

PI System Analytics, Fit for Purpose

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PI System Analytics – Fit for Purpose

ABSTRACT

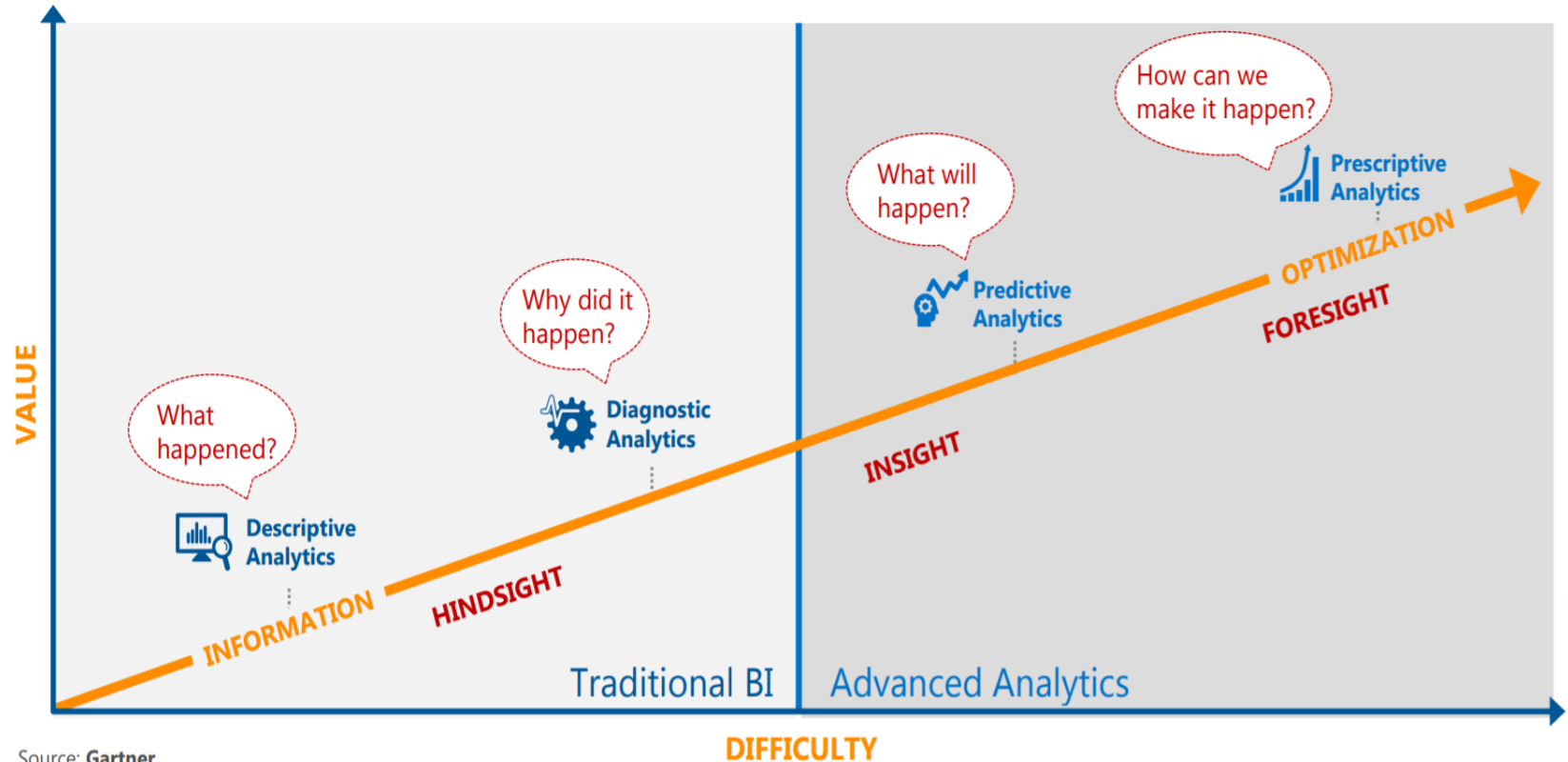
Attend this talk as we cover scenarios to illustrate the different levels of analytics that are fit-for-purpose when using the PI System - for example, what calculations and analysis do you do in AF, when do you use MATLAB for advanced calculations that hook into AF and when do you call on “data science and machine learning”.

Use cases will focus on equipment i.e. pump or motor or compressor etc. as well as on a process.

Layers of Analytics – View Thru’ Multiple Lenses

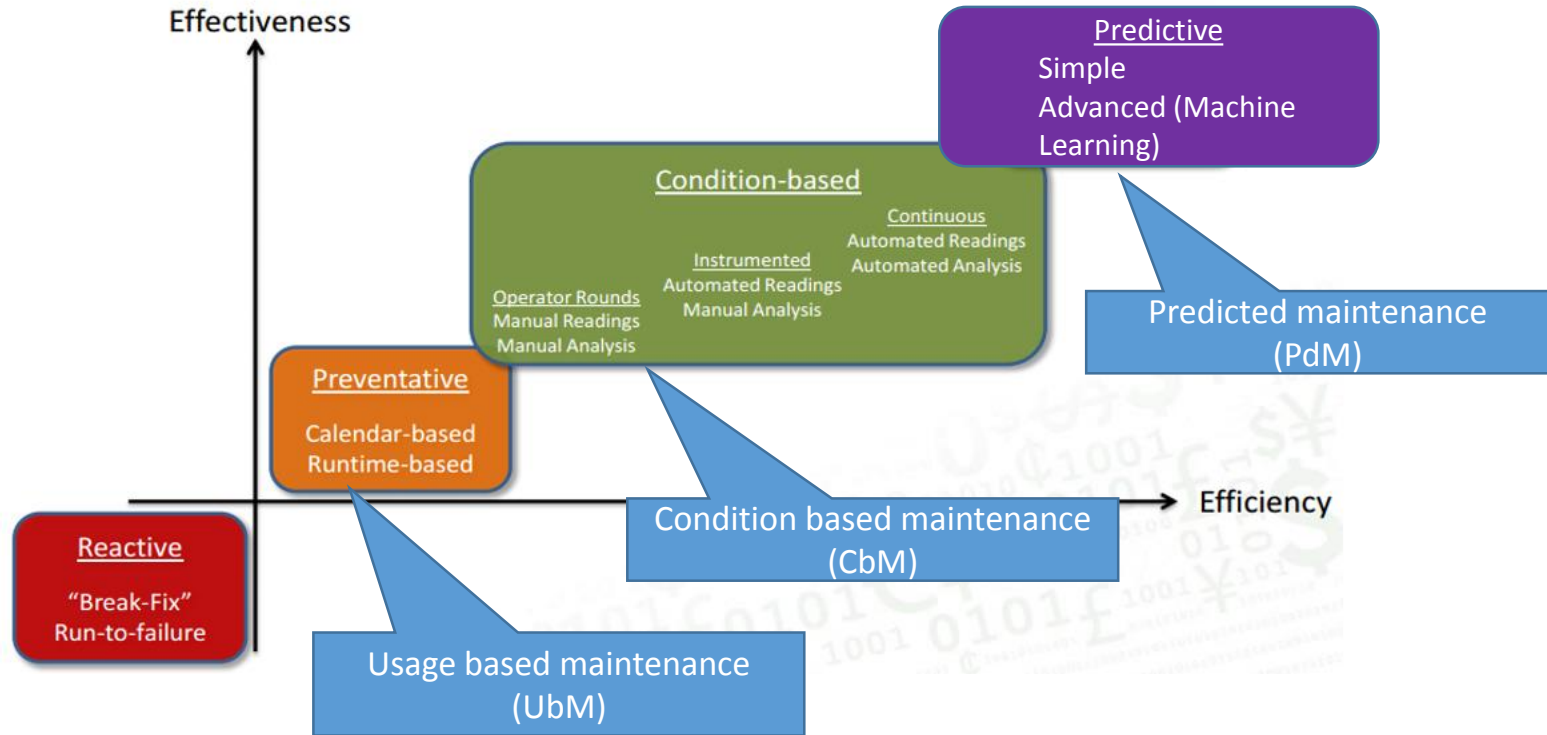
- Functional Scope - *Process Insight & Excellence*
 - Descriptive, diagnostic, predictive, prescriptive
- Business Scope - *Improved Reliability*
 - **Usage-based Maintenance** - UbM
 - **Condition-based Maintenance** - CbM
 - **Predictive Maintenance** – PdM
 - *Simple predictive (Advanced CbM)*
 - *Advanced predictive - Statistical, Machine learning...*
- Architectural Location
 - Edge device, Server or cloud based
 - Analytics during data collection?
- ...

Layers of Analytics - Process Operations



Source: Gartner

Layers of Analytics - Maintenance & Reliability

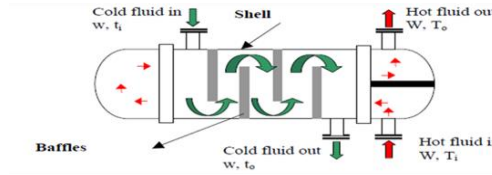


Layers of Analytics – View Thru’ Multiple Lenses

- Functional Scope - *Process Insight & Excellence*
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- Business Scope - *Improved Reliability*
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- ...

