Building PI System Assets and Analytics with AF

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1. PI System Basics

1.1 What is a PI System?

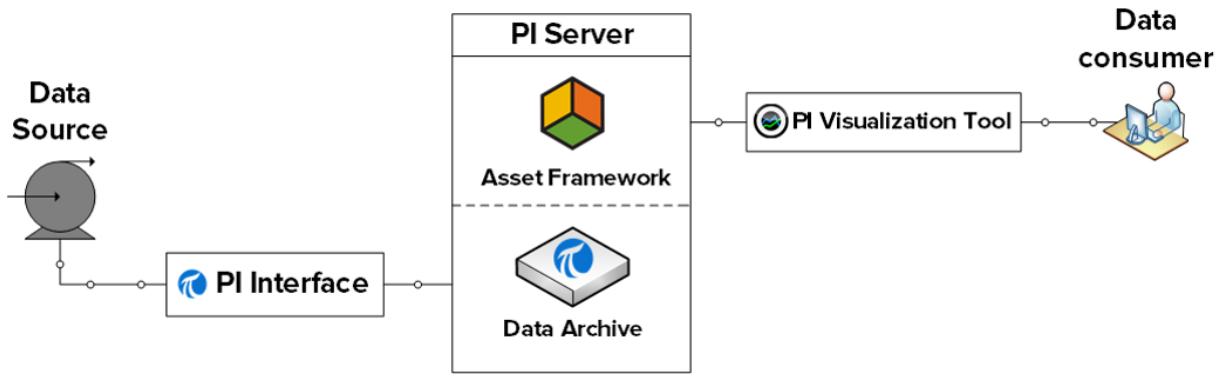
Objectives

- Define the components of a PI System.
- Draw a diagram of the architecture of a PI System.

1.1.1 The PI System described

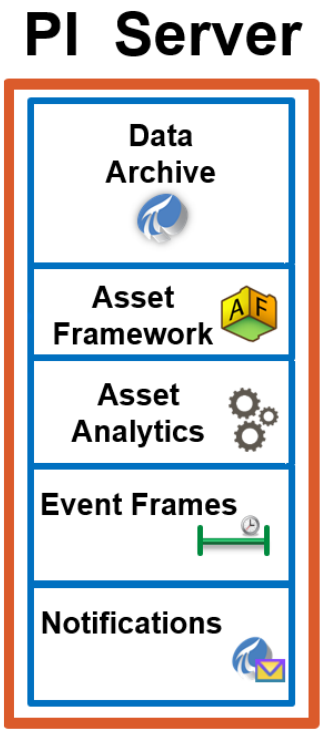
The PI System collects, stores, and manages data from your plant or process. Your data sources connect to one or more PI Interface nodes. The PI Interface nodes collect data from your data sources and store into the PI Data Archive.
Asset Framework (AF) organizes and enhances the data. Users consume the data by the use of a tool of the PI Visualization Suite (PVS) such as PI Vision.

The following is a diagram of the components of a simple PI System:



1.1.2 PI System Components

In a more detail, the following components constitute the PI Server:



Data Archive

The PI Data Archive is a component of the PI Server that provides efficient storage and archiving of time series data enabling high performance data retrieval by client software.

Note: Traditionally, the PI Data Archive was referred to as the "PI Server".

Asset Framework

PI Asset Framework (PI AF) is a single repository for asset-centric models, hierarchies, objects, and equipment. It integrates, contextualizes, refines, references, and further analyzes data from multiple sources, including one or more PI Data Archives and non-PI sources such as external relational databases.

Asset Analytics

A feature of PI Asset Framework (PI AF) used to create and manage analyses. Analyses read values of PI AF attributes, perform calculations, and write results to other attributes or create event frames.

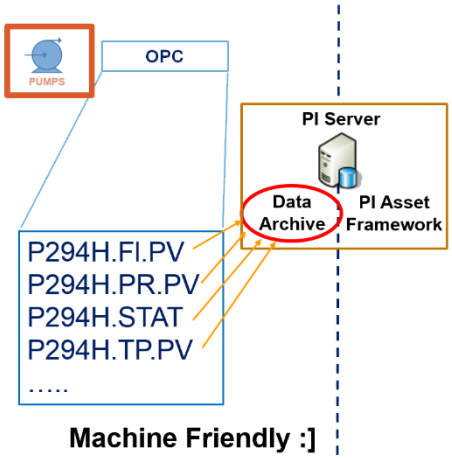
Event Frames

Event Frames help to capture, track, compare, or analyze important process or business events and their related data for a repeatable period of time. Event frames represent occurrences in your process that you want to know about, such as asset downtime, process excursions, equipment startup or shutdown, environmental excursions, product tracking batches, product runs, or operator shifts.

Notifications

The PI System can send notifications to users or systems when key events occur. You set conditions that define these events and specify notifications for them, including recipients and actions to take, such as what to do when a recipient is unavailable. In operation, the PI System detects the events you specified and automatically generates and sends out notifications for them.

1.1.3 Machine Friendly and Human Friendly Side in the PI System



Machine Friendly Side:

- PI Interfaces and Connectors
- PI Data Archive
- PI Tag

PI Interfaces and Connectors

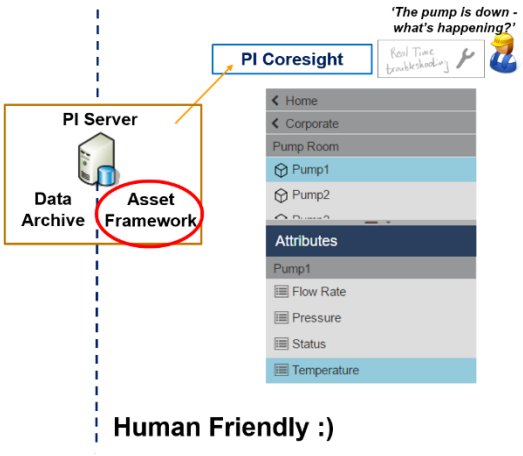
PI Interfaces collect data from external data sources, providing real-time, fault-tolerant data to the PI System.

PI Connectors are similar to PI Interfaces. They collect data from sensors and control systems. Different to interfaces, they also automatically create a PI Asset Framework (AF) model for your asset. (In that regard, also belong to the human friendly side)

PI Tag

A unique storage point for data in the PI System. It is simply a single point of measurement. A point represents a single named stream of data coming from an instrument, device or sensor (-> time-series data).

Note: A PI tag is the same as a **PI Point**.



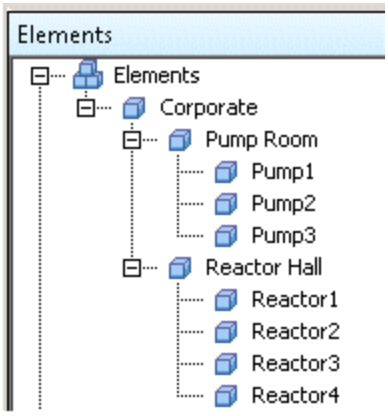
Human Friendly Side:

- PI Asset Framework
- Assets and Attributes
- Visualization Tools

Assets

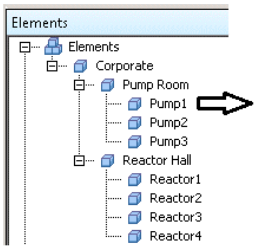
In AF, the equipment and processes that you want to monitor are called *assets*. An asset represents a logical or physical component of a process. Example assets include company locations, sites, and pieces of equipment.

