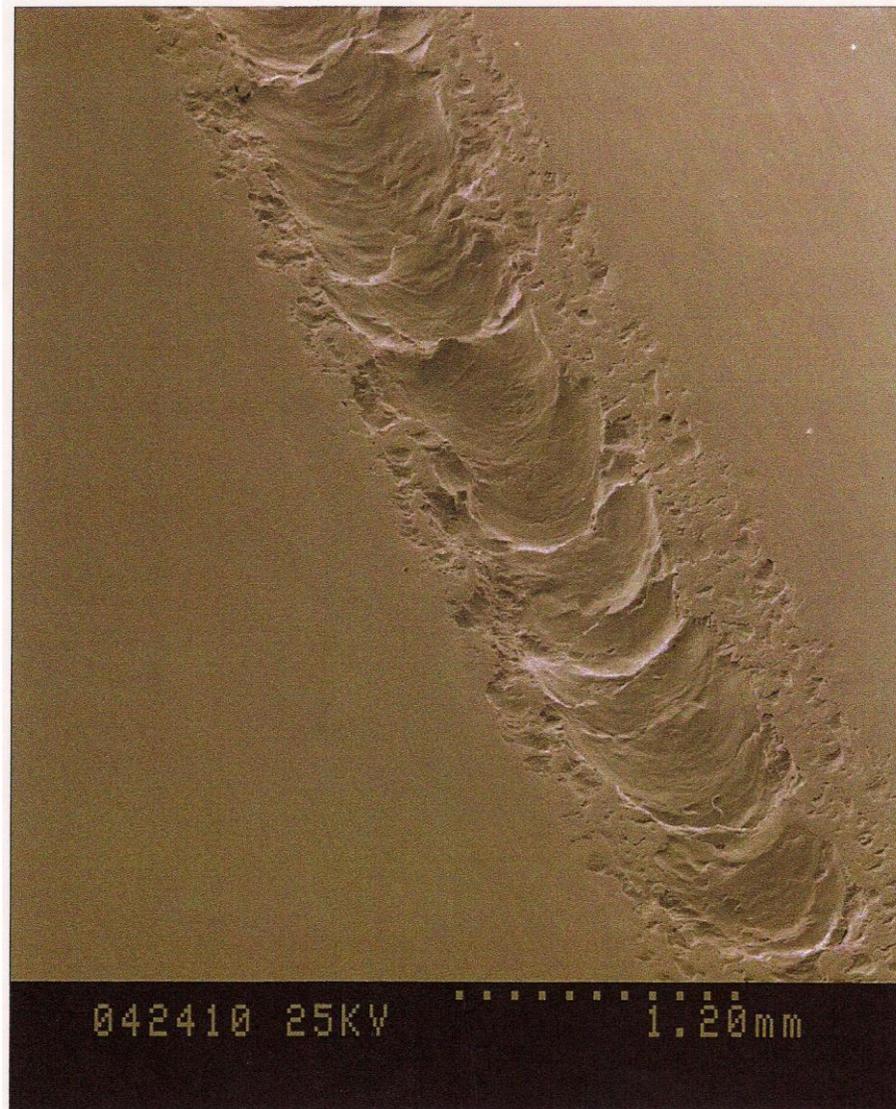


*High magnification SEM view of particles flattened onto drive end outer raceway running surface showing variety of particle sizes. Material has clearly been molten at the time of deposit. Magnification 4,500X.*

EIBD/Shaft Currents is directly related to 460V (USA) and 600V (Canada) motor VFD applications. A thorough [EIBD article](#) is available at [vibescorp.ca](http://vibescorp.ca).

## Electrically Induced Bearing Damage (EIBD) on a Bearing Race

This SEM image is from page 27 bearing race



*SEM image of the spalling observed on the inside surface of the outer raceway. Magnification 37.5X.*

EIBD/Shaft Currents is directly related to 460V (USA) and 600V (Canada) motor VFD applications. A thorough [EIBD article](#) is available at [vibescorp.ca](http://vibescorp.ca).



