
SKF
®

Low-speed bearing monitoring

Challenges and Solutions

BRCE
BEARING RELIABILITY CONFERENCE & EXPO

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Agenda

1. Low-speed bearing monitoring
   - Challenges
   - Solutions
2. SKF's commitment in this field (History, techniques, patents)
3. SKF Multi parameter measurements
4. Case studies
5. New approaches
   - HAL
   - AEE

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Challenges

Challenging monitoring applications

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- Large size bearings are usually more difficult to monitor due to:
- Low speed applications
  - Steady speed
  - Non-steady speed
- High “noise”, low bearing defect energy
- Contamination and insufficient lubrication

The most common problem is lack of understanding of:

- The application conditions
- The appropriate instrumentation, techniques, and configurations

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Low speed bearing monitoring – Issues

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- "Undetected" failures on slow speed machines leads to the assumption that finding them with vibration is not possible.
- In most cases, this originates from one or more common mistakes in setting up the vibration measurement in the first place.

- Some common errors include:
  - Low-frequency sensor use
  - Incorrect mounting method
  - Incorrect Enveloping filter selection
  - Inadequate measurement time length
  - Not accounting for non-steady speed
  - Not accounting for load zone

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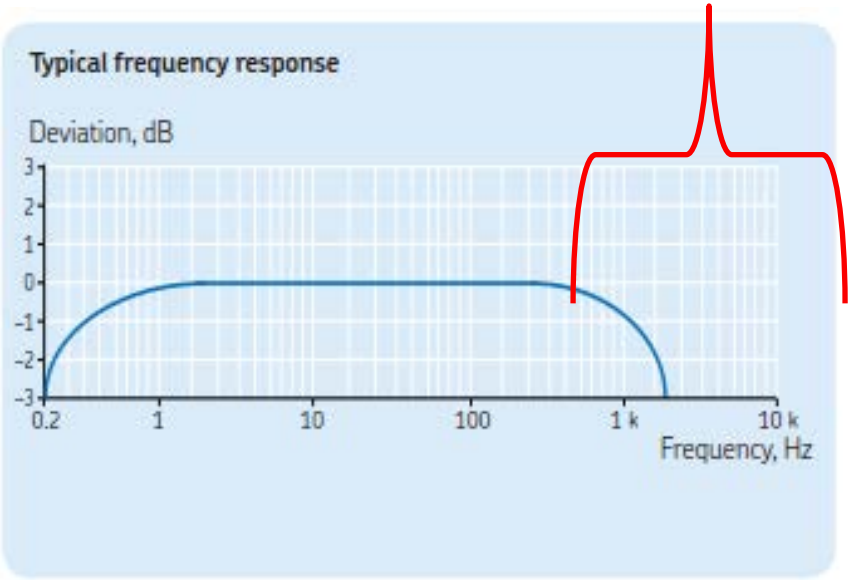
Low speed – low frequency accelerometers?

- There is a common misconception that a low frequency response accelerometer needs to be used on low speed machines because of the lower energy levels/bearing frequencies.
- A typical 500 mV/g low frequency model has a lower 3 dB point of only 0.2 Hz,
- However, the upper 3 dB point is only 2.3 kHz - well below the upper boundary of the demodulation BPF.
- The use of a standard 100 mV/g sensor is better – these typically have an upper 3 dB point around 14 kHz, fully encompassing the BPF range.

Frequency range:
±5%: 0,6 to 700 Hz
±10%: 0,4 to 1 000 Hz
±3 dB: 0,2 to **2 300 Hz**

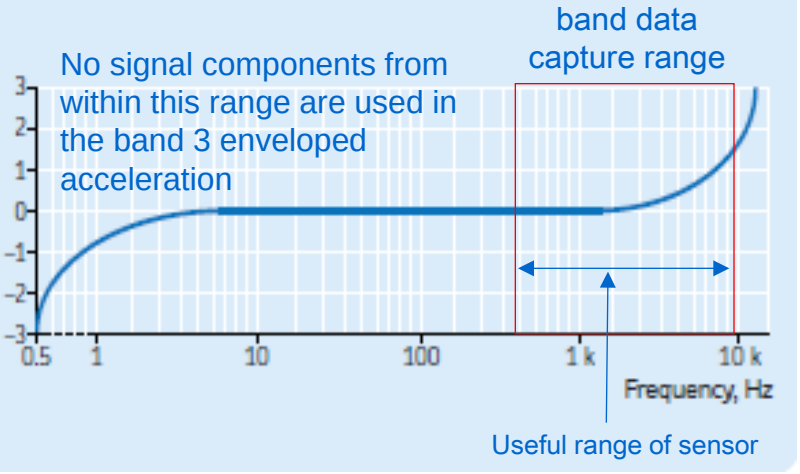
Impact energy



For low-speed – standard accelerometers

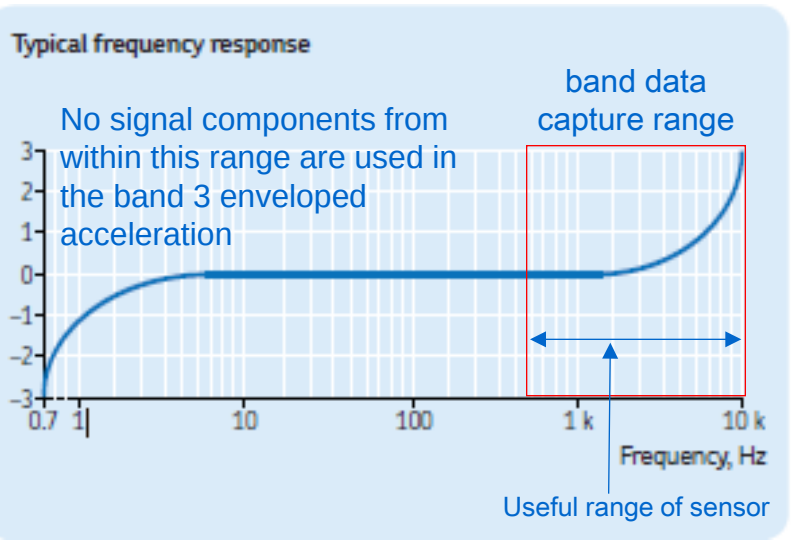
CMSS 2100

Frequency range:
±5%: 3,0 to 5 000 Hz
±10%: 1,0 to 9 000 Hz
±3 dB: 0,5 to 14 000 Hz



CMSS 2200 / CMSS 2200-M8

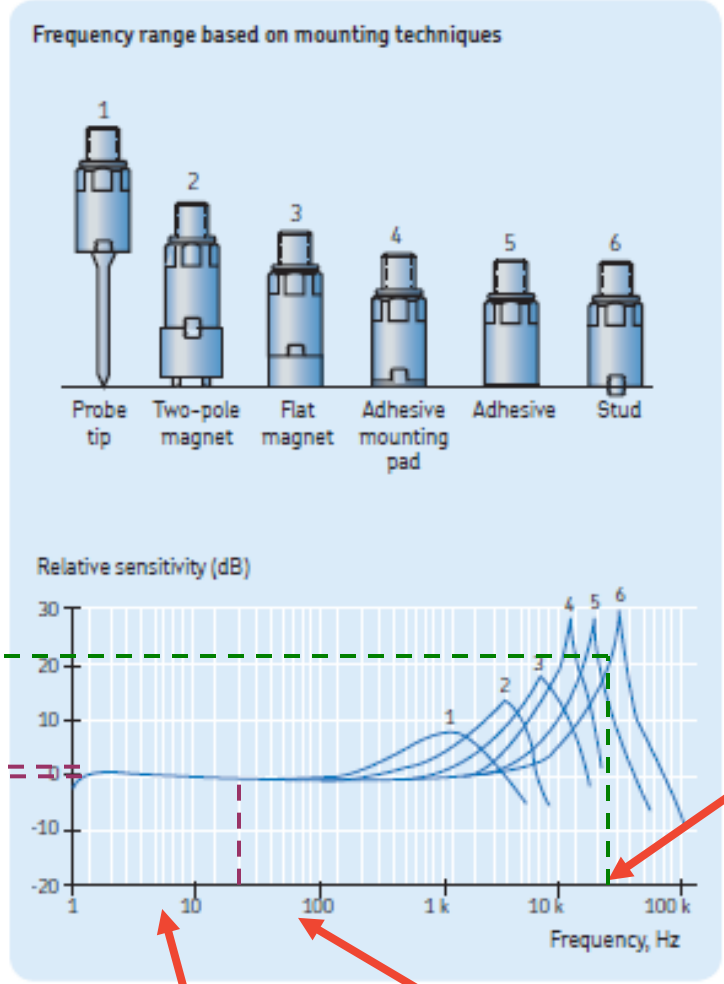
Frequency range:
±10%: 1,0 to 5 000 Hz
±3 dB: 0,7 to 10 000 Hz



For Bearing Analysis on machines with a low rotational speed and envelope band 3/4, one should still use the standard sensors!

Mounting is important – use stud mounting

ISO standard 5348



Non-linear response

Amplification by the sensor

Reference

Linear response

Near zero amplification by the sensor

Harmonics and energy from ‘over-rolling’ of a defect are still present in this range

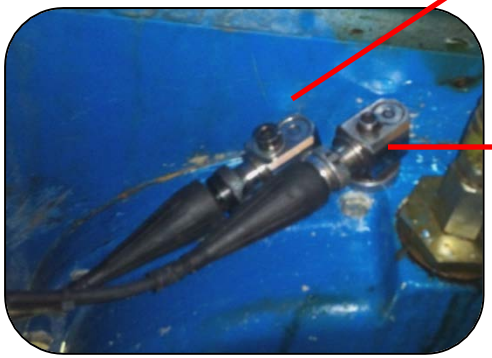
Fundamental bearing defect frequencies are in this range

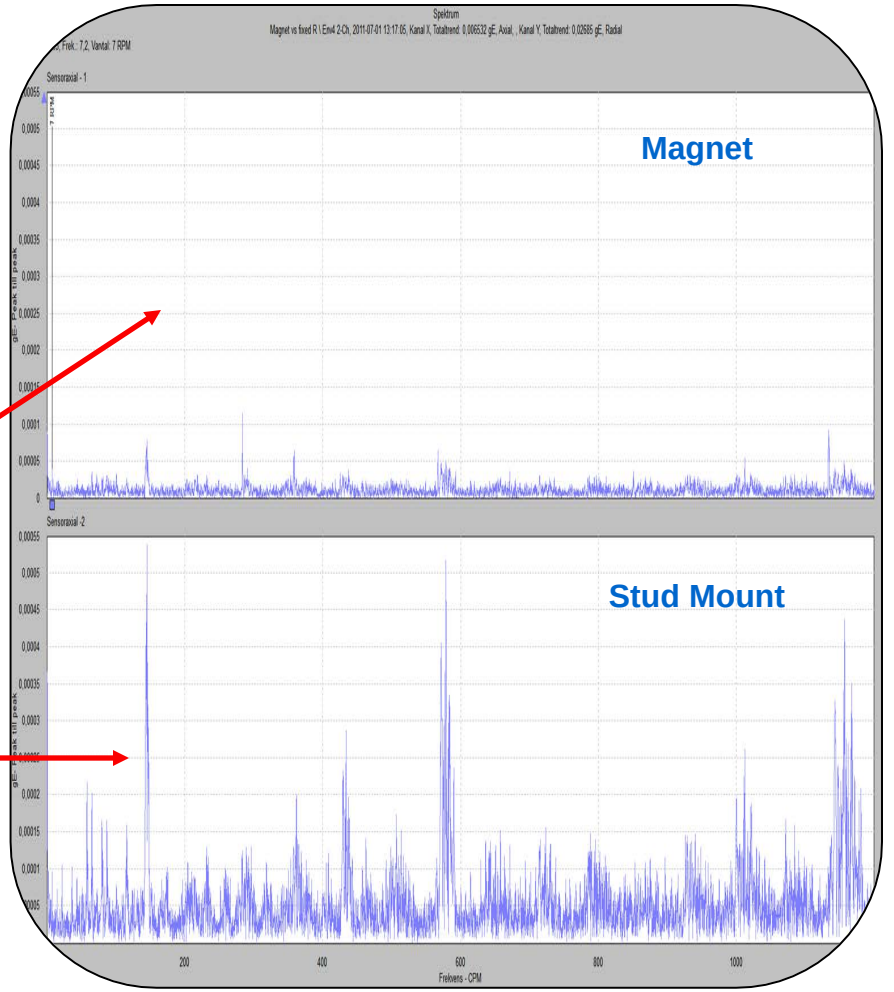
Noise from e.g. gearmesh can be in this area

Sensor mounting makes a big difference

- Here is an comparison between data recorded from two identical 100mV/g ring-mode sensors:
  - One mounted by drill & tap/stud
  - One mounted by magnet.

- This is true for most measurements, but particularly so for slow speed machines.

