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

Mike Horrocks, Technical Advisor
Keith Pierce, Technical Advisor

OSIsoft.

Agenda

- CBM Overview
- PI System and the CBM process
- CBM Resources

Terms & Definitions

PM/CM

APR

Predictive

APM

RCM

CBM

Condition Based Maintenance

PF

CM

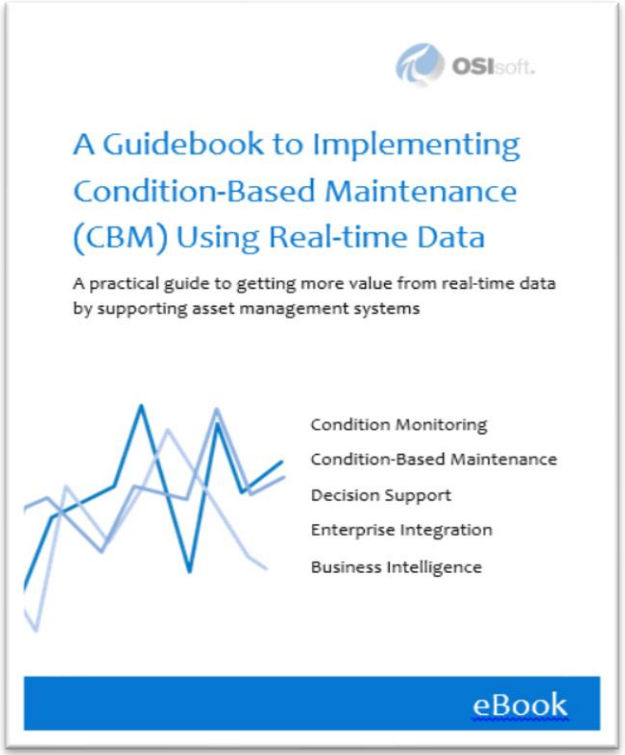
Condition Monitoring

RCA

CMMS

FMEA

CBM Prescriptive Guidance



Terms & Definitions

Implementation Guidance

PI System Overview for CBM

PI System Integration w/ CMMS

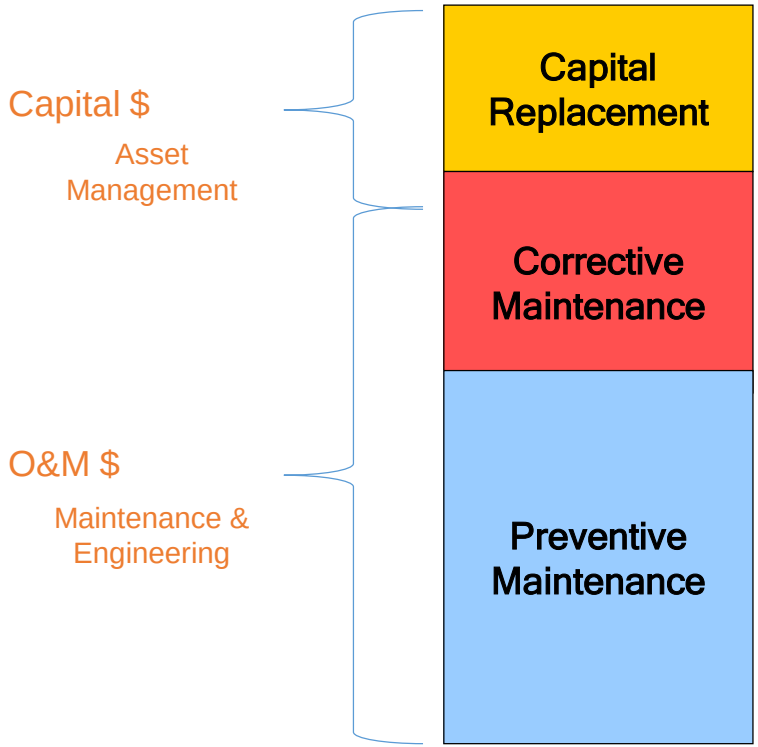
Enabling Opportunities

Solution Examples

Industry References

Maintenance Budget & Types

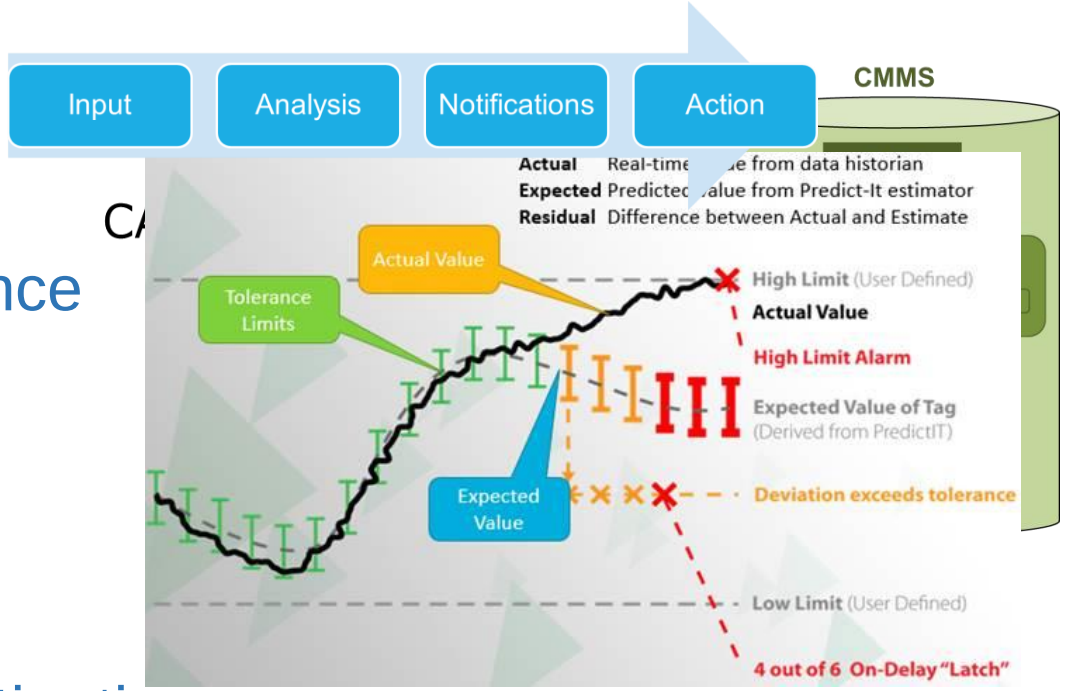
- Capital replacement
  - Replace or rebuild expensive assets
  - Major projects
  - Squeaky wheel gets the grease syndrome
- Corrective Maintenance (CM)
  - Repair a failure or degradation
  - Troubleshoot & Rework
  - Unscheduled often with downtime
- Preventive Maintenance (PM)
  - Usually time-based schedules
  - Clean & Inspect
  - Pack bearings
  - Filter check
  - Diagnostic Measurements & tests



- More targeted expenditures
- More planned, less disruptive
- Fewer PM's
- Some Corrective / Planned

