Panel: Transforming Your Equipment Maintenance Programs with the PI System

Moderator: Enrique Herrera
Panelists

Gary Foster
Sr. Manager Digitalization Partnership Development
(SKF)

Martin Davis
CIO
(DUNELM)

GOPAL
Gopalkrishnan
Solutions Architect
(OSIsoft)
Remote Equipment Performance

Andre Du Bruyn & Gary M. Foster, SKF
Gopal GopalKrishnan, OSIsoft, LLC.
IloT / Digitalization enables *Rotation for Life*

- extend bearing life
- eliminate unplanned mechanical downtime
- Rotating Equipment Performance skills
- Integrated data driven Operations & Maintenance information & planning
- Asset Performance Optimization

- Since 1907 SKF delivers Reliable Rotation – globally, via billions of bearings in virtually every industry segment
- For 30+ years SKF partnerships pioneer vibration based Condition Monitoring technology and work processes to improve asset reliability
SKF Reliability Services

- Vibration Analysis
- Balancing
- Lubricant Analysis
- Motor Current Analysis
- ODS
- Oil Analysis
- Thermography
- NDT

- Bearing Failure Analysis
- Bearing Selection
- Sealing Selection
- Lubrication Specifications

ODS - Operational Deflection Shape
NDT - Non-Destructive Testing
Rotation For Life (RFL)

**Objective:** RFL is a Rotating Equipment Performance program with focus on profitability.

- Bringing together SKF knowledge, technology and machine data with customer’s business processes, applications and practices.
- Increasing equipment operational and asset management excellence to help customers reduce cost and grow profits.

**RFL = Subscription based monthly fee**

- optimize bearing performance and asset reliability
The P-F Curve for a Bearing

More time to react based upon estimated remaining useful life of bearing:
- To be prepared to fix
- To minimize collateral damage
- To be able to remanufacture and reuse
- To be able to perform RCA

RCFA difficult
RCFA still possible
Remanufacturing still an option
Too late for remanufacturing

We may not prevent equipment from degrading toward failure, but we can prevent business consequences by intervening at appropriate time
Rotation for Life for Conveyor system
Sealed spherical roller bearings (SSRB)

Benefits
• 3+ times improvement in MTBF
• Maintenance cost reduction
• Significant environmental impact reduction, 60+% less lubrication

On-line conveyor health monitoring
• Real time automated collection and analysis, No data collection staff required
• SMS, email, control room alarms
• Full history and trending
• Seamless link to corporate data systems

Distributed automated lubrication system
• Correct lube, correct volume, correct place
• No people overhead
• Environmental impact
• Alarm system integration
Aligning asset maintenance with operations – failure modes, usage-based, condition-based and predictive (pattern recognition) maintenance

OSIsoft

Gopal GopalKrishnan, P.E., Solutions Architect
Keith Pierce, Principal Technical Advisor
Bryan Pope, Systems Engineer

ECG, Inc.
Mike Santucci

Allied Reliability
Preston Johnson,
Platform Lead, Intelligent Monitoring
Lab Description

Increasing equipment uptime means preventing failures before they happen; and in turn this requires you to have a list of likely failures and the appropriate condition monitoring for the process or equipment/component. Attend this lab to learn about failure modes, and corresponding monitoring techniques to prevent failures. The lab will also cover the use of operations data for a layered approach to uptime and reliability via usage based, condition-based and predictive (pattern recognition based) maintenance.

Usage-based maintenance includes using operational metrics such as motor run-hours, compressor starts/stops, grinder tonnage etc. And, condition-based maintenance utilizes measurements such as filter deltaP, bearing temperature, valve stroke travel, and others. Predictive maintenance can be simple predictive such as monitoring vibration (rms, peak etc.) to predict RUL (remaining useful life) or heat-exchanger fouling to schedule cleaning. Advanced predictive maintenance use cases include pattern recognition or other machine learning techniques for detecting anomalies/predicting failures.

Who should attend? Power User and Intermediate
Duration: 3 hours
Analytics for Maintenance & Reliability

- **Preventative**
  - Calendar-based
  - Runtime-based

- **Reactive**
  - "Break-Fix"
  - Run-to-failure

- **Condition-based**
  - Continuous
    - Instrumented
    - Automated Readings
    - Automated Analysis
  - Manual Analysis

- **Predictive**
  - Simple
  - Advanced (machine learning, APR,...)