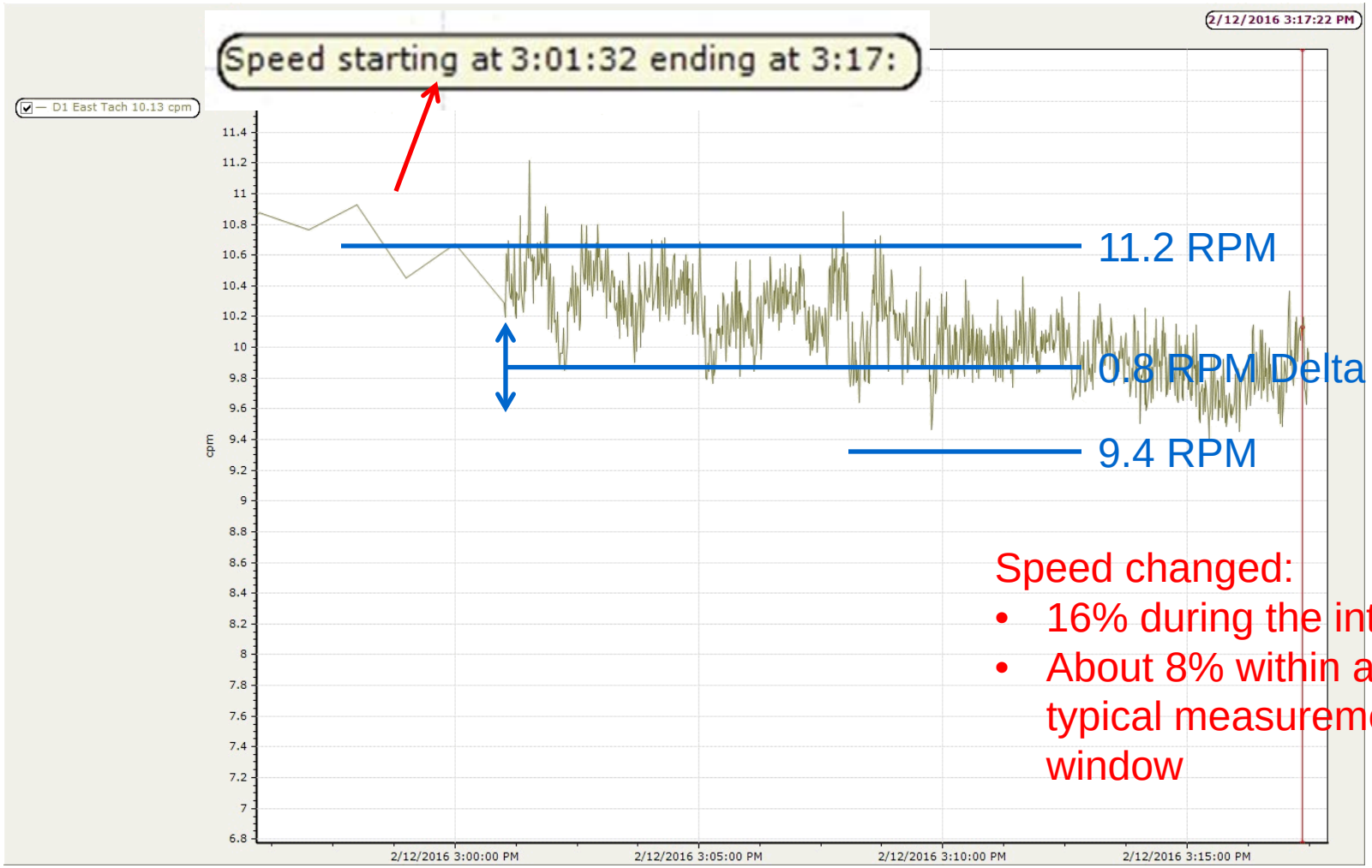




Constant speed?

- With low speed machines
  - Measurement times are longer
  - Typically we would like 10 – 15 events during the measurement time
- Constant speed
  - With long measurement times,
  - Slow variations in the speed can mask bearing frequencies

Speed variation over 16 minutes



Speed changed:

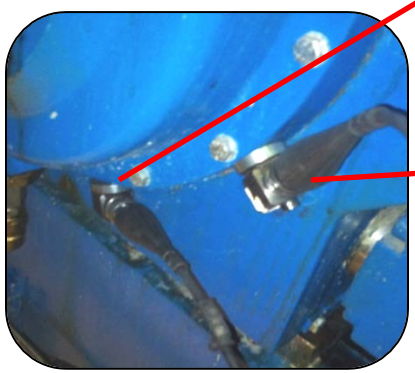
- 16% during the interval
- About 8% within a typical measurement window

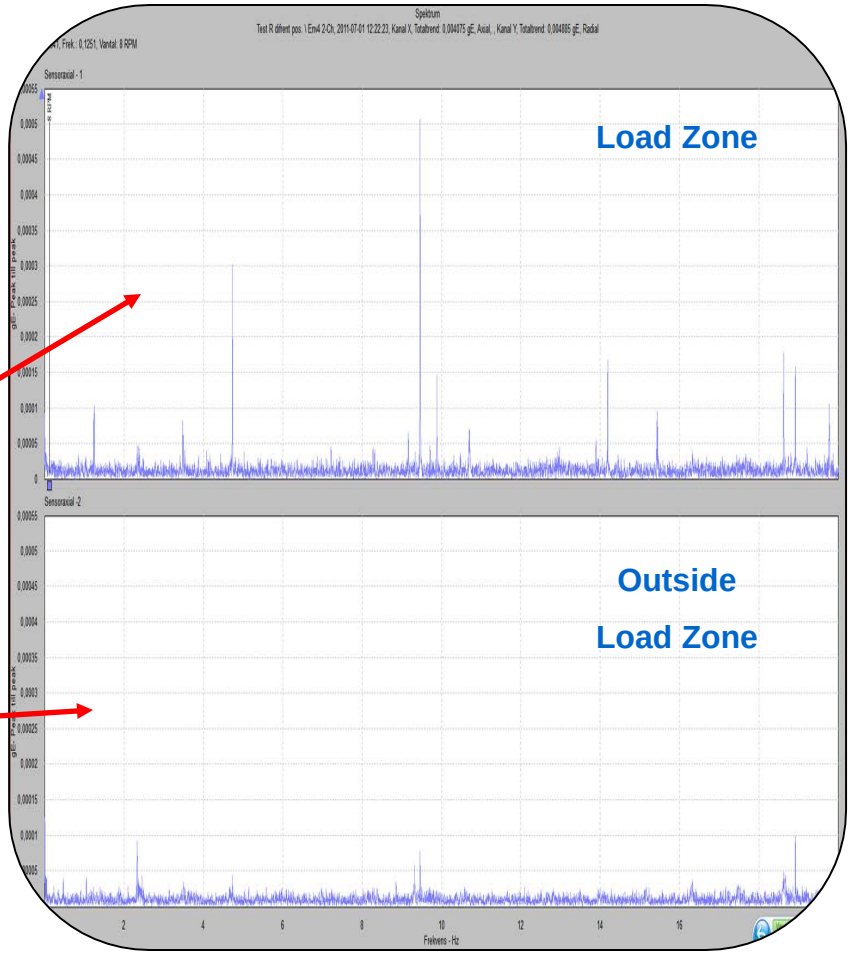
Sensor Location

- Small signals
  - Mounting the sensor will make some difference

Sensors – Load Zone

- The next consideration is location of the sensor – as close to the load zone of the bearing as possible.
- Again, here is an illustration.





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SKF Innovation in monitoring and tribology measurements

SKF bearing monitoring highlights

- Developed High-frequency detection technique (1990s)
- Pioneered the use of multi-filter acceleration enveloping in data collection devices (1990s)
- Patented (1985) and developed the use of practical acoustic emission measurements using data collectors, in order to use frequency analysis for diagnostics (1990s)
- Developed and patented HAL and CTA (2000s)
- Developed an patented RFT (Repetitive Fourier Transform)
- Developed Acoustic Emission Enveloping;
  - conducted extensive testing in relation to lubrication and bearing life

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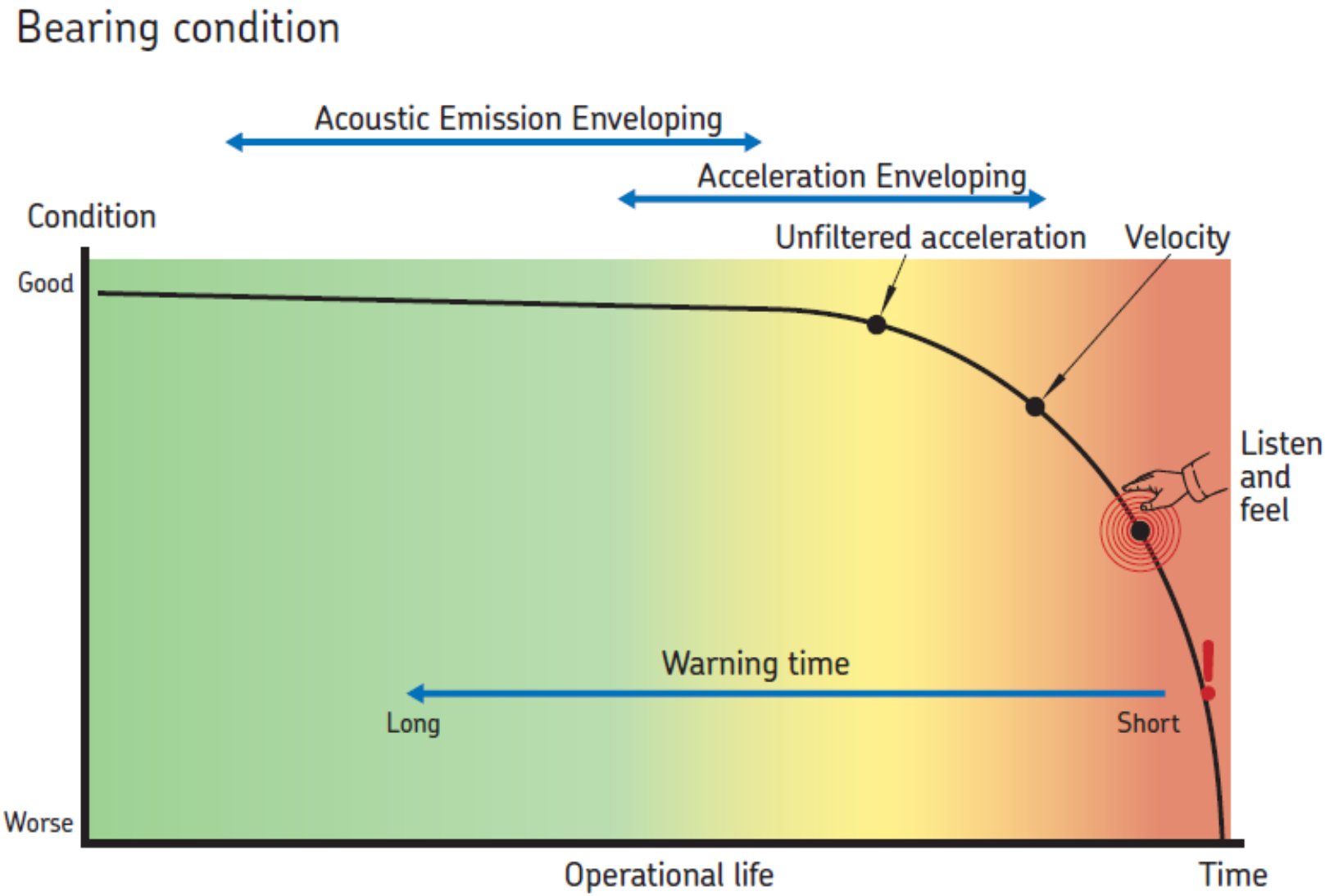
SKF Multi parameter measurements

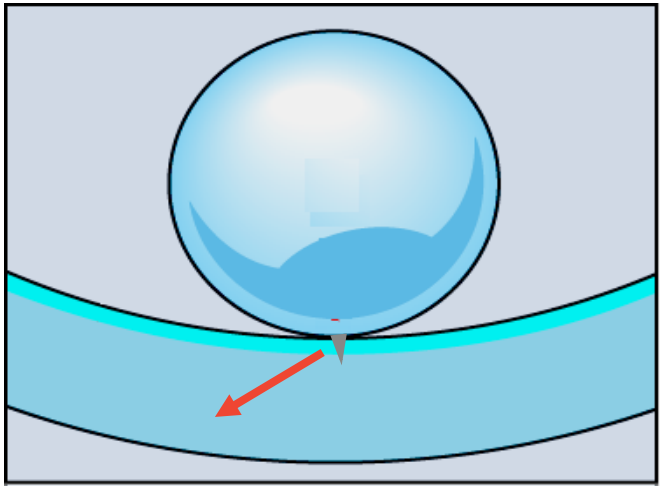
Multi-parameter measurements



Impact signals

Where do those bursts of energy come from?

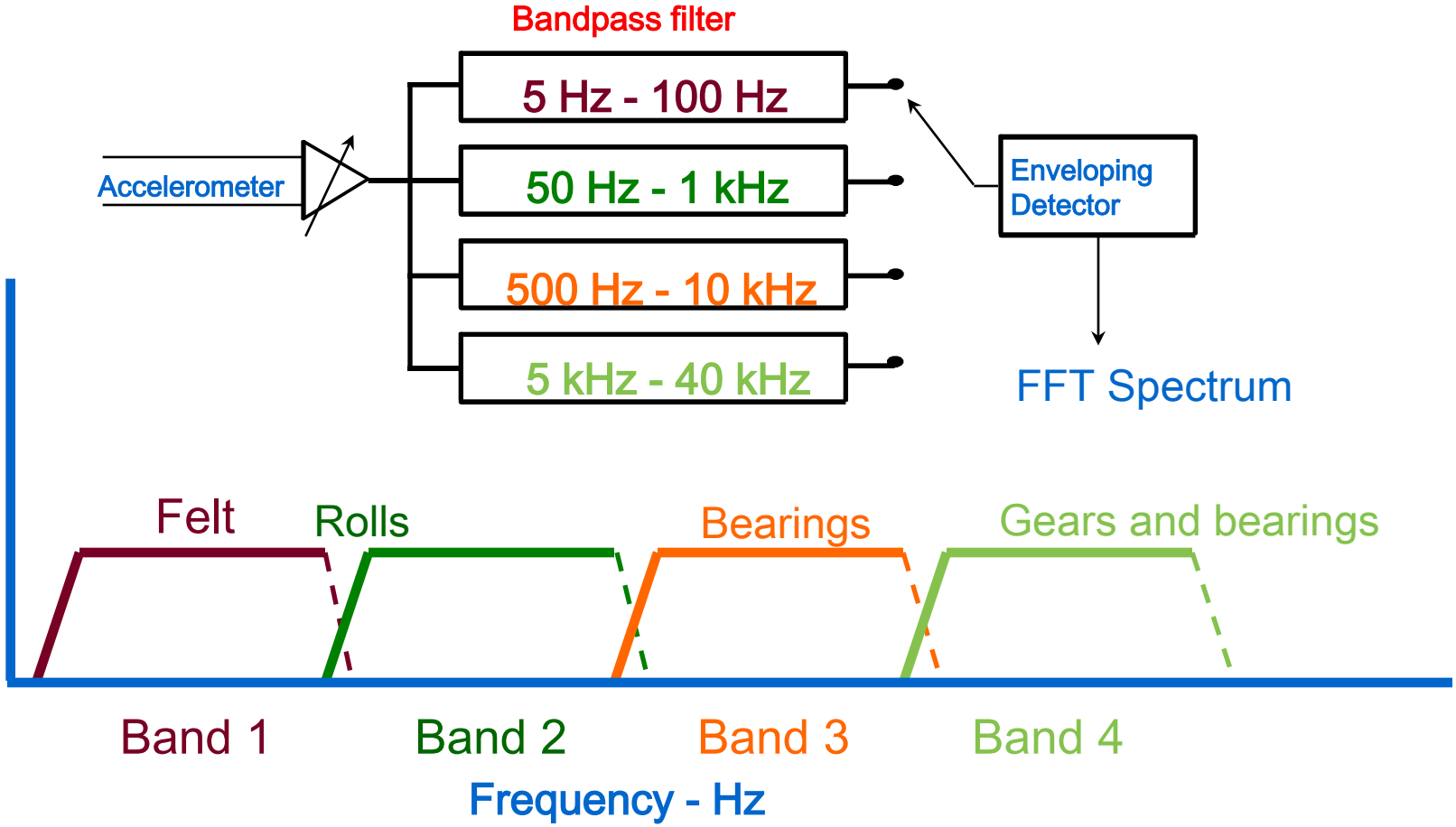
- Impacts – for instance, a rolling element rolling over a pit (defect)



