

# *A PRIMER ON USING VIBRATION ANALYSIS TO DETECT ROLLING ELEMENT BEARING FAILURES.*



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# General Suggestions:

Based on experience.

- Acceleration is more useful than velocity.
- Time & Impact analysis is more useful than frequency spectra.
- Use quality, hard mounted, accelerometer.
- Mount in/near load zone.
- Avoid use of hand probes.
- Be cautious with bonding & magnets.

## ***Bearing failure characteristics.***

For maintenance activities on motors, pumps, generators and HVAC equipment.

- The paper is a primer on aspects of rolling element bearing monitoring and failure detection.
- It's content is derived from a variety of sources and is meant as an informational piece only.
- No responsibility is assumed, or implied for its application.
- Bearing failure characteristics are complex and bearing manufacturers should be consulted for additional information on the subject.

**Let's Review:**

**Some of the basics!**

# ***FAILURE:*** ***A general definition***

- An unsatisfactory condition- out of spec or catastrophic.
- Failure to meet specified performance.
- Potential failure-Identifiable/quantifiable condition that indicates failure is imminent.

Note: Routine maintenance is not considered as failure, but time is typically counted as downtime.

# *Bearing Failure-Definition?*

When a bearing surface spall reaches 10 square mil inches. (Ref: Timken bearing manual.)

# *GENERAL- BEARING FAILURE MODES*

- Contact fatigue
- Wear
- Plastic flow
- Fracture

# SOME TYPICAL BEARING FAILURE MODES

## FATIGUE

Spalling-subsurface fatigue

Peeling-surface fatigue

## PROBABLE CAUSE

excessive load

lubrication

## WEAR

Fretting /surface corrosion

Abrasion

Scoring/Abrasion

Corrosion

Brinelling –

localized fretting/hardening

Smearing/pitting/fluting

vibration/looseness

contamination

defective seals

“ “

excessive vibration

excessive vibration

electric discharge

All cause  
High  
frequency  
impacting.

## PLASTIC FLOW/FRACTURES

Brinelling/denting

Material failure

excessive or point load

hot/cold working/latent defect

# ***MEAN FAILURE DEFINITIONS***

**MTBF = Mean time between subsequent failures in a system or family of similar components.**

**MTTF = Mean time to first failure in a family of similar components. This is the preferred definition for bearings because they are seldom repaired.**

**MTTR = Mean time to repair.**

## GENERAL CONCLUSIONS:

*Failures are random!*

Most studies have concluded that absent lubrication failures or other negligence, operational bearing failures generally conform to a Weibull exponential failure distribution. The Weibull characteristic is described in other tutorials available from DMC-CT.

# Interesting Question for you?

If you are running a machine with two bearings and each have MTTF estimates of one year. (8,760 hrs.) What are the odds of having problems within the next month?

The estimated probability of failure = 8%

Having problems within the next year?

The estimated probability of failure = 86.5%

Surprised???

That's why it is important to track both MTTF and Probability of Failure!

# Bearing LifeGuard™

- ....uses proven bearing failure diagnostic techniques with patented Multiple Discriminant Analysis Technology.™
- It provides immediate estimates on:
  - \*Life Expectancy
  - \*MTTF
  - \*Failure Probability
  - \*Financial Risk.

# Multiple Discriminant Analysis

## MANAGEMENT INFORMATION SCREEN

### PROBLEM DATA

IMBALANCE COUPLING  
GEAR MISALIGNMENT  
WARP SHAFT  
ECCENTRICITY BELT  
DEFECT BELT  
RESONANCE PULLEY  
ALIGN PULLEY BALANCE  
BLADE PASS

PROC

DYNAMIC  
FORCE  
NUMBER

### CONDITION INFORMATION

HF ENERGY  
STRESS WAVE IMPACTS  
ACOUSTIC EMISSION  
CREST FACTOR  
PEAK G IMPACTS  
KURTOSIS  
DEMODO ENVELOPE

PROC..

