Bearing Diagnostics and Prognostics Using PI

Reducing Unplanned Downtime

Rich Browner - Program Manager
Reliability Solutions
The Timken Company, Torrington Offices

59 Field Street
Torrington, CT 06790
(860) 626-2699 Phone
rich_browner@irco.com

TIMKEN




Company Background

- Leading bearing company in the U.S.
- 3rd largest bearing company in the world
- Torrington Company recently acquired from Ingersoll-Rand
- Timken now offers the most comprehensive array of bearing products on the market today

New Business Opportunity

- Help our industrial customers derive more value from their rotating equipment
- Suite of product-services to help end users select, install, operate and maintain bearings more effectively

Ensure Bearing Failure Does Not Cause Unplanned Shutdowns

- Enabled by the new communications infrastructure
- Bearing reliability data is key to success

Managed by PI

Identified Markets

- Need identified in the process industries
- Characteristics
  - Capital intensive processes
  - Bearings are a major component of machine efficiency
  - Cost of bearing low compared to cost of equipment downtime or failure
  - Improvements in operating efficiency translate into *top-line growth*
- Key operating goal is to maximize utilization of rotating equipment

Un-Served Need

- Current situation
  - Knowledge of current equipment health is typically lacking
- Future situation
  - Accurate predictions of equipment failure
- Serving that need requires:
  - Qualified real-time diagnosis of bearing condition
  - Accurate prognosis of future bearing performance

Anticipated Benefits

- Prior knowledge of the need for equipment maintenance will:
  - Increase uptime and throughput
  - Reduce maintenance and repair costs
  - Improve product quality

→ ***Reduced Costs***

- Benefits from reduced costs:

→ ***Increased Sales***

→ ***Top-Line Growth***

Role of PI

- PI manages critical condition data
  - Real-time process data (load, temp, pressure, flow)
  - Condition data (vibration & acoustic emissions – 1,000's of values in arrays)
  - Lubricating oil data (wear debris, moisture, condition – 1,000's of values in arrays)
- PI provides the connectivity within the information infrastructure
- Industrial Evolution enables us to manage equipment health remotely

Assembling the Solution

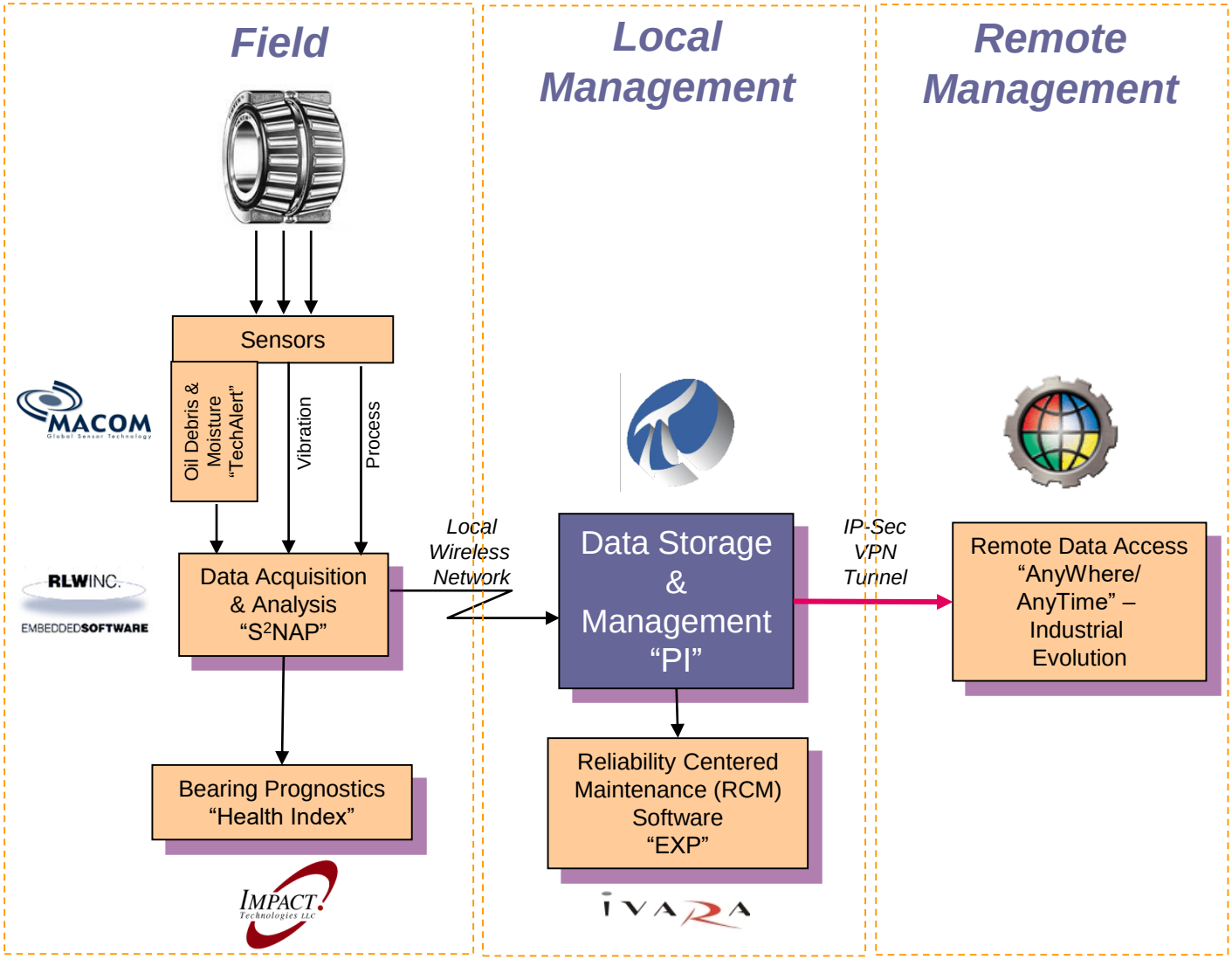
- Tools already exist - need to be assembled and applied to *prognosis*
- Timken working with a team of industry experts and products to accomplish this objective:
  - TechAlerts from Macom – oil debris monitoring sensors
  - S²NAP from RLW – local intelligence platform
  - EXP reliability software from Ivara – manages total asset health
  - PI from OSIsoft – manages real-time data and makes it available where needed
  - AnyWhere/AnyTime from Industrial Evolution – provides remote access for monitoring team
  - Diagnostic/Prognostic software from Impact Technologies – assesses bearing health




