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

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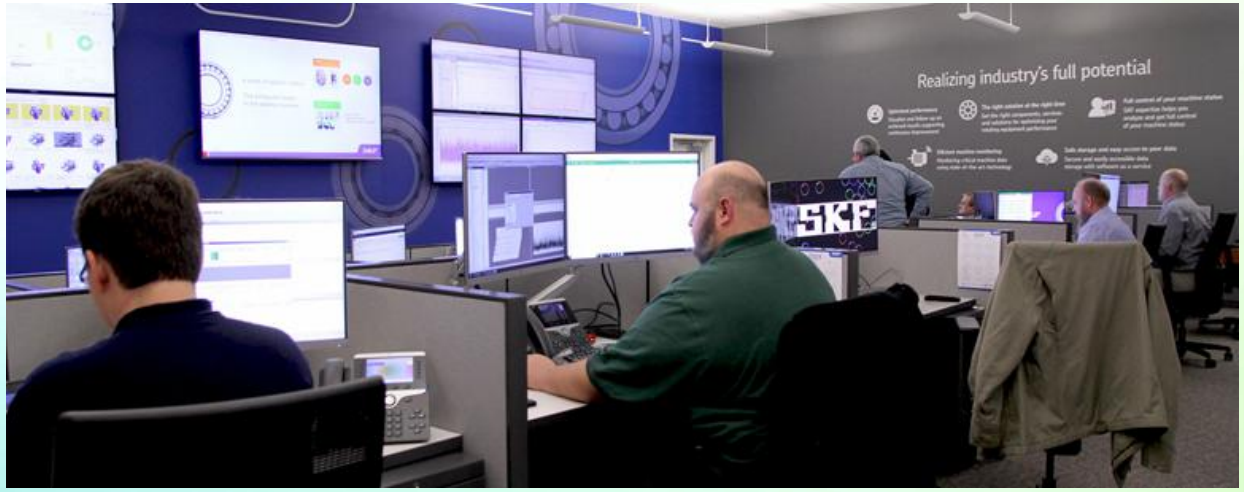
Gopal GopalKrishnan, OSIsoft, LLC.

Rotating equipment performance



Remote Equipment Performance Center, Birmingham, AL

- 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

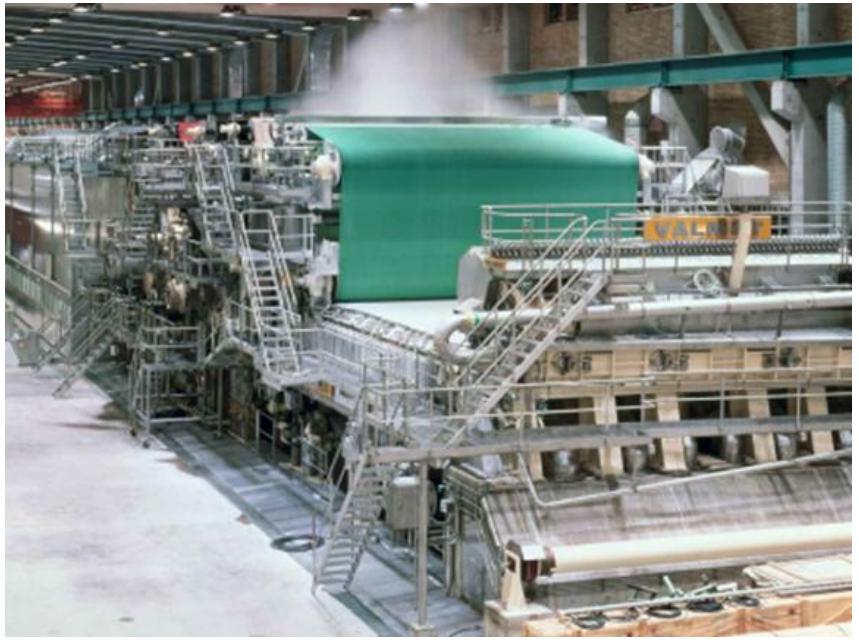
IIoT / Digitalization enables *Rotation for Life*

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

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



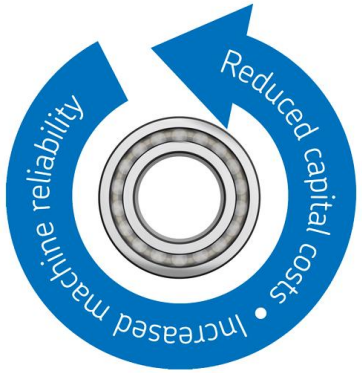
ODS - Operational Deflection Shape

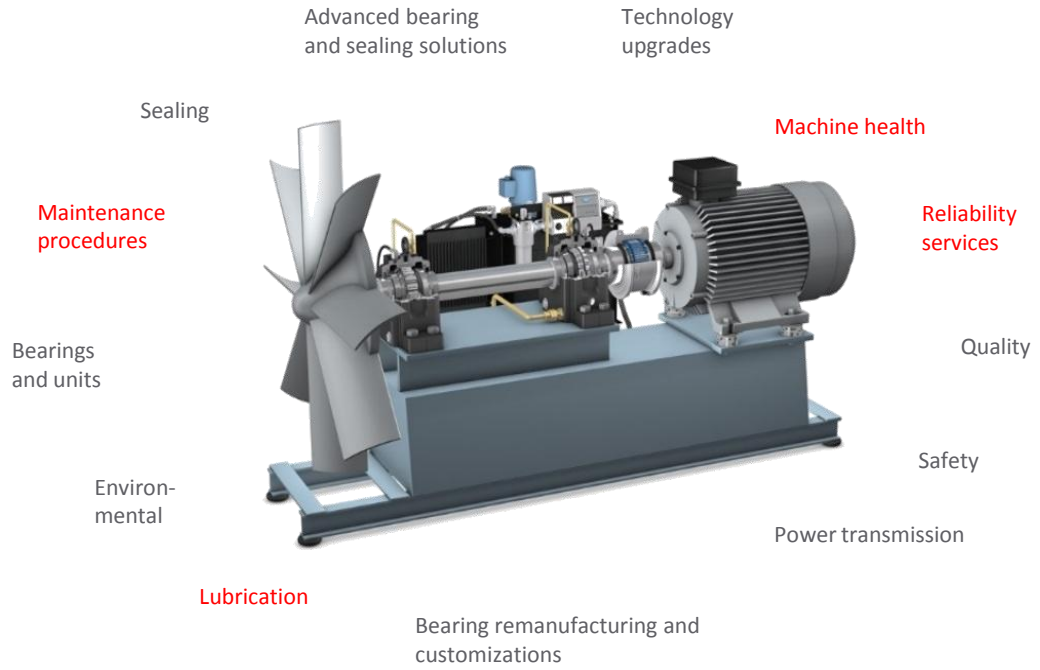
NDT - Non-Destructive Testing

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

Remanufacturing
still an option

Too late for
remanufacturing

Performance

Point of Defect

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 still possible

RCFA difficult

Time

We may not prevent equipment from degrading toward failure, but we can prevent business consequences by intervening at appropriate time

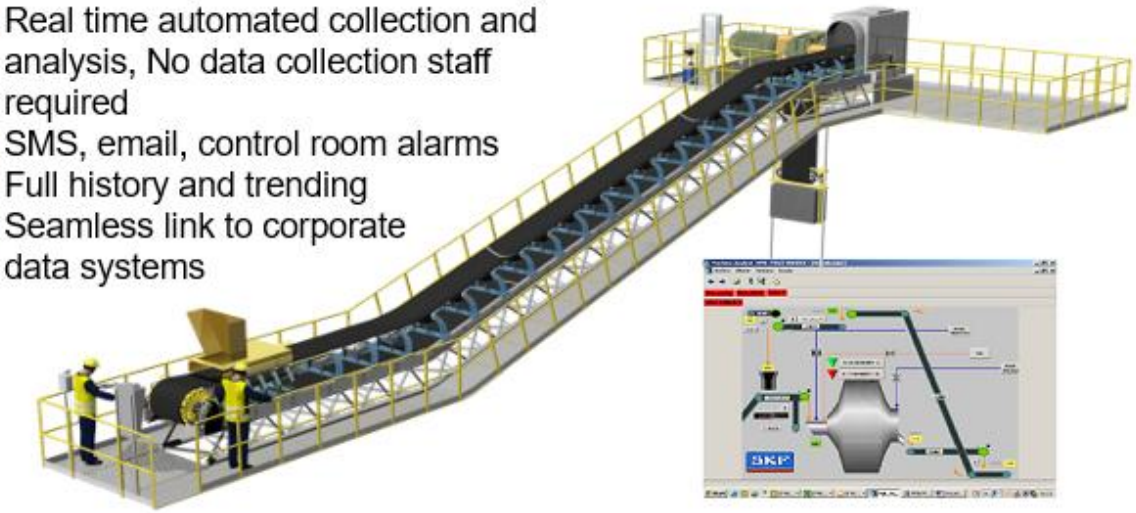
Rotation for Life for Conveyor system
Sealed spherical roller bearings (SSRB)

Benefits

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

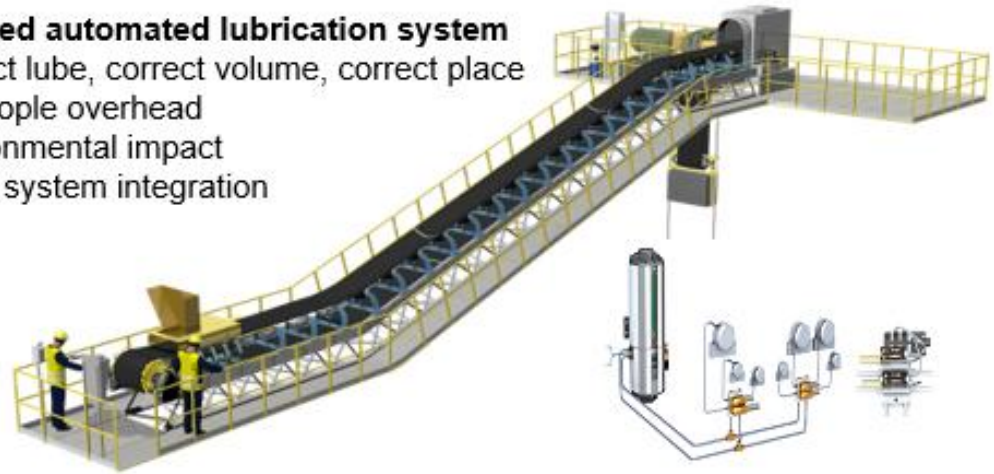
On-line conveyor health monitoring

- 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

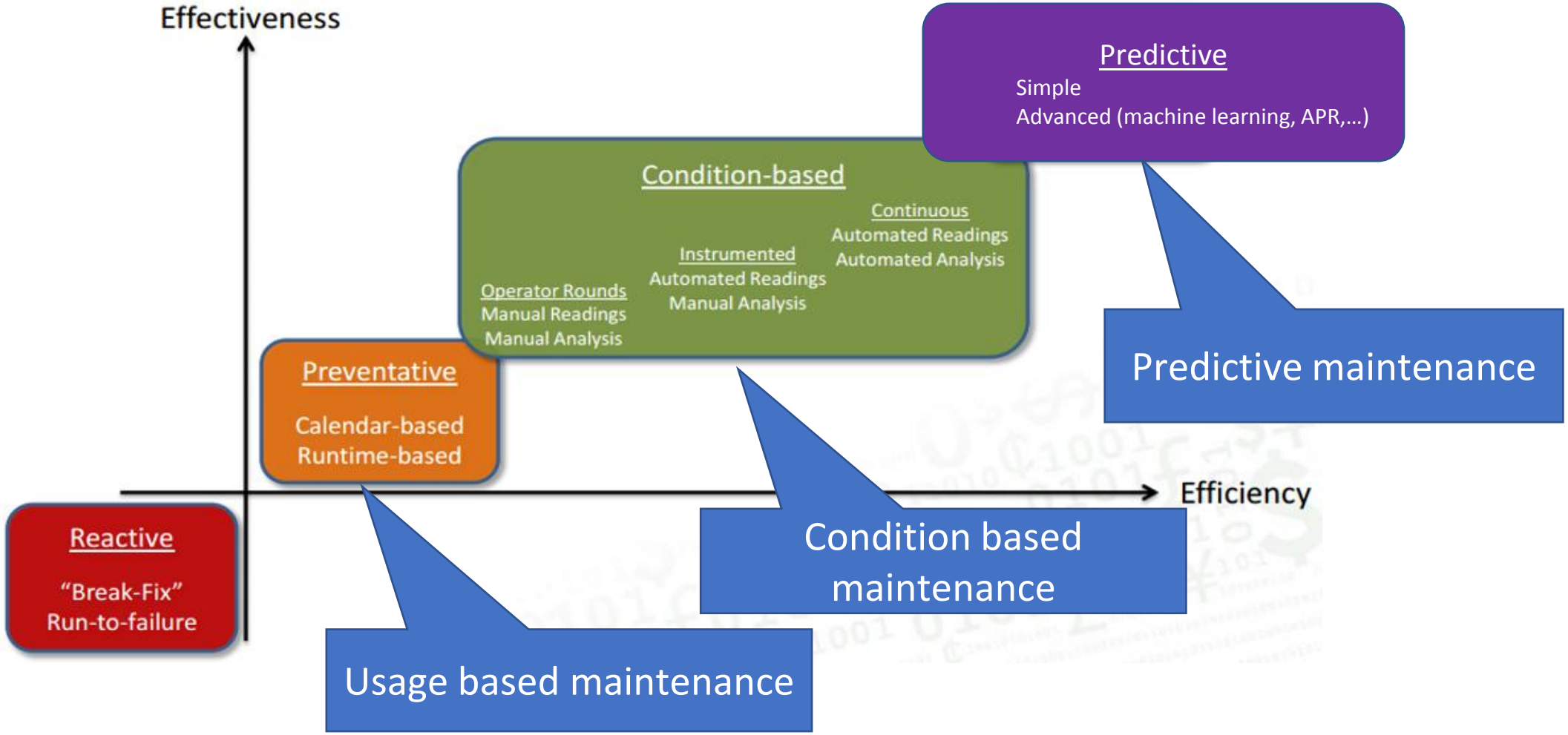
Lab Description

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



Topics

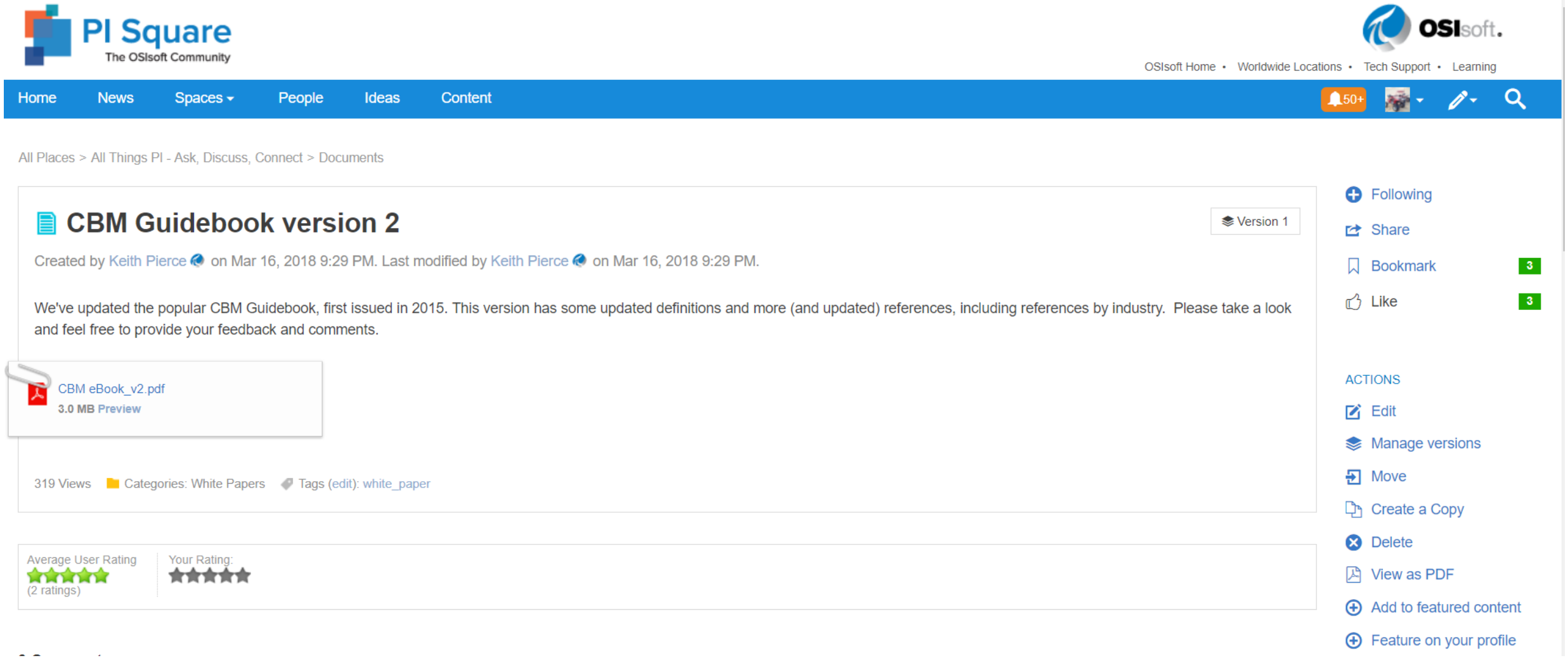
CBM - a strategy where the asset condition is factored into maintenance decisions