- Impact signals have a high frequency content
- These impacts can excite a resonance

gE Filter Selection

The acceleration enveloping process groups energy related to repetitive impulsive signals



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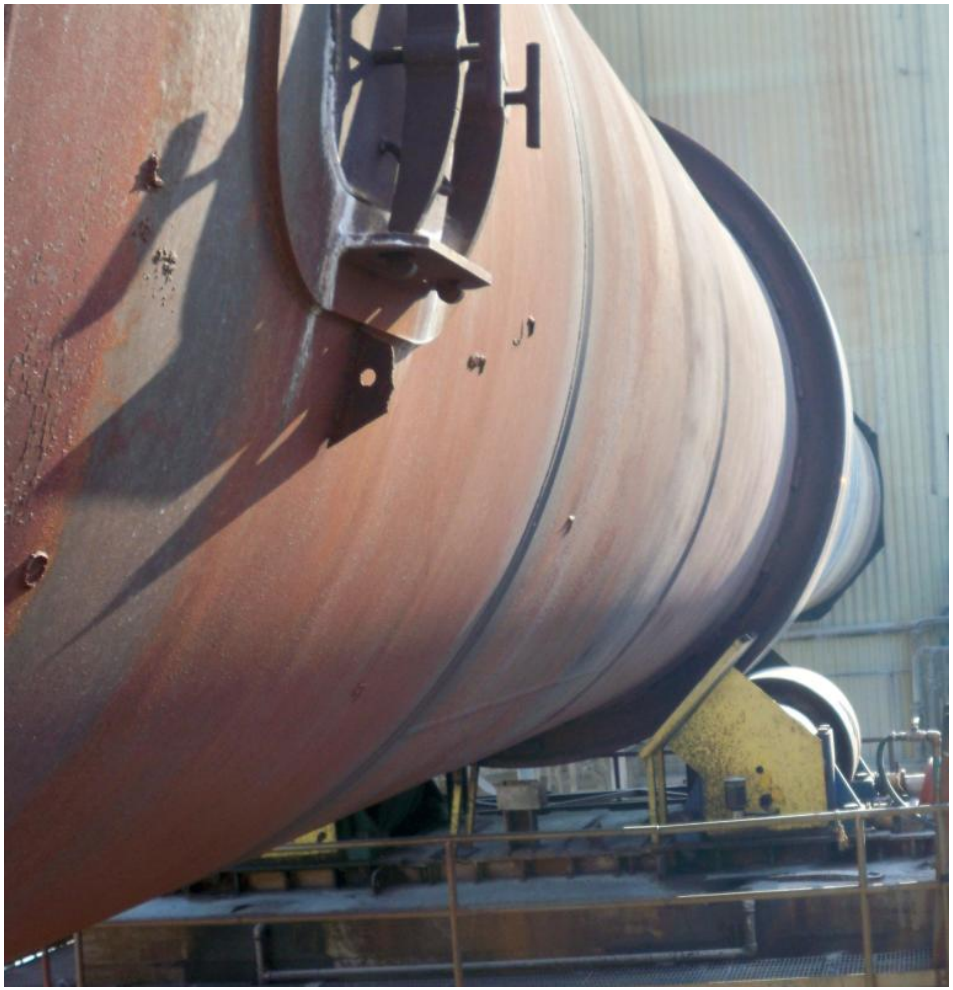
Case history / examples

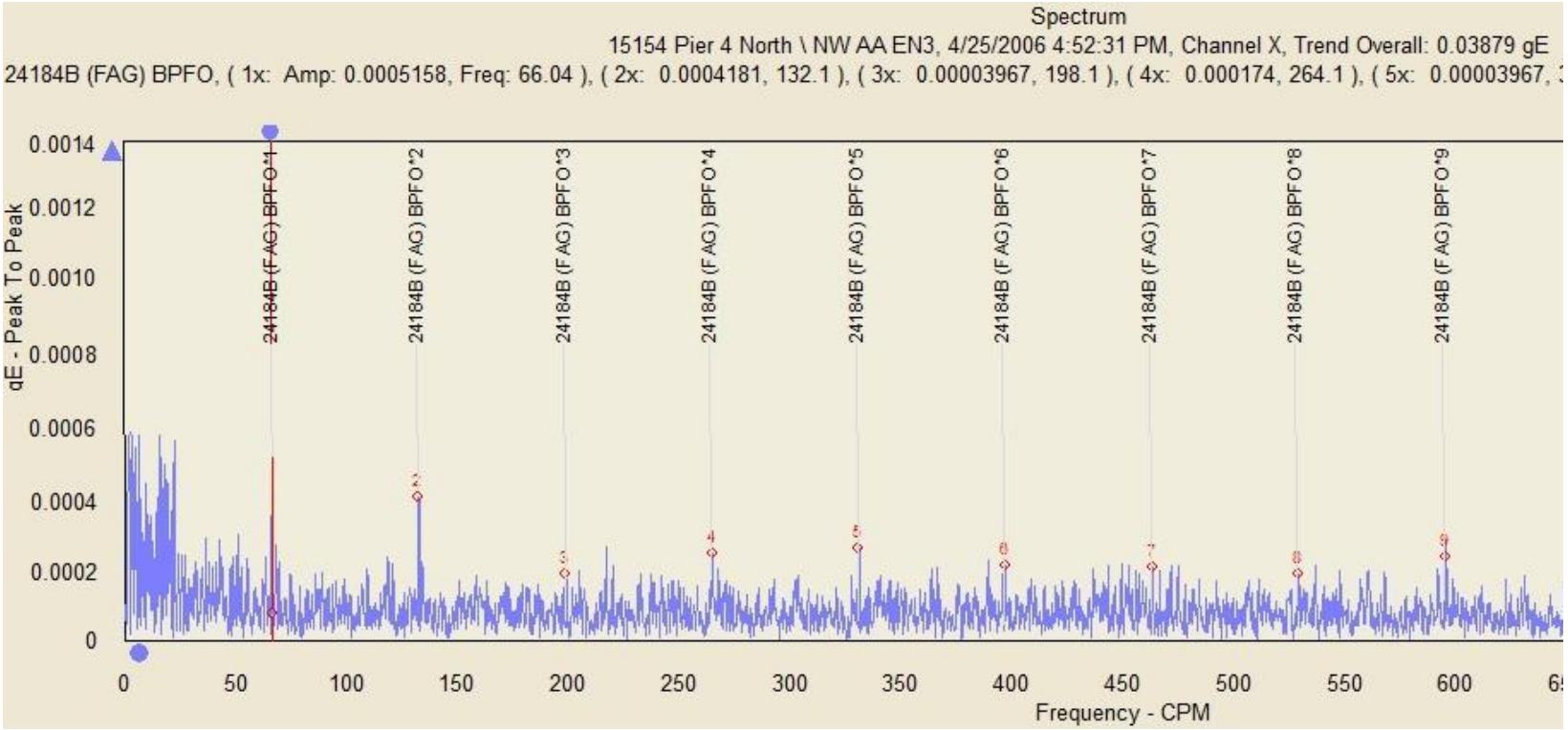
Case 1: Low, steady speed



This Lime Kiln Trunnion uses roller bearings that turn between 3 to 6 RPM

For years the predictive team at this facility tried to predict failures with no success.

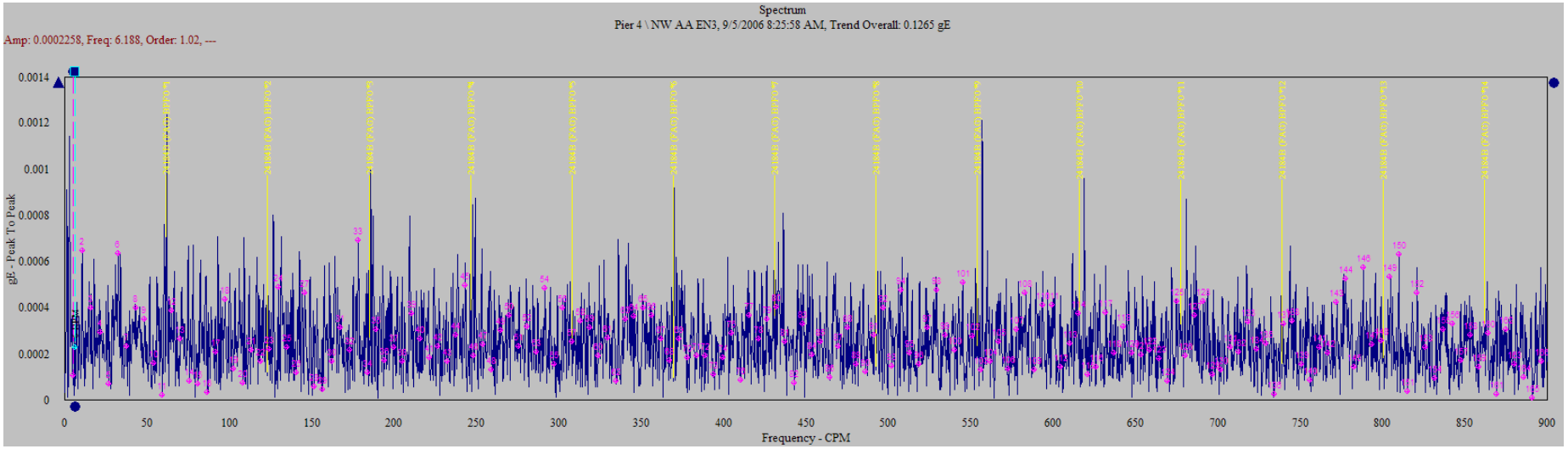
Early Detection of Very Slow Speed Defects

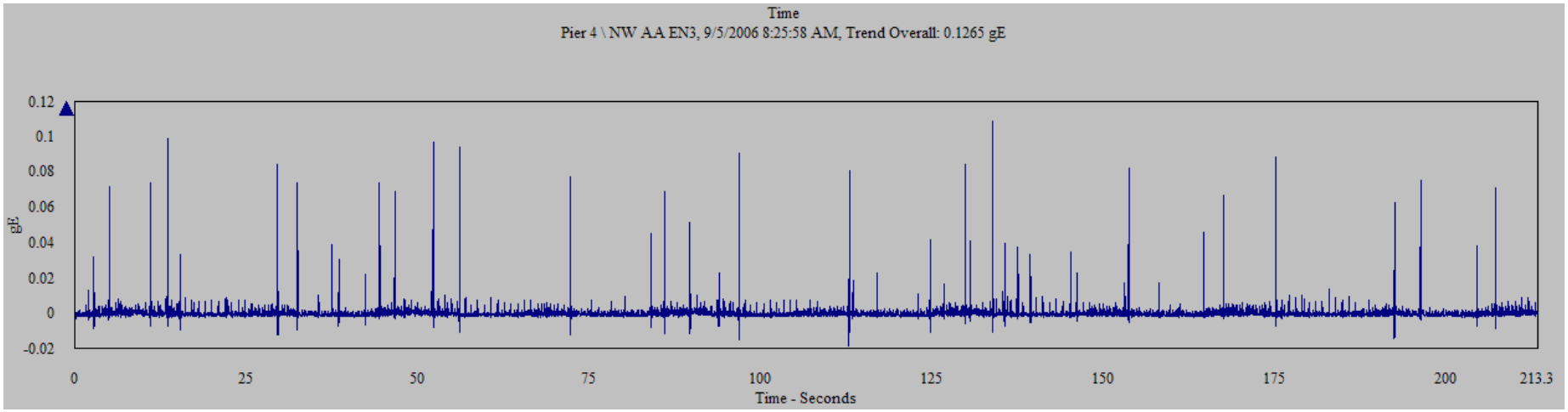


SKF Enveloped Acceleration detected the problem nearly 6 months before the bearing was removed from service.

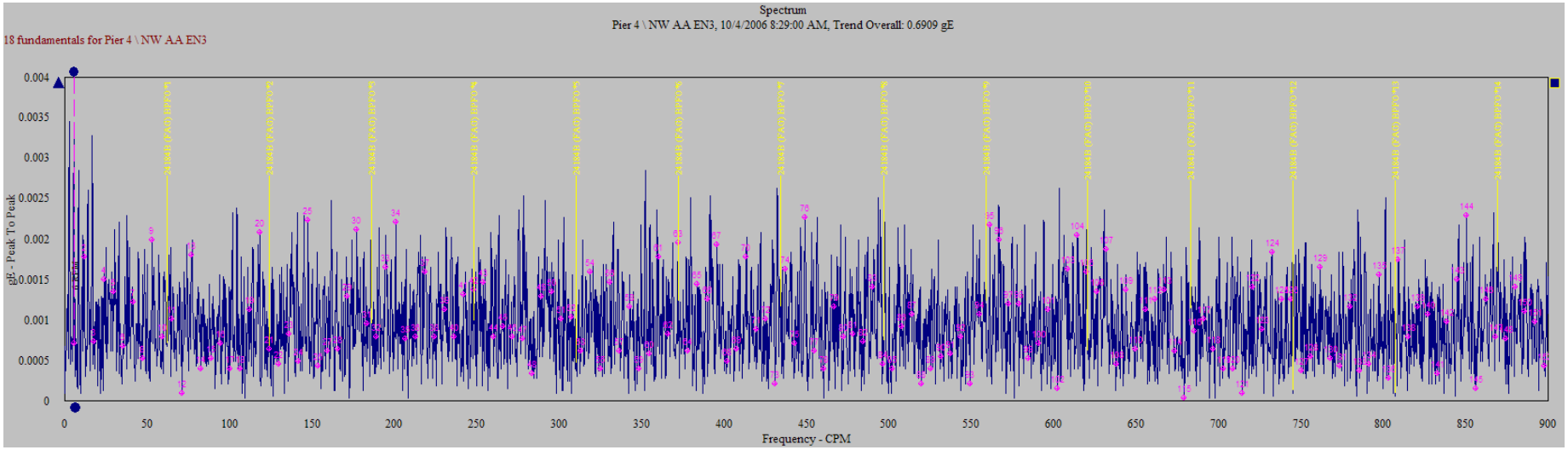
We watched it due to production schedule.

