OSIsoft UC 2017 Lab

Incorporating Condition Monitoring Data -Vibration, Infrared and Acoustic for Condition-based Maintenance

OSIsoft, LLC
1600 Alvarado Street
San Leandro, CA 94577 USA
Tel: (01) 510-297-5800
Web: http://www.osisoft.com

Published: March 6, 2017

Condition-based Maintenance – Hands-on Lab – OSIsoft Users Conference 2017

Lead: Gopal GopalKrishnan, P.E., Solution Architect

Lead: Keith Pierce, Solution Architect

Instructor: LP Page-Morin, Sr. Systems Engineer

Instructor: François Pelletier-Bouchard, Systems Engineer

Table of Contents

Table of Figures

Incorporating Condition Monitoring Data – Vibration, Infrared and Acoustic for Condition-based Maintenance

Lab Description

Traditionally, the PI System has worked with process data from plant instrumentation such as PLC and SCADA. However, newer IoT and edge device capabilities allow you to bring data from condition monitoring systems such as vibration, infrared (thermography), acoustic, etc. to the PI System. Take this lab to learn how to use condition-monitoring data along with process data in your condition-based maintenance programs to improve equipment uptime. The lab will also include the use of alert roll-ups, watch lists, KPIs and others for a holistic view of asset health and reliability.

Level: 200   Duration: 2 hours

Summary

Condition-based maintenance (CBM) is a strategy where you monitor the actual condition of an asset to decide what maintenance needs to be done – see wiki for a broader definition.

The learning objectives for this lab are:

- Understand the condition monitoring (CM) data collection process –with a live demo of a hand-held device used for collecting vibration, infrared and acoustic data for a motor
- Understand how the condition monitoring data is transformed and written to PI
- Configure condition assessment calculations for the CM data and recognize the use of dynamic thresholds for the CM data
- Incorporate CM data such as oil analysis (that may reside in external databases) in the condition assessment calculations
- Incorporate manual input CM data (aka operator rounds) from PI Manual Logger
- Create displays, notifications, alerts watch list etc. using various PI System capabilities and tools
- Review the PSE&G customer use case on combining PI System data with CM data for calculating asset health score

In this lab, we will use a hand-held device to collect vibration, infrared, and acoustic data. The device is a Windows 10 based unit (it can also be an iPad) with suitable attachments based on National Instruments http://www.ni.com technologies. Please see AR-C10 for hardware details.

Figure 1: AR-C10 Unit

With such condition monitoring (CM) data, typically we do not store the raw data in the PI System. Instead, the data is transformed, and aggregate/derived values are written to the PI System.

Even though you can store raw CM data in the PI System,
it is out-of-scope for this lab.

For vibration data, the raw time-series wave form may have 10,000 or more values per second, and often data is collected for several seconds (depending on the motor rpm and other analysis requirements). This time-series (time domain) data is converted to frequency-domain using FFT (Fast Fourier transform). And, calculated values derived from both time-series wave-form and FFT analysis are written to the PI System.

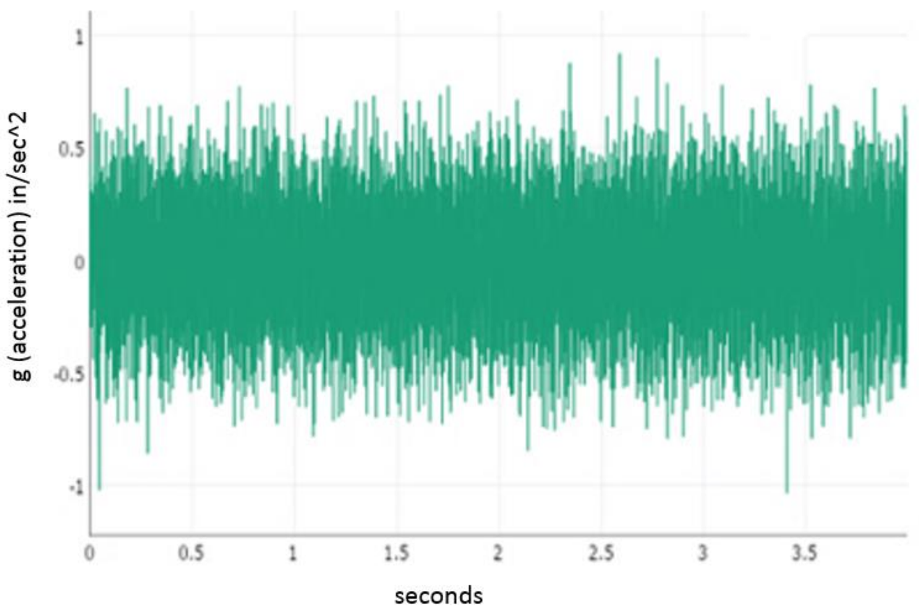


Figure 2: g (acceleration, y-axis) vs. time (x-axis) - Vibration time-series wave form, about 10,000 readings per second

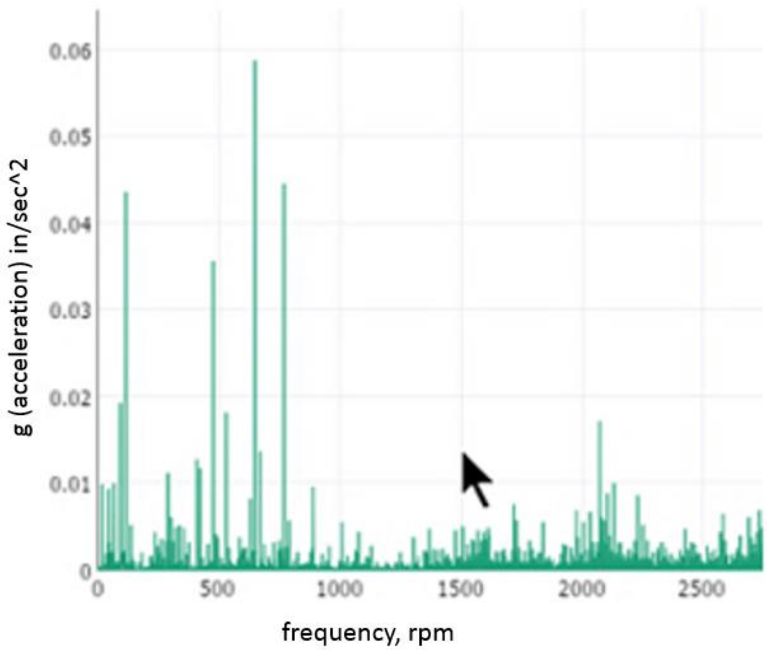
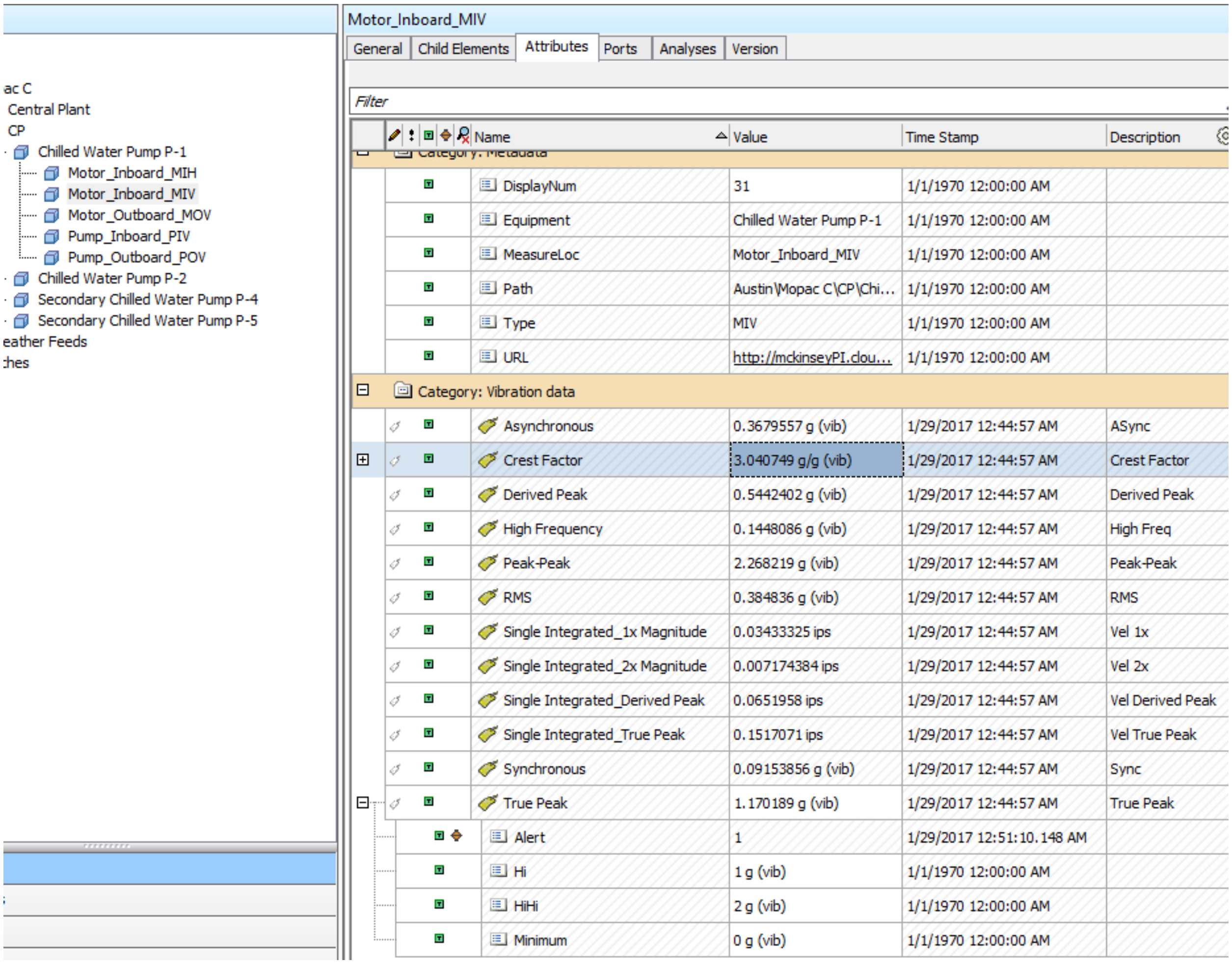


Figure 3: rms value g (acceleration, y-axis) vs. frequency (x-axis) - Vibration time-series waveform data is converted to frequency domain using FFT analysis



Name	Value	Time Stamp	Description
Category: Metadata			
DisplayNum	31	1/1/1970 12:00:00 AM	
Equipment	Chilled Water Pump P-1	1/1/1970 12:00:00 AM	
MeasureLoc	Motor_Inboard_MIV	1/1/1970 12:00:00 AM	
Path	Austin\Mopac C\CP\Chi...	1/1/1970 12:00:00 AM	
Type	MIV	1/1/1970 12:00:00 AM	
URL	http://mckinseyPI.clou...	1/1/1970 12:00:00 AM	
Category: Vibration data			
Asynchronous	0.3679557 g (vib)	1/29/2017 12:44:57 AM	ASync
Crest Factor	3.040749 g/g (vib)	1/29/2017 12:44:57 AM	Crest Factor
Derived Peak	0.5442402 g (vib)	1/29/2017 12:44:57 AM	Derived Peak
High Frequency	0.1448086 g (vib)	1/29/2017 12:44:57 AM	High Freq
Peak-Peak	2.268219 g (vib)	1/29/2017 12:44:57 AM	Peak-Peak
RMS	0.384836 g (vib)	1/29/2017 12:44:57 AM	RMS
Single Integrated_1x Magnitude	0.03433325 ips	1/29/2017 12:44:57 AM	Vel 1x
Single Integrated_2x Magnitude	0.007174384 ips	1/29/2017 12:44:57 AM	Vel 2x
Single Integrated_Derived Peak	0.0651958 ips	1/29/2017 12:44:57 AM	Vel Derived Peak
Single Integrated_True Peak	0.1517071 ips	1/29/2017 12:44:57 AM	Vel True Peak
Synchronous	0.09153856 g (vib)	1/29/2017 12:44:57 AM	Sync
True Peak	1.170189 g (vib)	1/29/2017 12:44:57 AM	True Peak
Alert	1	1/29/2017 12:51:10.148 AM	
Hi	1 g (vib)	1/1/1970 12:00:00 AM	
HiHi	2 g (vib)	1/1/1970 12:00:00 AM	
Minimum	0 g (vib)	1/1/1970 12:00:00 AM	

Figure 4: PI System Explorer screen showing the various AF attributes (see Category - Vibration data); values derived from time-series wave-form and FFT analysis for each sample are written to the PI System

Infrared – a non-contact technology – is convenient for measuring temperatures of mechanical equipment (motors), electrical equipment (circuit contacts), and others. The device interprets the image and estimates the temperature at the crosshair location and the temperature(s) are written to the PI System.

Figure 5: Infrared camera image for a motor – the crosshair identifies the location for estimating the surface temperature – Motor at 69.6 ºF (left image) and at 85.4 ºF (right image)

> Native infrared images can be stored in the PI System but is out-of-scope for this lab.

Ultrasonic measurements are made using acoustic sensors which measure sound waves, including high frequency sounds – above human hearing range. Acoustic sensors can “hear” the sounds from internal friction or metal deformation - in Figure 6, the ultrasound level increases from about 10dB to 40dB.

The raw acoustic waveform is similar to those for vibration. FFT analysis transforms the time-domain data to frequency-domain, and overall sound level in decibels (dB) is written to the PI System.

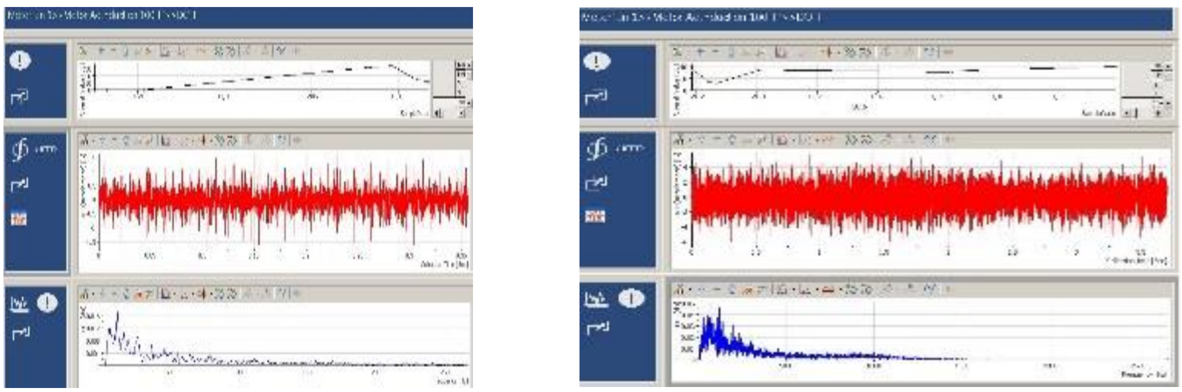


Figure 6: Acoustic time-series wave form (in red) and frequency plot (in blue); sound level has increased from 10 dB to 40 dB between the left and right sample for the same motor

Regarding condition assessment, with the CM data in the PI System, you can use the various PI System capabilities such as AF Analytics, Event Frames, Notifications, OSIsoft Visualization displays, watch-list, and others.