- 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

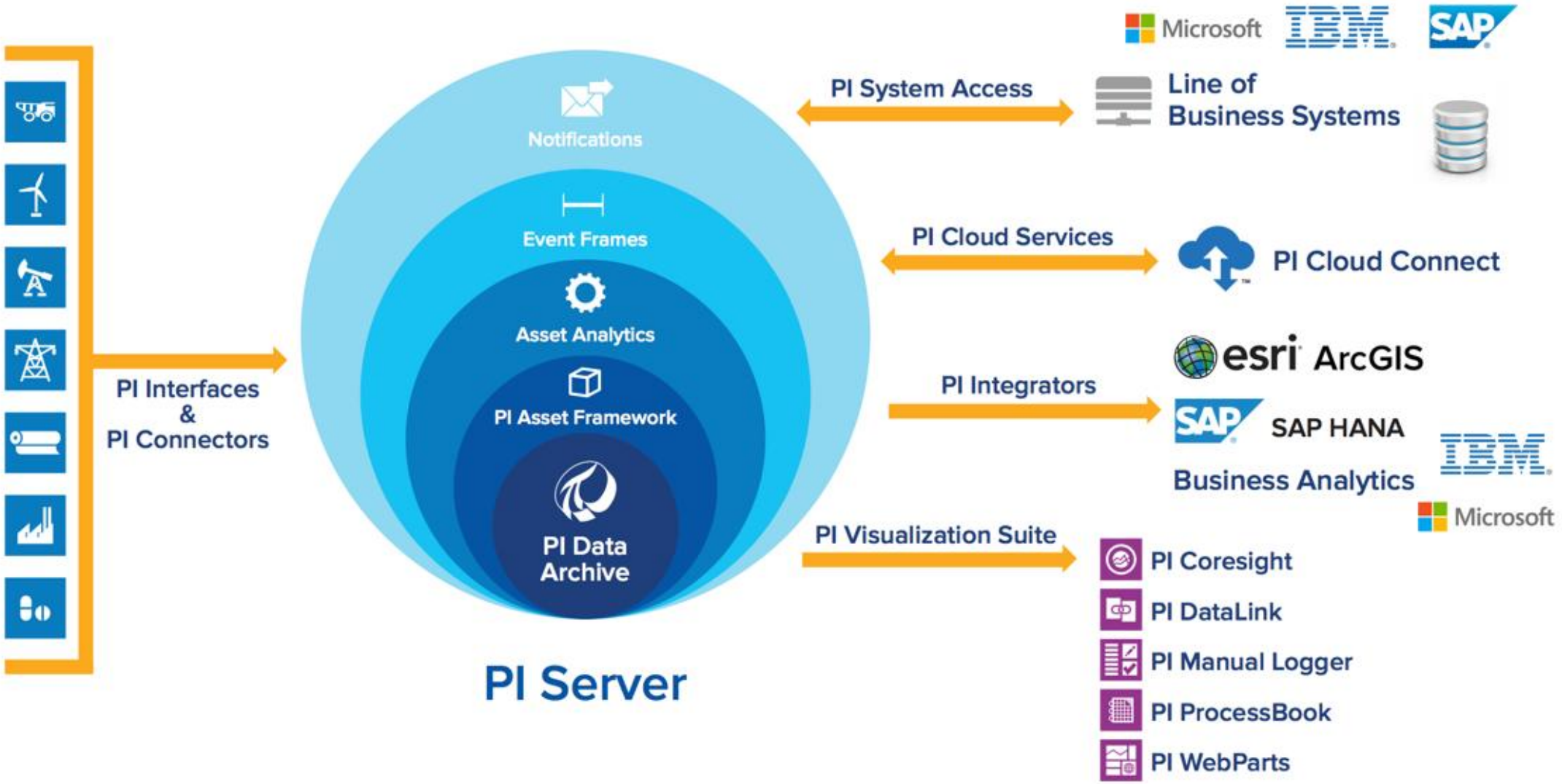


Process data vis-à-vis CM (Condition Monitoring) data

- 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)
  - …

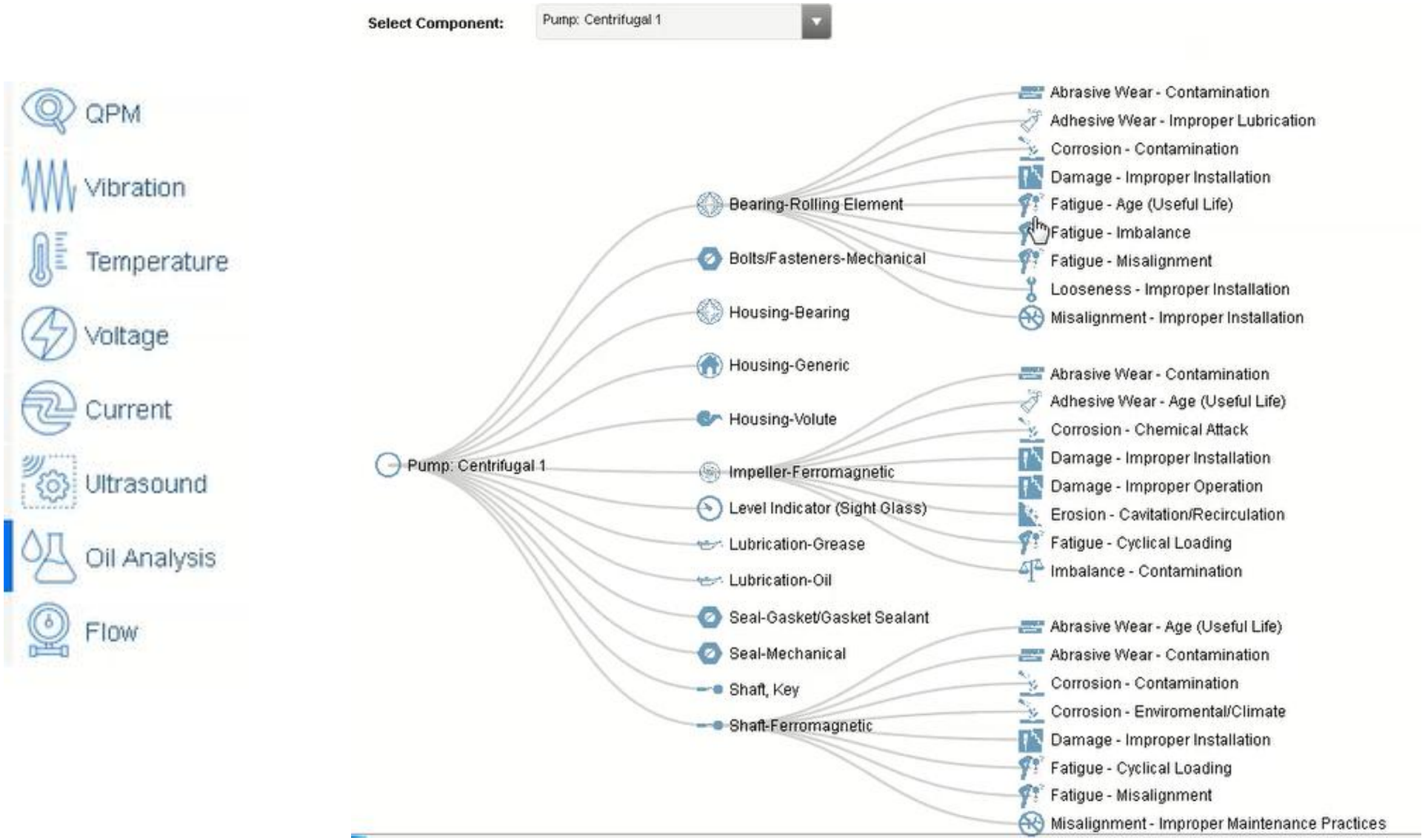
PI System – full stack – data flow



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
  - …
  - …

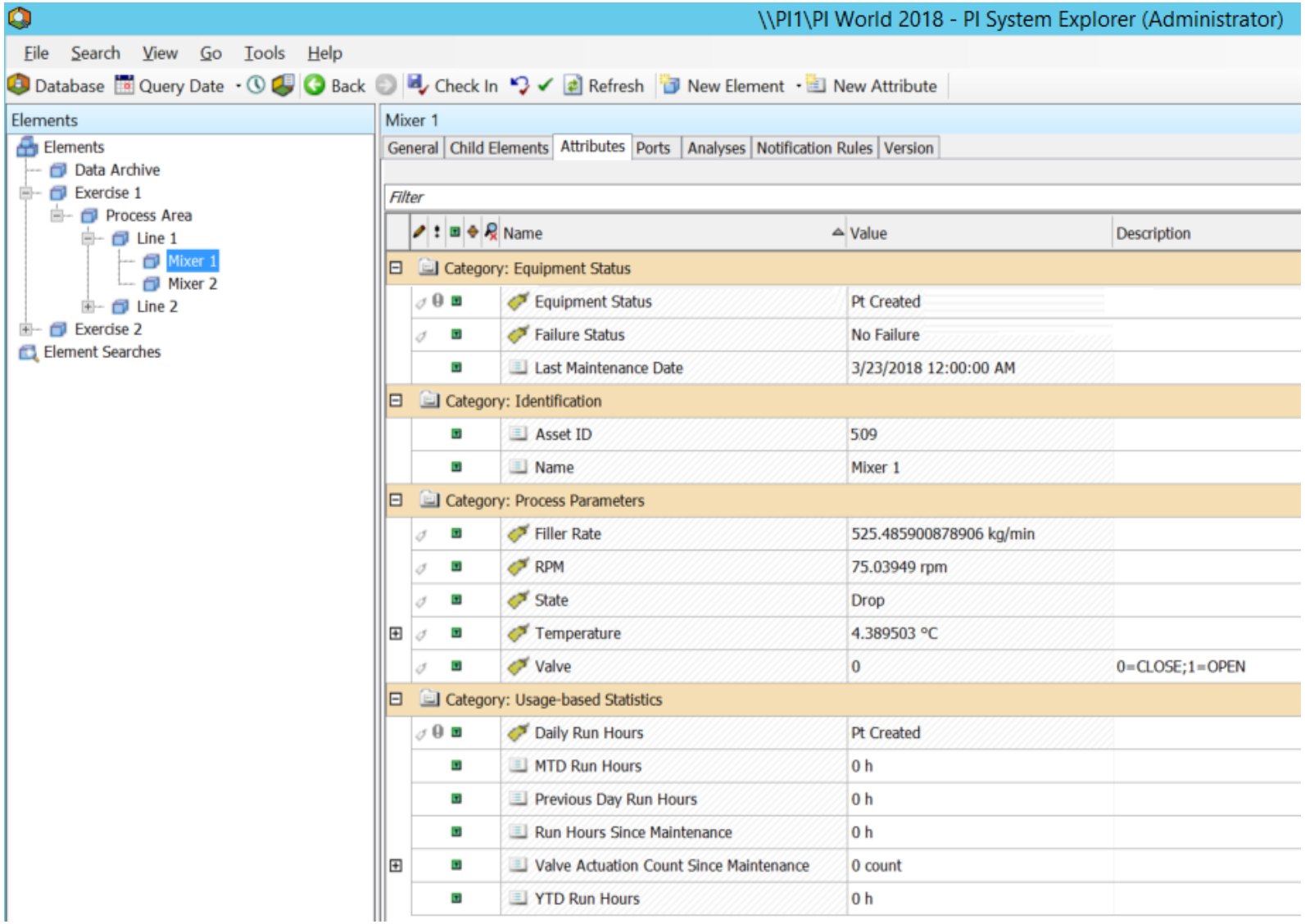
Failure modes and sensor coverage – Allied demo



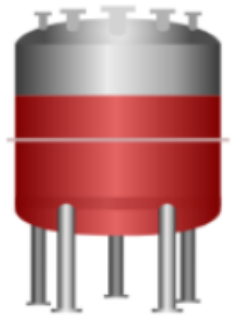
Ex. 1 – Usage based maintenance

- 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



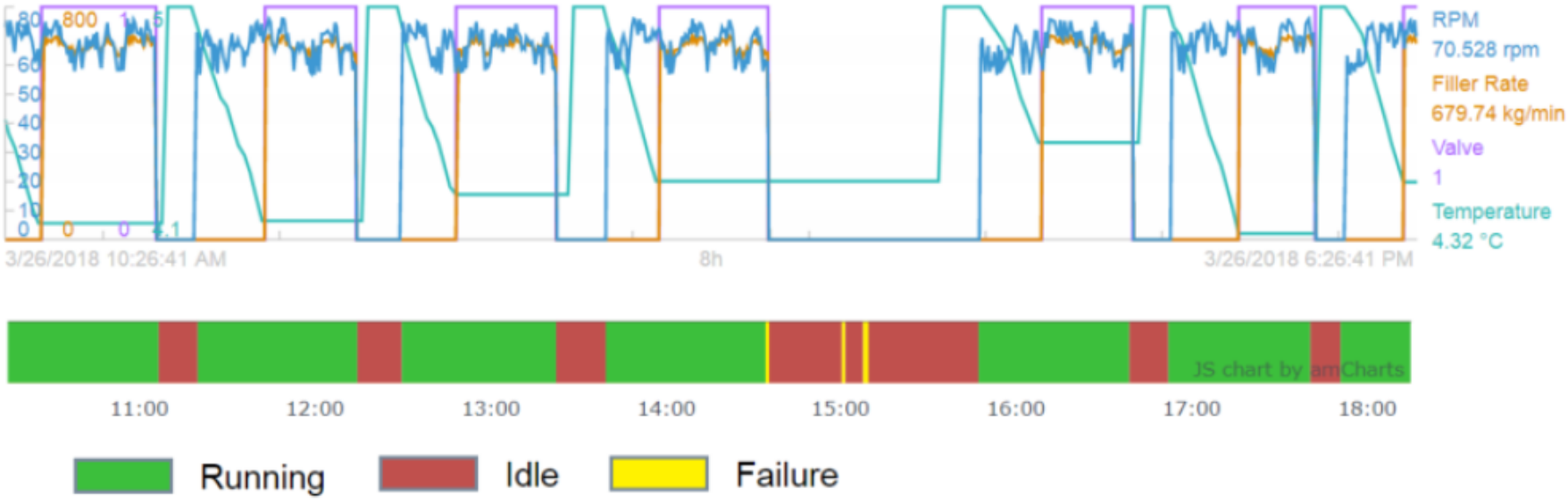
Ex. 1 – Usage based maintenance - Run Hours



Mixer 1

509

Name	Value
Mixer 1|Last Maintenance Date	3/26/2018 12:00:00 AM
Mixer 1|MTD Run Hours	55.643
Mixer 1|Previous Day Run Hours	16.244
Mixer 1|Run Hours Since Maintenance	14.827
Mixer 1|Valve Actuation Count Since Maintenance	16
Mixer 1|YTD Run Hours	55.643



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

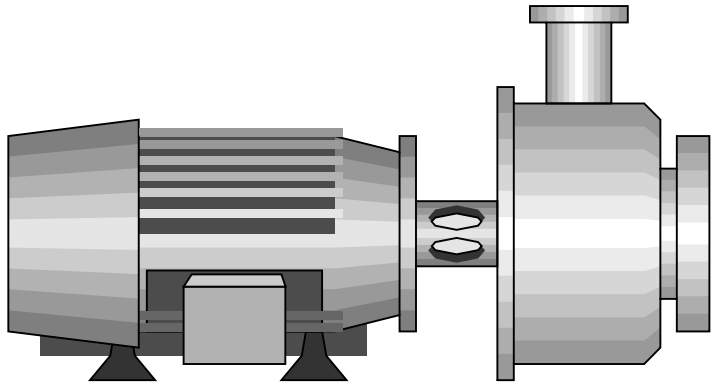
- **Shaft Seizure or Break**
- **Bearing Failure**
- **Seal Failure**
- **Vibration**
- **Fatigue**
- **Misalignment**

Lubrication

- **Viscosity**
- **Water**
- **Wear particles**

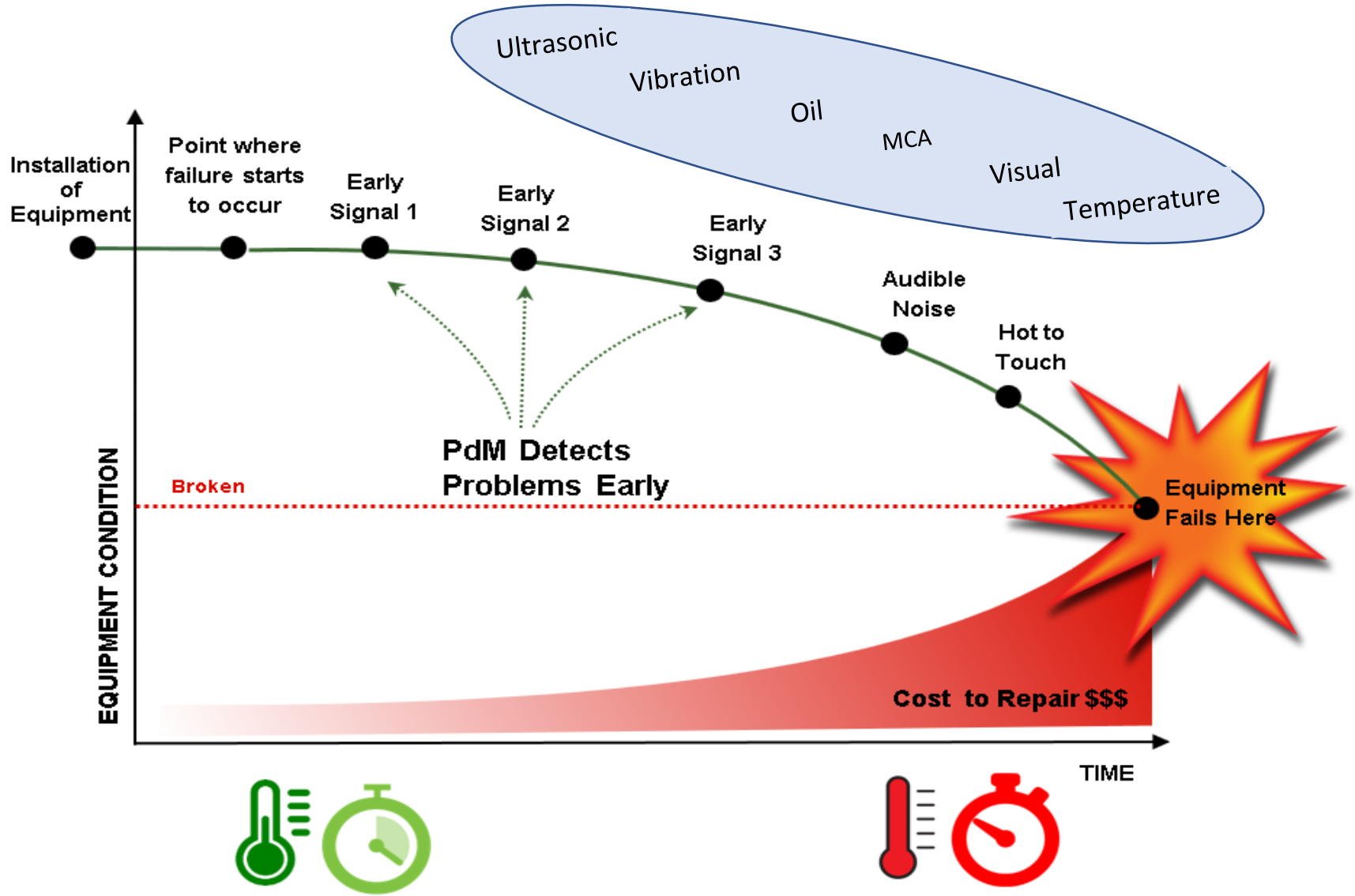
Motor

- **Rotor bar damage**
- **Eccentricity**
- **Mechanical looseness**

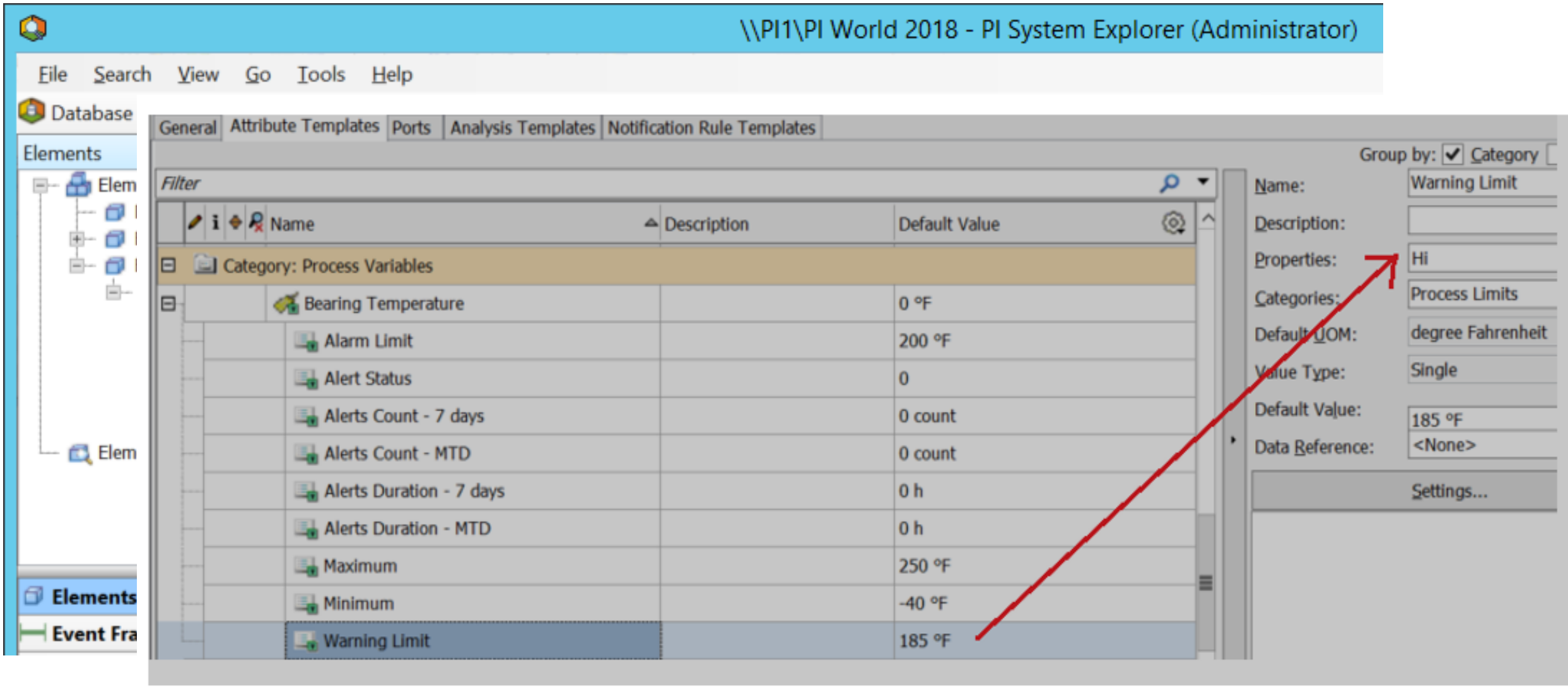


Pump/Motor Failure Modes

P-F Curve


Ultrasonic
Vibration
Oil
MCA
Visual
Temperature
Installation of Equipment
Point where failure starts to occur
Early Signal 1
Early Signal 2
Early Signal 3
Audible Noise
Hot to Touch
PdM Detects Problems Early
Broken
Equipment Fails Here
EQUIPMENT CONDITION
Cost to Repair $$$
TIME