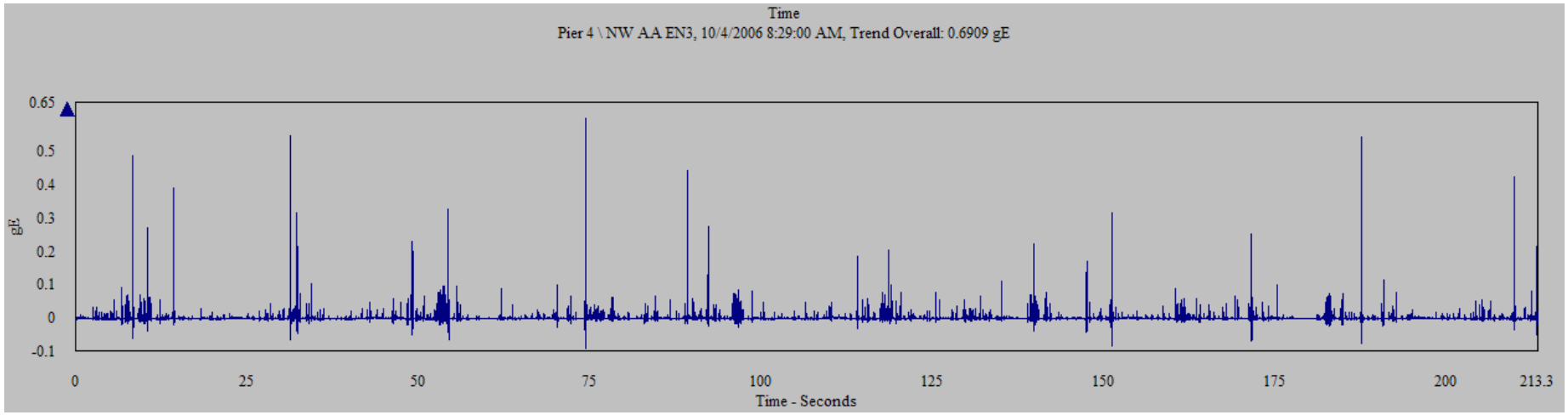
Sept 5- 5 months after initial detection





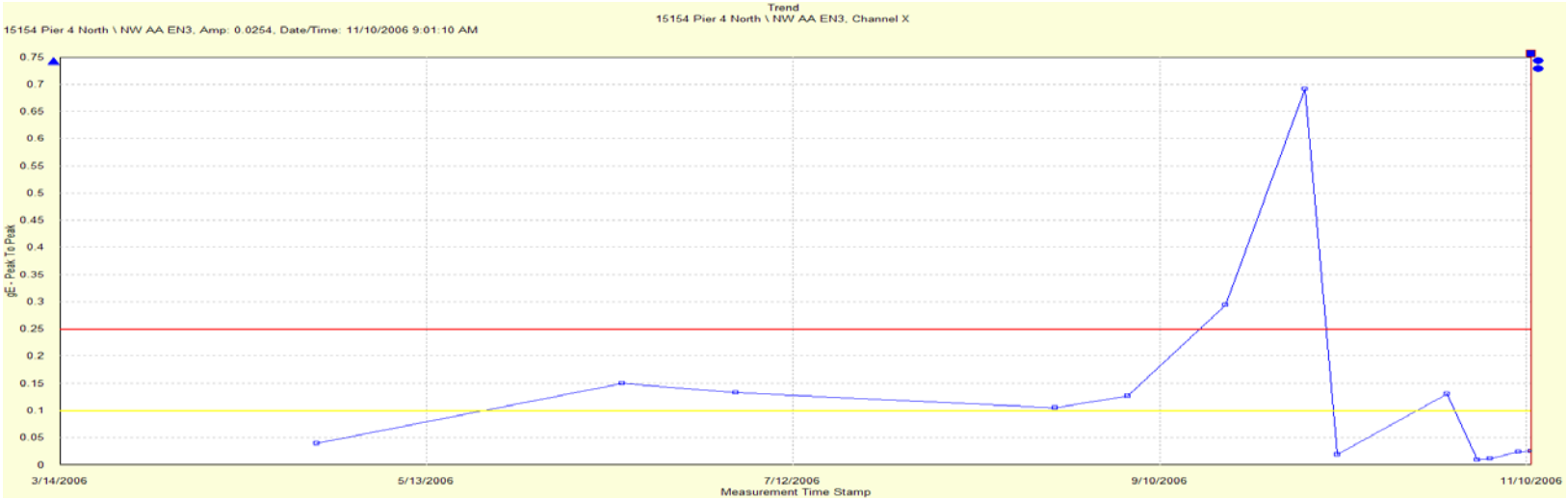
Oct 4- Failure is imminent





The FFT has no discernable peaks, but the overall is much higher now.

Trendable results aid in predicting time of failure



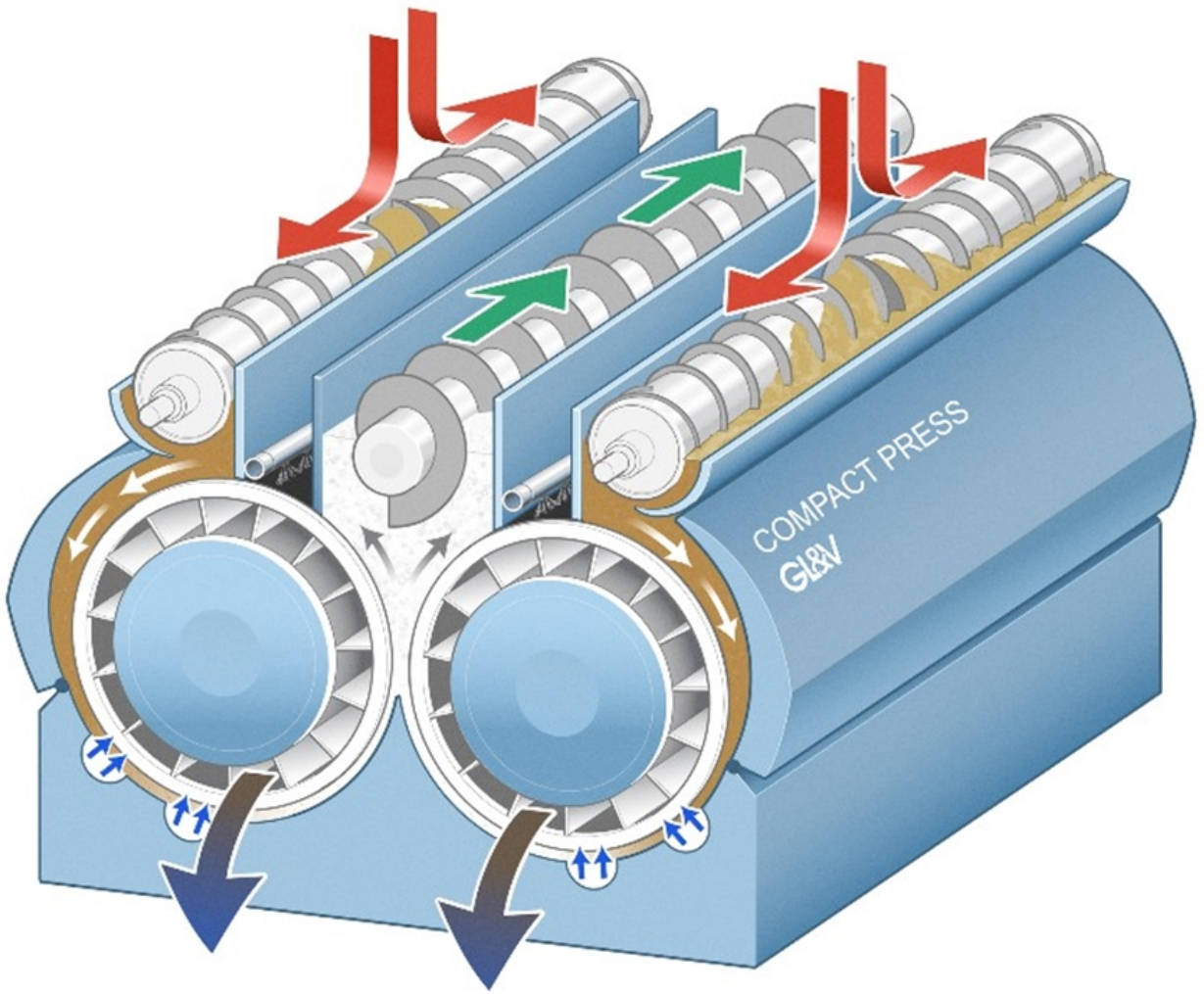
Signal processing filters selected properly- 30K-600Kcpm for bearings.

Database setup for several rotations of the shaft.

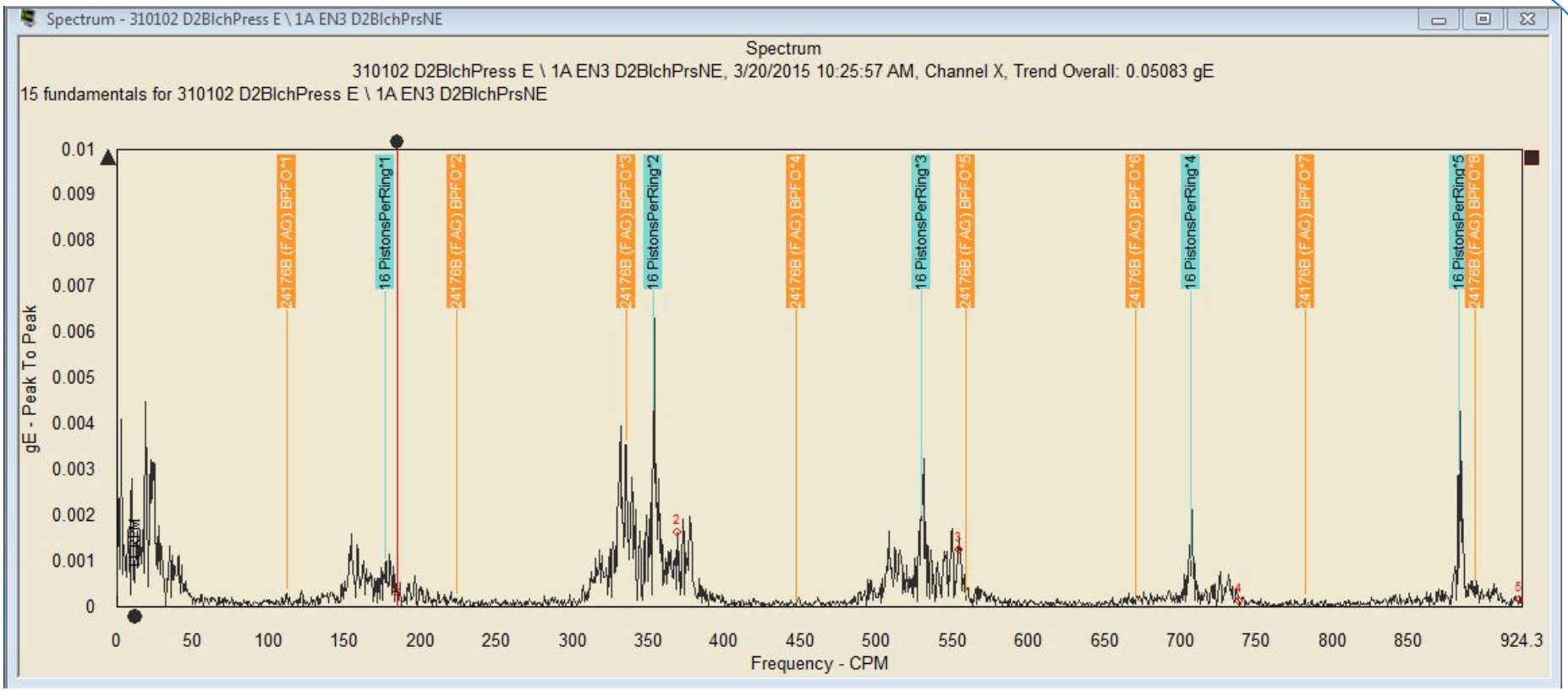
Appropriate choice of accelerometer and measurement location

Case 2 - Twin Roll Wash Press

What is a Twin Roll Wash Press?