BEARING  
CONDITION  
NUMBER

### UPON DATA COLLECTION

Settings Processed Data

timestamp = 4/15/2006 2:08:57 PM

Forecast period	90	Days
Estimated MTF	2380	Hours
Estimated Life	2185	Hours
Probability of Failure in forecast period	57.9	%
Short term Probability (14 day)	5.2	%
Risk Estimate (Forecast Period)	\$5786	CoAF \$10000

Bearing service recommended

Factors | Discriminants | MTF @BDF=10

# Bearing Condition Information

**Bearing Information for AssemblyID = [ BM 1 ]** ✖

Settings | Processed Data | Spectrum | Reading 1 |

timestamp = 3/29/2006 8:31:34 AM

Forecast period	<input type="text" value="90"/>	Days
Estimated MTTF	<input type="text" value="2160"/>	Hours
Estimated Life	<input type="text" value="1623"/>	Hours
Probability of Failure in forecast period	<input type="text" value="63"/>	%
Short term Probability (14 day)	<input type="text" value="6"/>	%
Risk Estimate (Forecast Period)	<input type="text" value="\$6321"/>	CoAF <input type="text" value="\$10000"/>

**Bearing  
service  
recommended**

Factors | Discriminants | MTTF @BDF=10

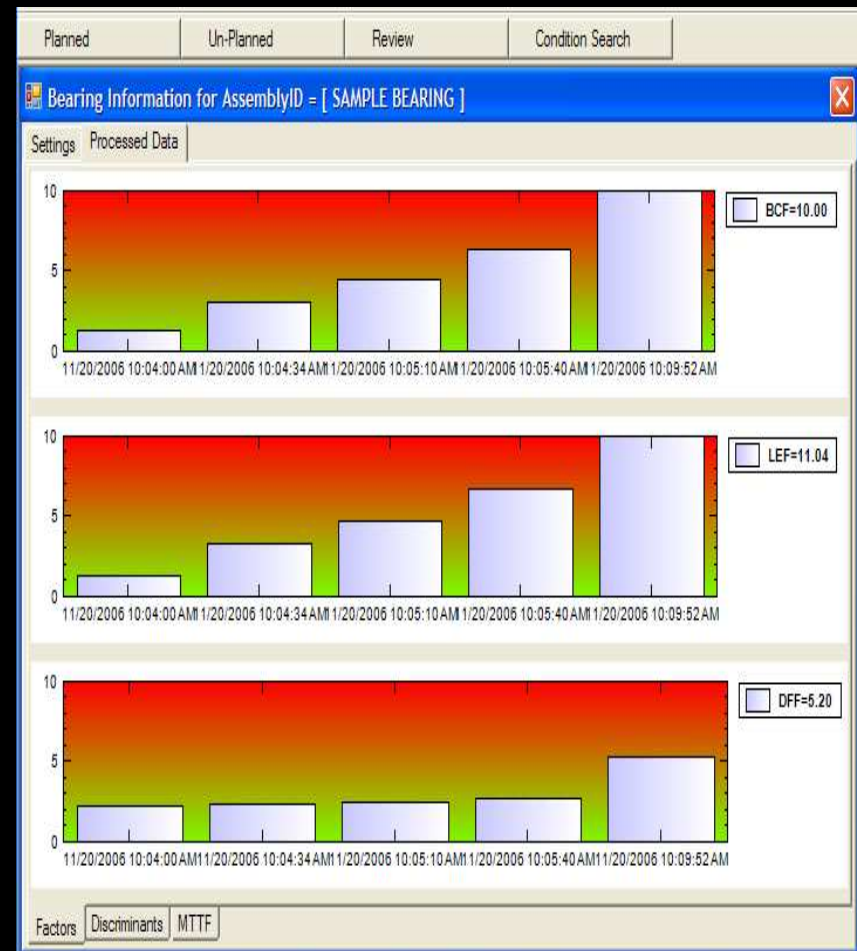
# INTEGRATED INFORMATION ON

- **DYNAMIC FORCE FACTOR- (DF)**  
INTEGRATES FORCING FUNCTIONS-IMBALANCE AND MISALIGNMENT THAT INFLUENCE AND REDUCE MTTF ..... and your MACHINE BEARING LIFE.
- **DEGRADATION FACTOR – (BD)**  
INTEGRATES THE ANALYTICAL DATA THAT INDICATE DEGRADATION OR CONDITION OF A BEARING  
,,,,,,and helps you see predict failure estimate.
- **LIFE EXPECTANCY FACTOR-(LE)**  
INTEGRATES BC + DF TO PRODUCE A USER SELECTED ESTIMATE OF REMAINING BEARING LIFE  
.....and provides it for you directly.