Assets are configured in AF as *elements*. The AF representation of all your assets and processes together is called an asset model, which is a hierarchical structure.

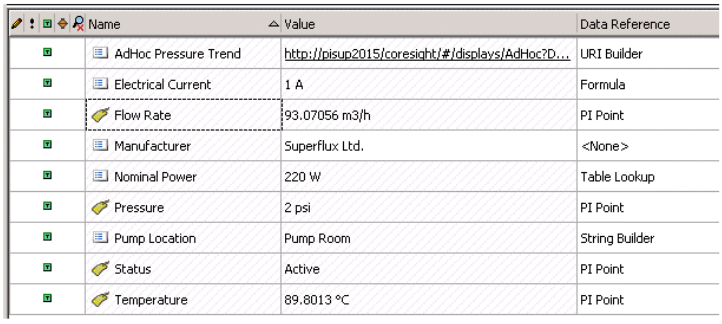


Attributes

An *attribute* represents a unique property associated with an asset.



Elements



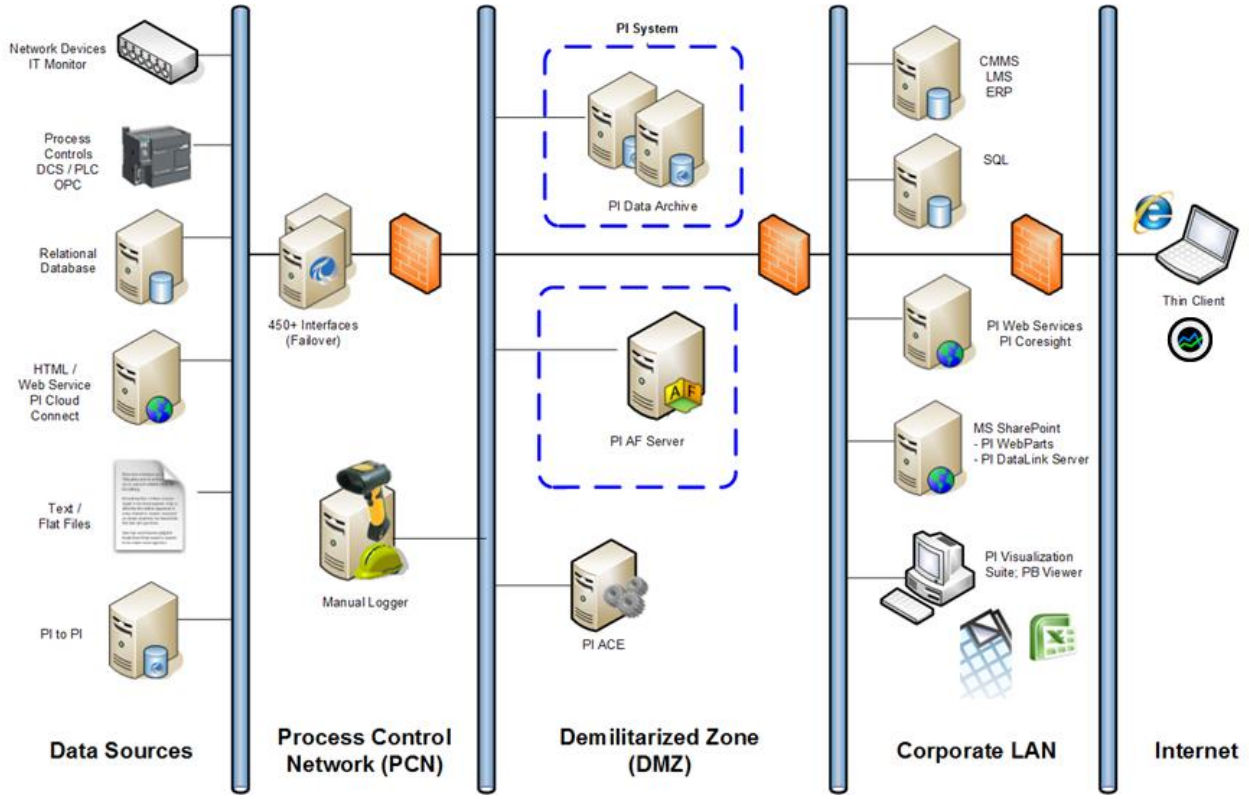
Name	Value	Data Reference
AdHoc Pressure Trend	http://pisup2015/coresight/#/displays/AdHoc?D...	URI Builder
Electrical Current	1 A	Formula
Flow Rate	93.07056 m3/h	PI Point
Manufacturer	Superflux Ltd.	<None>
Nominal Power	220 W	Table Lookup
Pressure	2 psi	PI Point
Pump Location	Pump Room	String Builder
Status	Active	PI Point
Temperature	89.8013 °C	PI Point

Attributes for Pump1

Attributes can hold simple values representing fixed information such as the manufacturer of a pump. Attributes can also reference a PI point, a formula, a value from a relational database or internal AF table, and other information.

1.1.4 Architecture of a Typical PI System

Sometimes the architecture can be very simple. Some customers have as few as one or two PI Interfaces feeding data to a Data Archive from which the data can be consumed by various applications. The following is an example of a fully developed PI System, which includes most of the widely used OSIsoft products.

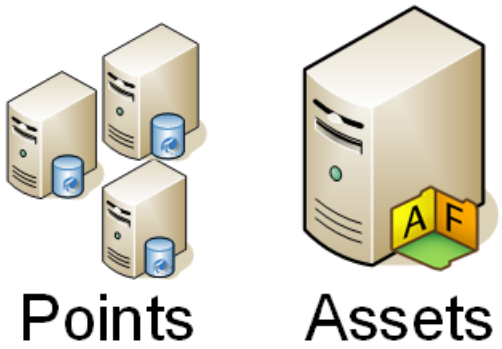


In the diagram above, two PI Data Archive computers are shown to represent a **PI Data Archive collective**. A collective is a configuration of multiple servers that act as a logical PI Data Archive server in your PI System to provide high availability (HA), disaster recovery, load distribution, and increased scalability. A collective consists of one primary server and one or more secondary servers.

For information on high availability options for PI Asset Framework refer to KB article: KB00634 - High Availability (HA) options for PI Asset Framework (PI AF)

Note: In computer security, a demilitarized zone, named after the military usage of the term and normally abbreviated to DMZ; also known as a Data Management Zone or Demarcation Zone or Perimeter Network, is a physical or logical subnetwork that contains and exposes an organization's external services to a larger, untrusted network, usually the Internet. The purpose of a DMZ is to add an additional layer of security to an organization's Local Area Network (LAN); an external attacker only has access to equipment in the DMZ, rather than the whole of the network. [Reference: http://en.wikipedia.org]

1.2 The Basic Building Blocks in the PI System



1.2.1 Point Properties

Data Archive points have a set of properties that define them (these properties are called attributes of the tag). Some common properties are defined in the following paragraphs.

Point Name

This is the unique name used to create points for storage in the Data Archive. Examples: P294H.FI.PV, M03_E1P1_MOTDRV1202_RUNSTAT

Descriptor

This is the human-friendly description of the Data Archive point. The descriptor is often a search criterion since the point name is not always intuitive. Often the point name is some sort of abbreviated convention and the descriptor captures the "full name."

Point source

Points can be related to their interfaces that collect the data by a point attribute called *pointsource*. Grouping by point source allows all of points associated with a particular device to be identified by searching for all points of a certain point source. This assumes that the user knows the point sources in use and that will not be true in some situations.