Technical Solution

- Local intelligent diagnostics and prognostics module with wireless access
- Modularized, open architecture
  - Enables system to be configured for specific needs of an individual application and user
- Intelligence located near the monitored asset
  - Large volumes of raw vibration data translated into smaller volume of meaningful information
  - Qualified diagnosis of equipment health and remaining useful life performed continuously in real time
- Diagnostic information transferred and stored in PI for local and remote management

System Architecture



OSIsoft Technology Used

- Data pushed by S²NAP every minute in XML format
- Data received and parsed and stored into PI
- 7,500 data points collected each time - includes 9 arrays of 500 points
- MDB and ACE used to deploy the Impact Technologies “Health Index” application
- ICE and MS-Excel used for viewing the diagnostics and prognosis

System Capabilities

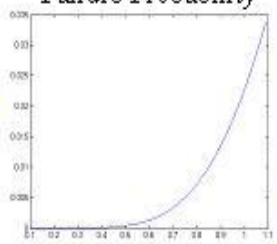
- Vibration sensing
  - Broadband analysis
  - High-frequency narrowband analysis
  - Demodulation
- Oil analysis
  - Wear debris
  - Moisture content
  - Oil condition
- Process data
- Data acquisition
- Data analysis
  - Advanced diagnostics
  - Prognostics
  - Decision support
- Wireless data transmission
- Connectivity via PI
  - Locally
  - To enterprise management
  - Remotely

Diagnostic/Prognostic Approach

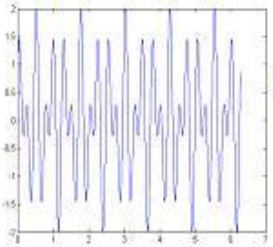
Model

$$\ln\left(\frac{1}{\Delta\zeta_i}\right) \propto \frac{N^{\nu}(\tau_i-\tau_l)^{c}\,\Delta V_i}{z_i^{h}}$$

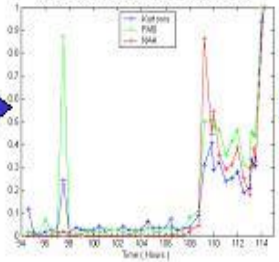
Failure Probability



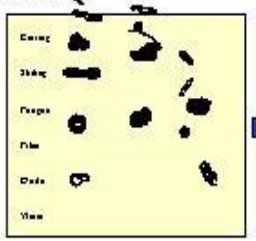
Vibration



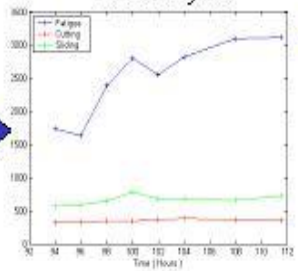
Vibration Features



Oil



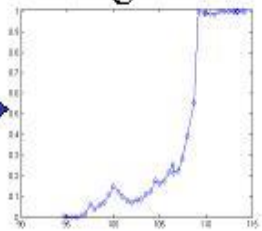
Oil Analysis



Fusion

$$\frac{\sum_{A\cap B=Hn} m_i(A)\cdot m_j(B)}{1-\sum_{A\cap B=0} m_i(A)\cdot m_j(B)}$$

Diagnosis



Prognosis

- Multiple sensor input provides improved diagnostic indicators and reduced false alarms

- Combined feature/model provides more accurate prognostics




Enabler for Improved Reliability

Timken will Improve the Reliability of Your Equipment

- Service implements advanced maintenance practices using RCM methodology
  - Makes intelligent operational decisions based on knowledge provided by this system
  - Enables comprehensive reliability services on rotating equipment
  - Facilitates reduced maintenance activity
  - Allows operators to focus more energy on their core business

Remote Access

- Uses Industrial Evolution web hosting capability
- People remote from the bearing can view results and analyze data
  - Plant personnel
  - Timken personnel
  - Macom, RLW & Impact Technologies personnel
- This will:
  - Increase the robustness of our diagnostic and prognostic capabilities
  - Allow us to monitor customers' equipment status in real time from anywhere
  - Enable our field service engineers to perform maintenance at the facility more effectively
  - Improve product designs for longer life and increased serviceability

Screen shots from our demo system:
www.osisoftdemo.com

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Timken - Overview

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Timken - Overview | Oil Debris - Slave Bearing | Oil Debris - Test Bearing #1 | Oil Debris - Test Bearing #2

Dashboard View

- ICE/Private/ice
- ICE/Public
  - 1 - Welcome
  - 2 - Airplane Tracker
  - 3 - Building Monitor
  - 4 - Cleveland Weather
  - 5 - JEA Water Plant
  - 6 - Timken
    - Oil Debris Test Bearing2
    - Oil Debris Test Bearing1
    - Oil Debris Slave Bearing

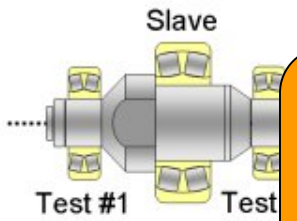
Frequency Analysis

Slave Bearing
Test Bearing #1
Test Bearing #2

Time Range

Start: *-8h
End: *
Apply

Test Rig #1



Double-click for an ad-hoc trend

Slave Bearing

Shaft

Descriptor	Value	Engineering Units
TR#1 Lube Oil Pressure	37.000	psi
TR#1 Lube Oil Temperature	38.000	°F
TR#1 Shaft Speed	39.000	RPM