- **Usage based maintenance**

- **Condition based maintenance**

- **Predictive maintenance**
CBM – a strategy where the asset condition is factored into maintenance decisions

- Failure modes and sensor coverage (Demo)
- Ex. 1: Usage based Preventive Maintenance
- Ex. 2: Condition Monitoring, Condition based Maintenance
- Ex. 3: Predictive Maintenance
  - 3a - Basic – Univariate - extrapolate the trend
  - 3b - Advanced – Multivariate - machine learning, APR, statistical etc.
  - Coal pulverizer – early fault detection for bearing failure using APR - Advanced Pattern Recognition
    - Engine Failure – PCA - TechCon 2016
    - Anomaly detection (HVAC - Air Handler) – SVM - TechCon 2017
    - Yeast manufacturing – process reliability, diagnostics - PI World 2019
  - Ex. 4: Overall Health Score
Timing

- 15 min - Overview and Lab objectives
- 15 min - Failure modes and sensor coverage – Allied demo
- 30 min - Ex 1 - Usage based
- 30 min - Ex 2 - Condition based
- 20 min - Ex 3a - Predictive - simple
- 40 min - Ex 3b - Predictive - advanced - Pulverizer (pattern recognition)
  - Overview/Demo
  - Build, Train, Validate and Deploy
- 10 min - Ex 4 - Overall health score
- 10 min - Q & A, Wrap
- 10 min - Buffer
CBM Guidebook version 2

Created by Keith Pierce on Mar 16, 2018 9:29 PM. Last modified by Keith Pierce on Mar 16, 2018 9:29 PM.

We've updated the popular CBM Guidebook, first issued in 2015. This version has some updated definitions and more (and updated) references, including references by industry. Please take a look and feel free to provide your feedback and comments.
Process data vis-à-vis CM (Condition Monitoring) data

- **Process data (continuous online measurements)**
  - Pressure, temperature, flowrate, level, amperage, voltage
  - Equipment states such as open/close, running/stopped
  - SCADA, PLCs, other instrumentation, IIoT...
  - Control, safety, environmental, process monitoring

- **CM data (may not be on-line and may not be continuous)**
  - Vibration
  - Infrared (Thermography)
  - Acoustic (Ultrasound)
  - Oil sampling - motor oil, transformer oil...
  - Motor current analysis
  - Strain-gauge (coke drums in a refinery)
  - ...

PI System – full stack – data flow
Overall PI System data Flow

- Collect the data
- Define context for the data – Equipment, Process...
- Calculations/Analytics - layers of analytics - simple/advanced
- Visualize
- Share, Notify, Take action
- Business integration with other tools (SAP, Maximo, Infor, Oracle...)
  - Update counters/measurement points/operating factors
  - Trigger work order
  - ...
  - ...

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Failure modes and sensor coverage – Allied demo
Ex. 1 – Usage based maintenance

- Motor - run-hours
- Pulverizer - tons of coal
- Transformer - load tap changer - count of operations
- Compressor - count of start/stop cycles
- Valve - count of open/close operations, amount of valve travel
- Filter - amount of liquid processed

...
Ex. 1 – Usage based maintenance - Run Hours
Ex. 1 – Usage based maintenance - Run Hours

Mixer 1
509

<table>
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<th>Name</th>
<th>Value</th>
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<td>Previous Day Run Hours</td>
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<td>Mixer 1</td>
<td>Run Hours Since Maintenance</td>
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<td>Mixer 1</td>
<td>Valve Actuation Count Since Maintenance</td>
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<td>Mixer 1</td>
<td>YTD Run Hours</td>
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RPM 70.528 rpm
Filler Rate 679.74 kg/min
Valve 1
Temperature 4.32 °C
Ex. 2 – Condition based maintenance

- Lubrication PM - on actual run-time, instead of calendar
- Analyzer re-calibration PM - drift exceeding 1%
- Filter change PM - measured pressure differential
- Compressor wash cycle - efficiency calculations
- Heat exchanger cleaning cycle - fouling or proxy
- Circuit switch - amount of time to open/close
- Rotating equipment - bearings high temperature
- Pulverizer - vibration, deflection
- Transformer - oil - dissolved gas analysis
Ex. 2 Condition Monitoring and Condition-based maintenance

Hydraulic Failure Modes
- Cavitation
- Pressure Pulsation
- Pump Recirculation
- Radial and Axial Thrust

Mechanical Failure Modes
- Shaft Seizure or Break
- Bearing Failure
- Seal Failure
- Vibration
- Fatigue
- Misalignment