# You may observe these metric trends over time

optimum < 1 (Green), near failure > 9 (Red)

- **BD overall bearing degrade/condition.**
- **LE Life Expectancy** reduction due to high BD+DF.
- **DF Dynamic Forces.** Due to imbalance, misalignment, high frequency impacting.



# Diagnostic Discriminant Trends

(All contribute to BD)

Optimum (green) <1----Severe Degrade (red) > 9

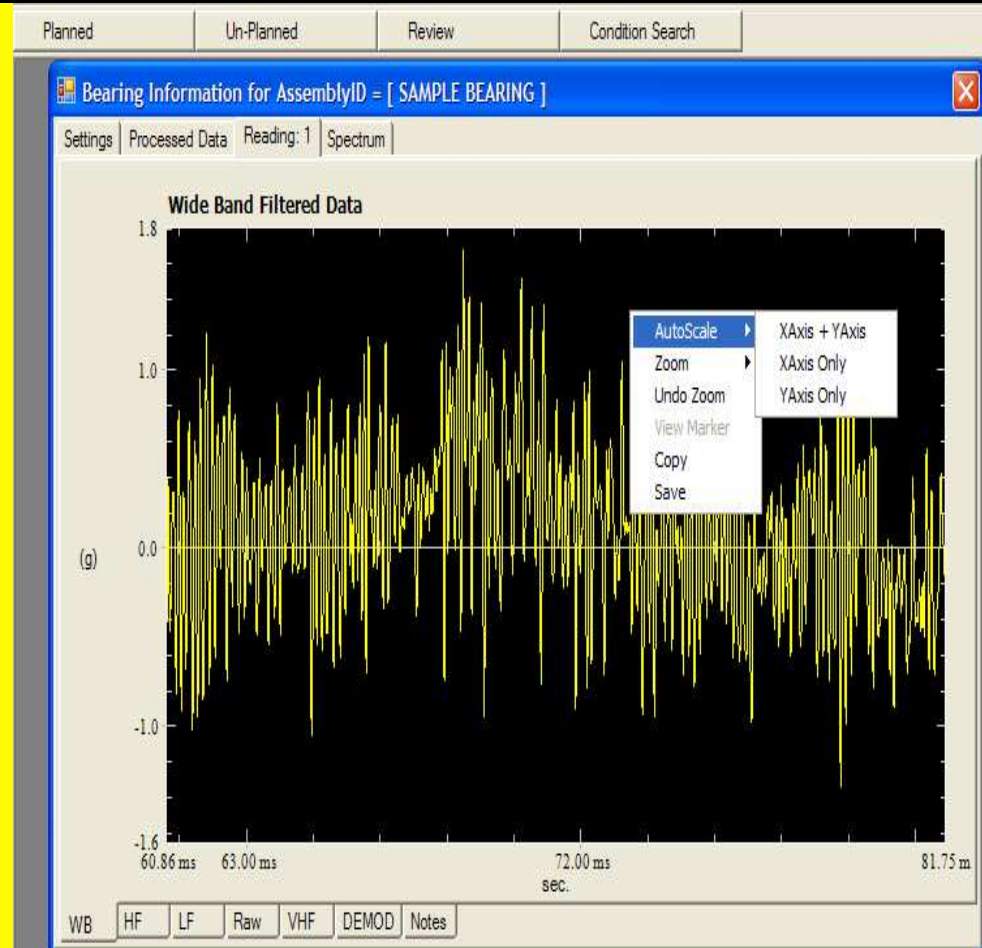
- **LF**-Low Frequency balance alignment forces.
- **HF**-sonic/ultra sonic energy detects surface roughness.
- **CF**- shock wave impact ratios detect surface crack spiking defects.
- **KF**-Kurtosis detects serious fatigue cracks and spalling defects
- **ED**-short duration ball/race impacting.



# Acceleration time waveform.

(Analyst selects Reading 1,2,...N tab.)

