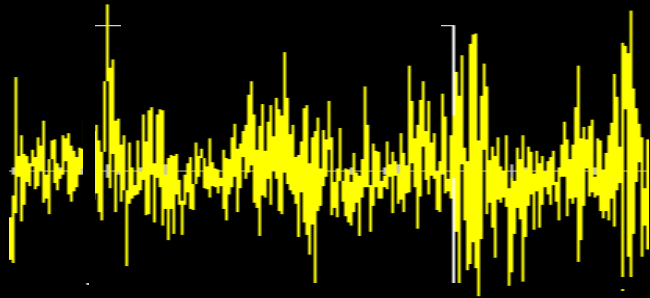


•Bearing LIFEGUARD TECHNOLOGY®



*A new approach to
rolling element bearing
monitoring and life extension*

•MULTIPLE DISCRIMINANT ANALYSIS™

Dynamic Measurement Consultants, LLC

sales@bearinglifeguard.com

1-877-358-4437

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US Patents: #6763312B1,-7.606.673

Background



- The initial work on testing the technical MDA approach was done in cooperation with the facility maintenance department at the University of Medicine & Dentistry (UMDNJ) in Newark, NJ.

UMDNJ Facility Power Plant

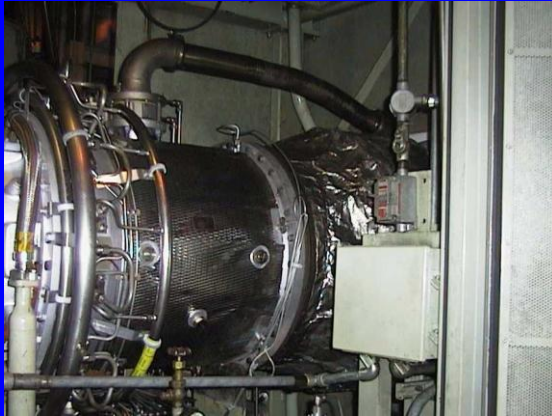
Cogen Plant - 10.5 MW

376,000 BTU/HR - Cascade Heat

474,000 LBS/HR - Steam

20,000 TONS - Refrigeration

2,200 KVA - Emergency Generator



General:



- The *useful operating life* of a rolling element bearing is influenced by a number of factors.
- Some are controlled by the designer, others are controlled by the user.
- BearingLifeGuard ® with Multiple Discriminant Analysis ® is a metrics based system for monitoring and optimizing factors under user control.

*MDA provides the user:
Immediate actionable estimates on:*

- The need for balance or alignment.
- When bearing service is recommended
- **When Financial risk exceeds routine repair cost.**
- Probability of bearing failure in forecast period.
- Financial risk of failure.
- MTTF and Reduced life.
- Estimated reliability of machine point.
- **‘Quick search’** to identify problem or high \$ risk machines.

Quick Overview:



- *What the system does!*
- *A quick overview of the features.*

Users do not need to know:



- Sophisticated vibration theory.
- Frequency spectra, or data analysis.
- Complex signal processing.
- Bearing/race dimensions.

To get immediate condition estimates !

Multiple Discriminant Analysis ®
provides information to help you:

1. Track department/company reliability.
2. Track your financial risk.
3. Monitor your machine life.
4. Be warned when life is reduced.
5. Estimate the probability of failure.
6. Develop PdM performance Metrics.

Easy Initial System Set up- by System Supervisor :

- Assigns access passwords and levels.
- Sets display warning levels for POF-Financial Risk-Dynamic Force
- Select # readings for trending- last 5-14-24-All
- Defines DB utility parameters: ID, machines, locations, flex rigid, gear drive, VFD, etc.
- Adjusts coefficients for RPM if needed.
- Can view time waveform, spectra when necessary.

Define assembly- Database Utility Program point setup

EditAssembly

Assembly

Machine Point: 12345 Organization ID: 1

Assembly Name: Constant Drive

Assembly Number: 2 Sensor Number: 1

Motor Characteristics

Rigid Mount Variable Speed Gear Drive

Default RPM: 1800 Teeth on Drive: 0

Accel. Sensitivity: 100 Gear Ratio: -Infinity

Cost of Failure (\$): 10000 Cost of Repair (\$): 1000

Notch 1 Low (Hz): 500 Notch 2 Low (Hz): 3000

Notch 1 High (Hz): 1000 Notch 2 High (Hz): 4000

Alarm Levels

Probability of Failure (%): 50

Dynamic Force Factor: 3

Location

Building Number: 1

Floor: 1

Room: 120D

Quit Update

**Push a collect/process button and get immediate answers:
ALERT INFORMATION – RISK EXCEEDS REPAIR COST.**

Bearing Information for AssemblyID = [USPS 2 5 28]

Settings | Processed Data | Reading: 5 | Spectrum

Time stamp = 6/19/2008 8:38:41 PM

Forecast period (days)	90	RPM	1725
Estimated RMTTF (hours)	4289		
Estimated Life (hours)	4109		
Probability of Failure in forecast period	30 %		
Short term Probability (14 day)	2.2 %	Reliability	70%
Risk Estimate (Forecast Period)	\$3004	CoAF	\$10000

Risk Cost exceeds Repair Cost

Factors | Discriminants | RMTTF

Select **Setting** Screen-Select waveform

- Shows Assembly Point Coefficients

Bearing Information for AssemblyID = [Demo Bearing 08]

Settings | Processed Data | Reading: 1 | Spectrum

Readings to plot

- Last 5
- Last 14
- Last 26
- All

Analyst / Engineer

Display Reading #

10/26/2011 3:26:22 PM

Engineering

		Def.	Min.	Max.
C2 KFD2 Scale	2	2.0	0.1	100.
C4 BDF Scale	1	1.0	0.2	100.
C5 DFF Gain	1	1.0	0.1	1500
C6 DFF HFF Contribution	0.2	0.2	0.0	0.6
C7 DFF LFF Contribution	0.8	0.8	0.7	4.0
C9 LEF DFF Contribution	0.2	0.2	0.1	0.5
Peak Scale	1	1.0	0.2	1500
S1 HFD Scale	1	1.0	0.25	1500
S2 EDD Scale	1	1.0	0.25	1500

Update

Supervisor_ADJUST S ASSEMBLY POINT PARAMETERS

Bearing Information for AssemblyID = [USPS 2]

Settings | Processed Data | Reading: 5 | Spectrum

Readings to plot

- Last 5
- Last 14
- Last 26
- All

Analyst / Engineer

Display Reading #

5/31/2008 3:26:02

Engineering

USPS 2

		Def.	Min.	Max.
C2 KFD2 Scale	<input type="text" value="2"/>	2.0	0.1	8.0
C4 BDF Scale	<input type="text" value="1"/>	1.0	0.2	4.0
C5 DFF Gain	<input type="text" value="1"/>	1.0	0.5	2.0
C6 DFF HFF Contribution	<input type="text" value="0.2"/>	0.2	0.0	0.6
C7 DFF LFF Contribution	<input type="text" value="0.8"/>	0.8	0.7	4.0
C9 LEF DFF Contribution	<input type="text" value="0.2"/>	0.2	0.1	0.5
Peak Scale	<input type="text" value="1"/>	1.0	0.2	4.0
S1 HFD Scale	<input type="text" value="1"/>	1.0	0.25	4.0
S2 EDD Scale	<input type="text" value="1"/>	1.0	0.25	8.0