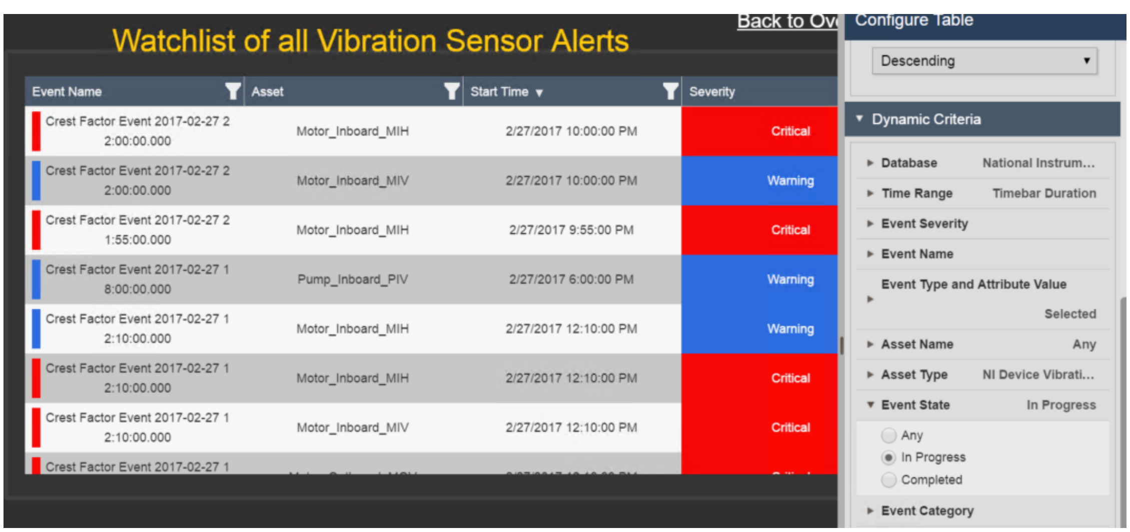


Figure 7: OSIsoft Visualization screen – Watch list of Alerts from vibration measurements exceeding threshold limits

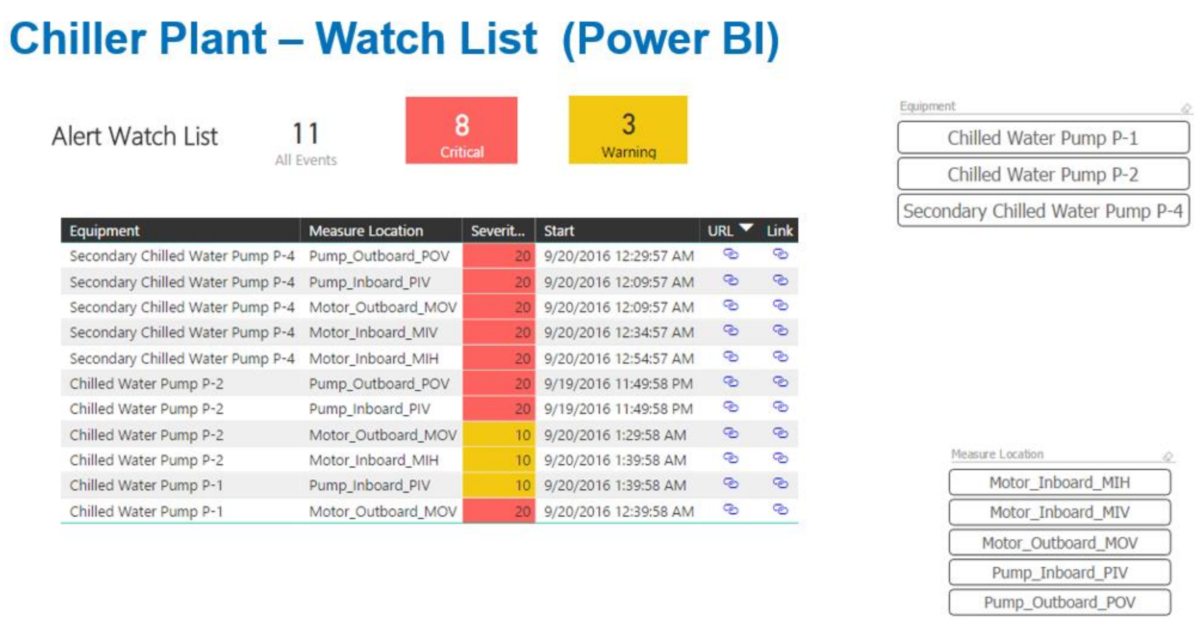


Figure 8: Microsoft Power BI screen - Watch list of Alerts from vibration measurements exceeding threshold limits

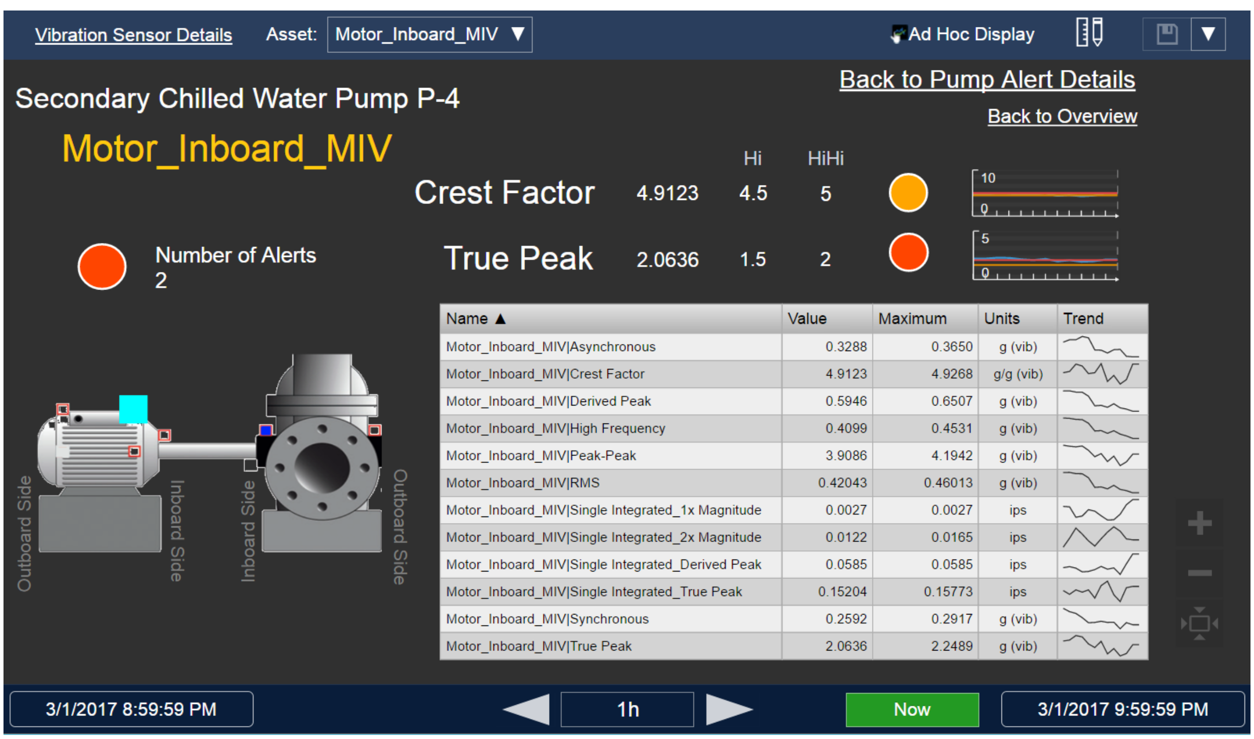


Figure 9: OSIsoft Visualization screen for Pump P-4 Motor Inboard Vertical

An example condition assessment for infrared temperature measurement is a rate-of-change logic, say, an increase of more than 20 ^{o}F in a 24-hour period for a motor running under similar operating conditions.

For acoustic data, an increase in the overall sound level (decibels) above a threshold level can be used to set an alert.

With access to both CM data and process data in the PI System, you can also specify dynamic threshold limits for condition assessment – for example, a higher vibration threshold for a pump at full load vs. another at partial load.

Finally, you can also combine SCADA/PLC data with CM data to calculate asset health score.

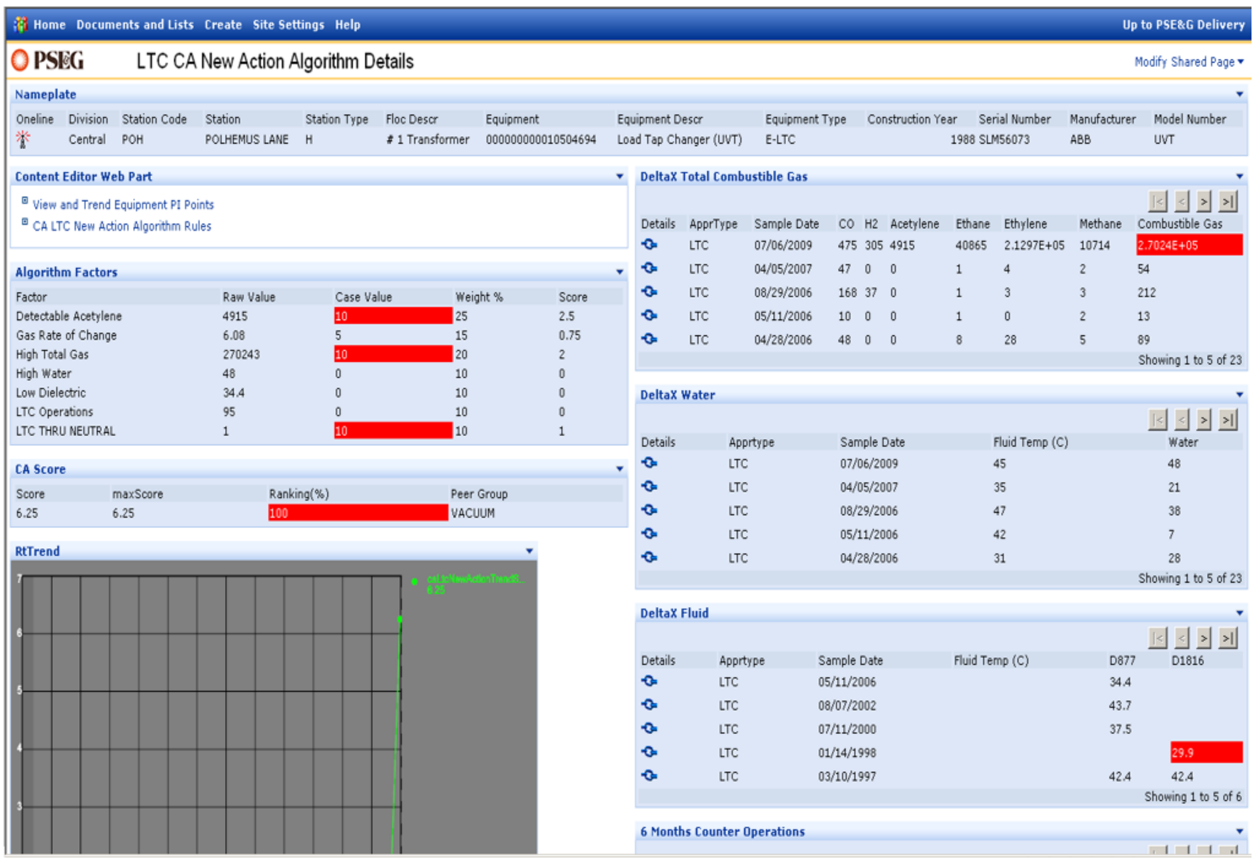


Figure 10 PSE&G use case showing asset health (condition assessment) score for a distribution transformer – load tap changer (LTC)

As previously mentioned, the learning objectives for this lab are:

- Understand the condition monitoring (CM) data collection process –the lab includes a live demo with a portable device for collecting vibration, infrared and acoustic data for a motor
- Understand how the condition monitoring data is transformed and written to PI
- Configure condition assessment calculations for the CM data and understand the use of dynamic thresholds for the CM data
- Incorporate CM data such as oil analysis (that may reside in external databases) in the condition assessment calculations
- Incorporate manual input CM data (aka operator rounds) from PI Manual Logger
- Create displays, notifications, alerts watch list etc. using various PI System capabilities and tools

PI System software

The VM (virtual machine) used for this lab has the following PI System software installed:

Software	Version
PI Data Archive	2016 R2
PI Asset Framework (PI AF) server	2017 (pre-release)
PI Asset Framework (PI AF) client (PI System Explorer)	2017 (pre-release)
PI Analysis & PI Notifications Services	2017 (pre-release)
OSIsoft Visualization	2017 (pre-release)
PI Web API	2017 (pre-release)
PI Connector for UFL	2016

For details on PI System software, please see http://www.osisoft.com/pi-system/pi-capabilities/product-list/

Exercise 1 – Use a hand-held device to collect Vibration, Infrared and Acoustic data

The device is a Windows10 unit (can also be an iPad) with suitable attachments based on National Instruments http://www.ni.com technologies. Please see AR-C10 for hardware details.

Figure 11: AR-C10 Device

Video demo – data collection with the AR-C10 device.

During the lab, the instructor will collect the data for a motor rotating at 1800 rpm.

Figure 12: AR-C10 device with three sensors connected to it.

In Exercise 2, since we need several vibration data samples for analysis, we will be using data from a continuous online system but with data similar to those collected by the hand-held device.

Exercise 2 – Analyze Vibration data

In this exercise, you analyze the accelerometer measurements from an online vibration data-collection system [National Instruments InsightCM](). Data is captured by the [NI cRIO]() module, an FFT analysis is performed at the edge, and select data is written to the PI System.

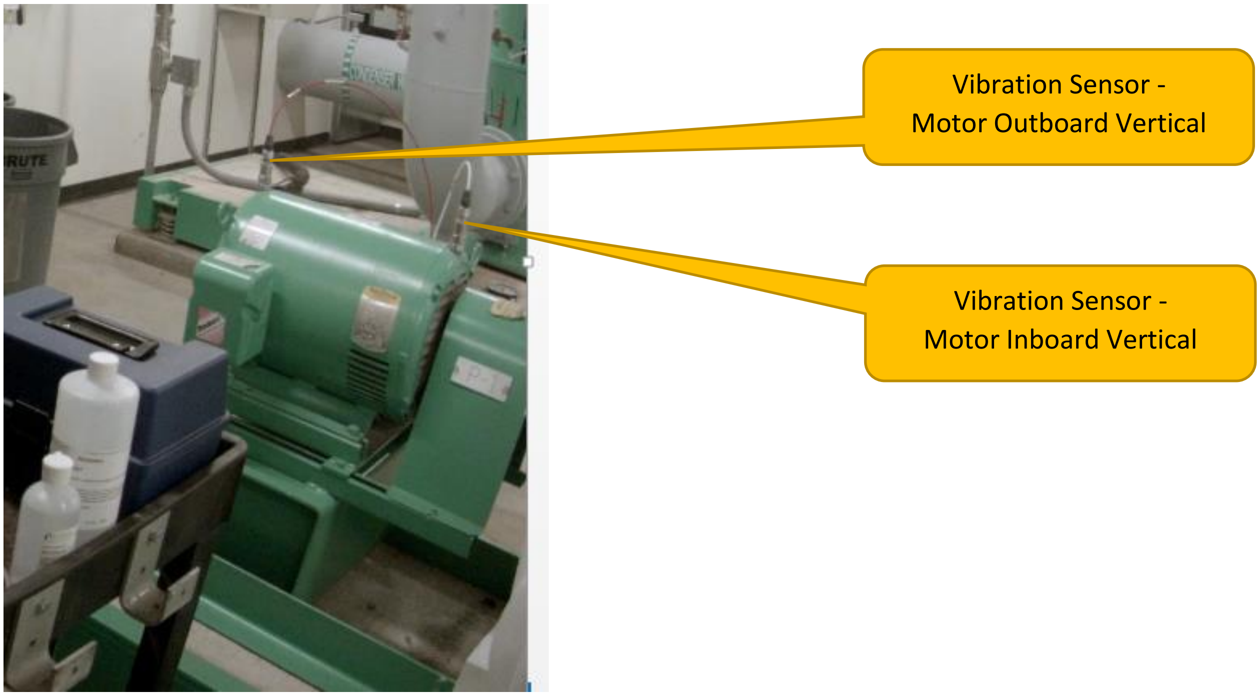


Figure 13: Vibration data collection for a Chilled Water Pump-Motor

The sensors installed on chilled water pumps (motor-pump assembly) are:

- Motor Inboard Vertical (MIV)
- Motor Inboard Horizontal (MIH)
- Motor Outboard Vertical (MOV)
- Pump Inboard Vertical (PIV)
- Pump Outboard Vertical (POV)

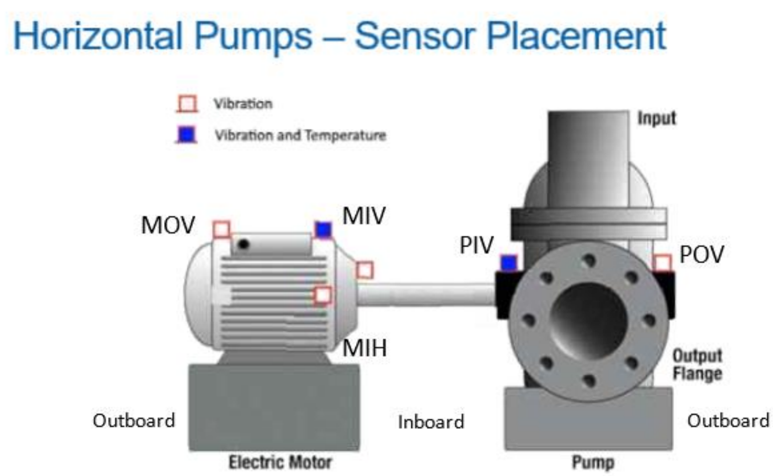
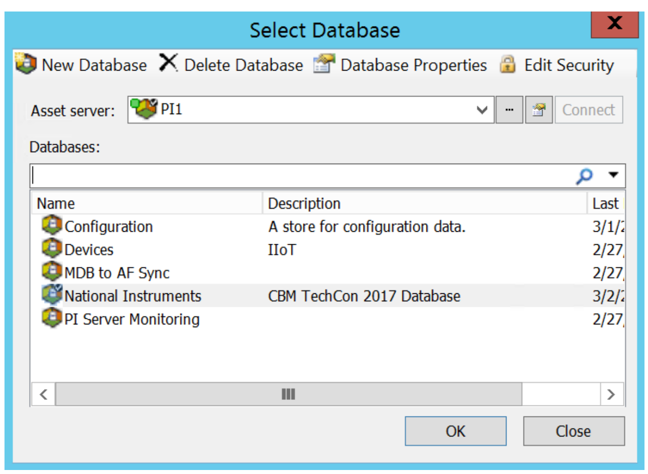


Figure 14: Chilled water pump-motor with vibration sensors

In Step 1, we review the vibration sensor data organized using the equipment hierarchy in PI Asset Framework. We also review the condition assessment calculations for setting alert levels when vibration exceeds defined threshold limits.