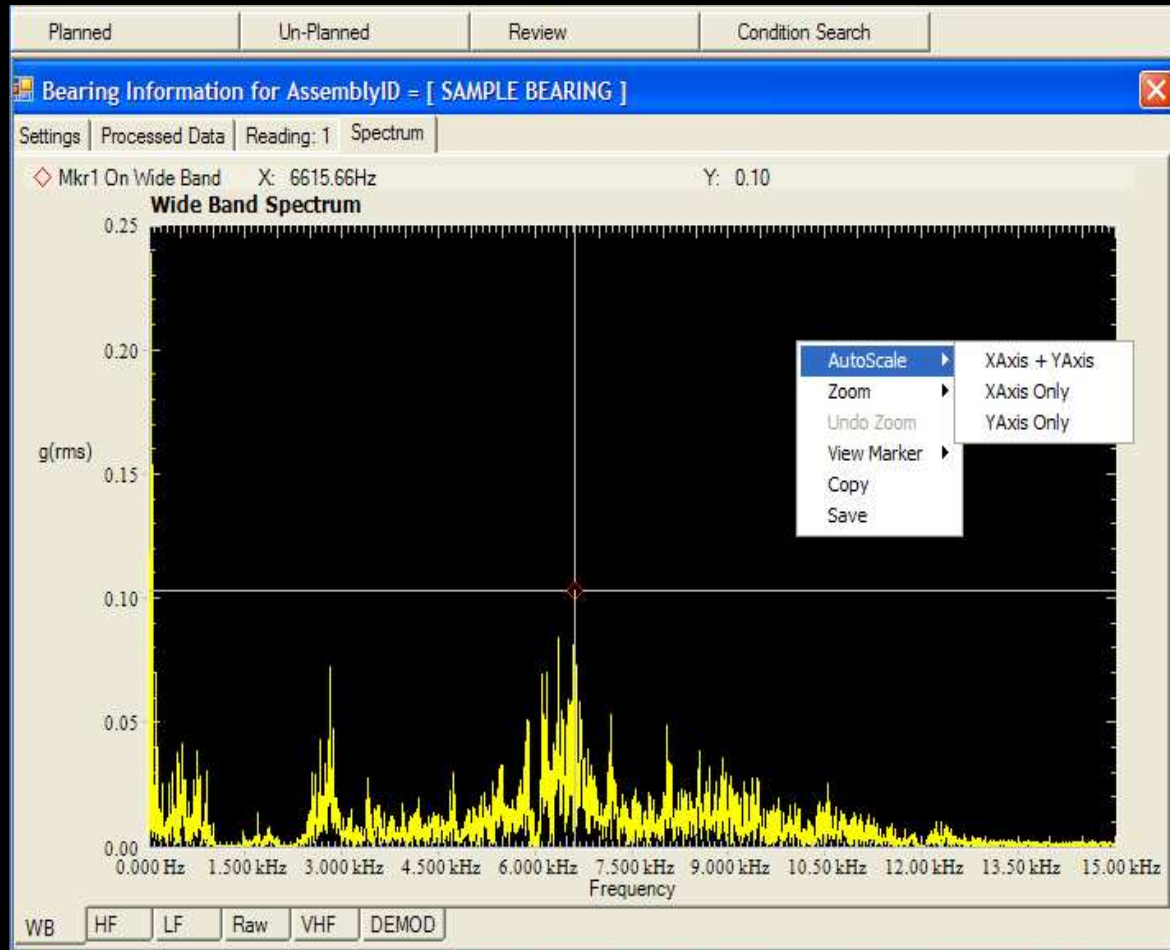
- Acceleration vs. time.
- Zoom for examination
- Auto or manual time or amplitude.
- Adjustable marker with g level read out.



# Acceleration Spectrum Display

(Analyst selects Spectrum tab.)