Descriptive Analytics – PI Asset Analytics

- Configure calculations for transparency and scale
- Math, statistical, and time-based functions
- Integration with MATLAB
- Testing and operationalization of predictive analysis models
- Condition-based notification
- Supports future data for forecasting



Heat Exchanger Key Performance Indicator:
Overall heat transfer coefficient

$$U = \frac{Q}{A \times \text{Corrected LMTD}}$$

RULE: IF the heat transfer coefficient is decreasing, THEN the Heat Exchanger FOULING !!!
Cleaning is required!

| Name | Expression | Value | Output Attribute |
|----------|--|-------|--------------------------------------|
| qs | //Shell side heat duty "Shell Side Mass Flow"*"Hot Side Temperature Difference" | | Heat Duty:Shell Side |
| qt | //Tube side heat duty "Tube Side Mass Flow"*"Cold Side Temperature Difference"*"Tube Side Heat Capacity"*3600 | | Heat Duty:Tube Side |
| qi+qt | | | Map |
| R | ("Hot Side Inlet Temperature"- "Hot Side Outlet Temperature")/("Cold Side Outlet Temperature"- "Cold Side Inlet Temperature") | | Map |
| S | ("Cold Side Outlet Temperature"- "Cold Side Inlet Temperature")/("Hot Side Inlet Temperature"- "Hot Side Outlet Temperature") | | Map |
| LMTD | Roundoff(((("Hot Side Inlet Temperature"- "Cold Side Outlet Temperature")/("Hot Side Outlet Temperature"- "Cold Side Inlet Temperature"))/Log((("Hot Side Inlet Temperature"- "Cold Side Inlet Temperature")/("Hot Side Outlet Temperature"- "Cold Side Inlet Temperature"))),1) | | LMTD |
| F | ((R+1)*0.5*Log((1-S*R)/(1-S)))/((1-R)*Log((2-S*(R+1*(R+1)*0.5))/(2-S*(R+1*(R+1)*0.5)))) | | Map |
| LMTDcorr | F*LMTD | | Map |
| U | Max(qs,qt)/("Area"*LMTDcorr) | | Calculated Heat Transfer Coefficient |

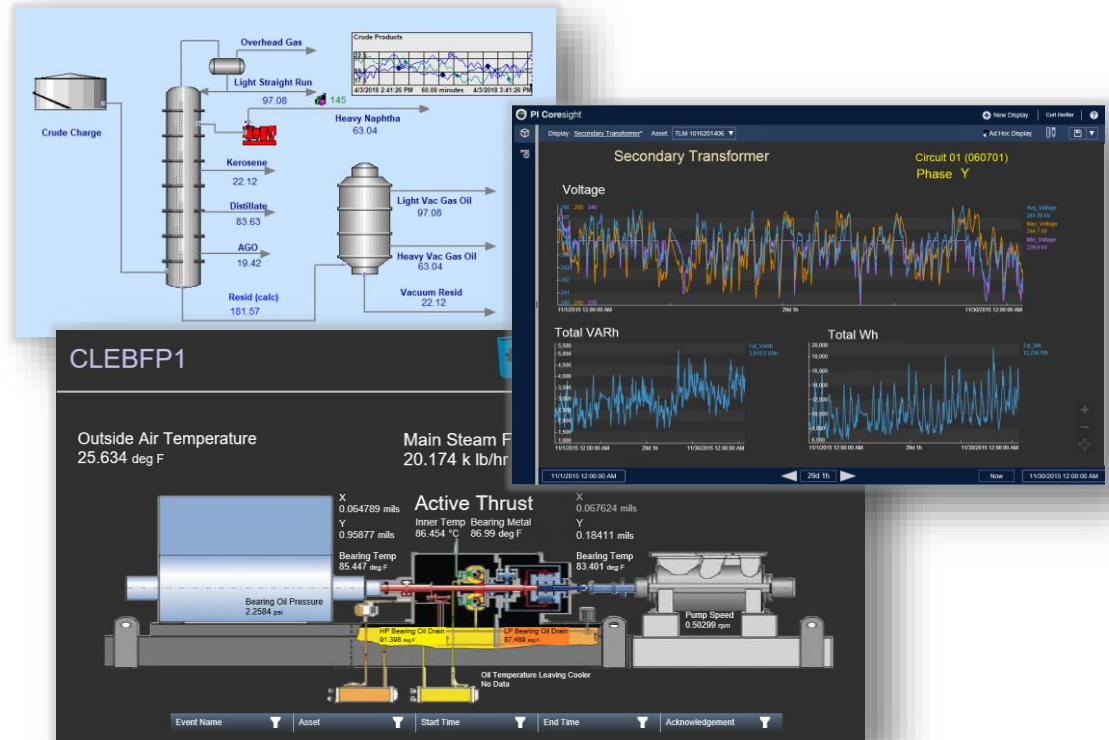
Calculation Steps:

1. Heat Duty, $Q = q_s + q_t$
 $q_s = W \times C_{ph} \times (T_1 - T_o) / 1000 / 3600$
 $q_t = W \times C_{pc} \times (t_o - t_i) / 1000 / 3600$
2. Hot Fluid Pressure Drop, $\Delta P_h = P_1 - P_o$
3. Cold fluid pressure drop, $\Delta P_c = p_i - p_o$
4. Temperature range hot fluid, $\Delta T = T_1 - T_o$
5. Temperature range cold fluid, $\Delta t = t_o - t_i$
6. Capacity ratio, $R = W \times C_{ph} / w \times C_{pc}$ (or) $(T_1 - T_o) / (t_o - t_i)$
7. Effectiveness, $S = (t_o - t_i) / (T_1 - t_i)$
8. LMTD
 LMTD Counter current Flow = $((T_1 - t_o) - (T_o - t_i)) / \ln((T_1 - t_o) / (T_o - t_i))$
 LMTD Co current Flow = $((T_1 - t_i) - (T_o - t_o)) / \ln((T_1 - t_i) / (T_o - t_o))$
 Correction factor for LMTD to account for Cross flow

$$F = \frac{(R + 1)^{1/2} \times \ln((1 - SR) / (1 - S))}{(1 - R) \times \ln \left\{ \frac{2 - S(R + 1 - (R + 1)^{1/2})}{2 - S(R + 1 + (R + 1)^{1/2})} \right\}}$$

Diagnostic Analytics – *Trending and Event Awareness*

- Access to operational data in real-time with tools suited to Operations.
- Supports ad hoc, self-service investigation.



Real-time Data is Different

- Transactional data is recorded in a tabular format with values associated by columns in each row.
- Real-time data is recorded with only time context, i.e. value and timestamp.

| | A ^B _C leakno | A ^B _C compute_0002 | A ^B _C city | A ^B _C grade | A ^B _C read_locat | A ^B _C map | A ^B _C plat | A ^B _C block | A ^B _C date_reptd |
|----|------------------------------------|--|----------------------------------|-----------------------------------|--|---------------------------------|----------------------------------|-----------------------------------|--|
| 1 | 7800201621 | 00201621 | San Jose | 3 | Under Drway o/m | 3411 | F07 | 040 | 11/28/2000 14:00:00 |
| 2 | 7801200081 | 01200081 | Santa Clara | 3 | o/m in s/e cor of Humbolt Ave | 3411 | B08 | 010 | 1/5/2001 11:00:00 |
| 3 | 7801200091 | 01200091 | Santa Clara | 3 | o/m 2' into property | 3411 | D06 | 028 | 1/4/2001 01:30:00 |
| 4 | 7801200121 | 01200121 | Santa Clara | 2 | o/m, 3' from sidewalk | 3411 | D06 | 012 | 1/16/2001 10:00:00 |
| 5 | 7801200841 | 01200841 | Santa Clara | 3 | 1% o/m under concrete pkstrip at e/end of drway | 3411 | A07 | 028 | 8/27/2001 11:00:00 |
| 6 | 7801200851 | 01200851 | Santa Clara | 3 | 1% under drway at curb & Gutter | 3411 | A08 | 015 | 8/28/2001 10:00:00 |
| 7 | 7803200121 | 03200121 | San Jose | 3 | 1575 Parkveiw Ave. | 3411 | H07 | 044 | 3/23/2003 09:48:00 |
| 8 | 7803200461 | 03200461 | Santa Clara | 3 | 1% in svc tee area o/main | 3411 | C07 | 026 | 11/10/2003 07:33:00 |
| 9 | 7806200241 | 06200241 | Santa Clara | 3 | s/w cor Princeton Wy x Princeton Ct on main | 3411 | C07 | 012 | 2/6/2006 13:15:00 |
| 10 | 7806200271 | 06200271 | Santa Clara | 3 | S/E cor Homestead x Lawrence Exwy valve frme&cover | 3411 | C07 | 016 | 2/7/2006 11:40:00 |
| 11 | 7806200351 | 06200351 | Santa Clara | 2 | O/M @ svc tee (Longside) | 3411 | C08 | 037 | 2/16/2006 10:00:00 |
| 12 | 7806200441 | 06200441 | Santa Clara | 3 | over main next to srvc tee | 3411 | D07 | 048 | 3/8/2006 13:00:00 |
| 13 | 7806200481 | 06200481 | Santa Clara | 2 | on main or tee | 3411 | D08 | 052 | 3/10/2006 09:45:00 |
| 14 | 7806200491 | 06200491 | Santa Clara | 2 | on main ovr sewer not venting to house | 3411 | D08 | 053 | 3/10/2006 10:00:00 |
| 15 | 7806200501 | 06200501 | Santa Clara | 2 | btwn #s 3145 & 3155 Mauricia Wy on main or tee | 3411 | D08 | 008 | 3/10/2006 11:25:00 |
| 16 | 7806200511 | 06200511 | Santa Clara | 3 | on tee S/O driveway | 3411 | D08 | 056 | 3/10/2006 14:00:00 |
| 17 | 7806200541 | 06200541 | Santa Clara | 3 | on tee | 3411 | D08 | 049 | 3/15/2006 13:30:00 |
| 18 | 7806200561 | 06200561 | San Jose | 2 | ovr main btwn Greendale & Auburn on Albany | 3411 | E08 | 014 | 3/16/2006 13:45:00 |
| 19 | 7806200611 | 06200611 | Santa Clara | 3 | 15' from drway about 15" in parkstrip @svc tee | 3411 | F07 | 041 | 3/22/2006 13:45:00 |
| 20 | 7806200641 | 06200641 | Santa Clara | 3 | 3% OVER MAIN NEXT TO SEWER | 3411 | G08 | 012 | 3/23/2006 14:00:00 |
| 21 | 7806200651 | 06200651 | San Jose | 3 | on main or srvc tee | 3411 | F08 | 072 | 3/24/2006 11:15:00 |
| 22 | 7806200681 | 06200681 | Santa Clara | 2+ | 5" in parkstrip fr/swk over tee on main 6' from... | 3411 | G07 | 006 | 3/28/2006 13:40:00 |
| 23 | 7806200701 | 06200701 | Santa Clara | 3 | 36' EO W p/l Olympus. 2% In water box | 3411 | G08 | 053 | 3/28/2006 13:00:00 |
| 24 | 7806200711 | 06200711 | Santa Clara | 2 | F/O o/main (under tree) | 3411 | H06 | 023 | 3/29/2006 11:00:00 |
| 25 | 7806200721 | 06200721 | Santa Clara | 2+ | o/svc/tee about 3' from drway in parkstrip | 3411 | G07 | 014 | 3/29/2006 13:10:00 |