Step 1: AF configuration for sensor data

1. Open **PI System Explorer**, and connect to the **National Instruments** PI AF database. If the top bar of the window does not show \\PI1\National Instruments, then click on the top toolbar Database button to select the PI AF database.



2. From the AF equipment hierarchy, drill down under Austin > Mopac C > CP > Chilled Water Pump P-1 > **Motor_Inboard_MIV**. Click on the Attributes tab.

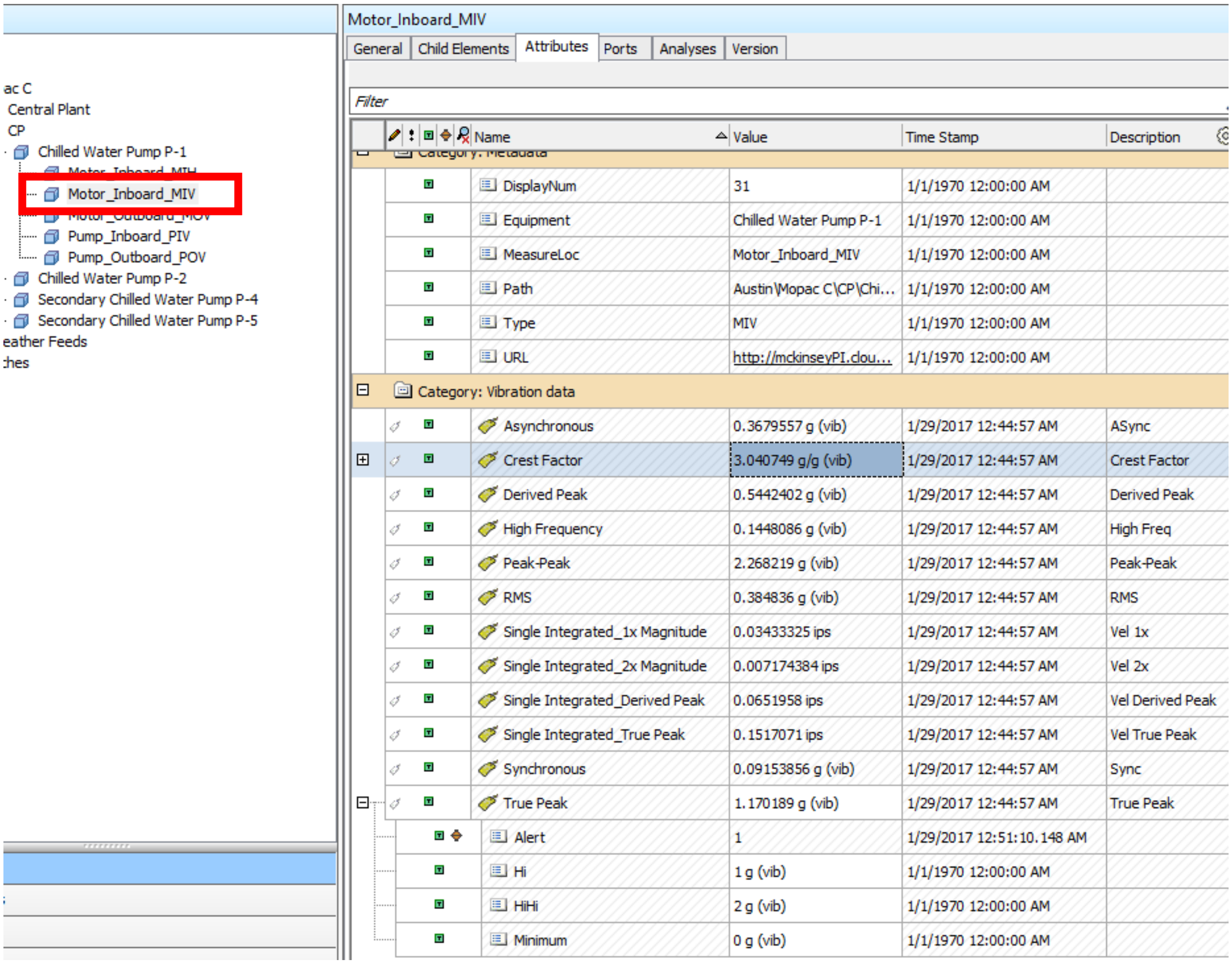


Figure 15: PI System Explorer screen showing readings for the MIV (Motor Inboard Vertical) vibration sensor; note the Hi, and HiHi limit settings for the True Peak alert calculation

3. Select the **Crest Factor** attribute and expand its child attributes to view the limits. Repeat the same for the **True Peak** attribute. The limits are defined in AF - but these can also be referenced from an external system using the Table Lookup feature.
4. Select the **Motor_Inboard_MIH** (horizontal sensor) element of the **Chilled Water Pump P-1**, and confirm that the attributes are the same. Both Pump P-1 and P-2 use same Element Template, named **NI Device Vibration**.

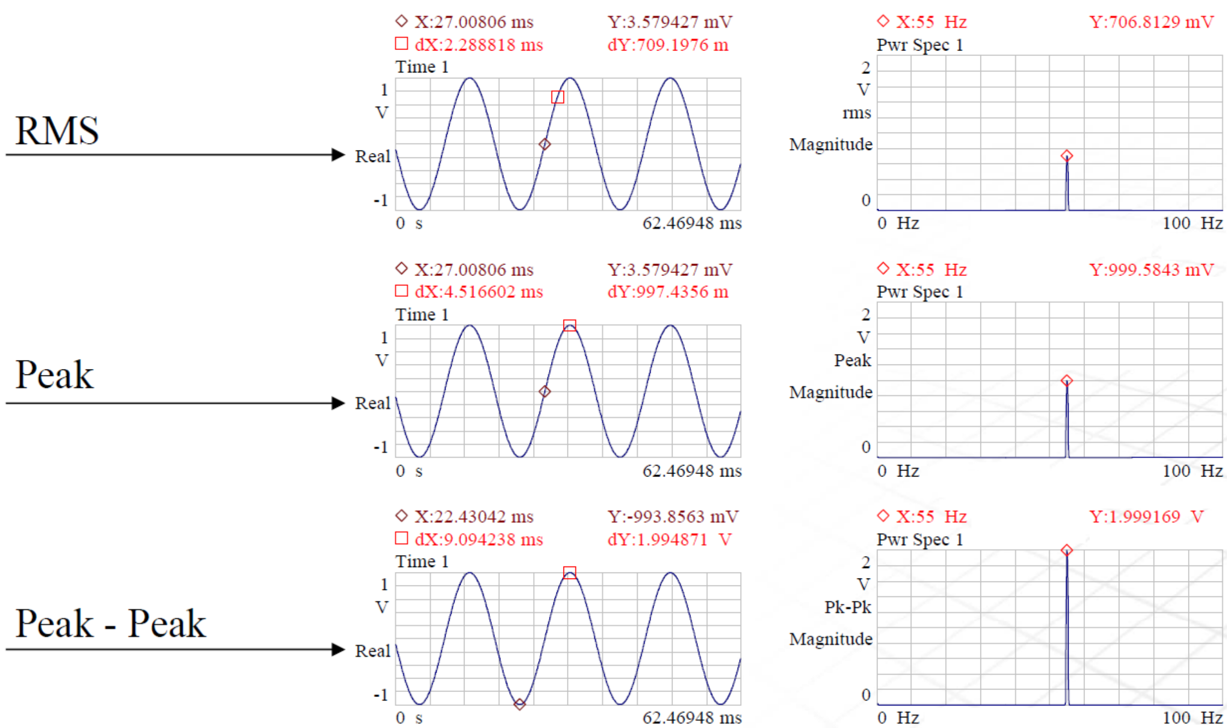
Note: Your vibration data collection vendor may not expose the same number of calculated values as provided by National Instruments and shown in the Attributes category.

The definition for a few of the attributes are:

Vibration Data	Definition
True Peak	The maximum of the positive peak and negative peak
Peak-Peak	The positive peak minus the negative peak
RMS	The root mean square of the signal
Derived Peak	RMS × √2
Crest Factor	True Peak / RMS

Please see http://zone.ni.com/reference/en-XX/help/374419A-01/cmanlsmain/features_definitions/ for more details.

To better understand Peak, Peak-to-Peak, and RMS values, please see the diagrams below for a sine wave:



Step 2: Condition assessment

The vibration sensor measurements are written to the PI System every 5 minutes. The figure below shows a simple threshold-based Hi alert calculation for the Crest Factor.

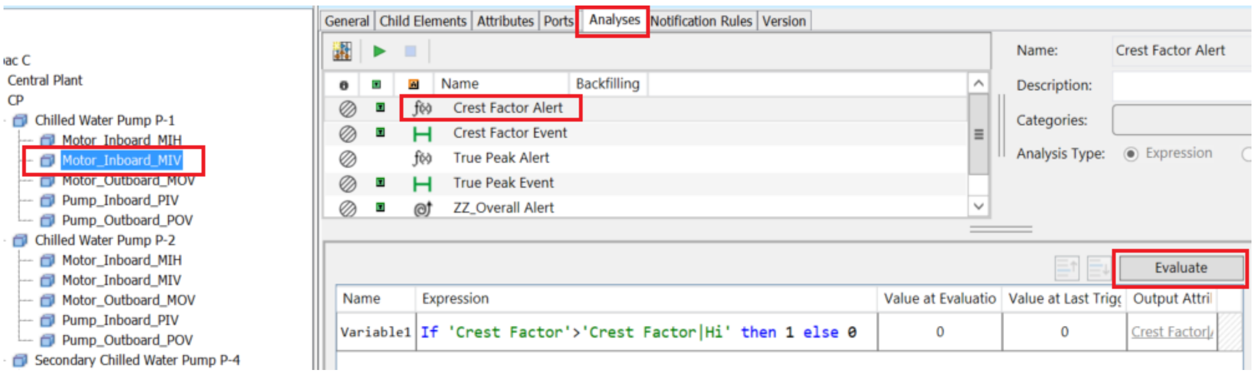
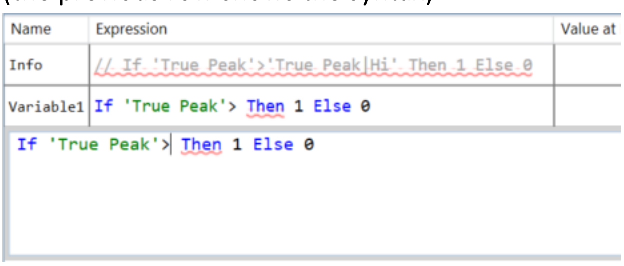


Figure 16: Alert calculation for Crest Factor

1. Select Chilled Water Pump P-1 > **Motor_Inboard_MIV** element and review the calculations in the Analyses tab as shown in the above figure.
2. Select the **Crest Factor Alert** analysis and examine its Expression, then click the **Evaluate** button. Value at Evaluation will show 0 (Not Active) or 1 (Active).
3. Next, select the **True Peak Alert** analysis.
4. Write an expression to test whether or not the True Peak data is above the Hi limit.
   a. Position the cursor in the **Variable1** Expression, where it states "*Type an expression*" (the previous row shows the syntax)

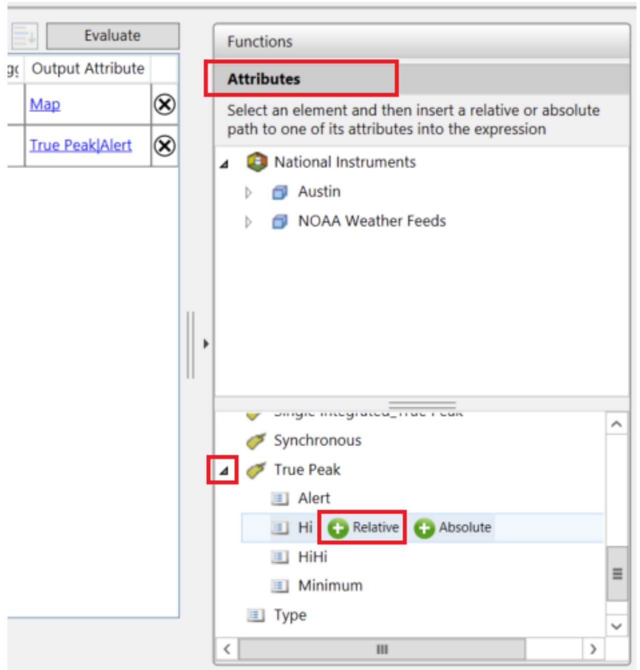


b. An If-Then-Else statement will be used along with a simple "greater-than" comparison to determine if the alert flag should be set to 0 or 1.

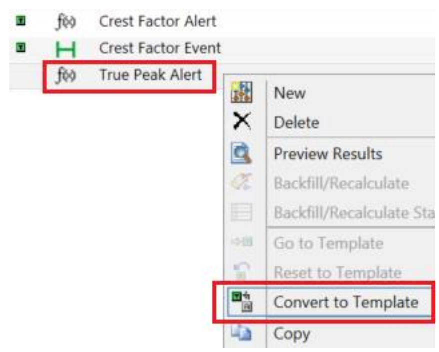
c. Start typing the following expression (Intellisense like feature helps you to quickly complete the expression):

If 'True Peak'> Then 1 Else 0

d. Then add the reference to the **Hi** limit next to the greater-than (">") sign. Do this by selecting - add a **Relative** reference to the **Hi** attribute. Please ensure that you first select the **Attributes** section from the right-hand side panel (at the bottom) as shown in this figure →



5. Evaluate the newly added expression using the **Evaluate** button.
6. Save your changes by clicking the Check In button from the top toolbar.
7. This analysis expression now only exists for the inboard vertical vibration sensor of pump P-1.
   In order to deploy this analysis to all vibration sensors of the same type, right-click the **True Peak Alert** analysis from the list of analyses, and select **Convert to Template**.
8. Confirm that the analysis has propagated to all sensors with current Element template.



The analysis executes every time new vibration data comes into the PI System. If the value is above the Hi threshold, then the Alert flag will be set to 1 - for both Crest Factor and True Peak.

Step 3: Alert rollup

The individual alerts can be rolled up to get an overall Alert level for an asset or a group of assets. Please see **ZZ_Overall Alert** – it uses the Rollup calculation to sum all alerts from each sensor location.