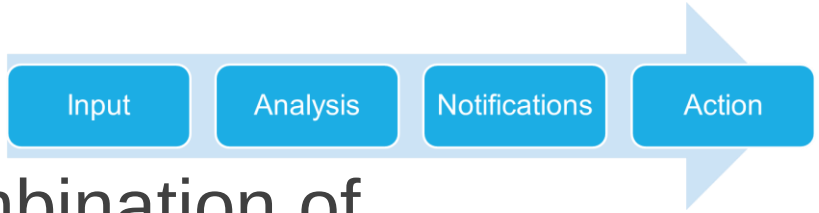
CBM can mean different things

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



It's a journey – not a destination

#1 Condition Monitoring



- May be any single or combination of performance indicators
  - Vibration (with operational data)
  - Efficiency (and degradation over time)
  - Temperature (compared to usage and ambient conditions)
  - May be simple or complex
  - Incidence over time may be critical

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

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

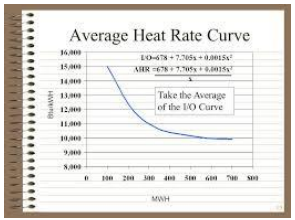
Category: Nominal Values	
BHP_Nominal	8710.27322604474 BHP
FuelRate_Nominal	71.1036975854648 MCFH
HeatRate_Nominal	8163.19944739005 BTU(LHV)/BHP-hr
PCD_Nominal	205.15303353481 psi
T5_Nominal	1394.59524035539 °F
T7_Nominal	925.386891989674 °F

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

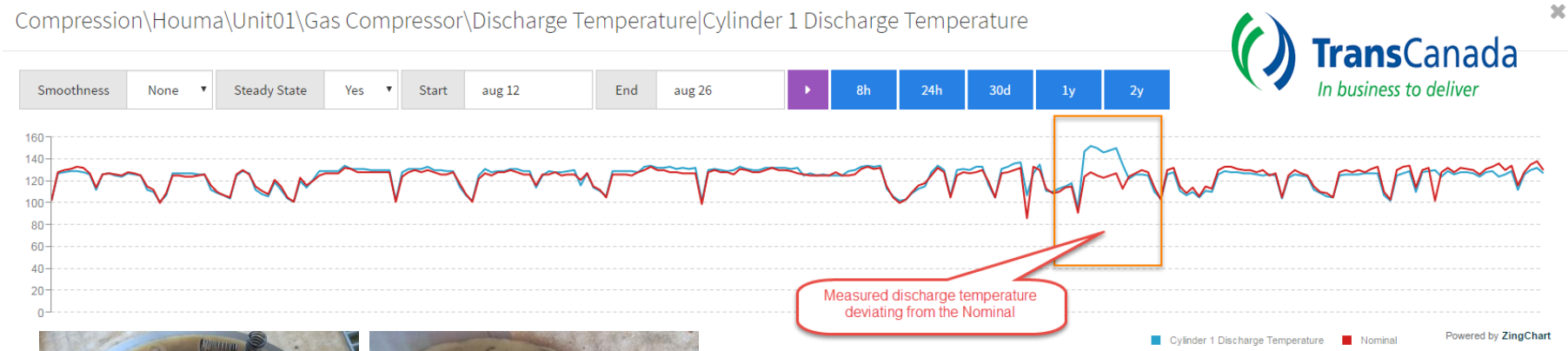
Calculate Actual Heat Rate

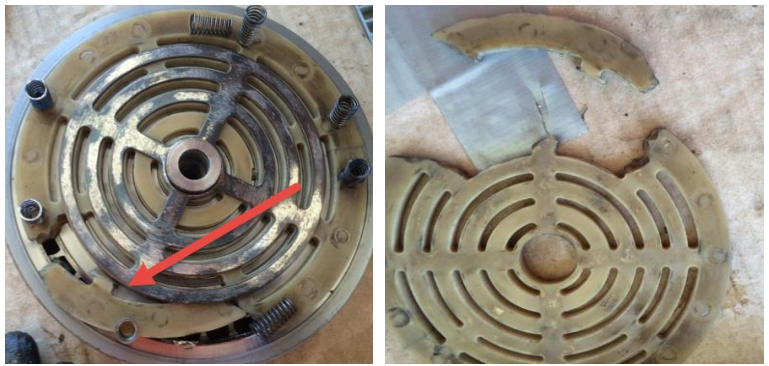
Data Reference: Formula

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.

#2 Preventive Maintenance (CBM)

- Usage-based PM's
  - Run hours
  - Start / Stop counts
  - Tonnage processed

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

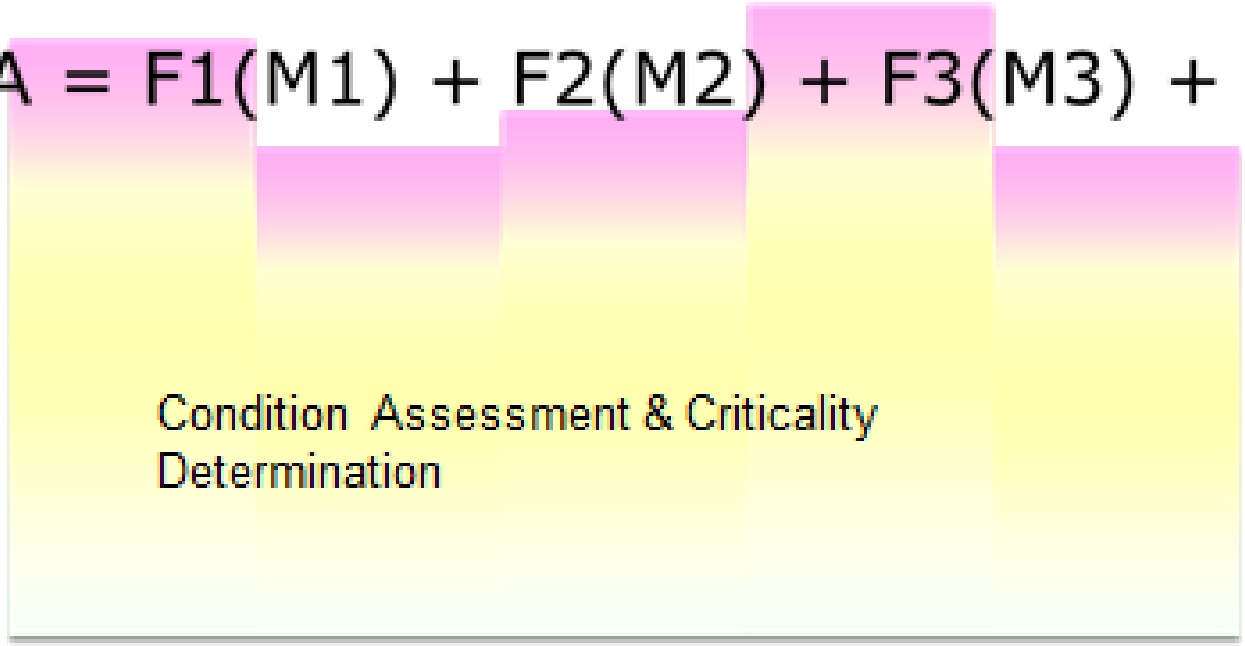
Asset Name	# of PMs: Scheduled Basis	# of PMs: Conditional Basis	# of unnecessary PMs Avoided
PUMP-1149	28	0	28
PUMP-1150	28	12	16
PUMP-1151	28	0	28
PUMP-1152	28	21	7
Totals	**112**	**33**	**79**