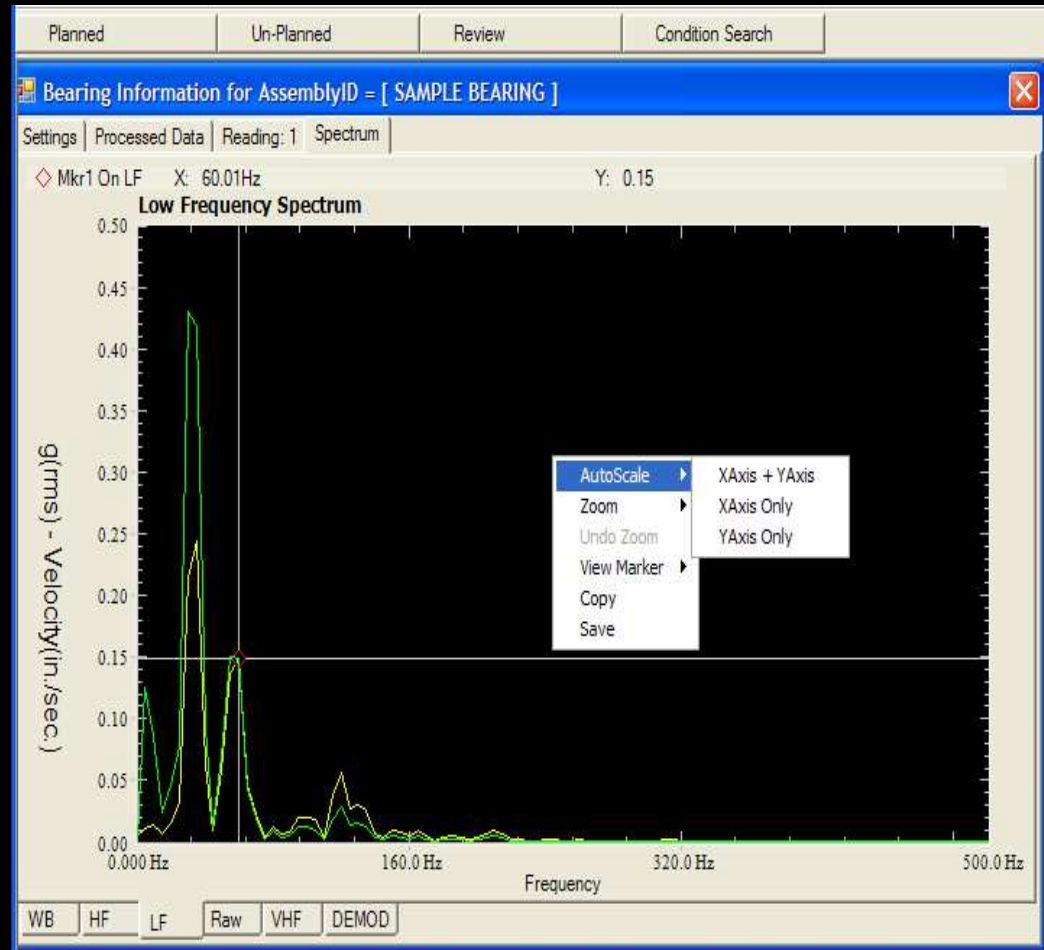
- Zoom
- X-Y axis
- Auto or manual
- Marker allows display of frequency – g level.