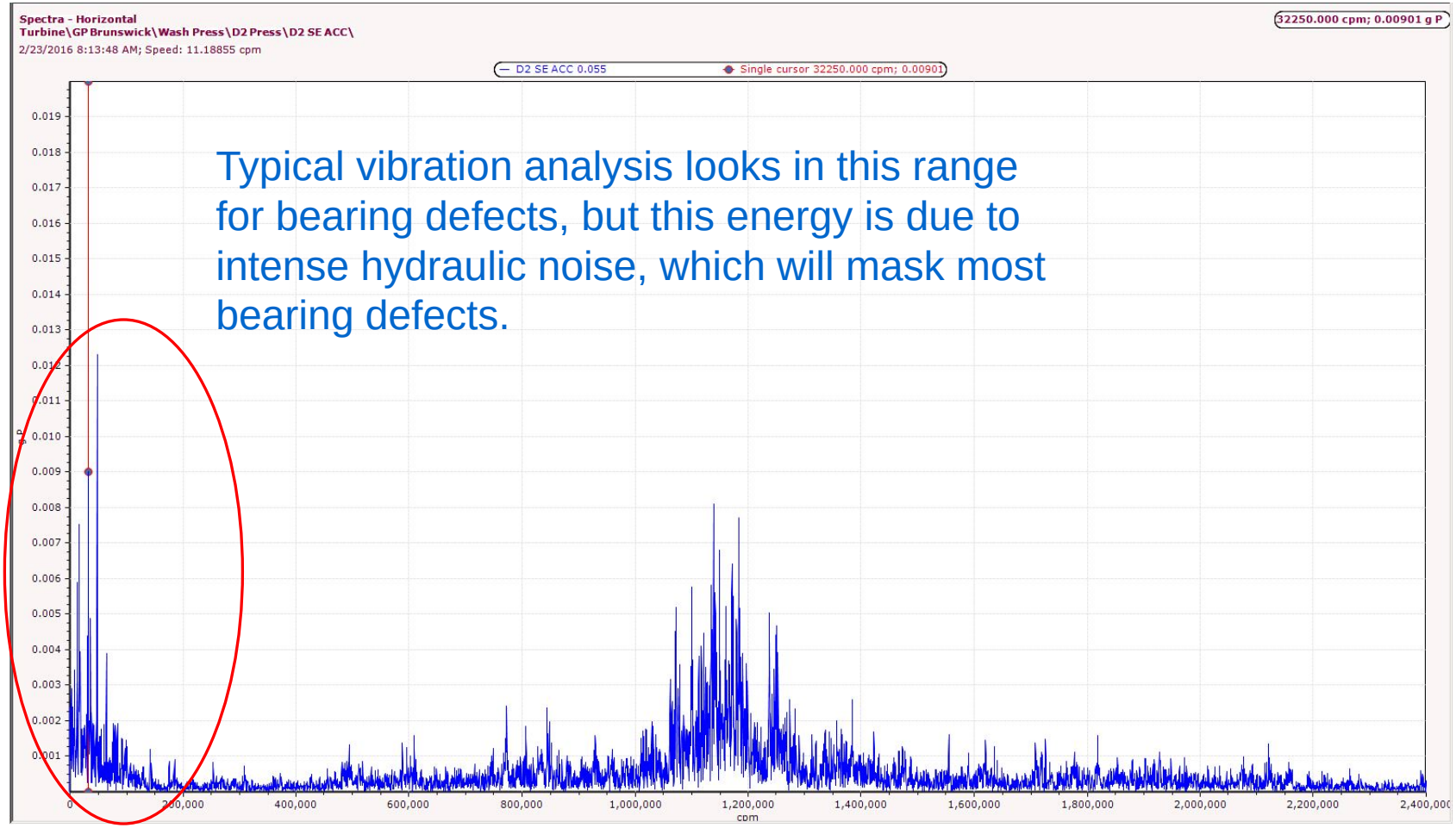


Wash Press vibration obscured by nuisance frequencies

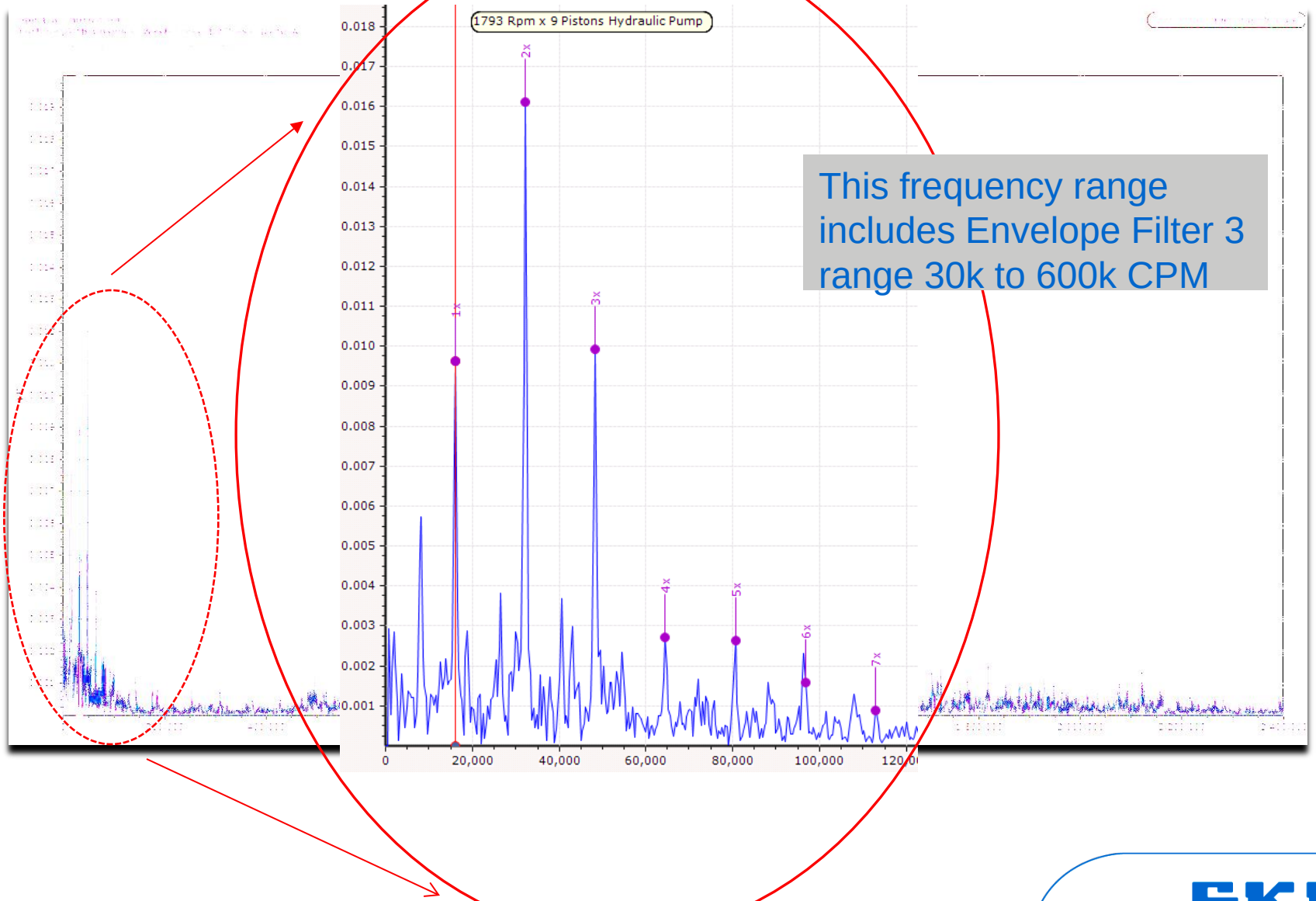


- Hydraulic noise dominates the frequency range of the Env3 filter.
- The speed varies constantly while collecting data
  - indicated by wide skirts around the hydraulic pulsation energy.
- We will need to apply IMx Order Tracking.

Full range spectrum shows areas of interest

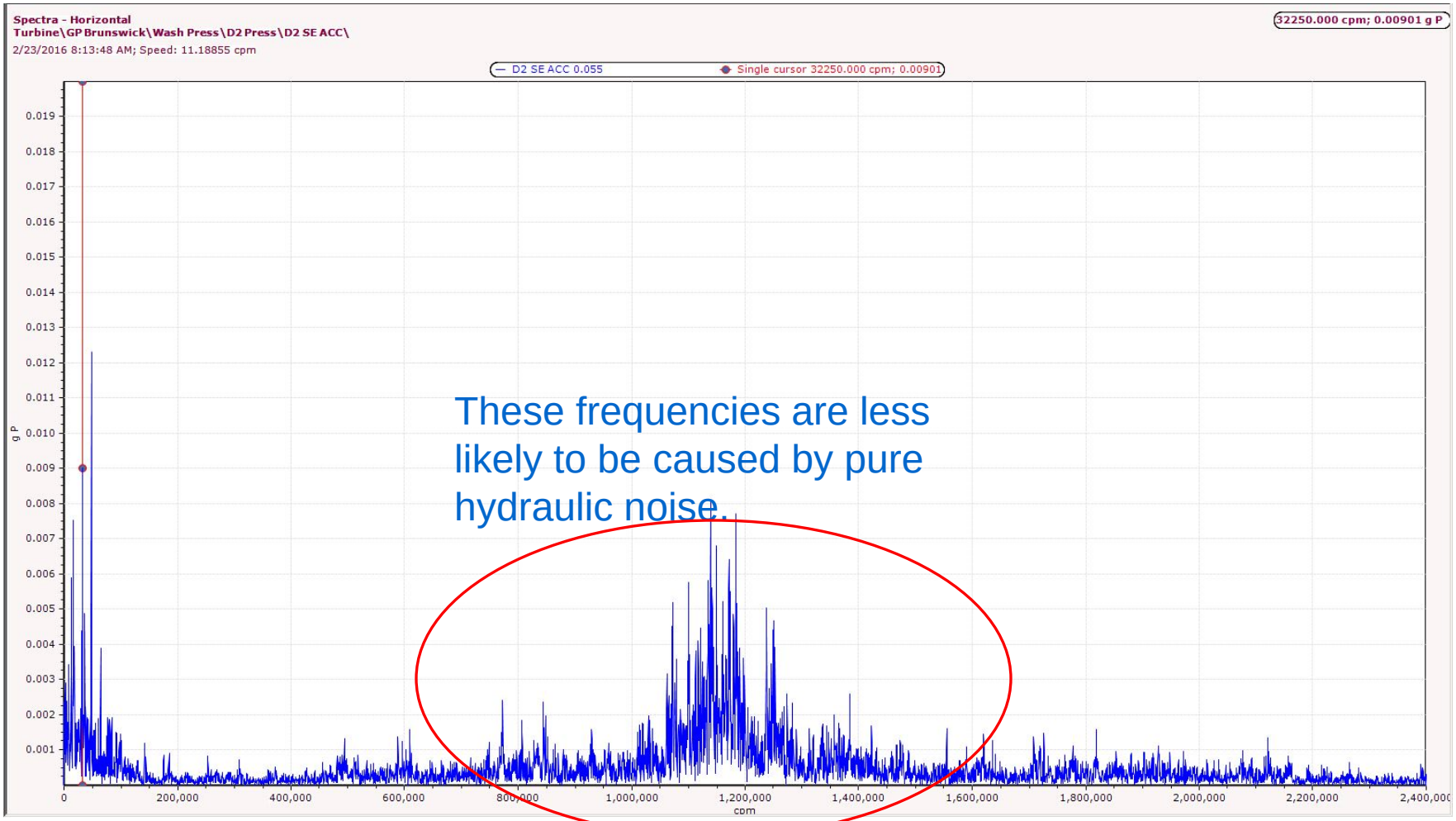


Hydraulic noise dominates lower frequencies



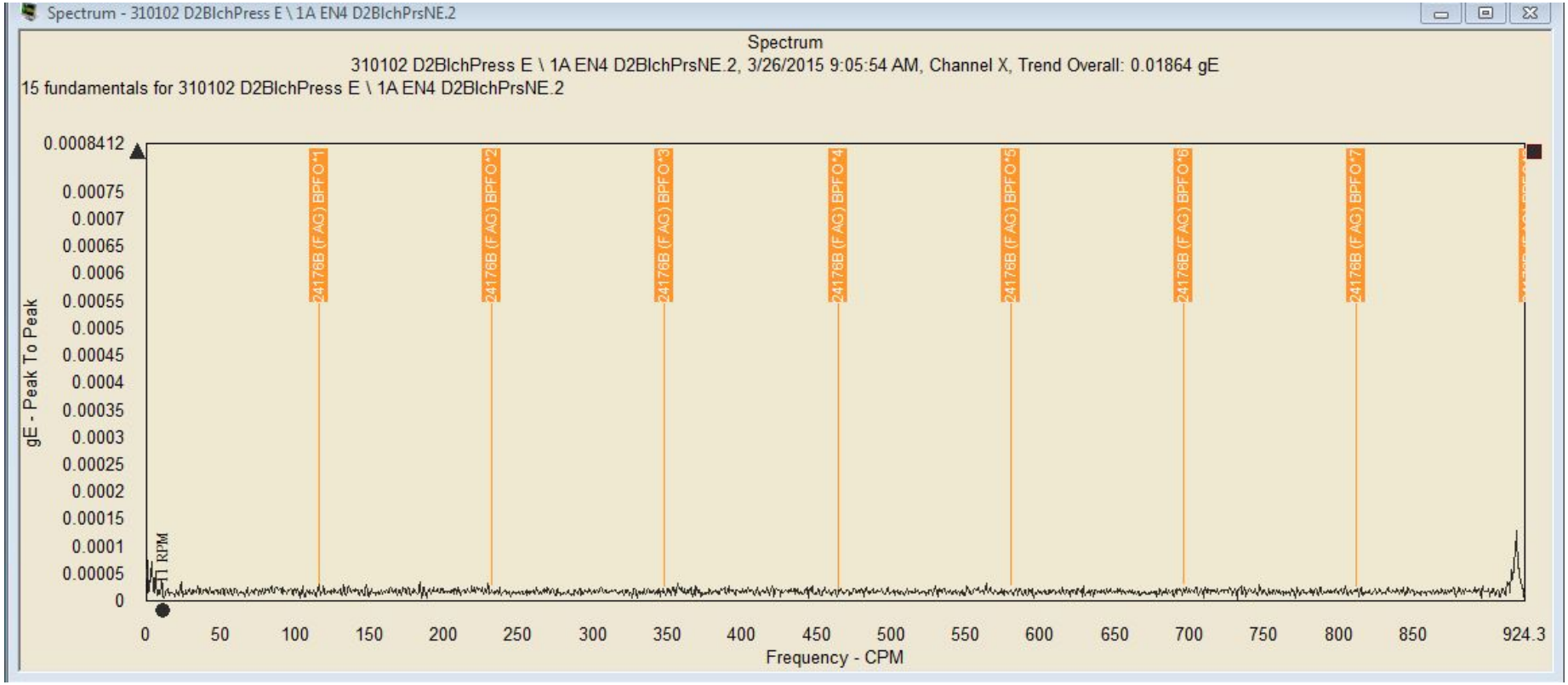
This frequency range includes Envelope Filter 3 range 30k to 600k CPM