Update

SELECT TREND

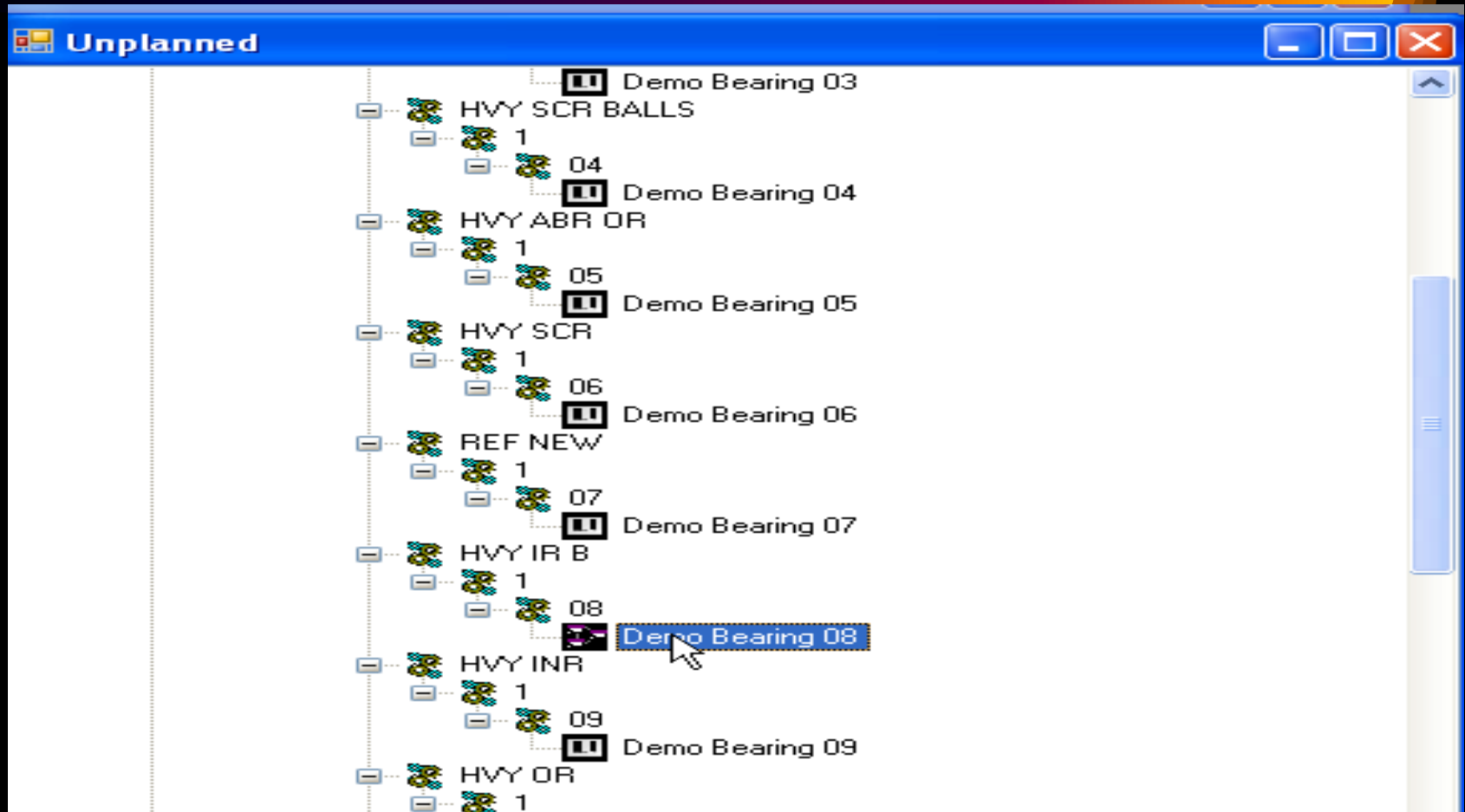
SELECT READING

MODIFY COEFFICIENTS

User- Can review all collected data- From the Assembly Tree



Selects Assembly Point for Review

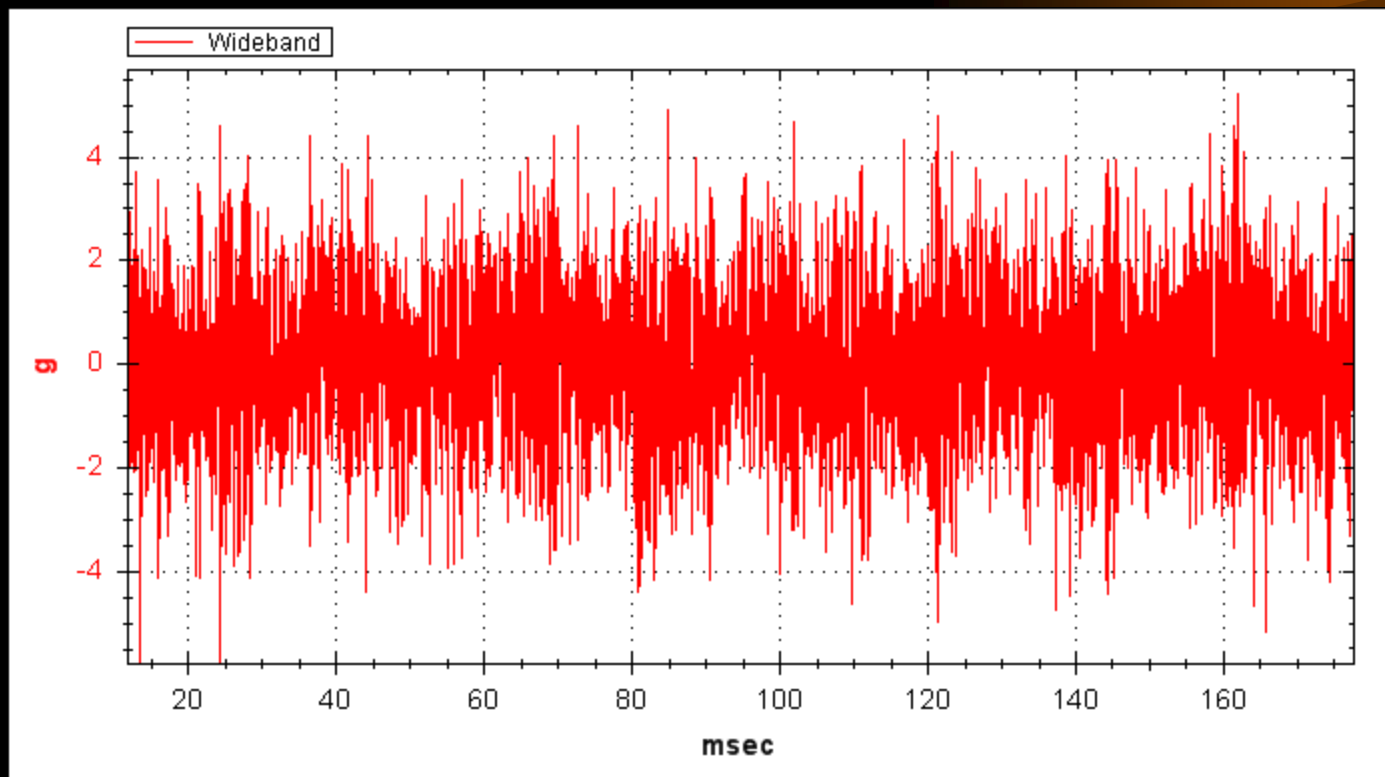


- May show multiple points for review!
- Compare waveform, time or spectra

The image displays two side-by-side software windows, each titled "Bearing Information for AssemblyID = [Demo Bearing 08]" and "Bearing Information for AssemblyID = [Demo Bearing 07]". Both windows have a "Settings" tab and a "Processed Data" tab. The left window shows a time stamp of 10/26/2011 3:26:22 PM and a forecast period of 90 days at 1725 RPM. It lists an estimated RMTTF of 3716 hours, an estimated life of 3595 hours, a short-term probability of 2.7% (14 days), a 35.8% probability of failure in the forecast period, and a risk estimate of \$3580. A yellow box highlights the text "Risk Cost exceeds Repair Cost". The right window shows a time stamp of 10/26/2011 3:27:53 PM with the same 90-day forecast period and 1725 RPM. It lists a significantly higher estimated RMTTF of 43200 hours, an estimated life of 42532 hours, a short-term probability of .1% (14 days), a 1.1% probability of failure in the forecast period, and a risk estimate of \$111. Both windows also show a CoAF of \$10000 and a reliability of 64.2% (left) and 98.9% (right).

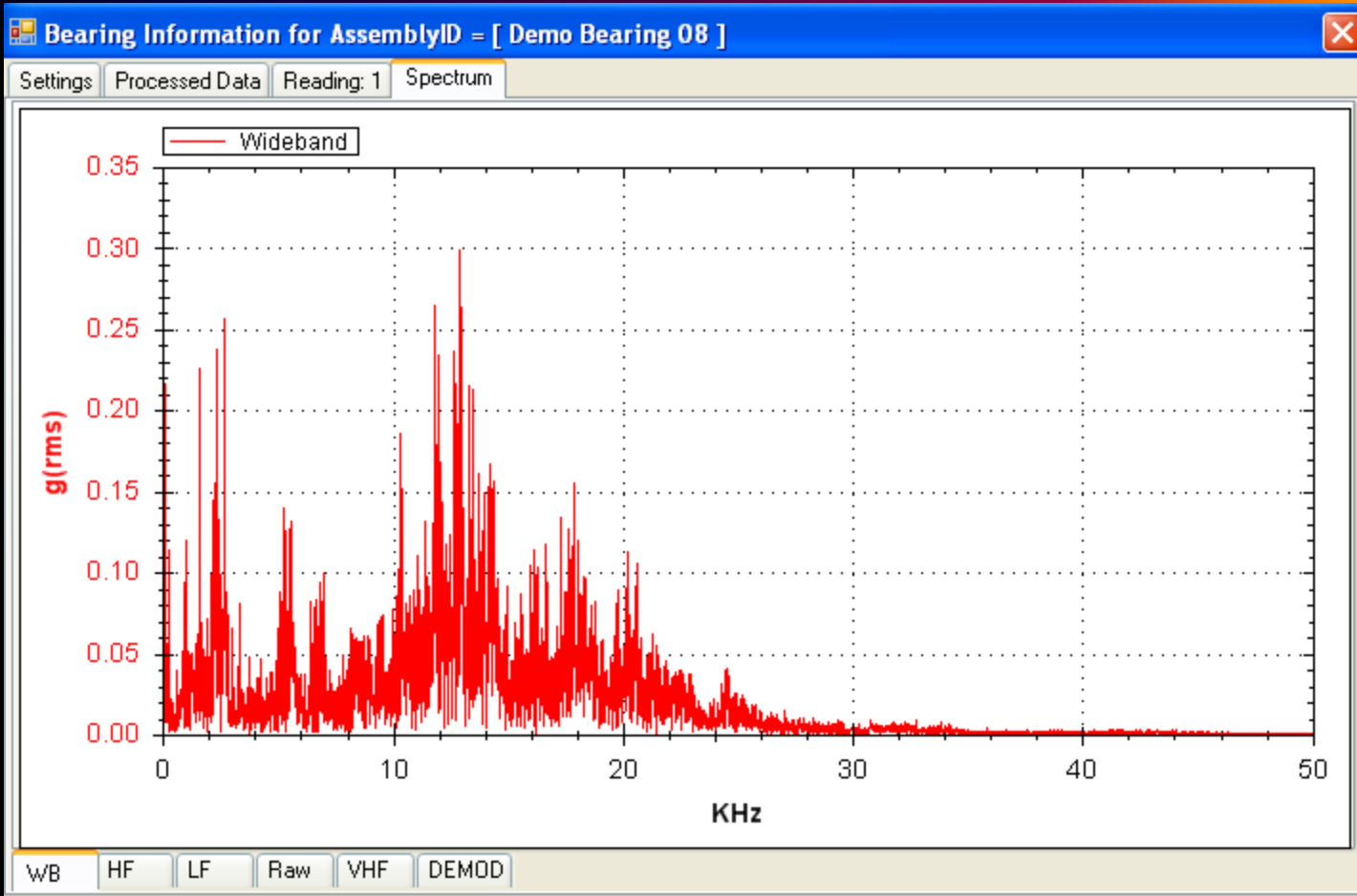
Parameter	Value (Demo Bearing 08)	Value (Demo Bearing 07)
Time stamp	10/26/2011 3:26:22 PM	10/26/2011 3:27:53 PM
Forecast period (days)	90	90
RPM	1725	1725
Estimated RMTTF (hours)	3716	43200
Estimated Life (hours)	3595	42532
Short term Probability (14 day)	2.7 %	.1 %
Probability of Failure in forecast period	35.8 %	1.1 %
Reliability	64.2 %	98.9 %
Risk Estimate (Forecast Period)	\$3580	\$111
CoAF	\$10000	\$10000

*Engineer may view time waveform s-
tab selected wide band- high frequency-low
frequency-demod w/zoom capability.*



Engineer may view Spectra display.