# Low Frequency Spectrum Display.

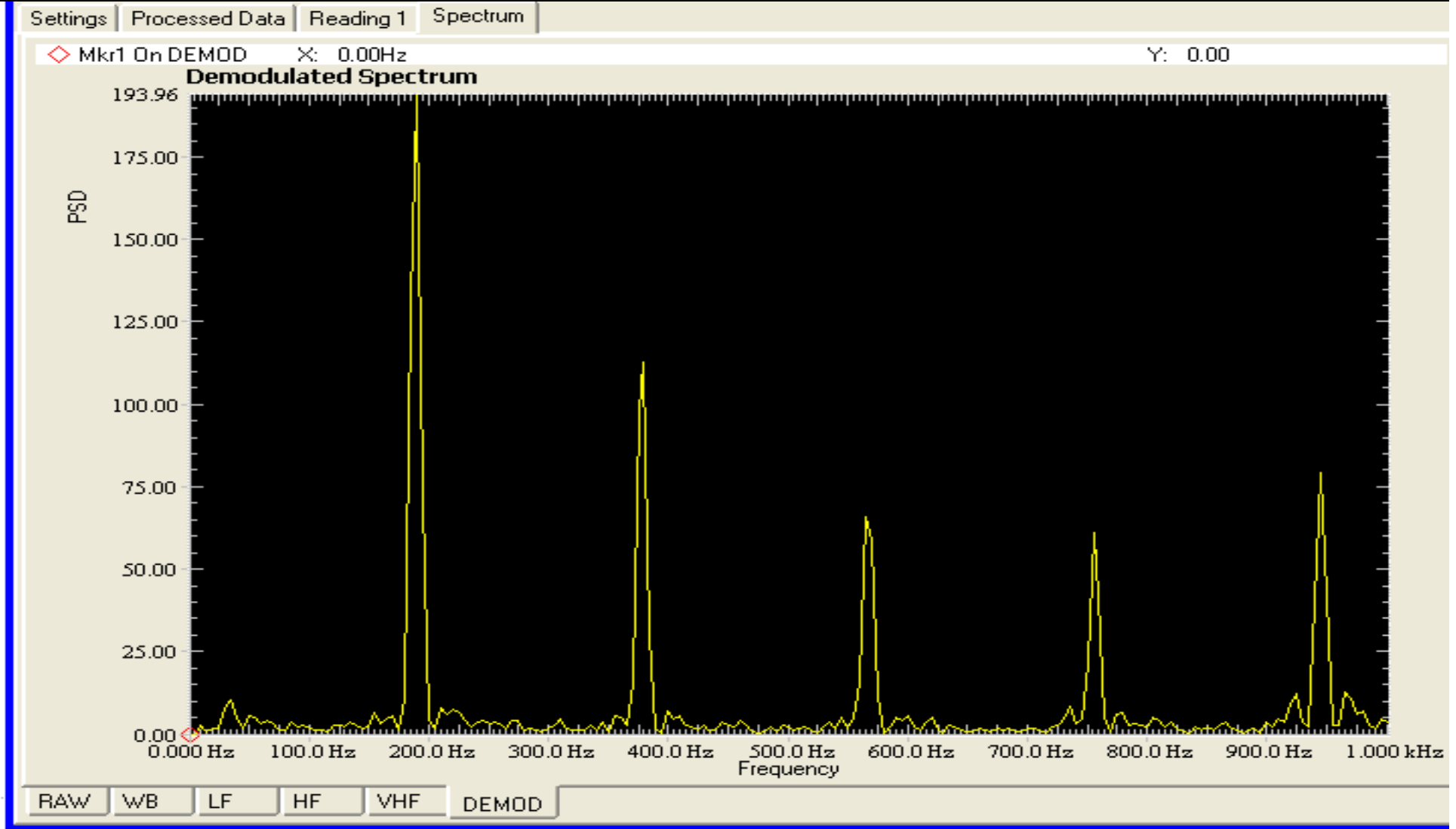
## Velocity & g level (User selects-Spectrum-LF)

- Display in Velocity (in/sec-rms)  
g (rms)
- Zoom X-Y axis
- Auto or manual
- Frequency-Amplitude marker.



# Demodulated Frequency Spectrum

Showing clear ball/race impacts.



