



Asset Monitoring and Condition-based Maintenance (CBM) with the PI System

Gopal GopalKrishnan, P.E., Solutions Architect
Keith Pierce, Technical Advisor



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

APR

Predictive APM

RCM

CBM

PF

CM

Condition Based Maintenance

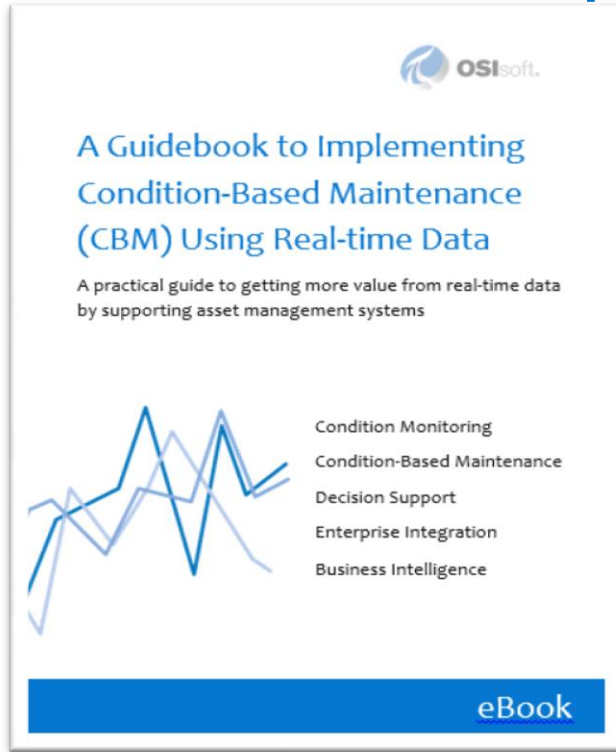
Condition Monitoring

RCA

CMMS

FMEA

CBM Prescriptive Guidance



Terms & Definitions

Implementation Guidance

PI System Overview for CBM

PI System Integration w/ CMMS

Enabling Opportunities

Solution Examples

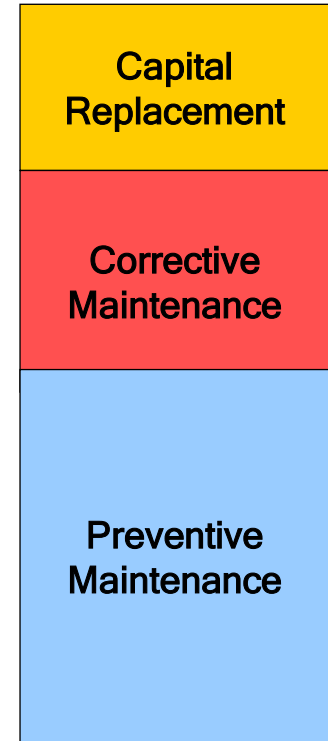
Industry References

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

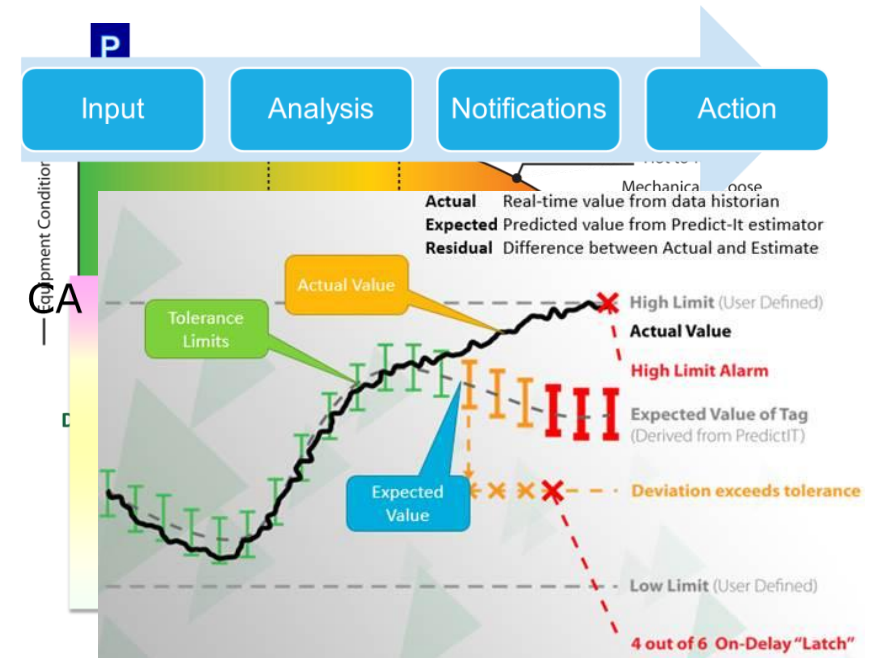
Capital \$
Asset
Management

O&M \$
Maintenance &
Engineering



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

Equipment	Daily Run Hours	Lifetime Run Hours	During Last Period	Period	Since Last Service	Last Service	Next Service
Agitator 1204	<div><div></div>4.51</div>	7,975	0	3mo	387	1/10/2016	11/10/2016
Agitator 1205	<div><div></div>23.79</div>	10,119	2,154	3mo	409	2/23/2016	10/3/2016
Agitator 1304	<div><div></div>23.49</div>	9,908	2,118	3mo	697	2/11/2016	12/13/2016
Agitator 1305	<div><div></div>23.49</div>	9,908	2,118	3mo	697	2/11/2016	12/1/2016
Fan 5163	<div><div></div>19.71</div>	8,554	1,174	3mo	2,664	10/1/2015	5/1/2016
Fan 5164	<div><div></div>23.97</div>	9,292	2,022	3mo	3,566	10/2/2015	5/2/2016
Fan 8144	<div><div></div>14.44</div>	9,839	2,112	3mo	3,635	10/5/2015	5/5/2016
Pump 3809	<div><div></div>15.16</div>	8,587	1,949	3mo	3,218	10/10/2015	5/10/2016
Pump 3810	<div><div></div>23.97</div>	9,618	2,079	3mo	3,837	9/23/2015	7/1/2016

San Francisco Public Utilities Commission

Results of Pilot



Asset Name	# of PMs: Scheduled Basis	# of PMs: Conditional Basis	# of unnecessary PMs Avoided
PUMP-1149	28	0	28
PUMP-1150	28	12	16
PUMP-1151	28	0	28
PUMP-1152	28	21	7
Totals	112	33	79

100 Main Pumps =
\$1.8MM Annually

- 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!