Point setup based on frequency distribution



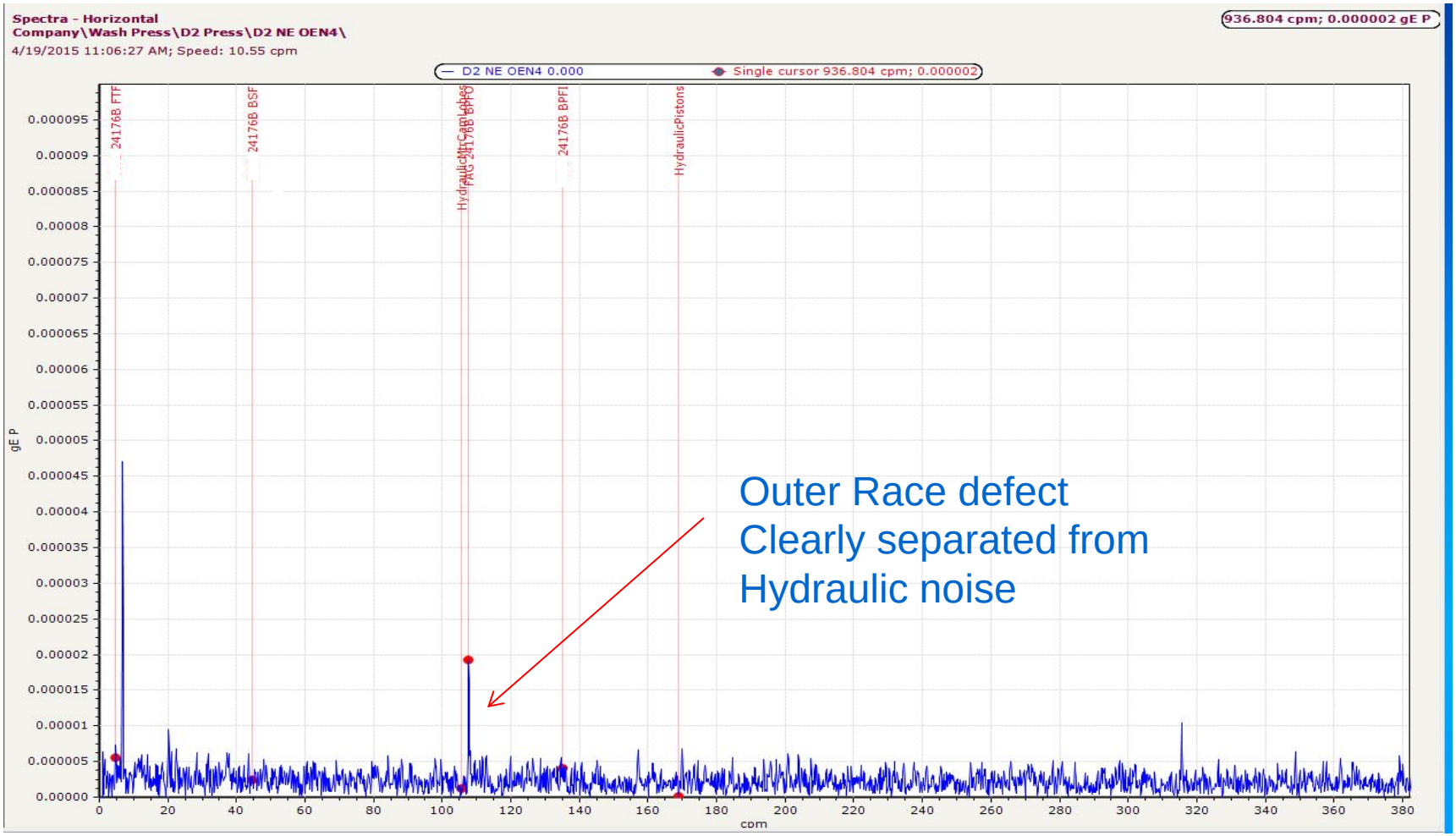
Envelope Filter 4 is good choice to remove the hydraulic noise but leaves energy from bearing defects.

Vibration peaks obscured



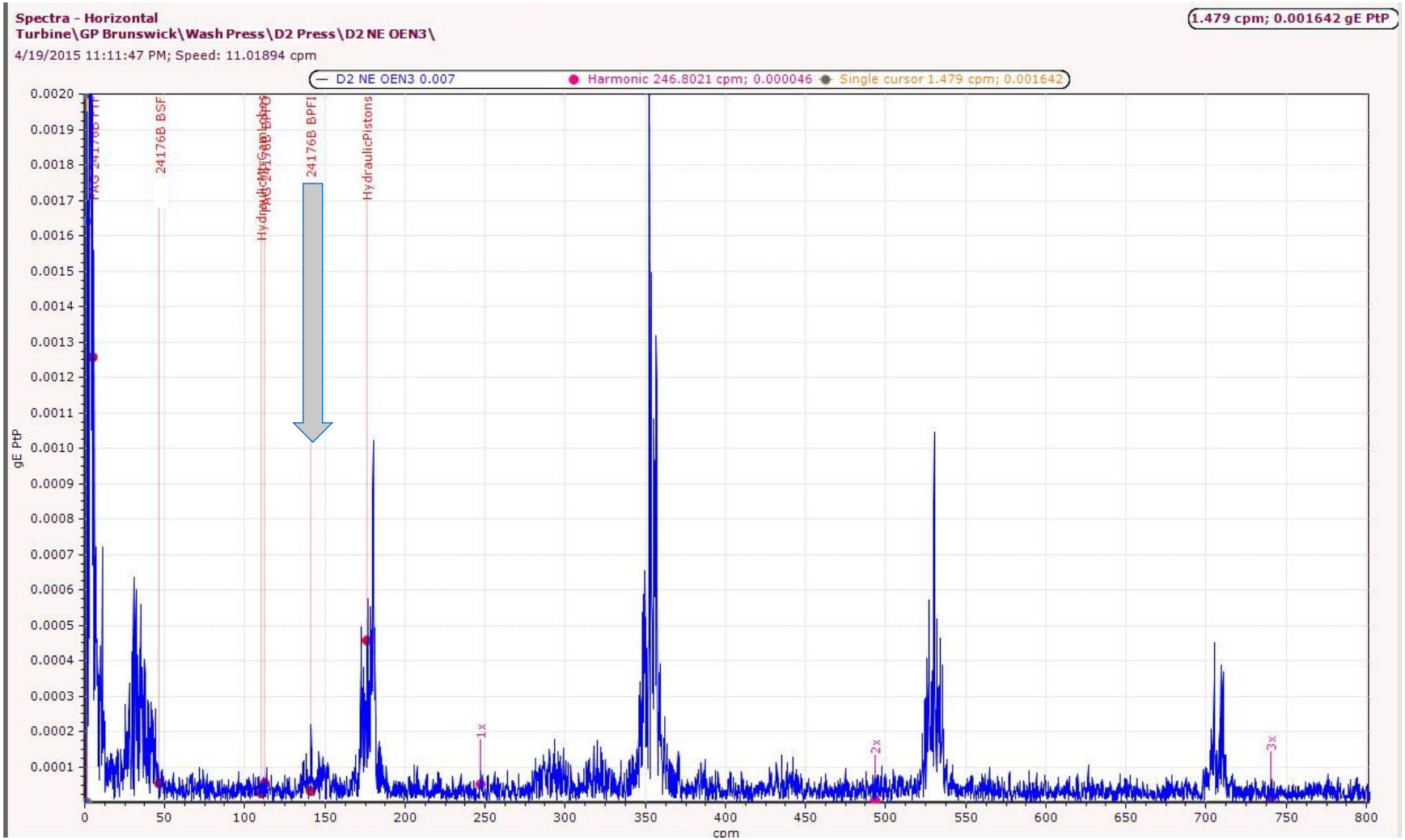
Envelope Filter 4 has been applied but still no bearing defects appear.
The machine speed varies during the Measurement time

Drive Side Bearing- Outer Race defect identified



This clean data was collected by using envelope band 4 filtering.
Additionally, SKF's IMx Real Time Order tracking was applied.

Drive End Bearing- Inner Race defect identified



After removal- Outer Race defects

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Deep pits in both roller paths
through out load zone

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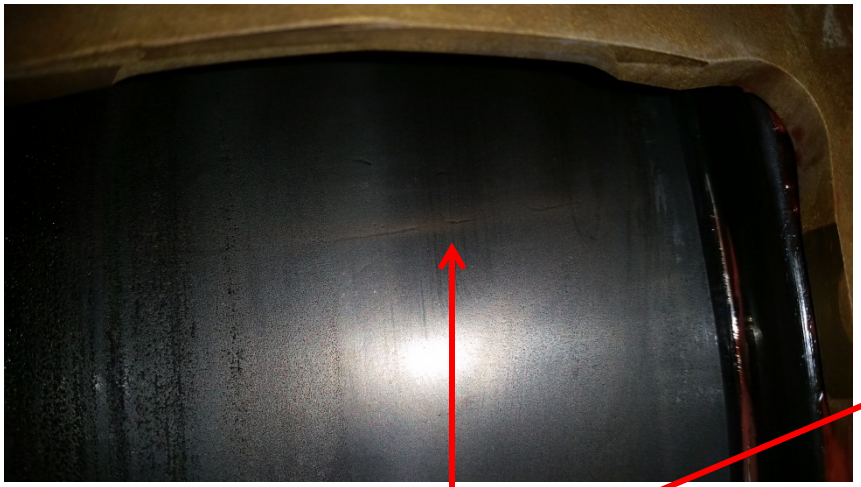
Inner Race, Press Side Roller Path



Press Side

Motor Side

Inner Race etching
at roller interfaces

Outboard edge
corrosion pitting

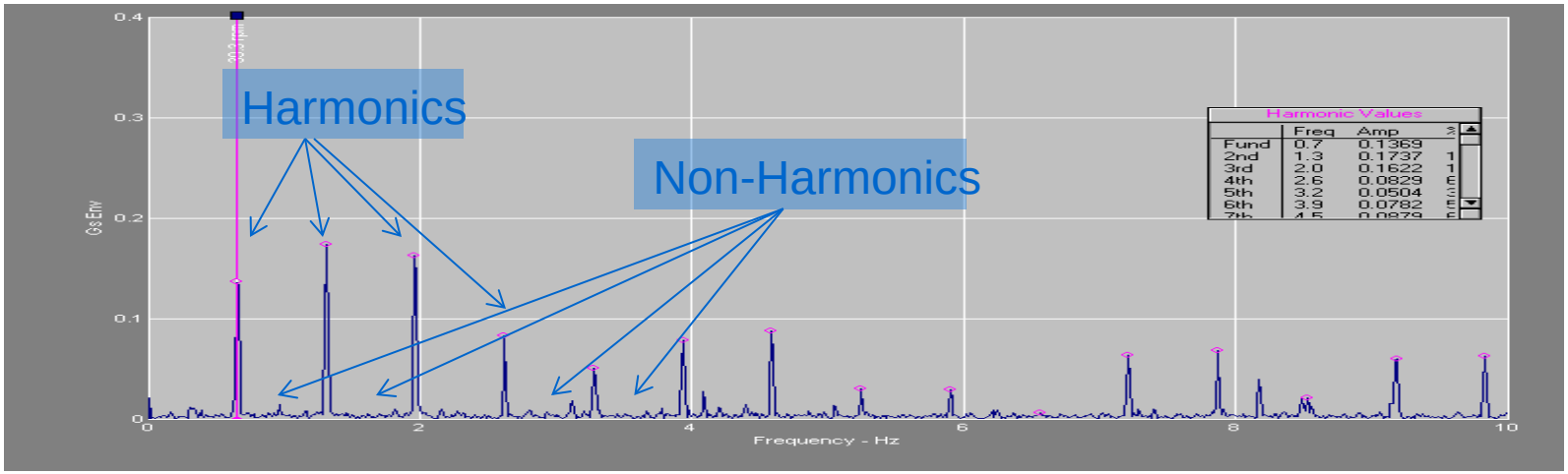
Press Side

Motor Side

5

New approaches

HAL/HAI – Harmonic Activity Index



Harmonic Content / Non-Harmonic Content

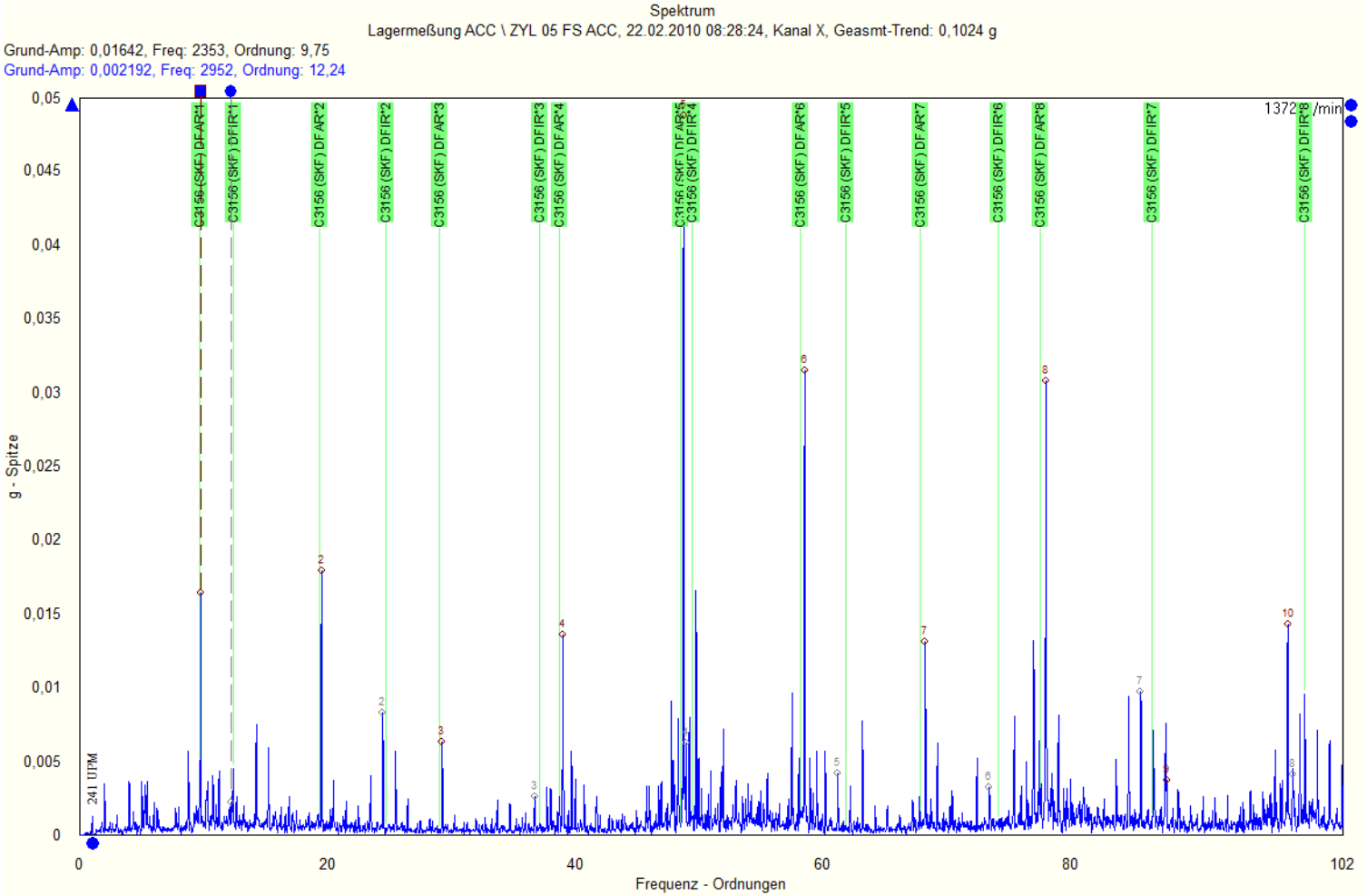
Dimensionless; more “universal” alarm set-up for example