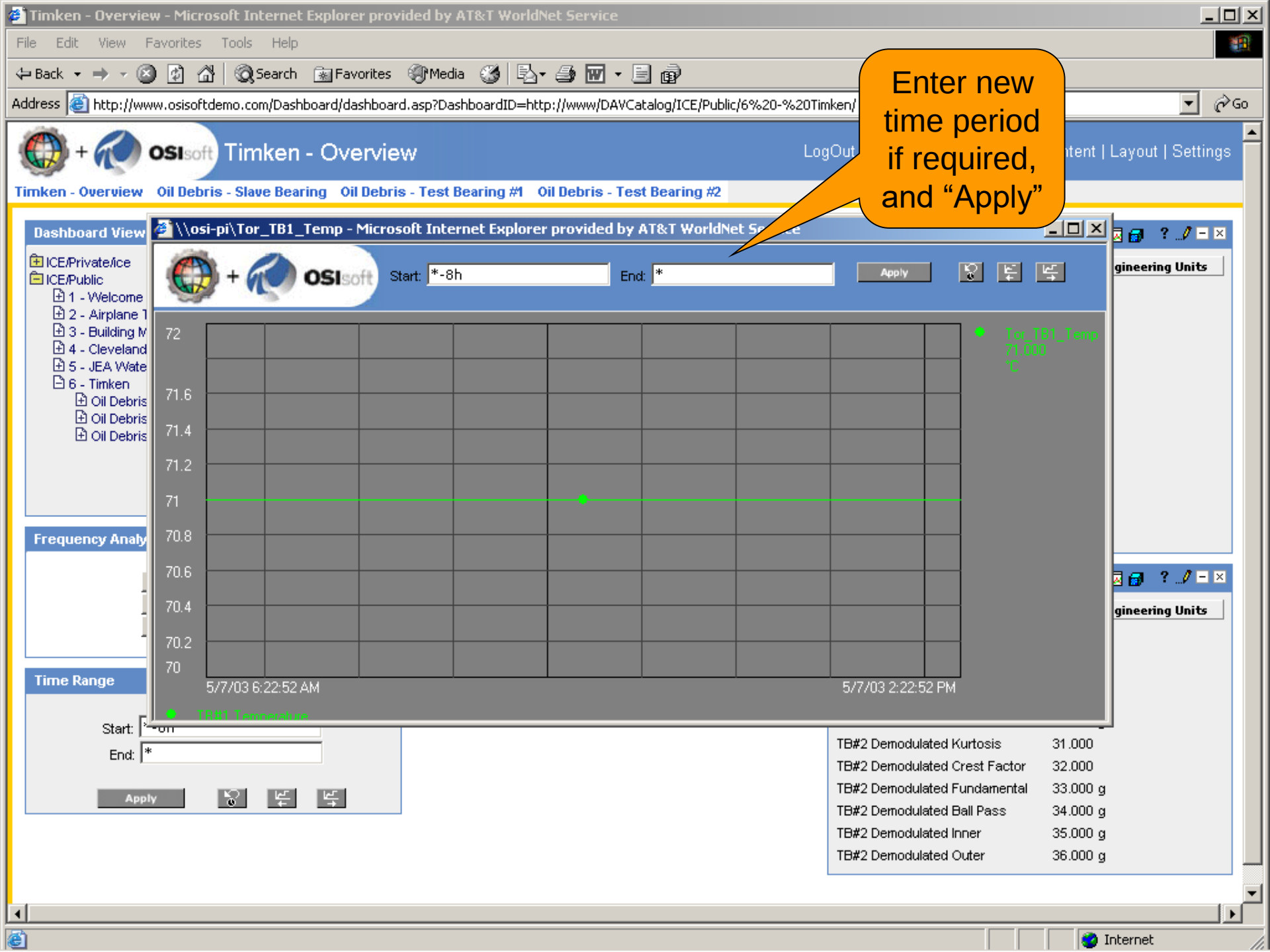
Test Bearing #1

Descriptor	Value	Engineering Units
TB#1 Temperature	71.000	°C
TB#1 RMS Vibration	14.000	g
TB#1 Broadband RMS	15.000	g
TB#1 Broadband Kurtosis	16.000	
TB#1 Broadband Crest Factor	17.000	
TB#1 Demodulated RMS	18.000	g
TB#1 Demodulated Kurtosis	19.000	
TB#1 Demodulated Crest Factor	20.000	
TB#1 Demodulated Fundamental	21.000	g
TB#1 Demodulated Ball Pass	22.000	g
TB#1 Demodulated Inner	23.000	g
TB#1 Demodulated Outer	24.000	g

Test Bearing #2

Descriptor	Value	Engineering Units
TB#2 Temperature	88.000	°C
TB#2 RMS Vibration	26.000	g
TB#2 Broadband RMS	27.000	g
TB#2 Broadband Crest Factor	29.000	
TB#2 Demodulated RMS	30.000	g
TB#2 Demodulated Kurtosis	31.000	
TB#2 Demodulated Crest Factor	32.000	
TB#2 Demodulated Fundamental	33.000	g
TB#2 Demodulated Ball Pass	34.000	g
TB#2 Demodulated Inner	35.000	g
TB#2 Demodulated Outer	36.000	g

Internet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Timken - Overview
LogOut
Layout | Settings
Timken - Overview
Oil Debris - Slave Bearing
Oil Debris - Test Bearing #1
Oil Debris - Test Bearing #2
Enter new time period if required, and "Apply"
\\osi-pi\Tor_TB1_Temp - Microsoft Internet Explorer provided by AT&T WorldNet Service
Start: *-8h
End: *
Apply
72
71.6
71.4
71.2
71
70.8
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70.4
70.2
70
5/7/03 6:22:52 AM
5/7/03 2:22:52 PM
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Dashboard View
ICE/Private/ice
ICE/Public
1 - Welcome
2 - Airplane T
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4 - Cleveland
5 - JEA Wate
6 - Timken
Oil Debris
Oil Debris
Oil Debris
Frequency Analy
Time Range
Start:
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TB#2 Demodulated Kurtosis 31.000
TB#2 Demodulated Crest Factor 32.000
TB#2 Demodulated Fundamental 33.000 g
TB#2 Demodulated Ball Pass 34.000 g
TB#2 Demodulated Inner 35.000 g
TB#2 Demodulated Outer 36.000 g
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Timken - Overview | Oil Debris - Slave Bearing | Oil Debris - Test Bearing #1 | Oil Debris - Test Bearing #2