Lubrication
- Viscosity
- Water
- Wear particles

Motor
- Rotor bar damage
- Eccentricity
- Mechanical looseness

Pump/Motor Failure Modes
Ex. 2 Condition based maintenance – Bearing temperature
Ex. 2 Condition based maintenance – Bearing temperature

### Number and Duration of High Bearing Temperature Alerts

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<th>Asset</th>
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<th>Bearing Temperature</th>
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<th>Asset</th>
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Ex. 3a Simple Predictive – extrapolate the trend – compressor efficiency
Ex. 3a Simple Predictive - air heater fouling

Air heater tube plugging at a coal power plant over 450 days
Ex. 3b - Advanced Predictve - pulverizer - early fault detection
Ex. 3b - Advanced Predictive - pulverizer - early fault detection
Predict engine failure – Principal Components - TechCon 2016 Lab
100 engines, 20+ sensors per engine, aggregate data/operating cycle
~200 cycles of operation per engine
how long to failure? remaining useful life (RUL)

Anomaly detection (HVAC - Air Handler) - Support Vectors - TechCon 2017 Lab
7 sensors
~6 months of operations, 5 minute data
damper stuck open? temperature transmitter failed?
air supply fan constraint? where are the system constraints...

Yeast manufacturing – fermenter - monitoring and diagnostics - PI World 2019 Lab
...
Ex. 4 Condition Assessment – Overall Asset Health Score
### Ex. 4 Health Score - Transformer

![Image showing Health Score and LTC Neutral Count]

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<td>Weight</td>
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## Asset Health Score

### LTC CA-Action New Summary Report

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<th>Floc Descr</th>
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<th>Equip Descr</th>
<th>Score</th>
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Asset Health Score – PSE&G example
Other resources

OSIsoft Users Conf. 2017 TechCon Lab Notes  Incorporating Process data with Condition Monitoring data...

OSIsoft Users Conf. 2016 TechCon Lab Notes  Condition-based Maintenance with PI AF

OSIsoft Users Conf. 2015 Presentation  Keeping Assets Healthy – PI System’s Role in Asset Maintenance

PSE&G use case showing asset health score  http://www.osisoft.com/Presentations/Condition-Based-Maintenance/

Allied Reliability Group

ECG Inc
## Contact Information

<table>
<thead>
<tr>
<th>Name</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gopal Gopal Krishnan, P.E.</td>
<td><a href="mailto:gopal@osisoft.com">gopal@osisoft.com</a></td>
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Asset Monitoring and Condition-based Maintenance (CBM) with the PI System

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Keith Pierce, Technical Advisor

OSIsoft
Takeaways

• CBM can mean different things – whom do you ask?

• PI System covers major portions of the CBM workflow
  • AF Analytics applied to maintenance/reliability (usage-based, condition-based, predictive)

• As appropriate, include machine condition monitoring data
  • vibration, oil analysis, thermography...

• Get started now – make PI part of the maintenance business process

• Ask about CBM workshops (speak to us or your Account Manager)

• CBM Lab at PI World 2019 - Day 3 afternoon and Day 4 morning
Terms & Definitions

PM/CM
Predictive
APM

APR
RCM
RCA

CMMS
FMEA

CBM
Condition Based Maintenance

CM
Condition Monitoring
CBM Prescriptive Guidance

Terms & Definitions

Implementation Guidance

PI System Overview for CBM

PI System Integration w/ CMMS

Enabling Opportunities

Solution Examples

Industry References
Maintenance Budget & Types

• Capital replacement
  • Replace or rebuild expensive assets
  • Major projects
  • Squeaky wheel gets the grease syndrome

• Corrective Maintenance (CM)
  • Repair a failure or degradation
  • Troubleshoot & Rework
  • Unscheduled often with downtime

• Preventive Maintenance (PM)
  • Usually time-based schedules
  • Clean & Inspect
  • Pack bearings
  • Filter check
  • Diagnostic Measurements & tests

Capital $  
Asset Management

Corrective Maintenance

O&M $  
Maintenance & Engineering

Preventive Maintenance

Capital Replacement
CBM can mean different things

- Condition Monitoring
- Incipient Failure Detection
- Condition Assessment
- CBM Preventive Maintenance
- APR – Advanced Pattern Recognition

It’s a journey – not a destination
CBM - Analytics

- Usage assessment - runhours
  - hours, tonnage, starts/stops, ...
- Condition assessment - machine or process
  - efficiency, vibration (peak), thermography (hot spot)...
- Predictive - Simple - extrapolate a trend
- Predictive - Advanced and APR models
- Asset Health Score
## Run Hours Display