56.902 03-SEP-2016 11:23 AM

Real-time Data Requires Context

Time

63.781 03-SEP-2016 11:19 AM

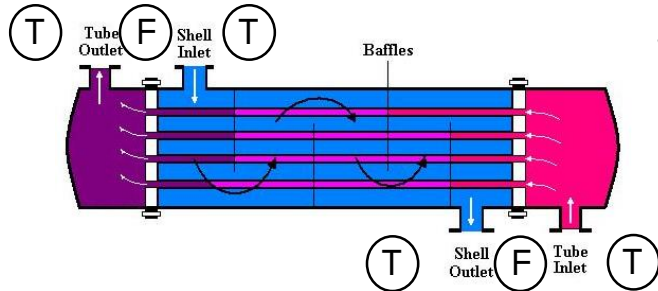
56.902 03-SEP-2016 11:23 AM

58.341 03-SEP-2016 11:41 AM

Asset

Scientific Actions

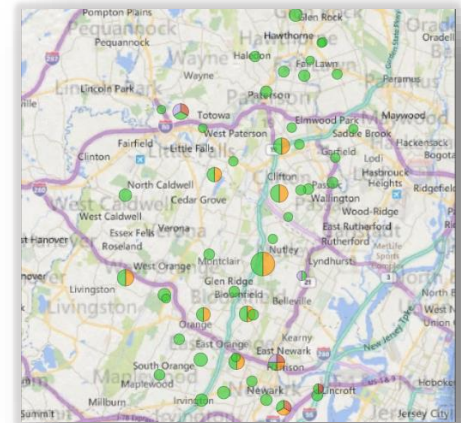
Location



$$H = z + \frac{p}{\rho g} + \frac{v^2}{2g} = h + \frac{v^2}{2g}$$



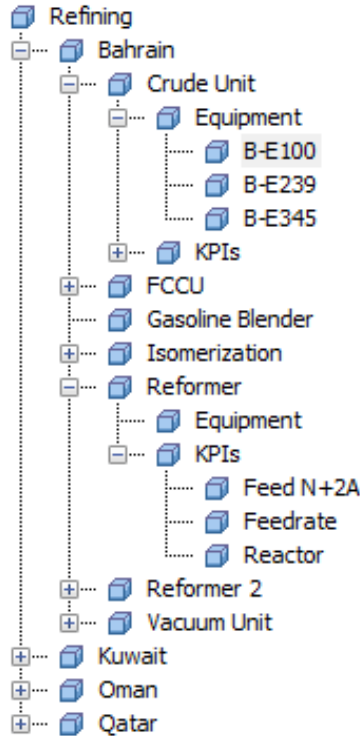
Daniel Bernoulli
(1700 – 1782)



Real-time Data Requires Context

Asset Hierarchy

- Plant
- Process
- Assets
- Process Context
- Location
- Specifications



Process Context

Location

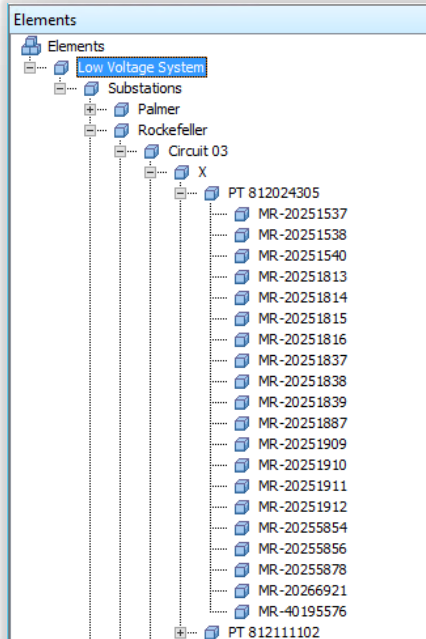
Specifications

| Category: Process Data | | | |
|--------------------------|--|------------------------------|---------------------|
| <input type="checkbox"/> | | Cold Side Inlet Temperature | 77.1157989501953 °F |
| <input type="checkbox"/> | | Cold Side Outlet Temperature | 131.192291259766 °F |
| <input type="checkbox"/> | | Hot Side Inlet Temperature | 374.601501464844 °F |
| <input type="checkbox"/> | | Hot Side Outlet Temperature | 292.926361083984 °F |

| Category: Location | | | |
|--------------------------|--|-----------|----------------------------|
| <input type="checkbox"/> | | Address | 2265 W Salinas St, San ... |
| <input type="checkbox"/> | | Latitude | 29.43027 |
| <input type="checkbox"/> | | Longitude | -98.518172 |

| Category: Specifications | | | |
|--------------------------|--|-------------|------------------------|
| <input type="checkbox"/> | | Area | 1200 ft2 |
| <input type="checkbox"/> | | Coefficient | 75.66 BTU per F ft2 Hr |
| <input type="checkbox"/> | | Service | Crude vs. Naphtha |

PI AF Provides Context to Real-time Data



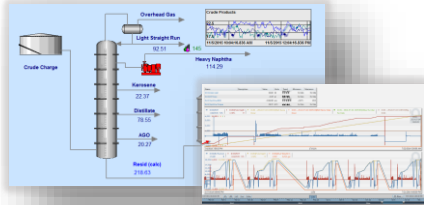
The screenshot shows a data table titled 'Transformer Study' with the user 'OSIcort'. The table has columns for Substation, TimeStamp, Circuit, Phase, Pole Transformer, Avg_Voltage, Max_Voltage, Min_Voltage, Tot_VARh, and Tot_Wh. The data is filtered for the time range 11/15 12:00:00 AM to 1/31/16 12:00:00 AM. The row for 11/1/2015 12:02:00 is highlighted in red.

| Substation | TimeStamp | Circuit | Phase | Pole Transformer | Avg_Voltage | Max_Voltage | Min_Voltage | Tot_VARh | Tot_Wh |
|------------|--------------------|------------|-------|------------------|-------------|-------------|-------------|----------|-----------|
| Palmer | 11/1/2015 12:00:00 | Circuit 01 | X | PT 411054401 | 250.151 | 250.385 | 249.977 | 566.962 | 1,831.385 |
| Palmer | 11/1/2015 12:01:00 | Circuit 01 | X | PT 411054401 | 250.151 | 250.385 | 249.977 | 566.887 | 1,831.140 |
| Palmer | 11/1/2015 12:02:00 | Circuit 01 | X | PT 411054401 | 250.152 | 250.385 | 249.977 | 566.812 | 1,830.895 |
| Palmer | 11/1/2015 12:03:00 | Circuit 01 | X | PT 411054401 | 250.152 | 250.385 | 249.977 | 566.738 | 1,830.65 |
| Palmer | 11/1/2015 12:04:00 | Circuit 01 | X | PT 411054401 | 250.152 | 250.385 | 249.978 | 566.663 | 1,830.405 |
| Palmer | 11/1/2015 12:05:00 | Circuit 01 | X | PT 411054401 | 250.152 | 250.385 | 249.978 | 566.588 | 1,830.160 |
| Palmer | 11/1/2015 12:06:00 | Circuit 01 | X | PT 411054401 | 250.152 | 250.385 | 249.978 | 566.513 | 1,829.915 |
| Palmer | 11/1/2015 12:07:00 | Circuit 01 | X | PT 411054401 | 250.152 | 250.386 | 249.978 | 566.439 | 1,829.671 |
| Palmer | 11/1/2015 12:08:00 | Circuit 01 | X | PT 411054401 | 250.152 | 250.386 | 249.978 | 566.364 | 1,829.426 |
| Palmer | 11/1/2015 12:09:00 | Circuit 01 | X | PT 411054401 | 250.152 | 250.386 | 249.979 | 566.289 | 1,829.181 |
| Palmer | 11/1/2015 12:10:00 | Circuit 01 | X | PT 411054401 | 250.153 | 250.386 | 249.979 | 566.215 | 1,828.936 |
| Palmer | 11/1/2015 12:11:00 | Circuit 01 | X | PT 411054401 | 250.153 | 250.386 | 249.979 | 566.140 | 1,828.691 |
| Palmer | 11/1/2015 12:12:00 | Circuit 01 | X | PT 411054401 | 250.153 | 250.386 | 249.979 | 566.065 | 1,828.446 |
| Palmer | 11/1/2015 12:13:00 | Circuit 01 | X | PT 411054401 | 250.153 | 250.386 | 249.979 | 565.991 | 1,828.201 |
| Palmer | 11/1/2015 12:14:00 | Circuit 01 | X | PT 411054401 | 250.153 | 250.386 | 249.980 | 565.916 | 1,827.956 |
| Palmer | 11/1/2015 12:15:00 | Circuit 01 | X | PT 411054401 | 250.153 | 250.387 | 249.980 | 565.841 | 1,827.712 |
| Palmer | 11/1/2015 12:16:00 | Circuit 01 | X | PT 411054401 | 250.153 | 250.387 | 249.980 | 565.767 | 1,827.467 |
| Palmer | 11/1/2015 12:17:00 | Circuit 01 | X | PT 411054401 | 250.153 | 250.387 | 249.980 | 565.692 | 1,827.222 |
| Palmer | 11/1/2015 12:18:00 | Circuit 01 | X | PT 411054401 | 250.154 | 250.387 | 249.980 | 565.617 | 1,826.977 |
| Palmer | 11/1/2015 12:19:00 | Circuit 01 | X | PT 411054401 | 250.154 | 250.387 | 249.981 | 565.543 | 1,826.732 |
| Palmer | 11/1/2015 12:20:00 | Circuit 01 | X | PT 411054401 | 250.154 | 250.387 | 249.981 | 565.468 | 1,826.487 |
| Palmer | 11/1/2015 12:21:00 | Circuit 01 | X | PT 411054401 | 250.154 | 250.387 | 249.981 | 565.393 | 1,826.242 |