Dashboard View

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    - Oil Debris Test Bearing1
    - Oil Debris Slave Bearing

Frequency Analysis

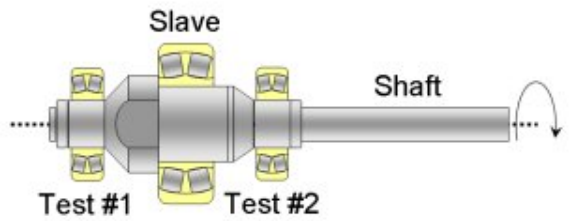
Slave Bearing
Test Bearing #1
Test Bearing #2

Time Range

Start: *-8h
End: *
Apply

Click to download data to spectrum analysis spreadsheet

Test Rig #1



Slave Bearing

Shaft

Descriptor	Value	Engineering Units
TR#1 Lube Oil Pressure	37.000	psi
TR#1 Lube Oil Temperature	38.000	°F
TR#1 Shaft Speed	39.000	RPM

Test Bearing #1

Descriptor	Value	Engineering Units
TB#1 Temperature	71.000	°C
TB#1 RMS Vibration	14.000	g
TB#1 Broadband RMS	15.000	g
TB#1 Broadband Kurtosis	16.000	
TB#1 Broadband Crest Factor	17.000	
TB#1 Demodulated RMS	18.000	g
TB#1 Demodulated Kurtosis	19.000	
TB#1 Demodulated Crest Factor	20.000	
TB#1 Demodulated Fundamental	21.000	g
TB#1 Demodulated Ball Pass	22.000	g
TB#1 Demodulated Inner	23.000	g
TB#1 Demodulated Outer	24.000	g

Test Bearing #2

Descriptor	Value	Engineering Units
TB#2 Temperature	88.000	°C
TB#2 RMS Vibration	26.000	g
TB#2 Broadband RMS	27.000	g
TB#2 Broadband Crest Factor	29.000	
TB#2 Demodulated RMS	30.000	g
TB#2 Demodulated Kurtosis	31.000	
TB#2 Demodulated Crest Factor	32.000	
TB#2 Demodulated Fundamental	33.000	g
TB#2 Demodulated Ball Pass	34.000	g
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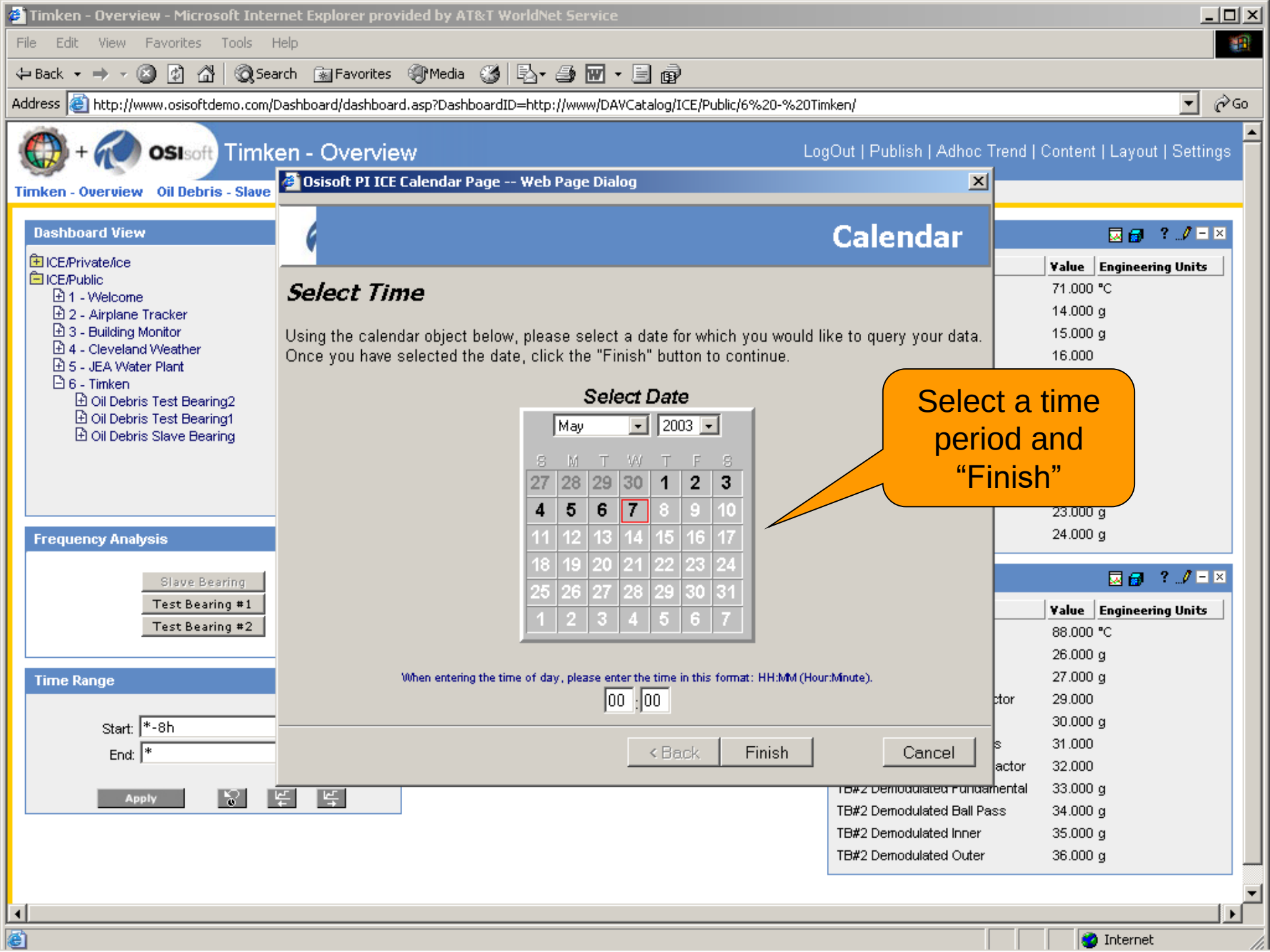
TB#2 Demodulated Outer	36.000	g