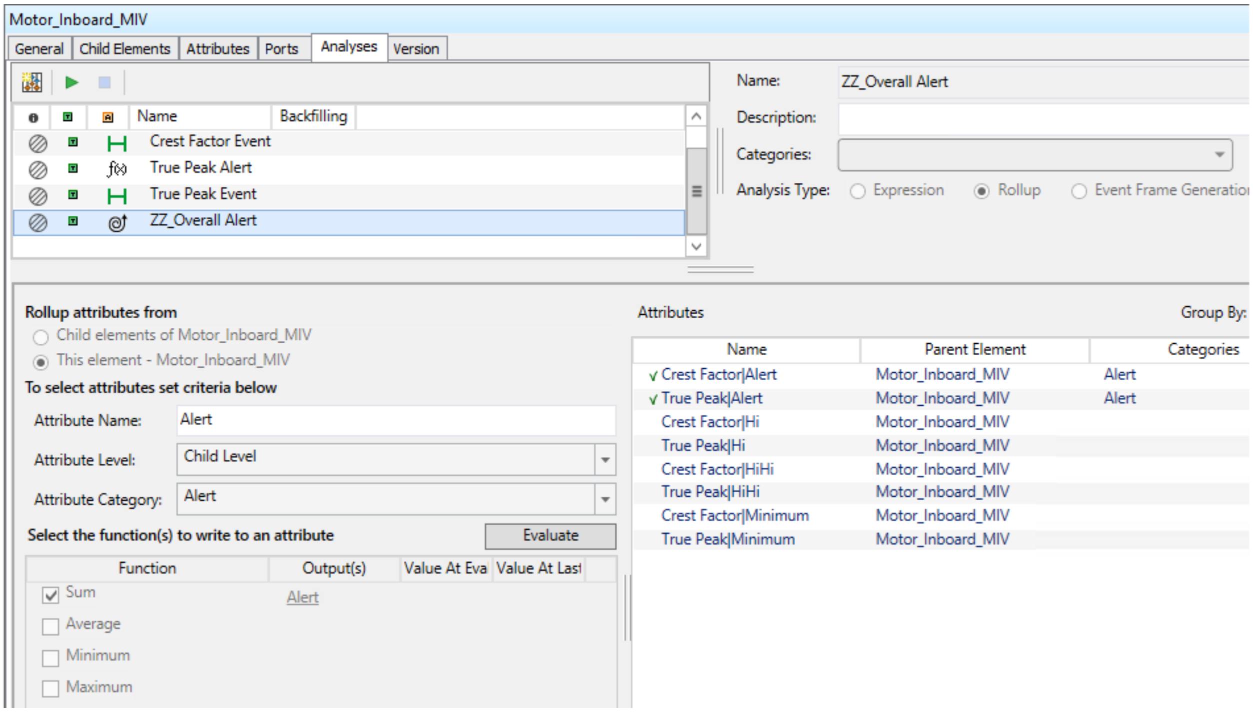
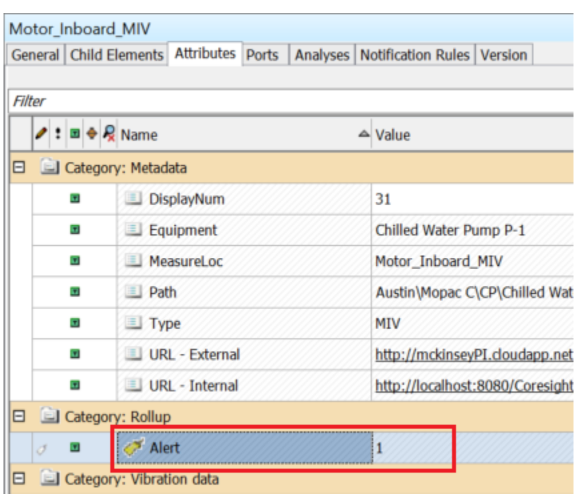


Figure 17: Motor Inboard Vertical (MIV) vibration sensor alert rollup.

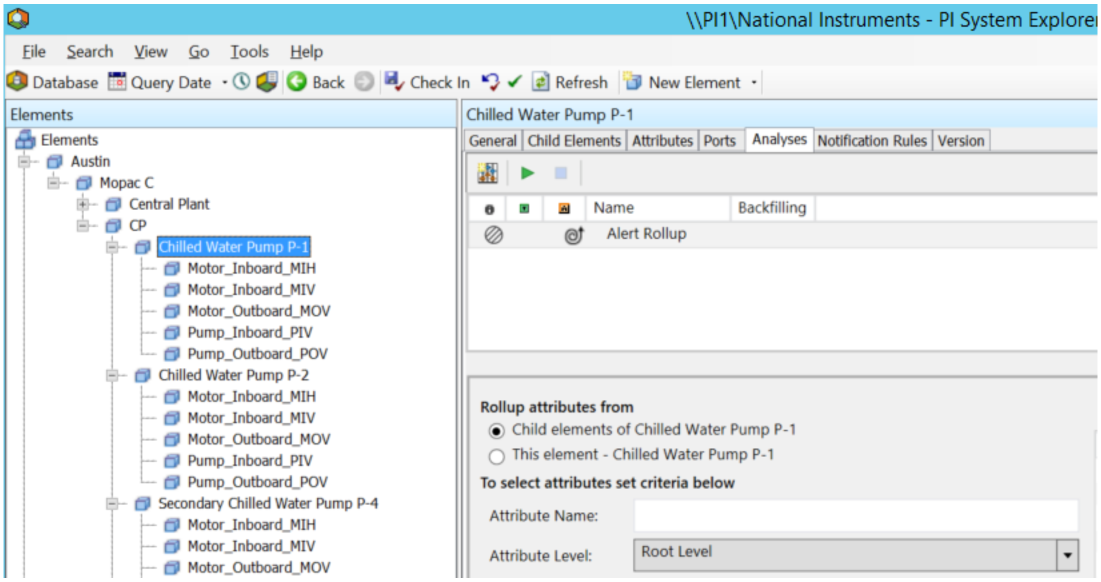
1. Review **ZZ_Overall Alert** rollup analysis for one of the vibration sensor element as shown in the above figure.
2. Note the rollup configuration where a filter retrieves only the child attributes named **Alert**. The rollup analysis then sums the alert value for all the attributes, and writes the result to its own Alert attribute.
3. Click the **Evaluate** button, and confirm the same value is available by examining the **Alert** attribute of the element.



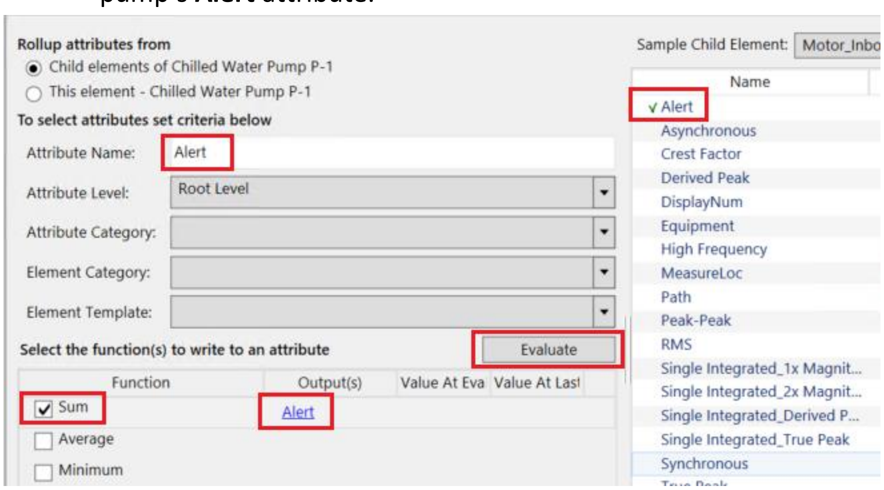
The total number of alerts is now at each sensor level, but it is also useful to have it at the pump level, and eventually, at the plant/site, division, company level.

This is especially useful when high-level dashboards need to show aggregated or rolled-up data. Let us now configure a rollup for the pump level assets.

4. Select the **Chilled Water Pump P-1** element from the left hierarchy and select its **Analyses** tab.



5. Finalize the configuration of the **Alert Rollup** analysis.
   a. Filter by **Attribute Name**, by entering the value **Alert**.
   b. Confirm that the filter found an attribute from the right-hand side list of attributes.
   c. Check the **Sum** function to perform a sum of Alert values and map its output to the pump's **Alert** attribute.



6. Click the **Evaluate** button to confirm a valid calculation.
7. Click on the Check In button from the top toolbar to save your changes.
8. Assign this analysis to the pump template by right-clicking the **Alert Rollup** analysis and selecting **Convert to Template**.

Note that this analysis is configured to execute periodically, every 30 seconds.

Step 4: Visualization of the data and alerts

We use OSIsoft Visualization to visualize the measurement data from the sensors. Click on the URL below to display the alert status for the chilled water pumps:

https://pi1.pischool.int/PIVision/#/Displays/38/Pumps-Alert-Overview

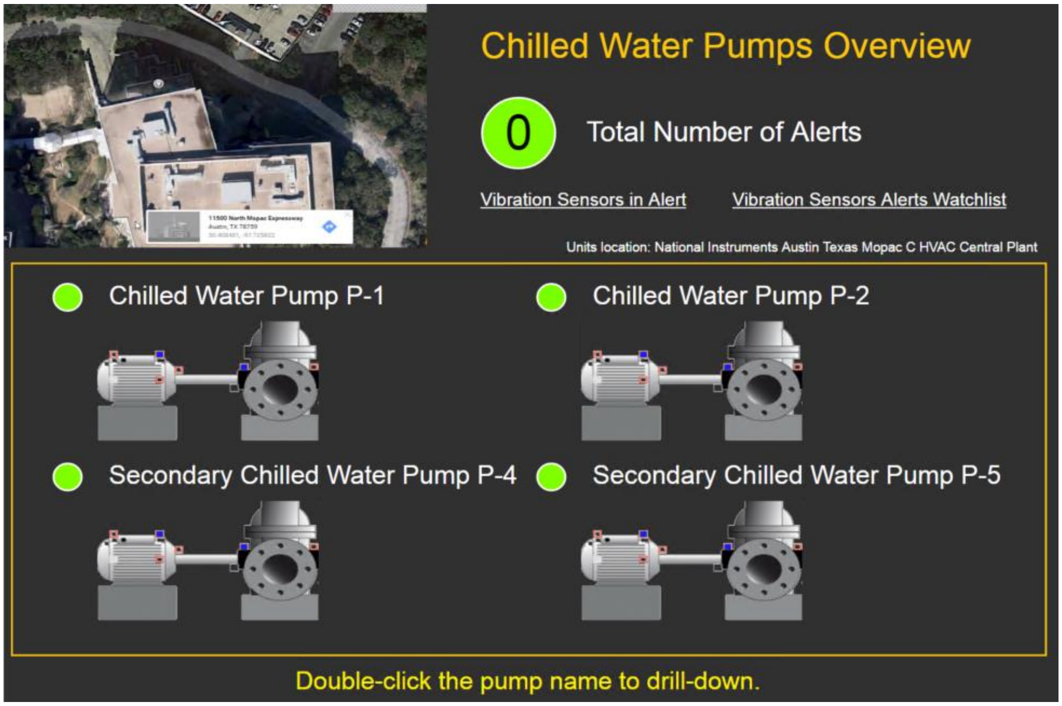


Figure 18: Home screen for the chilled water pumps alert monitoring

The following screen show how to drill-down and navigate among related displays:

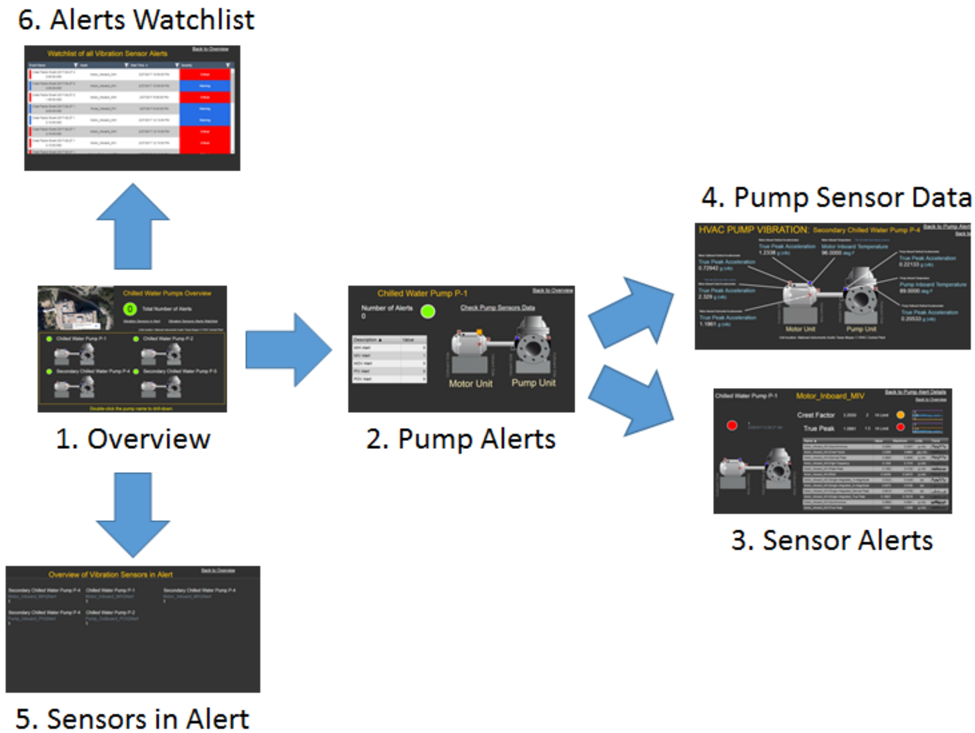


Figure 19: OSIsoft Visualization drill-down capability for chilled water pump alerts

Displays 2, 3, and 4 shown above are element relative and re-usable for similar assets.

Navigate to the Sensor Alerts display from the above figure (https://pi1.pischool.int/PIVision/#/Displays/40/Vibration-Sensor-Details).

1. From the **Asset** pick list, select a different vibration sensor. Hover over the element name to see the full AF path with the pump name.

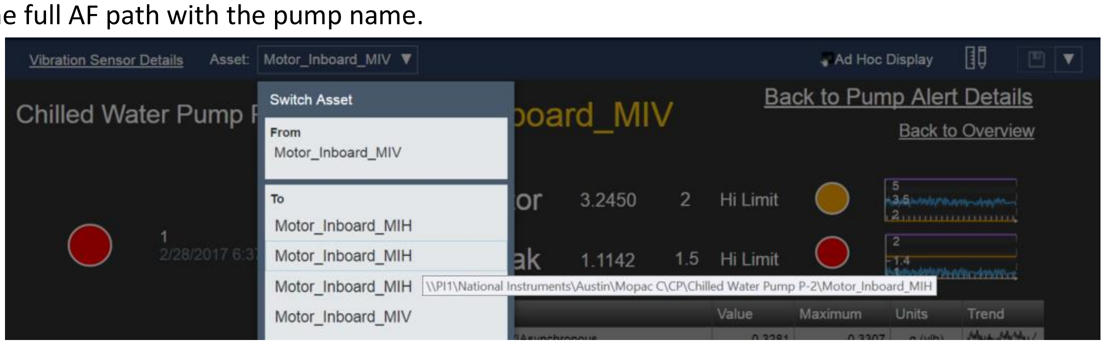


Figure 20: Switch asset pick-list for the Vibration Sensor Details display

The most recent release of OSIsoft Visualization introduces a new Collections feature.

2. Navigate to the Sensors in Alert display (https://pi1.pischool.int/PIVision/#/Displays/42/Vibration-Sensors-Alert-Overview) to view a list of all Alert attributes for all vibration sensors.