# ONE CUSTOMER'S SUCCESS STORY! 350 horsepower centrifugal compressor



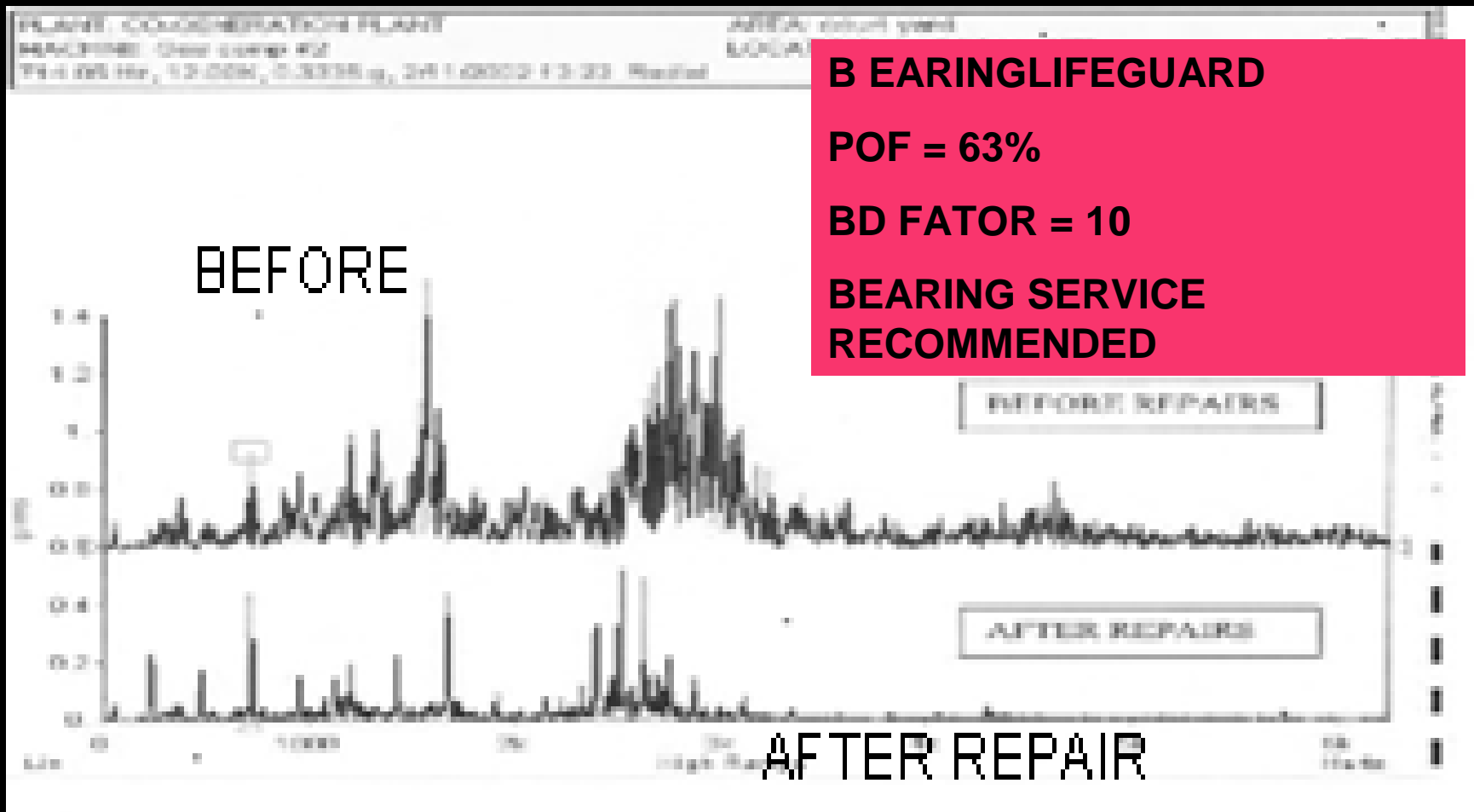
## PRESENTATION TO MANAGEMENT:

Financial risk  $\approx$  \$155,000.

Cost of routine repair  $\approx$  \$12,000.

Bearing Probability of Failure within 90 days=63%.

**Easy decision!**



A grainy, black and white photograph of a removed bearing. A yellow callout box with a black border is positioned in the upper center, containing the text "PHOTO OF REMOVED BEARING" and "Catastrophic Failure avoided." A yellow lightning-bolt-shaped pointer extends from the bottom of the callout box to the bearing. The bearing itself is a circular component with a textured, possibly metallic surface, showing some internal structure and a central hole. The background is dark and indistinct.

PHOTO OF REMOVED BEARING  
Catastrophic Failure avoided.

# Facility Manager's Desired List

- Trends- reliability, condition, downtime cost by facility, building or floor.
- How do we measure reliability/ downtime cost?
- Are we getting better? How do we know?
- Where are the key problems, high cost areas? How can we reduce the cost/risk?
- Reliable indicator of when to tear down machine.
- How do we compare with other similar facilities?
- **Managers act on information not spectra!**

# *Metrics Based Condition Management*

Easier to use.  
Easier to understand.  
Timely Information.  
Fastest data collection  
Reduced Training Costs  
Extends Equipment Life.  
Focus on Financial Impact.  
Better Reporting of \$ results.  
Better Communication.  
More Effective Program

For more Information  
on the benefits of Bearing LifeGuard in  
a  
Metrics based  
Total Facility Maintenance Program

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