Point type

This is the attribute that specifies the data type for the values that a point stores. The possible point types are:

int16, int32, float16, float32, float64, digital, string, BLOB, timestamp

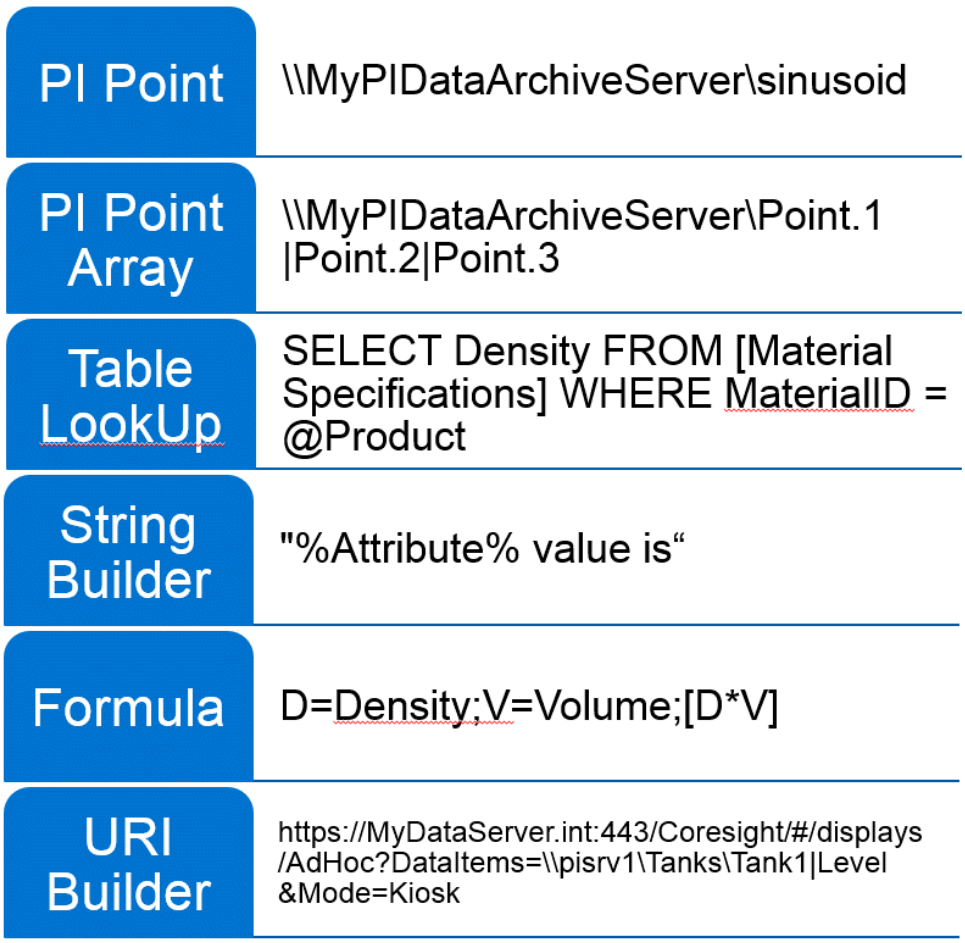
1.2.2 Attribute Data Reference Types

Attributes represent a unique property associated with an asset. The *Data Reference Type* of an attribute defines from where to get the data for the attribute. The following Data Reference Types exist:

- PI Point
- PI Point Array
- Formula
- Table Lookup
- String Builder
- URI Builder

Note: <none> means there is a static value for this attribute.

Data Reference Types (Setting Examples)

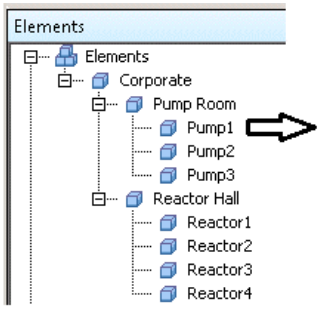


1.2.3 Directed Activity – Assets Defined: Data Reference Types

You are invited to watch what the instructor is doing or perform the same steps at the same time to explore the different concepts presented in this chapter or section.

Problem Description

Identify the type of attribute data references in the AF Server.



Elements

Name	Value	Data Reference
AdHoc Pressure Trend	http://pisup2015/coresight/#/displays/AdHoc?D...	URI Builder
Electrical Current	1 A	Formula
Flow Rate	93.07056 m3/h	PI Point
Manufacturer	Superflux Ltd.	<None>
Nominal Power	220 W	Table Lookup
Pressure	2 psi	PI Point
Pump Location	Pump Room	String Builder
Status	Active	PI Point
Temperature	89.8013 °C	PI Point

Attributes for Pump1

Questions

Identify the corresponding Data Reference Type of the following attributes:

1. **Nominal Power:** There is a list with the nominal pressures for all the pumps in the pump room and information can be read out of that list.

   _____

2. **Flow Rate**: receives actual measurements from the data source. There is a related tag in the PI Data Archive.

   _____

3. **Pump Location:** Specifies the location of the pump. The location corresponds to the name of the parent element.

   _____

4. **Electrical Current:** maximum amperage of a pump. The electrical current of a pump is calculated from the nominal power of the pump and the voltage (220 V).

   _____

5. **Manufacturer:** brand of the pump. This information never changes.

   _____

6. **AdHoc Pressure trend:** link to PI Vision with parameters to specify the element and the attribute and the start and end time for the trend.

   _____

1.3 Time and the PI System

Objectives

- Define the time abbreviations in the PI System.
- Define the time expressions in the PI System.
- Introduction to Future Data.
- Explain how the PI System handles times zones and daylight savings time (DST).

You can use a special syntax, called PI System time, when specifying inputs for timestamps and time intervals. The PI System time uses specific abbreviations, which you combine to create time expressions.

1.3.1 PI System Time Abbreviations

When specifying a PI System time, you can use specific abbreviations that represent time units and reference times.

Abbreviation	Time-unit
s	second
m	minute
h	hour
d	day
w	week
mo	month
y	year

To specify time units, you can specify the abbreviation, the full time unit, or the plural version of the time unit, such as s, second, or seconds. You must include a valid value with any time unit. If specifying seconds, minutes, or hours, you can specify a fractional value. You cannot specify fractional values for other time units.

Abbreviation	Full	Reference-time
*		Current time.
t (or T)	today	00:00:00 (midnight) of the current day
y (or Y)	yesterday	00:00:00 (midnight) of the previous day

Abbreviation	Full	Reference-time
sun	Sunday	00:00:00 (midnight) on the most recent Sunday
mon	Monday	00:00:00 (midnight) on the most recent Monday
tue	Tuesday	00:00:00 (midnight) on the most recent Tuesday
wed	Wednesday	00:00:00 (midnight) on the most recent Wednesday
thu	Thursday	00:00:00 (midnight) on the most recent Thursday
fri	Friday	00:00:00 (midnight) on the most recent Friday
sat	Saturday	00:00:00 (midnight) on the most recent Saturday

1.3.2 PI System Time Expressions

The PI System time expressions can include a reference-time and a time offset, indicated by a direction (either + or -) and a time unit with a value. PI System time expressions might include:

- Only a reference time, such as “y”
- Only a time offset, such as “+3h”
- A reference-time with a time offset, such as “y+3h”

A reference-time can be a fixed time, such as “24-aug-2012 09:50:00”, or a valid reference-time abbreviation, such as “t”.

You can only include one time offset in an expression. Including multiple offsets can lead to unpredictable results. For example, the following time expressions are not valid:

1.3.3 Timestamp Specification

To specify inputs for timestamps, you can enter time expressions that contain:

Fixed times

A fixed time always represents the same time, regardless of the field or the current time.