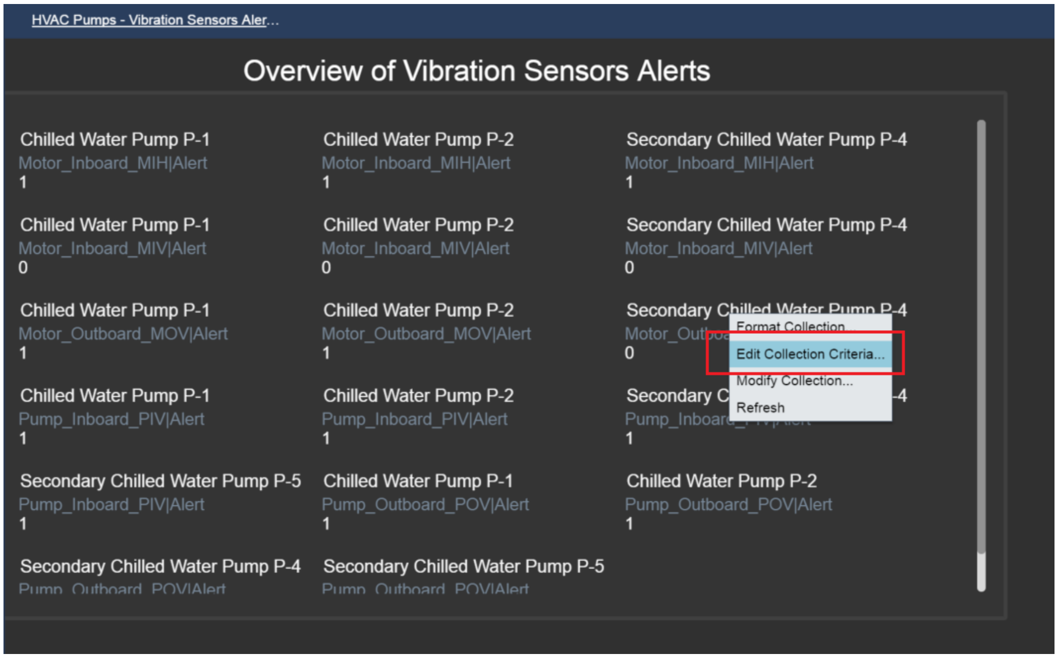
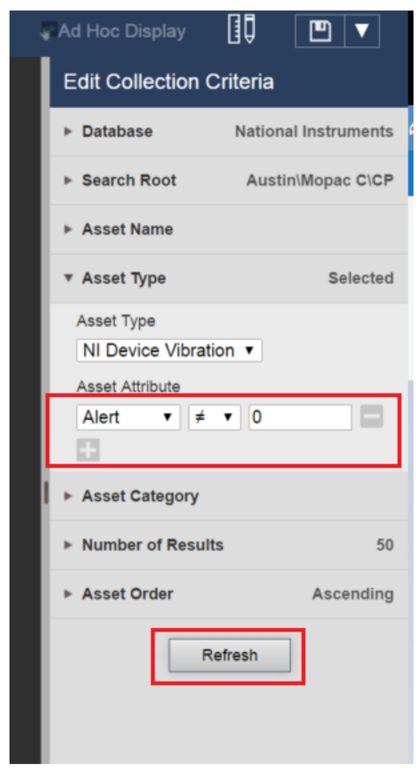


Figure 21: OSIsoft Visualization Vibration Sensors Alert Overview display

In Collections, you can use dynamic filters:

3. Right-click the **Collection** symbol on the screen, and select **Edit Collection Criteria…**
4. Expand the **Asset Type** section in the right-hand pane. It already has a filter criterion; the next step shows the details for adding a filter.
5. Click the + sign to add an **Asset Attribute** filter criteria.
    a. Select the **Alert** attribute.
    b. Select the not equal sign.
    c. Type in a value of **0**.
6. Click the **Refresh** button at the bottom of the pane to apply the changes.



Step 5: Event Frames

The vibration sensor Elements include analyses to create event frames for each alert as shown in the figures below:

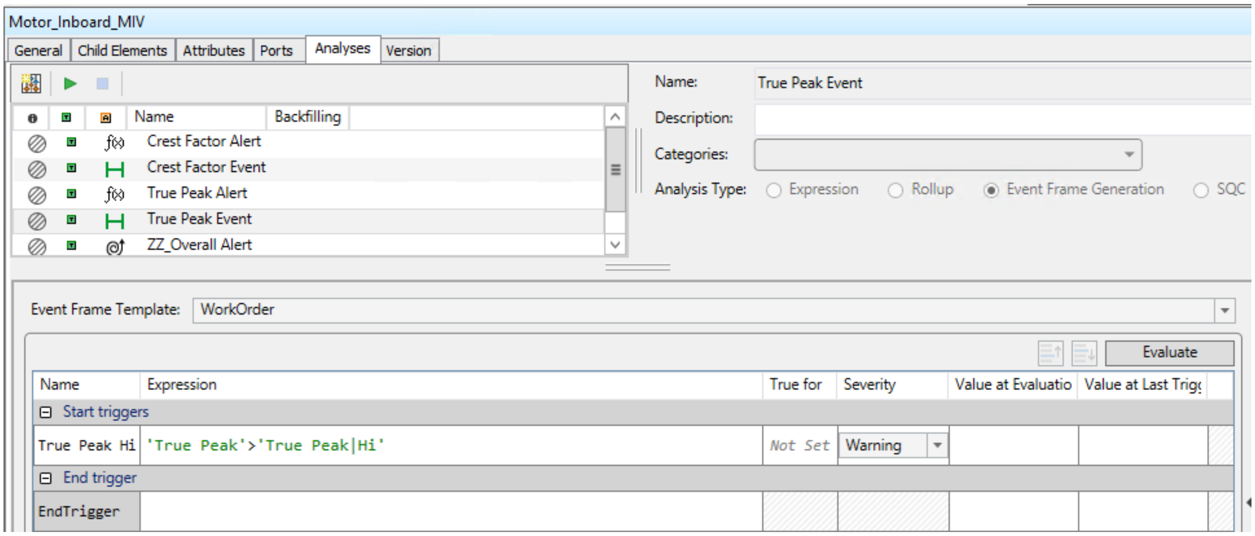
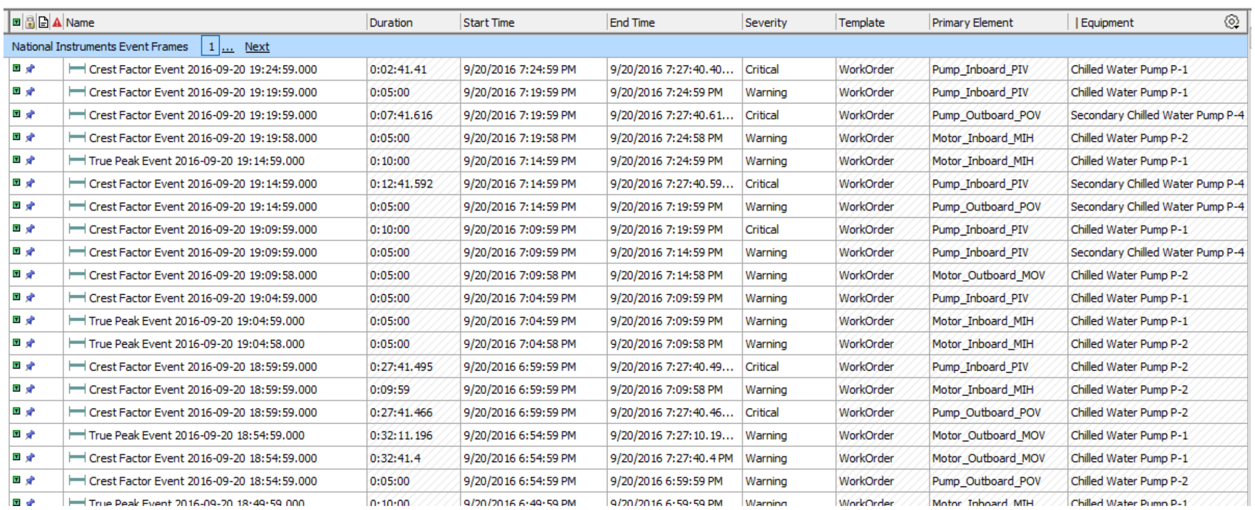


Figure 22: AF Analysis to generate Event Frames



National Instruments Event Frames 1 ... Next

Name	Duration	Start Time	End Time	Severity	Template	Primary Element	Equipment
Crest Factor Event 2016-09-20 19:24:59.000	0:02:41.41	9/20/2016 7:24:59 PM	9/20/2016 7:27:40.40...	Critical	WorkOrder	Pump_Inboard_PIV	Chilled Water Pump P-1
Crest Factor Event 2016-09-20 19:19:59.000	0:05:00	9/20/2016 7:19:59 PM	9/20/2016 7:24:59 PM	Warning	WorkOrder	Pump_Inboard_PIV	Chilled Water Pump P-1
Crest Factor Event 2016-09-20 19:19:59.000	0:07:41.616	9/20/2016 7:19:59 PM	9/20/2016 7:27:40.61...	Critical	WorkOrder	Pump_Outboard_POV	Secondary Chilled Water Pump P-4
Crest Factor Event 2016-09-20 19:19:58.000	0:05:00	9/20/2016 7:19:58 PM	9/20/2016 7:24:58 PM	Warning	WorkOrder	Motor_Inboard_MIH	Chilled Water Pump P-2
True Peak Event 2016-09-20 19:14:59.000	0:10:00	9/20/2016 7:14:59 PM	9/20/2016 7:24:59 PM	Warning	WorkOrder	Motor_Inboard_MIH	Chilled Water Pump P-1
Crest Factor Event 2016-09-20 19:14:59.000	0:12:41.592	9/20/2016 7:14:59 PM	9/20/2016 7:27:40.59...	Critical	WorkOrder	Pump_Inboard_PIV	Secondary Chilled Water Pump P-4
Crest Factor Event 2016-09-20 19:14:59.000	0:05:00	9/20/2016 7:14:59 PM	9/20/2016 7:19:59 PM	Warning	WorkOrder	Pump_Outboard_POV	Secondary Chilled Water Pump P-4
Crest Factor Event 2016-09-20 19:09:59.000	0:10:00	9/20/2016 7:09:59 PM	9/20/2016 7:19:59 PM	Critical	WorkOrder	Pump_Inboard_PIV	Chilled Water Pump P-1
Crest Factor Event 2016-09-20 19:09:59.000	0:05:00	9/20/2016 7:09:59 PM	9/20/2016 7:14:59 PM	Warning	WorkOrder	Pump_Inboard_PIV	Secondary Chilled Water Pump P-4
Crest Factor Event 2016-09-20 19:09:58.000	0:05:00	9/20/2016 7:09:58 PM	9/20/2016 7:14:58 PM	Warning	WorkOrder	Motor_Outboard_MOV	Chilled Water Pump P-2
Crest Factor Event 2016-09-20 19:04:59.000	0:05:00	9/20/2016 7:04:59 PM	9/20/2016 7:09:59 PM	Warning	WorkOrder	Pump_Inboard_PIV	Chilled Water Pump P-1
True Peak Event 2016-09-20 19:04:59.000	0:05:00	9/20/2016 7:04:59 PM	9/20/2016 7:09:59 PM	Warning	WorkOrder	Motor_Inboard_MIH	Chilled Water Pump P-1
True Peak Event 2016-09-20 19:04:58.000	0:05:00	9/20/2016 7:04:58 PM	9/20/2016 7:09:58 PM	Warning	WorkOrder	Motor_Inboard_MIH	Chilled Water Pump P-2
Crest Factor Event 2016-09-20 18:59:59.000	0:27:41.495	9/20/2016 6:59:59 PM	9/20/2016 7:27:40.49...	Critical	WorkOrder	Pump_Inboard_PIV	Chilled Water Pump P-2
Crest Factor Event 2016-09-20 18:59:59.000	0:09:59	9/20/2016 6:59:59 PM	9/20/2016 7:09:58 PM	Warning	WorkOrder	Motor_Inboard_MIH	Chilled Water Pump P-2
Crest Factor Event 2016-09-20 18:59:59.000	0:27:41.466	9/20/2016 6:59:59 PM	9/20/2016 7:27:40.46...	Critical	WorkOrder	Pump_Outboard_POV	Chilled Water Pump P-2
True Peak Event 2016-09-20 18:54:59.000	0:32:11.196	9/20/2016 6:54:59 PM	9/20/2016 7:27:10.19...	Warning	WorkOrder	Motor_Outboard_MOV	Chilled Water Pump P-1
Crest Factor Event 2016-09-20 18:54:59.000	0:32:41.4	9/20/2016 6:54:59 PM	9/20/2016 7:27:40.4 PM	Warning	WorkOrder	Motor_Outboard_MOV	Chilled Water Pump P-1
Crest Factor Event 2016-09-20 18:54:59.000	0:05:00	9/20/2016 6:54:59 PM	9/20/2016 6:59:59 PM	Warning	WorkOrder	Pump_Outboard_POV	Chilled Water Pump P-2
True Peak Event 2016-09-20 18:49:59.000	0:10:00	9/20/2016 6:49:59 PM	9/20/2016 6:59:59 PM	Warning	WorkOrder	Motor_Inboard_MIH	Chilled Water Pump P-1

Figure 23: Alert events along with their severity

The event frames use a template of type **Work Order**.

Event frames can be configured to include all the required information for integration with CMMS (Computerized Maintenance Management System) such as SAP PM, IBM Maximo, Oracle EAM, and others – to trigger a Work Order, or update a Meter reading etc.

1. From PI System Explorer, navigate to the **Event Frames** section.
2. Expand the **Event Frame Search 1** object.

3. Select any **True Peak Event** and explore its properties from the middle pane.

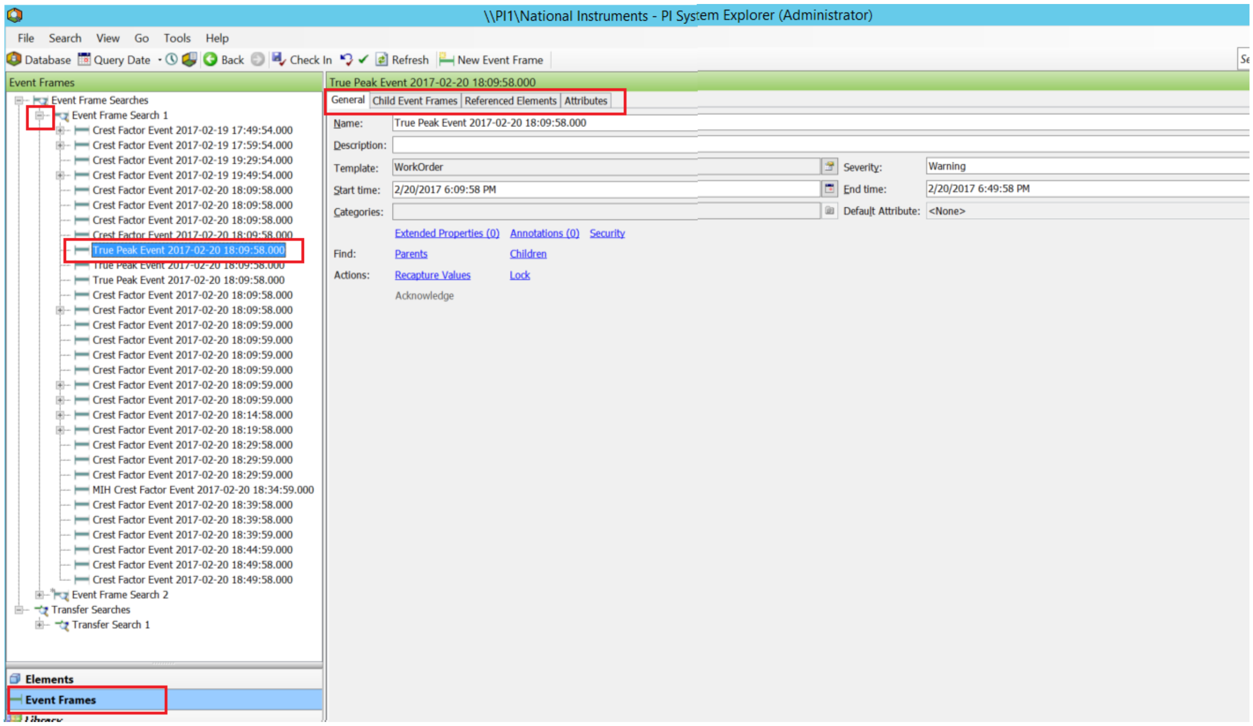


Figure 24: Selecting a True Peak Event from the Event Frames section

Let us now force the generation of some alerts, and some **Work Order** events. In order to trigger an alert, simply lower the value of the **Hi** limit of a sensor.