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**“EIBD” – One Solution Applied = Use Sealed Bearings, clean out factory grease and pack with Electro conductive Grease.**

**Electro Conductive Grease has proven to prevent EIBD for over ten years at various locations. VFD applications ranging from 10HP to 125HP.**



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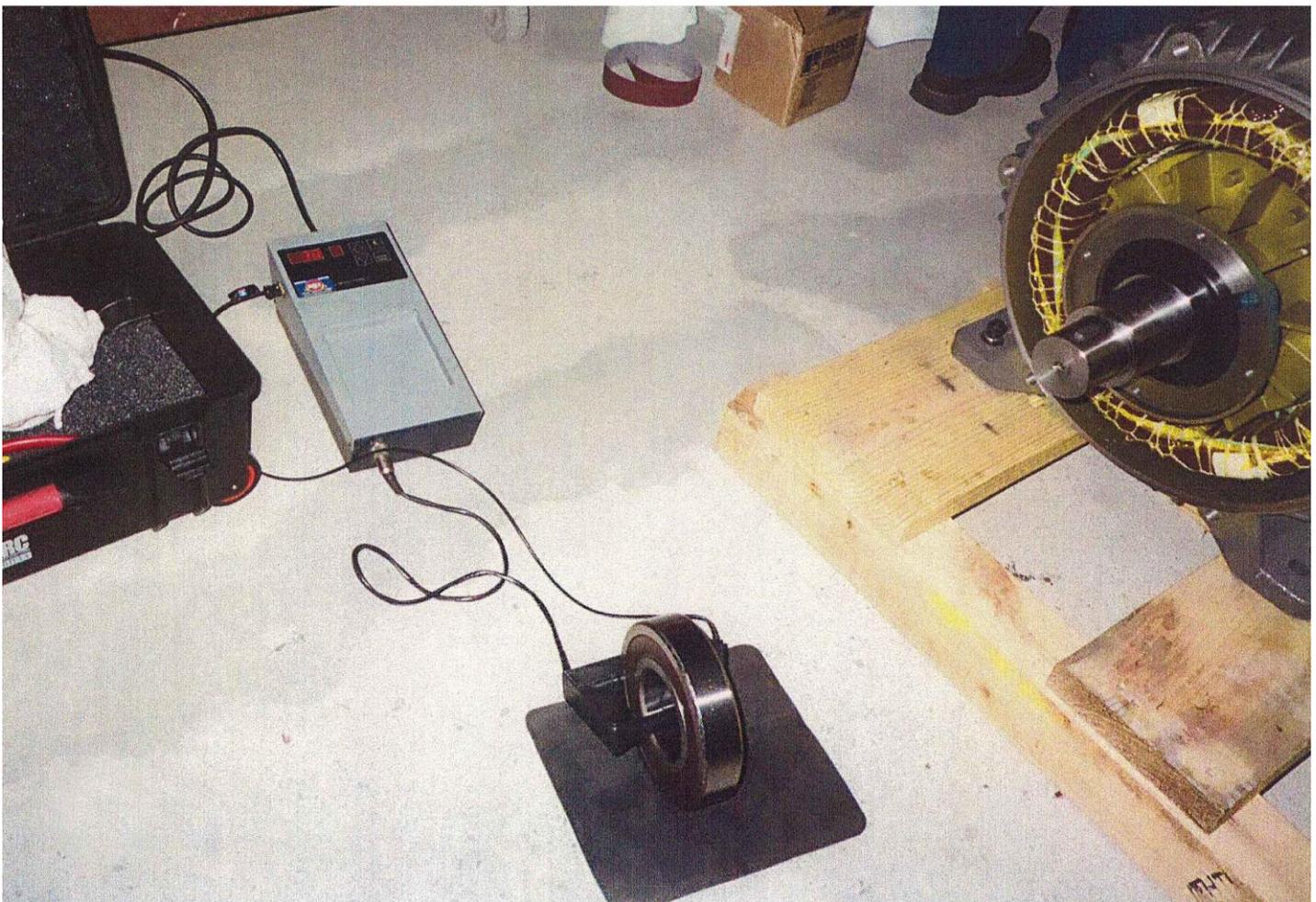
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**Always use an electronic bearing heater to heat bearing inner race to 110C prior to installation on a motor shaft.**