Calculating Expected Heat Rate

_CoeffType	ECMax
A	3.01916
B	0
C	-140.82336
D	0
E	3431.05804
F	0
G	-39811.23565
H	0
I	226037.87046
J	0
K	-524290.83316
L	0
M	0
N	0
O	0
P	0
Q	0

Lookup curve-fit coefficients from SQL Table
(Manufacturer Performance Curves)

Data Reference: Table Lookup

Settings...

```
SELECT CoefficientValue FROM PerformanceCentrifeff WHERE PerformanceModelID = @[PerformanceModelID] AND CoefficientType = @[_CoeffType] AND CoefficientOrder = 1
```

Real-time Streaming Analytics

$$Q = \frac{\Delta P_{DD} * kh}{141.2 \mu B_0 \left\{ \ln \frac{r_c}{r_w} - \frac{3}{4} + S \right\}}$$

Category: Nominal Values		
	BHP_Nominal	8710.27322604474 BHP
	FuelRate_Nominal	71.1036975854648 MCFH
	HeatRate_Nominal	8163.19944739005 BTU(LHV)/BHP-hr
	PCD_Nominal	205.15303353481 psi
	T5_Nominal	1394.59524035539 °F
	T7_Nominal	925.386891989674 °F

Apply curve-fit to calculate Nominal Heat Rate

Data Reference: Formula

Settings...

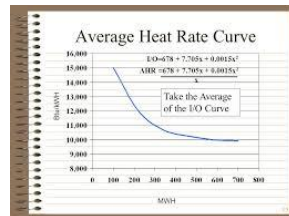
```
S=..[Driver [Steady Speed;A=,|A;B=,|B;C=,|C;D=,|D;E=,|E;F=,|F;G=,|G;H=,|H;I=,|I;J=,|J;K=,|K;L=,|L;M=,|M;N=,|N;O=,|O;P=,|P;Q=,|Q;X=FC_MaxSpeed;[if not(S) then 0 else (A + C*X^2 + G*X^3 + I*X^4 + K*X^5 + M*X^6 + O*X^7 + Q*X^8)/((1 + B*X + D*X^2 + F*X^3 + H*X^4 + J*X^5 + L*X^6 + N*X^7 + P*X^8))]
```

Calculate Actual Heat Rate

Data Reference: Formula

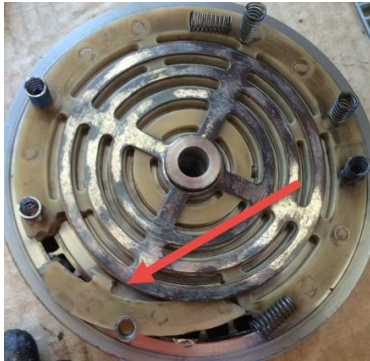
Settings...

```
A=Unit_BHP;B=Unit_Fuel;C=Unit_BTU;[if badval(A) or badval(B) then 0 else if A<=30 then 0 else (B*(1000*C*0.915))/A]
```



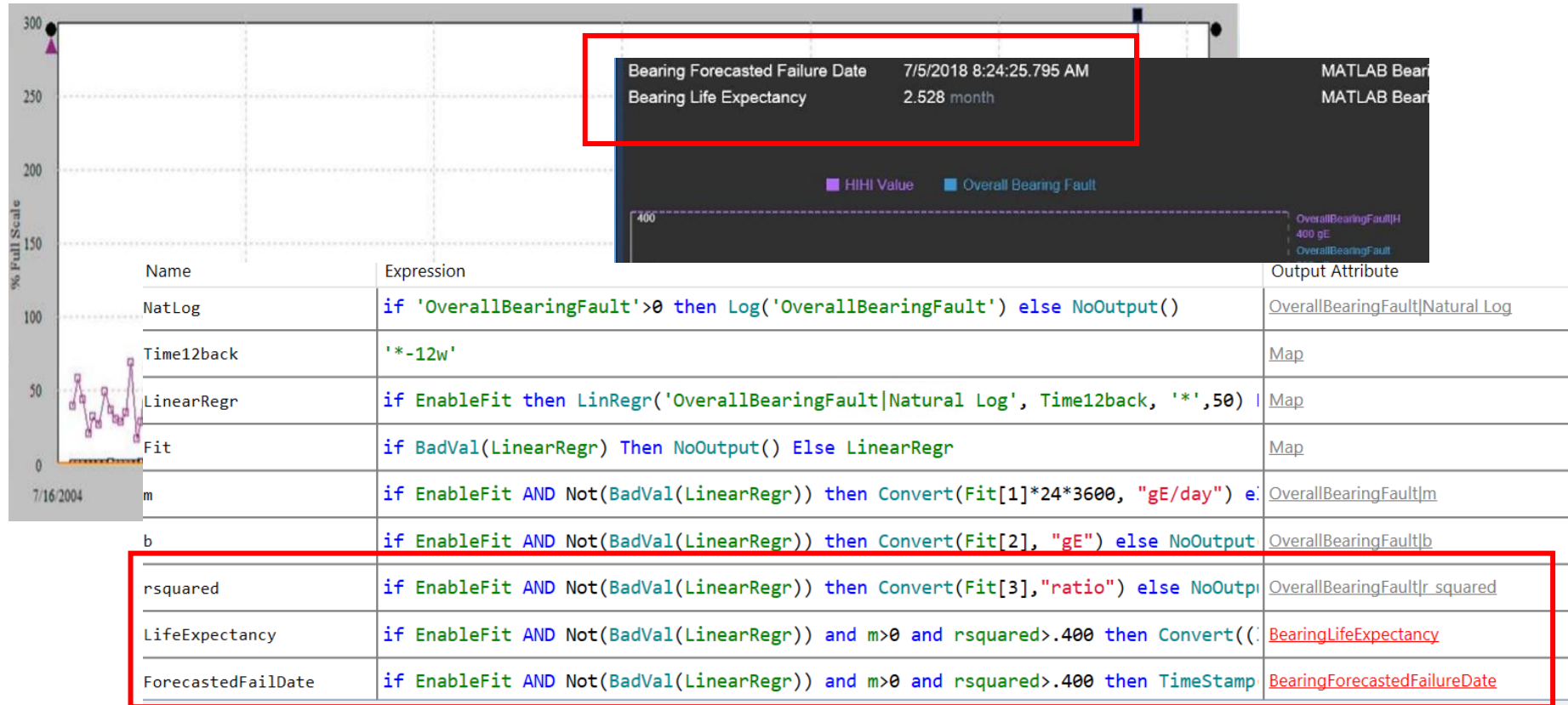
Example of Predictive Analytics in PI AF – Expected vs Actual