Input	Meaning
23-aug-12 15:00:00	3:00 p.m. on August 23, 2012
25-sep-12	00:00:00 (midnight) on September 25, 2012

Reference-time Abbreviations

A reference-time abbreviation represents a time relative to the current time.

Input	Meaning
*	Current time (now)
3-1 or 3/1	00:00:00 (midnight) on March 1 of the current year
2011	00:00:00 (midnight) on the current month and day in the year 2011
25	00:00:00 (midnight) on the 25th of the current month
t	00:00:00 on the current date (today)
y	00:00:00 on the previous date (yesterday)
tue	00:00:00 on the most recent Tuesday

Reference-time Abbreviations or Fixed Times with a Time Offset

When included with a fixed time or a reference-time abbreviation, a time offset adds or subtracts from the specified time.

Input	Meaning
*-1h	One hour ago
t+8h	08:00:00 (8:00 a.m.) today
y-8h	16:00:00 (4:00 p.m.) the day before yesterday
mon+14.5h	14:30:00 (2:30 p.m.) most recent Monday
sat-1m	23:59:00 (11:59 p.m.) last Friday

Time Offsets

Entered alone in a time field, time offsets specify a time relative to an implied reference-time. The implied reference-time depends on the field where you enter the expression:

- For a start time, the reference-time is the current clock time.
- For an end time, the reference-time is the start time.
- For a single time stamp, the reference-time is the current clock time.

Time field	Input	Meaning
Start time	-1d	One day before the current clock time (24 hours before the current clock time)
End time	+6h	Six hours after the start time
End time	-30m	30 minutes before the start time
Time stamp	-15s	15 seconds before the current clock time

1.3.4 Future Data

Future data is data associated with a future time stamp. Data Archive 2015 allows storage and retrieval of data with time stamps beyond current time, allowing you to store data within a time range of January, 1970 through January, 2038. With Data Archive 2015 you can capture and analyze data with future time stamps, and use PI visualization tools to graphically create possible forecasts or predictions for your business.

Just as with historical data, to specify inputs for timestamps, you can enter time expressions previous discussed fixed time, reference times, and reference-time abbreviations or fixed times with a time offset. The difference being the timestamp will be in the future. Some example expressions are:

Input	Meaning
*+1h	An hour from now
t+3d	Three days from today at midnight
Y+1y	A year from yesterday

1.3.5 How Does the PI System Adjust for Time Zones and DST?

The short answer is: we do not!

When we collect data, we convert it to UTC (Universal Coordinated Time), or what used to be called Greenwich Mean Time (GMT). This means that each day has exactly 24 hours. The local machine clock of the user looking at the data makes any adjustments for time, such as time zone or DST.

If your region observes DST, once a year the day will look like it has 23 hours and another 25, but the PI Server never knows anything other than 24-hour days.

In addition, because the clients and PI Server know what time zone they are in, the data can be viewed with respect to the *server time* or the c*lient time*. This is determined by a setting in the client tool.

1.3.6 Exercise – PI System Times

This solo or group activity is designed to maximize learning in a specific topic area. Your instructor will have instructions, and will coach you if you need assistance during the activity.

Problem Description

Determine the "real" dates and times indicated by the PI System times in the table below:
(assume now: Tuesday, 20-May-2014 10:12:23 AM)

Abbreviation	Answer
* - 30m	
T-1d	
y + 8h	
12 8:	
Tuesday – 2d	

Express the following times in valid PI System time abbreviations:

Abbreviation	Answer
Today at 6:30 AM	
Monday at 5:45 am	
12 hours ago	
The first day this month	
Tomorrow at 7:00 AM	
2 hours from now	

2. Introducing Asset Framework

2.1 PI AF Server

2.1.1 AF Server Installation and Software Requirements

In a production environment, the AF Server component is typically installed on a dedicated Windows server machine.

For the database management the AF Server is using a **Microsoft SQL Server**, which has to be defined during the AF server installation. The default name of the SQL database used for AF is **PIFD**.

The client program for AF is PI System Explorer (PSE), which is used to configure and maintain the asset structure.

AF Server is compatible with several SQL Server versions (SQL Server 2008 or later; for a complete list refer to AF Server software requirements). The PI AF server works with 32-bit or 64-bit SQL Server versions.

Several SQL Server editions are supported: Express, Standard, Business Intelligence, Enterprise, Datacenter. The Express version is free of charge, but has several limitations. Depending on your AF asset structure size and the AF functions you are using (such as audit trail functionality), the Express version may not be sufficient. Refer to related OSIsoft Hardware System Sizing recommendations.

The SQL Server can reside on the same machine as the AF Server or on another machine. It is possible to use an existing SQL Server that is also used for other applications.

SQL Server Requirements for PI AF High Availability

To take advantage of the PI AF High Availability (HA Collective) feature, the primary collective member must run SQL Server Standard Edition, SQL Server Business Intelligence, SQL Server Enterprise Edition, or SQL Server Datacenter Edition. SQL Server does not need to reside on the same machine as PI AF Server.

SQL Server Requirements for PI AF Audit Trail Functionality

The PI AF Audit Trail feature requires SQL Server Enterprise edition for supported SQL Server versions of SQL Server 2014 and earlier.

The PI AF Audit Trail feature is also supported in:

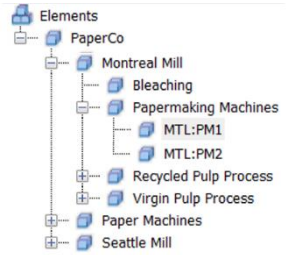
- SQL Server 2016 (Windows Update or Microsoft KB 3164398 required)
- SQL Server 2016 SP1 Enterprise or Standard Editions
- SQL Server 2017 Enterprise or Standard Editions (Windows Version Only)

For complete information about the system requirements for the AF Server, refer to the AF Server software requirements.

2.1.2 Asset Framework Key Features

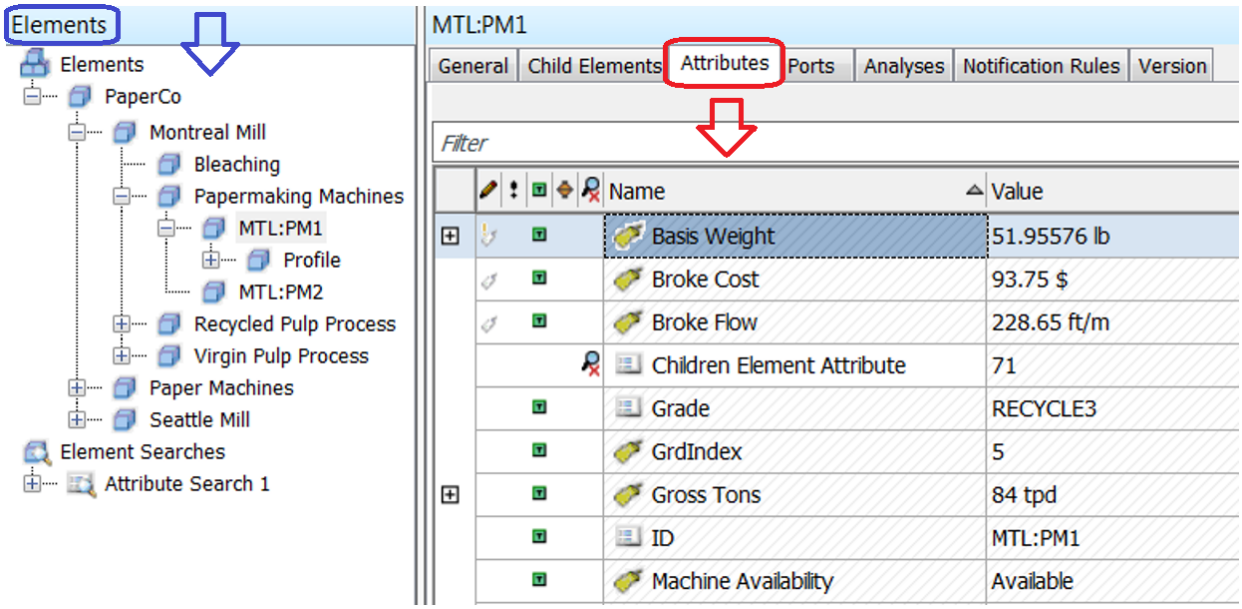
Asset Framework provides an additional data layer in the PI System. It is based on an asset model of your plant that is defined by the customer. The model consists of elements and attributes.