100 Main Pumps = $1.8MM Annually

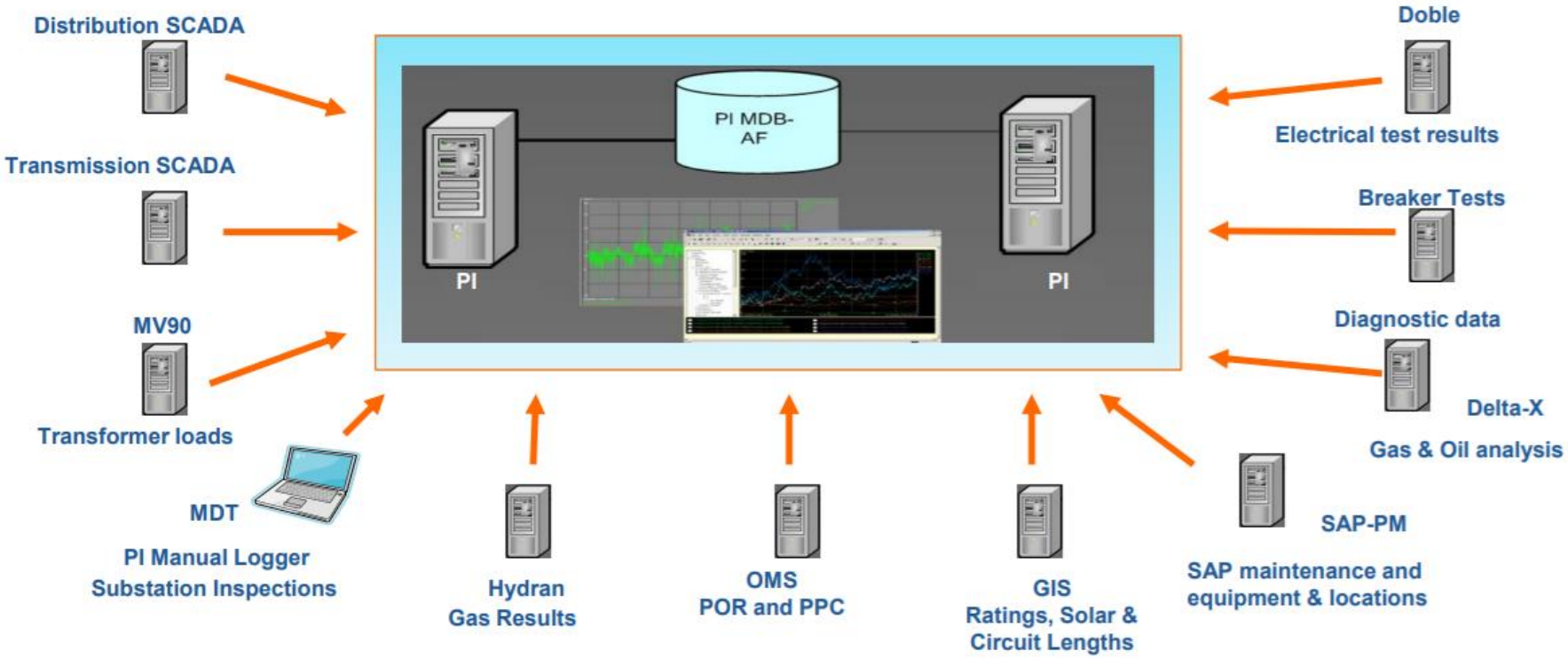
- Over the 28 month simulation, 79 unnecessary PM's identified
- Each set costs approximately $2,100
- Annual savings for the 4 pumps is $71,100

#3 Condition Assessment

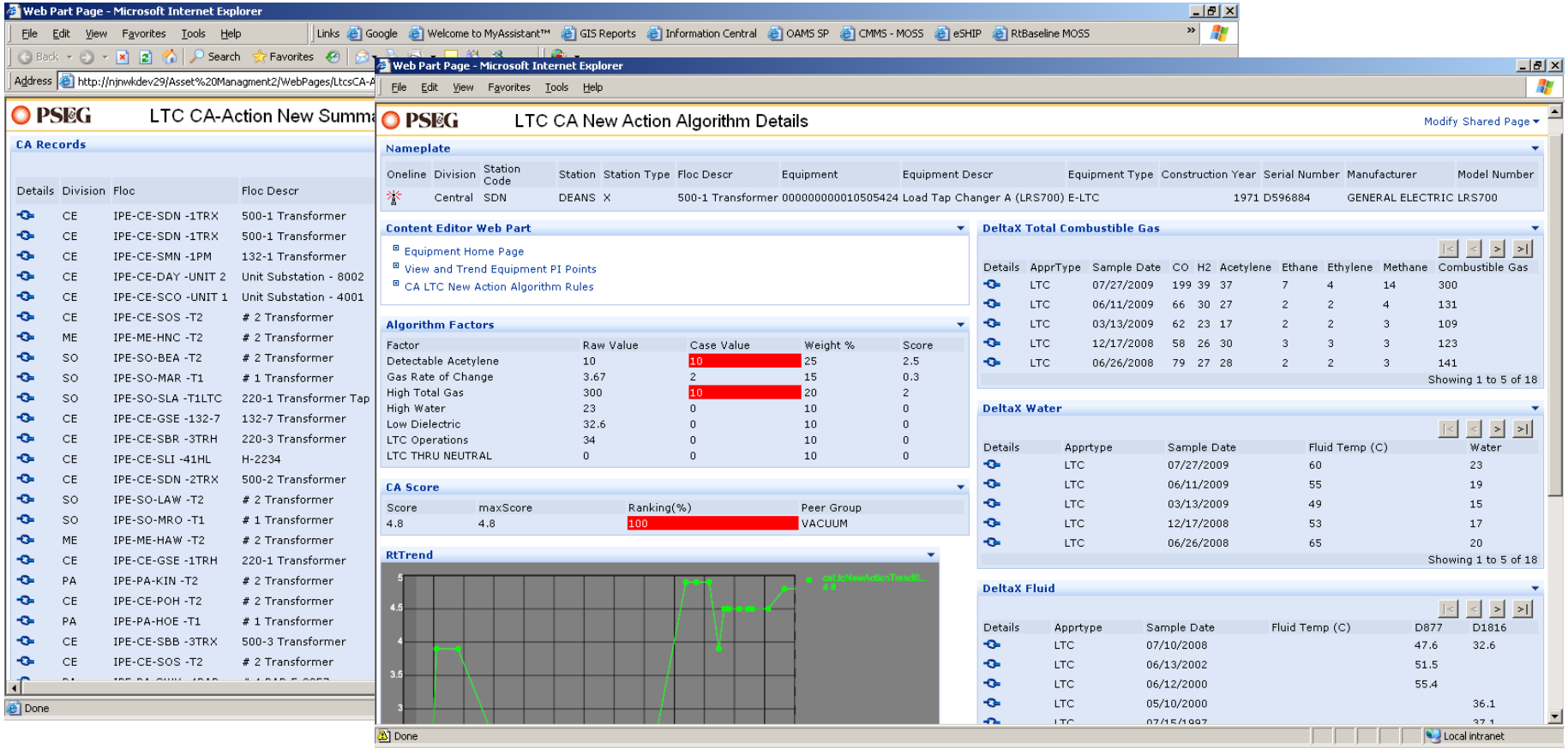
$$CA = F1(M1) + F2(M2) + F3(M3) + \ldots$$