Compression\Houma\Unit01\Gas Compressor\Discharge Temperature\Cylinder 1 Discharge Temperature

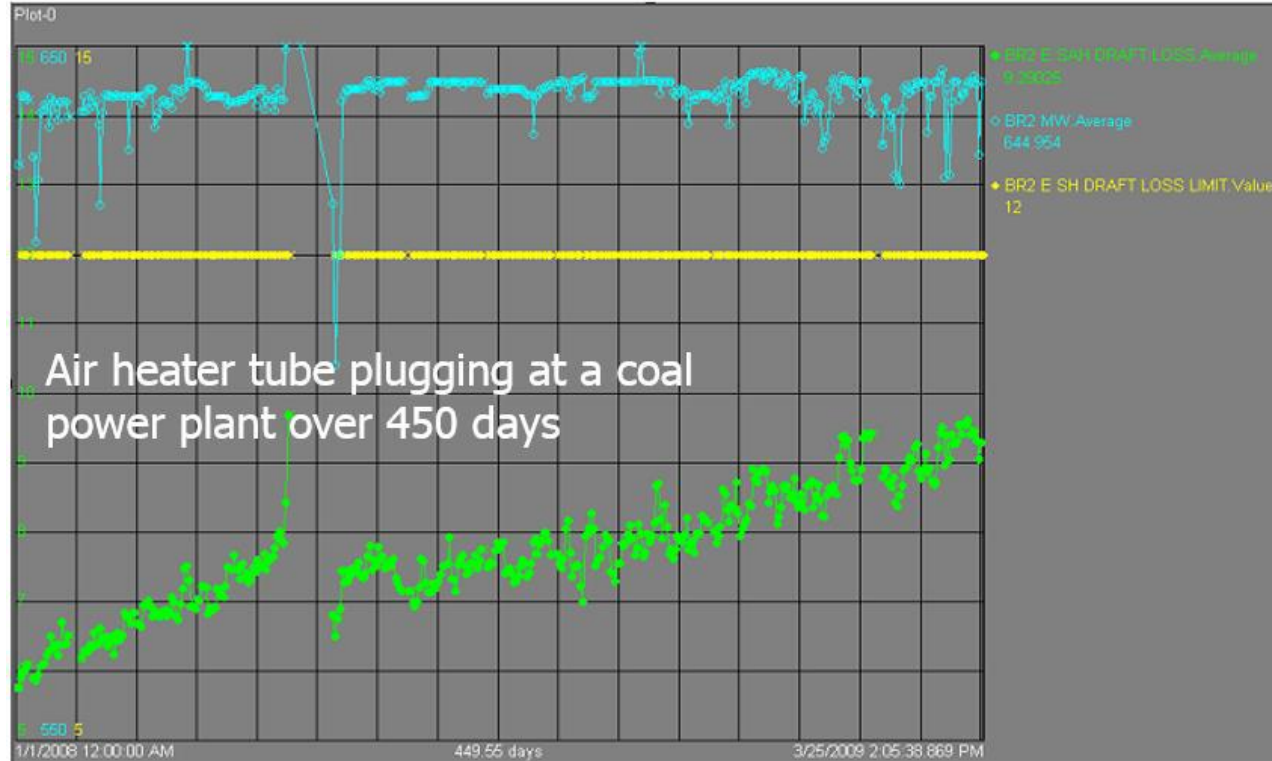


Found partially damaged compressor valve.
The valve was replaced in a planned & controlled manner.

Maintenance – Simple Predictive – RUL (remaining useful life)



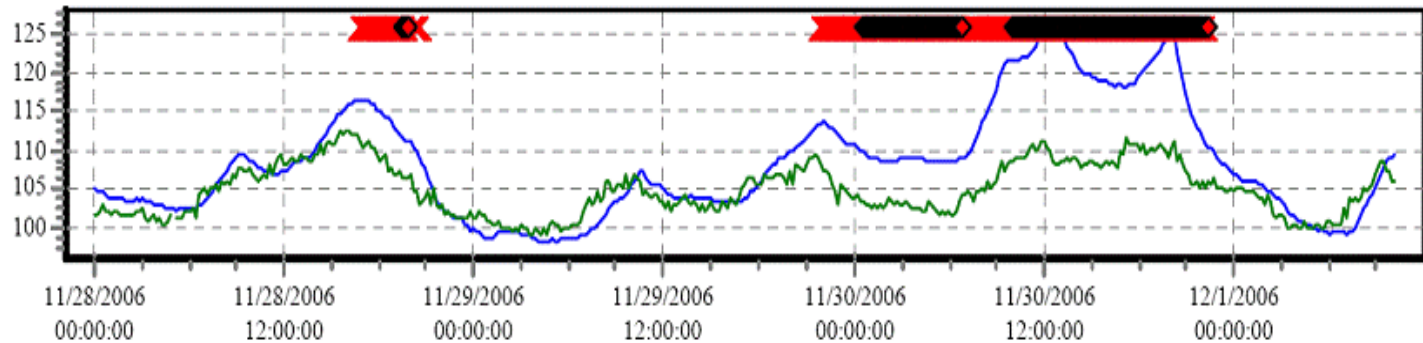
Simple Predictive - air heater fouling



Advanced Pattern Recognition - Fan Motor Bearing

Temperature movement on FD Fan Motor outboard bearing - about 17 degrees above expected

3D124-3TE273, WEST FD FAN MTR OUTBD BRG (DEGF)