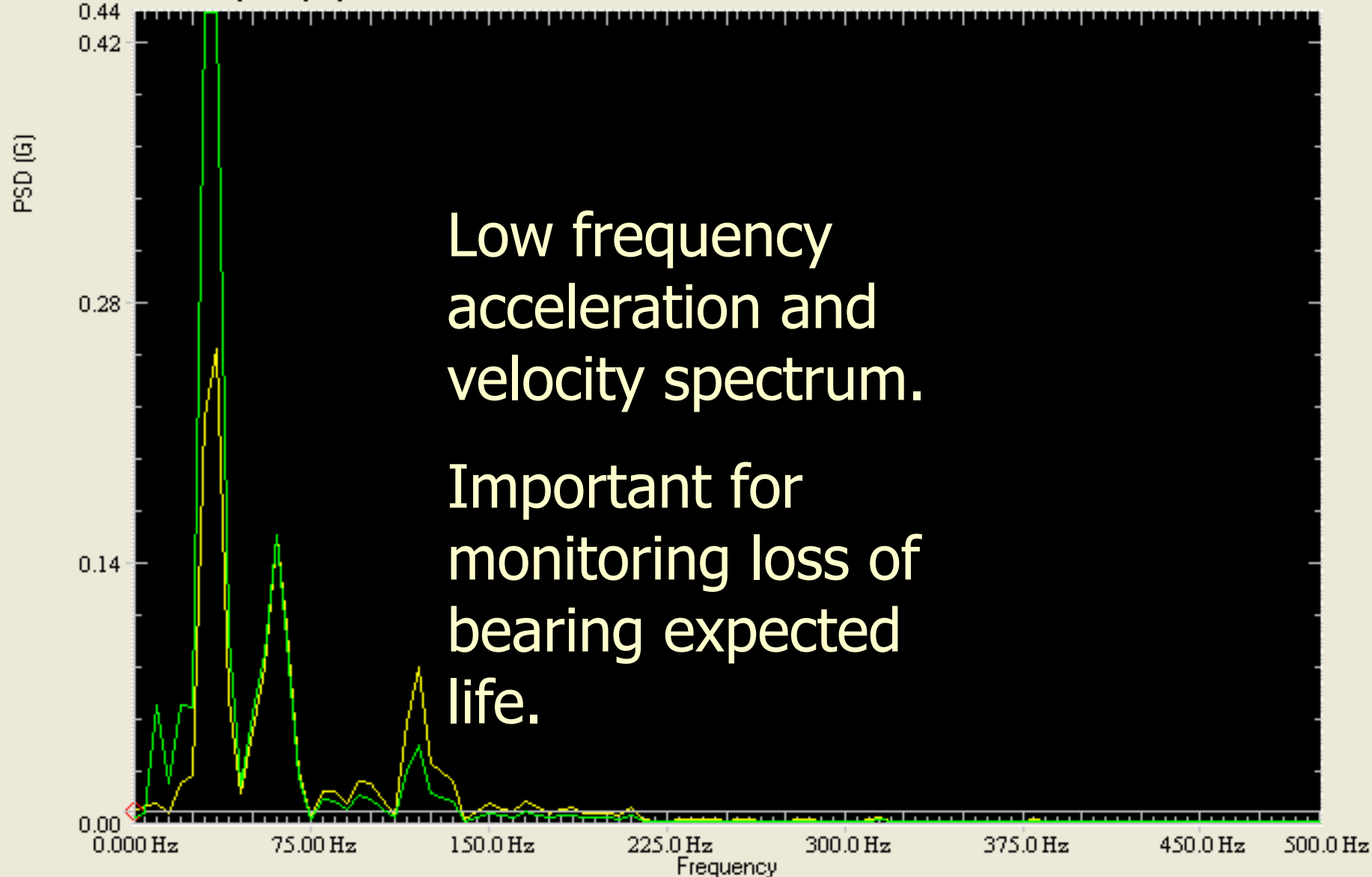
6 Tab selects unfiltered, wide band, low freq., demod, w/zoom



◇ Mkr1 On LF X: 0.00Hz

Y: 0.01

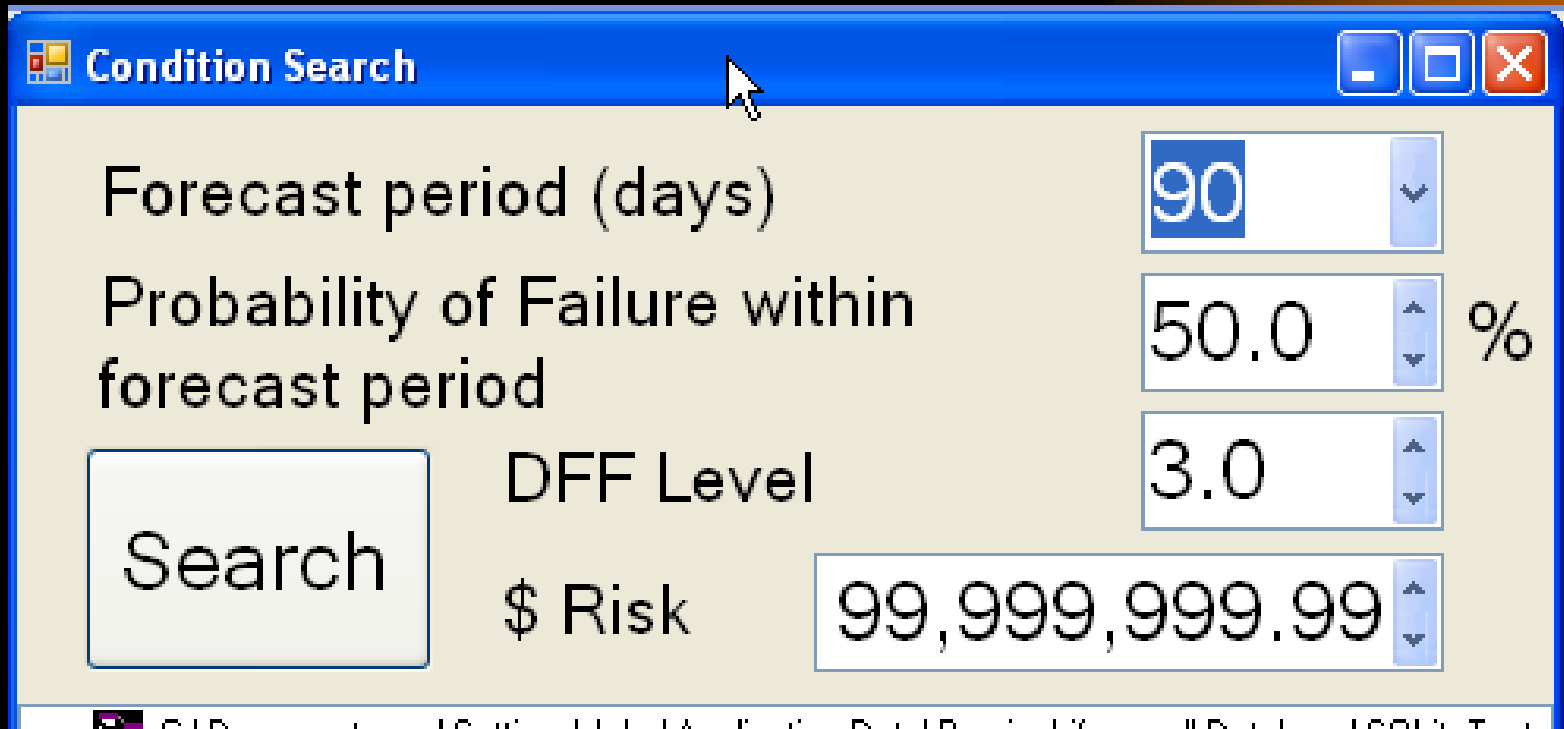
Low Frequency Spectrum



Low frequency acceleration and velocity spectrum.

Important for monitoring loss of bearing expected life.

*Quick Database Search- Finds units with problems-
Properly allocate resources!
High : POF-Imbalance -alignment –Financial Risk*



The image shows a screenshot of a software dialog box titled "Condition Search". The dialog box has a blue title bar with standard window controls (minimize, maximize, close) on the right. The main area is light yellow and contains several input fields and a button. A mouse cursor is pointing at the top of the dialog box.

Forecast period (days)	90	
Probability of Failure within forecast period	50.0	%
DFF Level	3.0	
\$ Risk	99,999,999.99	

Search

- How does the system do this?



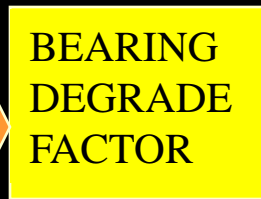
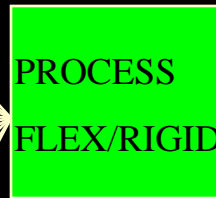
*A look at MDA Diagnostics?
[Multiple Discriminant Analysis ®.]*

MDA CONVERTS THESE ELEMENTS TO METRIC FACTORS

VIBRATION DATA

- IMBALANCE
- COUPLING GEAR
- MISALIGNMENT
- WARPED SHAFT
- ECCENTRICITY
- BELT DEFECT BELT
- RESONANCE
- PULLEY ALIGN
- PULLEY BALANCE
- BLADE PASS
- BEARING- CAGE
- BEARING INNER
- BEARING OUTER
- BALL
- PITTING
- FRETTING
- SCORING
- SPALLING

DATA INTEGRATION

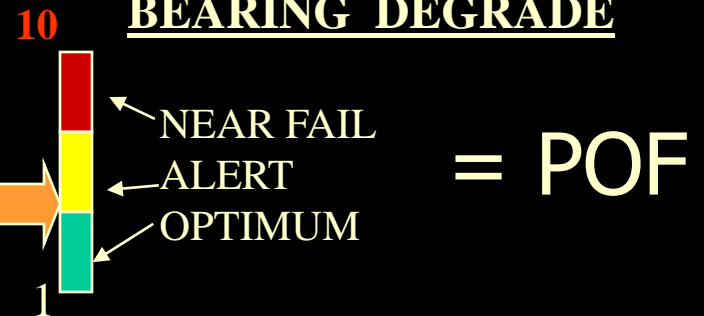


INFORMATION

DYNAMIC FORCES

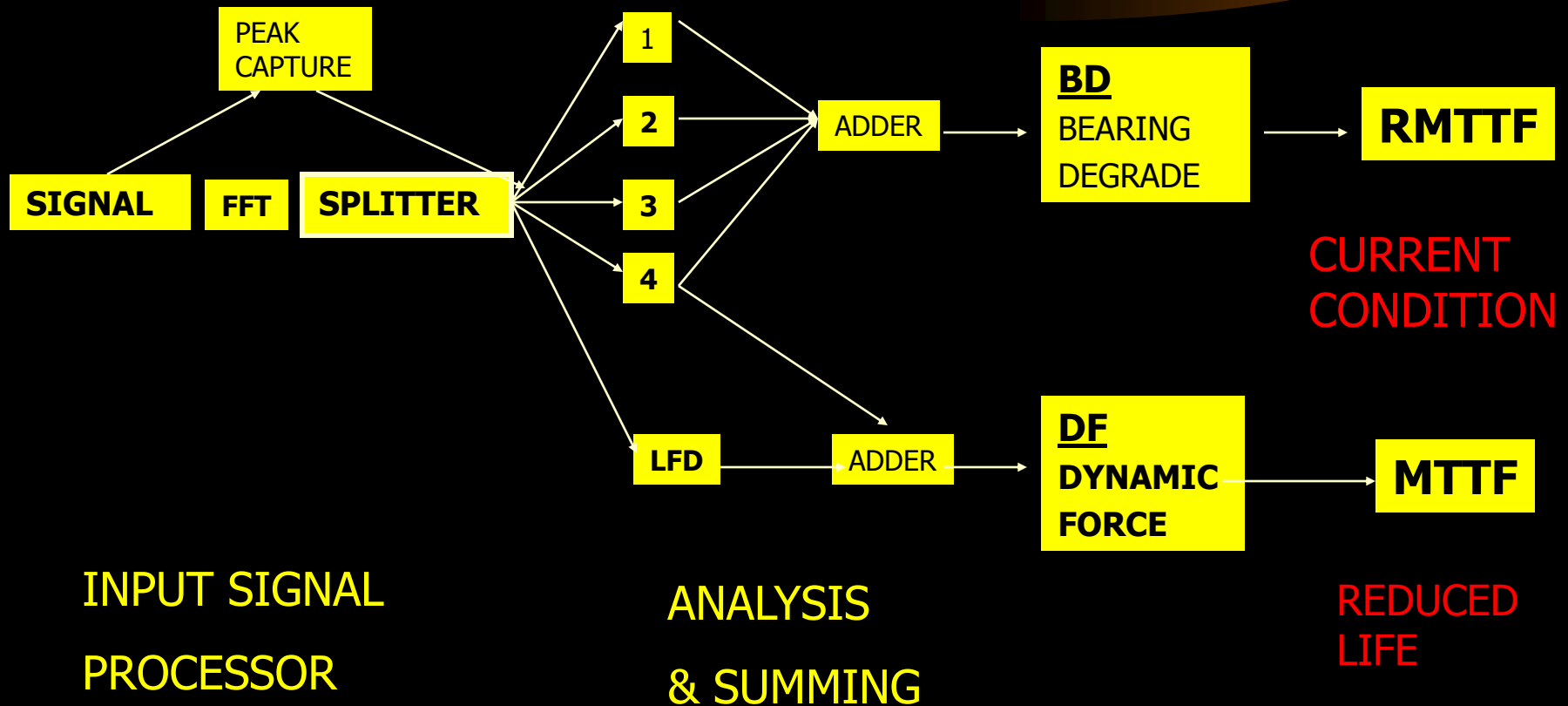


BEARING DEGRADE




US PATENT # 6,762,312 OTHER PATENTS PENDING

MDA MTTF LIFE EXPECTANCY?