PSE&G – Consolidate & Correlate Data

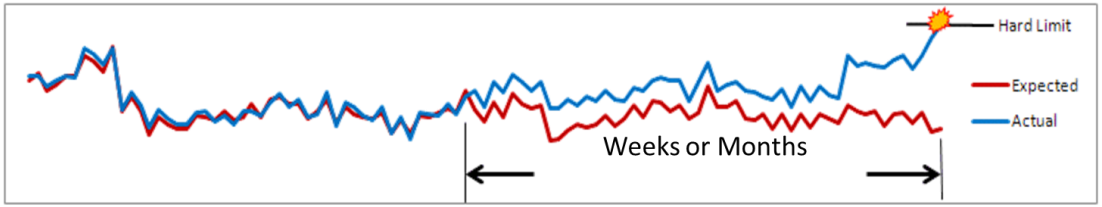


Asset List with Score



#4 Advanced Pattern Recognition (APR)

- Anomaly Detection
- Use history to build a model
- Statistical Techniques compare now to history



Exception Reporting

Define “Normal” Behavior (Model) for Each Point

Alarm on the Residual (Actual – Expected) > Limit

Focus on What’s Different - Anomalies

THE CHALLENGE – CALCULATE AN EXPECTED VALUE FOR EVERY LOAD AND AMBIENT CONDITION

Operational Diagnostics Centre

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

CHALLENGE

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

OSIsoft PI and APR

- ECG's PredictIT (APR) technology is fast & easy
- An Operational Diagnostics Centre (ODC) put experts & information together
- ODC also uses PI system for deep dive investigations

RESULTS

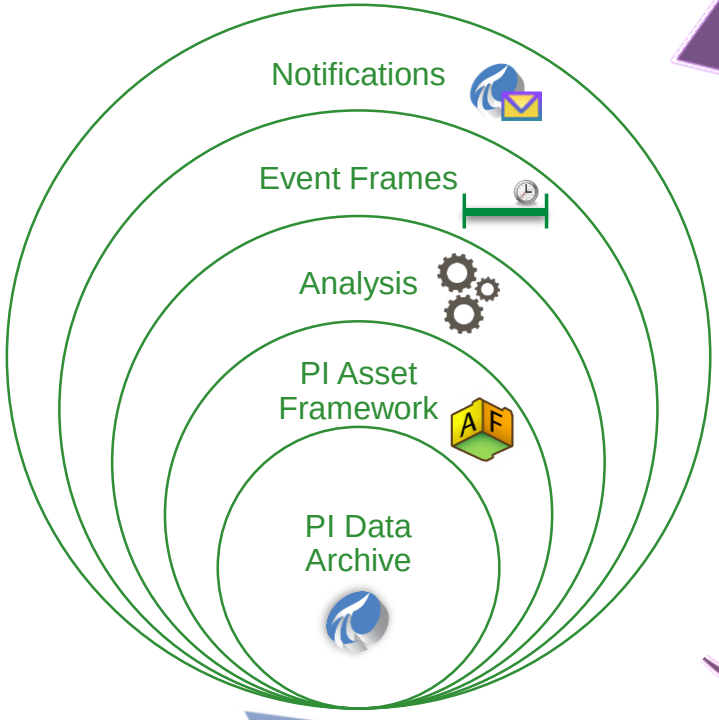
$18.7M of avoided losses in 3 years ($8.5M in one year)

- ODC delivers significant tangible benefits
- OSIsoft PI enables data transformation and other improvements