Supporting Analytics with Contextualized Data

Real-Time Decision Analysis

Retrospective & Predictive Analysis



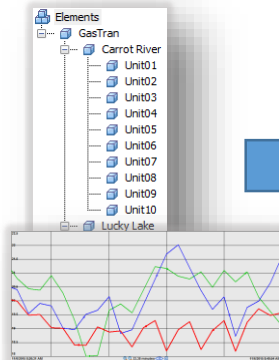
Time and Event
Trending & Awareness

Specialized Models
Simulation & Optimization

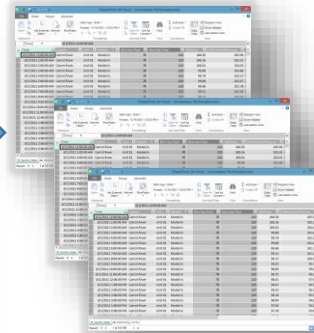
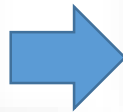
$$Q = \frac{\Delta P_{DD} * kh}{141.2\mu B_0 \left\{ \ln \frac{r_e}{r_w} - \frac{3}{4} + S \right\}}$$

Descriptive
Condition & Performance

PI Integrator for
Business Analytics



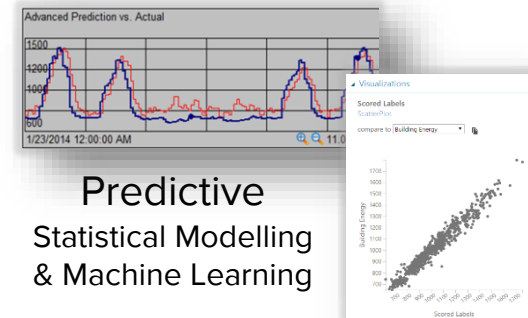
Time, Event and
Asset Context



Tabular
Context



Visual
Dashboards &
Multidimensional Assessment

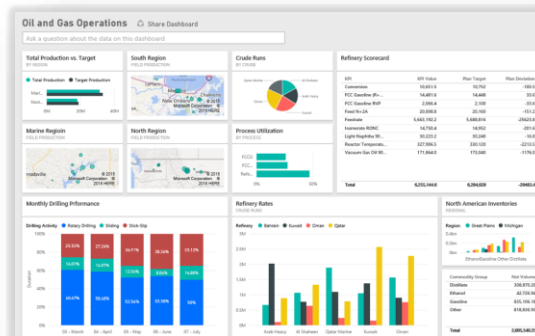


Predictive
Statistical Modelling
& Machine Learning

Common Ground between Technological
Contexts

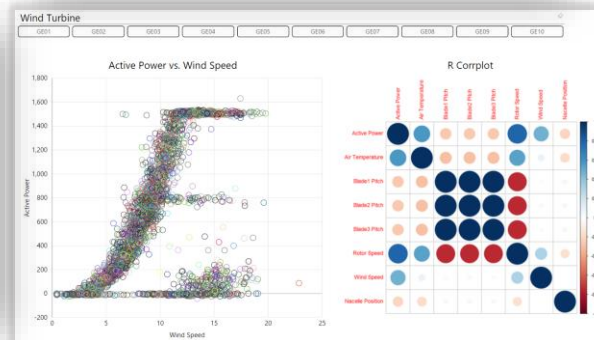
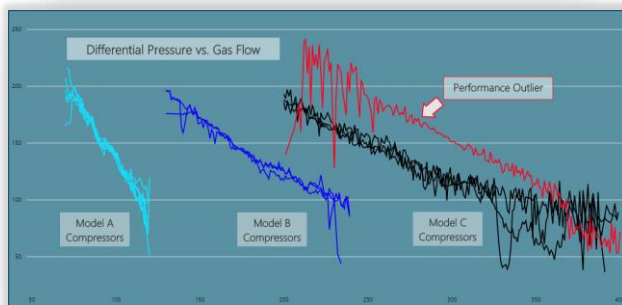
Diagnostic Analytics – Multidimensional Visualization, Dashboards

Business Analysis
Product inventories



Dashboards
Collaboration

Asset Performance
Benchmarking



Analytics
Measurement
Correlation

Feed Drying Process - Process and Regeneration Cycles

Also see PI World 2018 Layers of Analytics Hand-on Lab

- Molecular sieve dryers remove water from hydrocarbon feedstock before entering reactor
- Proper regeneration is critical to avoid corrosion in acidic reaction
- Cyclic operation between Process and Regeneration cycles
- Regeneration cycle is indicated by high be outlet temperatures

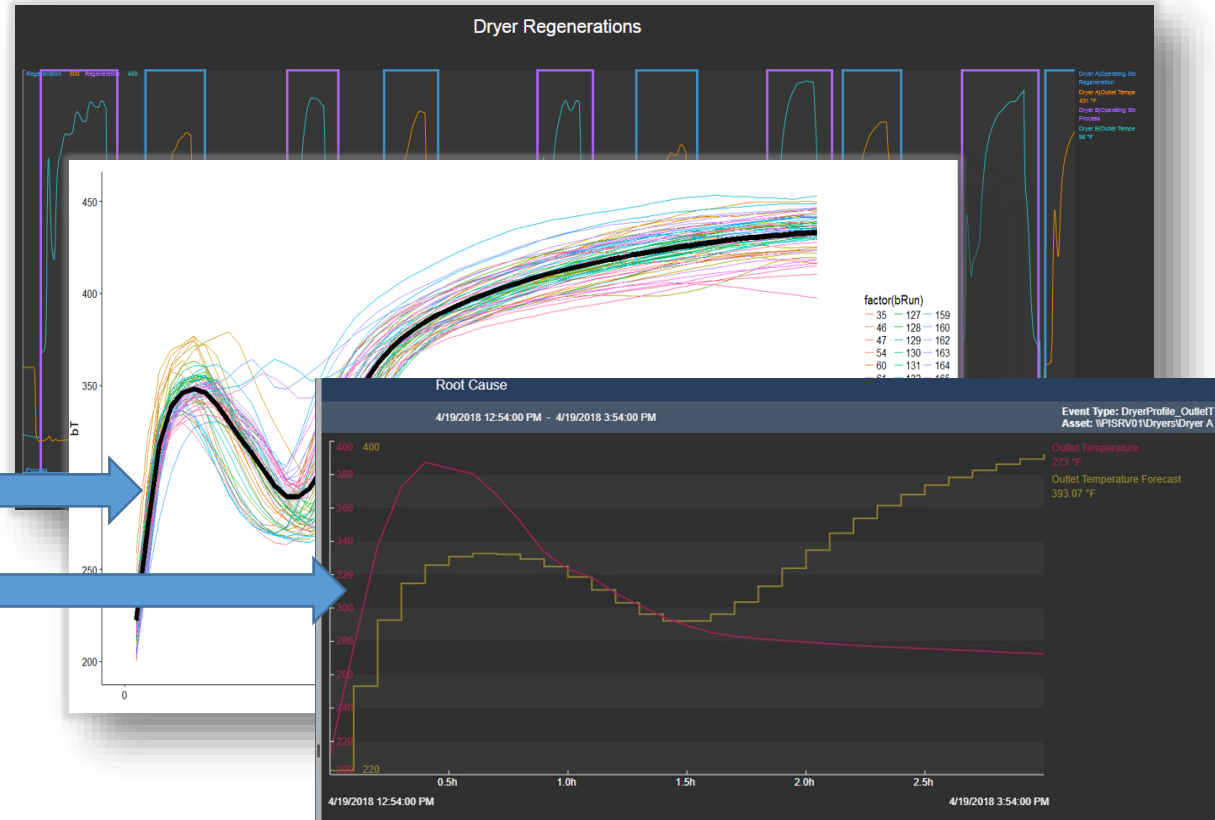
Dryer A Regeneration

Dryer B Regeneration



Predictive Analytics – *Dryer Regeneration Guidance for Operations*

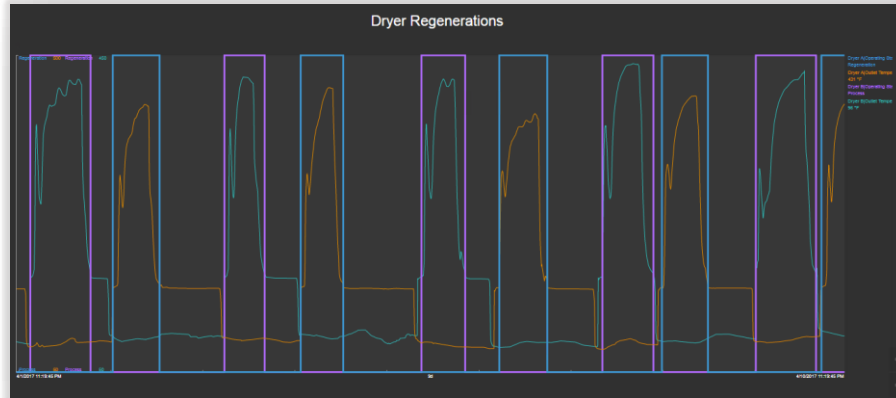
- During Regeneration, monitor bed Outlet Temperature against a modeled profile, notify operator of deviations
- Prepare data using AF Analytics and Event Frames
- Publish dataset for model development and training
- Develop model in R/MATLAB
- Operationalize model using AF Analytics and R/MATLAB



Feed Dryer Status – Regeneration Event Frames

- AF Analytic defines the beginning and end of regeneration cycle
- Digital state for each dryer with Process of Regeneration states
- Start temp. = 170 F,
End temp = 175 F
- Confirm five hours since last regeneration to avoid short cycles caused by initial temperature fluctuation
- Backfill through 2017

```
If('Outlet Temperature' >= 'Outlet Temperature|Start of Regeneration Temperature'  
    And PrevVal('Operating State', '*-5h') = "Process")  
Then (If PrevVal('Operating State', '*')="Regeneration"  
    Then NoOutput()  
    Else "Regeneration")  
Else  
    (If('Outlet Temperature' <= 'Outlet Temperature|End of Regeneration Temperature'  
        And PrevVal('Operating State', '*-5h') = "Regeneration")  
    Then (If PrevVal('Operating State', '*') = "Process"  
        Then NoOutput()  
        Else "Process")  
    Else NoOutput())
```