WHY METRICS?

*“ Because if you can’t measure it,
you can’t control it.”*



**METRICS HELP YOU QUANTIFY
PERFORMANCE!**

The **BD METRIC** provides information on actual BEARING DEGRADATION.

METRIC RANGE 1-10

1

1-2 = Optimum near L_{10} life

2-4 = Early degrade state

4-7 = Second Degrade State (Monitor)

7-10 = Final Degrade State (Replace)

METRIC = 10 63% PROBABILITY OF FAILURE IN 90 DAYS

The DF METRIC – a measure of
Dynamic Forces that Reduce life!

METRIC RANGE 1-10

4.5

1-2=Optimum life

2-4=Reduced Life (Monitor)

4-7=Excessive (Take Action)

7-10=Danger! (Shut down)

* High DF cost \$ - Check for Imbalance,
Misalignment, or other low frequency problems!

The **LE METRIC** estimates remaining
BEARING LIFE = $C_1DF + C_2BC$

METRIC RANGE 1-10

4

1-2 = Optimum near L_{10} life

2-4 = 10 to 30% life reduction

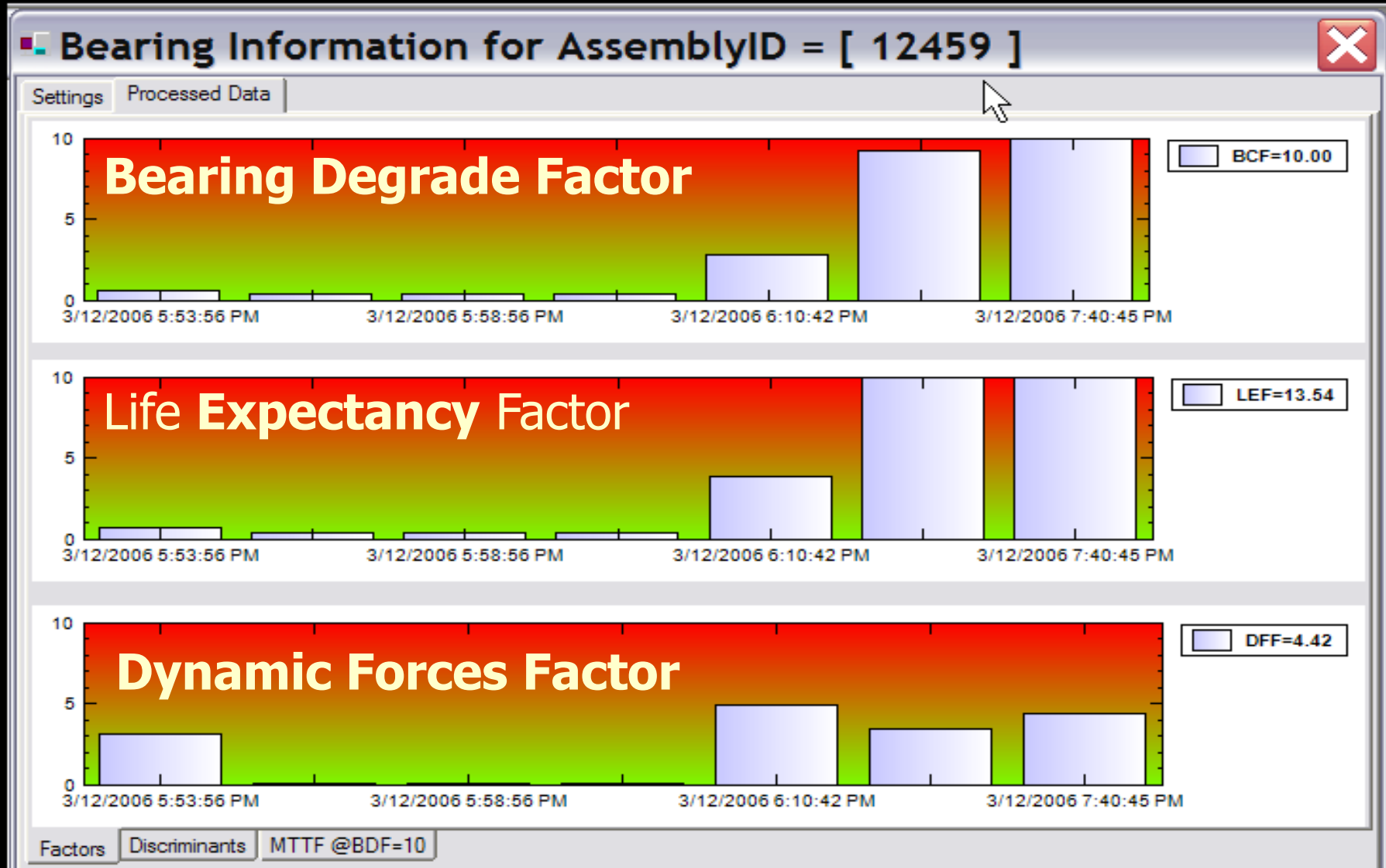
4-7 = 30 to 70% life reduction

7-10 = 70 to 90% life reduction

METRIC = 4 to 7

Life reduction costs \$!

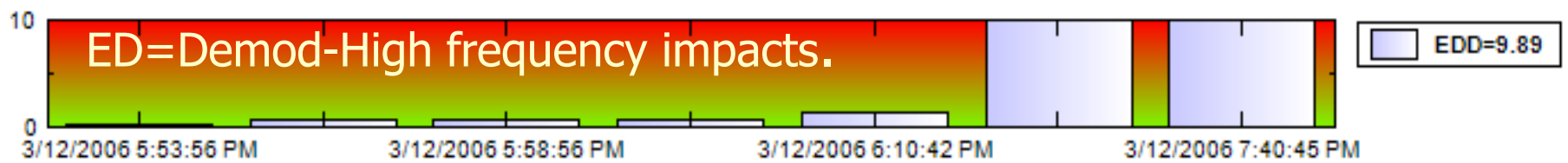
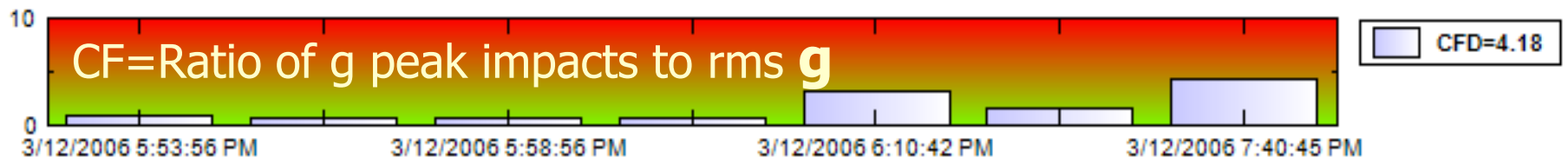
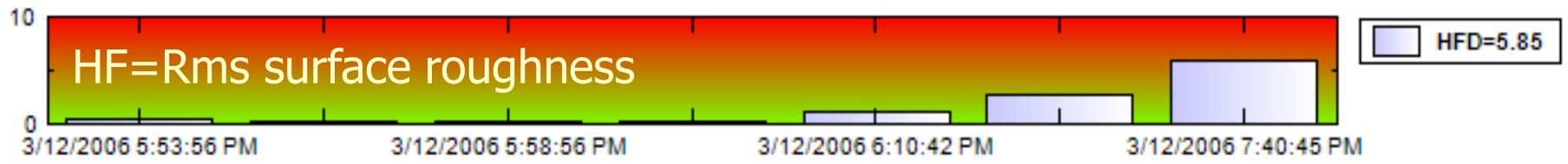
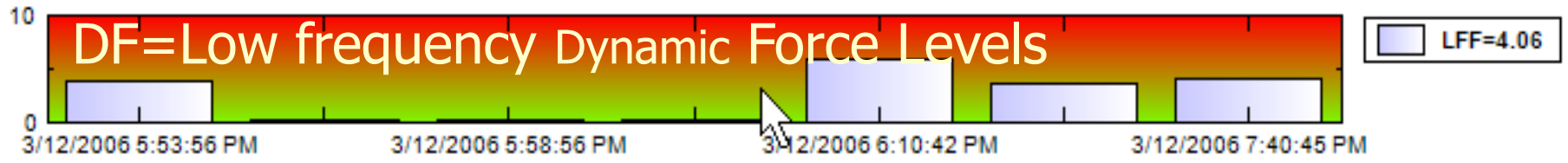
For Trending the *FACTOR METRICS*: 1 (Like new)-----10 (Near fail state.)



TREND -DISCRIMINANT METRICS: [0-10].



Settings Processed Data

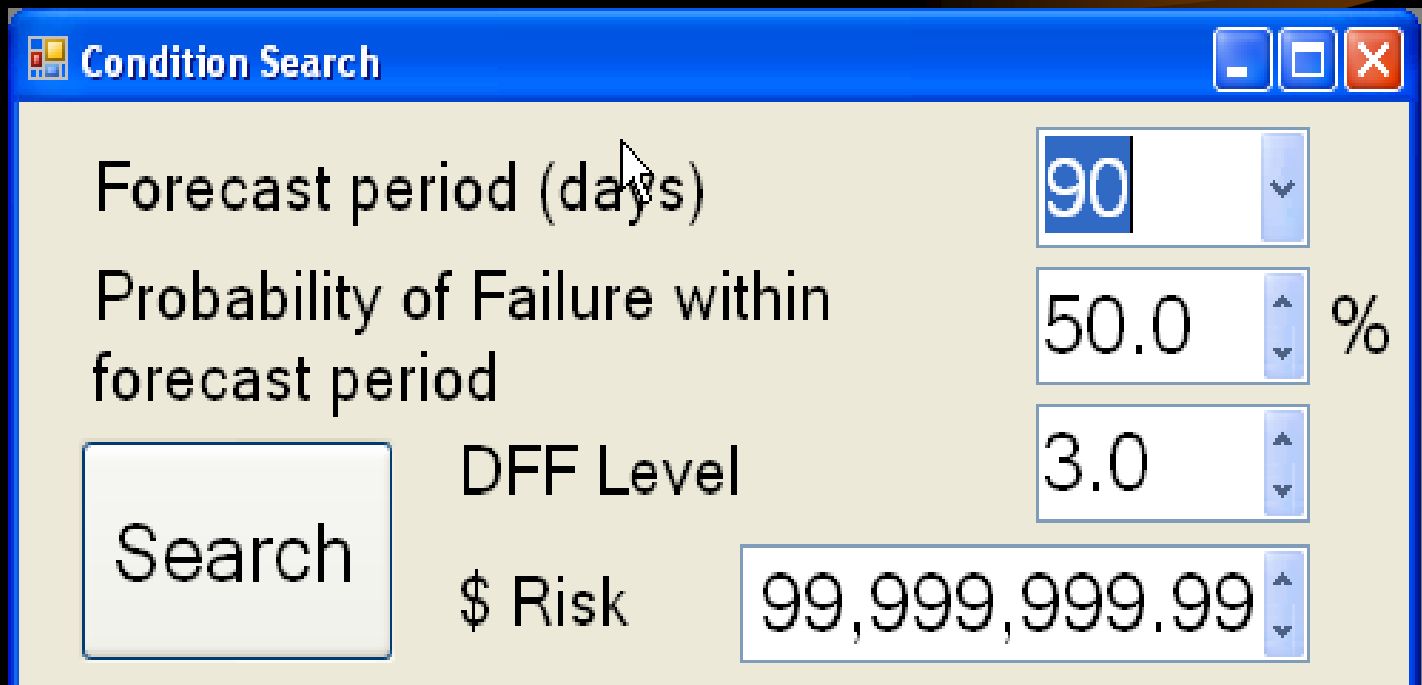


Factors Discriminants MTTF @BDF=10



Putting Metrics to Work!