Presented at PI World San Francisco April 2018

PI System's role in CBM

PI Interfaces & PI Connectors

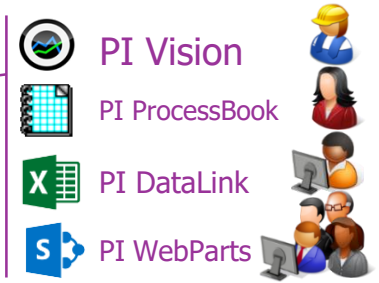


PI Server

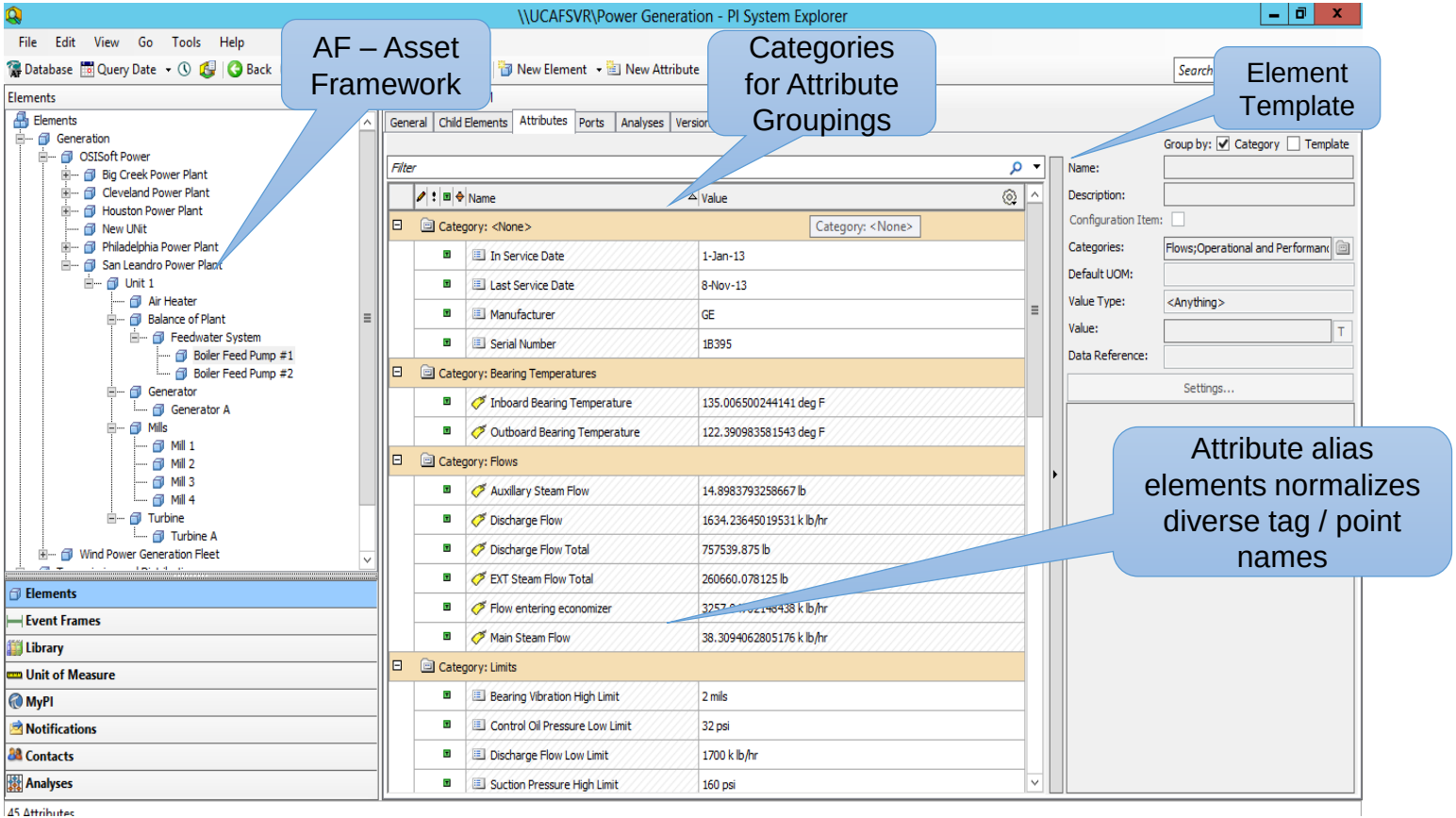
PI Integrators & PI System Access

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

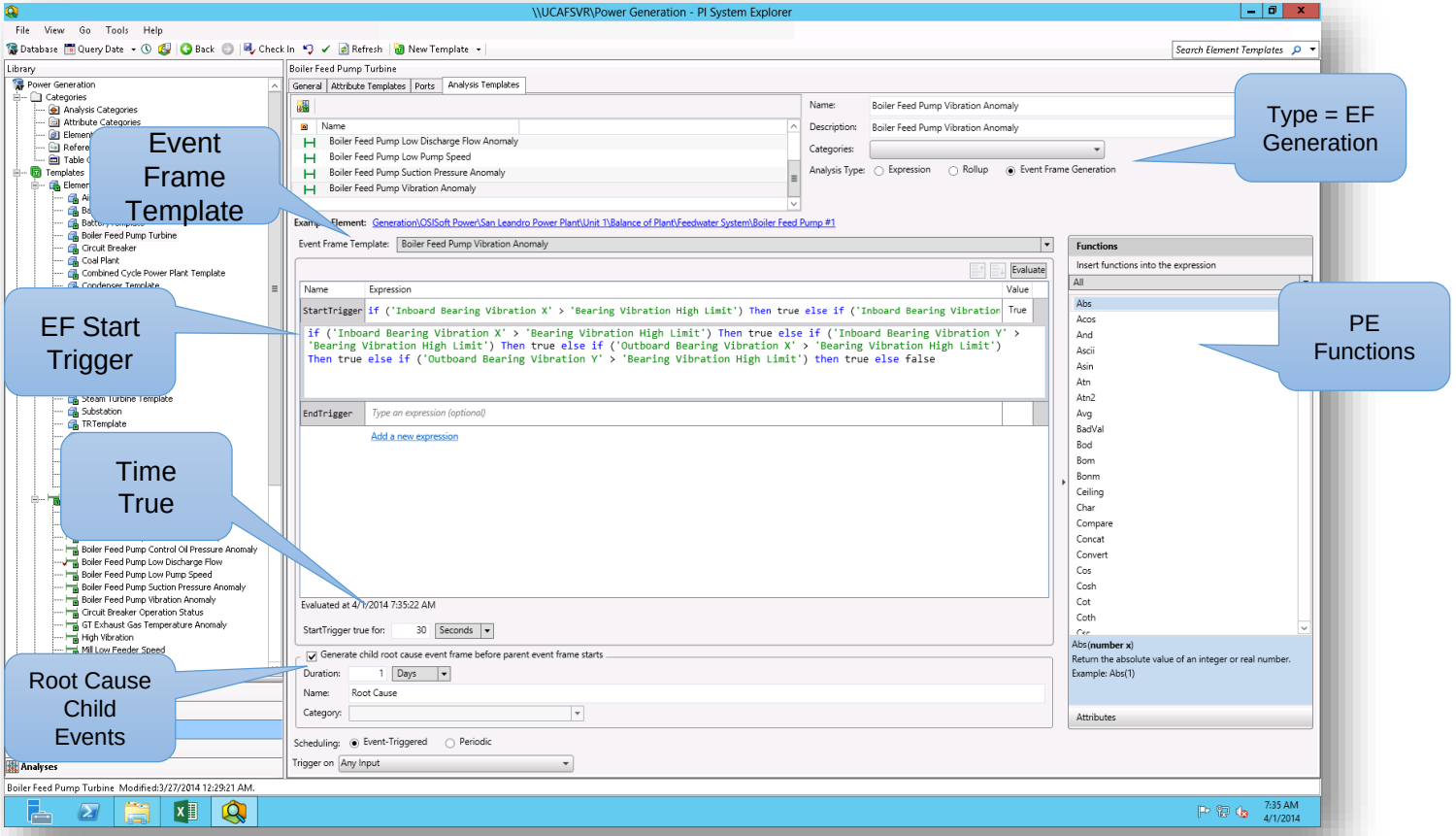
PI Visualization Suite



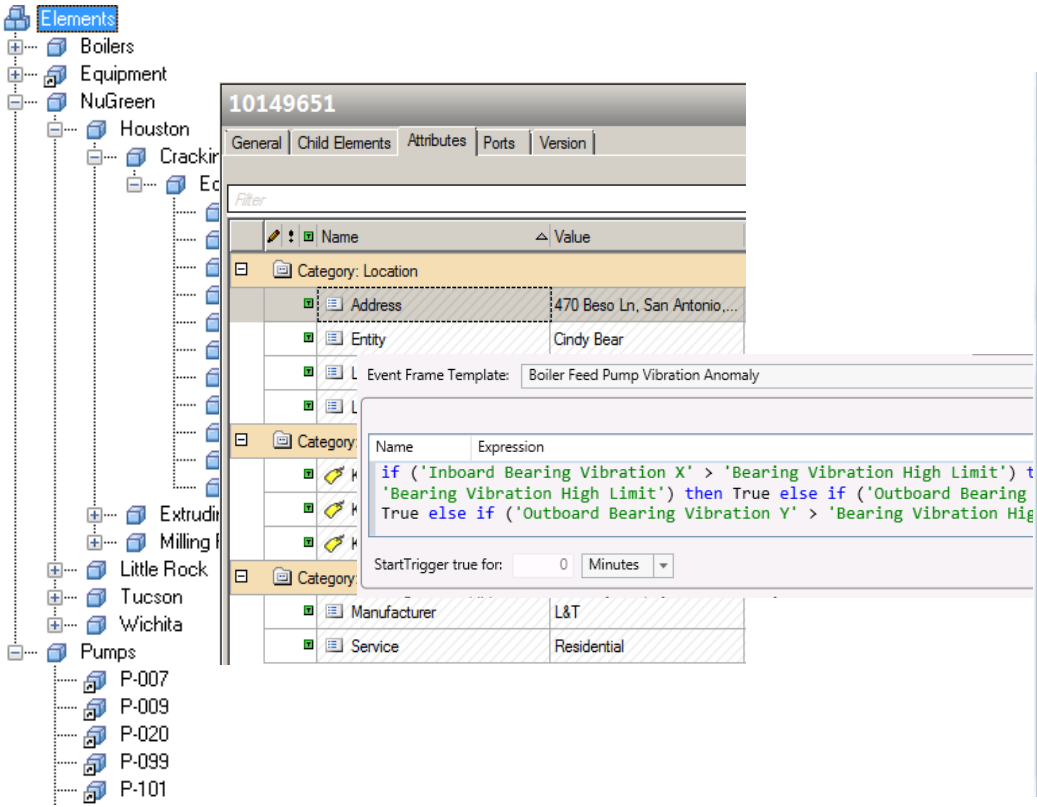
Asset Context in PI AF

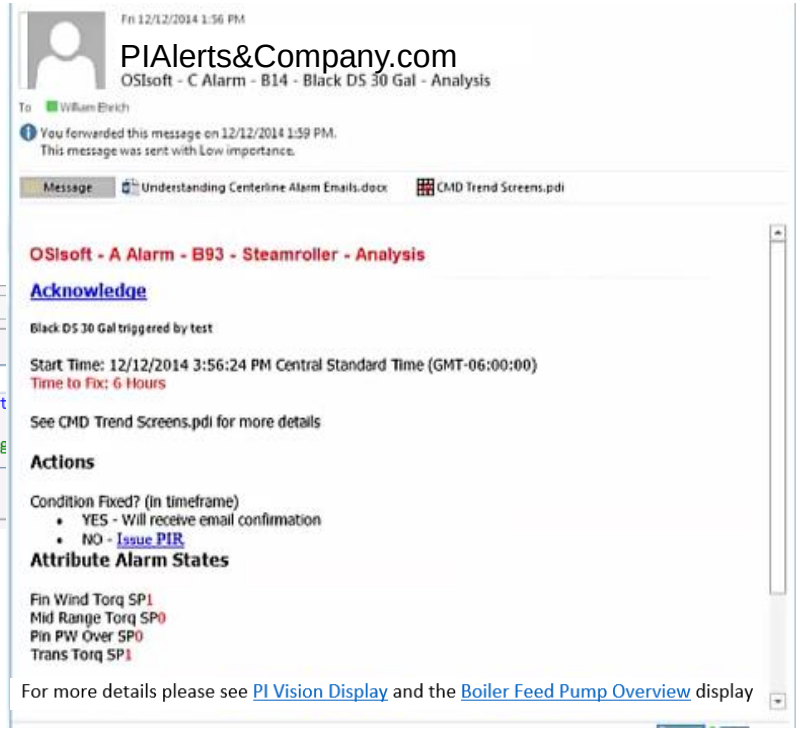


Event Detection

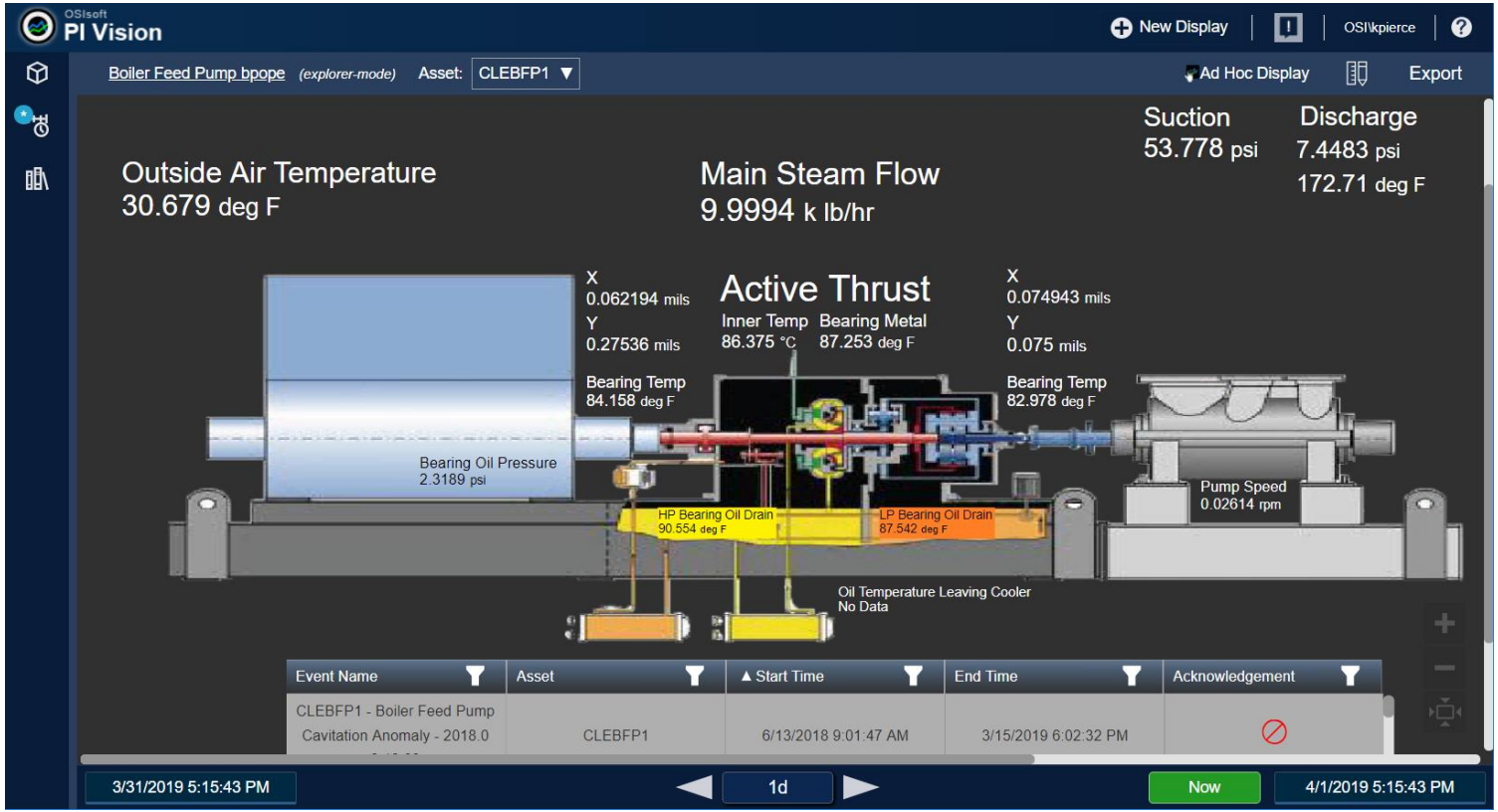


Monitoring Asset Conditions

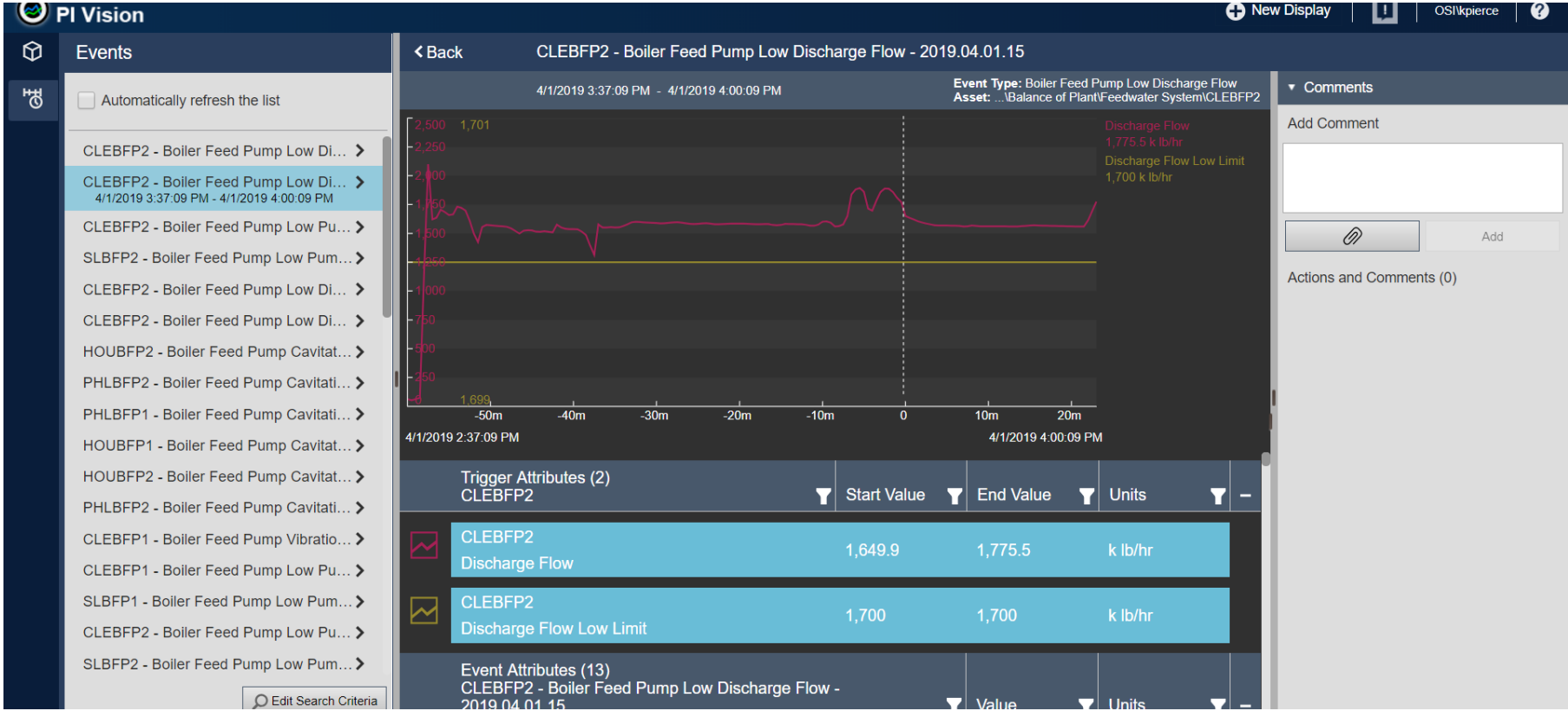




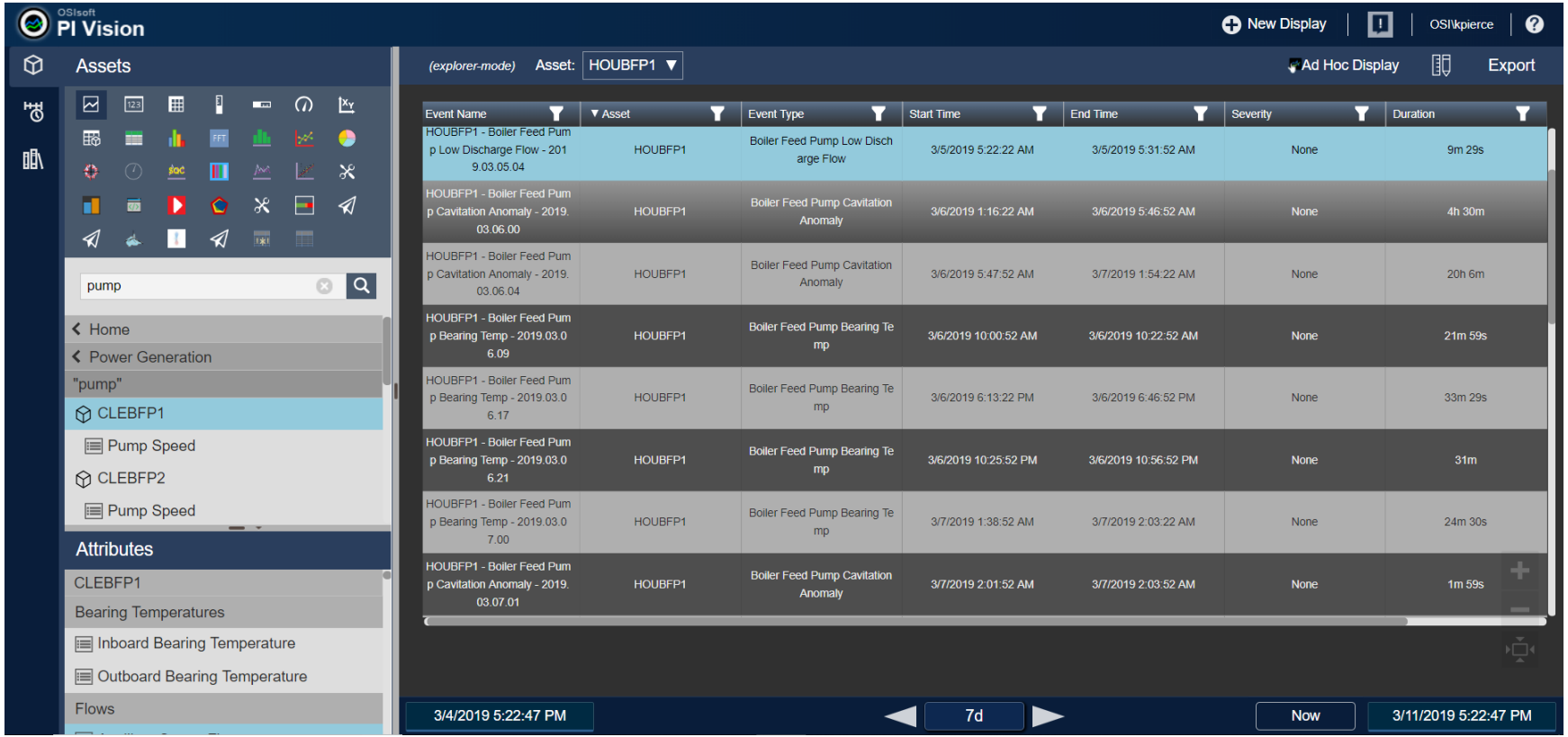
Boiler Feed Pump Overview



Boiler Feed Pump Event Analysis



Event Table Watchlist



Condition Monitoring Report

Time Period

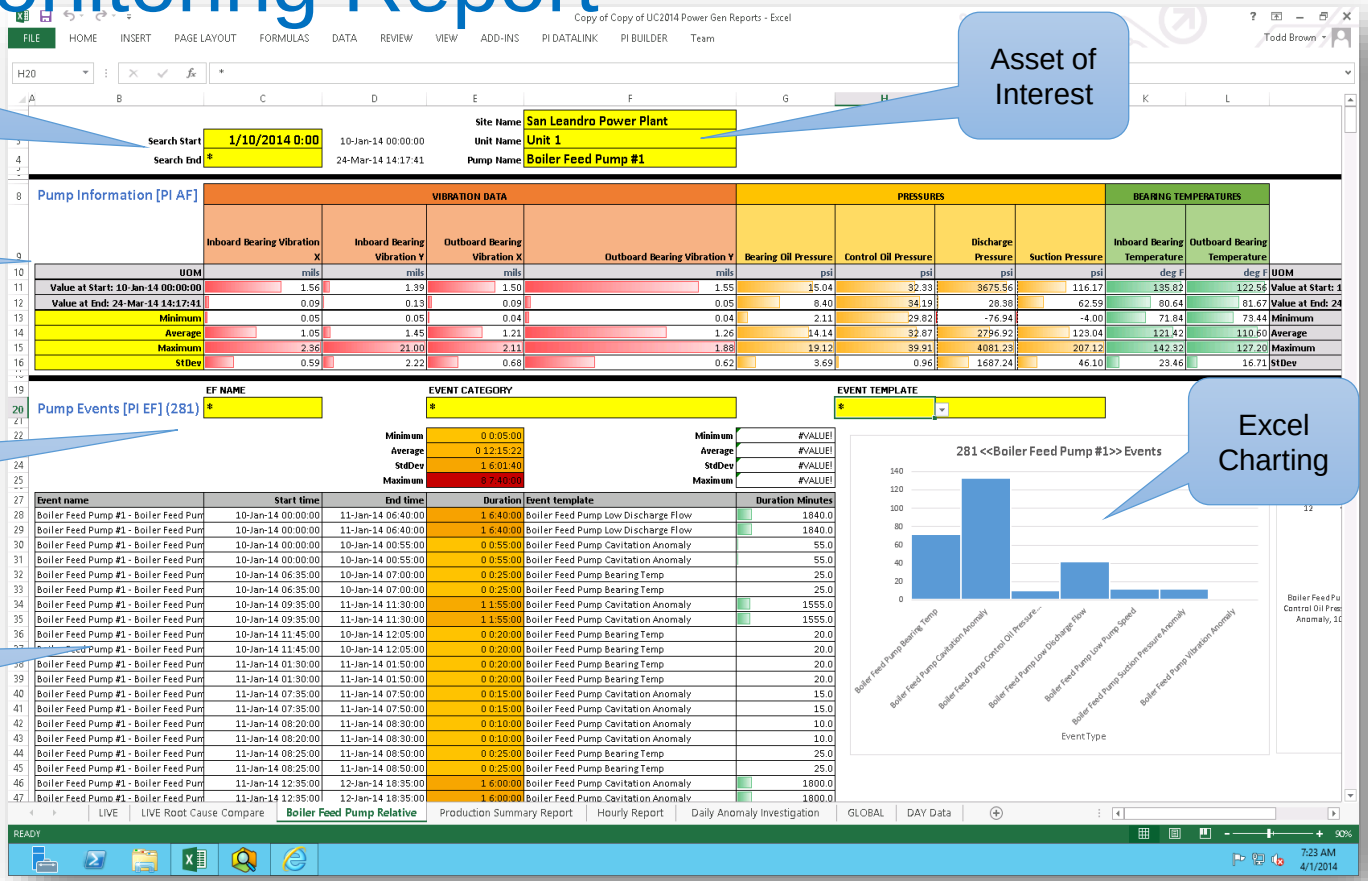
Asset of Interest

Real Time Summaries

Filter Events