### Report - Critical Motors - Run Hours

Last Update: 3-12-2016

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Daily Run Hours</th>
<th>Lifetime Run Hours</th>
<th>During Last Period</th>
<th>Period</th>
<th>Since Last Service</th>
<th>Last Service</th>
<th>Next Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agitator 1204</td>
<td>4.51</td>
<td>7,975</td>
<td>0</td>
<td>3mo</td>
<td>387</td>
<td>1/10/2016</td>
<td>11/10/2016</td>
</tr>
<tr>
<td>Agitator 1304</td>
<td>23.49</td>
<td>9,908</td>
<td>2,118</td>
<td>3mo</td>
<td>697</td>
<td>2/11/2016</td>
<td>12/13/2016</td>
</tr>
<tr>
<td>Agitator 1305</td>
<td>23.49</td>
<td>9,908</td>
<td>2,118</td>
<td>3mo</td>
<td>697</td>
<td>2/11/2016</td>
<td>12/1/2016</td>
</tr>
<tr>
<td>Fan 5163</td>
<td>19.71</td>
<td>8,554</td>
<td>1,174</td>
<td>3mo</td>
<td>2,664</td>
<td>10/1/2015</td>
<td>5/1/2016</td>
</tr>
<tr>
<td>Fan 5164</td>
<td>23.97</td>
<td>9,292</td>
<td>2,022</td>
<td>3mo</td>
<td>3,566</td>
<td>10/2/2015</td>
<td>5/2/2016</td>
</tr>
<tr>
<td>Pump 3809</td>
<td>15.16</td>
<td>8,587</td>
<td>1,949</td>
<td>3mo</td>
<td>3,218</td>
<td>10/10/2015</td>
<td>5/10/2016</td>
</tr>
<tr>
<td>Pump 3810</td>
<td>23.97</td>
<td>9,618</td>
<td>2,079</td>
<td>3mo</td>
<td>3,837</td>
<td>9/23/2015</td>
<td>7/1/2016</td>
</tr>
</tbody>
</table>
San Francisco Public Utilities Commission

Results of Pilot

<table>
<thead>
<tr>
<th>Asset Name</th>
<th># of PMs: Scheduled Basis</th>
<th># of PMs: Conditional Basis</th>
<th># of unnecessary PMs Avoided</th>
</tr>
</thead>
<tbody>
<tr>
<td>PUMP-1149</td>
<td>28</td>
<td>0</td>
<td>28</td>
</tr>
<tr>
<td>PUMP-1150</td>
<td>28</td>
<td>12</td>
<td>16</td>
</tr>
<tr>
<td>PUMP-1151</td>
<td>28</td>
<td>0</td>
<td>28</td>
</tr>
<tr>
<td>PUMP-1152</td>
<td>28</td>
<td>21</td>
<td>7</td>
</tr>
<tr>
<td>Totals</td>
<td>112</td>
<td>33</td>
<td>79</td>
</tr>
</tbody>
</table>

- Over the 28-month simulation, 79 sets of unnecessary monthly Preventative Maintenance procedures were identified.
- Each set of monthly maintenance procedures costs approximately $2100.00
- This equals an annual savings of $71,100.00 for only four assets!

100 Main Pumps = $1.8MM Annually
Calculating Expected Heat Rate

- Lookup curve-fit coefficients from SQL Table (Manufacturer Performance Curves)
  
  $$Q = \frac{\Delta P_{DD} \cdot kh}{141.2 \mu B_0 \left\{ \ln \frac{r_2}{r_1} - \frac{3}{4} + 5 \right\}}$$

- Apply curve-fit to calculate Nominal Heat Rate

- Calculate Actual Heat Rate
Example of Predictive Analytics in PI AF – Expected vs Actual

Found partially damaged compressor valve. The valve was replaced in a planned & controlled manner.
Maintenance – Simple Predictive – RUL (remaining useful life)
Simple Predictive - air heater fouling

Air heater tube plugging at a coal power plant over 450 days
After detection, the filters were found dirty, replaced, and the real time oil level and temps dropped back to the model expected value.
# AGL – Diagnostic Center

Reduce unplanned generation losses across a mixed technology portfolio of > 10,000 MW

## Challenge

- Improve capability to sense active failure modes at the earliest possible opportunity and take actions to avoid loss
  - Data isolated and scattered
  - Multiple SCADA technologies in play
  - No access to real time data