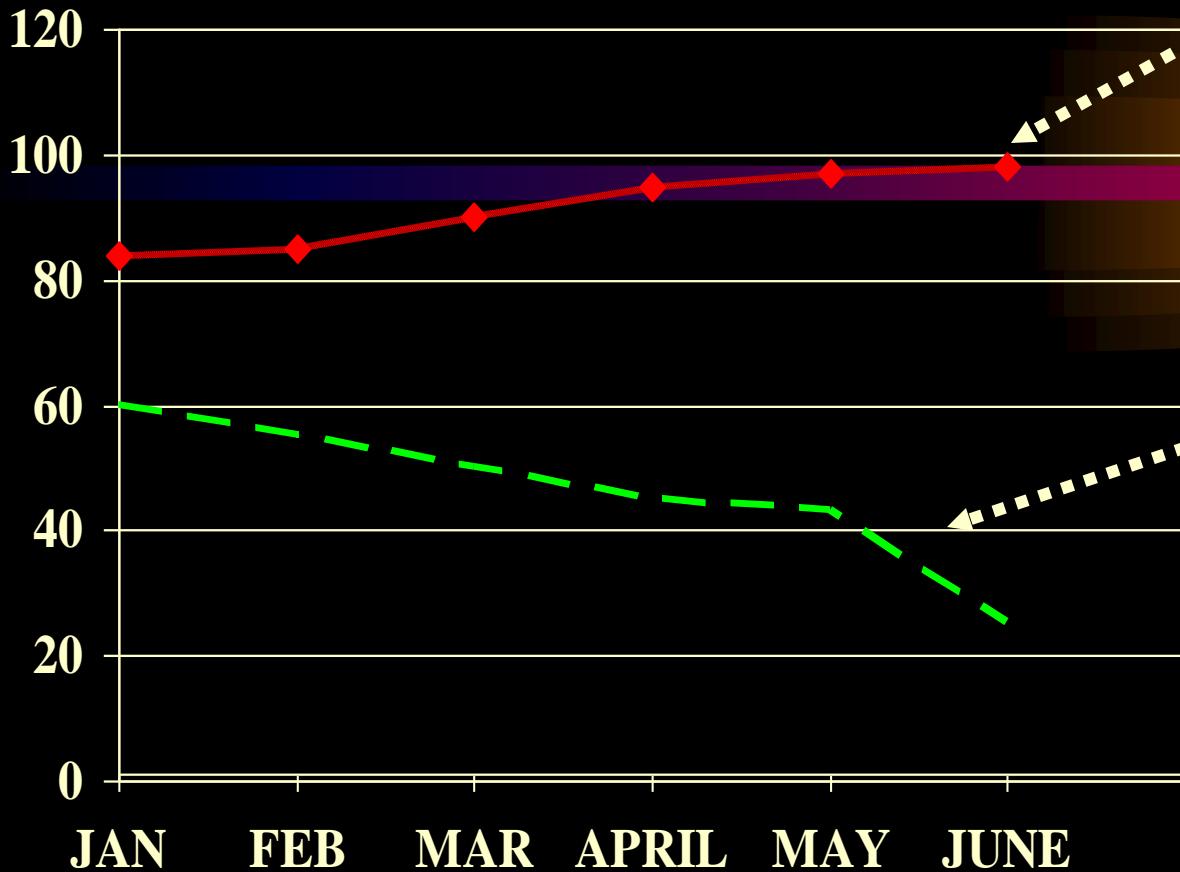
Use Metrics to Search your facility to find machines in need of attention:



The image shows a screenshot of a software dialog box titled "Condition Search". The dialog box has a blue title bar with standard window controls (minimize, maximize, close). The main area is light yellow and contains several input fields and a button. A mouse cursor is pointing at the "Forecast period (days)" field.

Forecast period (days)	90	
Probability of Failure within forecast period	50.0	%
Search	DFP Level	3.0
	\$ Risk	99,999,999.99

SAMPLE FACILITY



AVERAGE RELIABILITY

\$ FINANCIAL RISK

TREND RELIABILITY/RISK ESTIMATES

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.

POF = Probability of failure in forecast period.

Thinking MTTF can pay dividends!

Example: Possible cost savings

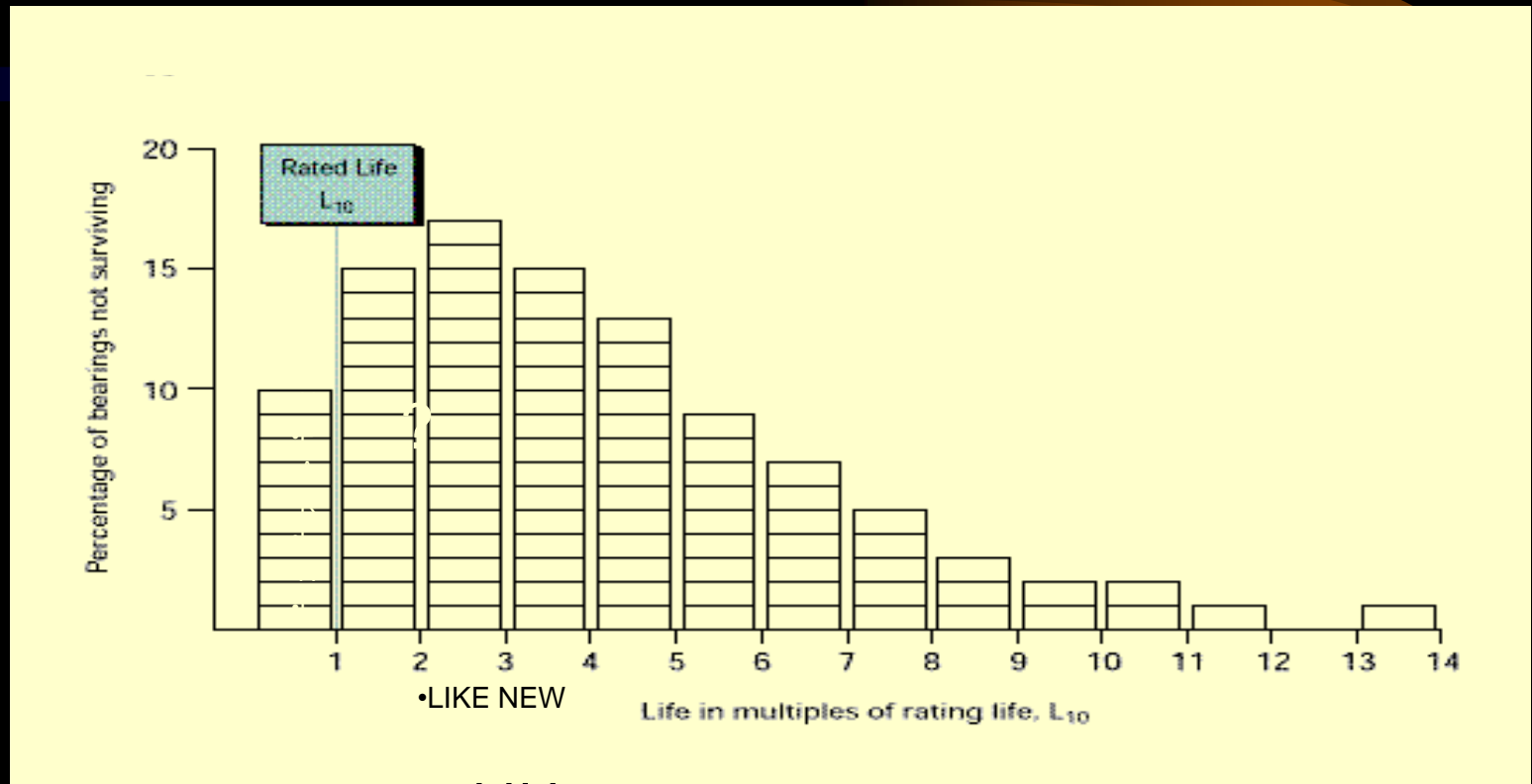
- Machine has an estimated cost of repair of \$12,000 and an MTTF of 2 years.
- 63% chance you'll have to tear it down within the next 2 years.
- Estimated cost per year = $\$12,000/2 = \$6000/\text{year}$.
- Increase the MTTF to 5 years the POF drops to $\approx .18$ the cost/year drops to $\approx \$2175/\text{yr}$. or Savings of $\$3825/\text{year}$.

BEARING FAILURE PATTERNS

- THE WEIBULL DISTRIBUTION.
- THEY DON'T ALL FAIL AT ONCE!
- ILLUSTRATES THE IMPORTANCE OF SURVEYING BEARING POPULATIONS FOR CONDITION INFORMATION.

The pattern of failure @ rated load L_{10} converted to Weibull exponential failure distribution

Number of failed bearings.