4. Navigate back to the **Elements** section of PI System Explorer.
5. Select the *\\PI1\National Instruments\Austin\Mopac C\CP\Chilled Water Pump P-1\Motor_Inboard_MIV* element.
6. Look at its **Attributes**, and expand the **Crest Factor** or the **True Peak** attribute level.

7. Modify the value of the **Hi** attribute to a lower value such that Crest Factor or True Peak will go into Alert.

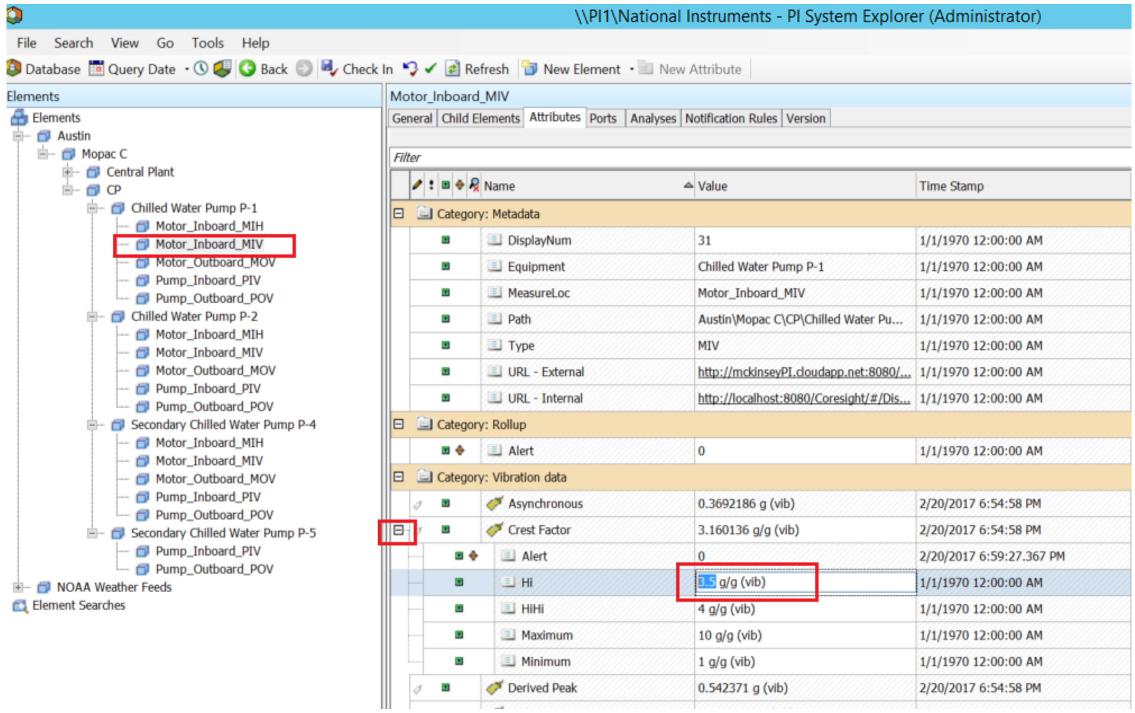


Figure 25: Lowering the Hi limit of the Crest Factor attribute

8. While waiting for new vibration measurement data to come in (every 5minutes), look in the **Analyses** tab to **Evaluate** the event frame generation analysis.

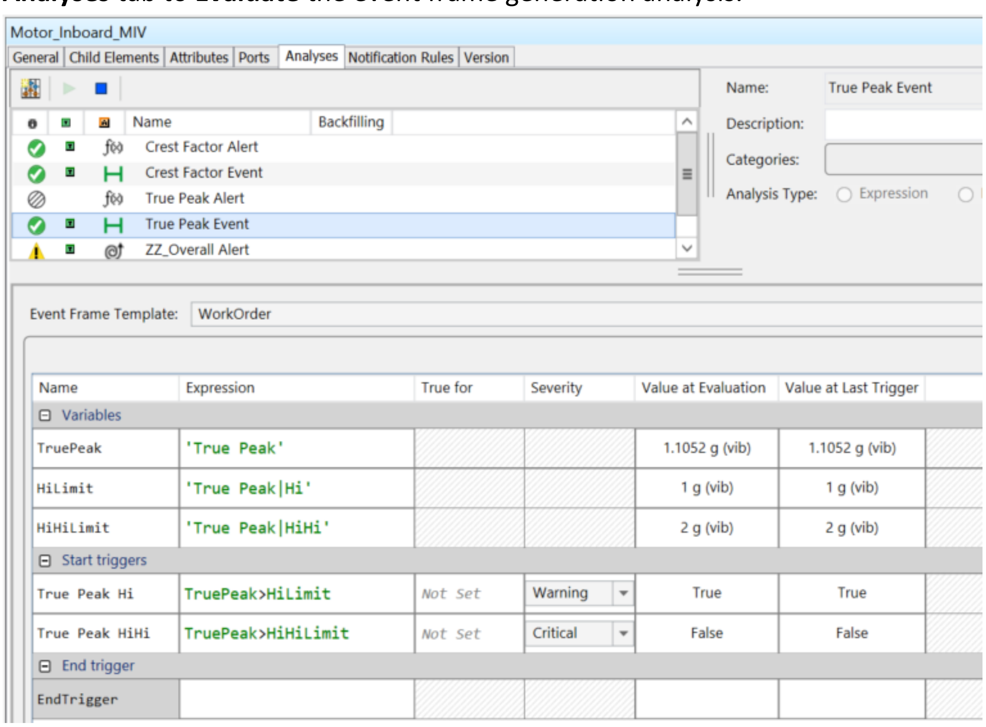


Figure 26: True Peak - Analysis for event frame generation

Step 6: Event Frames as a Watch List using OSIsoft Visualization

OSIsoft Visualization **Events Table** (new feature) is used to build a watch list.

1. Navigate to the overview screen (https://pi1.pischool.int/PIVision/#/Displays/38/Pumps-Alert-Overview) and click the **Vibration Sensors Alerts Watchlist** link (will bring you to: https://pi1.pischool.int/PIVision/#/Displays/45/Vibration-Sensor-Alerts-Watchlist).
2. The watch list shows the event frames currently in progress. Confirm this by right-clicking the events table and selecting **Configure Table…**
3. From the right hand pane, expand the **Event State** section to see the **In Progress** filter.

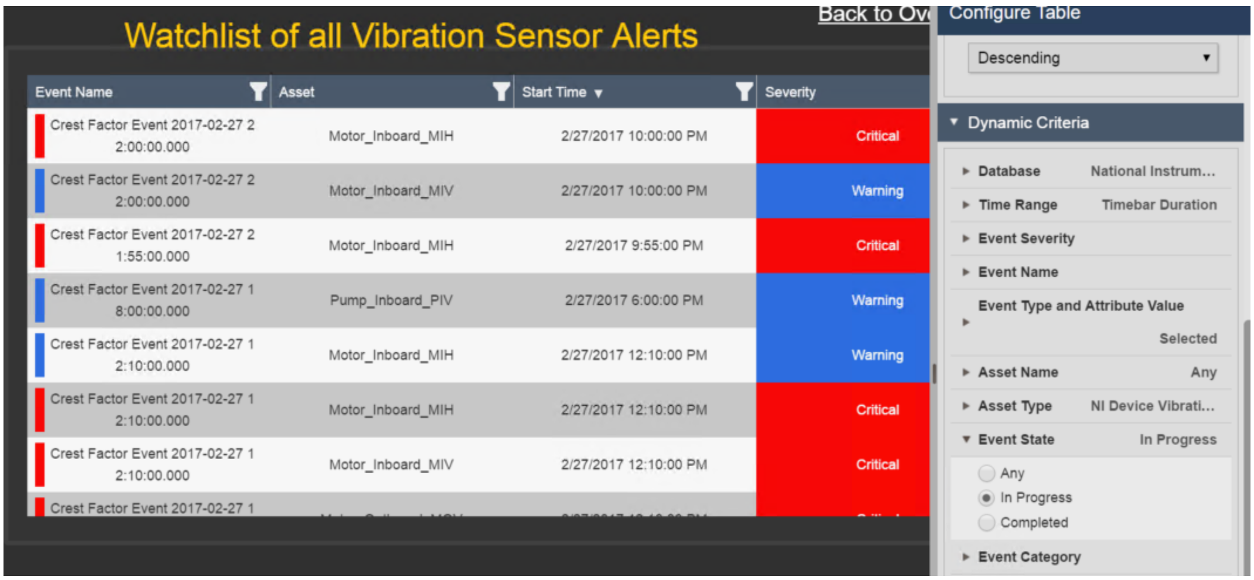


Figure 27: Alerts Watch List using OSIsoft Visualization Events Table

4. Double-click on an event in the table to see the Details window. Items showing the red Critical state indicate those exceeding HiHi limit; the items in blue Warning indicate those exceeding the Hi limit.

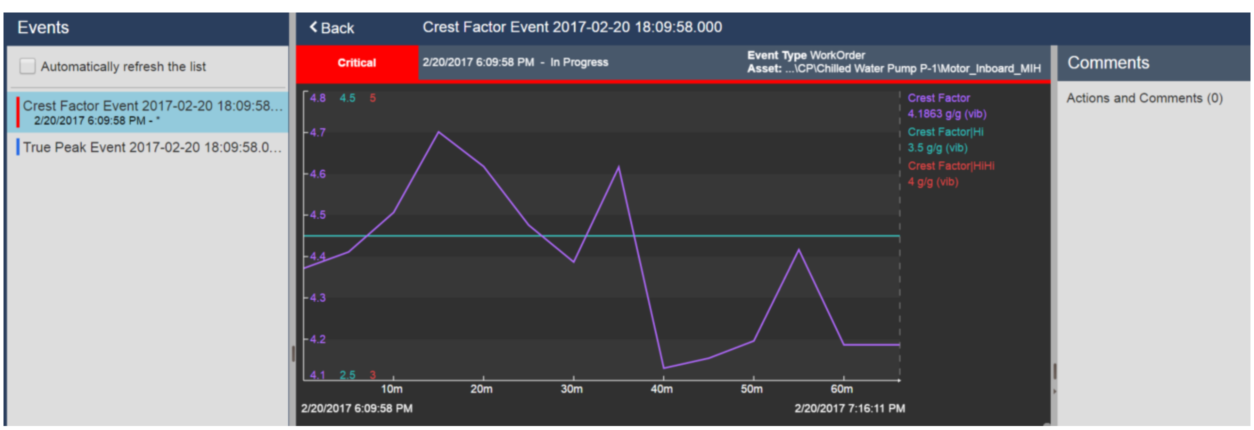


Figure 28: OSIsoft Visualization details page for an Event Frame

Exercise 3 – Other Data Types

Other condition monitoring data, such as temperature readings, acoustic data, lab results from oil analysis, etc. are all part of the condition assessment done to ensure equipment reliability. In this exercise, let us look at three different kinds of measurements and how they are used for CBM.

A. Motor Oil Lab Results and AF Table

Motor oil analysis for critical motors are often performed on a regular basis.

Hangtown >> Finishing Area >> Force Variation Testing & Buffing Area >> Force Variation Testing & Buffing Proc >> #1 FV Hydraulic Unit >> 10002374 RESEVOIR >> Hydraulic Systems >1000 PSI - Sampling Schedule: 90 days

Sample Information	Sample Dates	Product Information
Sample ID: 4011 Lab ID: 633611 Analyst: Angie Borella	Sampled: 7/27/2016 Received: 7/27/2016 Completed: 7/28/2016	Manufacturer: Mobil Viscosity: 68

High Limit Alarm | High Limit Alert | Low Limit

	Wear Metals (ppm)												Contaminate Metals (ppm)		Multi-Source Metals (ppm)				Additive Metals (ppm)				
Sample Date	Iron	Chromium	Aluminum	Copper	Lead	Tin	Silver	Nickel	Cadmium	Vanadium	ANTIWEAR LOSS	OXIDATION / SULFATE	Silicon	Sodium	Manganese	Boron	Molybdenum	Titanium	Magnesium	Calcium	Barium	PHOSPHORUS	Zinc
7/27/2016	1	0	0	8	0	0	0	0	0	0	0.000	24.390	1	1	0	0	0	0	0	51	0	329	424
4/18/2016	1	0	0	7	0	0	0	0	0	0	0.000	24.830	1	1	0	1	0	0	0	52	0	327	429
1/19/2016	1	0	0	8	0	0	0	0	0	0	0.000	22.770	1	1	0	0	0	0	0	52	0	327	443
10/30/2015	1	0	0	7	0	0	0	0	0	0	0.000	22.550	1	2	0	1	0	0	0	53	0	336	452
7/23/2015	1	0	0	5	0	0	0	0	0	0	0.000	23.640	1	0	0	0	0	0	0	55	0	338	439
4/21/2015	1	0	0	5	0	0	0	0	0	0	0.000	24.140	1	0	0	0	0	0	0	52	0	340	460

	Contaminates	Fluid Properties				
Sample Date	WATER (BY ABSORPTION)	Oxidation abs/cm	Nitration abs/cm	Viscosity 40 C cSt	KARL FISCHER	TOTAL ACID NUMBER
7/27/2016	0.000	2.544	4.176	62.8	28.6	0.38
4/18/2016	0.000	2.563	3.993	61.9	18.4	0.37
1/19/2016	0.000	2.533	3.664	62.8	56.3	0.34
10/30/2015	0.000	2.627	3.884	62.7	72.4	0.41
7/23/2015	0.000	2.639	3.909	62.6	24.1	0.41
4/21/2015	0.000	2.639	4.024	61.9	22.6	0.40

	Particle Count (particles / mL)								
Sample Date	>4MM	>6MM	>14MM	>20MM	>30MM	>40MM	ISO PC>4	ISO PC>6	ISO PC>14
7/27/2016	2505	471	52	14	4	3	19	16	13
4/18/2016	5875	823	42	13	5	4	20	17	13
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

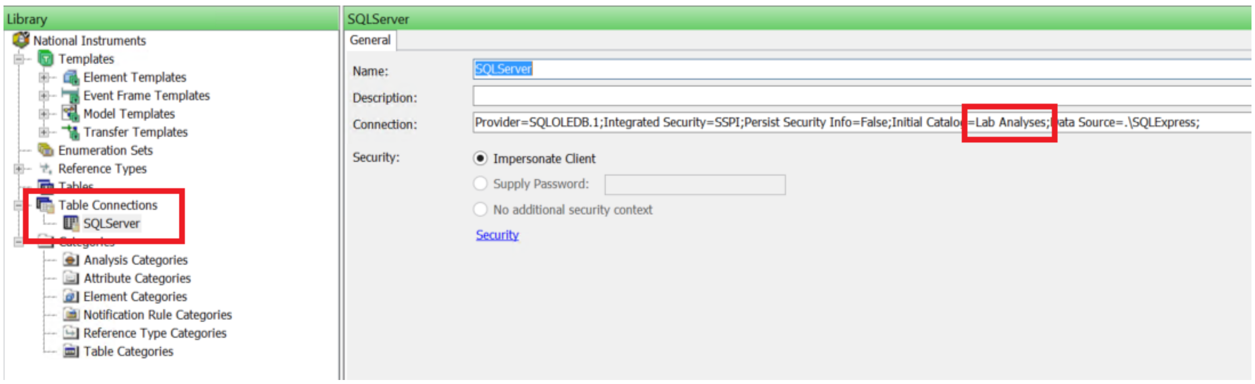
Figure 29 Sample motor oil analysis report

These lab results may exist in an external database but they can be referenced and used as part of condition assessment in an AF calculation via PI AF Table.

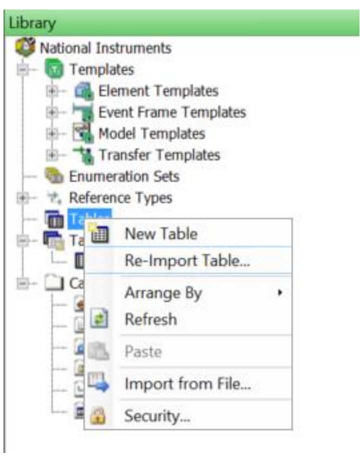
Step1: Data from an external database

1. In PI System Explorer, navigate to the Library section.

2. Expand Table Connections, and select **SQLServer**. A connection has already been established between PI Asset Framework and a SQL Server database that holds lab results, called **Lab Analyses**.