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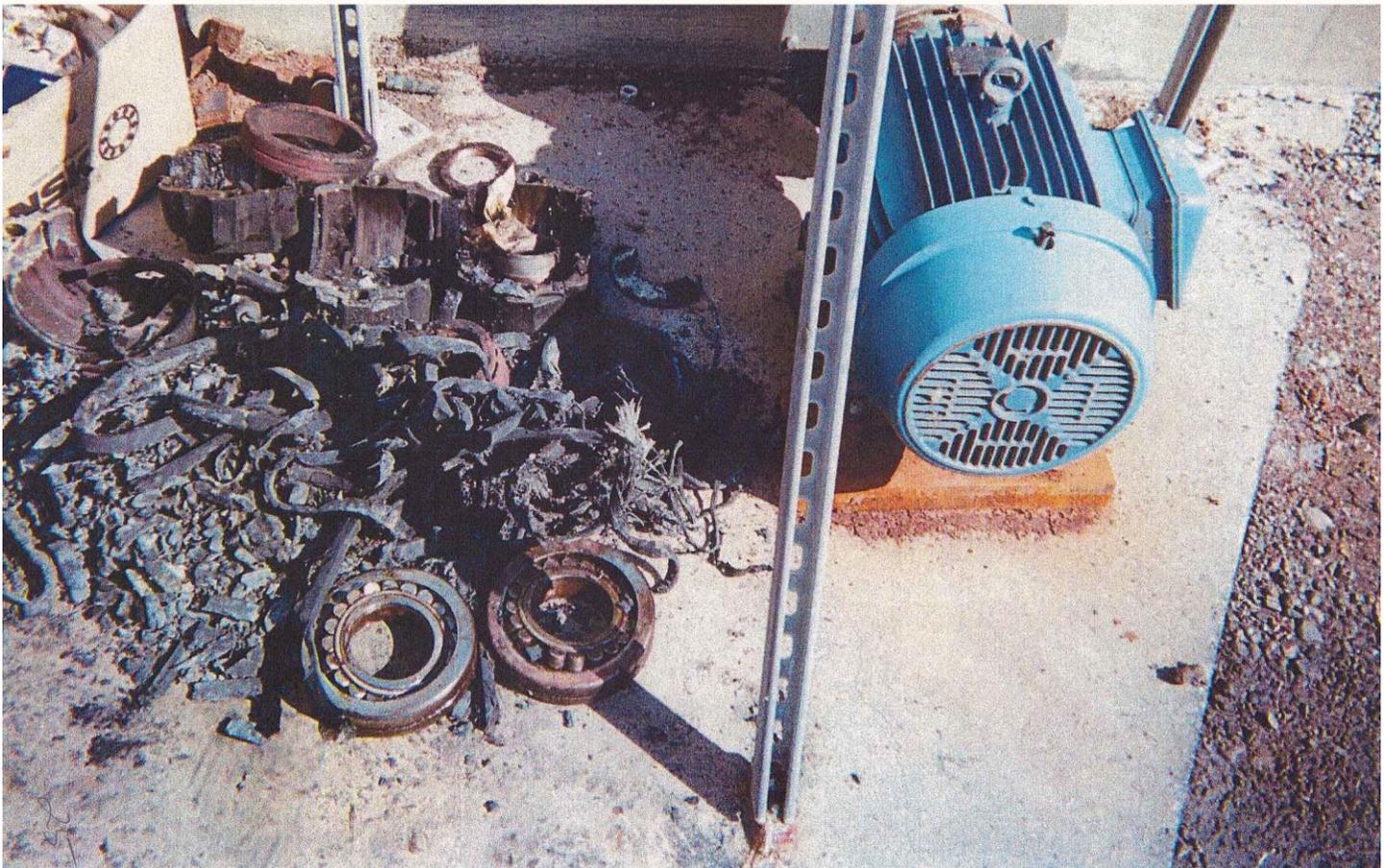
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**Due to looseness on the shaft and most likely moisture contamination these fan bearings failed, and caused the belts to catch on fire.**