Ex. 2 Condition based maintenance – Bearing temperature



Ex. 2 Condition based maintenance – Bearing temperature

Ex2-BearingTemperatureAlerts

Ad Hoc Display

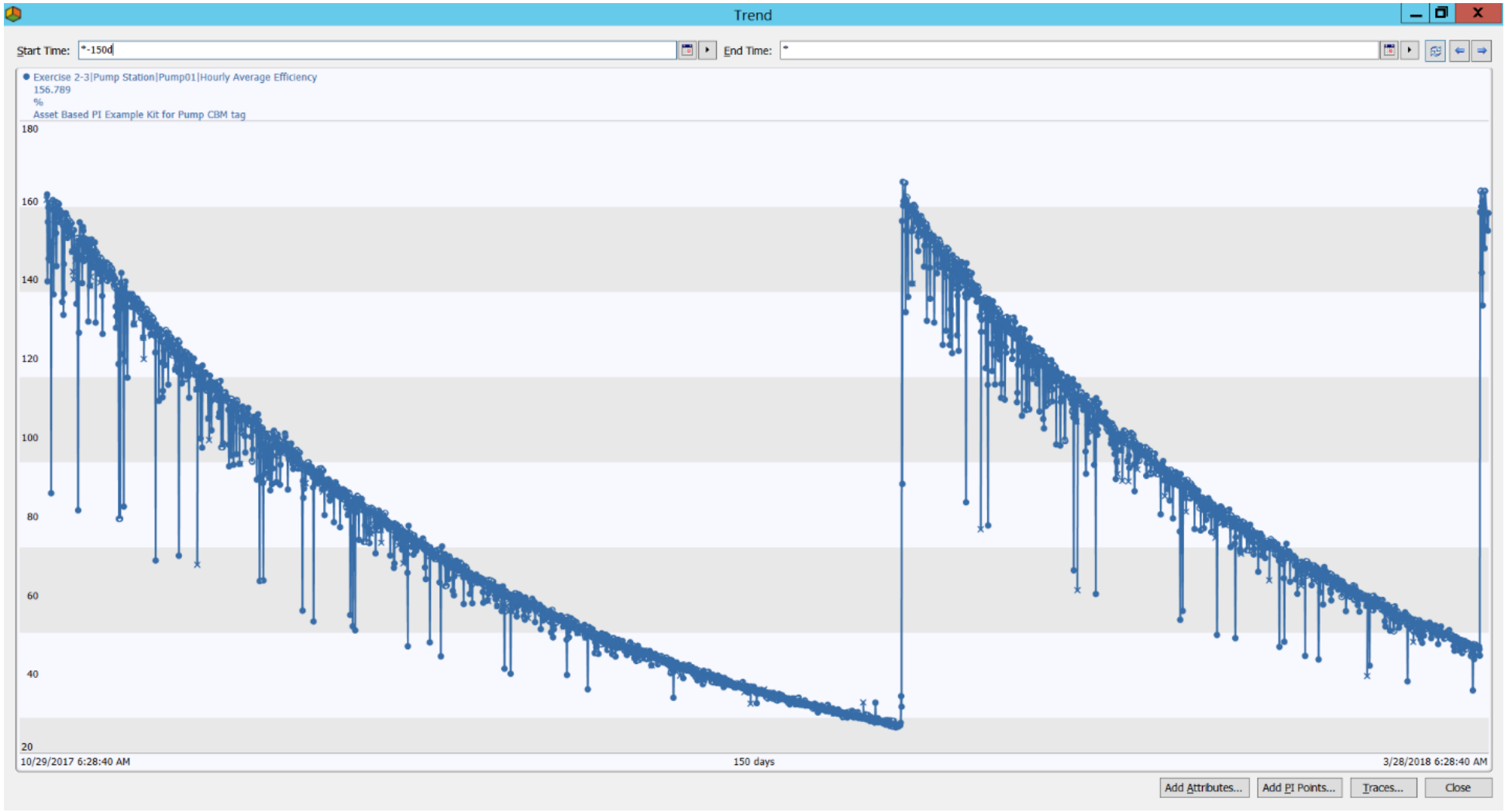
Number and Duration of High Bearing Temperature Alerts

Asset	Bearing Temperature|Alerts Count - 7 days	Bearing Temperature|Alerts Count - MTD	Bearing Temperature|Alerts Duration - 7 days	Bearing Temperature|Alerts Duration - MTD ▼
Pump01	32.0	110.0	15.2 h	26.8 h
Pump04	37.0	104.0	14.7 h	26.0 h
Pump02	28.0	98.0	12.1 h	24.3 h
Pump05	30.0	90.0	12.3 h	22.0 h
Pump03	23.0	97.0	9.7 h	19.6 h

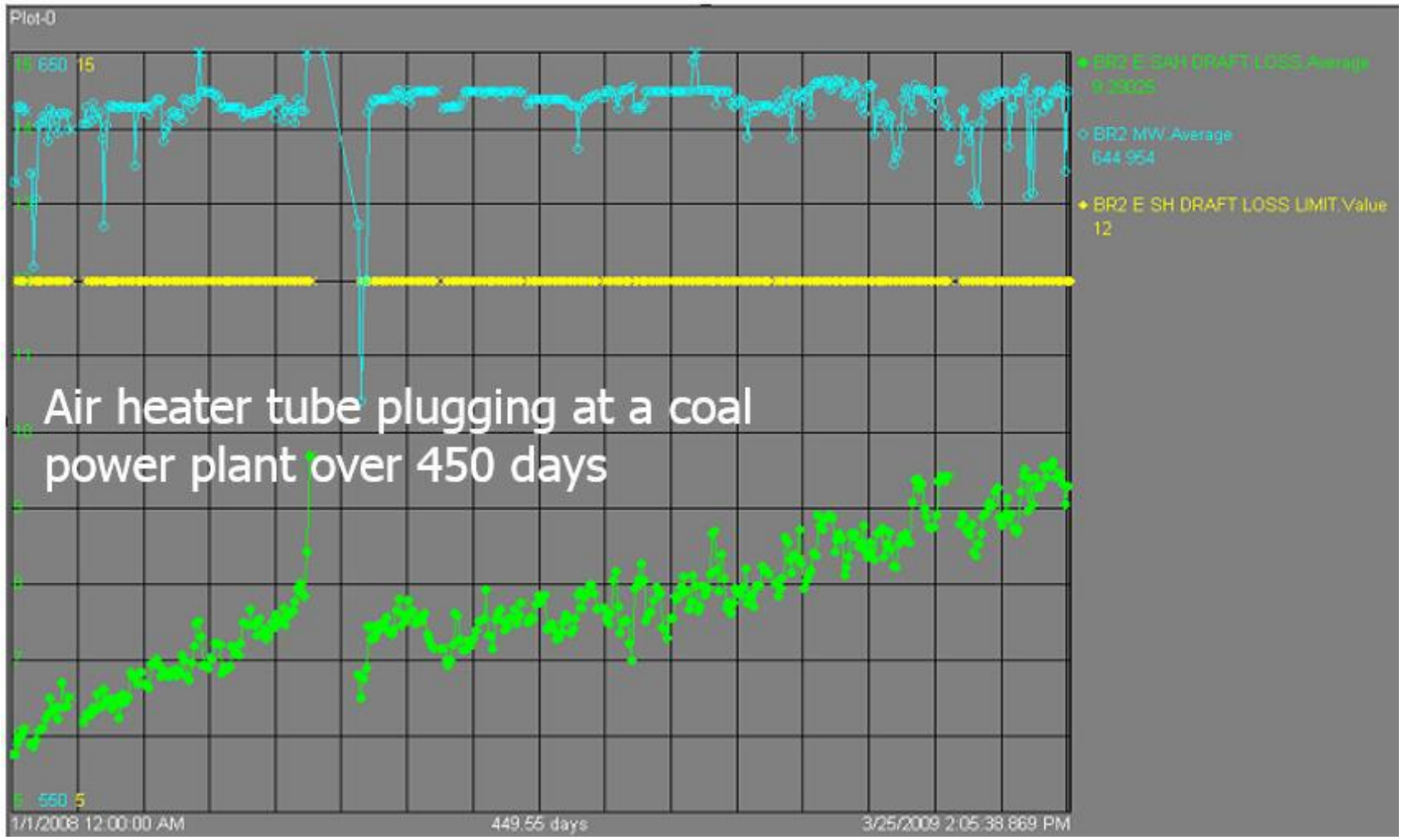
Watchlist of High Bearing Temperature Alerts

Event Name	Asset	Start Time	End Time	Reason	Acknowledged By	Acknowledged Date	Acknowledgement
High Bearing Temp_2018-03-27 05:25:00	PUMP04	3/27/2018 5:25:00 AM	3/27/2018 6:00:00 AM				Acknowledge
High Bearing Temp_2018-03-27 06:40:00	PUMP01	3/27/2018 6:40:00 AM	3/27/2018 7:15:00 AM				Acknowledge
High Bearing Temp_2018-03-27 07:50:00	PUMP01	3/27/2018 7:50:00 AM	3/27/2018 8:30:00 AM				Acknowledge
High Bearing Temp_2018-03-27 07:50:00	PUMP02	3/27/2018 7:50:00 AM	3/27/2018 8:25:00 AM				Acknowledge
High Bearing Temp_2018-03-27 09:00:00	PUMP05	3/27/2018 9:00:00 AM	3/27/2018 9:40:00 AM				Acknowledge
High Bearing Temp_2018-03-27 09:00:00	PUMP04	3/27/2018 9:00:00 AM	3/27/2018 9:40:00 AM				Acknowledge
High Bearing Temp_2018-03-27 09:40:00	PUMP03	3/27/2018 9:40:00 AM	3/27/2018 10:15:00 AM				Acknowledge
High Bearing Temp_2018-03-27 11:05:00	PUMP02	3/27/2018 11:05:00 AM	3/27/2018 11:30:00 AM				Acknowledge

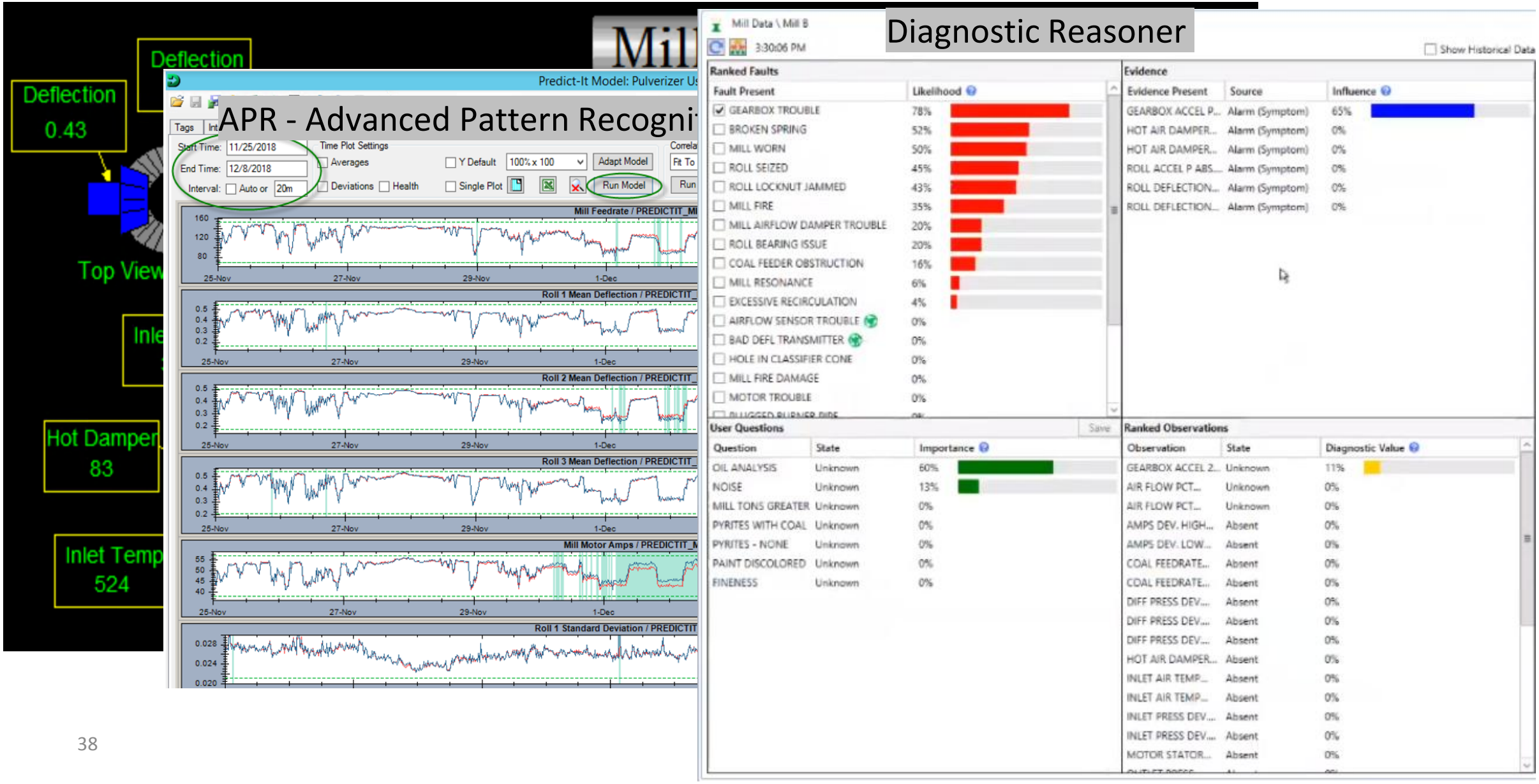
Ex. 3a Simple Predictive – extrapolate the trend – compressor efficiency



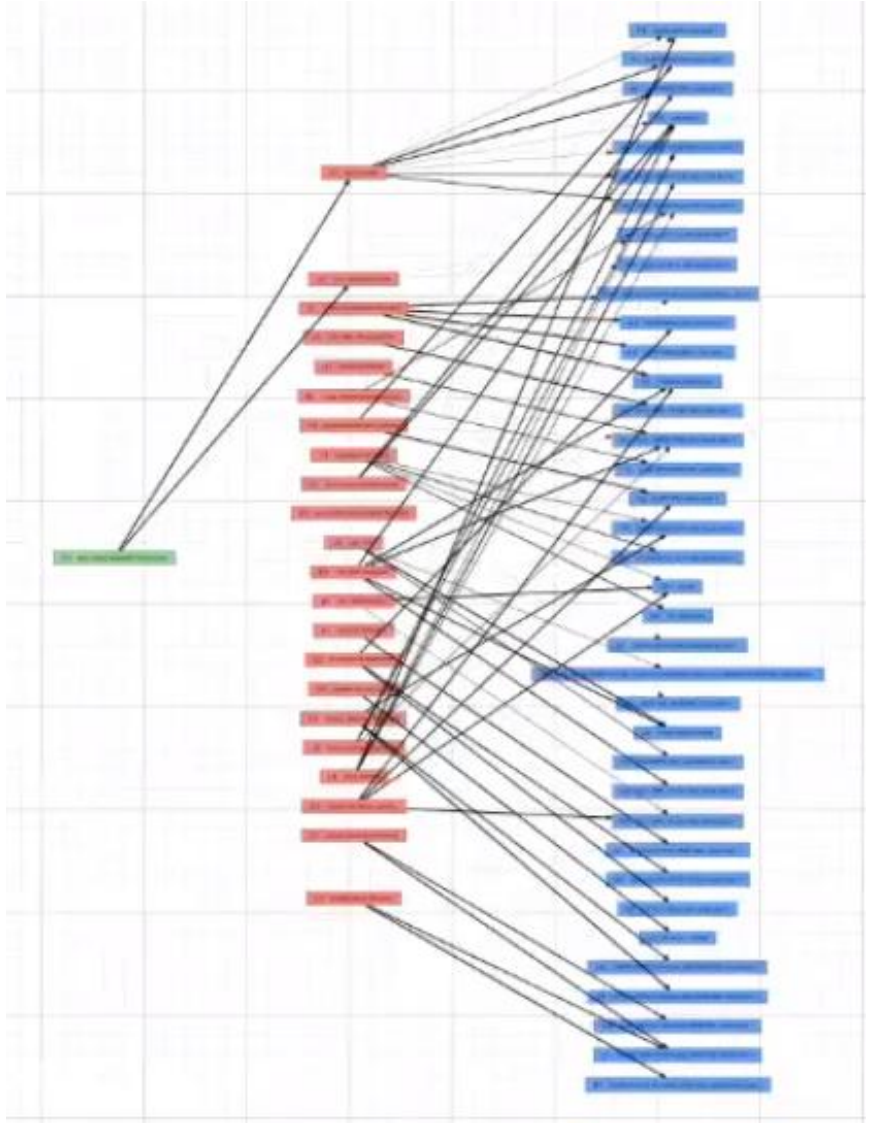
Ex. 3a Simple Predictive - air heater fouling