The model organizes and structures the data according to objects that customers are most familiar with, such as physical objects in their processes like reactors, transformers and meters.



Since the AF asset model can span PI Data Archives, it allows customers to organize and search for PI System information across multiple PI Data Archives.

The basis for the asset model is an **Element**, which contains **Attributes** that can reference PI System data, design data or data from other systems:



AF Event frames allow users to associate or bookmark events, which occur over a time span with those assets.

Asset Analytics provides real time calculation engine that allows users to configure, schedule and run calculations written using Performance Equation syntax acting on their AF attributes. Calculation results can be stored as time series data in PI Points or create event frames, notifications can automatically be sent out for them if needed.

Client applications including but not limited to, PI Vision, PI DataLink, PI ProcessBook and PI Integrators can utilize the asset models to provide context driven displays, reports and analyses.

2.2 PI System Explorer Components

2.2.1 Directed Activity – Familiarize with the PI System Explorer Components

In this part of the class, you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

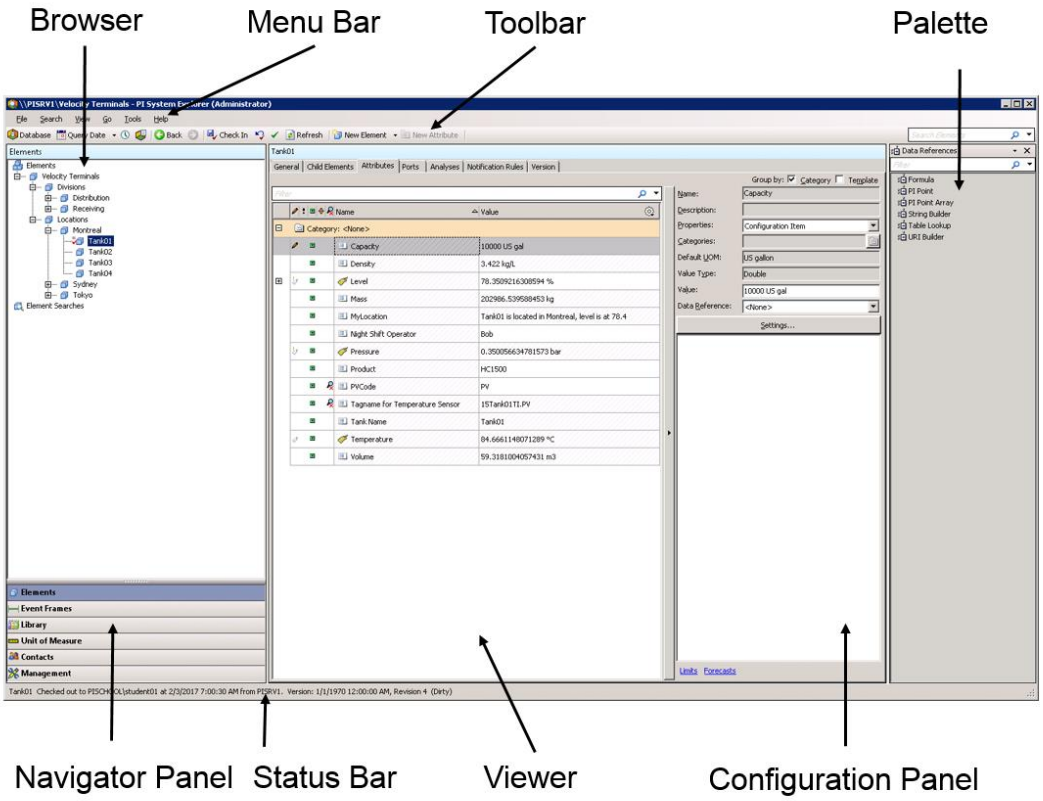
Problem Description

You may follow along as your instructor shows and explains the PI System Explorer components and their general use.

Approach

Click on the PI System Explorer icon in the task bar to start the program.

Note: the very first start of PI System Explorer can take some time. In the beginning, no dialog box is displayed. Subsequent starts will be much faster.



Navigator Panel

PI System objects are grouped into sections displayed in the Navigator Panel. Groups appearing by default include Elements, Event Frames, Library, and Unit of Measure and Management.

Menu Bar / Toolbar

Use these options for such tasks as opening/creating a database, searching for elements or contacts, applying and checking in changes, setting view options, and so forth. Menus and the Toolbar are context sensitive and will present different options depending on what section is selected from the Navigator Panel.

Browser

Use the Browser to select the objects you want to work on and display in the Viewer panel. The Browser displays the PI System objects that have been added to the AF database, such as elements, templates, notifications, etc. Depending on the section selected from the Navigator Panel, the following will be available from the Browser:

- **Elements**: Elements represent either physical or logical entities in your process. They can be organized in several hierarchies. An element can be created from a template or created from scratch. When based on a template, the element derives its initial attribute configurations from the template. Later modifications to the template will propagate to all elements based on said template.

- **Event Frames**: An event frame is any event, defined by a start time, an end time, and a context. Event frames also have attributes containing supporting data. Event Frames can represent downtime events, process and environmental excursions, material transfer events, equipment maintenance events, batch processing steps, safety incidents, and any other events important to your organization. A transfer is a special type of event frame that marks the movement of material in discrete quantities.

- **Library**: This is a collection of objects that can be re-used throughout the AF hierarchy. Types of objects that appear in the Library include Categories, Element Templates, Enumeration Sets, Reference Types, and Tables.

- **Units of Measure (UOM)**: The UOM database provides automatic handling of simple conversions between units of measure for attributes of the same UOM class. A UOM class is defined by the fundamental dimensions of its measurement. Examples of UOM classes are Mass, Volume, and Density. The UOM database comes preloaded with numerous standard unit-of-measure classes and conversion factors. You can extend these classes by adding new units of measure, as well as new measurement classes. The implementation of UOM is based on the International System of Units (SI).

- **Management**: This section provides a summary of all analyses and notification rules configured on the current AF database. It allows you to perform administrative tasks like starting, stopping and backfilling.

Viewer

This is the primary work area. Use it to create and edit elements, attributes, templates, tables, contacts, notifications, analyses, and so forth. When configuring attributes through the Viewer, the Configuration Panel comes into view allowing you to make configuration changes.

Configuration Panel

The configuration panel is used to configure properties associated with attributes. These properties include categories, attribute references, units, data types, and values for static attributes.

Palette

The Palette displays templates, data references and contacts that can be associated with objects being defining in the Viewer. Often the Palette is hidden to optimize screen real estate.