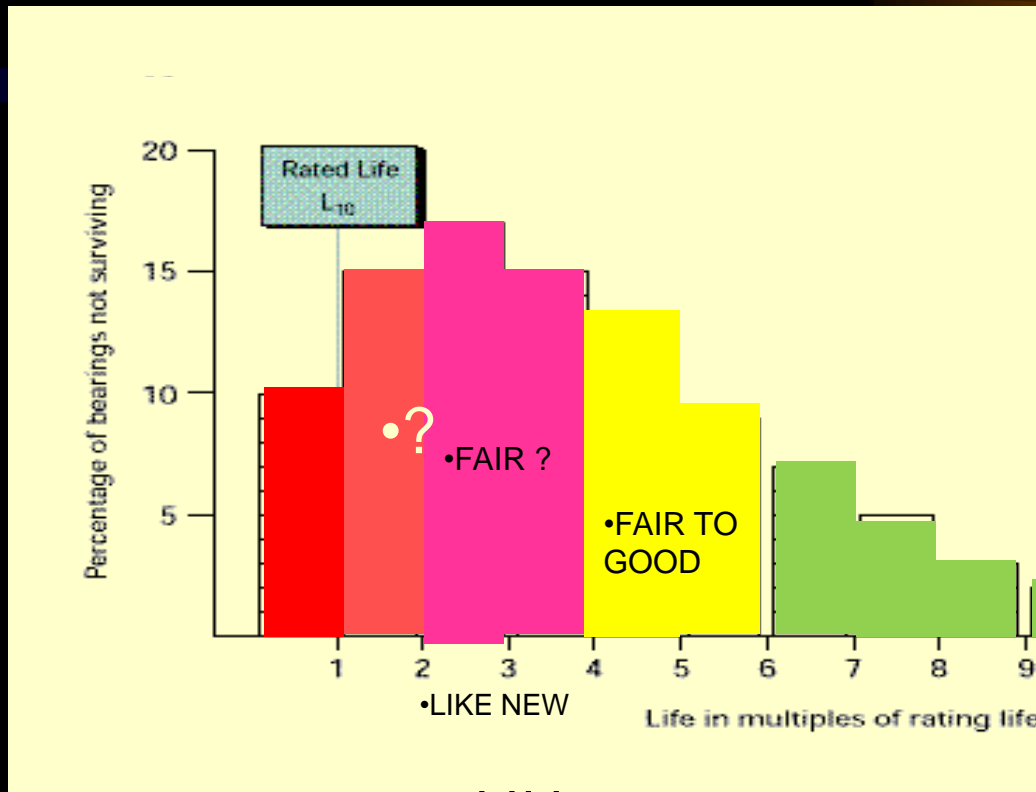
•Variance from 1 to >14 times L_{10} life. Operating life will depend on static and dynamic operating load and other factors.

•Ref: Timken Bearing Manual
•Note: At rated load.

L10 converted to Weibull exponential failure distribution

The rate of failure

- They don't all fail at once:
- This tells you the rate at which they are 'likely' to fail.
 - $\approx 10\%$ will fail in one L10 life at rated load.
 - $\approx 25\%$ will fail in two L10. Etc
 - $\approx 63.2\%$ within 4.52 L10 (MTTF)
 - Most will fail within 15 life spans.
 - The DL10 'Design life' ; the time would be changed to multiples of L10 but the pattern would be similar.
 - The PdM user needs to know what stage a bearing is in!



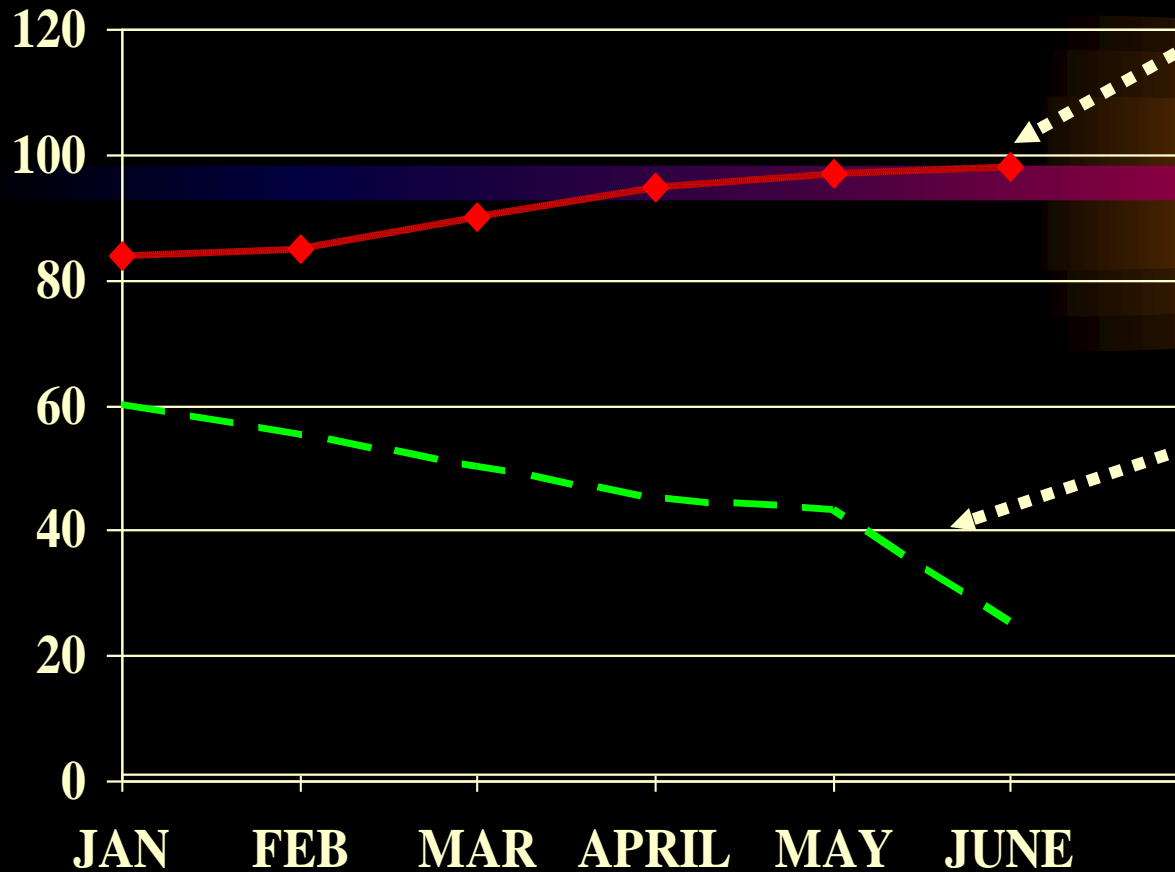
Number of failed bearings.

• Variance from 0.5 to >14 times L_{10} life. Operating life will depend on static and dynamic operating load and other factors.

• Ref: T
• Note:

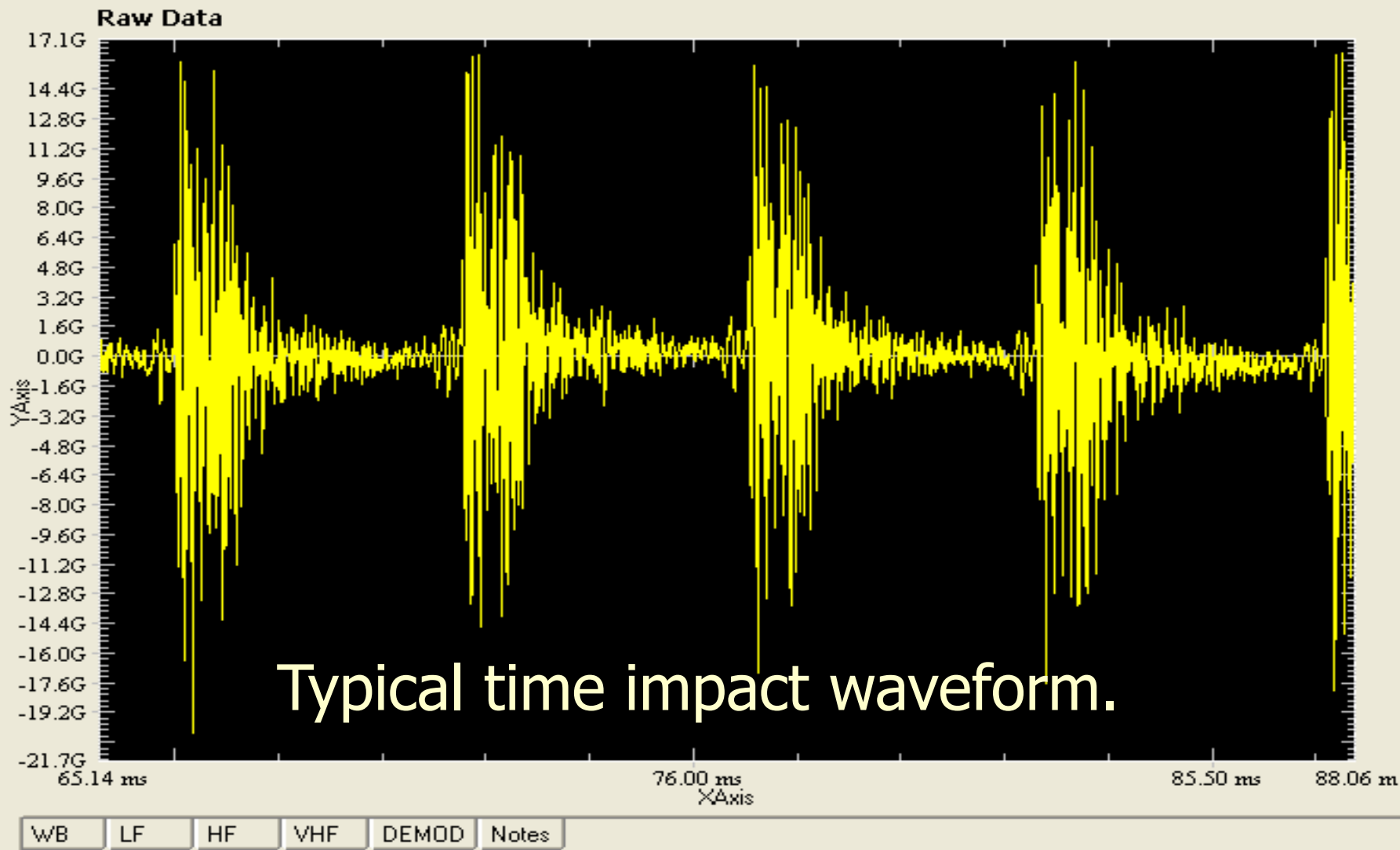
YOU CAN TRACK YOUR FACILITY

**AVERAGE
RELIABILITY**



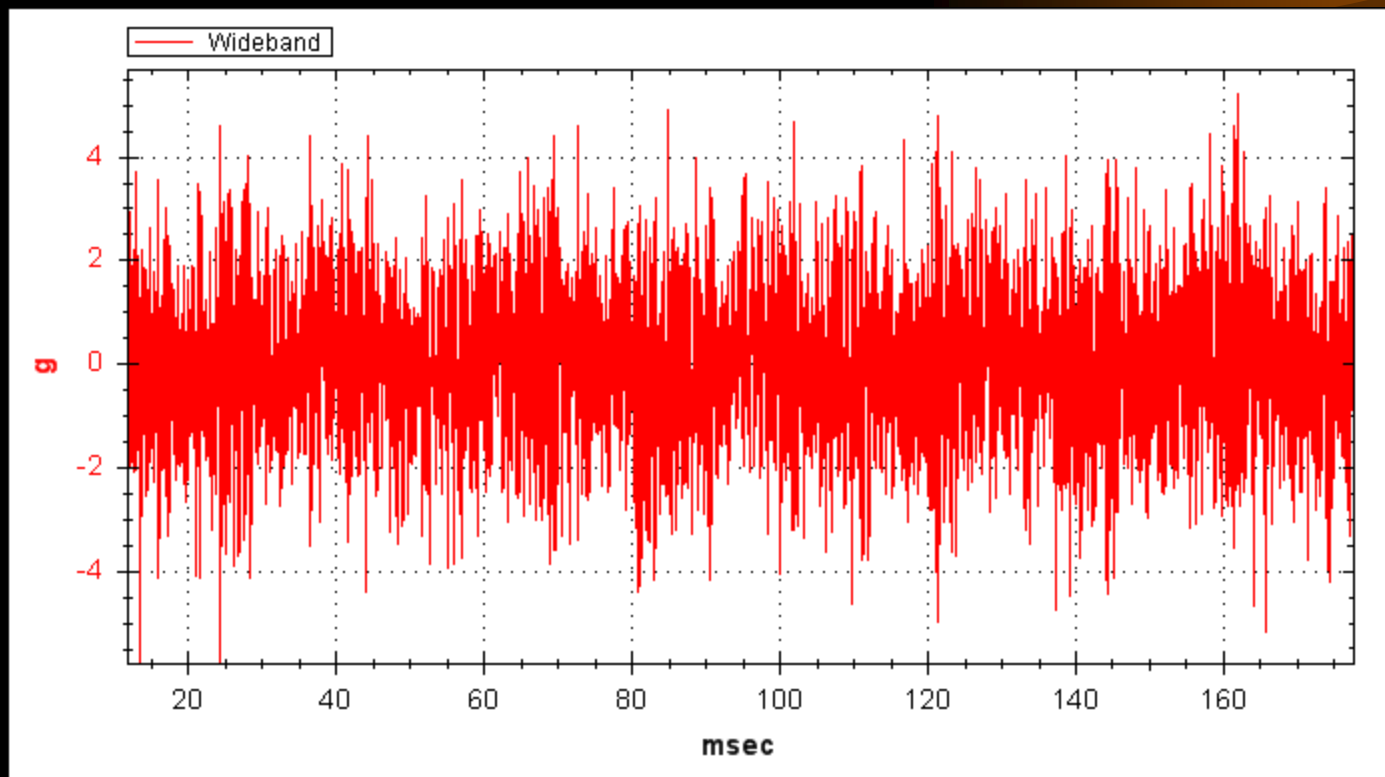
\$ FINANCIAL RISK

RELIABILITY/COST ESTIMATE TREND



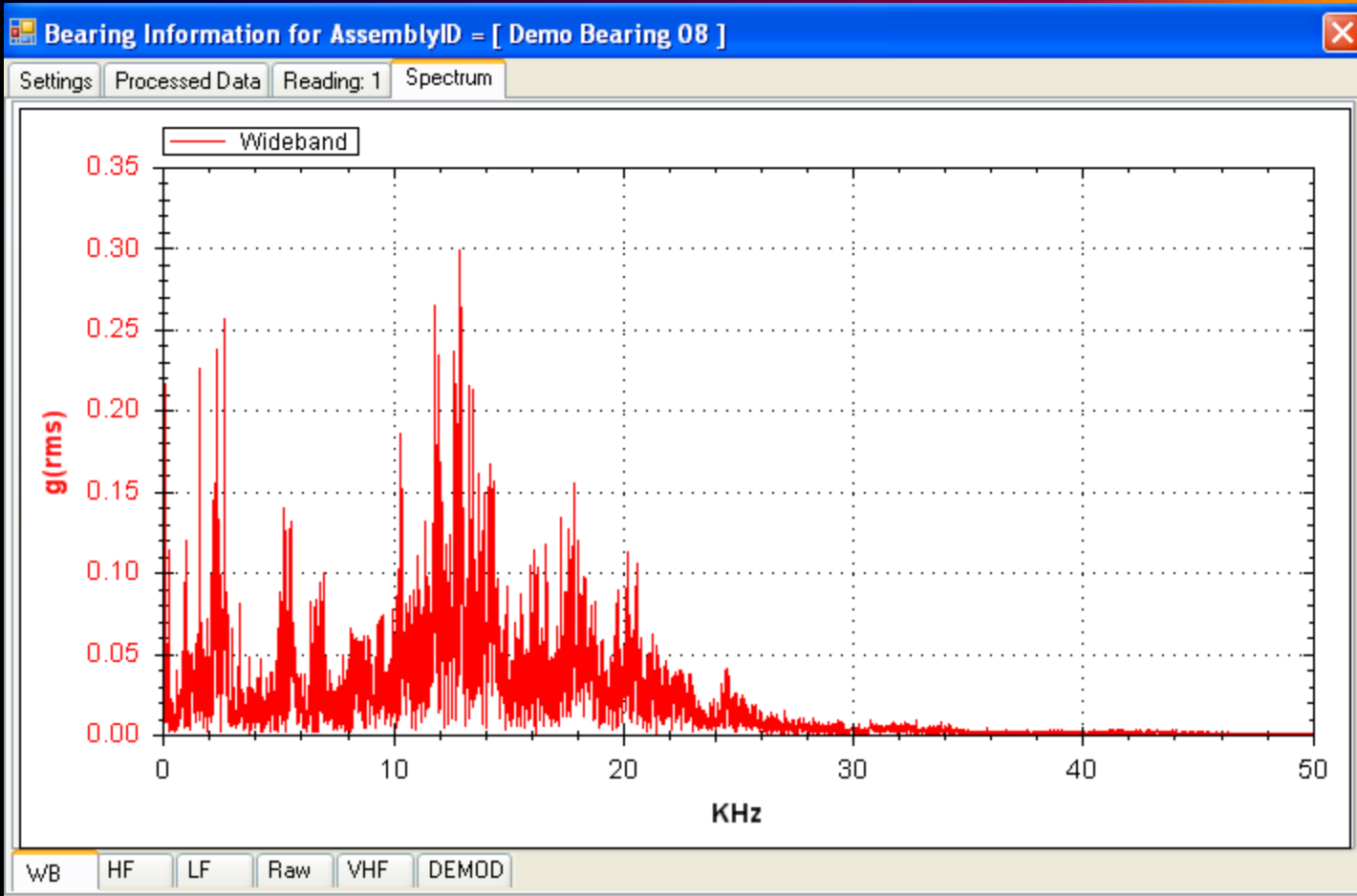
TAB SELECTED TIME WAVEFORM - RAW. WIDE BAND, HIGH FREQUENCY, LOW FREQUENCY, DEMODULATED.

*Engineer may view time waveform s-
tab selected wide band- high frequency-low
frequency-demod w/zoom capability.*



Engineer may view Spectra display.

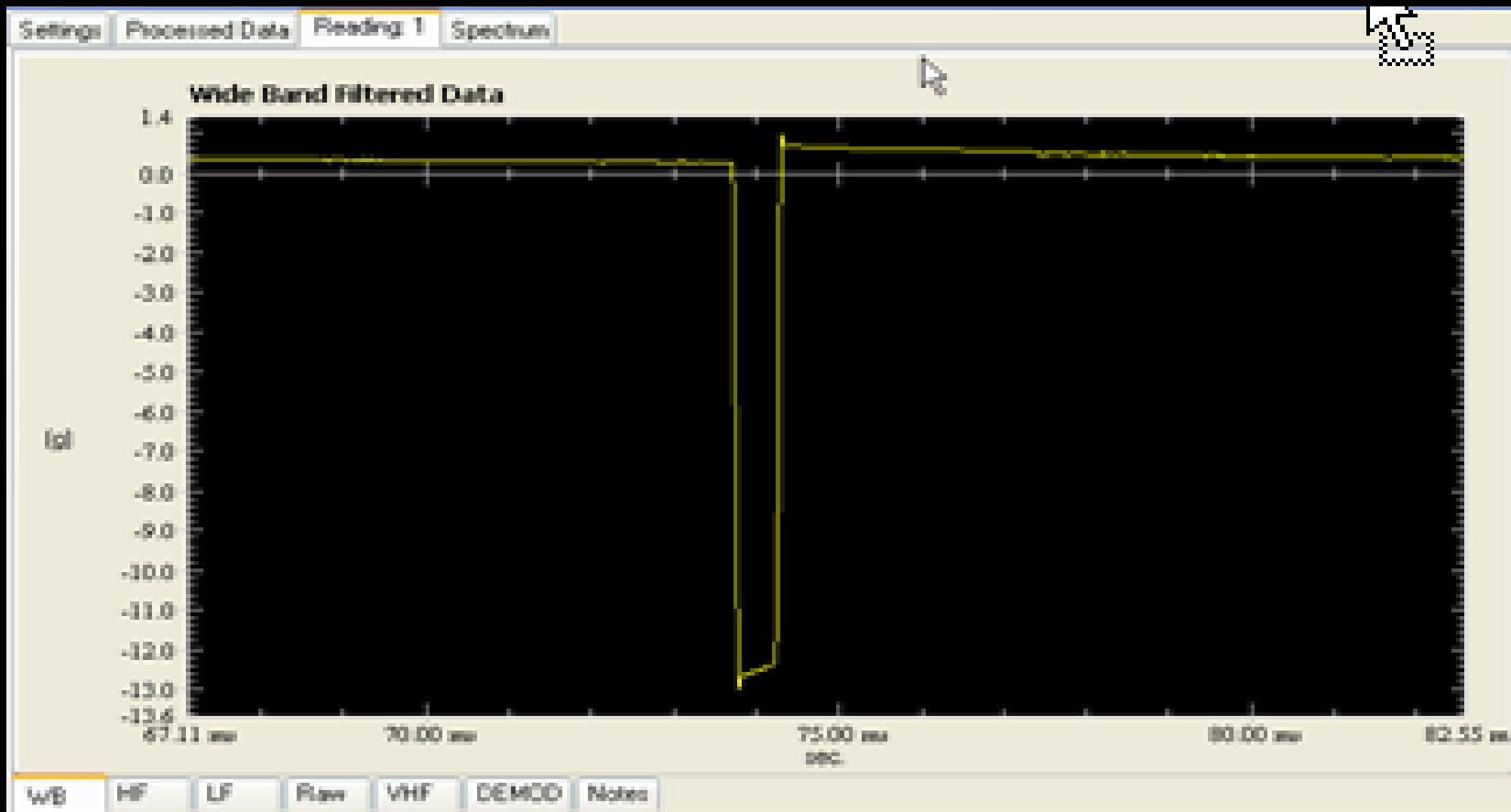
6 Tab selects unfiltered, wide band, low freq., demod, w/zoom