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

Phase #2: Install and commission Advanced Pattern Recognition Technology

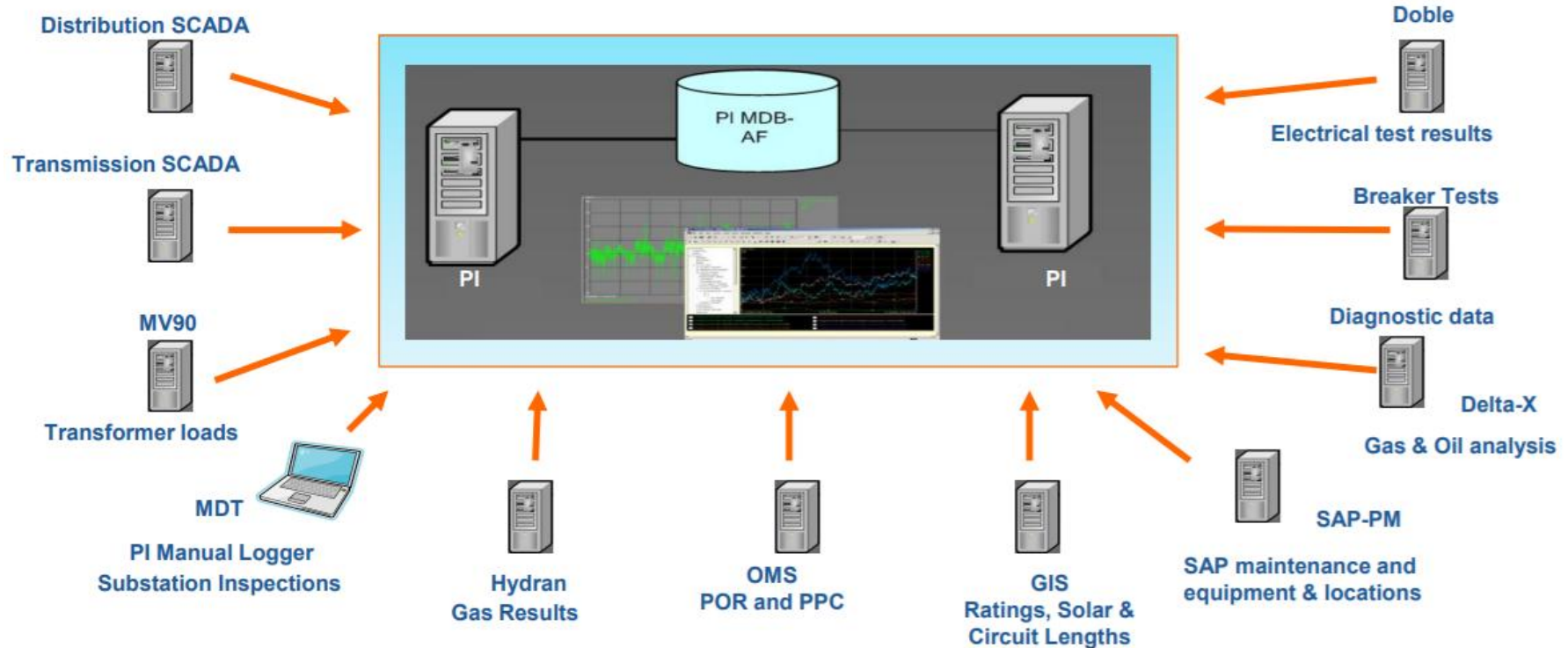
- Predict It (APR) technology was fast to install and did not require a large data base (it uses Pi directly)
- A Centralised Operational Diagnostics Centre (ODC) reduced the number of recourses required and increased the level of skills
- ODC also uses PI system for deep dive investigations

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



Asset List with Score

Web Part Page - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Address http://njnwkddev29/Asset%20Management2/WebPages/LtcsCA-A

PSEG LTC CA-Action New Summary

CA Records

Details	Division	Floc	Floc Descr
	CE	IPE-CE-SDN -1TRX	500-1 Transformer
	CE	IPE-CE-SDN -1TRX	500-1 Transformer
	CE	IPE-CE-SMN -1PM	132-1 Transformer
	CE	IPE-CE-DAY -UNIT 2	Unit Substation - 8002
	CE	IPE-CE-SCO -UNIT 1	Unit Substation - 4001
	CE	IPE-CE-SOS -T2	# 2 Transformer
	ME	IPE-ME-HNC -T2	# 2 Transformer
	SO	IPE-SO-BEA -T2	# 2 Transformer
	SO	IPE-SO-MAR -T1	# 1 Transformer
	SO	IPE-SO-SLA -T1LTC	220-1 Transformer Tap
	CE	IPE-CE-SLE -132-7	132-7 Transformer
	CE	IPE-CE-SBR -3TRH	220-3 Transformer
	CE	IPE-CE-SLI -41HL	H-2234
	CE	IPE-CE-SDN -2TRX	500-2 Transformer
	SO	IPE-SO-LAW -T2	# 2 Transformer
	SO	IPE-SO-MRO -T1	# 1 Transformer
	ME	IPE-ME-HAW -T2	# 2 Transformer
	CE	IPE-CE-GSE -1TRH	220-1 Transformer
	PA	IPE-PA-KIN -T2	# 2 Transformer
	CE	IPE-CE-POH -T2	# 2 Transformer
	PA	IPE-PA-HOE -T1	# 1 Transformer
	CE	IPE-CE-SBB -3TRX	500-3 Transformer
	CE	IPE-CE-SOS -T2	# 2 Transformer

PSEG LTC CA New Action Algorithm Details

Nameplate

Online	Division	Station Code	Station	Station Type	Floc Descr	Equipment	Equipment Descr	Equipment Type	Construction Year	Serial Number	Manufacturer	Model Number
	Central	SDN	DEANS	X	500-1 Transformer	000000000010505424	Load Tap Changer A (LRS700) E-LTC			1971 D596884	GENERAL ELECTRIC	LRS700

Content Editor Web Part

- Equipment Home Page
- View and Trend Equipment PI Points
- CA LTC New Action Algorithm Rules

Algorithm Factors

Factor	Raw Value	Case Value	Weight %	Score
Detectable Acetylene	10	10	25	2.5
Gas Rate of Change	3.67	2	15	0.3
High Total Gas	300	10	20	2
High Water	23	0	10	0
Low Dielectric	32.6	0	10	0
LTC Operations	34	0	10	0
LTC THRU NEUTRAL	0	0	10	0

CA Score

Score	maxScore	Ranking(%)	Peer Group
4.8	4.8	100	VACUUM

RtTrend

DeltaX Total Combustible Gas

Details	ApprType	Sample Date	CO	H2	Acetylene	Ethane	Ethylene	Methane	Combustible Gas
	LTC	07/27/2009	199	39	37	7	4	14	300
	LTC	06/11/2009	66	30	27	2	2	4	131
	LTC	03/13/2009	62	23	17	2	2	3	109
	LTC	12/17/2008	58	26	30	3	3	3	123
	LTC	06/26/2008	79	27	28	2	2	3	141