Ex. 3b - Advanced Predictve - pulverizer - early fault detection



Ex. 3b - Advanced Predictve - pulverizer - early fault detection



Mill Data \ Mill B

3:30:06 PM

Diagnostic Reasoner

Show Historical Data

Ranked Faults

Fault Present	Likelihood
GEARBOX TROUBLE	78%
BROKEN SPRING	52%
MILL WORN	50%
ROLL SEIZED	45%
ROLL LOCKNUT JAMMED	43%
MILL FIRE	35%
MILL AIRFLOW DAMPER TROUBLE	20%
ROLL BEARING ISSUE	20%
COAL FEEDER OBSTRUCTION	16%
MILL RESONANCE	6%
EXCESSIVE RECIRCULATION	4%
AIRFLOW SENSOR TROUBLE	0%
BAD DEFL TRANSMITTER	0%
HOLE IN CLASSIFIER CONE	0%
MILL FIRE DAMAGE	0%
MOTOR TROUBLE	0%

Evidence

Evidence Present	Source	Influence
GEARBOX ACCEL P...	Alarm (Symptom)	65%
HOT AIR DAMPER...	Alarm (Symptom)	0%
HOT AIR DAMPER...	Alarm (Symptom)	0%
ROLL ACCEL P ABS...	Alarm (Symptom)	0%
ROLL DEFLECTION...	Alarm (Symptom)	0%
ROLL DEFLECTION...	Alarm (Symptom)	0%

User Questions

Save

Question	State	Importance
OIL ANALYSIS	Unknown	60%
NOISE	Unknown	13%
MILL TONS GREATER	Unknown	0%
PYRITES WITH COAL	Unknown	0%
PYRITES - NONE	Unknown	0%
PAINT DISCOLORED	Unknown	0%
FINENESS	Unknown	0%

Ranked Observations

Observation	State	Diagnostic Value
GEARBOX ACCEL 2...	Unknown	11%
AIR FLOW PCT...	Unknown	0%
AIR FLOW PCT...	Unknown	0%
AMPS DEV. HIGH...	Absent	0%
AMPS DEV. LOW...	Absent	0%
COAL FEEDRATE...	Absent	0%
COAL FEEDRATE...	Absent	0%
DIFF PRESS DEV...	Absent	0%
DIFF PRESS DEV...	Absent	0%
DIFF PRESS DEV...	Absent	0%
HOT AIR DAMPER...	Absent	0%
INLET AIR TEMP...	Absent	0%
INLET AIR TEMP...	Absent	0%
INLET PRESS DEV...	Absent	0%
INLET PRESS DEV...	Absent	0%
MOTOR STATOR...	Absent	0%

Other predictive – statistical, machine learning …

DISCUSSION Only

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)

Link

Anomaly detection (HVAC - Air Handler) - Support Vectors - TechCon 2017 Lab

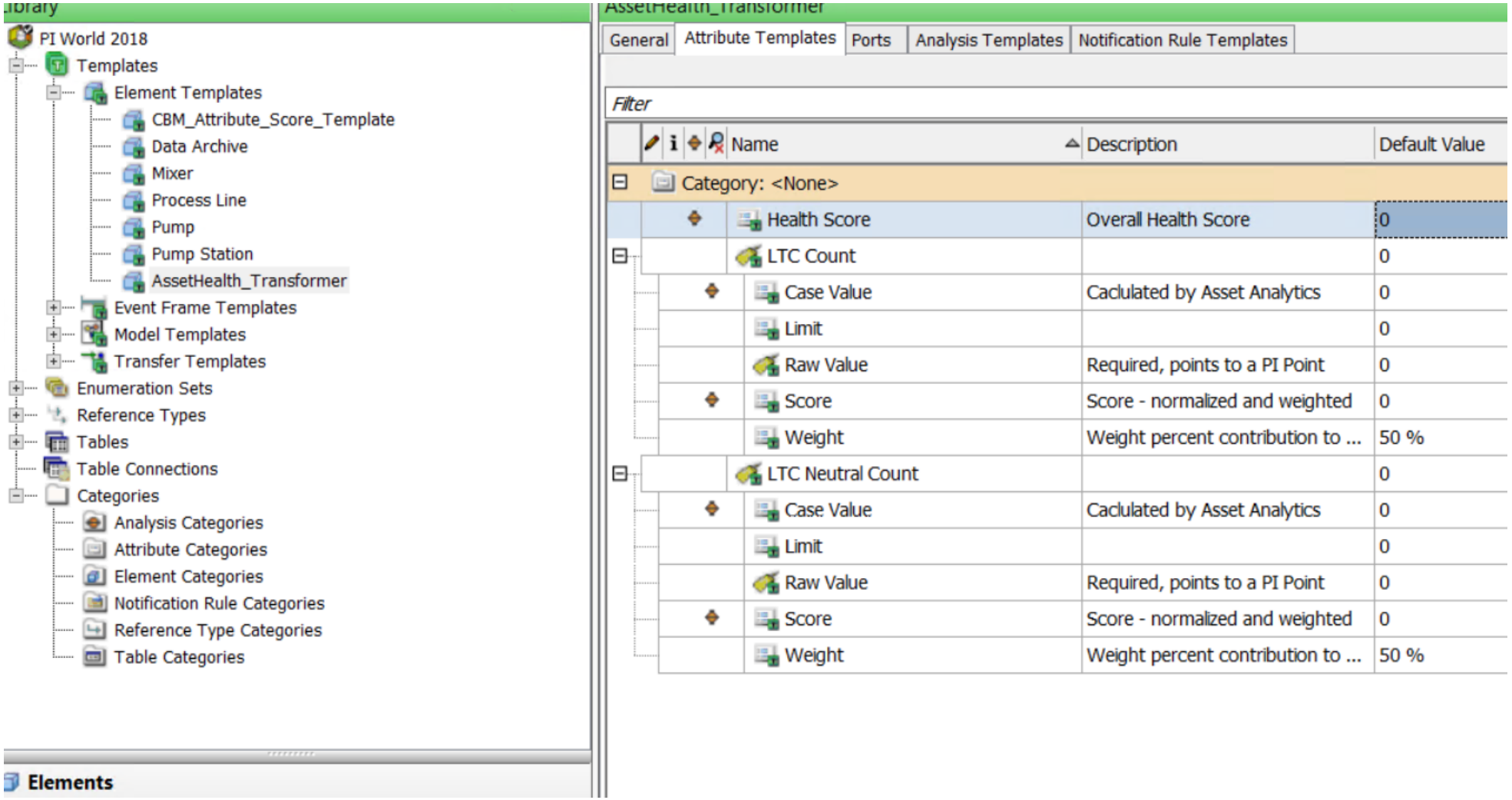
7 sensors
~6 months of operations, 5 minute data
damper stuck open? temperature transmitter failed?
air supply fan constraint? where are the system constraints…

Link

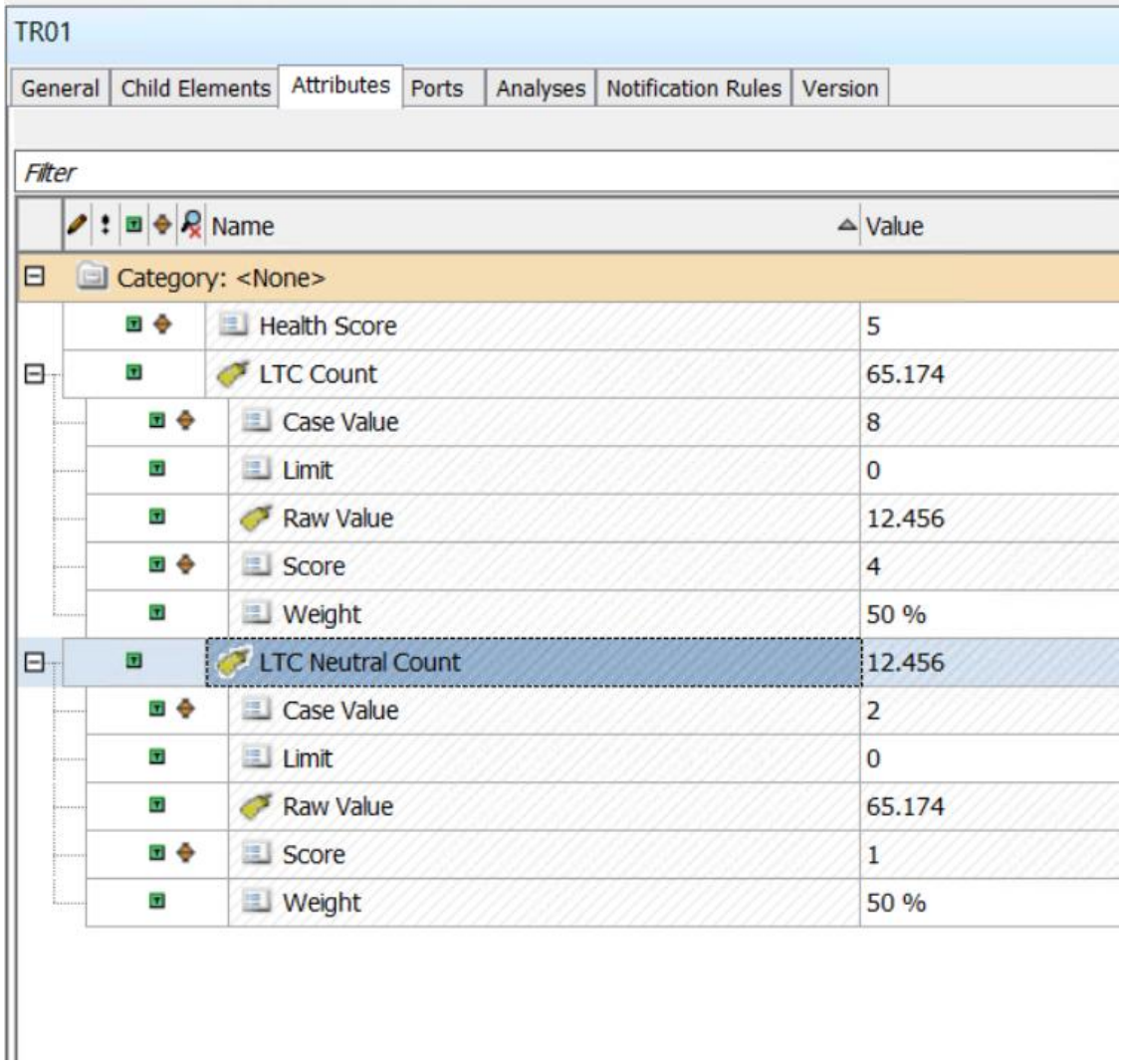
Yeast manufacturing – fermenter - monitoring and diagnostics - PI World 2019 Lab

…

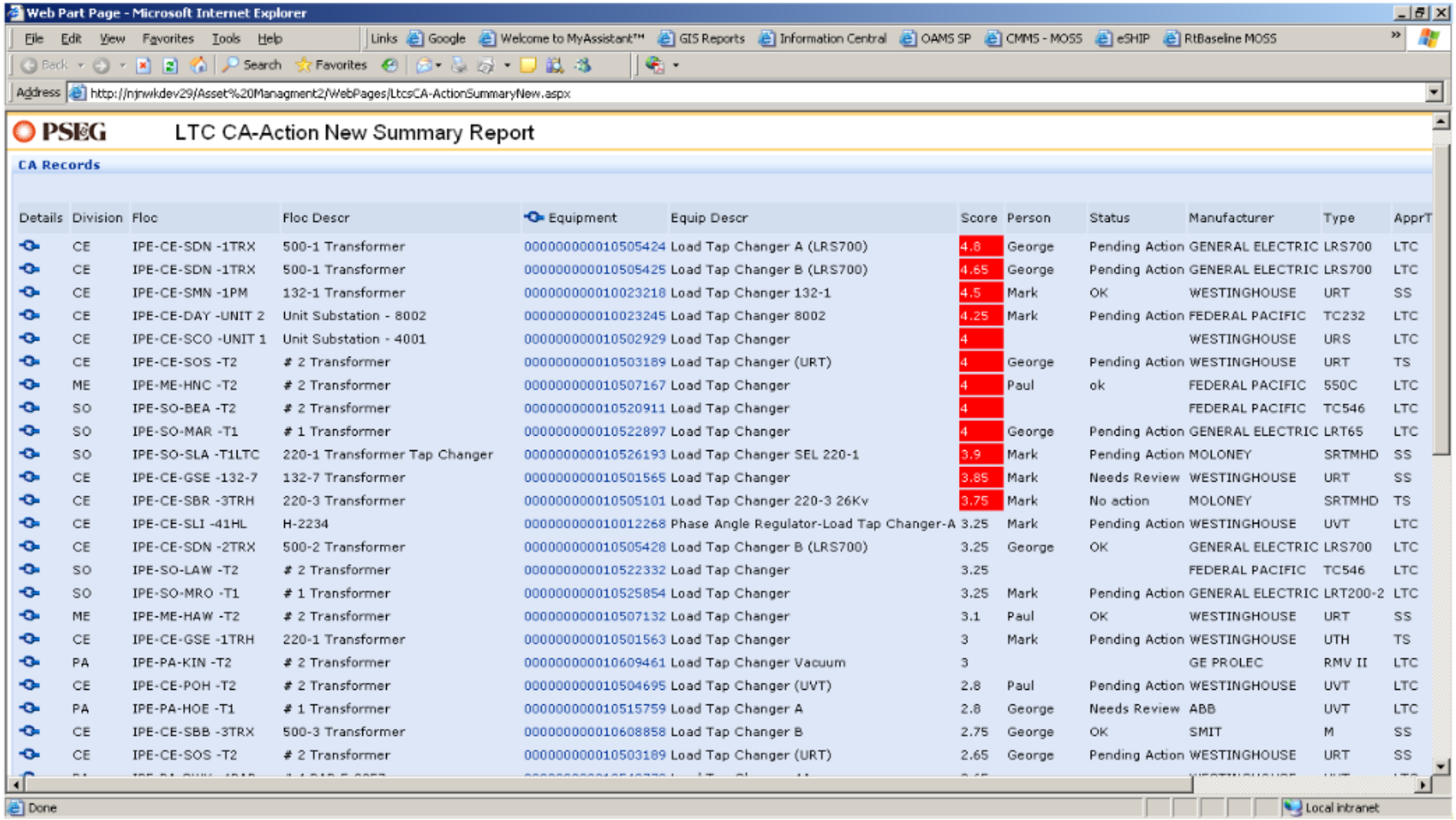
Ex. 4 Condition Assessment – Overall Asset Health Score