- 1 – Clear
- ~2.5 – Alert
- ~5 and above – Danger

Set up as a derived POINT

SKF Patented Technology

Frequency spectrum



Example 3 : Dryer bearing

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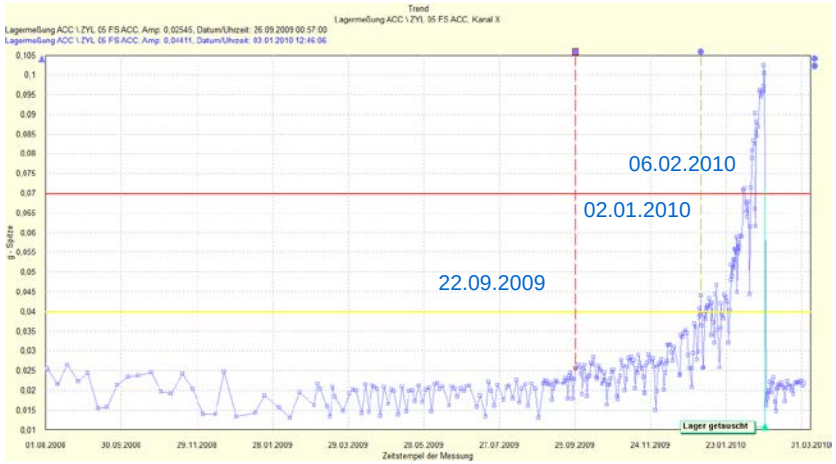
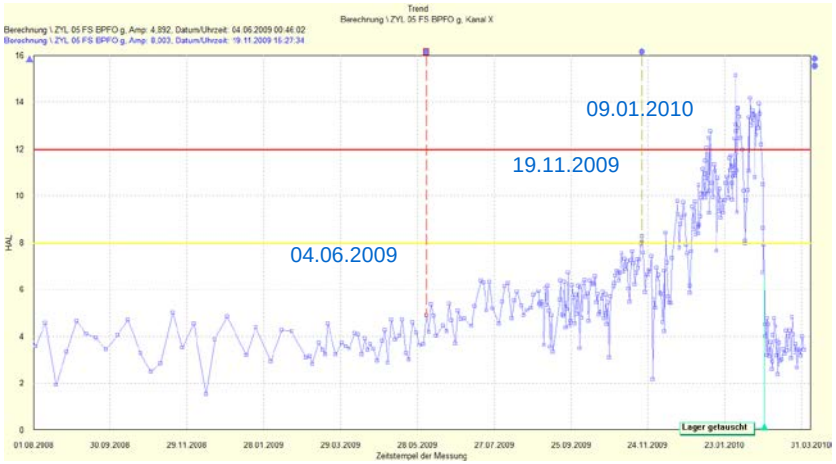
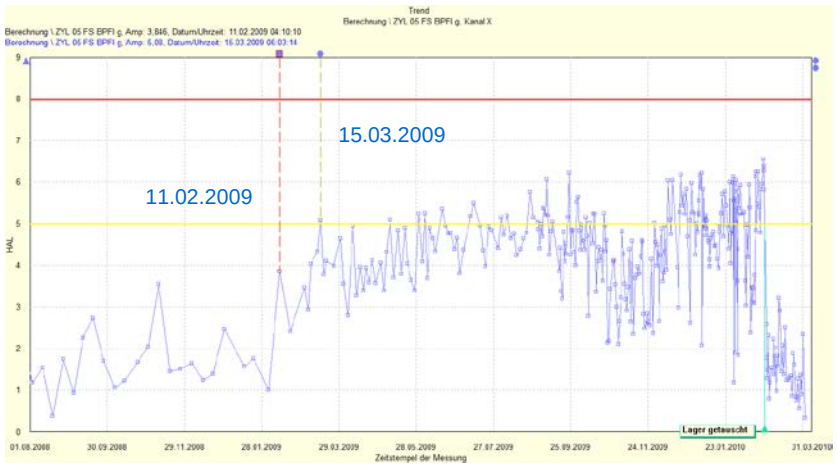
Vibration trend