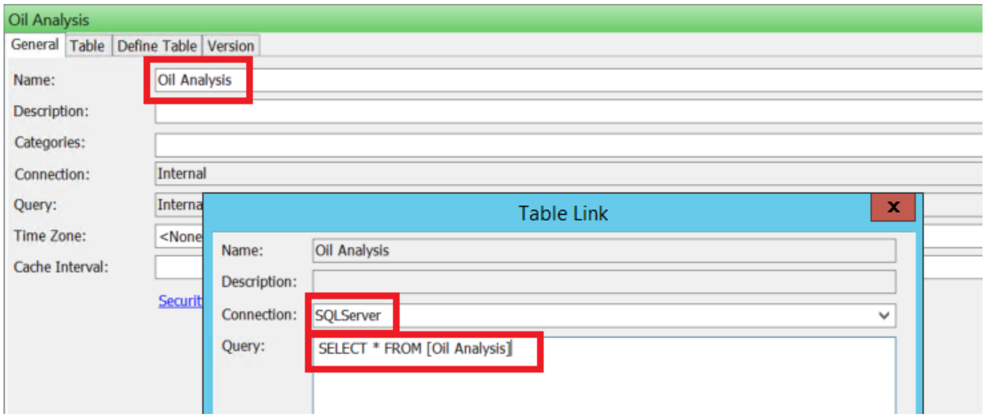


3. Create a PI AF Table to reference the lab result. Right-click the **Tables** and select **New Table**.



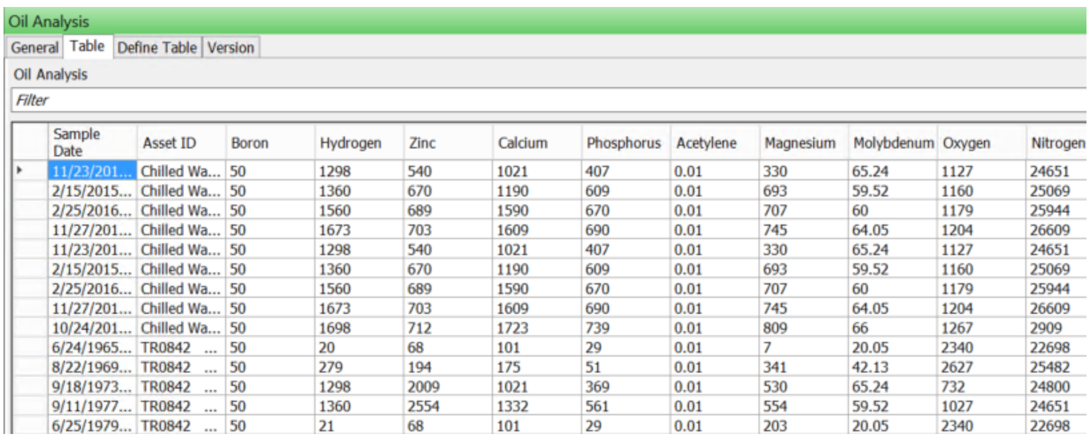
4. Enter **Oil Analysis** in the **Name** field.

5. Click the **Link** button at the bottom of the configuration pane. Select **SQLServer** for the **Connection** field, and then enter the following SQL query to reference the Oil Analysis table: *SELECT * FROM [Oil Analysis]*



The SQL query tells AF to select everything (or *) from the Oil Analysis table. Click **OK** to confirm the query.

6. Confirm that the data is now available by selecting the **Table** tab.


Oil Analysis

General | Table | Define Table | Version

Oil Analysis

Filter

Sample Date	Asset ID	Boron	Hydrogen	Zinc	Calcium	Phosphorus	Acetylene	Magnesium	Molybdenum	Oxygen	Nitrogen
11/23/201...	Chilled Wa...	50	1298	540	1021	407	0.01	330	65.24	1127	24651
2/15/2015...	Chilled Wa...	50	1360	670	1190	609	0.01	693	59.52	1160	25069
2/25/2016...	Chilled Wa...	50	1560	689	1590	670	0.01	707	60	1179	25944
11/27/201...	Chilled Wa...	50	1673	703	1609	690	0.01	745	64.05	1204	26609
11/23/201...	Chilled Wa...	50	1298	540	1021	407	0.01	330	65.24	1127	24651
2/15/2015...	Chilled Wa...	50	1360	670	1190	609	0.01	693	59.52	1160	25069
2/25/2016...	Chilled Wa...	50	1560	689	1590	670	0.01	707	60	1179	25944
11/27/201...	Chilled Wa...	50	1673	703	1609	690	0.01	745	64.05	1204	26609
10/24/201...	Chilled Wa...	50	1698	712	1723	739	0.01	809	66	1267	2909
6/24/1965...	TR0842 ...	50	20	68	101	29	0.01	7	20.05	2340	22698
8/22/1969...	TR0842 ...	50	279	194	175	51	0.01	341	42.13	2627	25482
9/18/1973...	TR0842 ...	50	1298	2009	1021	369	0.01	530	65.24	732	24800
9/11/1977...	TR0842 ...	50	1360	2554	1332	561	0.01	554	59.52	1027	24651
6/25/1979...	TR0842 ...	50	21	68	101	29	0.01	203	20.05	2340	22698

7. Click the top-toolbar Check In button to save the changes.

Step 2: Confirm that the Oil Analysis data is now available via PI AF attributes

1. Navigate to the **Elements** section in PI System Explorer and navigate to [\\PI1\National Instruments\Austin\Mopac C\CP\Secondary Chilled Water Pump P-4]().
2. Select the **Attributes** tab, and confirm that the attributes in **Oil Analysis** category show the oil analysis lab data. You may have to click the top-toolbar **Refresh** button.

Category: Oil Analysis	
Calcium	1190 ppm
Copper	3 ppm
Iron	10 ppm
Magnesium	693 ppm
Phosphorus	609 ppm
Sodium	11 ppm
Zinc	670 ppm

The lab data for Oil Analysis can now be used (in the same manner as any other sensor data) as part of condition assessment and to trigger events and notifications.

B. Infrared Temperature Readings, PI Manual Logger, and Notifications

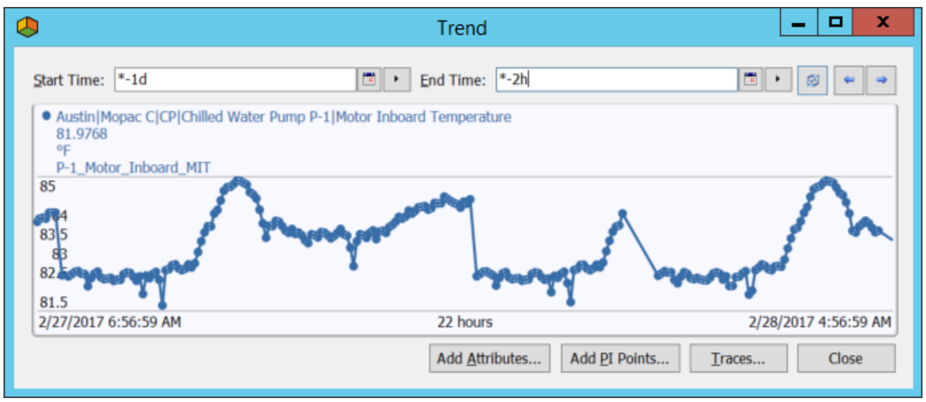
Often, temperature or infrared readings are collected using portable data collectors.

If a device such as the AR-C10 (see Exercise 1) is available, then it sends the data directly to the PI System. However, if are using another device without direct write capability to PI, then you can use PI Manual Logger on a tablet or phone to manually input the reading.

In this section, we review manual input data for a temperature reading and its use with PI Notification to send an email as an alert for an out-of-spec reading.

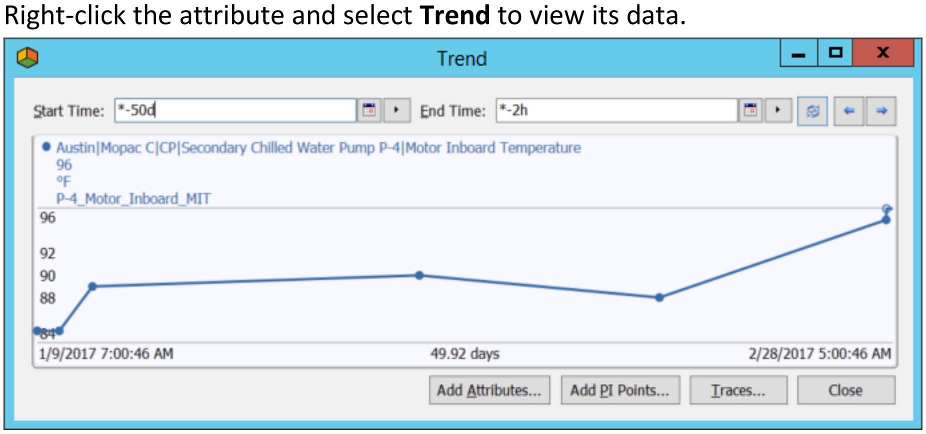
Step 1: Examine the available temperature data

1. Navigate to **\\PI1\National Instruments\Austin\Mopac C\CP\Chilled Water Pump P-1**, and check its **Motor Inboard Temperature** attribute. This temperature sensor is online and data is collected in real-time via an interface to the BMS (building management system). Right-click the attribute and select **Trend** to view its data.



2. Navigate to **\\PI1\National Instruments\Austin\Mopac C\CP\Secondary Chilled Water Pump P-4**. The secondary chilled water pumps have not been instrumented with temperature sensors for continuous online data collection. As such, temperature readings (from an infrared device) is entered manually in PI-Manual Logger.

   Right-click the attribute and select **Trend** to view its data.



Step 2: Temperature rate of change analysis, and PI Notification

1. Select the **Analyses** tab of the Secondary Chilled Water Pump P-4 element.
2. Select the **High Temperature RateOfChange** analysis from the list. The expression triggers an event frame generation when the rate of change for the temperature is greater than 0.25 °F per day. The manual data collection via operator rounds is done once a week.

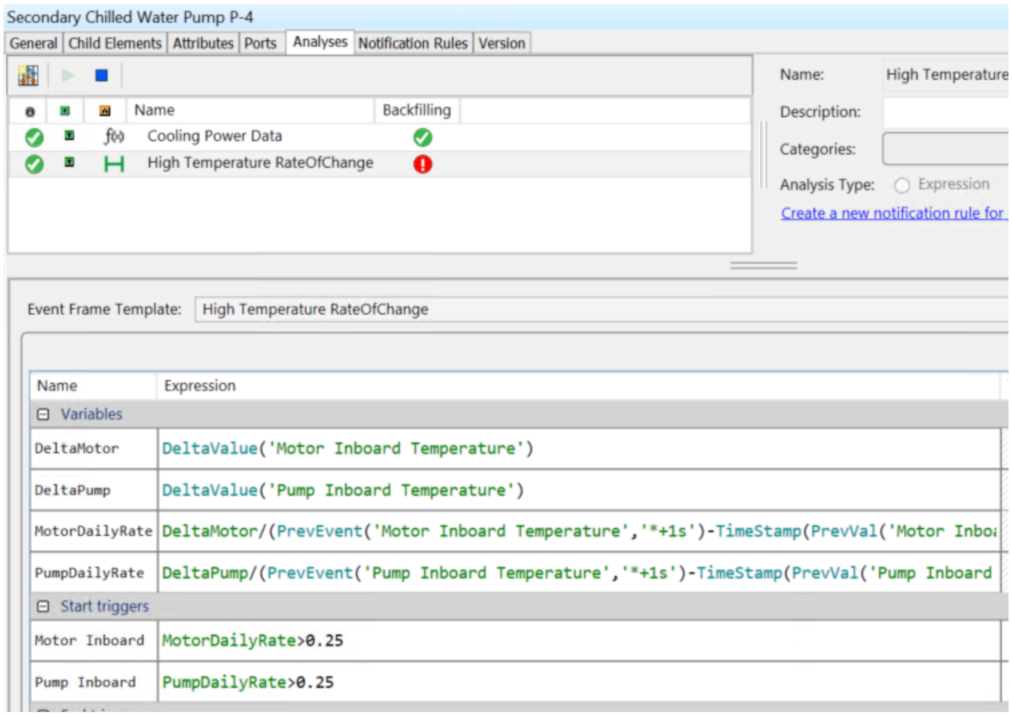
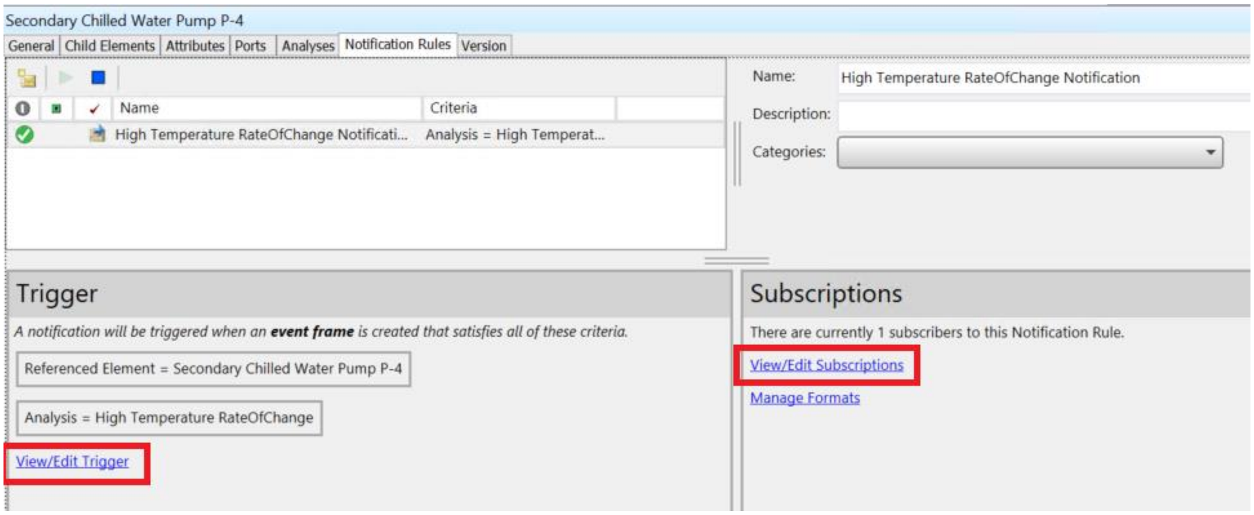


Figure 30: Rate of change Expression analysis

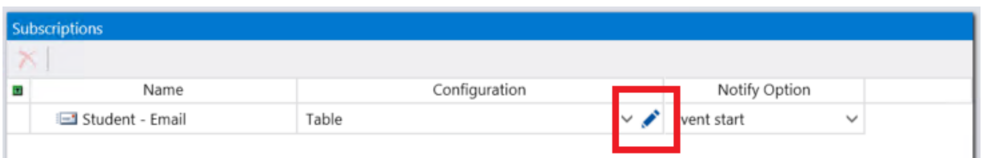
3. Evaluate the expressions to see whether the alert is true.

Step 3: Examine the Notification rule for the high temperature Event Frame

1. Select the **Notification Rules** tab for the Secondary Chilled Water Pump P-4 element.
2. Click the **View/Edit Trigger** to confirm that a notification will be triggered when a High Temperature RateOfChange Event Frame is triggered.



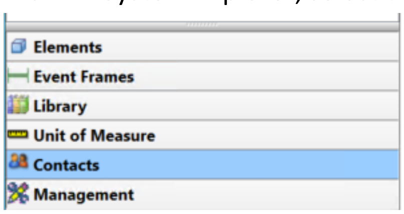
3. Click the **View/Edit Subscriptions** to review the email format; click the pencil icon next to the format field.