Ex. 4 Health Score - Transformer

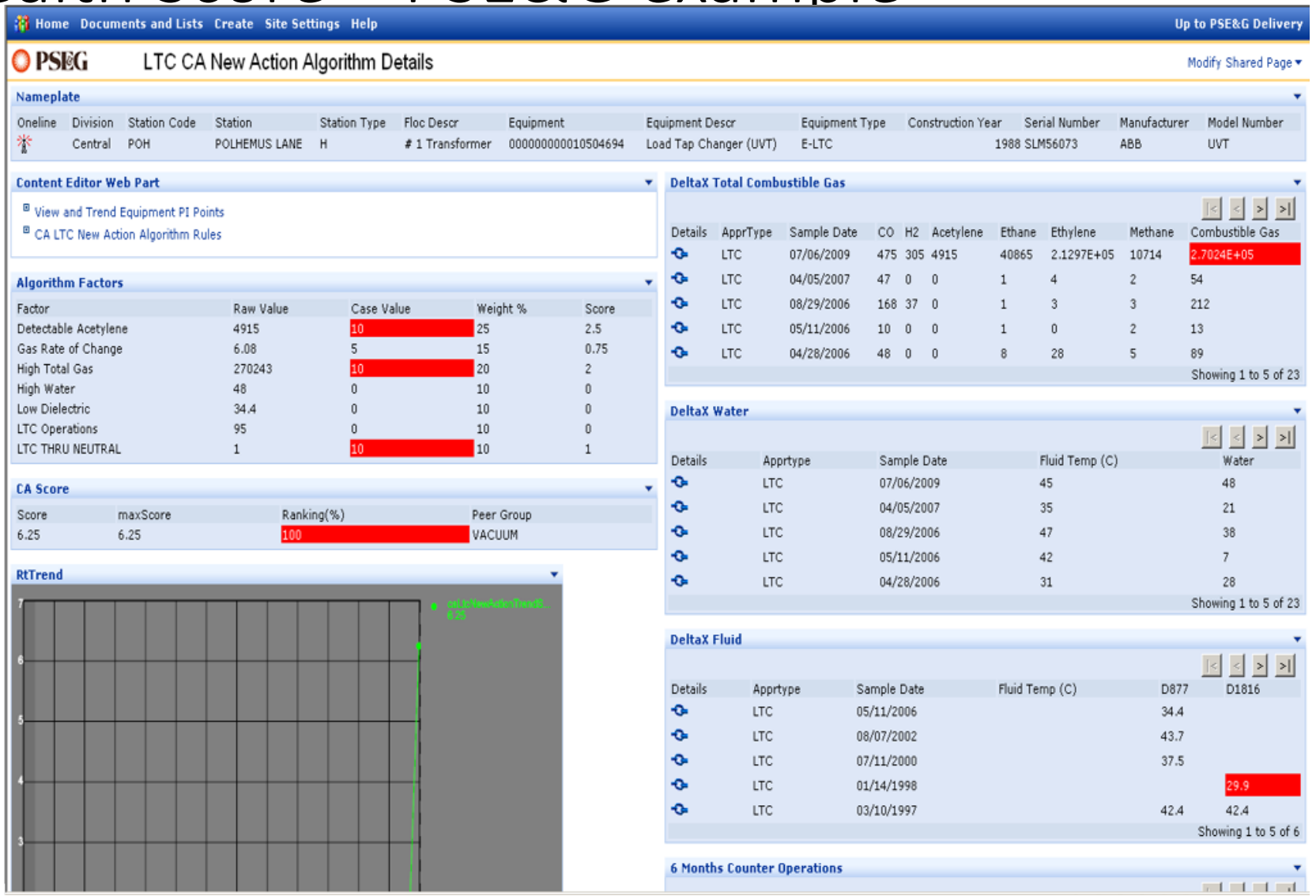


Asset Health Score



Details	Division	Floc	Floc Descr	Equipment	Equip Descr	Score	Person	Status	Manufacturer	Type	ApprT
	CE	IPE-CE-SDN -1TRX	500-1 Transformer	000000000010505424	Load Tap Changer A (LRS700)	4.8	George	Pending Action	GENERAL ELECTRIC	LRS700	LTC
	CE	IPE-CE-SDN -1TRX	500-1 Transformer	000000000010505425	Load Tap Changer B (LRS700)	4.65	George	Pending Action	GENERAL ELECTRIC	LRS700	LTC
	CE	IPE-CE-SMN -1PM	132-1 Transformer	000000000010023218	Load Tap Changer 132-1	4.5	Mark	OK	WESTINGHOUSE	URT	SS
	CE	IPE-CE-DAY -UNIT 2	Unit Substation - 8002	000000000010023245	Load Tap Changer 8002	4.25	Mark	Pending Action	FEDERAL PACIFIC	TC232	LTC
	CE	IPE-CE-SCO -UNIT 1	Unit Substation - 4001	000000000010502929	Load Tap Changer	4			WESTINGHOUSE	URS	LTC
	CE	IPE-CE-SOS -T2	# 2 Transformer	000000000010503189	Load Tap Changer (URT)	4	George	Pending Action	WESTINGHOUSE	URT	TS
	ME	IPE-ME-HNC -T2	# 2 Transformer	000000000010507167	Load Tap Changer	4	Paul	ok	FEDERAL PACIFIC	550C	LTC
	SO	IPE-SO-BEA -T2	# 2 Transformer	000000000010520911	Load Tap Changer	4			FEDERAL PACIFIC	TC546	LTC
	SO	IPE-SO-MAR -T1	# 1 Transformer	000000000010522897	Load Tap Changer	4	George	Pending Action	GENERAL ELECTRIC	LRT65	LTC
	SO	IPE-SO-SLA -T1LTC	220-1 Transformer Tap Changer	000000000010526193	Load Tap Changer SEL 220-1	3.9	Mark	Pending Action	MOLONEY	SRTMHD	SS
	CE	IPE-CE-GSE -132-7	132-7 Transformer	000000000010501565	Load Tap Changer	3.85	Mark	Needs Review	WESTINGHOUSE	URT	SS
	CE	IPE-CE-SBR -3TRH	220-3 Transformer	000000000010505101	Load Tap Changer 220-3 26Kv	3.75	Mark	No action	MOLONEY	SRTMHD	TS
	CE	IPE-CE-SLI -41HL	H-2234	000000000010012268	Phase Angle Regulator-Load Tap Changer-A	3.25	Mark	Pending Action	WESTINGHOUSE	UVT	LTC
	CE	IPE-CE-SDN -2TRX	500-2 Transformer	000000000010505428	Load Tap Changer B (LRS700)	3.25	George	OK	GENERAL ELECTRIC	LRS700	LTC
	SO	IPE-SO-LAW -T2	# 2 Transformer	000000000010522332	Load Tap Changer	3.25			FEDERAL PACIFIC	TC546	LTC
	SO	IPE-SO-MRO -T1	# 1 Transformer	000000000010525854	Load Tap Changer	3.25	Mark	Pending Action	GENERAL ELECTRIC	LRT200-2	LTC
	ME	IPE-ME-HAW -T2	# 2 Transformer	000000000010507132	Load Tap Changer	3.1	Paul	OK	WESTINGHOUSE	URT	SS
	CE	IPE-CE-GSE -1TRH	220-1 Transformer	000000000010501563	Load Tap Changer	3	Mark	Pending Action	WESTINGHOUSE	UTH	TS
	PA	IPE-PA-KIN -T2	# 2 Transformer	000000000010609461	Load Tap Changer Vacuum	3			GE PROLEC	RMV II	LTC
	CE	IPE-CE-POH -T2	# 2 Transformer	000000000010504695	Load Tap Changer (UVT)	2.8	Paul	Pending Action	WESTINGHOUSE	UVT	LTC
	PA	IPE-PA-HOE -T1	# 1 Transformer	000000000010515759	Load Tap Changer A	2.8	George	Needs Review	ABB	UVT	LTC
	CE	IPE-CE-SBB -3TRX	500-3 Transformer	000000000010608858	Load Tap Changer B	2.75	George	OK	SMIT	M	SS
	CE	IPE-CE-SOS -T2	# 2 Transformer	000000000010503189	Load Tap Changer (URT)	2.65	George	Pending Action	WESTINGHOUSE	URT	SS

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

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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

Condition Based Maintenance

PF

CM

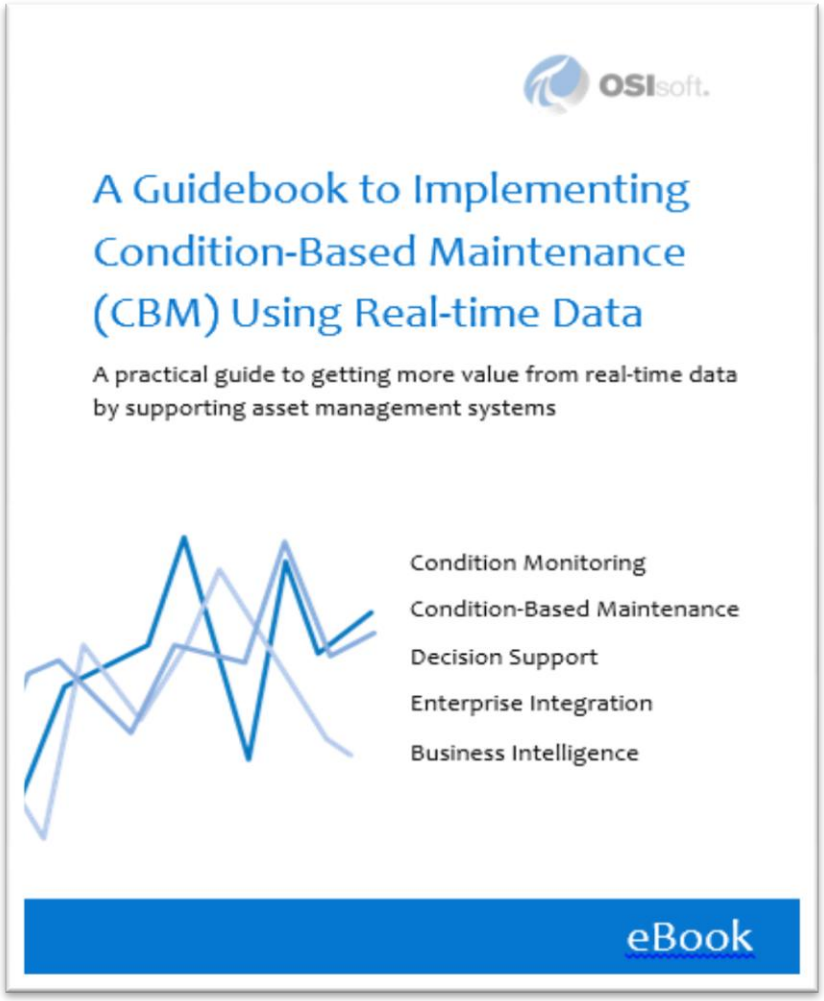
Condition Monitoring

RCA

CMMS

FMEA

CBM Prescriptive Guidance



Terms & Definitions

Implementation Guidance

PI System Overview for CBM

PI System Integration w/ CMMS

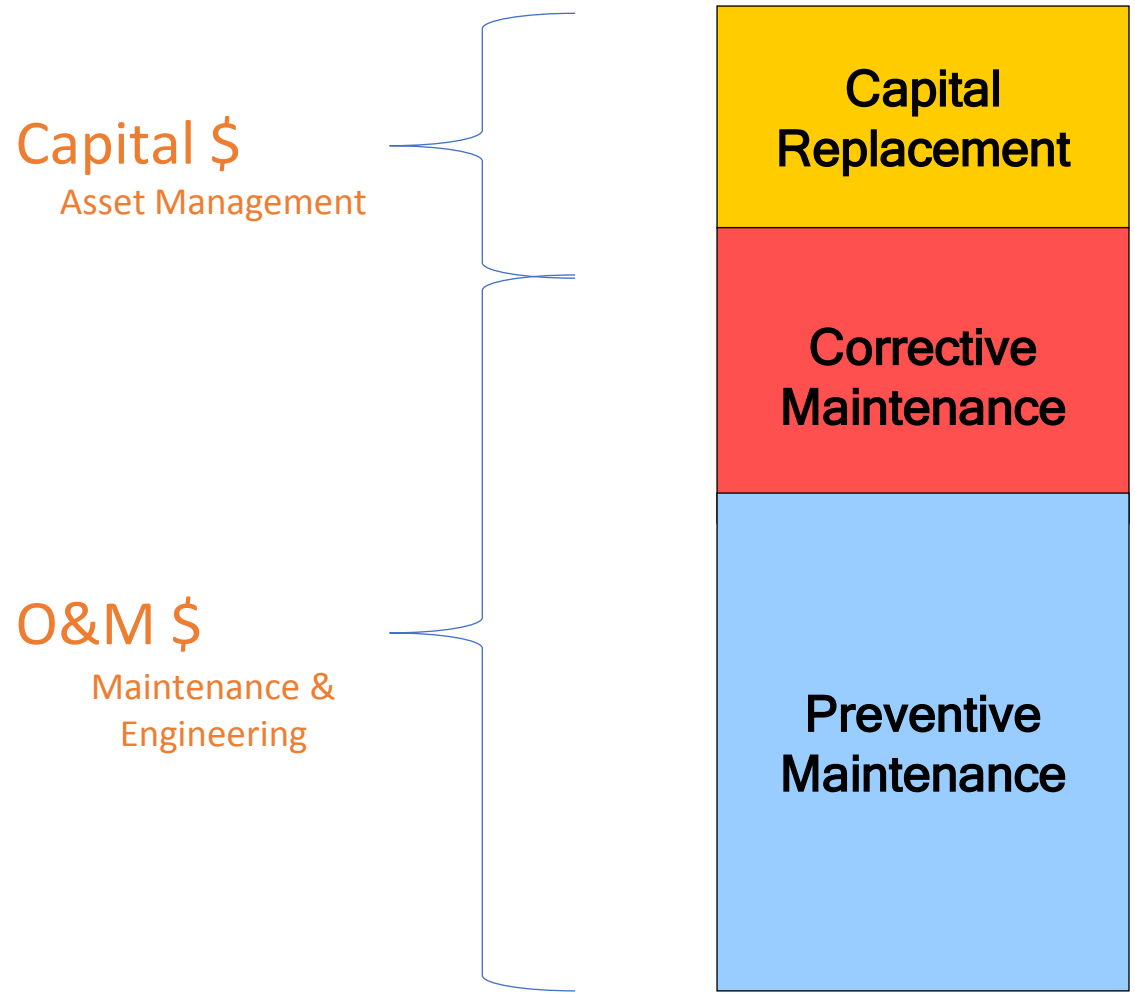
Enabling Opportunities

Solution Examples

Industry References

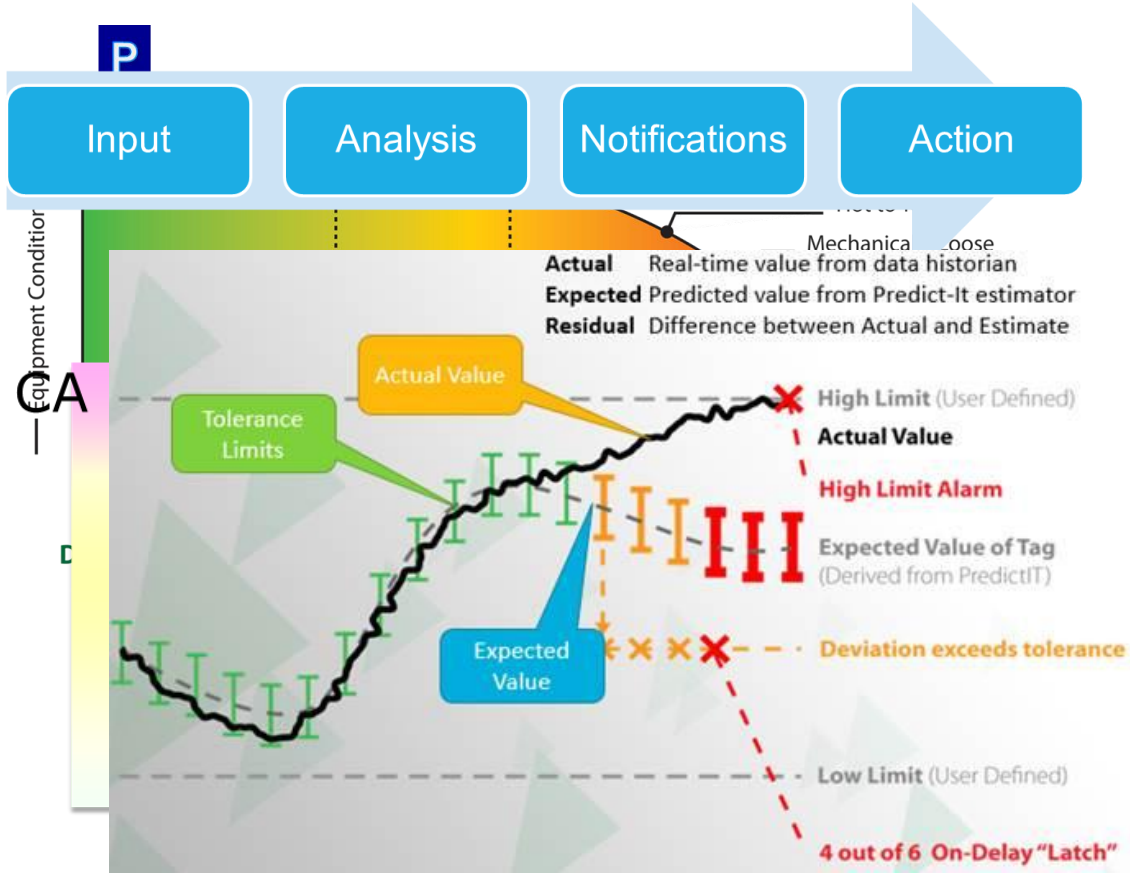
Maintenance Budget & Types

- 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



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

OSIsoft.

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	4.51	7,975	0	3mo	387	1/10/2016	11/10/2016
Agitator 1205	23.79	10,119	2,154	3mo	409	2/23/2016	10/3/2016
Agitator 1304	23.49	9,908	2,118	3mo	697	2/11/2016	12/13/2016
Agitator 1305	23.49	9,908	2,118	3mo	697	2/11/2016	12/1/2016
Fan 5163	19.71	8,554	1,174	3mo	2,664	10/1/2015	5/1/2016
Fan 5164	23.97	9,292	2,022	3mo	3,566	10/2/2015	5/2/2016
Fan 8144	14.44	9,839	2,112	3mo	3,635	10/5/2015	5/5/2016
Pump 3809	15.16	8,587	1,949	3mo	3,218	10/10/2015	5/10/2016
Pump 3810	23.97	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

TransCanada
In business to deliver

_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

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

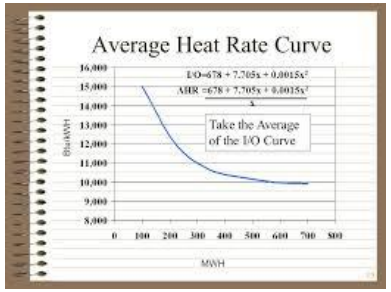
Category: Nominal Values	
BHP_Nominal	8710.27322604474 BHP
FuelRate_Nominal	71.1036975854648 MCFH
HeatRate_Nominal	8163.19944739005 BTU(LHV)/BHP-hr
PCD_Nominal	205.15303353481 psi
T5_Nominal	1394.59524035539 °F
T7_Nominal	925.386891989674 °F

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 + E*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)]
```



Unit_Heat_Rate_Actual	9843.68334570345 BTU(LHV)/BHP-hr

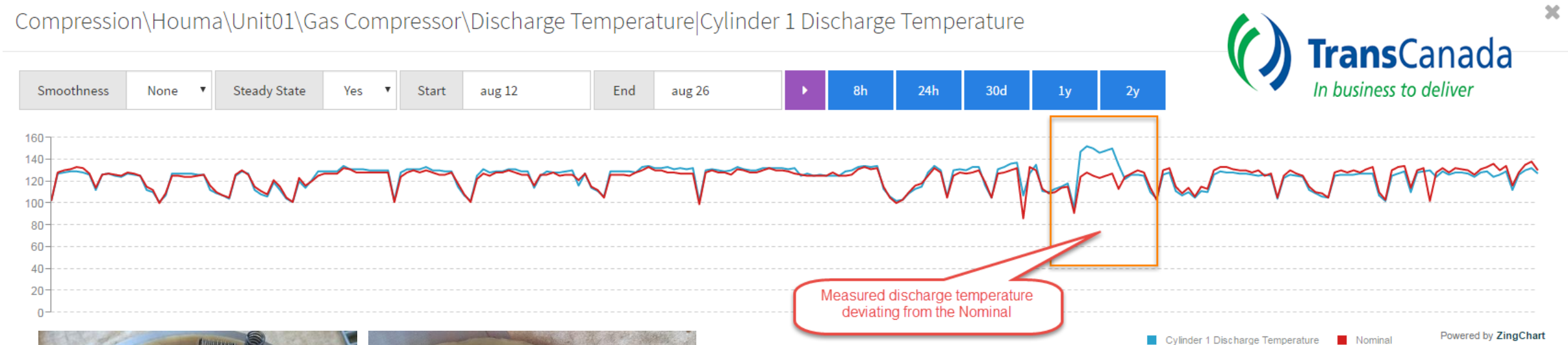
Calculate Actual Heat Rate

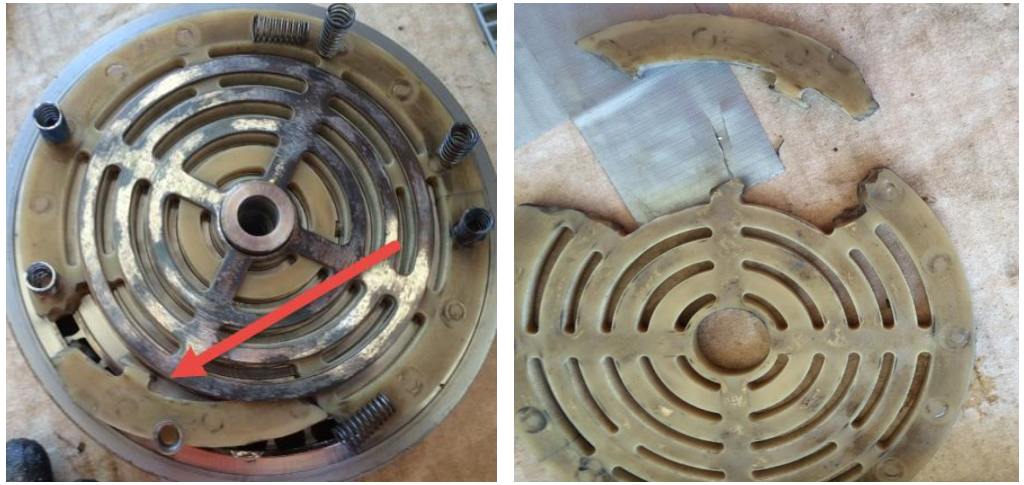
Data Reference: Formula

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]
```