Internet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Timken - Overview
Oil Debris - Slave
Dashboard View
ICE/Private/ice
ICE/Public
1 - Welcome
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Oil Debris Test Bearing2
Oil Debris Test Bearing1
Oil Debris Slave Bearing
Frequency Analysis
Slave Bearing
Test Bearing #1
Test Bearing #2
Time Range
Start: *-8h
End: *
Apply
Osisoft PI ICE Calendar Page -- Web Page Dialog
Calendar
Select Time
Using the calendar object below, please select a date for which you would like to query your data.
Once you have selected the date, click the "Finish" button to continue.
Select Date
May
2003
S M T W T F S
27 28 29 30 1 2 3
4 5 6 7 8 9 10
11 12 13 14 15 16 17
18 19 20 21 22 23 24
25 26 27 28 29 30 31
1 2 3 4 5 6 7
When entering the time of day, please enter the time in this format: HH:MM (Hour:Minute).
00 : 00
< Back
Finish
Cancel
Select a time period and "Finish"
Value
Engineering Units
71.000 °C
14.000 g
15.000 g
16.000
23.000 g
24.000 g
88.000 °C
26.000 g
27.000 g
29.000
30.000 g
31.000
32.000
33.000 g
TB#2 Demodulated Ball Pass
34.000 g
TB#2 Demodulated Inner
35.000 g
TB#2 Demodulated Outer
36.000 g
Internet

Osisoft PI ICE Frequency Analysis - Microsoft Internet Explorer provided by AT&T WorldNet Service

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Loading MS-Excel...

Please wait while the proper values are placed into the required spreadsheet. 1500 values to query and load.
This may take a moment (typical load time: 30 seconds).

\ ...Loading... /

If Excel fails to load correctly, click here to close this window.

Internet

Osisoft PI ICE Frequency Analysis - Microsoft Internet Explorer provided by AT&T WorldNet Service

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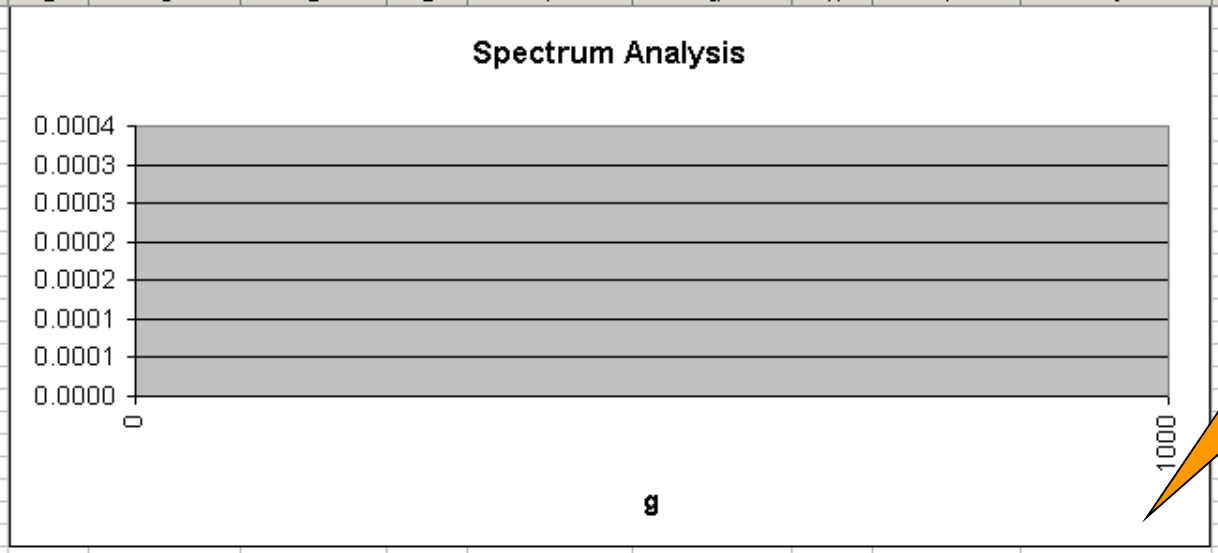
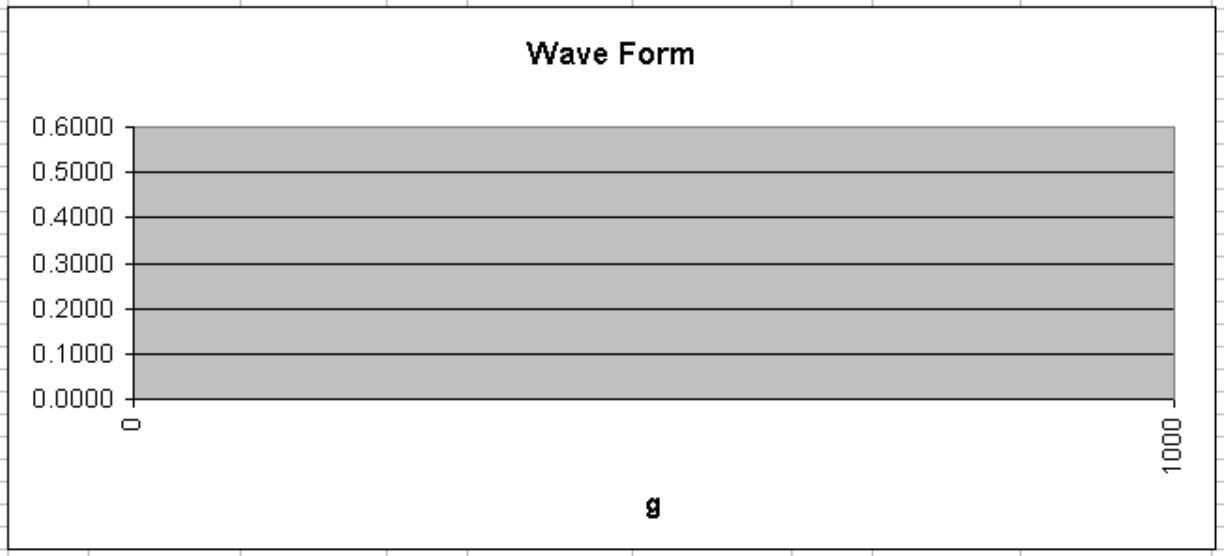
F95 =((F593-F81)/512)*A95