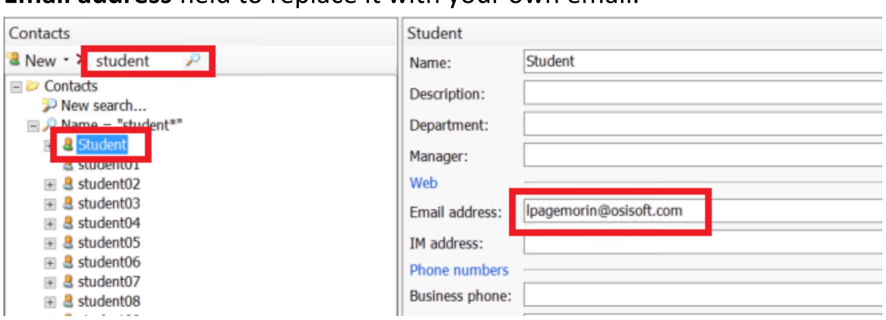
4. Note that the email includes URL links in the bottom portion of the email body, one URL for using from within the lab VM environment (internal link), and another URL that can be used from any external computer or device (external link).

Step 4: Modify the Student's email address to receive the notification in your inbox

1. From PI System Explorer, select the Contacts section from the bottom left of the screen.



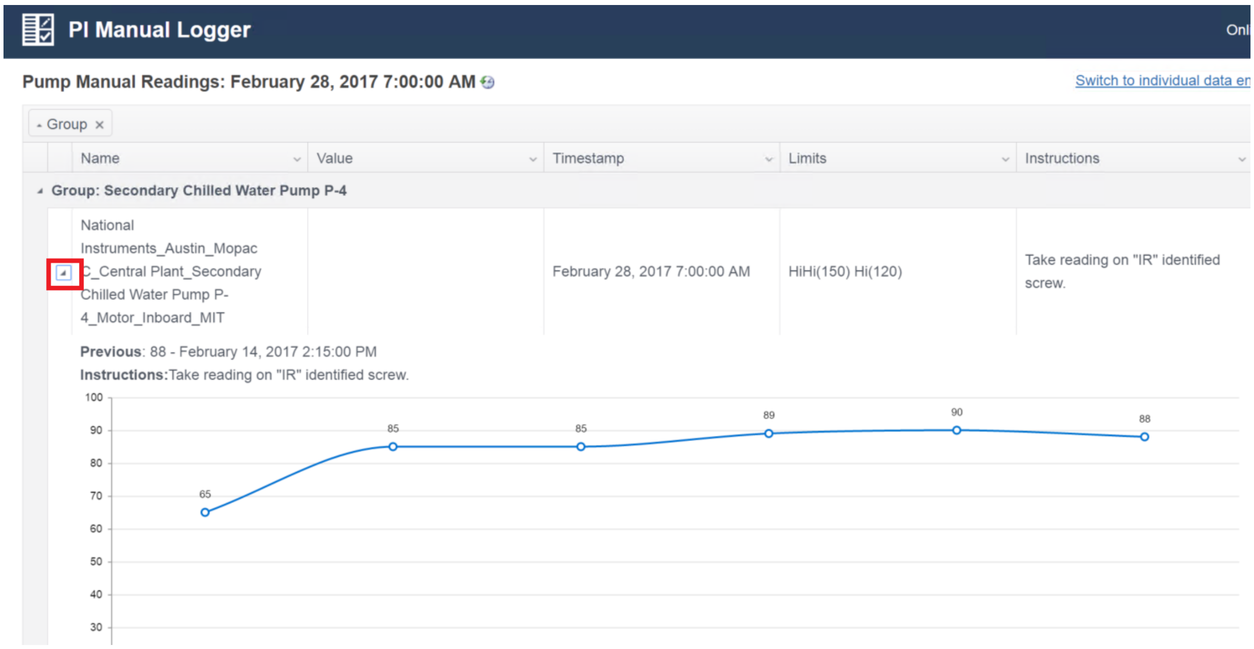
2. Type **student** in the search field near the top, then select the **Student** contact, and edit the **Email address** field to replace it with your own email.



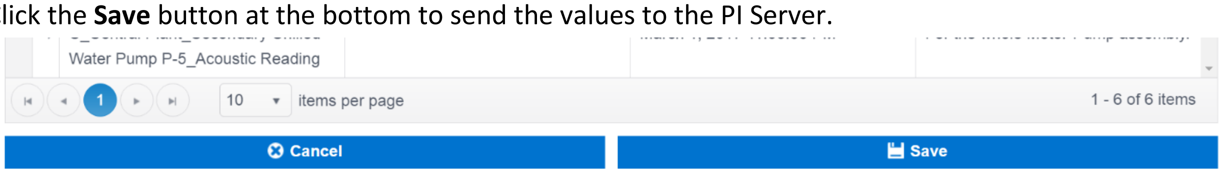
3. Click the top-toolbar Check In button to save the changes.

Step 5: Use PI Manual Logger to enter a value that will trigger an alert

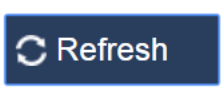
1. Launch **PI Manual Logger Tour** shortcut from the VM desktop, or click the link below:
   https://pi1.pischool.int:6443/piml.web/#/tourrun?id=new&name=Pump+Manual+Readings
   This opens a new tour run to enter temperature and acoustic data for pumps P-4 and P-5.
   It shows the current timestamp at the top of the screen. Click the **Switch to grid data entry view** link found in the top right of the screen.
2. Expand the first tag to see the previous data entries:



3. Enter values for up to six (6) tags, making sure to enter at least one very high value for a temperature to trigger an event frame generation.
4. Click the **Save** button at the bottom to send the values to the PI Server.



5. In the PI Manual Logger Web homepage, click **Refresh** to clean any tour run information.



Step 6: Verify Notification delivery and web visualization of the alert

1. Confirm that an Event Frame has been generated for either Pump P-4 or P-5 and that you received an email.

Reply Reply All Forward IM

Mon 27-Feb-2017 23:16

pitechcon2017@gmail.com

New HighTemp_2017-02-27 20:15 for Secondary Chilled Water Pump P-4!

To Louis-Philippe Page-Morin

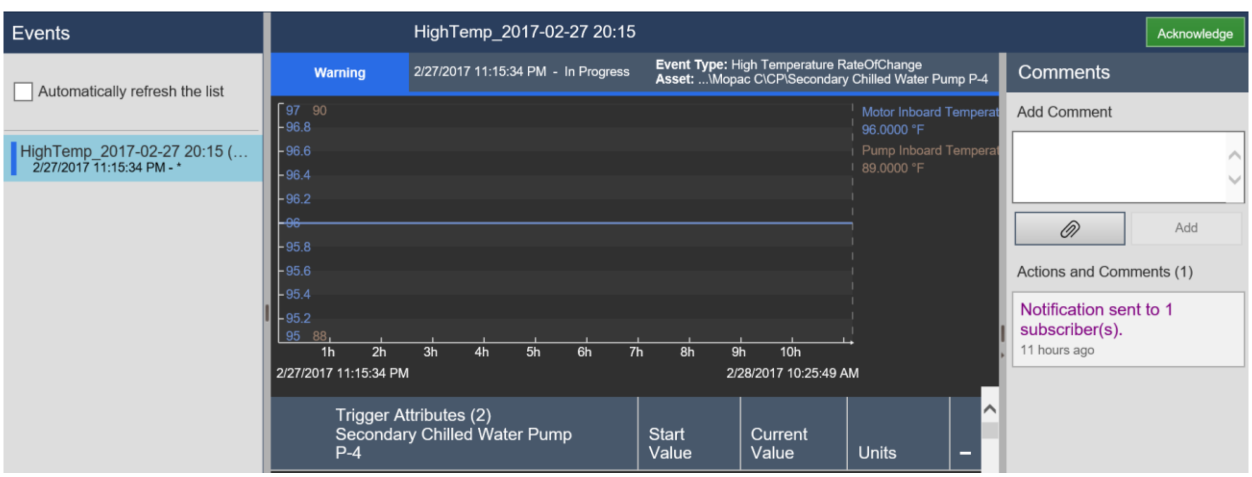
Event: HighTemp_2017-02-27 20:15
Name: High Temperature RateOfChange Notification

Start Time: 2/27/2017 8:15:34 PM Pacific Standard Time (GMT-08:00:00)
Target: Austin\Mopac C\CP\Secondary Chilled Water Pump P-4
Trigger: Start Trigger Name **Severity:** Warning

Attribute	Value	Time
Motor Inboard Temperature	96 °F	2/27/2017 8:15:34 PM Pacific Standard Time (GMT-08:00:00)
Pump Inboard Temperature	89 °F	2/27/2017 8:15:34 PM Pacific Standard Time (GMT-08:00:00)

View notification details
Internal link: https://pi1.pischool.int/pivision/#/EventDetails?server=PI1&eventid=2862dcb8-a7f0-4f21-0000-0000000974bd
External link: https://3796vlecs1.cloudapp.net/pivision/#/EventDetails?server=PI1&eventid=2862dcb8-a7f0-4f21-0000-0000000974bd

2. Use the links at the bottom to navigate to the Notification details page. The link takes you to a Coresight display.
   Copy-paste the internal link in the browser address bar from within the lab VM.
   If prompted for login, enter the following credentials (user: pischool\student01, password: student). If you get an error, use the **Notification Page Example** shortcut from the desktop to open the details page from a previous notification.
3. Review the notification details page. Note the **Acknowledge** button in the upper right (optional), and the **Add Comment** section. The acknowledgement workflow ensures that someone will look into the event.



4. Acknowledge the notification by clicking the green **Acknowledge** button. Then enter a comment by typing in something inside the **Add Comment** box, and then by clicking the Add button. Note that you can also attach a file (including a picture, video etc.) to the event.

C. Acoustic Data and Dynamic Threshold

In the previous example, we used a rate of change logic to trigger an event/notification. However, for early detection of degrading equipment conditions, your condition assessment can be based dynamic thresholds for Limit values that reflect the current operating context. For example, the Hi Limit threshold for a chilled water pump at full load can be proportionately higher than one running at partial load.

As such, let us look at the acoustic readings, but in the context of the cooling power corresponding to the chilled water pump load.

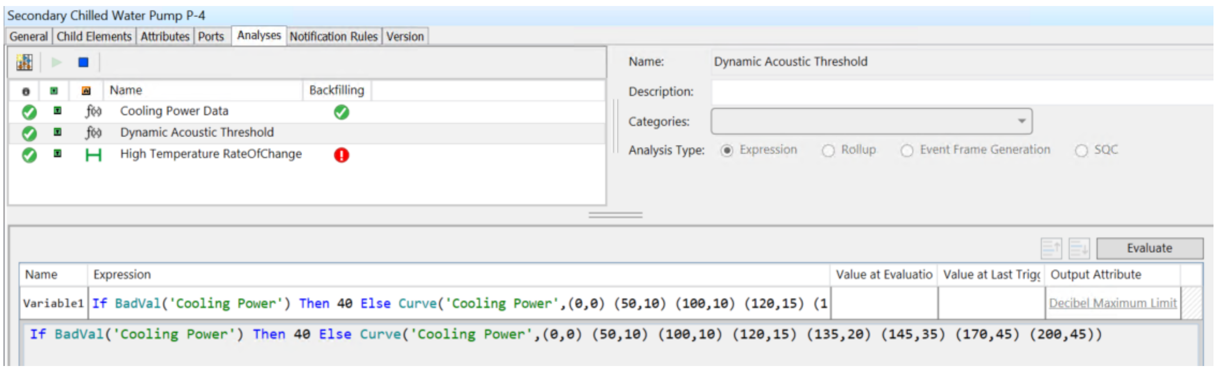
Step 1: Examine the acoustic data and cooling power

1. Navigate to the **\\PI1\National Instruments\Austin\Mopac C\CP\Secondary Chilled Water Pump P-4** element.
2. Examine its **Attributes** from the **Acoustic** category.
3. Right-click the **Cooling Power** attribute and select **Trend** to see that the cooling power varies with time.

The varying cooling power is incorporated into the condition assessment as a dynamic threshold for the acoustic dB limit which determines whether the motor-pump assembly is making more noise than expected for a given cooling power value.

Step 2: Review the dynamic acoustic limit

1. Select the **Analyses** tab of the Pump P-4 asset.
2. Select the **Dynamic Acoustic Threshold** from the list.



3. The Curve() function is used to map the acoustic Hi limit (Y) with its corresponding cooling power value (X).

Using AF calculation, the acoustic limit is written to the PI Server to illustrate how it varies with the cooling power.

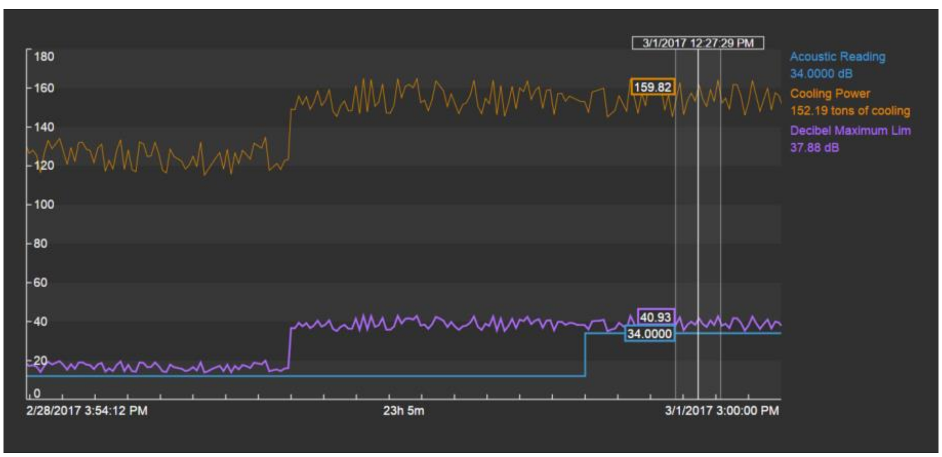


Figure 31: OSIsoft Visualization trend showing the acoustic reading against its dynamic Hi limit

Note that the Decibel Limit (purple trace) varies with the cooling power (orange trace). Also note that the acoustic readings (blue trace) are below the Decibel Limit (purple trace).

You can also use an XY chart to view the acoustic readings and its limit.

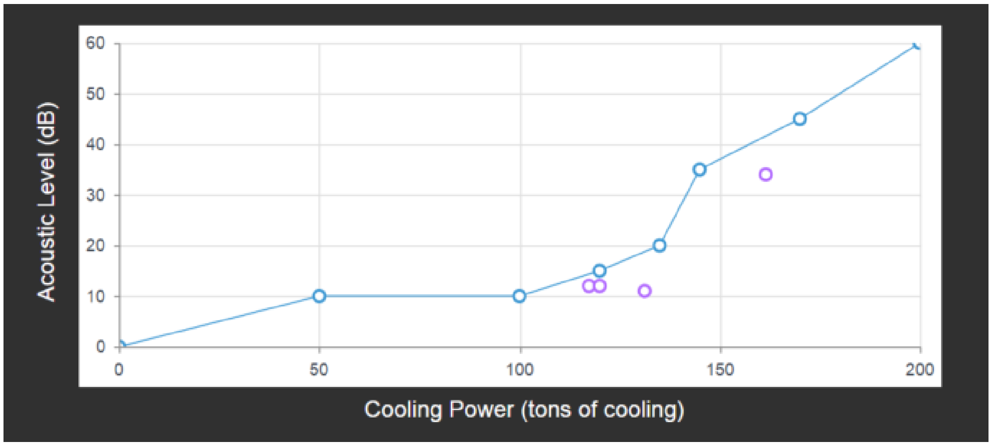


Figure 32: OSIsoft Visualization XY Chart showing the last 4 acoustic readings (purple) against its limit curve (blue)

This concludes the hands-on portion of the lab.

In summary, we covered the learning objectives stated at the beginning of the lab:

- Understand the condition monitoring (CM) data collection process – with a live demo of a hand-held device used for collecting vibration, infrared and acoustic data for a motor
- Understand how the condition monitoring data is transformed and written to PI
- Configure condition assessment calculations for the CM data and recognize the use of dynamic thresholds for the CM data
- Incorporate CM data such as oil analysis (that may reside in external databases) in the condition assessment calculations
- Incorporate manual input CM data (aka operator rounds) via PI Manual Logger
- Create displays, notifications, alerts watch list etc. using various PI System capabilities and tools
- Review the PSE&G customer use case on combining PI System data with CM data for calculating asset health score

Please take a few minutes to give us your feedback https://www.surveymonkey.com/r/QMBJP2G.

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