Showing 1 to 5 of 18

DeltaX Water

Details	ApprType	Sample Date	Fluid Temp (C)	Water
	LTC	07/27/2009	60	23
	LTC	06/11/2009	55	19
	LTC	03/13/2009	49	15
	LTC	12/17/2008	53	17
	LTC	06/26/2008	65	20

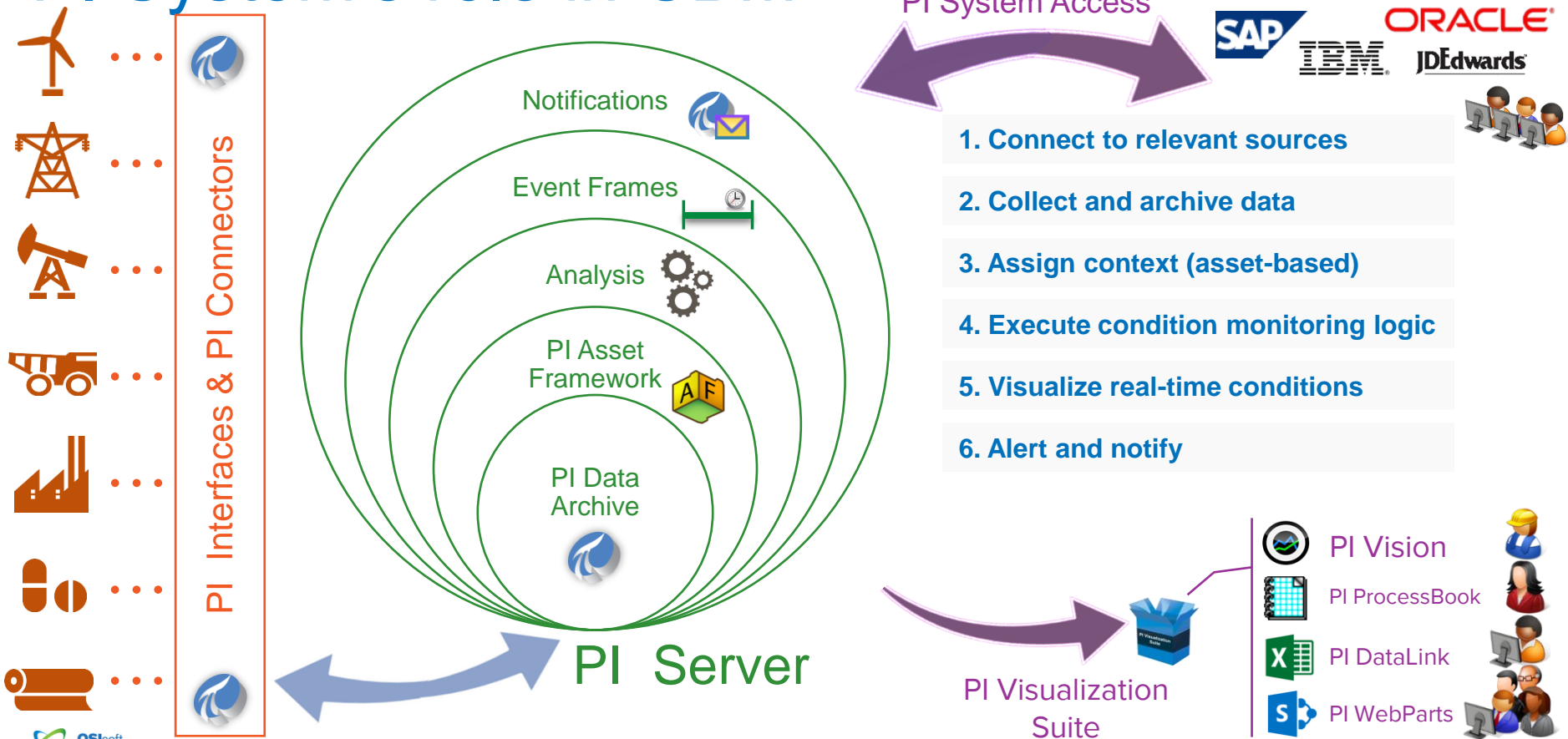
Showing 1 to 5 of 18

DeltaX Fluid

Details	ApprType	Sample Date	Fluid Temp (C)	D877	D1816
	LTC	07/10/2008		47.6	32.6
	LTC	06/13/2002		51.5	
	LTC	06/12/2000		55.4	
	LTC	05/10/2000			36.1
	LTC	07/15/1997			27.1

Done

PI System's role in CBM



Asset Context in PI AF

The screenshot displays the PI System Explorer application window. The left pane shows a hierarchical tree of elements under 'Generation', including power plants and units. The main pane shows a table of attributes for a selected element, categorized by groups like 'In Service Date', 'Bearing Temperatures', 'Flows', and 'Limits'. The right pane shows the 'Element Template' configuration for the selected element, including fields for Name, Description, Categories, and Value Type.

AF – Asset Framework

Categories for Attribute Groupings

Element Template

Attribute alias elements normalizes diverse tag / point names

Category	Attribute	Value
Category: <None>	In Service Date	1-Jan-13
	Last Service Date	8-Nov-13
	Manufacturer	GE
	Serial Number	1B395
Category: Bearing Temperatures	Inboard Bearing Temperature	135.006500244141 deg F
	Outboard Bearing Temperature	122.390983581543 deg F
Category: Flows	Auxiliary Steam Flow	14.8983793258667 lb
	Discharge Flow	1634.23645019531 k lb/hr
	Discharge Flow Total	757539.875 lb
	EXT Steam Flow Total	260660.078125 lb
	Flow entering economizer	3253.21162148438 k lb/hr
	Main Steam Flow	38.3094062805176 k lb/hr
Category: Limits	Bearing Vibration High Limit	2 mils
	Control Oil Pressure Low Limit	32 psi
	Discharge Flow Low Limit	1700 k lb/hr
	Suction Pressure High Limit	160 psi