Vibration and oil debris distribution data populates spreadsheet and analysis is performed automatically

Test Bearing #1

Internet

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OSIsoft Timken - Overview

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Timken - Overview | Oil Debris - Slave Bearing | Oil Debris - Test Bearing #1 | Oil Debris - Test Bearing #2

Dashboard View

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    - Oil Debris Slave Bearing

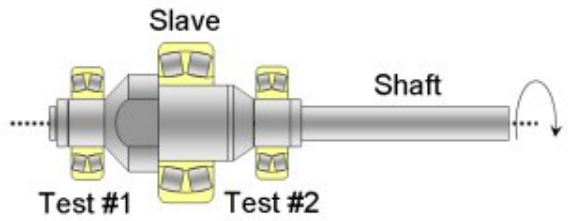
Frequency Analysis

Slave Bearing
Test Bearing #1
Test Bearing #2

Time Range

Start: *-8h
End: *
Apply

Test Rig #1



Slave Bearing

Shaft

	Value	Engineering Units
Pressure	37.000	psi
Temperature	38.000	°F
eed	39.000	RPM

Click to view oil debris analysis

Test Bearing #1

Descriptor	Value	Engineering Units
TB#1 Temperature	71.000	°C
TB#1 RMS Vibration	14.000	g
TB#1 Broadband RMS	15.000	g
TB#1 Broadband Kurtosis	16.000	
TB#1 Broadband Crest Factor	17.000	
TB#1 Demodulated RMS	18.000	g
TB#1 Demodulated Kurtosis	19.000	
TB#1 Demodulated Crest Factor	20.000	
TB#1 Demodulated Fundamental	21.000	g
TB#1 Demodulated Ball Pass	22.000	g
TB#1 Demodulated Inner	23.000	g
TB#1 Demodulated Outer	24.000	g

Test Bearing #2

Descriptor	Value	Engineering Units
TB#2 Temperature	88.000	°C
TB#2 RMS Vibration	26.000	g
TB#2 Broadband RMS	27.000	g
TB#2 Broadband Crest Factor	29.000	
TB#2 Demodulated RMS	30.000	g
TB#2 Demodulated Kurtosis	31.000	
TB#2 Demodulated Crest Factor	32.000	
TB#2 Demodulated Fundamental	33.000	g
TB#2 Demodulated Ball Pass	34.000	g
TB#2 Demodulated Inner	35.000	g
TB#2 Demodulated Outer	36.000	g

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Oil Debris - Test Bearing #1 - Microsoft Internet Explorer provided by AT&T WorldNet Service

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Oil Debris - Test Bearing #1

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Time Range

Start: *-8h

End: *

Apply

Ferrous Metal (Counts)

Descriptor	Value
TB#1 Ferrous Metal Counts 0-100 µm	57.000
TB#1 Ferrous Metal Counts 100-200 µm	58.000
TB#1 Ferrous Metal Counts 200-400 µm	59.000
TB#1 Ferrous Metal Counts 400-800 µm	60.000
TB#1 Ferrous Metal Counts >800 µm	61.000

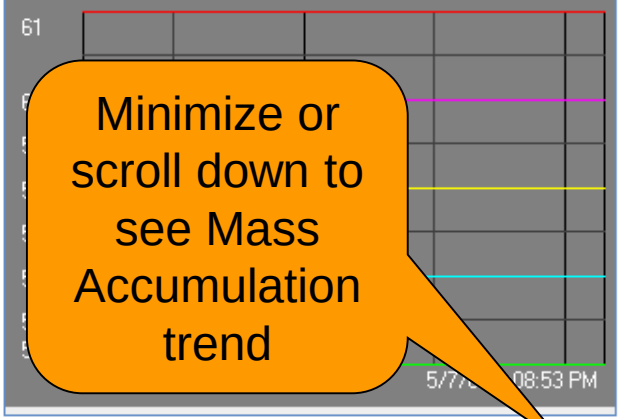
Non-Ferrous Metal (Counts)

Descriptor	Value
TB#1 Non-Ferrous Metal Counts 100-200 µm	62.000
TB#1 Non-Ferrous Metal Counts 200-400 µm	63.000
TB#1 Non-Ferrous Metal Counts 400-800 µm	64.000
TB#1 Non-Ferrous Metal Counts 800-1600 µm	65.000
TB#1 Non-Ferrous Metal Counts >1600 µm	66.000

Distribution

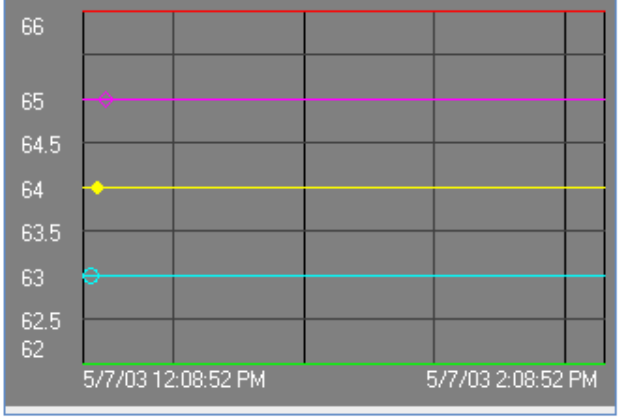
Descriptor	Value
TB#1 Ferrous Mass Accumulation	67.000
TB#1 Ferrous Mass Debris Range	68.000
TB#1 Ferrous Mass Rolling Average	69.000
TB#1 Ferrous Mass Rate of Change	70.000
TB#1 Temperature	71.000
TB#1 TechAlert 10	72.000
TB#1 TechAlert 20	73.000

Distribution Ferrous Metals



Minimize or scroll down to see Mass Accumulation trend

Distribution Non-Ferrous Metals



Mass Accumulation

Internet

Oil Debris - Test Bearing #1 - Microsoft Internet Explorer provided by AT&T WorldNet Service

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Oil Debris - Test Bearing #1