Status Bar

Check the status bar after clicking an item in the Browser to see its status. For example, last modification time, if the object is checked out or if a notification is currently loading.

2.3 Connecting to a PI System

Objectives

- Describe the different ways we can connect to a PI System.
- Connect to an AF Server.
- Examine your connected credentials.
- Connect to a Data Archive.
- Create a new connection to a Data Archive.

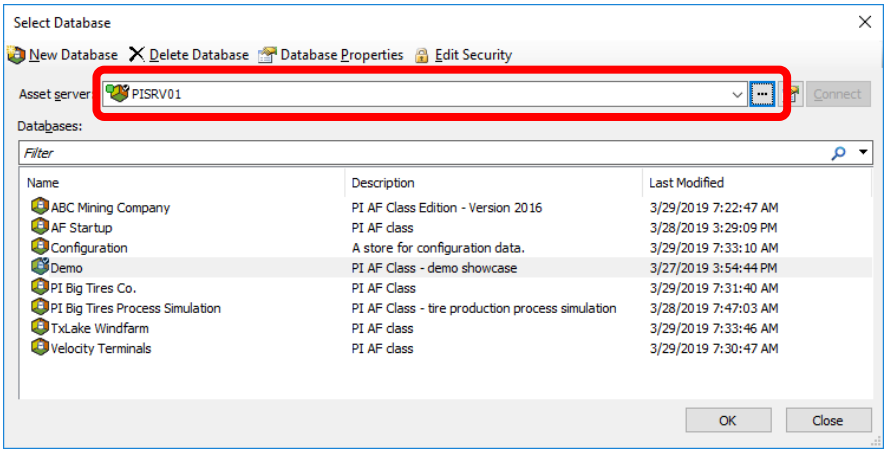
2.3.1 What Do We Connect for Data?

During this class, the PI System data will be retrieved mainly using PSE. A connection to an AF Server will be needed to access all the metadata related to your assets while a connection to the Data Archive will be required to access the process data from the Data Archive points.

2.3.2 Connecting to a AF Server

To connect to the AF Server simply open PSE. The default AF Server was set during installation, so you will be automatically connected to it. If a default AF database has already been defined, PSE will automatically connect to it as well. If no default AF database has been defined, a window will pop up and you will be invited to create a new AF database.

It is possible to see which AF server the user is connected to by selecting the Database button on the toolbar. The *Select Database* dialog box will show the current server name in the top drop-down “AF Server” list.



To connect to a different available AF server, simply select it from the drop-down AF Server menu and click on the *Connect* button.

2.3.3 Directed Activity – Examining Credentials When Connecting to the AF Server

In this part of the class, you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

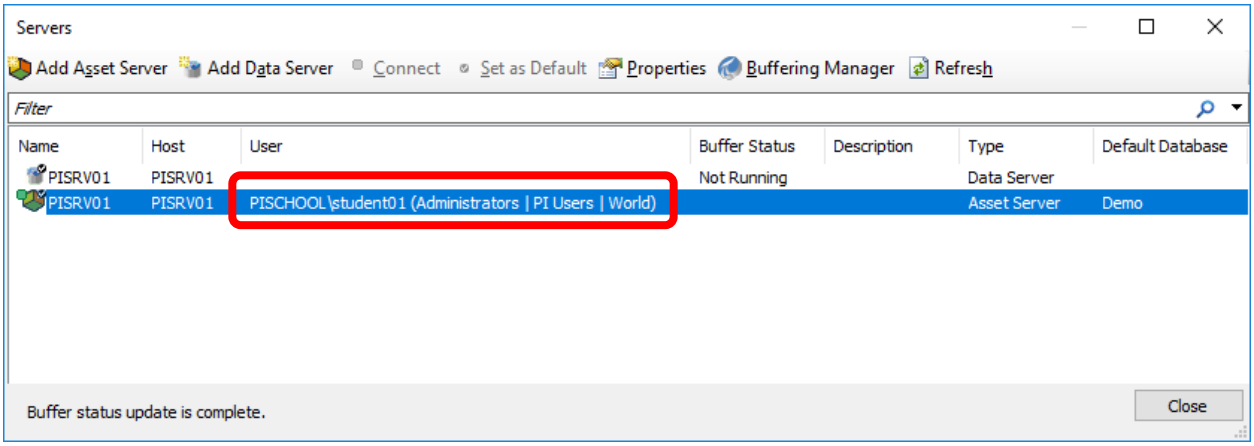
Problem Description

You may follow along as your instructor shows you how to validate connections to Data Archives and AF servers.

Approach

Click on the PI System Explorer icon in the task bar to start the program.

To find out the credentials being used for connecting to the AF Server, go to *File* > *Connections*…

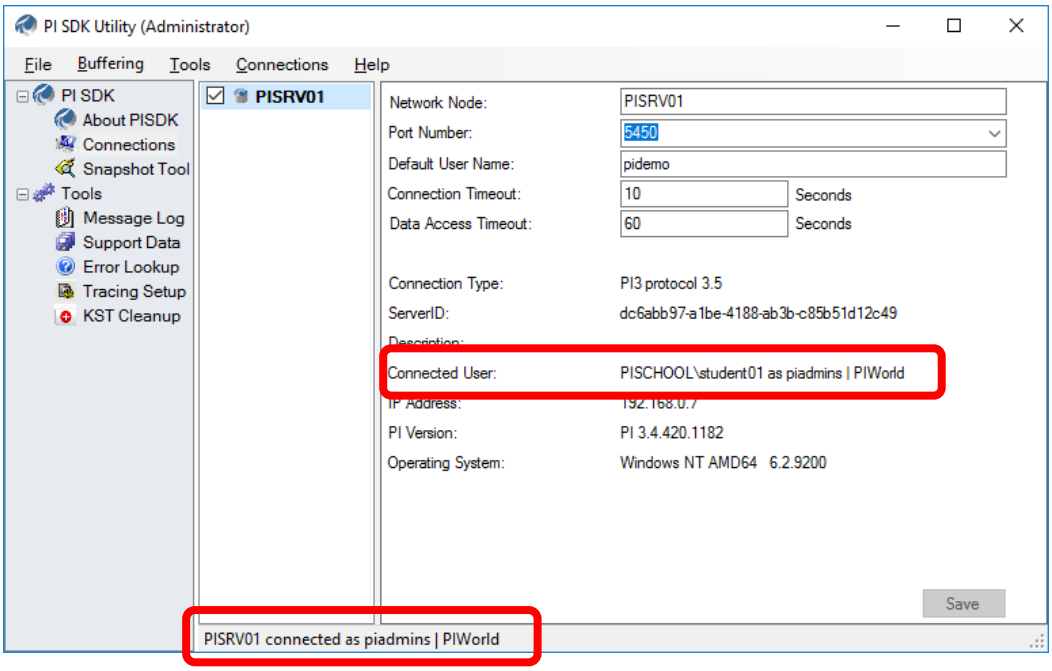


2.3.4 Connecting to a Data Archive

You can validate your connection to the Data Archive via PSE. Notice AF Server icon ( ) is different than Data Archive server icon ( ).

The PI SDK utility provides you with more features to configure and diagnose connections to the Data Archive.

Open the PI SDK Utility (PI System > PISDKUtility (64-bit)). From the *PI-SDK* > *Connections* section, the Data Archive servers configured on the local machine are displayed. To validate a connection to a Data Archive, simply check the checkbox next to its name or IP address. If connection succeeds, connection information will be shown.