Event Detection

The screenshot displays the 'Boiler Feed Pump Turbine' configuration window in the PI System Explorer. The 'Analysis Templates' tab is active, showing a list of templates on the left and a detailed configuration for 'Boiler Feed Pump Vibration Anomaly' on the right. The configuration includes fields for Name, Description, Categories, and Analysis Type (set to Event Frame Generation). The 'Event Frame Template' section shows the 'StartTrigger' expression: `if ('Inboard Bearing Vibration X' > 'Bearing Vibration High Limit') Then true else if ('Inboard Bearing Vibration Y' > 'Bearing Vibration High Limit') Then true else if ('Outboard Bearing Vibration X' > 'Bearing Vibration High Limit') Then true else if ('Outboard Bearing Vibration Y' > 'Bearing Vibration High Limit') then true else false`. The 'EndTrigger' field is empty. The 'Evaluated at' timestamp is 4/1/2014 7:35:22 AM. The 'StartTrigger true for:' duration is set to 30 seconds. The 'Generate child root cause event frame before parent event frame starts' checkbox is checked. The 'Duration' is set to 1 day, and the 'Name' is 'Root Cause'. The 'Category' is set to 'High Vibration'. The 'Scheduling' is set to 'Event-Triggered' and 'Trigger on' is 'Any Input'. The 'Functions' panel on the right lists various functions, including 'Abs', 'Acos', 'And', 'Ascii', 'Asin', 'Atn', 'Atn2', 'Avg', 'BadVal', 'Bod', 'Bom', 'Bomm', 'Ceiling', 'Char', 'Compare', 'Concat', 'Convert', 'Cos', 'Cosh', 'Cot', 'Coth', and 'Crc'. The 'Abs' function is highlighted, showing its description: 'Return the absolute value of an integer or real number. Example: Abs(1)'.

Event Frame Template

EF Start Trigger

Time True

Root Cause Child Events

Type = EF Generation

PE Functions

Monitoring Asset Conditions

The screenshot displays the PIWorld software interface. On the left is a hierarchical tree of assets. The main panel shows the details for asset 10149651, including tabs for General, Child Elements, Attributes, Ports, and Version. The General tab is active, showing a table with columns Name and Value. The table lists various attributes such as Category, Address, Entity, Event Frame Template, and Manufacturer. A script is visible in the 'Expression' field, and a 'StartTrigger true for' dropdown is set to 0 Minutes.

Assets Tree:

- Boilers
- Equipment
- NuGreen
- Houston
 - Crackin
 - Ec
- Extruder
- Milling
- Little Rock
- Tucson
- Wichita
- Pumps
 - P-007
 - P-009
 - P-020
 - P-099
 - P-101

Asset 10149651 Details:

Name	Value
Category: Location	
Address	470 Beso Ln, San Antonio,...
Entity	Cindy Bear
Event Frame Template	Boiler Feed Pump Vibration Anomaly
Category	
Name	Expression
	if ('Inboard Bearing Vibration X' > 'Bearing Vibration High Limit') then True else if ('Outboard Bearing Vibration X' > 'Bearing Vibration High Limit') then True else if ('Outboard Bearing Vibration Y' > 'Bearing Vibration High Limit') then True else False
StartTrigger true for:	0 Minutes
Manufacturer	L&T
Service	Residential

The screenshot shows an email alert from PIAerts&Company.com. The email is dated Fri 12/12/2014 1:56 PM and is addressed to William Reich. The subject is OSisoft - C Alarm - B14 - Black DS 30 Gal - Analysis. The email body contains the following information:

OSisoft - A Alarm - B93 - Steamroller - Analysis

[Acknowledge](#)

Black DS 30 Gal triggered by test

Start Time: 12/12/2014 3:56:24 PM Central Standard Time (GMT-06:00:00)
Time to Fix: 6 Hours

See CMD Trend Screens.pdf for more details

Actions

Condition Fixed? (in timeframe)

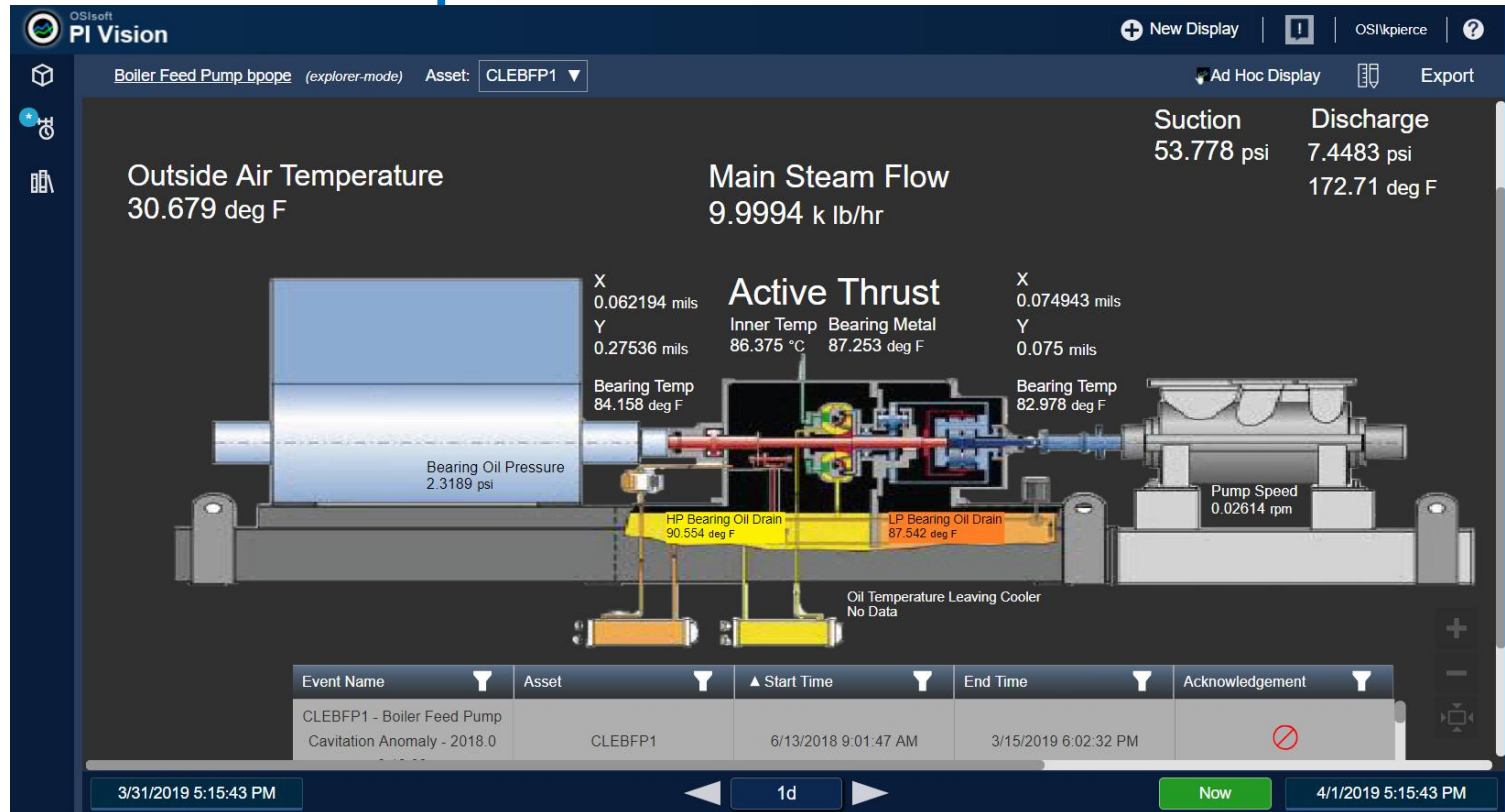
- YES - Will receive email confirmation
- NO - [Issue PIR](#)