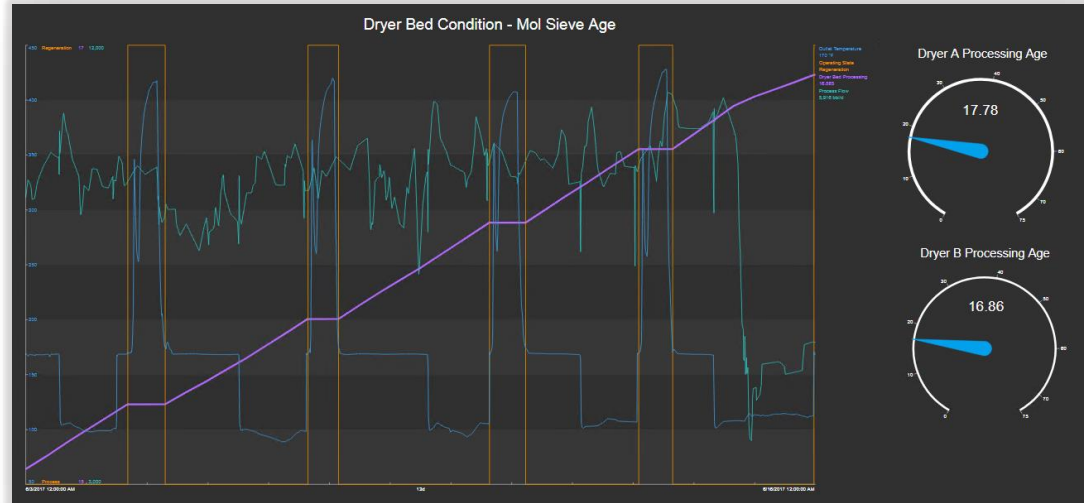


Feed Dryer Bed Age – “Dryer Bed Processing Age”

- AF Expression analytic determines processing age of molecular sieve desiccant
- Enables bed balancing for maximum service
- Calculate Lifetime Total Dried Feed, converts total volume from a volumetric rate
- Processing age :

$$\frac{\text{Lifetime Total Dried Feed}}{\text{Loaded Wt. of Mol. Sieve}}$$

- Backfill through 2017



```
If ('Operating State' = "Process"  
    And Not(BadVal('Process Flow'))  
    And Not(BadVal(PrevVal('Process Flow','*'))))  
Then 'Lifetime Total Dried Feed' +  
    TagTot('Process Flow', PreviousProcessFlowTime, '*')  
Else NoOutput()
```

Dryer Regeneration – Publishing Summarized Dataset

- Leverage AF model to Select, Shape and Publish tabular views to a variety of endpoints
- Event Views publish Event Frame data in either Summarized or Sampled structures
- Sampled view combines aggregations taken over the Event Frame duration with Asset data sampled at intervals throughout the duration

The screenshot displays the 'Feed Dryer Regenerations' application interface. The top navigation bar includes 'Select Data', 'Modify View', and 'Publish' options. The main content area is divided into several sections:

- Source Events:** Shows 'Server' as 'CHERTLER7450' and 'Database' as 'Dryers'. A search bar is present with the placeholder text 'Enter event name or string match pattern'.
- Event Frames:** A list of event frames is shown, with 'Dryer A' and 'Dryer B' selected.
- Attributes:** A list of attributes is displayed, including 'Molecular Sieve Loading', 'Operating State', 'Outlet Temperature', 'Process Flow', 'Regenerant Flow', 'Regenerant Return Drum Level', 'Regenerant Return Drum Pressure', and 'Regenerant Temperature'. The 'Regenerant Return Drum Pressure' attribute is highlighted.
- Search Shape:** A tree view shows the 'Event Shape' and 'Asset Shape' options. The 'Event Shape' section is highlighted with a red box and labeled 'Event Frame Attributes'. It includes attributes like 'Avg Hot Oil Valve Position', 'Avg Outlet Temp', 'Avg Regen Drum Level', 'Avg Regen Temp', 'Dryer Processing Age', 'Max Outlet Temp', 'Max Processed Moisture', and 'Max Regen Temp'. The 'Asset Shape' section is also highlighted with a red box and labeled 'Asset Element Attributes'. It includes attributes like 'Dryer A', 'Dryer Pressure', 'Outlet Temperature', 'Regenerant Flow', and 'Regenerant Temperature'.
- Matches:** A list of matches is shown, with 'Found 52 Matches' indicated. The matches are listed as 'Dryer A Regeneration' events with timestamps, such as '01-02-17 00:00' through '01-21-17 15:36'.

Dryer Regeneration - *Sampled Event Publication*

Interpolated Values – 6 min.

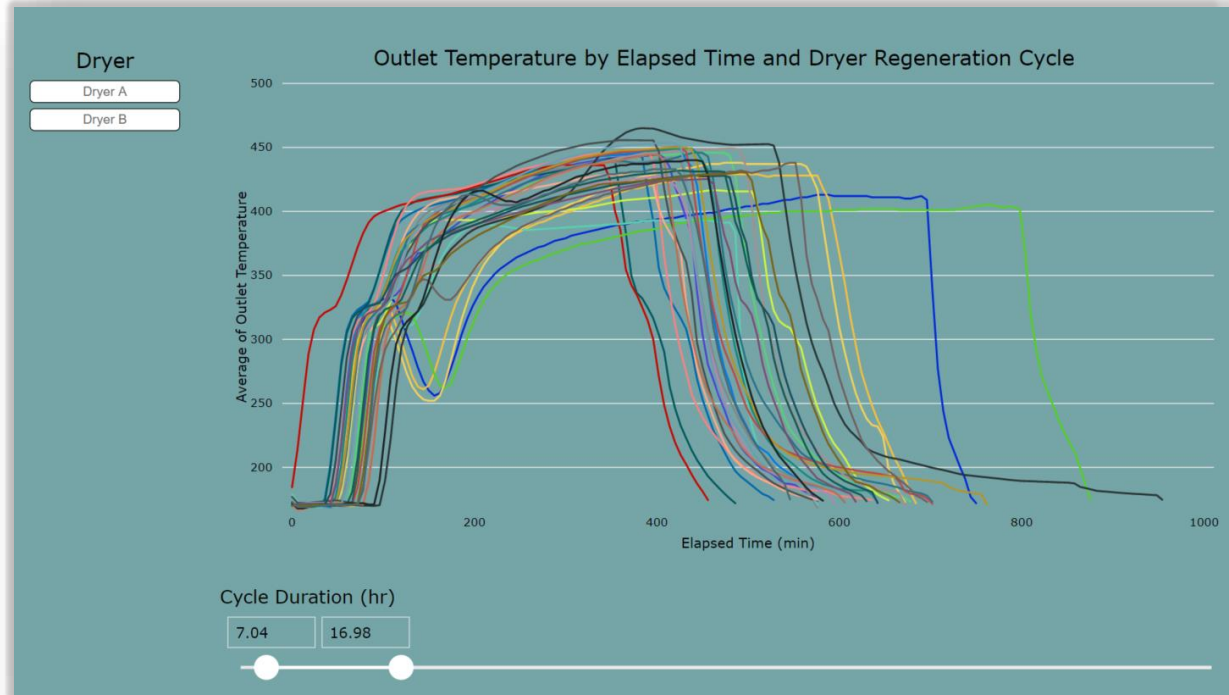
Event Frame Attributes\Features

| Dryer | Time Stamp | Duration | Elapsed Time | Dryer Pressure | Outlet Temperature | Regenerant Flow | Regenerant Tempe. |
|---------|----------------------|----------|--------------|----------------|--------------------|-----------------|-------------------|
| Dryer A | 1/2/2017 12:00:00 AM | 5.3 | 0 | 170.4697 | 436.9 | 603.2525 | 496.1 |
| Dryer A | 1/2/2017 12:06:00 AM | 5.3 | 6 | 170.4824 | 437.8 | 603.6448 | 496.2 |
| Dryer A | 1/2/2017 12:12:00 AM | 5.3 | 12 | 170.495 | 438.6 | 605.063 | 496.4 |
| Dryer A | 1/2/2017 12:18:00 AM | 5.3 | 18 | 170.5076 | 439.5 | 599.6411 | 496.8 |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| Dryer A | 1/2/2017 5:18:00 AM | 5.3 | 318 | 204.1571 | 173.8 | 314.5962 | 287.9 |
| Dryer B | 1/2/2017 7:00:00 AM | 9.6 | 0 | 169.723 | 170.2 | 596.6678 | 480.7 |
| Dryer B | 1/2/2017 7:06:00 AM | 9.6 | 6 | 170.4792 | 170.3 | 598.8013 | 484.8 |
| Dryer B | 1/2/2017 7:12:00 AM | 9.6 | 12 | 171.0217 | 170.4 | 597.2024 | 487.9 |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| Dryer B | 1/2/2017 4:36:00 PM | 9.6 | 576 | 168.8051 | 174.9 | 896.8521 | 173.8 |
| Dryer A | 1/2/2017 7:00:00 PM | 11.3 | 0 | 169.5046 | 170 | 596.4086 | 425.6 |
| Dryer A | 1/2/2017 7:06:00 PM | 11.3 | 6 | 170.3642 | 170.1 | 598.5709 | 442.7 |
| Dryer A | 1/2/2017 7:12:00 PM | 11.3 | 12 | 170.2456 | 170.2 | 600.7331 | 466.3 |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| Dryer A | 1/3/2017 4:54:00 AM | 11.3 | 594 | 167.147 | 196.4 | 547.8572 | 173.4 |
| Dryer B | 1/3/2017 8:48:00 AM | 9.3 | 0 | 169.3378 | 170.2 | 592.8909 | 491.6 |
| Dryer B | 1/3/2017 8:54:00 AM | 9.3 | 6 | 168.1517 | 171.1 | 617.2303 | 490 |
| Dryer B | 1/3/2017 9:00:00 AM | 9.3 | 12 | 167.7706 | 205.2 | 617.502 | 488.7 |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |

| Dryer Regeneration Cycle | Avg Outlet Temp | Avg Regen Temp | Dryer Processing Age | Total Processed Feed |
|-------------------------------------|-----------------|----------------|----------------------|----------------------|
| Dryer A Regeneration 01-02-17 00:00 | 319.9179 | 229.7132 | 0.0005072668 | 4474.716 |
| " | " | " | " | " |
| " | " | " | " | " |
| " | " | " | " | " |
| " | " | " | " | " |
| " | " | " | " | " |
| Dryer B Regeneration 01-02-17 07:00 | 357.6974 | 404.2589 | 0.05128649 | 2742.962 |
| " | " | " | " | " |
| " | " | " | " | " |
| " | " | " | " | " |
| " | " | " | " | " |
| Dryer A Regeneration 01-02-17 19:00 | 332.5292 | 364.0818 | 0.1004348 | 5302.277 |
| " | " | " | " | " |
| " | " | " | " | " |
| " | " | " | " | " |
| " | " | " | " | " |
| Dryer B Regeneration 01-03-17 08:48 | 357.8753 | 399.4613 | 0.1699348 | 6347.083 |
| " | " | " | " | " |
| " | " | " | " | " |
| " | " | " | " | " |
| " | " | " | " | " |