Events

Excel Charting



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

CBM Customer References

Portland General Electric - power generation Experience-using-the-PI-System-for-Full-Featured-Vibration-Monitoring
Ameren - nuclear power generation A-new-paradigm-in-utility-condition-based-maintenance
Vistra Energy (Luminant) - power Cloud-Transformation-in-a-Nationwide-Power-Producer
Barrick Gold - metals & mining Mine-Haul-Truck-Health-Monitoring-System
EQT - natural gas pipeline Reliability-Centered-Maintenance-Program
King County - waste water treatment PI-as-a-Maintenance-Tool
PSE&G - electricity distribution - transformers Condition-Based-Maintenance-Case-Study
PSE&G - electricity distribution - circuits Extending-Condition-Based-Maintenance-Program-to-Underground-Networks/
Petronas - oil & gas PROTEAN---Rotating-Equipment-Analytics-in-PI-AF
Silicon Valley Power - power generation Optimizing-Predictive-Maintenance-by-Integrating-Vibration-Data-and-Process-Data
SNCF - railways Using-Operational-Data-for-the-Future-Maintenance-of-the-French-Rail-Infrastructure
Alyeska Pipeline - oil & gas Achieving-Reliability-Centered-Maintenance-and-Diagnostics-with-the-PI-System
ADNOC - oil & gas Improving-Equipment-Reliability-and-Availability-through-Real-time-Data
Las Vegas Valley Water District - water treatment Evaluating-Efficiency-and-Predicting-Maintenance-with-Existing-Data-Using-PI-AF-and-Asset-Analytics
Chevron – oil exploration Condition-Based-Maintenance-and-Smart-Monitoring-in-Frade-FPSO-with-the-PI-System
Vattenfall – hydro power Deploying-a-Condition-Based-Maintenance-Strategy-in-the-Hydro-Power-Business
PowerStream - electricity distribution Equipment-Failure-is-Not-an-Option
GenOn Energy - power Proactive-Maintenance-Data-Gateway-Built-on-the-OSIsoft-PI-System-Infrastructure
Uniper - power How-OSIsoft-PI-supports-Unipers-Maintenance-Strategy-Planning
ESB - power Using-the-PI-System-in-Power-Generation-Operation-and-Maintenance-to-Optimise-Commercial—Environment
MOL – oil refinery Supporting-Operational-Availability-by-Connecting-the-PI-System-and-SAP-PM
OSIsoft Introduction-to-Asset-Monitoring-and-Condition-based-Maintenance-with-the-PI-System
OSIsoft Getting-started-with-iiot-sensors (may need to register – free)

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

- Mike Horrocks
- Technical Advisor
- mhorrocks@osisoft.com

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

Questions?

Please wait for the **microphone**

State your **name & company**

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