Attribute Alarm States

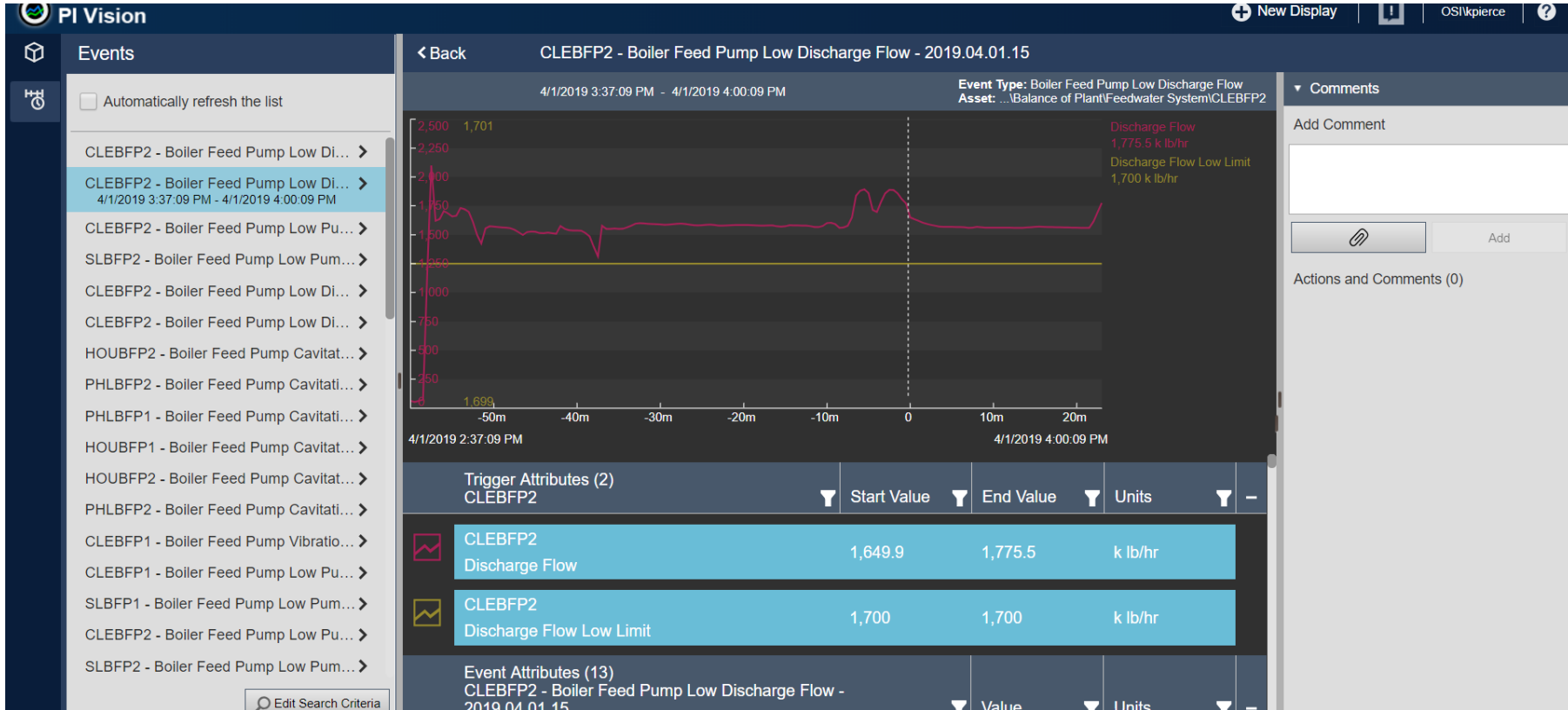
Fin Wind Torq SP1
Mid Range Torq SP0
Pin PW Over SP0
Trans Torq SP1

For more details please see [PI Vision Display](#) and the [Boiler Feed Pump Overview](#) display

Boiler Feed Pump Overview



Boiler Feed Pump Event Analysis



Event Table Watchlist

OSIsoft PI Vision

(explorer-mode) Asset: HOUBFP1

Ad Hoc Display Export

Event Name	Asset	Event Type	Start Time	End Time	Severity	Duration
HOUBFP1 - Boiler Feed Pump Low Discharge Flow - 2019.03.05.04	HOUBFP1	Boiler Feed Pump Low Discharge Flow	3/5/2019 5:22:22 AM	3/5/2019 5:31:52 AM	None	9m 29s
HOUBFP1 - Boiler Feed Pump Cavitation Anomaly - 2019.03.06.00	HOUBFP1	Boiler Feed Pump Cavitation Anomaly	3/6/2019 1:16:22 AM	3/6/2019 5:46:52 AM	None	4h 30m
HOUBFP1 - Boiler Feed Pump Cavitation Anomaly - 2019.03.06.04	HOUBFP1	Boiler Feed Pump Cavitation Anomaly	3/6/2019 5:47:52 AM	3/7/2019 1:54:22 AM	None	20h 6m
HOUBFP1 - Boiler Feed Pump Bearing Temp - 2019.03.06.09	HOUBFP1	Boiler Feed Pump Bearing Temp	3/6/2019 10:00:52 AM	3/6/2019 10:22:52 AM	None	21m 59s
HOUBFP1 - Boiler Feed Pump Bearing Temp - 2019.03.06.17	HOUBFP1	Boiler Feed Pump Bearing Temp	3/6/2019 6:13:22 PM	3/6/2019 6:46:52 PM	None	33m 29s
HOUBFP1 - Boiler Feed Pump Bearing Temp - 2019.03.06.21	HOUBFP1	Boiler Feed Pump Bearing Temp	3/6/2019 10:25:52 PM	3/6/2019 10:56:52 PM	None	31m
HOUBFP1 - Boiler Feed Pump Bearing Temp - 2019.03.07.00	HOUBFP1	Boiler Feed Pump Bearing Temp	3/7/2019 1:38:52 AM	3/7/2019 2:03:22 AM	None	24m 30s
HOUBFP1 - Boiler Feed Pump Cavitation Anomaly - 2019.03.07.01	HOUBFP1	Boiler Feed Pump Cavitation Anomaly	3/7/2019 2:01:52 AM	3/7/2019 2:03:52 AM	None	1m 59s