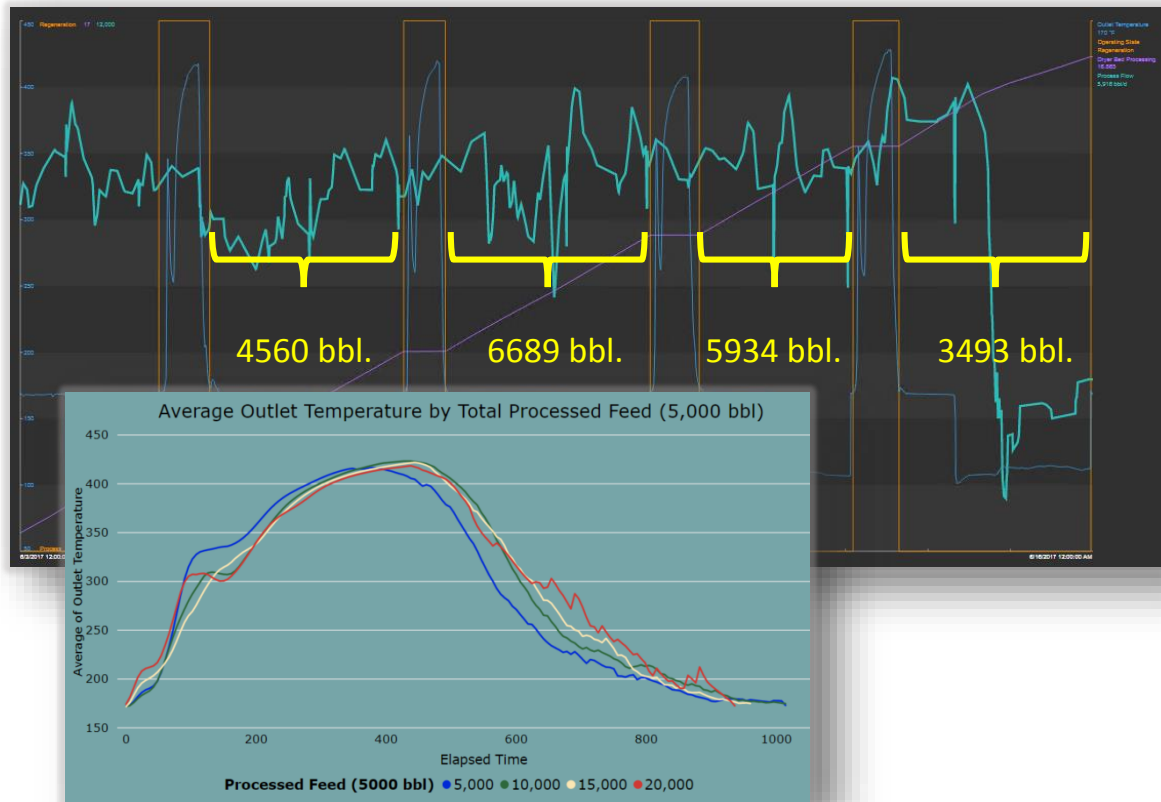
Diagnostic Analysis - *Event Frame Evaluation*

- Sampled Event View dataset imported into Power BI.
- Shows outlet temperature profiles for all Event Frames with filters for dryer asset and cycle duration.
- Filter Event Frames to remove outliers from analysis.
- Acceptable Regeneration cycle durations between 7 and 17 hours.



Dryer Regeneration - *Additional Feature for Refinement*

- Determine if total barrels of feed processed during the Process cycle prior to each regeneration affects outlet temperature profile
- Analysis in Power BI

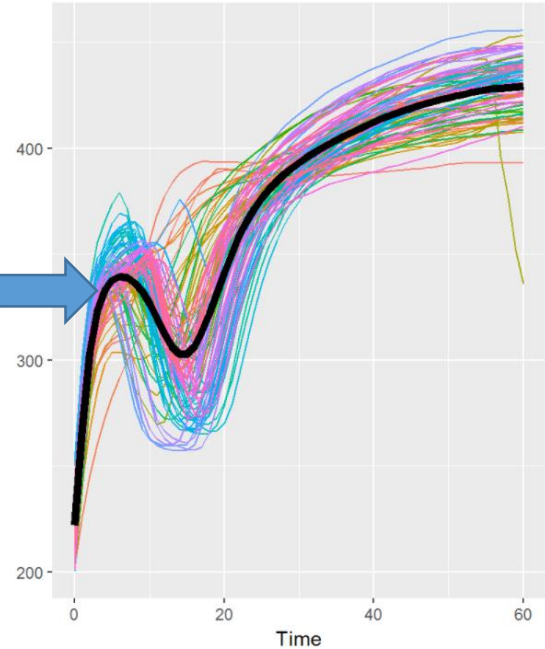
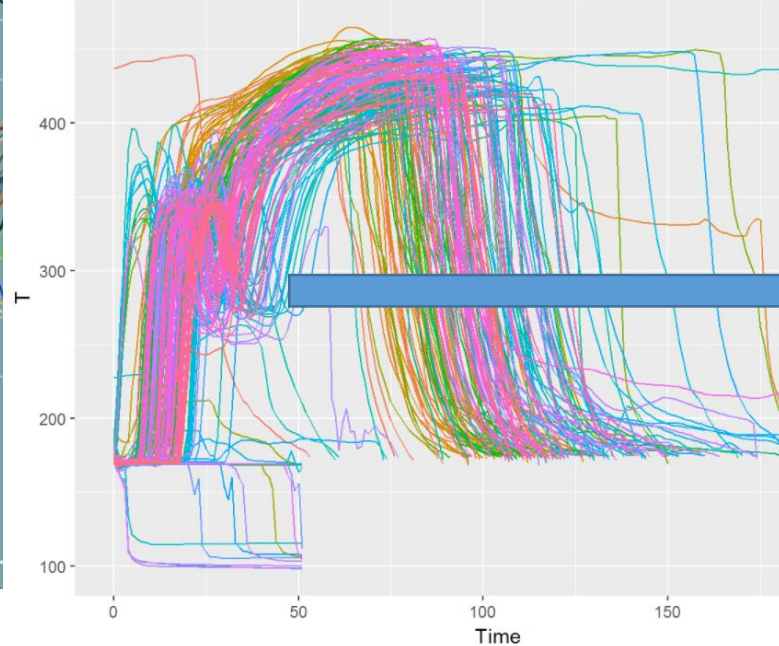
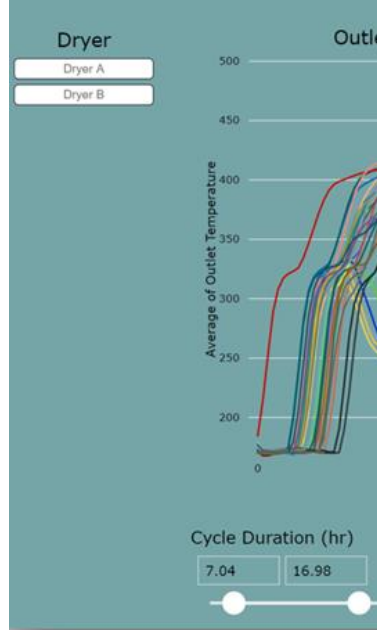


Layers of Analytics – View Thru’ Multiple Lenses

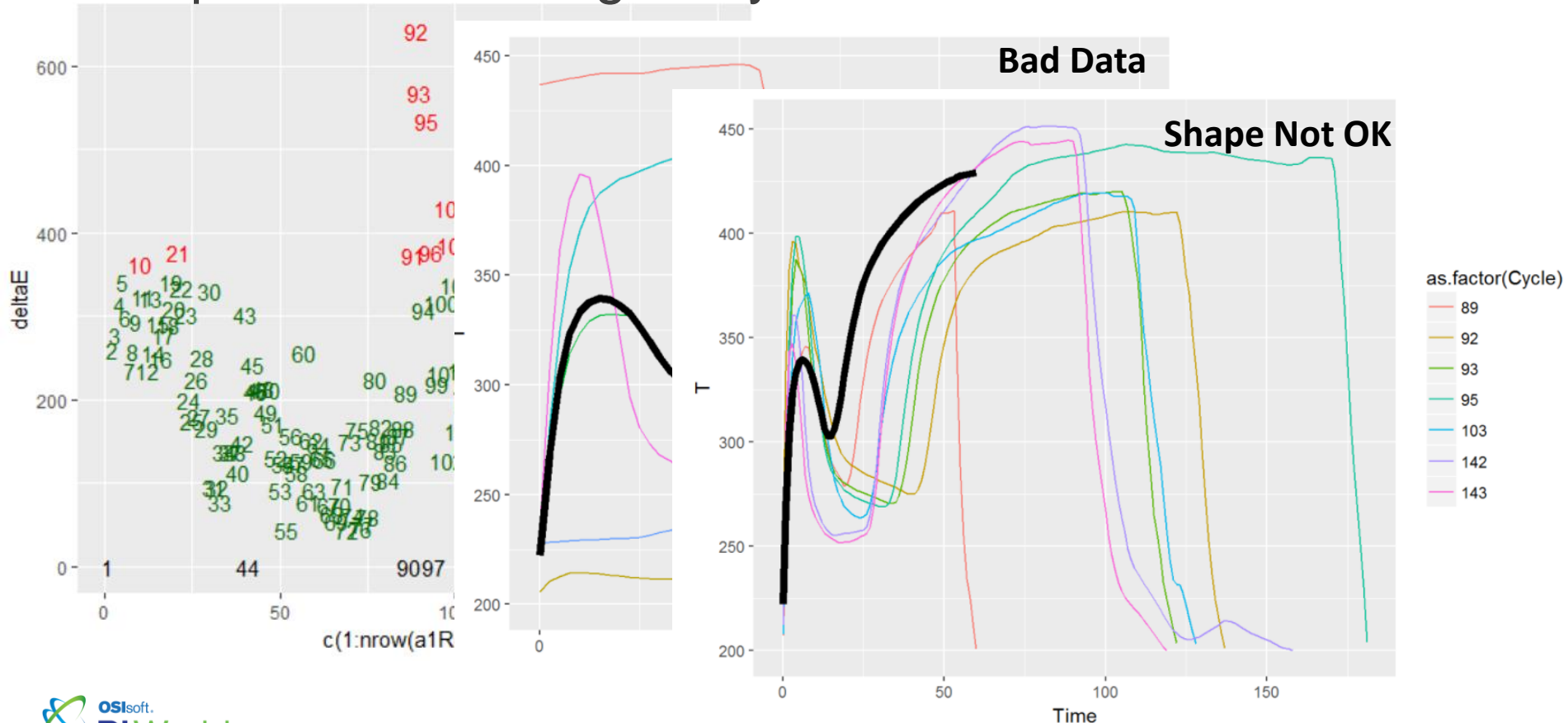
- Functional Objective - *Process Insight & Excellence*
 - Descriptive, diagnostic, predictive, prescriptive
- Business Scope - *Improved Reliability*
 - **Usage-based Maintenance** - UbM
 - **Condition-based Maintenance** - CbM
 - **Predictive Maintenance** - PdM
- Architectural Location
 - Edge device, Server or cloud based
- ...
- ...