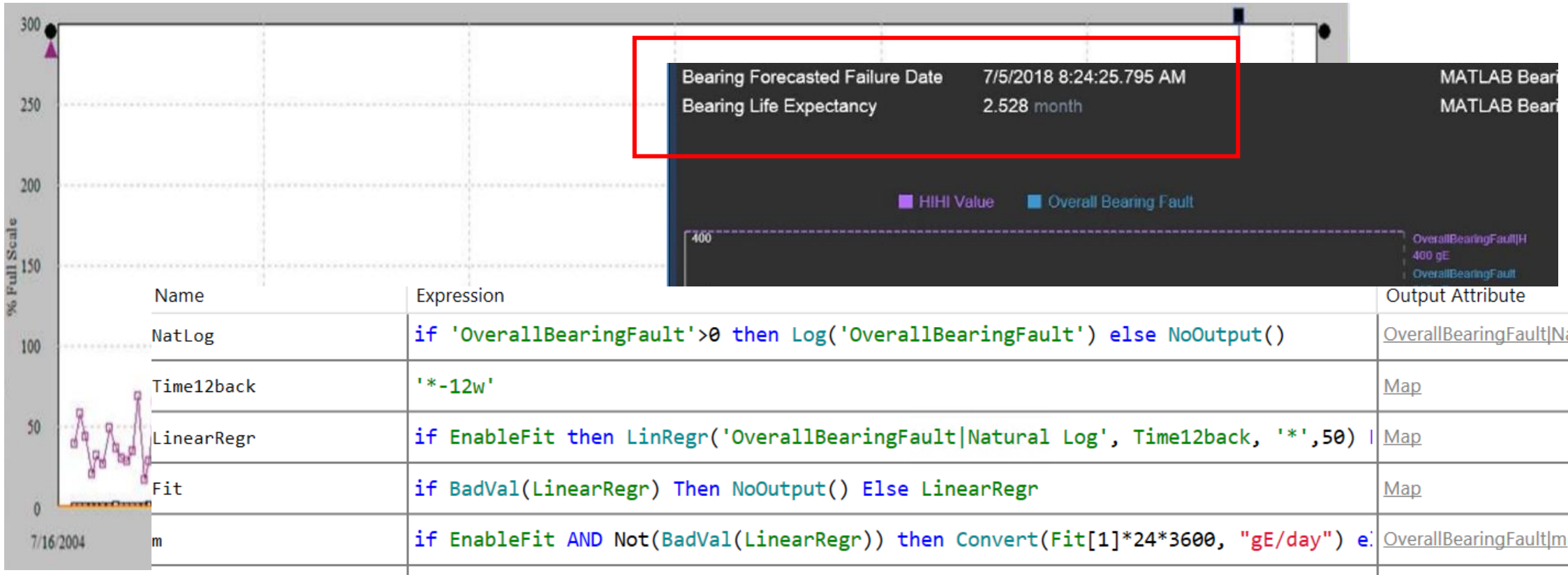
Example of Predictive Analytics in PI AF – Expected vs Actual





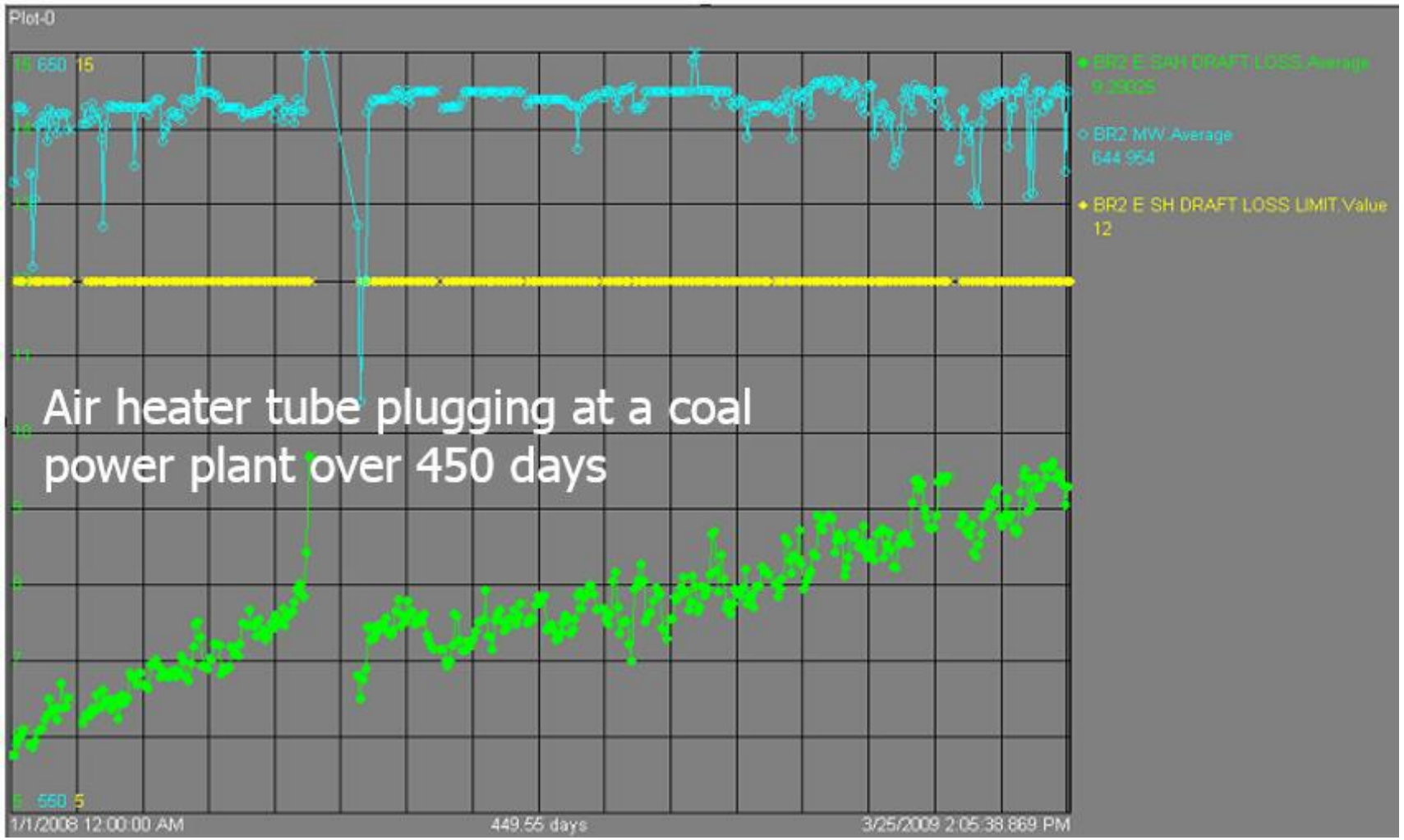
Found partially damaged compressor valve.
The valve was replaced in a planned & controlled manner.

Maintenance – Simple Predictive – RUL (remaining useful life)



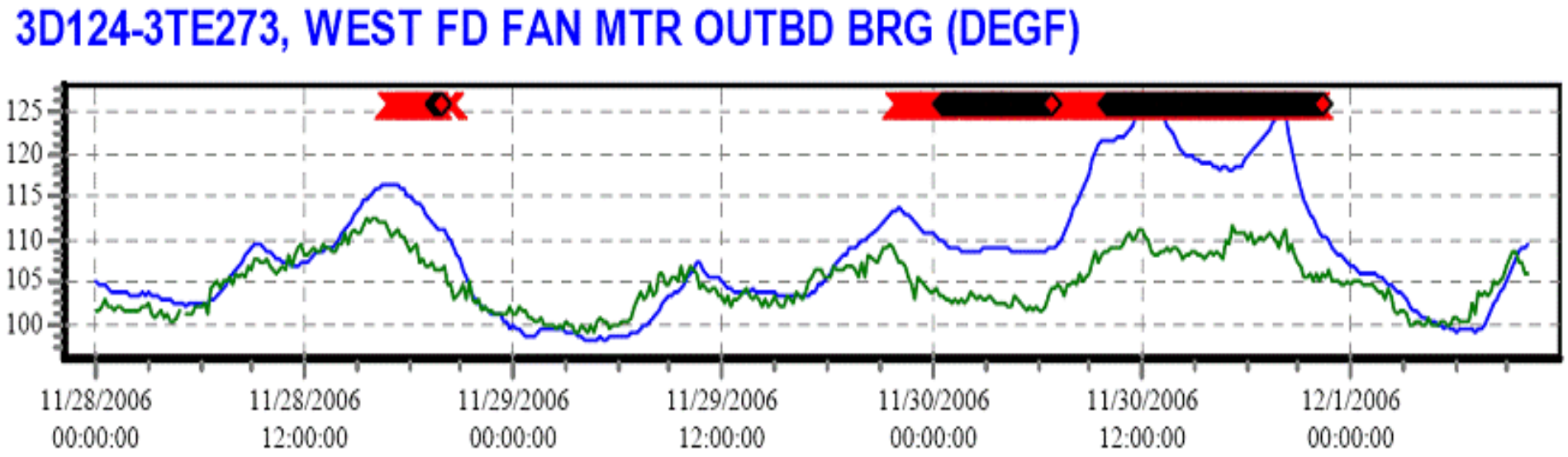
Name	Expression	Output Attribute
NatLog	`if 'OverallBearingFault'>0 then Log('OverallBearingFault') else NoOutput()`	OverallBearingFault|Natural Log
Time12back	`'*-12w'`	Map
LinearRegr	`if EnableFit then LinRegr('OverallBearingFault|Natural Log', Time12back, '*',50) I`	Map
Fit	`if BadVal(LinearRegr) Then NoOutput() Else LinearRegr`	Map
m	`if EnableFit AND Not(BadVal(LinearRegr)) then Convert(Fit[1]*24*3600, "gE/day") e:`	OverallBearingFault|m
b	`if EnableFit AND Not(BadVal(LinearRegr)) then Convert(Fit[2], "gE") else NoOutput`	OverallBearingFault|b
rsquared	`if EnableFit AND Not(BadVal(LinearRegr)) then Convert(Fit[3],"ratio") else NoOutp`	OverallBearingFault|r_squared
LifeExpectancy	`if EnableFit AND Not(BadVal(LinearRegr)) and m>0 and rsquared>.400 then Convert((:`	BearingLifeExpectancy
ForecastedFailDate	`if EnableFit AND Not(BadVal(LinearRegr)) and m>0 and rsquared>.400 then TimeStamp`	BearingForecastedFailureDate

Simple Predictive - air heater fouling



Advanced Pattern Recognition - Fan Motor Bearing

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



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

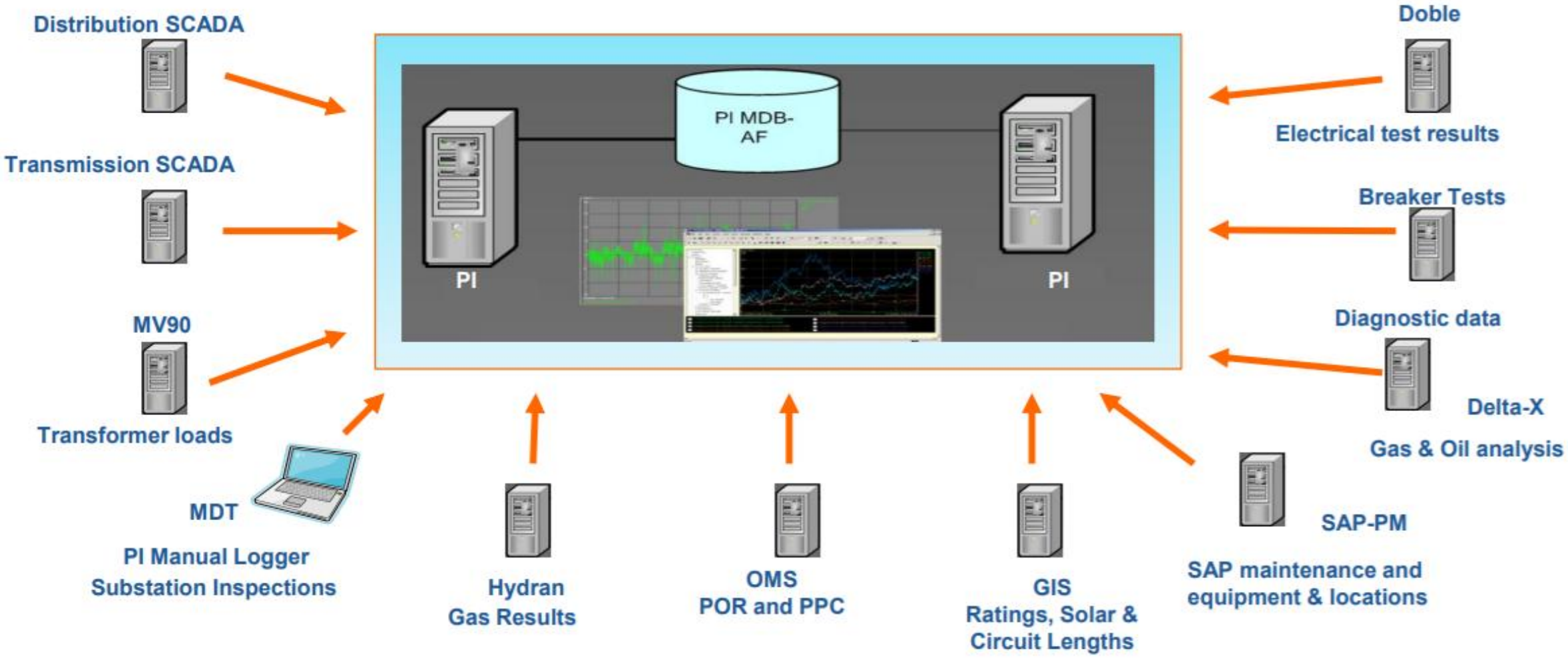
RESULTS

$18.7M of avoided losses in 3 years (from a standing start)