## Solution

- **Phase #1:** Centralise all real time data via OSIsoft PI
  - Predict It (APR) technology was fast to install and did not require a large data base (it uses PI directly)
  - A Centralised Operational Diagnostics Centre (ODC) reduced the number of recourses required and increased the level of skills
  - ODC also uses PI system for deep dive investigations

- **Phase #2:** Install and commission Advanced Pattern Recognition Technology

## Results

- $18.7M of avoided losses in 3 years (from a standing start)
- $8.5M of savings last financial year

- ODC delivers significant tangible benefits
- OSIsoft PI enables data transformation and the pursuit many other business improvements
- ODC technology now focusing on process safety uplift
PSE&G – Consolidate & Correlate Data

- Distribution SCADA
- Transmission SCADA
- MV90
- Transformer loads
- MDT
- PI Manual Logger Substation Inspections
- Hydran Gas Results
- OMS POR and PPC
- GIS Ratings, Solar & Circuit Lengths
- SAP maintenance and equipment & locations
- Doble
- Electrical test results
- Breaker Tests
- Diagnostic data
- Delta-X Gas & Oil analysis
- SAP-PM
PI System’s role in CBM

1. Connect to relevant sources
2. Collect and archive data
3. Assign context (asset-based)
4. Execute condition monitoring logic
5. Visualize real-time conditions
6. Alert and notify

PI Integrators & PI System Access

PI Vision
PI ProcessBook
PI DataLink
PI WebParts
Asset Context in PI AF

AF – Asset Framework
Categories for Attribute Groupings
Element Template
Attribute alias elements normalizes diverse tag / point names
Event Detection

Event Frame Template

EF Start Trigger

Time True

Root Cause Child Events

Type = EF Generation

PE Functions
Monitoring Asset Conditions

PIAlerts&Company.com

OSisoft - A Alarm - B93 - Steamroller - Analysis

Acknowledgment

Actions

Condition Fixed? (in timeframe) YES - Will receive email confirmation NO - Issue PIR

Attribute Alarm States

For more details please see PI Vision Display and the Boiler Feed Pump Overview display.
Boiler Feed Pump Overview

Outside Air Temperature
30.679 deg F

Main Steam Flow
9.9994 k lb/hr

Active Thrust
Inner Temp 86.375 °C
Bearing Metal 97.253 deg F

Bearing Oil Pressure
2.3189 psi

Pump Speed
0.02614 rpm
Boiler Feed Pump Event Analysis
Event Table Watchlist
Condition Monitoring Report

- **Time Period**
- **Asset of Interest**
- **Real Time Summaries**
- **Filter Events**
- **Excel Charting**

**Events**

1. **Pump Information (PI AP)**
2. **Events (PI EP)**
3. **Excel Charting**
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• As appropriate, include machine condition monitoring data
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PI System - CBM Resources

- Corporate Site – General info and use case search, webinars,…
- CBM Guidebook – Reference material on CBM and Condition Monitoring
- Technical Support – technical resources, downloads, questions,…
- PI Square and CBM – Lots of resources
- PI Community – Peer discussions and OSIsoft moderation, industry groups, development resources, whitepapers, webinars,…
- YouTube – training and introduction videos
- PI Learning – online courses, course materials,…
- Incorporating machine condition monitoring data
Other resources

OSIsoft Users Conf. 2016 TechCon Lab Notes  Condition-based Maintenance with PI AF

OSIsoft Users Conf. 2015 Presentation  Keeping Assets Healthy – PI System’s Role in Asset Maintenance

Calculating Asset Health Score - OSIsoft vCampus 2013 Lab Notes

PSE&G use case showing asset health score  http://www.osisoft.com/Presentations/Condition-Based-Maintenance/

http://www.ni.com/condition-monitoring

National Instruments InsightCM™ Enterprise for Condition Monitoring

Allied Reliability Group AR-C10 Data Collector for Condition Monitoring

MetrixSetpoint Condition Monitoring

Emerson Vibration Monitoring
CBM Ideas for Workshop

- Pump / Motor Usage
- Pump / Motor Start – Stop Cycles, Duty Cycles
- Calculate Efficiencies, Anomalies, etc.
- Energy per Unit Processed (e.g. MG/D)
- Predictive / Maintenance Event Detection & Analyses
- SAP, Maximo etc. integration
Asset Monitoring and Condition-based Maintenance (CBM) with the PI System

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Questions?

Please wait for the **microphone**

State your **name & company**

Please remember

**TO DOWNLOAD APP, SEARCH OSISOFT**
Thank You

Merci
Danke
Gracias
Grazie
Optional: Click to add a takeaway you wish the audience to leave with.