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Time Range

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End: *

Apply

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TB#1 Non-Ferrous Metal Counts 800-1600 µm	65.000
TB#1 Non-Ferrous Metal Counts >1600 µm	66.000

Distribution

Descriptor	Value
TB#1 Ferrous Mass Accumulation	67.000
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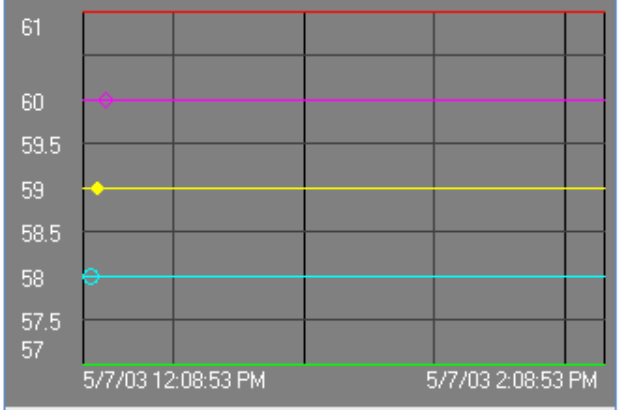
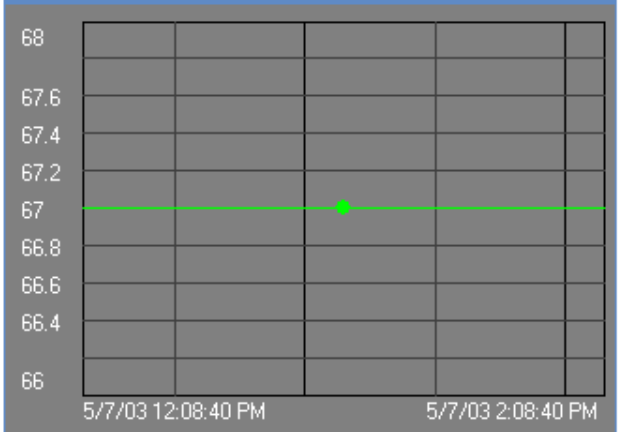
TB#1 TechAlert 20	73.000

Distribution Ferrous Metals



Distribution Non-Ferrous Metals

Mass Accumulation



Internet

Timken - Overview - Microsoft Internet Explorer provided by AT&T WorldNet Service

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Timken - Overview

LogOut | Publish | Adhoc Trend | Content | Layout | Settings

Timken - Overview | Oil Debris - Slave Bearing | Oil Debris - Test Bearing #1 | Oil Debris - Test Bearing #2

Dashboard View

- ICE/Private/ice
- ICE/Public
  - 1 - Welcome
  - 2 - Airplane Tracker
  - 3 - Building Monitor
  - 4 - Cleveland Weather
  - 5 - JEA Water Plant
  - 6 - Timken
    - Oil Debris Test Bearing2
    - Oil Debris Test Bearing1
    - Oil Debris Slave Bearing

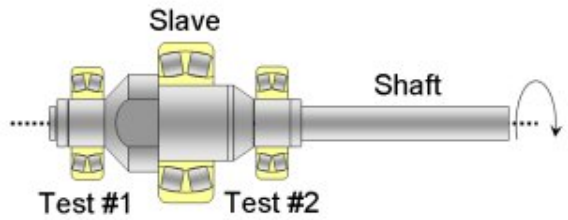
Frequency Analysis

Slave Bearing
Test Bearing #1
Test Bearing #2

Time Range

Start: *-8h
End: *
Apply

Test Rig #1



Slave Bearing

Shaft

Descriptor	Value	Engineering Units
TR#1 Lube Oil Pressure	37.000	psi
TR#1 Lube Oil Temperature	38.000	°F
TR#1 Shaft Speed	39.000	RPM

Test Bearing #1

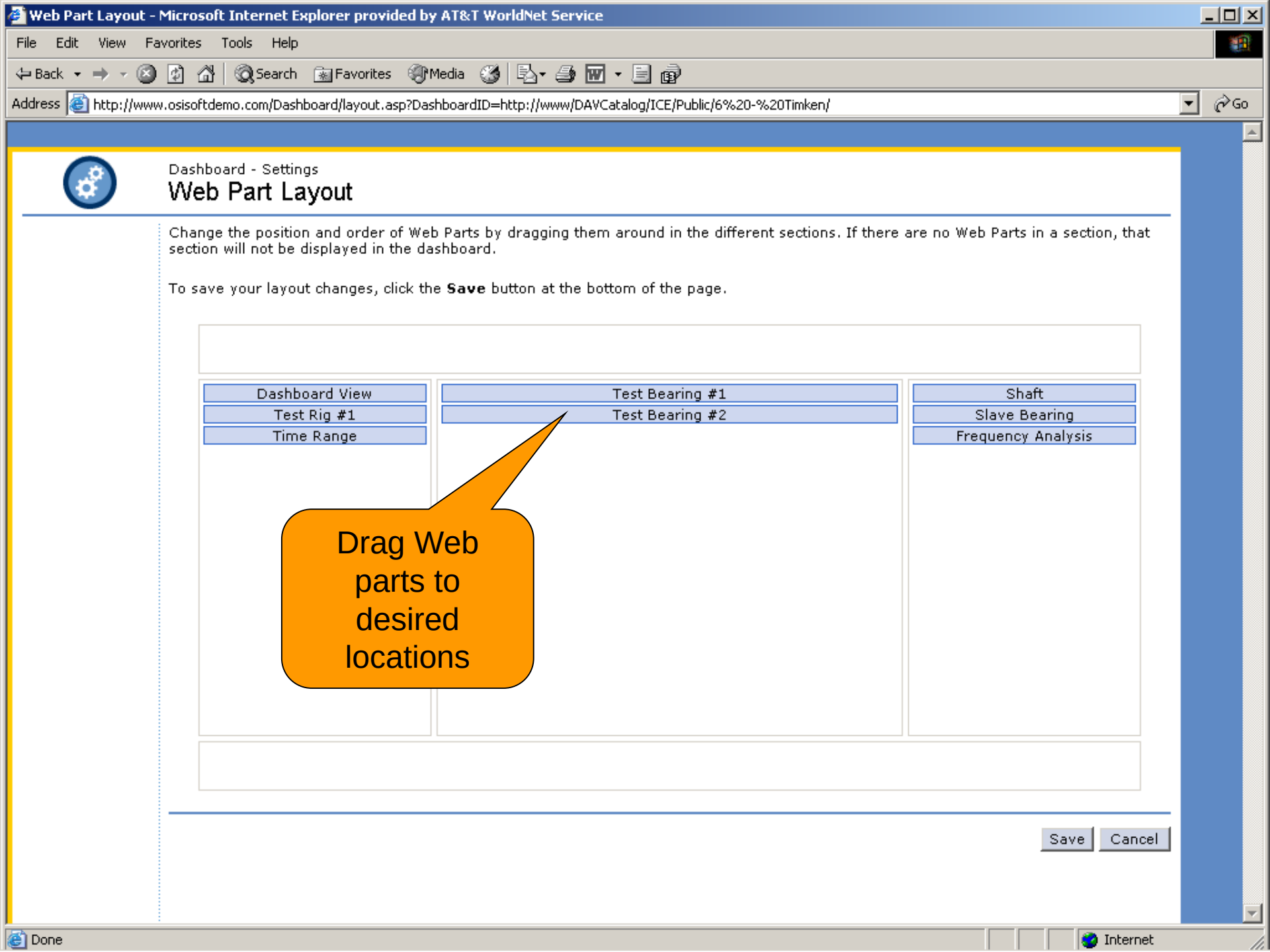
Descriptor	Value	Engineering Units
TB#1		
TB#1		
TB#1		
TB#1		
TB#1		
TB#1 Demodulated RMS		
TB#1 Demodulated Kurtosis	19.000	
TB#1 Demodulated Crest Factor	20.000	
TB#1 Demodulated Fundamental	21.000	g
TB#1 Demodulated Ball Pass	22.000	g
TB#1 Demodulated Inner	23.000	g
TB#1 Demodulated Outer	24.000	g