The user that was used to authenticate on the Data Archive will be shown in the status bar and the connection information section on the right.

Note: The PI SDK Utility is a particularly useful tool to troubleshoot permission issues.

2.4 Finding Data

Objectives

- Demonstrate the ability to find element data within the Asset Framework (AF) hierarchy.
- Demonstrate the ability to search for points from within PI System Explorer (PSE).
- Examine point attributes.

2.4.1 Directed Activity – Finding Elements and Attributes

In this part of the class, you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

PI System Explorer has two element search options: a quick search and an advanced search with multiple search criteria.

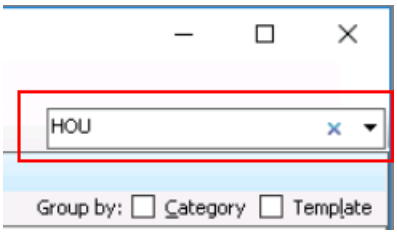
Activity Objectives

- Perform a quick element search based on a name pattern
- Perform an element search with multiple search criteria.
- Perform an attribute search.

Approach

Quick Element Search

1. Open the PI Big Tires Co. AF database in PSE, select Elements in the Navigator.
2. Explore the element hierarchy: it contains 3 locations (Houston, Montreal and Philadelphia (“Philly”)) with four presses in each location.
3. Enter **HOU** into the quick search and click on Enter.



4. Enter **HOU*Press** into the quick search and click on Enter.

Note: The search is shown with a little asterisk . When you select Save from the context menu, the search will be available the next time you log into PI System Explorer. When you select Rename from the context menu, the search will be renamed and saved.

Advanced Element Search (multiple search criteria)

5. From the PSE menu, select Search – Element Search…
6. (optional) If criteria were cached from the last search, click the blue "x" in the search line on the top to reset.
7. Enter criteria to search for the presses in Montreal (Element Search Root= Montreal, template= PressTemplate), click on Search to get the results.
8. Enter ***1** in name field to specify another criteria, click on Search to get the results.

Note: *All Descendants* specifies whether the search returns elements from the selected levels and all levels below. The option should be set to true in most cases. The Name field can make use of the wildcard characters (* and ?).

9. Reset the criteria. When you specify a template (e.g. PressTemplate) you can add a criteria for an attribute value. Search for all presses with Press Status = "Running".

Attribute Search

10. From the PSE menu, select Search – Attribute Search…
11. Select PI Big Tires Co. AF database.
12. Enter **Press Status** into the attribute name field. Make sure the *Search Sub-Elements* option is selected. Click Search. Result: the Press Status attributes for all 12 presses are listed. Click on OK.

2.4.2 Directed Activity – Finding Points within PSE

In this part of the class, you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

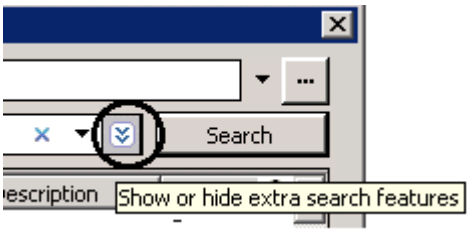
A Tag Search window is available from PSE in order to find the appropriate point to map to a PI Point Element Attribute. This tag search window is accessible from the Search – Tag Search… menu item.

Activity Objectives

- Understand the search capabilities and options of PSE Tag Search.

Approach

1. From the PSE menu, select Search – Tag Search…
2. (optional) If criteria were cached from the last search, click the blue "x" in the search line on the top to reset.
3. Search for tags matching the name pattern **CD*158**
4. Search for tags matching the name pattern **CD?158.** What is the difference to the previous search results?
5. By default, this window allows searching using a point name mask. If you click on the control to display extra search features, you will get more options to further refine the search using additional common point attributes like the descriptor.



Enter criteria to search for all tags with point source=R and name= sinus*.

3. A Walkthrough of AF

3.1 What does Asset Framework (AF) do for me?

The *PI Data Archive* is focuses on a points database and is extremely good at storing vast amounts of data collected by interfaces. It allows easy and performant retrieval of time-series data. The PI Data Archive architecture is scalable, maintainable and highly available.

The *Asset Framework (AF)* supplements the architecture by providing a Meta-data structure for all data in the organization ("Data Directory"). Asset Framework (AF) has a rich set of features and functions to organize and enhance the data in the PI Data Archive. Because it offers user-friendly access to the data it is the preferred way for users to interact with their PI system data.

What are the benefits of Asset Framework?

Easy way to navigate throughout the system

The hierarchical asset structure gives a convenient way for navigation that can also be used by people, who are not familiar with the technical details of how the data is retrieved from the data source.

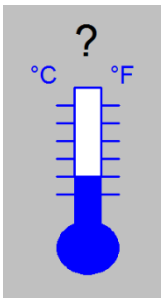
Unify data from disparate source systems

PI Point attributes get their data from PI Data Archives. AF is not limited to one PI Data Archive. Attributes can refer to multiple PI Data Archive Servers (either standalone or collective)

The origin of data can also be a relational database. While some attributes of an element representing a reactor are time-series data coming from PI tags (such as the temperature), data for some other attributes can be from an external database (such as the physical characteristics or inventory data).

All attributes are listed side by side giving the user a comprehensive insight into all the relevant data of the asset.

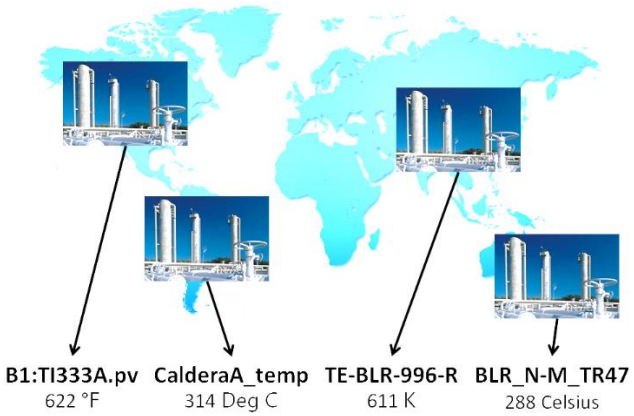
Supports different Units of Measure



PI Asset Framework (PI AF) attributes are associated with specific Units of Measure. AF is preloaded with numerous standard unit-of-measure classes and conversion factors based on the International System of Units (SI). It also supports user defined classes and Units of Measure. For example, the source unit for a temperature sensor attribute in a reactor in the USA can be associated with degrees Fahrenheit, the corresponding attribute for a reactor in Italy can be associated with degrees Celsius. When working with the data (doing calculations or displaying the data) this is properly taken into account.

Standardization with Templates

At many sites there are no rigorous naming standards for the points. There may be missing descriptions and/or engineering units. The PI System is often used to integrate information from different sources and these sources may not have been configured consistently:



Element templates in AF provide the basis for standardization. When applied for elements that represent the same type equipment, all elements have the same set of attributes with a consistent, user friendly naming. The attributes have same unit of measurement, same data type, the same description, etc. This allows a harmonized, consistent representation of your system.

Another benefit of using templates is the quick creation of many elements of the same type.

Powerful Calculation Options (Asset Analytics)

Users can configure, schedule and run calculations written using PI Performance Equation (PE) syntax acting on their PI Asset Framework (PI AF) attributes. PE expressions, Rollup calculations and generation of PI Event Frames based on trigger conditions are all supported analysis types. In addition, analysis templates enable users to manage their analyses in a standardized and consistent manner. Typical applications are Key Performance Indicator (KPI) calculations and condition based maintenance (CBM).