3/4/2019 5:22:47 PM 7d Now 3/11/2019 5:22:47 PM

Assets: Home, Power Generation, "pump", CLEBFP1, Pump Speed, CLEBFP2, Pump Speed, Attributes, CLEBFP1, Bearing Temperatures, Inboard Bearing Temperature, Outboard Bearing Temperature, Flows

Condition Monitoring Report

Time Period

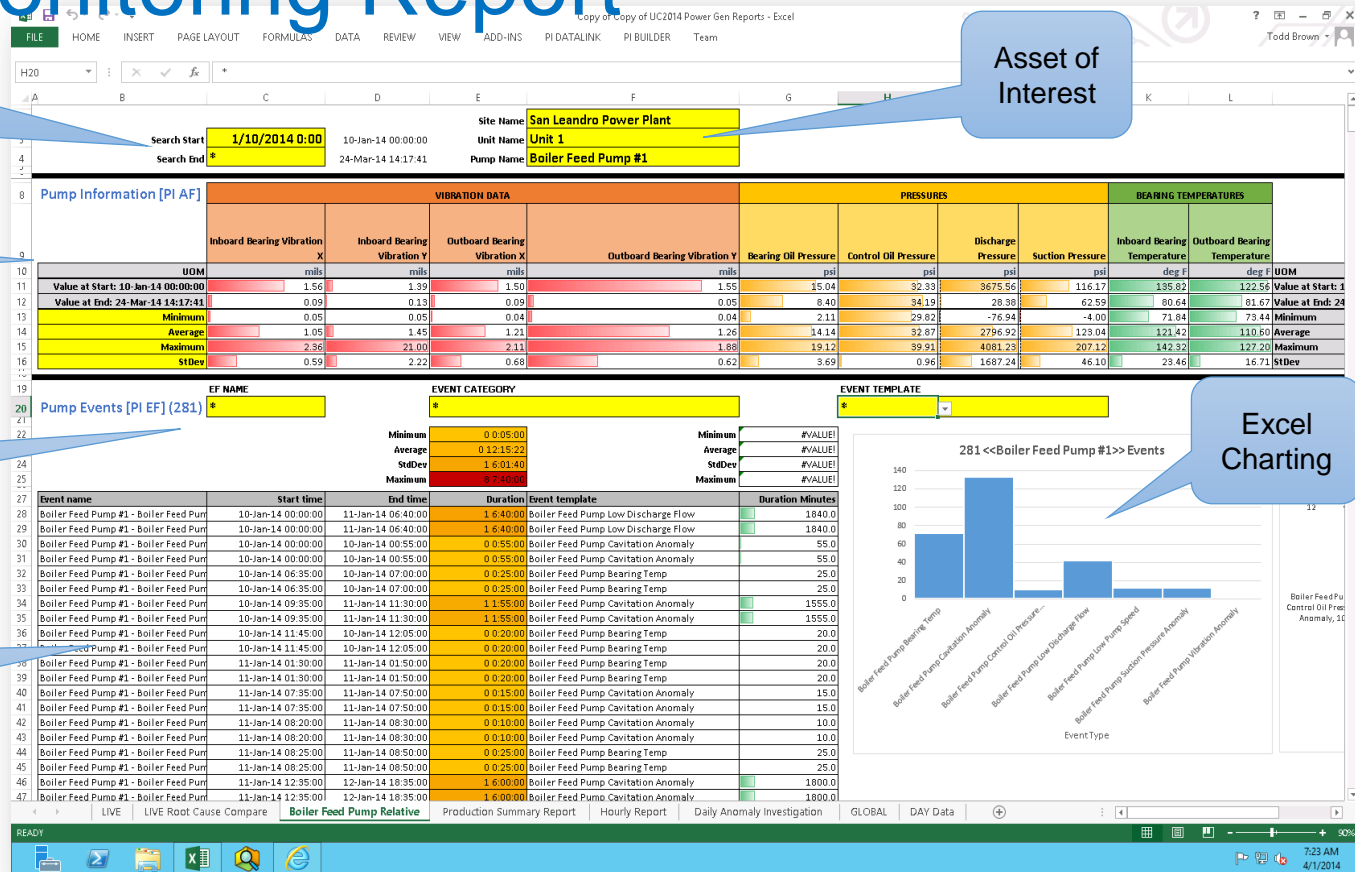
Asset of Interest

Real Time Summaries

Filter Events

Events

Excel Charting



Takeaways

- CBM can mean different things – whom do you ask?
- PI System covers major portions of the CBM workflow
 - Layers of 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 - Day3 afternoon and Day4 morning](#)

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](#)

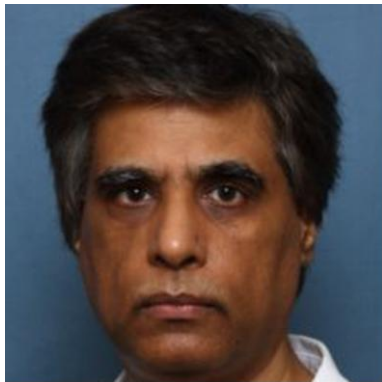
[MetrixSetpoint Condition Monitoring](#)

[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



- Gopal Gopalkrishnan, P.E.
- Solutions Architect
- gopal@osisoft.com



- Keith Pierce
- Technical Advisor
- kpierce@osisoft.com

Questions?

Please wait for
the **microphone**

State your
name & company



Please remember

TO DOWNLOAD
APP, SEARCH
OSISOFT



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App Store



GET IT ON
Google Play