HAL calculation of the outer ring frequency



HAL calculation of the inner ring frequency



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Example: Conti-press

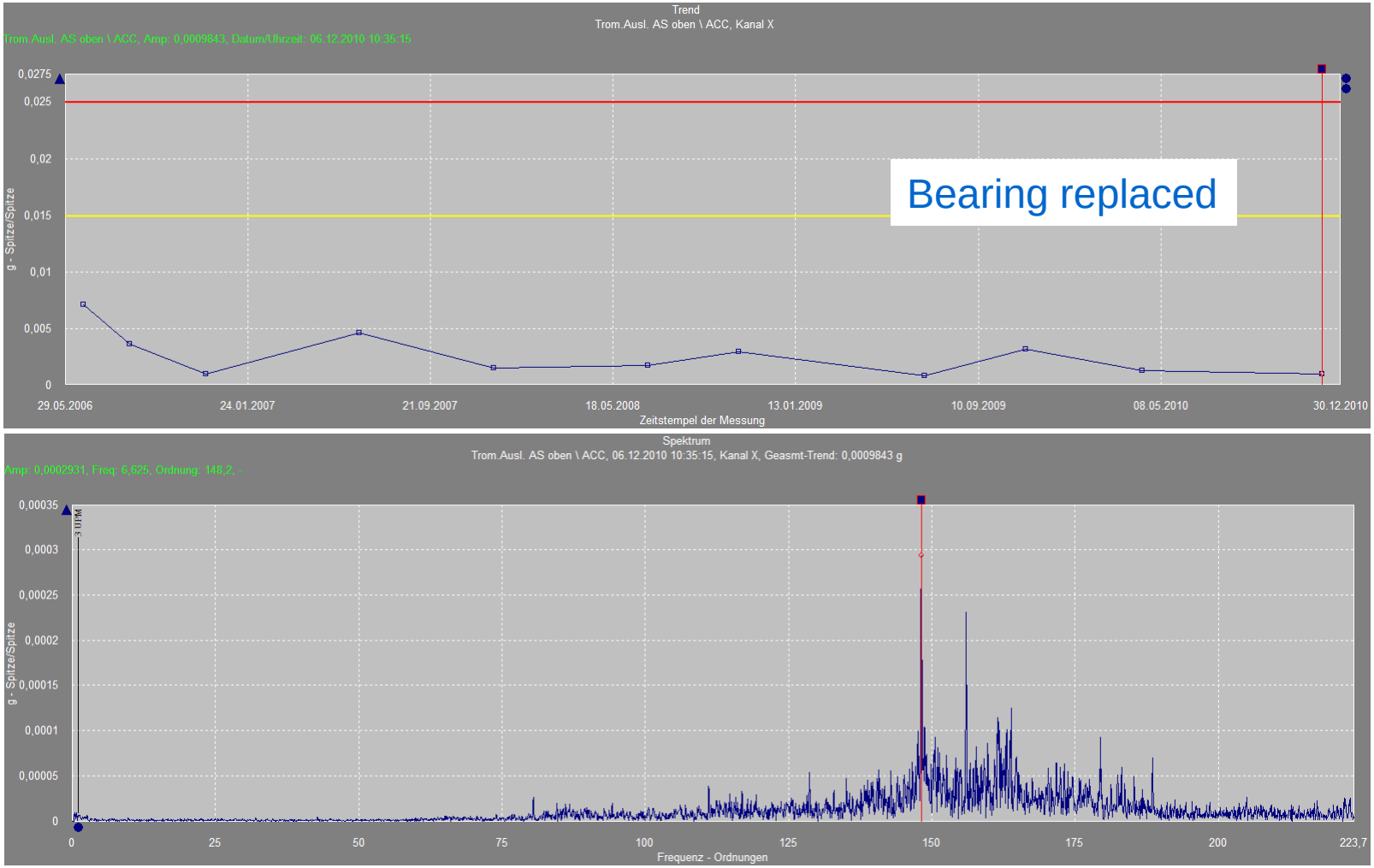
Conti-press

Speed main bearing: 3 – 7 rpm

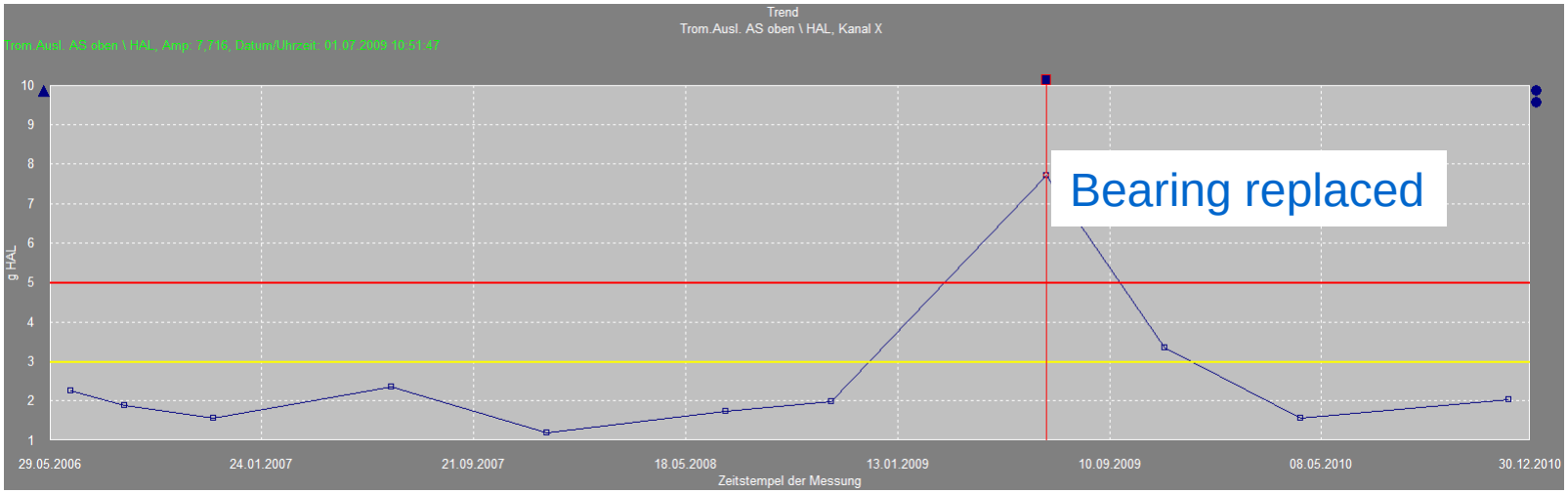
Bearing type: Spherical roller Bearing

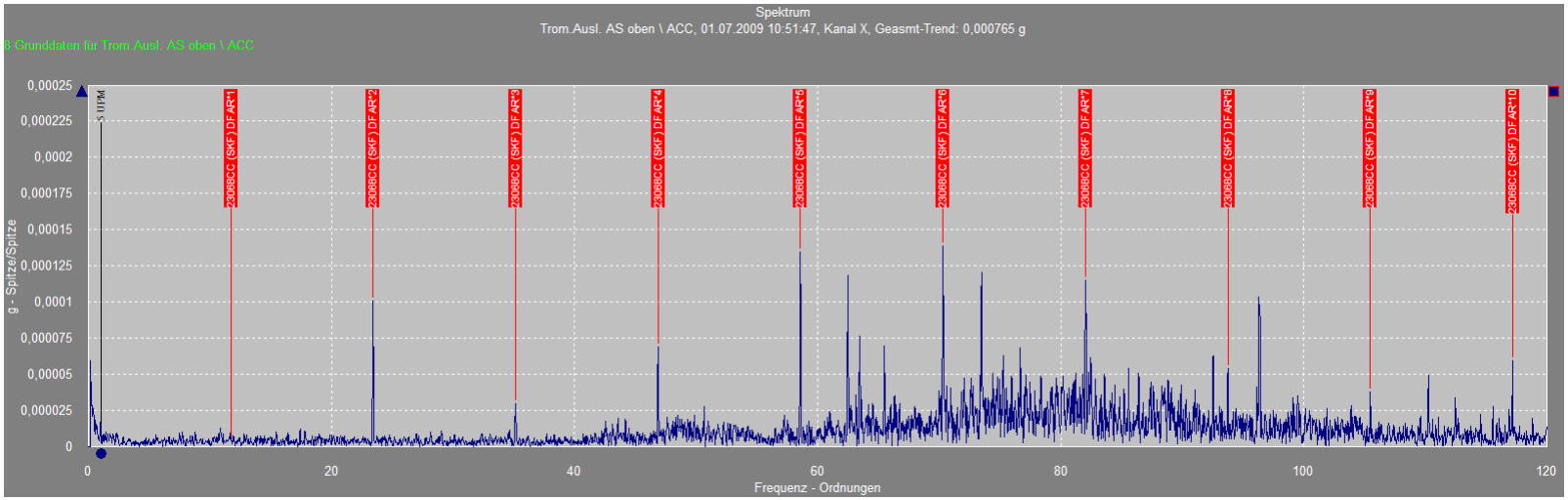
bearings

Trend with overall evaluation

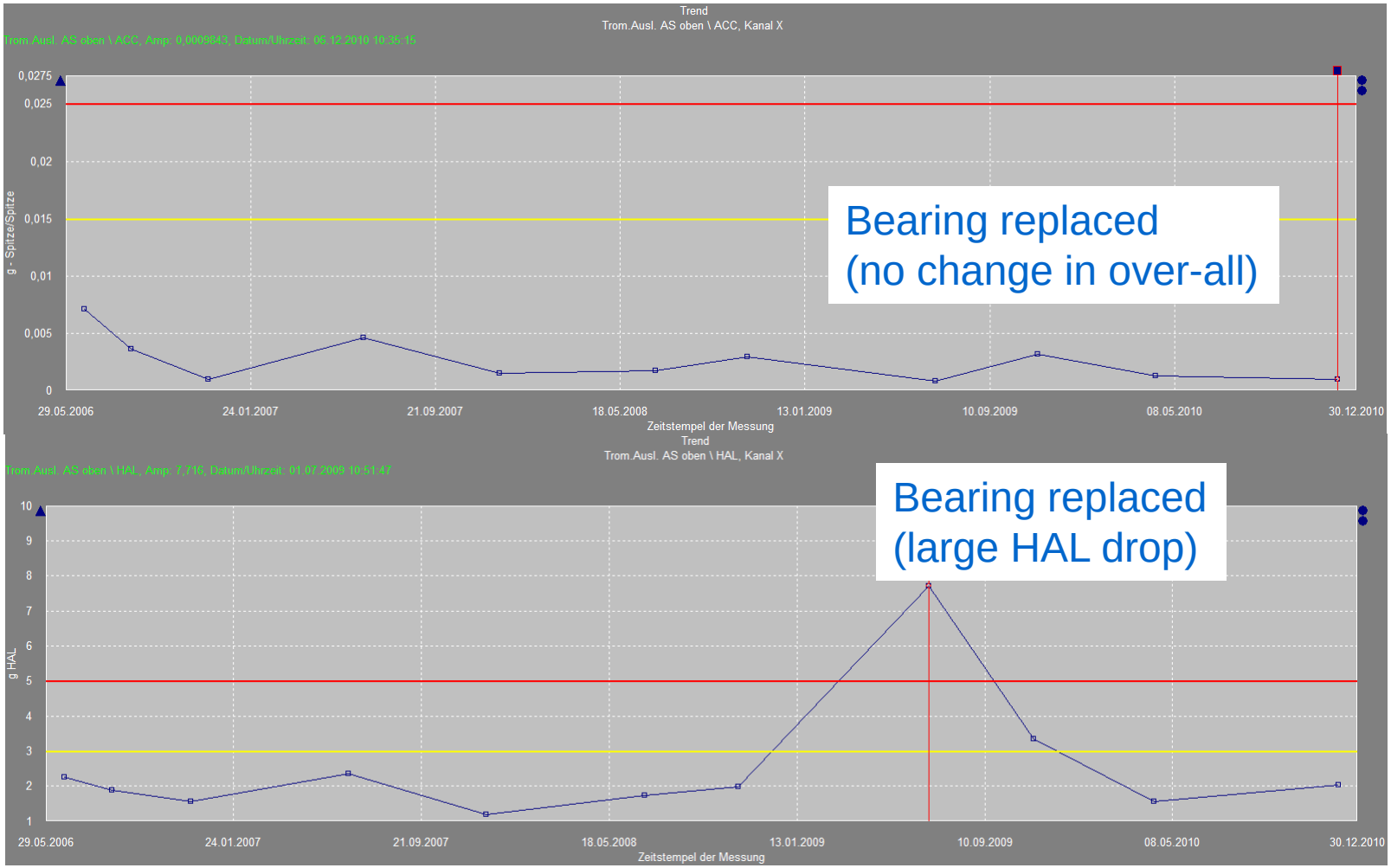


Trend with HAL evaluation





Comparison between overall and HAL evaluation



Bearing replaced (January 2010)

Early bearing failure detection

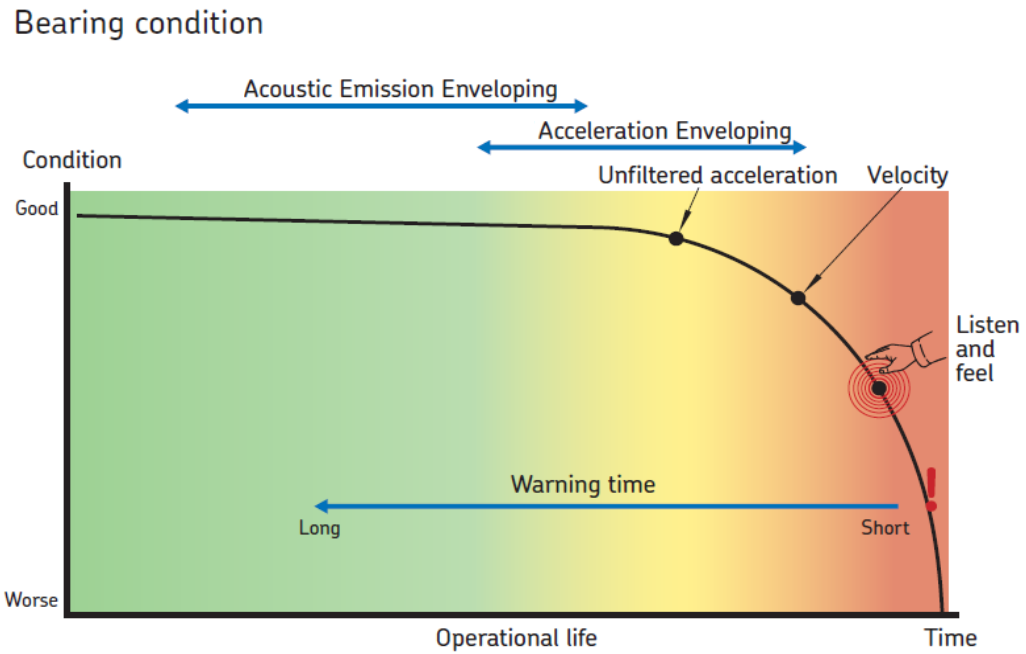
Typical bearing failure modes include:

- Fatigue ~34%
- Poor Lubrication ~36%
- Contamination ~14%
- Poor fitting ~16%

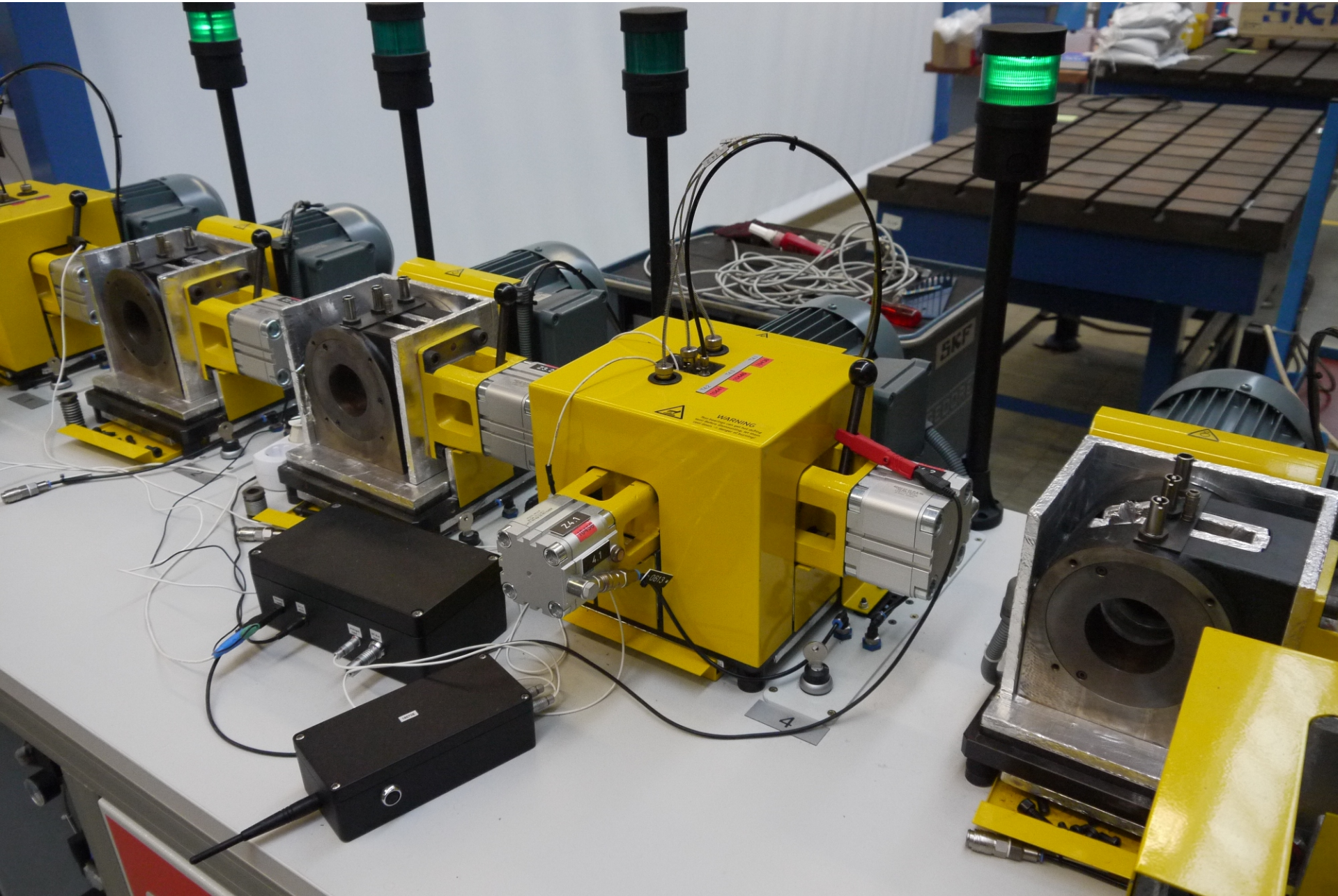
Poor Lubrication and Contamination results in ~50% of premature bearing failures!

Using a technique like AEE can help to detect poor lubrication and contamination.

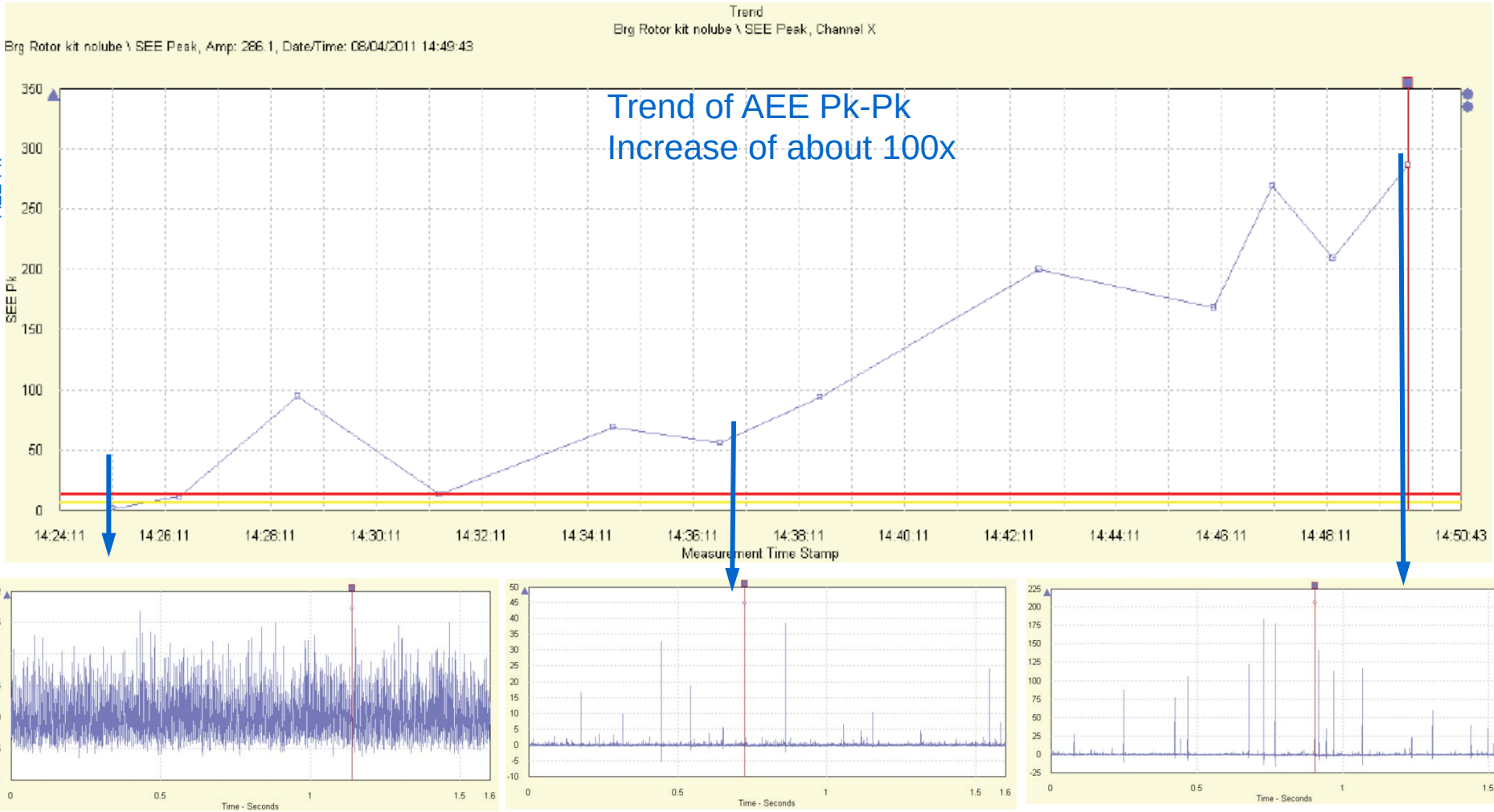
If corrected, it can help to prevent further bearing damage.



Test Rig used for Acoustic Emission Envelope



Trend in AEE and Lubrication Film



Questions?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