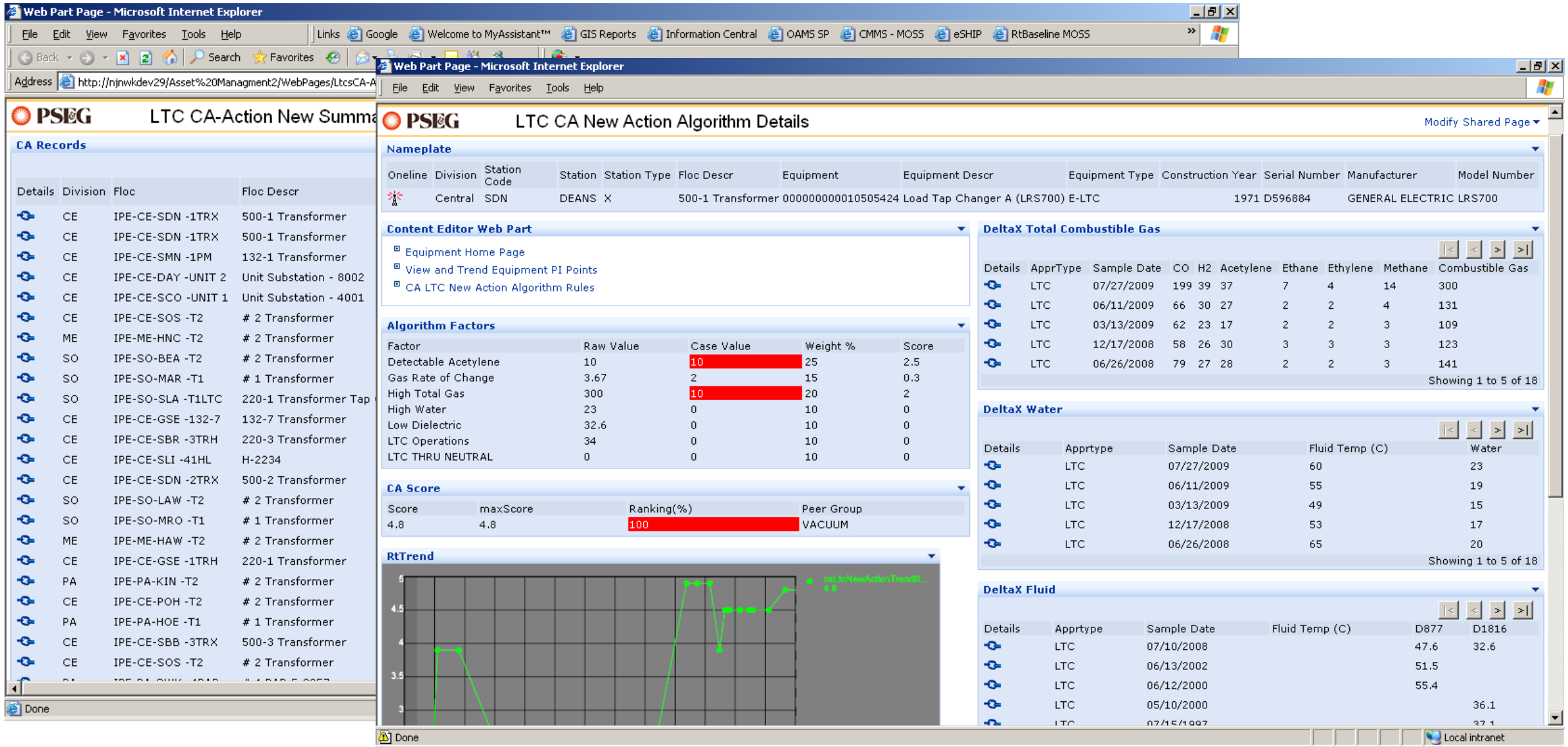
$8.5M of savings last financial year

- 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

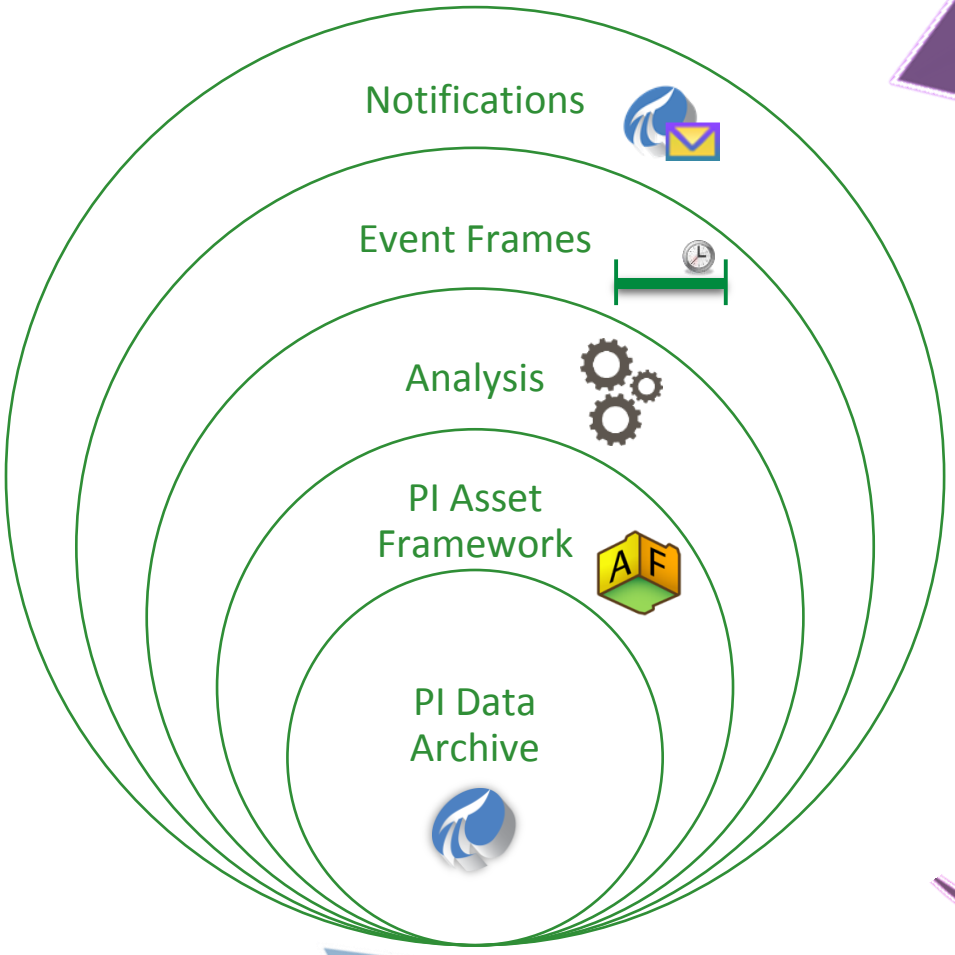
PSE&G – Consolidate & Correlate Data



Asset List with Score



PI System's role in CBM



PI Server

PI Integrators & PI System Access

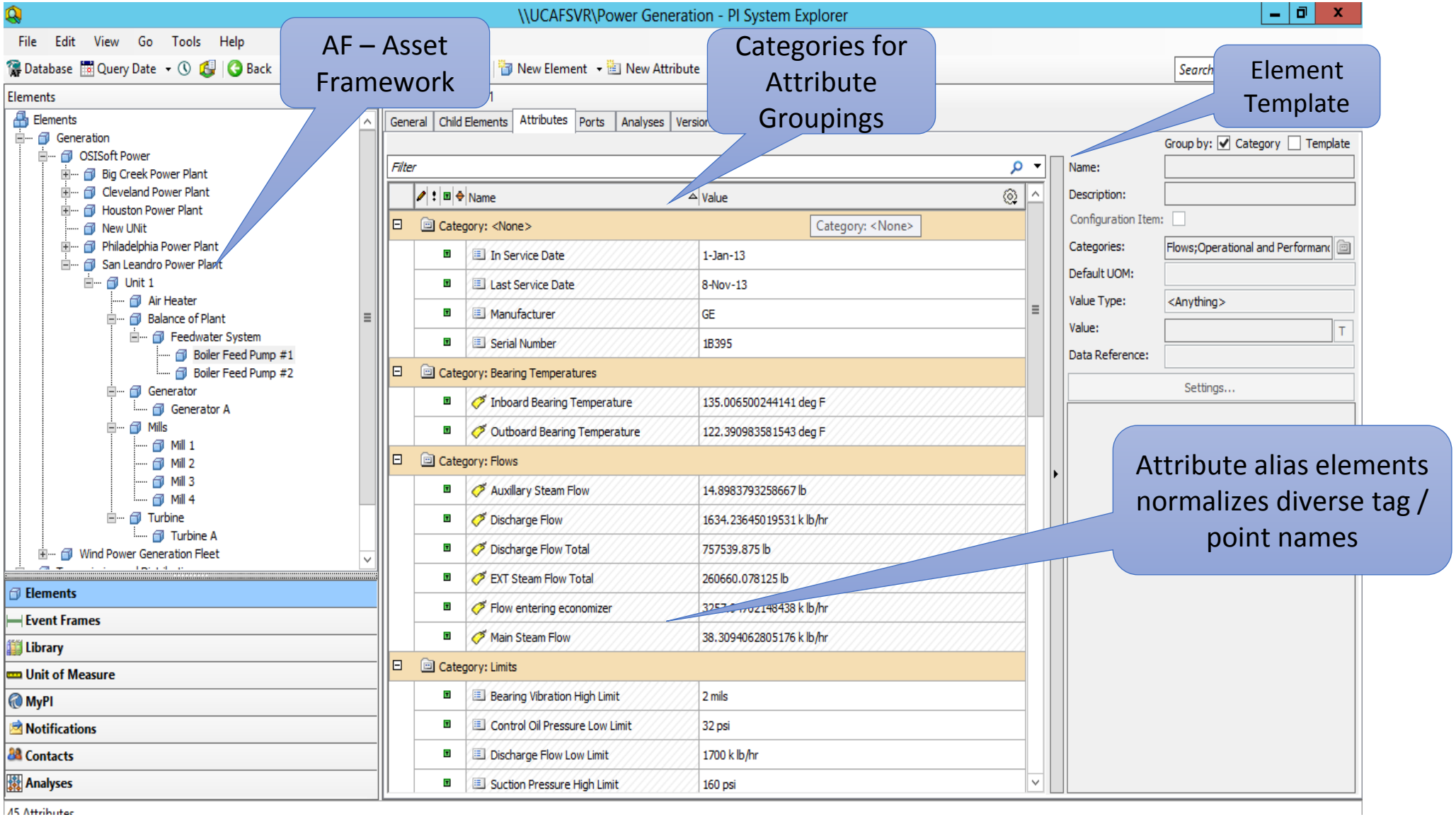
Microsoft SQL Server · infor · sas · SAP · ORACLE · IBM · JDEdwards