Click to personalize layout

Test Bearing #2

Descriptor	Value	Engineering Units
TB#2 Temperature	88.000	°C
TB#2 RMS Vibration	26.000	g
TB#2 Broadband RMS	27.000	g
TB#2 Broadband Crest Factor	29.000	
TB#2 Demodulated RMS	30.000	g
TB#2 Demodulated Kurtosis	31.000	
TB#2 Demodulated Crest Factor	32.000	
TB#2 Demodulated Fundamental	33.000	g
TB#2 Demodulated Ball Pass	34.000	g
TB#2 Demodulated Inner	35.000	g
TB#2 Demodulated Outer	36.000	g

Internet


Web Part Layout - Microsoft Internet Explorer provided by AT&T WorldNet Service
File Edit View Favorites Tools Help
Back Search Favorites Media
Address http://www.osisoftdemo.com/Dashboard/layout.asp?DashboardID=http://www/DAVCatalog/ICE/Public/6%20-%20Timken/
Go
Dashboard - Settings
Web Part Layout
Change the position and order of Web Parts by dragging them around in the different sections. If there are no Web Parts in a section, that section will not be displayed in the dashboard.
To save your layout changes, click the Save button at the bottom of the page.
Dashboard View
Test Rig #1
Time Range
Test Bearing #1
Test Bearing #2
Shaft
Slave Bearing
Frequency Analysis
Drag Web parts to desired locations
Save
Cancel
Done
Internet

Timken - Overview - Microsoft Internet Explorer provided by AT&T WorldNet Service

File Edit View Favorites Tools Help

Back Search Favorites Media

Address http://www.osisoftdemo.com/Dashboard/dashboard.asp?DashboardID=http://www/DAVCatalog/ICE/Public/6%20-%20Timken/

Go

Timken - Overview

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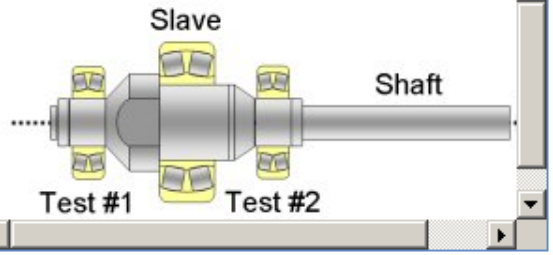
Timken - Overview | Oil Debris - Slave Bearing | Oil Debris - Test Bearing #1 | Oil Debris - Test Bearing #2

Dashboard View

- ICE/Private/ice
- ICE/Public

Test Rig #1



Time Range

Start: *-8h

End: *

Apply

Test Bearing #1

Descriptor	Value	Engineering Units
TB#1 Temperature	71.000	°C
TB#1 RMS Vibration	14.000	g
TB#1 Broadband RMS	15.000	g
TB#1 Broadband Kurtosis	16.000	
TB#1 Broadband Crest Factor	17.000	
TB#1 Demodulated RMS	18.000	g
TB#1 Demodulated Kurtosis	19.000	
TB#1 Demodulated Crest Factor	20.000	
TB#1 Demodulated Fundamental	21.000	g
TB#1 Demodulated Ball Pass	22.000	g
TB#1 Demodulated Inner	23.000	g
TB#1 Demodulated Outer	24.000	g

Test Bearing #2

Descriptor	Value	Engineering Units
TB#2 Temperature	88.000	°C
TB#2 RMS Vibration	26.000	g
TB#2 Broadband RMS	27.000	g
TB#2 Broadband Crest Factor	29.000	
TB#2 Demodulated RMS	30.000	g
TB#2 Demodulated Kurtosis	31.000	
TB#2 Demodulated Crest Factor	32.000	
TB#2 Demodulated Fundamental	33.000	g
TB#2 Demodulated Ball Pass	34.000	g
TB#2 Demodulated Inner	35.000	g
TB#2 Demodulated Outer	36.000	g

Shaft

Descriptor	Value	Engineering Units
TR#1 Lube Oil Pressure	37.000	psi
TR#1 Lube Oil Temperature	38.000	°F
TR#1 Shaft Speed	39.000	RPM

Slave Bearing

Frequency Analysis

Slave Bearing

Test Bearing #1

Test Bearing #2

Done

Internet

Demo

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