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## Woods Axial Two-Stage Fan

### AS-1A

Bearing shown: Motor (ODE)  
Inner Raceway

Defects= True Brinelling

January 6, 2007

**COMPLYWORKS**

 **Alcumus**  
ContractorCheck

 **Avetta**

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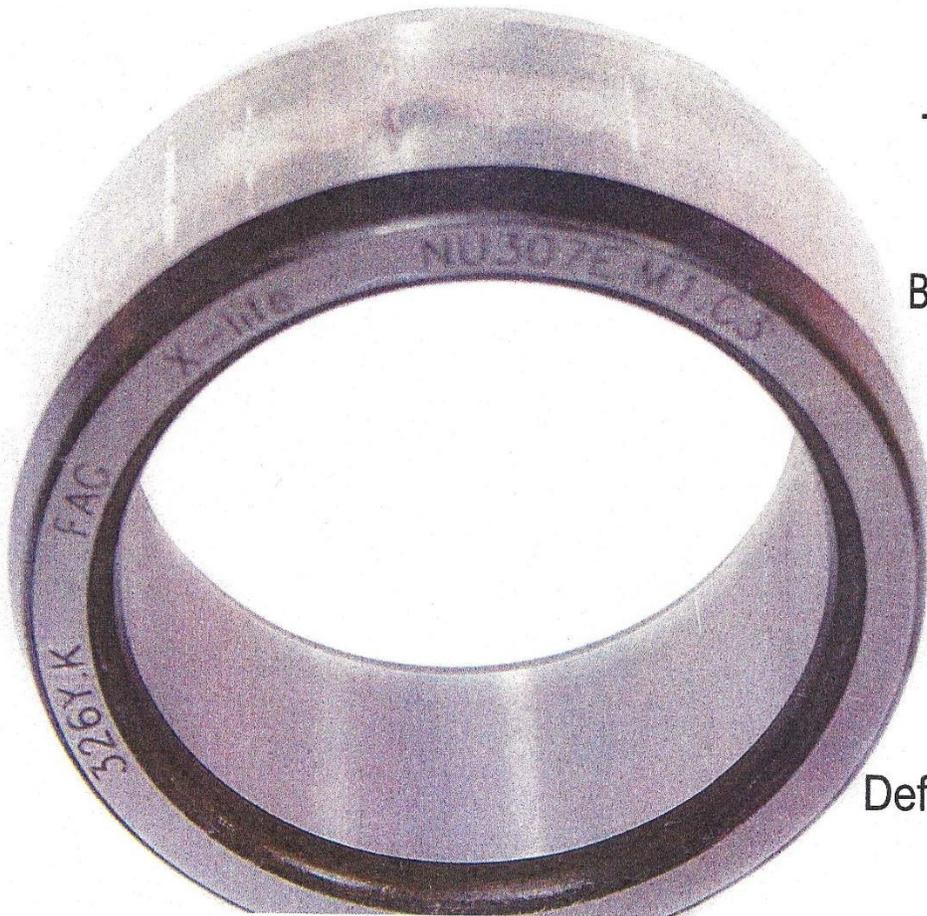
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Woods Axial  
Two-Stage Fan

AS-1A

Bearing shown: Motor (ODE)  
Inner Raceway

Defects= True Brinelling  
January 6,2007



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**These bearing parts were cut in half to show moisture contamination in a vertical shaft cooling tower. The average life span of new fan bearings on this site is only three years.**