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

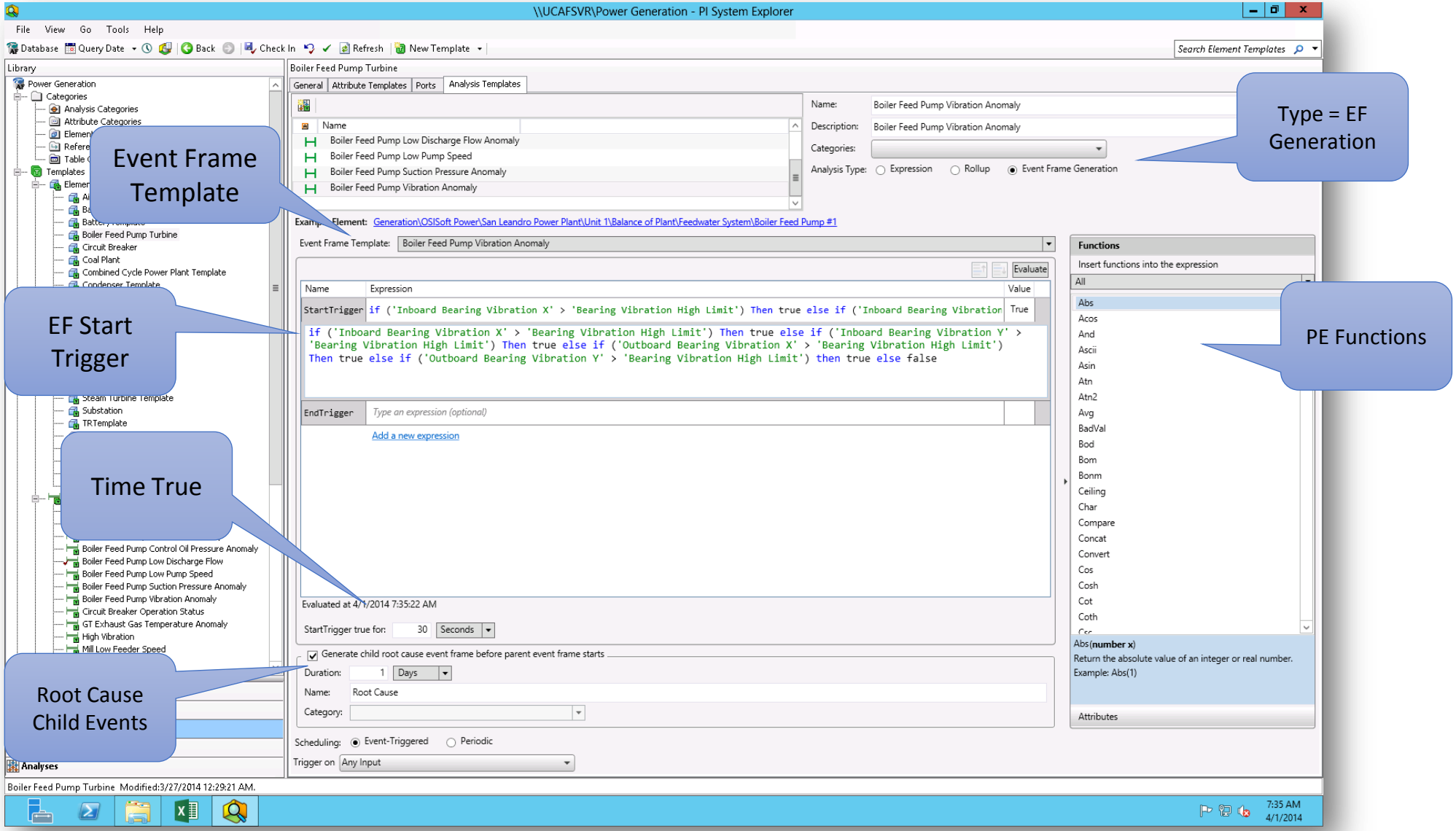
PI Visualization Suite

- PI Vision
- PI ProcessBook
- PI DataLink
- PI WebParts

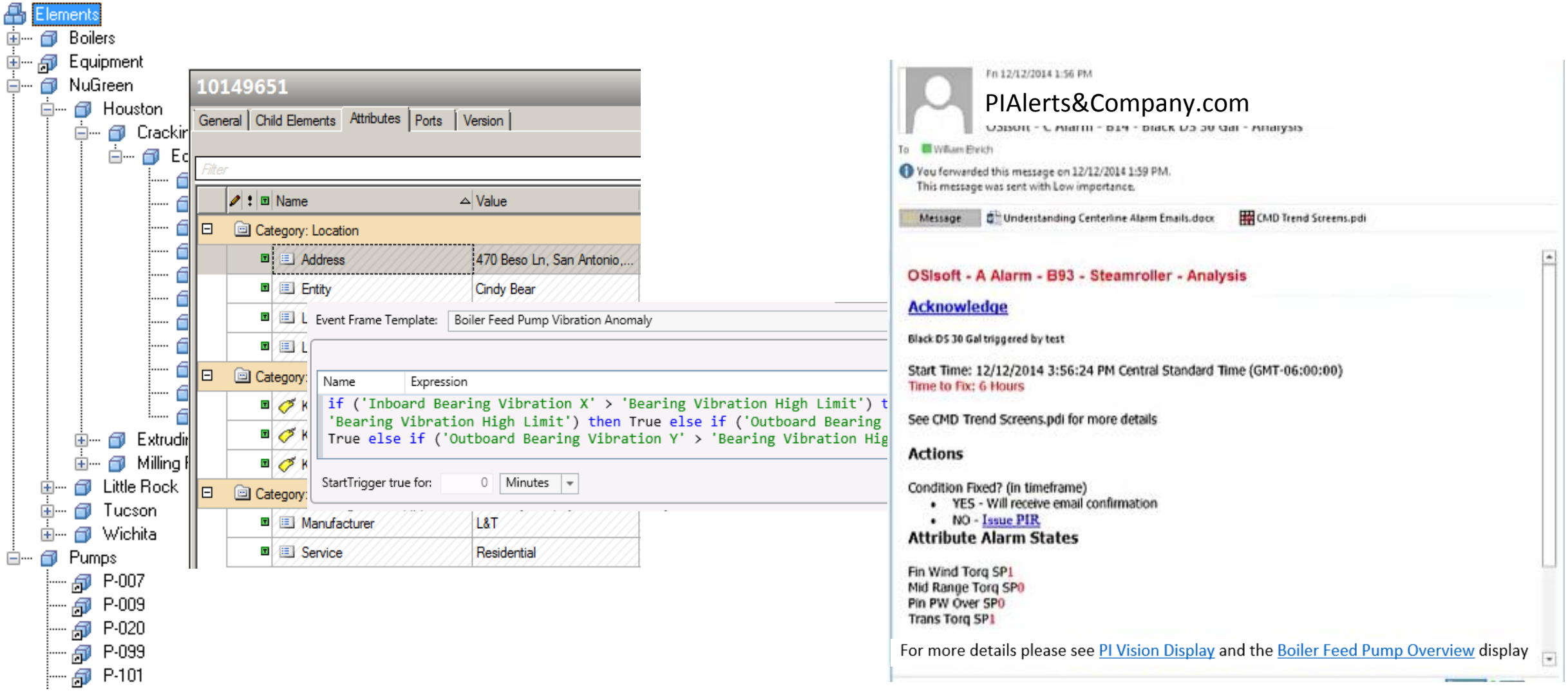
Asset Context in PI AF



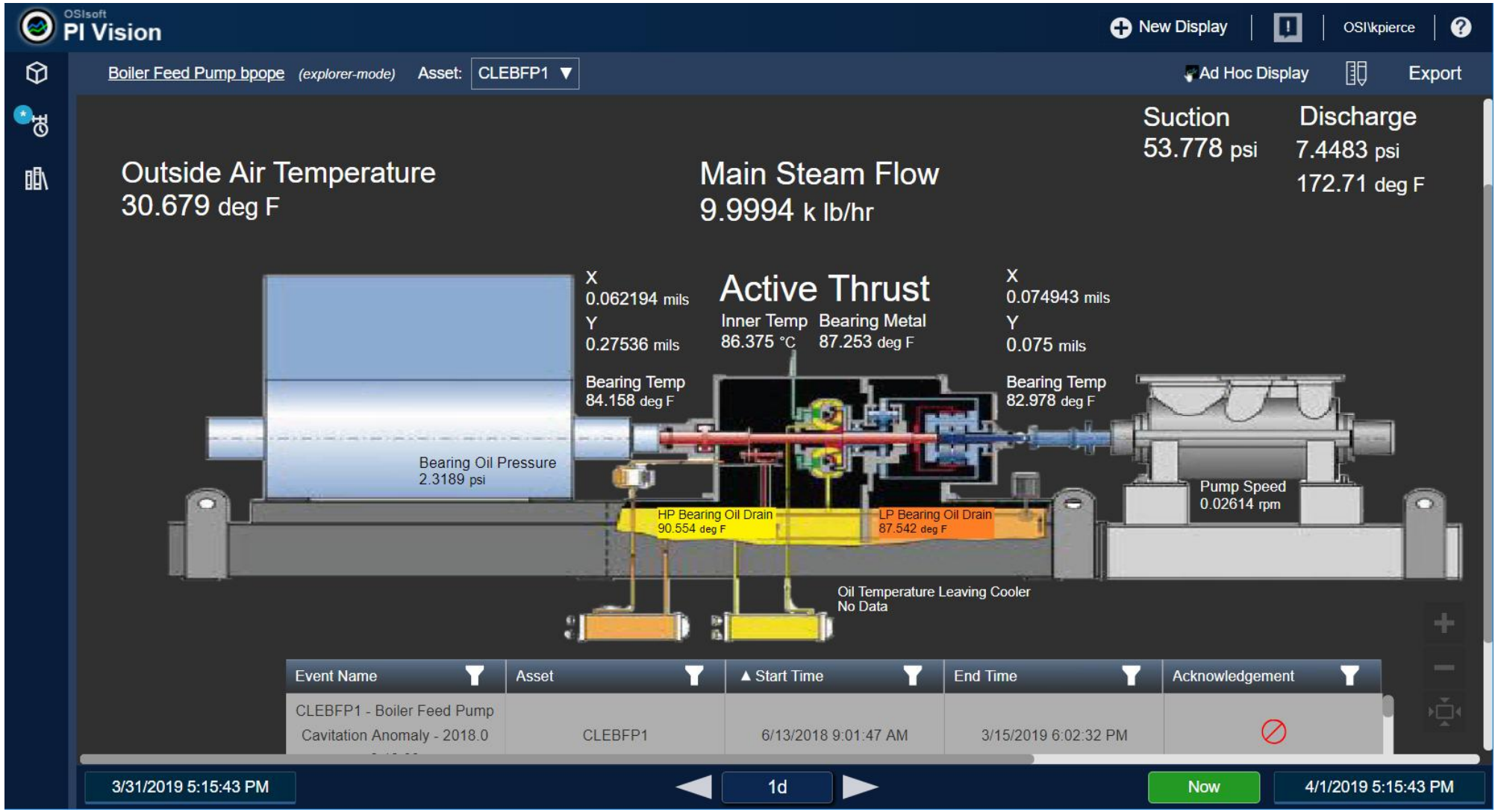
Event Detection



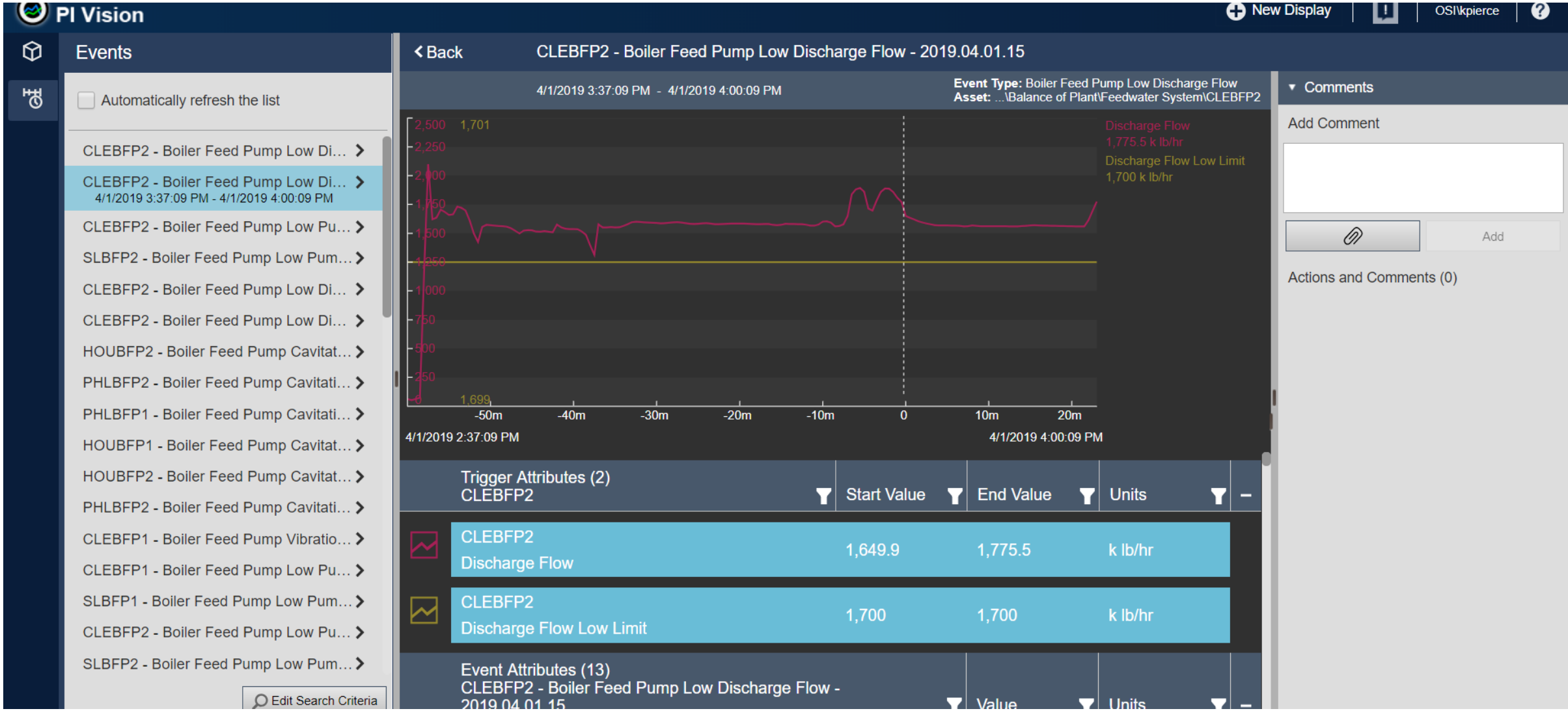
Monitoring Asset Conditions



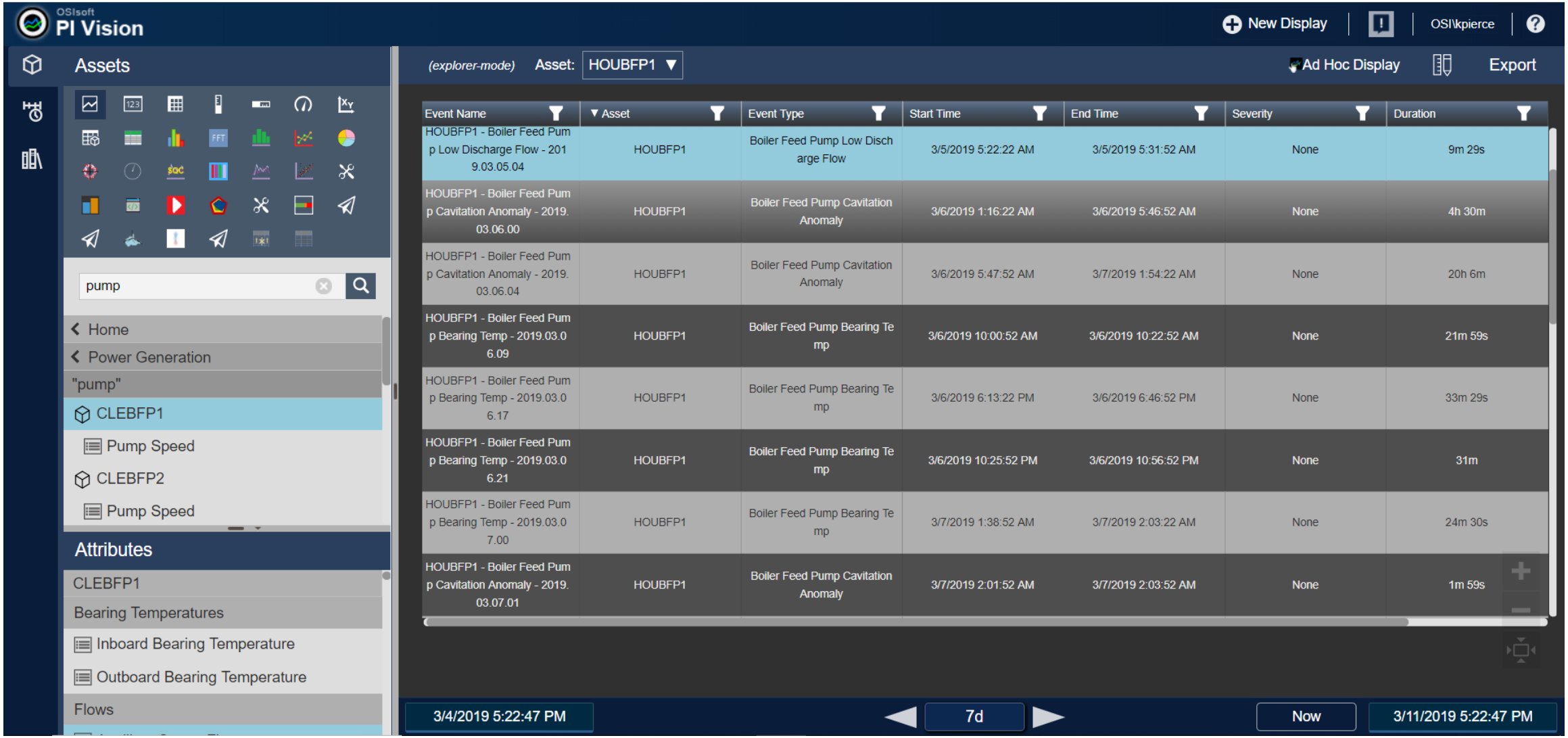
Boiler Feed Pump Overview



Boiler Feed Pump Event Analysis



Event Table Watchlist



Condition Monitoring Report

Time Period

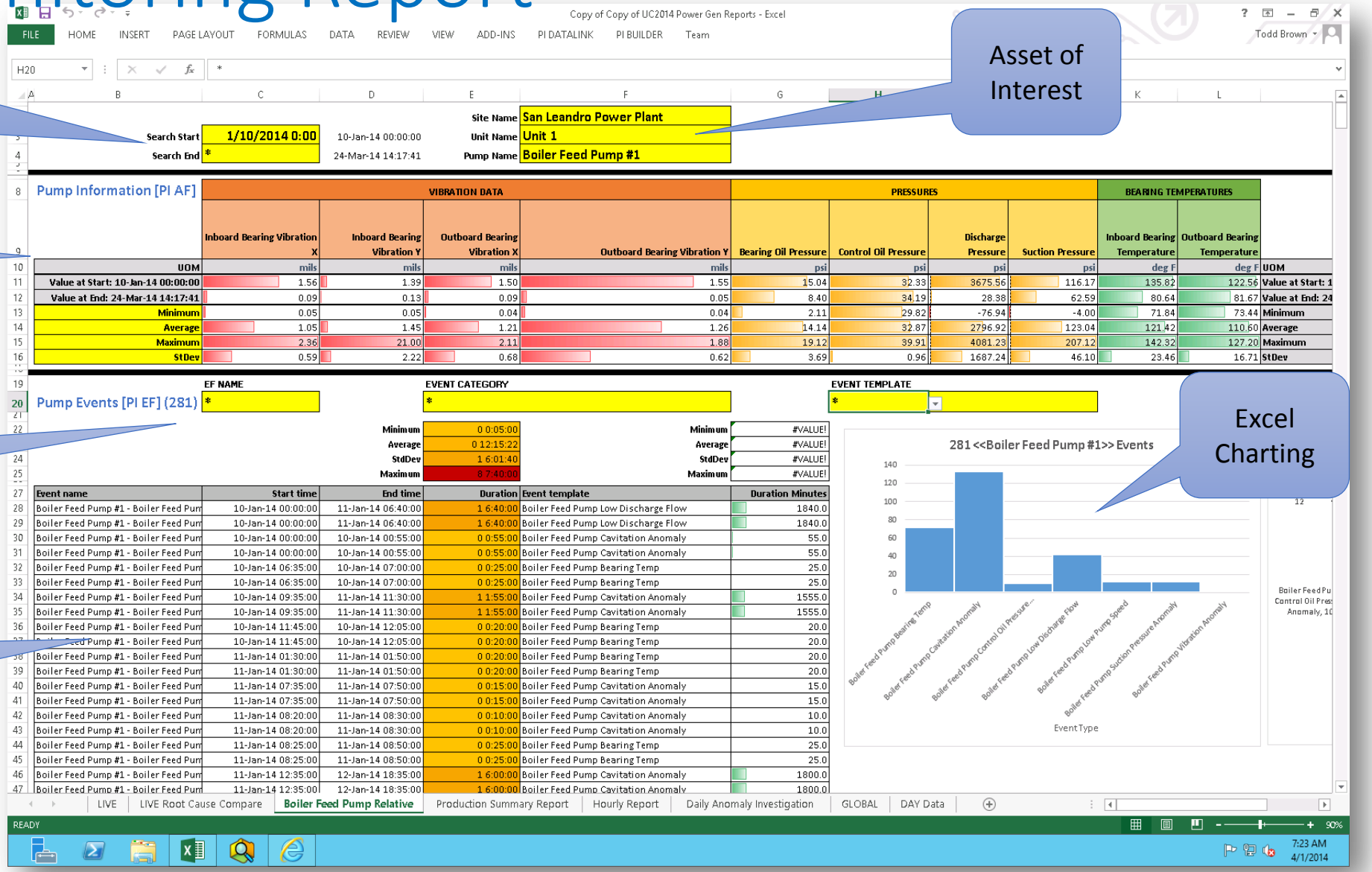
Asset of Interest

Real Time Summaries

Filter Events

Excel Charting

Events



Copy of Copy of UC2014 Power Gen Reports - Excel

Search Start	1/10/2014 0:00	10-Jan-14 00:00:00	Site Name	San Leandro Power Plant	
Search End	*	24-Mar-14 14:17:41	Unit Name	Unit 1	
			Pump Name	Boiler Feed Pump #1	

Pump Information [PI AF]

	VIBRATION DATA				PRESSURES				BEARING TEMPERATURES		
	Inboard Bearing Vibration X	Inboard Bearing Vibration Y	Outboard Bearing Vibration X	Outboard Bearing Vibration Y	Bearing Oil Pressure	Control Oil Pressure	Discharge Pressure	Suction Pressure	Inboard Bearing Temperature	Outboard Bearing Temperature	
UOM	mils	mils	mils	mils	psi	psi	psi	psi	deg F	deg F	UOM
Value at Start: 10-Jan-14 00:00:00	1.56	1.39	1.50	1.55	15.04	32.33	3675.56	116.17	135.82	122.56	Value at Start: 1
Value at End: 24-Mar-14 14:17:41	0.09	0.13	0.09	0.05	8.40	34.19	28.38	62.59	80.64	81.67	Value at End: 24
Minimum	0.05	0.05	0.04	0.04	2.11	29.82	-76.94	-4.00	71.84	73.44	Minimum
Average	1.05	1.45	1.21	1.26	14.14	32.87	2796.92	123.04	121.42	110.60	Average
Maximum	2.36	21.00	2.11	1.88	19.12	39.91	4081.23	207.12	142.32	127.20	Maximum
StDev	0.59	2.22	0.68	0.62	3.69	0.96	1687.24	46.10	23.46	16.71	StDev

Pump Events [PI EF] (281)

EF NAME	EVENT CATEGORY	EVENT TEMPLATE
*	*	*

	Duration		Duration Minutes
Minimum	0 0:05:00	Minimum	#VALUE!
Average	0 12:15:22	Average	#VALUE!
StDev	1 6:01:40	StDev	#VALUE!
Maximum	8 7:40:00	Maximum	#VALUE!

Event name	Start time	End time	Duration	Event template	Duration Minutes
Boiler Feed Pump #1 - Boiler Feed Pum	10-Jan-14 00:00:00	11-Jan-14 06:40:00	1 6:40:00	Boiler Feed Pump Low Discharge Flow	1840.0
Boiler Feed Pump #1 - Boiler Feed Pum	10-Jan-14 00:00:00	11-Jan-14 06:40:00	1 6:40:00	Boiler Feed Pump Low Discharge Flow	1840.0
Boiler Feed Pump #1 - Boiler Feed Pum	10-Jan-14 00:00:00	10-Jan-14 00:55:00	0 0:55:00	Boiler Feed Pump Cavitation Anomaly	55.0
Boiler Feed Pump #1 - Boiler Feed Pum	10-Jan-14 00:00:00	10-Jan-14 00:55:00	0 0:55:00	Boiler Feed Pump Cavitation Anomaly	55.0
Boiler Feed Pump #1 - Boiler Feed Pum	10-Jan-14 06:35:00	10-Jan-14 07:00:00	0 0:25:00	Boiler Feed Pump Bearing Temp	25.0
Boiler Feed Pump #1 - Boiler Feed Pum	10-Jan-14 06:35:00	10-Jan-14 07:00:00	0 0:25:00	Boiler Feed Pump Bearing Temp	25.0
Boiler Feed Pump #1 - Boiler Feed Pum	10-Jan-14 09:35:00	11-Jan-14 11:30:00	1 1:55:00	Boiler Feed Pump Cavitation Anomaly	1555.0
Boiler Feed Pump #1 - Boiler Feed Pum	10-Jan-14 09:35:00	11-Jan-14 11:30:00	1 1:55:00	Boiler Feed Pump Cavitation Anomaly	1555.0
Boiler Feed Pump #1 - Boiler Feed Pum	10-Jan-14 11:45:00	10-Jan-14 12:05:00	0 0:20:00	Boiler Feed Pump Bearing Temp	20.0
Boiler Feed Pump #1 - Boiler Feed Pum	10-Jan-14 11:45:00	10-Jan-14 12:05:00	0 0:20:00	Boiler Feed Pump Bearing Temp	20.0
Boiler Feed Pump #1 - Boiler Feed Pum	11-Jan-14 01:30:00	11-Jan-14 01:50:00	0 0:20:00	Boiler Feed Pump Bearing Temp	20.0
Boiler Feed Pump #1 - Boiler Feed Pum	11-Jan-14 01:30:00	11-Jan-14 01:50:00	0 0:20:00	Boiler Feed Pump Bearing Temp	20.0
Boiler Feed Pump #1 - Boiler Feed Pum	11-Jan-14 07:35:00	11-Jan-14 07:50:00	0 0:15:00	Boiler Feed Pump Cavitation Anomaly	15.0
Boiler Feed Pump #1 - Boiler Feed Pum	11-Jan-14 07:35:00	11-Jan-14 07:50:00	0 0:15:00	Boiler Feed Pump Cavitation Anomaly	15.0
Boiler Feed Pump #1 - Boiler Feed Pum	11-Jan-14 08:20:00	11-Jan-14 08:30:00	0 0:10:00	Boiler Feed Pump Cavitation Anomaly	10.0
Boiler Feed Pump #1 - Boiler Feed Pum	11-Jan-14 08:20:00	11-Jan-14 08:30:00	0 0:10:00	Boiler Feed Pump Cavitation Anomaly	10.0
Boiler Feed Pump #1 - Boiler Feed Pum	11-Jan-14 08:25:00	11-Jan-14 08:50:00	0 0:25:00	Boiler Feed Pump Bearing Temp	25.0
Boiler Feed Pump #1 - Boiler Feed Pum	11-Jan-14 08:25:00	11-Jan-14 08:50:00	0 0:25:00	Boiler Feed Pump Bearing Temp	25.0
Boiler Feed Pump #1 - Boiler Feed Pum	11-Jan-14 12:35:00	12-Jan-14 18:35:00	1 6:00:00	Boiler Feed Pump Cavitation Anomaly	1800.0
Boiler Feed Pump #1 - Boiler Feed Pum	11-Jan-14 12:35:00	12-Jan-14 18:35:00	1 6:00:00	Boiler Feed Pump Cavitation Anomaly	1800.0

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

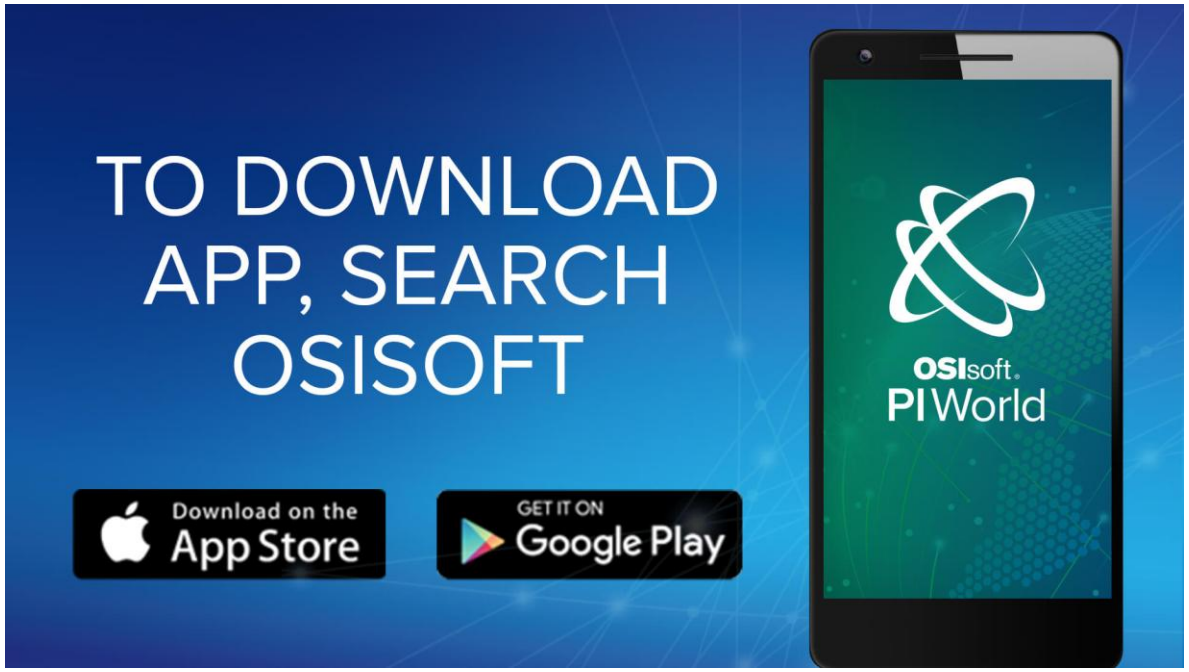
- Keith Pierce
- Technical Advisor
- kpierce@osisoft.com

Questions?

Please wait for the **microphone**

State your **name & company**

Please remember




謝謝
KEA LEBOHA
TAPADH LEIBH
고맙습니다
DZIĘKUJĘ CI
БАЯРЛАЛАА
MISAOTRA ANAO
SALAMAT
NGIYABONGA
GRÁCIES
OBRIGADO
شكرا
TEŞEKKÜR EDERIM
DANKIE
TERIMA KASIH
DANKON
TANK
TAPADH LEAT
KÖSZÖNÖM
MULȚUMESC
СПАСИБО
OSIsoft
PI World
FAAFETAI
HVALA
PAKMET CIЗГЕ
ESKERRIK ASKO
GO RAIBH MAITH AGAT
HVALA
ХВАЛА ВАМ
MAHADSANID
БЛАГОДАРЯ
GRACIAS
THANKYOU
TEŞEKKÜR EDERIM
ТИ БЛАГОДАРАМ
DANK JE
ΕΥΧΑΡΙΣΤΩ
GRATIAS TIBI
GRAZIE
ДЗЯКУЙ
TAK
DANKE
AČIŪ
SALAMAT
MAHALO IĀ ‘OE
TAKK SKAL DU HA
DI OU MÈSI
RAHMAT
MERCI
GRAZZI
ÞAKKA ÞÉR
ありがとうございました
ĎAKUJEM
HATUR NUHUN
PAXMAT САГА
SIPAS JI WERE
TERIMA KASIH
MATUR NUWUN
CẢM ƠN BẠN
UA TSAUG RAU KOJ
FALEMINDERIT
WAZVIITA
ТИ БЛАГОДАРАМ
СИПОС

Merci

谢谢

Спасибо

Danke

Gracias

Thank You

감사합니다

ありがとう

Grazie

Obrigado

Optional: Click to add a takeaway you wish the audience to leave with.