Predictive and Prescriptive - Shape Metrics – Golden Run

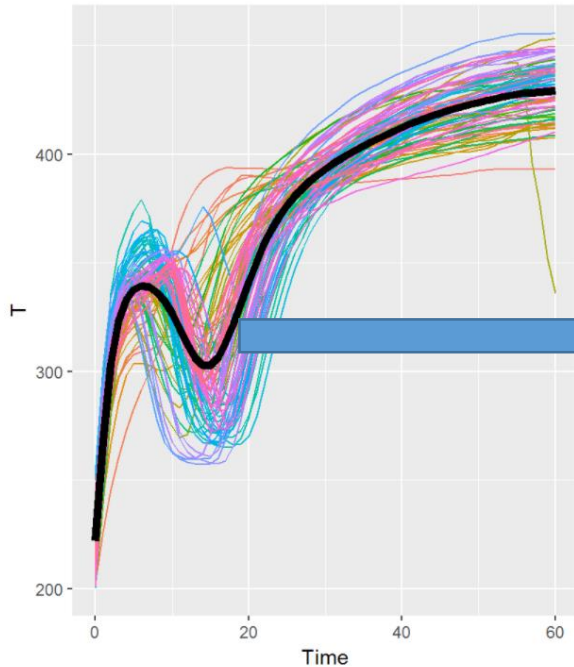
| | Id | Dryer | TimeStamp.StartTime.Local | TimeStamp.EndTime.Local | TimeStamp.Local | Duration | ElapsedTime | Dryer Pressure | Outlet Temperature | Rege | |
|---|----|---------|---------------------------|-------------------------|----------------------|----------|-------------|----------------|--------------------|-------|--------------------------|
| 1 | 1 | Dryer A | 1/2/2017 12:00:00 AM | 1/2/2017 5:18:00 AM | 1/2/2017 12:00:00 AM | 5.3 0 | 170.4697 | 436.9 | 603.2525 | 496.1 | Dryer A Regnerat |
| 2 | 2 | Dryer A | 1/2/2017 12:00:00 AM | 1/2/2017 5:18:00 AM | 1/2/2017 12:06:00 AM | 5.3 6 | 170.4824 | 437.8 | 603.6448 | 496.2 | Dryer A Regnerat |
| 4 | 3 | Dryer A | 1/2/2017 12:00:00 AM | 1/2/2017 5:18:00 AM | 1/2/2017 12:12:00 AM | 5.3 12 | 170.495 | 438.6 | 605.063 | 496.4 | Dryer A Regneration 01-C |
| 5 | 4 | Dryer A | 1/2/2017 12:00:00 AM | 1/2/2017 5:18:00 AM | 1/2/2017 12:18:00 AM | 5.3 18 | 170.5076 | 439.5 | 599.6411 | 496.8 | Dryer A Regnerat |
| 6 | 5 | Dryer A | 1/2/2017 12:00:00 AM | 1/2/2017 5:18:00 AM | 1/2/2017 12:24:00 AM | 5.3 24 | 170.5202 | 440.3 | 604.8259 | 496.8 | Dryer A Regnerat |
| 7 | 6 | Dryer A | 1/2/2017 12:00:00 AM | 1/2/2017 5:18:00 AM | 1/2/2017 12:30:00 AM | 5.3 30 | 170.5328 | 441.2 | 600.6193 | 496.2 | Dryer A Regnerat |
| 8 | 7 | Dryer A | 1/2/2017 12:00:00 AM | 1/2/2017 5:18:00 AM | 1/2/2017 12:36:00 AM | 5.3 36 | 170.5454 | 442.1 | 600.6193 | 497.2 | Dryer A Regneration 01-C |



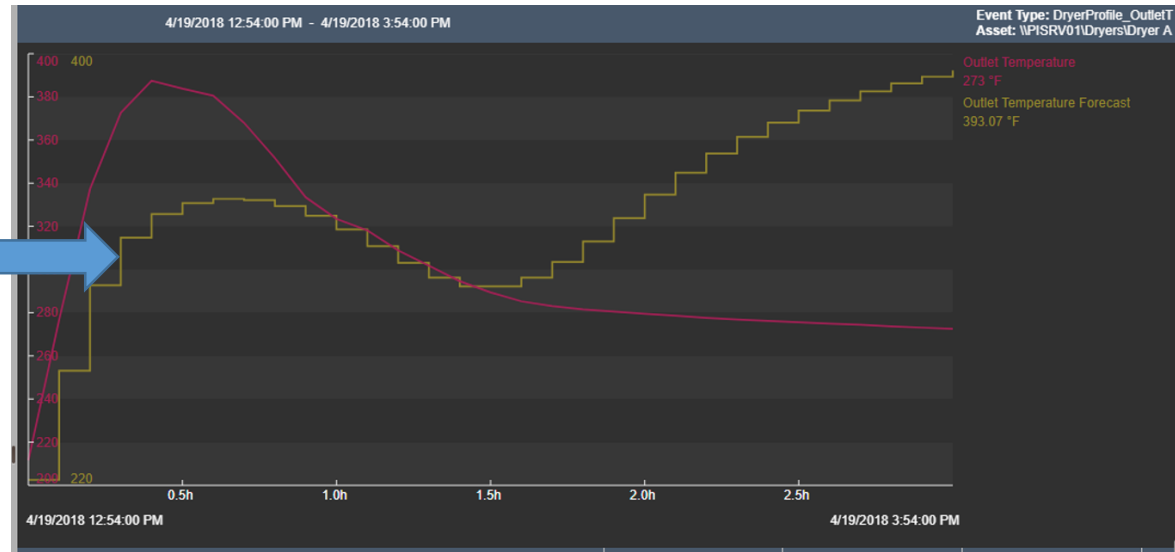
Shape Metrics - Regen Cycles Not OK or Bad Data



Operationalize - Expected Temperature Profile (Prescriptive)



Via Future data tag



Shape Metrics - Operationalize the Model

Score the real time Temperature profile data

is the Temperature profile as expected?

can the difference from ideal be stated quantitatively?

even if dissimilar, did we deliver enough energy?

what false alarms can I avoid?

after an alert, what corrective actions can I take?

| Name | Expression | Value at Evaluation | Value at Last Trigger | Output Attribute |
|--------------|----------------------------|---------------------|-----------------------|------------------|
| ShapeMeasure | IF 'Operating State'='Rege | | | Map |

Functions

Insert functions into the expression

MATLAB

CurveFitting.calcCurveDistance

Shape Metrics - Operationalize the Model

The screenshot displays the OSIsoft PI Vision interface. On the left, a configuration pane shows a variable named 'IdealData' with a MATLAB Eval block containing the logic: `If (ArrayLength(CurrentData, 1) > 0, IdealData, 0)`. The main area shows an email notification from 'pismtprelay@gmail.com' with the subject 'Dryer A generated a...' and a message: 'The Outlet Temperature profile for Dryer A at 12:54:00 PM Pacific Daylight Time...'. Below the email are links for 'Event Details Hyperlink' and 'https://5000vlecs.cloudapp.net/'. On the right, the 'Root Cause' analysis window is open, showing a line graph of 'Outlet Temperature' over time. The graph shows a peak around 0.5h and a subsequent decline. Below the graph is a table of trigger and event attributes.

| Trigger Attributes (2) | | Start Value | End Value | Units | |
|------------------------|-----------------------------|-------------|-----------|-------|--|
| Dryer A | DeltaAUC | 907.46 | 909.95 | | |
| Dryer A | DeltaE | 352.81 | 352.79 | | |
| Event Attributes (3) | | Value | Units | | |
| Root Cause | Outlet Temperature | 272.5 | °F | | |
| Root Cause | Outlet Temperature Forecast | 393.07 | °F | | |

3 hours into the process

Layers of Analytics – View Thru’ Multiple Lenses

- Functional Scope - *Process Insight & Excellence*
 - Descriptive, diagnostic, predictive, prescriptive
- Business Scope - *Improved Reliability*
 - **Usage-based Maintenance** - UbM
 - **Condition-based Maintenance** - CbM
 - **Predictive Maintenance** – PdM
 - *Simple predictive (Advanced CbM)*
 - *Advanced predictive - Statistical, Machine learning...*
- Architectural Location
 - Edge device, Server or cloud based
- ...

Maintenance – Usage and Condition based

- **Usage-based Maintenance - UbM**
 - **Motor Run-hours**
 - **Compressor starts/stops**
 - **Transformer – Load Tap Changer – Counts of Operations, Count thru' Neutral**
 - ...
- **Condition-based Maintenance - CbM**
 - **Delta P across a filter**
 - **High bearing temperature**
 - **High vibration**
 - ...