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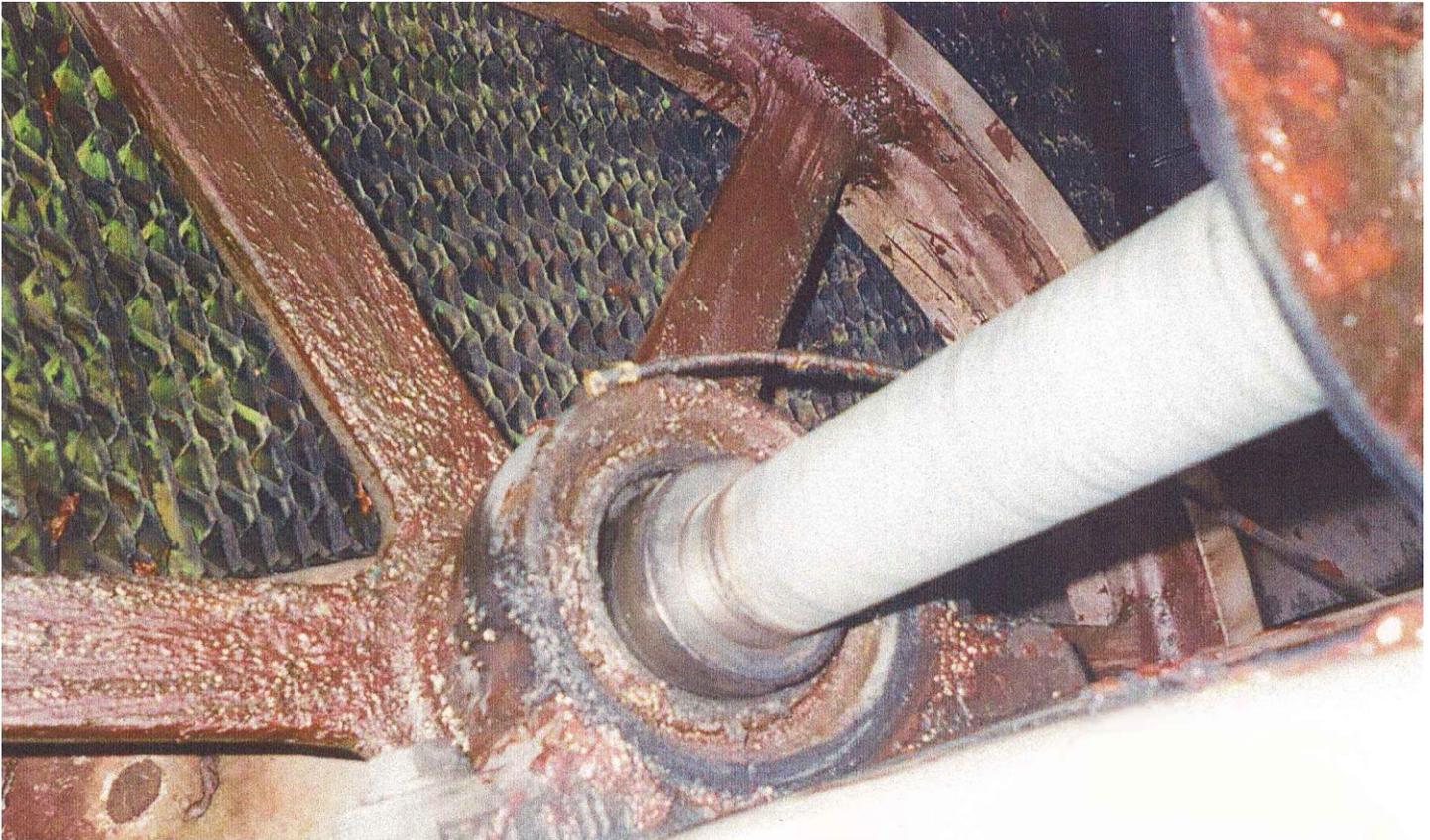


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**This cooling tower fan drive end bearing failed within two years of running time. The cause was determined to be moisture contamination.**



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**This cooling tower fan opposite end bearing failed within eight years of running time. The causes are cage failure, lack of lubrication or moisture contamination.**



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