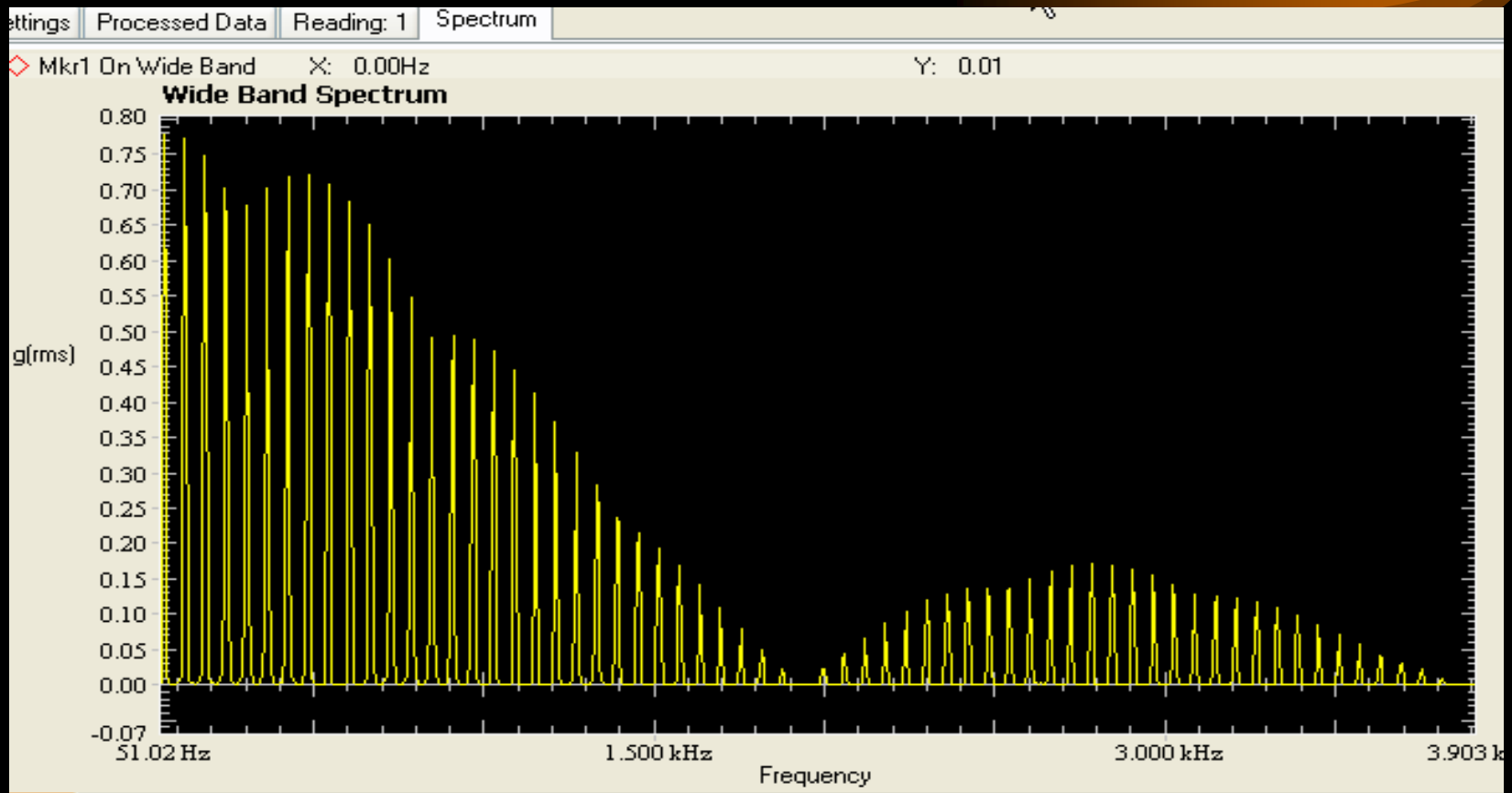
Problems with FREQUENCY ANALYSIS!

WHY IT MAY NOT BE ENOUGH!

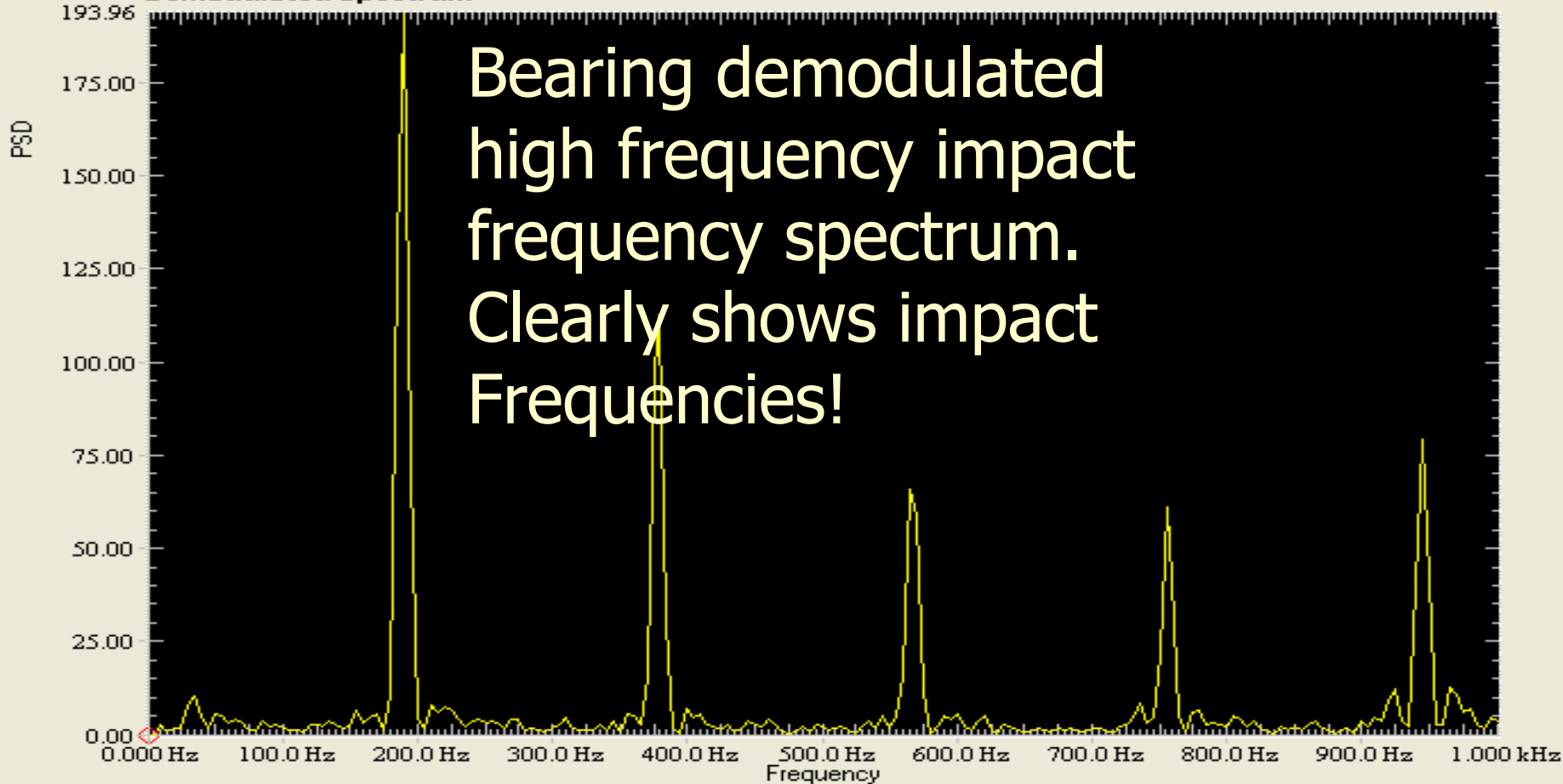
Example: frequency analysis of a one millisecond impulse.



Generated broad band spectra of impact. No clear single frequency!



Demodulated Spectrum



Bearing demodulated
high frequency impact
frequency spectrum.
Clearly shows impact
Frequencies!

**TAB SELECTED- WIDE BAND, HIGH FREQUENCY
LOW FREQUENCY, DEMODULATED.**

Bearing LifeGuard MDA- a new way to look at bearing monitoring and machine life extension.

It provides immediate information on:

- **Life shortening imbalance/alignment**
- **bearing condition.**
- **bearing expected life.**
- **the probability of failure in a selected forecast period.**
- **the financial risk of inaction or failure.**
- **recommended action.**
- **Metrics for benchmarking.**

The system also makes available raw acceleration signals and spectra for more detailed analysis if required.

MDA ® provides answers:

- It examines multiple proven technologies
 - It rejects unwanted noise.
 - Combines and analyzes the results.
 - It uses the result to estimate reliability.
 - Uses the Manufacturer's L10 equation and the Weibull Reliability equation.
 - It allows quantitative storage and cataloging information on specific Machines and assemblies.
- ISO system automatically allows use from 200 to 12,000 RPM.

**Push a collect/process and get immediate answers:
ALERT INFORMATION – RISK EXCEEDS REPAIR COST.**

Bearing Information for AssemblyID = [USPS 2 5 28]

Settings | Processed Data | Reading: 5 | Spectrum

Time stamp = 6/19/2008 8:38:41 PM

Forecast period (days)	90	RPM	1725
Estimated RMTTF (hours)	4289		
Estimated Life (hours)	4109		
Probability of Failure in forecast period	30 %		
Short term Probability (14 day)	2.2 %	Reliability	70%
Risk Estimate (Forecast Period)	\$3004	CoAF	\$10000

Risk Cost exceeds Repair Cost

Factors | Discriminants | RMTTF

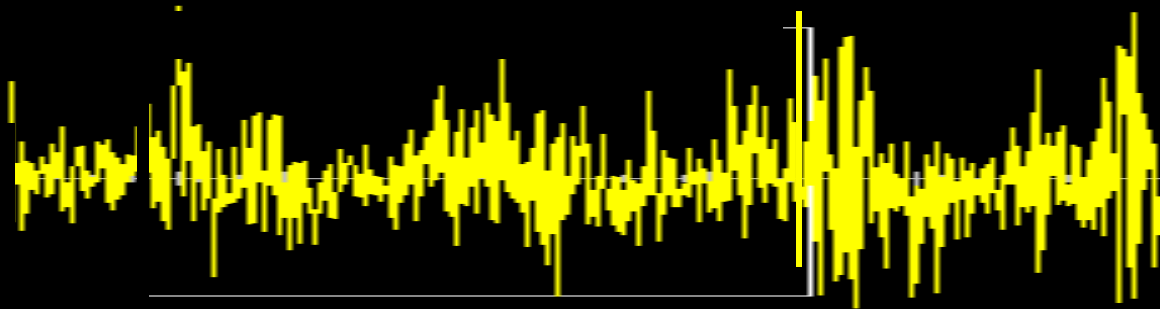
Reference material used in this presentation.

- Shock & Vibration Handbook, Cycil Harris, 3rd Edition
- Rolling Element Bearings-Tedric Harris, 3rd Edition
- RCM, Condition Monitoring or both? Richard Overman, Veridian Engineering, Maintenance Technology, Jan. 02.
- NASA-Reliability Centered Maint. & Commissioning. [Appendix A], Feb. 2002
- The McGraw-Hill Dictionary of Scientific & Technical Terms-5th Edition.
- Mil Handbook 217E
- SAE JA 1011 Surface Vehicle/Aerospace Std.-Evaluation Criteria for Reliability Centered Maintenance.
- Vibra-Metrics Inc. Vibration Reference Guide.

Suggested: Use the 5 S approach!

- **Standards**..... Establish acceptable vendor quality standards
- **Specifications** ,, Add to vendor purchase specifications
- **Screening** Sample vendor deliveries, local/central
- **Statistics** ,, ,, ,, ,, ,, ,, ,, ,, Monitor/track/analyze operating failures
- **Study** Determine root cause of failures.

BEARING **LIFEGUARD TECHNOLOGY**™



Questions? sales@bearinglifeguard.com

Information in this presentation is provided for illustration of LIFEGUARD TECHNOLOGY & MDA principles only. Use for other purposes without express permission of DMC, LLC is strictly prohibited.

US PATENT #6,763,312 B1
other patents pending.