Maintenance – Usage based

See PI World 2018 CBM
Hand-on Lab

\\PI1\PI World 2018 - PI System Explorer (Administrator)

File Search View Go Tools Help

Database Query Date Back Check In Refresh New Element New Attribute

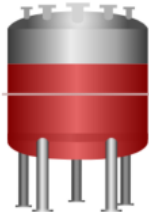
Elements

- Elements
 - Data Archive
 - Exercise 1
 - Process Area
 - Line 1
 - Mixer 1
 - Mixer 2
 - Line 2
 - Exercise 2
 - Element Searches

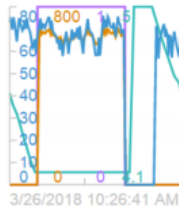
Mixer 1

General Child Elements Attributes Ports Analyses Notification Rules Version

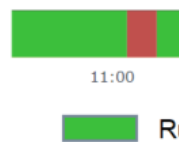
Filter



Mixer 1
509



3/26/2018 10:26:41 AM



11:00

| 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 |

| Name | Value | Units |
|-------------------------------------|-----------------------|-------|
| Mixer 1 Last Maintenance Date | 3/26/2018 12:00:00 AM | |
| Mixer 1 MTD Run Hours | 55.143 | h |
| Mixer 1 Previous Day Run Hours | 16.244 | h |
| Mixer 1 Run Hours Since Maintenance | 14.327 | h |
| Mixer 1 Valve Actuation Count Since | 16 | count |

| Name | Value | Units |
|-------------------------------------|-----------------------|-------|
| Mixer 1 Last Maintenance Date | 3/23/2018 12:00:00 AM | |
| Mixer 1 MTD Run Hours | 7.5494 | h |
| Mixer 1 Previous Day Run Hours | 0 | h |
| Mixer 1 Run Hours Since Maintenance | 7.5494 | h |
| Mixer 1 Valve Actuation Count Since | 62 | count |

| Name | Value | Units |
|-------------------------------------|-----------------------|-------|
| Mixer 2 Last Maintenance Date | 3/25/2018 12:00:00 AM | |
| Mixer 2 MTD Run Hours | 55.889 | h |
| Mixer 2 Previous Day Run Hours | 16.317 | h |
| Mixer 2 Run Hours Since Maintenance | 30.733 | h |
| Mixer 2 Valve Actuation Count Since | 34 | count |

| Name | Value | Units |
|-------------------------------------|-----------------------|-------|
| Mixer 2 Last Maintenance Date | 3/24/2018 12:00:00 AM | |
| Mixer 2 MTD Run Hours | 7.4606 | h |
| Mixer 2 Previous Day Run Hours | 0 | h |
| Mixer 2 Run Hours Since Maintenance | 7.4606 | h |
| Mixer 2 Valve Actuation Count Since | 53 | count |

Maintenance – Condition based

See PI World 2018 CBM
Hand-on Lab

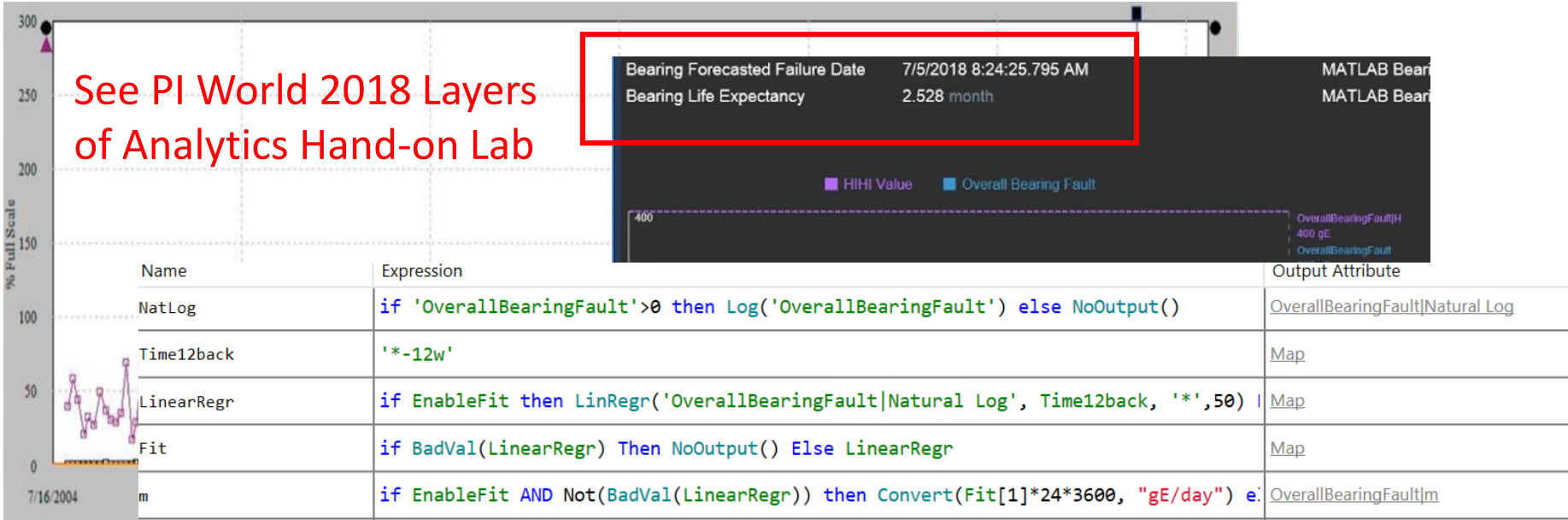
The screenshot displays the PI System Explorer interface. On the left, a tree view shows the hierarchy: Elements > Pump Station > Pump01 through Pump05. The main area shows a table titled "Ex2-BearingTemperatureAlerts" with the subtitle "Number and Duration of High Bearing Temperature Alerts". Below this is a "Watchlist of High Bearing Temperature Alerts" table.

| 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 |

| Event Name | Asset | Start Time | End Time | Reason | Acknowledged By | Acknowledged Date | Acknowledgement |
|---|--------|-----------------------|-----------------------|--------|-----------------|-------------------|------------------------------|
| High Bearing Temp_2018-0 3-27 05:25:00 | PUMP04 | 3/27/2018 5:25:00 AM | 3/27/2018 6:00:00 AM | | | | <button>Acknowledge</button> |
| High Bearing Temp_2018-0 3-27 06:40:00 | PUMP01 | 3/27/2018 6:40:00 AM | 3/27/2018 7:15:00 AM | | | | <button>Acknowledge</button> |
| High Bearing Temp_2018-0 3-27 07:50:00 | PUMP01 | 3/27/2018 7:50:00 AM | 3/27/2018 8:30:00 AM | | | | <button>Acknowledge</button> |
| High Bearing Temp_2018-0 3-27 07:50:00 | PUMP02 | 3/27/2018 7:50:00 AM | 3/27/2018 8:25:00 AM | | | | <button>Acknowledge</button> |
| High Bearing Temp_2018-0 3-27 09:00:00 | PUMP05 | 3/27/2018 9:00:00 AM | 3/27/2018 9:40:00 AM | | | | <button>Acknowledge</button> |
| High Bearing Temp_2018-0 3-27 09:00:00 | PUMP04 | 3/27/2018 9:00:00 AM | 3/27/2018 9:40:00 AM | | | | <button>Acknowledge</button> |
| High Bearing Temp_2018-0 3-27 09:40:00 | PUMP03 | 3/27/2018 9:40:00 AM | 3/27/2018 10:15:00 AM | | | | <button>Acknowledge</button> |
| High Bearing Temp_2018-0 3-27 11:05:00 | PUMP02 | 3/27/2018 11:05:00 AM | 3/27/2018 11:30:00 AM | | | | <button>Acknowledge</button> |

Maintenance – Predictive – RUL (remaining useful life)

See PI World 2018 Layers of Analytics Hand-on Lab



Bearing Forecasted Failure Date 7/5/2018 8:24:25.795 AM
 Bearing Life Expectancy 2.528 month

| 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) | 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 |

Predictive – Statistical, Machine Learning ...

Predict engine failure – Principal Components - TechCon 2016 [Link](#)

100 engines, 20+ sensors per engine, aggregated data per cycle

~200 cycles of operation per engine

how long to failure?

Anomaly detection (HVAC - Air Handler) - Support Vectors - TechCon 2017 [Link](#)

7 sensors

~6 months of operations, 5 minute data

damper stuck open? temperature transmitter failed? air supply fan constraint?

Shape Metrics (profiles of operating variables) - PI World 2018 Lab

...

Layers of Analytics – View Thru’ Multiple Lenses

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 - Descriptive, diagnostic, predictive, prescriptive
- Business Scope - *Improved Reliability*
 - **Usage-based Maintenance** - UbM
 - **Condition-based Maintenance** - CbM
 - **Predictive Maintenance** – PdM
 - *Simple predictive (Advanced CbM)*
 - *Advanced predictive - Statistical, Machine learning...*
- Architectural Location
 - Edge device, Server or cloud based
 - Analytics during data collection? (National Instruments, InsightCM)
- ...

OSIsoft Virtual Learning Environment

- Access to the hands-on labs developed for the past two Users Conferences (~40)
 - PI Products
 - PI System Development
 - Condition Based Maintenance
 - **Analytics with PI System Data**
- Hosted PI System on the Microsoft Azure Cloud
- Monthly or Yearly Subscription
 - Available to all customers via credit card payment
 - Free to EA Customers and Dev Club Members
- Great for Customer Demos
 - Elevate Awareness for OT and Data Science (IT?)
- <https://learning.osisoft.com>

| Yearly | | |
|--|--------|--------|
| AF SDK Getting Started Guide | Manual | Launch |
| Asset Based PI Example Kits | Manual | Launch |
| Field Service Scripts | Manual | Launch |
| PI Programming (Japanese) | Manual | Launch |
| TechCon 2016: Administering and Managing the PI Server | Manual | Launch |
| TechCon 2016: Advanced PI Web API | Manual | Launch |
| TechCon 2016: Advanced Programming with PI AF SDK | Manual | Launch |
| TechCon 2016: Build Better Reports with PI SQL Framework | Manual | Launch |
| TechCon 2016: Build Web-Based Real-Time Dashboards | Manual | Launch |
| TechCon 2016: Collecting Data using the new PI Connector for UFL | Manual | Launch |
| TechCon 2016: Condition Based Maintenance with PI AF | Manual | Launch |
| TechCon 2016: Developing Cross-platform Mobile Apps Using Apache Cordova and PI Web API | Manual | Launch |
| TechCon 2016: Downtime Analysis with Event Frames | Manual | Launch |
| TechCon 2016: Operational Insights Using Real-time Dashboards and Self-service Business Intelligence | Manual | Launch |

Thank You



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- OSIssoft, LLC

Questions

Please wait for the **microphone** before asking your questions



State your **name & company**

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Спасибо

Danke

Gracias

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Grazie

Obrigado