3.2 Introducing Elements and Attributes

3.2.1 Directed Activity – Velocity Terminals

In this part of the class, you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

Activity Objectives

- Create an AF element with attributes using PI Point, Table Lookup, and Formula data references.
- Define the value types and units of measure for attributes in the element and in the element template.
- Create and populate an AF table.
- Create an AF element template from an element.
- Extend the template with new attributes and see how these affect the original element.
- Create an AF enumeration set and use it for data validation in a template.
- Create an element from a template.
- Move AF Elements under a parent element.
- Create more elements with the PI Builder Excel add-in.

Problem Description

You are working for Velocity Terminals, a chemical company producing various chemicals. The company has a number of storage tanks located in different countries that they would like to monitor. You have been tasked with creating an asset model for these tanks in AF.

Approach

Follow the instructor as he or she performs steps to create various AF objects that will lead to the creation of a single PI ProcessBook display to monitor all of Velocity Terminals' tanks.

You will have opportunities to work on your own later on in the course. For now follow and listen closely to the information in this initial exploration of AF.

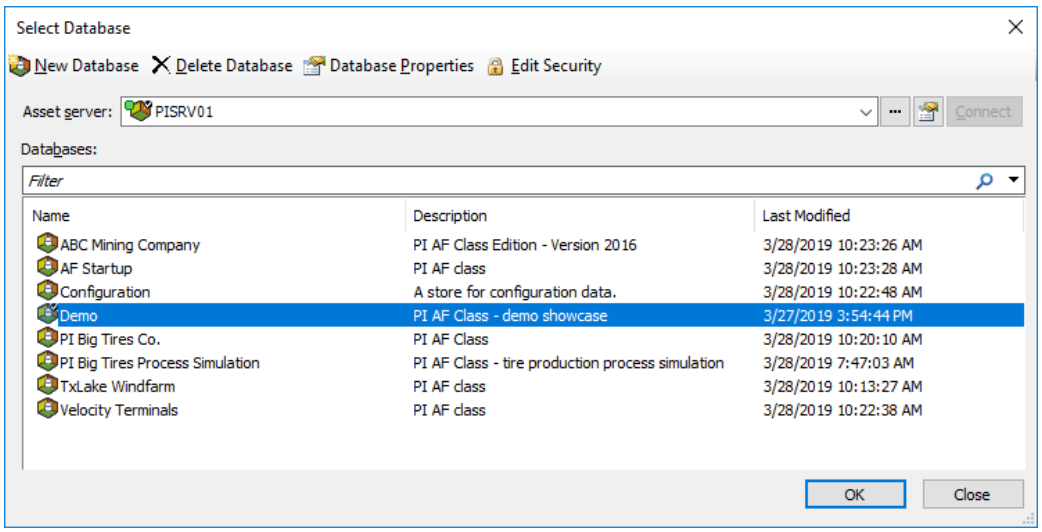
3.2.2 Creating and Selecting AF Databases

Open PSE from the start menu and, if necessary, connect to the AF server PISRV01.

If PSE opens normally, choose *File* > *Database*. If PSE does not open and a pop-up appears, click on the *Select* option to get to the Select Database window.

To create a new database, right-click anywhere in the list of databases and choose *New Database* or click on the New Database button on the toolbar.

To select the existing database for entering the Velocity Terminals structure, select ***AF Startup*** and click the OK button or double-click on it to open the database.



About Databases

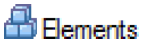
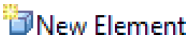
PISRV01 setup for training has many AF databases, which are specific for class exercises. In practice, it may be better to build fewer, larger databases. That is because references in AF only work within the same database; it is not possible to compare elements and values across databases. Companies may find it better to organize their database at the business unit level and not the plant level.

The Configuration database

As an administrator, it is possible to view a database called Configuration. Do not use this database to organize your assets as it is only shown to administrators and used to store configuration data for PI System software.

3.2.3 Creating AF Elements

Make sure the Elements section is selected from the Navigator Panel and create a new element called Tank01.

From the Browser, right-click on  and select *New Element* or click the  button from the toolbar and select <None> as the element template.

Under the *General* tab from the Viewer, change the name of the element to *Tank01*.

About Elements

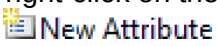
The element is the basic building block of AF. It is an organizational feature that can be thought of like a folder. It has relationships with other elements and has searchable characteristics. An elements has no Data Reference and does not have a value. Elements are generally organized hierarchically, though this is not required.

Elements represent physical or logical entities in your process, this can be: equipment, lines, products, systems, organizations or sites. They can be based on a template or created without one, although later sections will emphasize the fact that templates are highly recommended.

Elements in a AF database must be uniquely named to their path. An element named “Transformer” can exist under an element named “System A” while another element named “Transformer” can exist under “System B”. However, two elements named “Transformer” can not coexist under the same element “System A”. It is recommended that unique names are considered for all elements regardless of their position in the hierarchy.

The name of an element can contain any character except control characters or any of the following (; ? ` ‘ “ \ | {} []).

3.2.4 Creating AF Attributes

From the Viewer, select the *Attributes* tab and then right-click on the white space to select *New Attribute* to define attributes or click the  button from the toolbar.

As with elements, attributes must also be uniquely named along their path within the element they belong to. Attributes can have a configured constant value or can get a value dynamically from a Data Reference.

Value Type

The **Value Type** field for the attributes defines the format the value itself will have. The various types will be familiar to those with programming experience. In general, value type Double can be used for most analog/numeric values and value type String for everything else. Other types may also be useful in certain circumstances. For example, a value type of Boolean allows either a 0 or a 1, which is represented as False (0) or True (1).

Display Digits

The **Display Digits** field (new in AF 2018) can be used to control the number of digits you want to see for the attribute: zero or positive numbers indicate the number of digits to display to the right of the decimal point. A negative number indicates the number of significant digits to display. In this case, the absolute value of Display Digits is the number of significant digits

If your AF Server version is before 2018, the functionality is like for Display Digits = -5

Example (Value= 23.45)

Display Digits	Format
3	23.450
2	23.45
1	23.5
0	23
-1	2E+001
-2	23
-4	23.45
-5 (default)	23.45

Three (3) attributes will be created for Tank01. Start configuring the attributes using the table below:

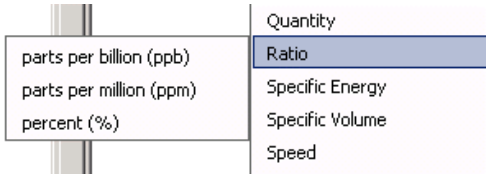
Attribute Name	Default UOM	Value Type	Value	Display Digits
Capacity	US gal (Volume)	Double	20,000	-5
Level	% (Ratio)	Double	N/A	2
Volume	m3 (Volume)	Double	N/A	3

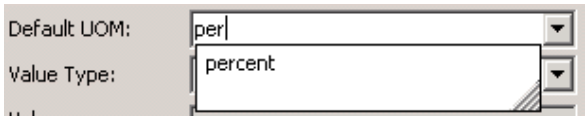
Units of Measures for Attributes

Attributes will generally be assigned units of measures (UOM). These UOM are organized into comparable classes. The Default UOM configuration field defines the default unit of measure to use to display the attribute's values. This default unit of measure does not need to be the same as the instrumentation. Later sections will show how this can be used.

Note: **Always assign a unit of measurement!** Do not leave this undefined. This will avoid misinterpretation of the measurement in all subsequent operations.

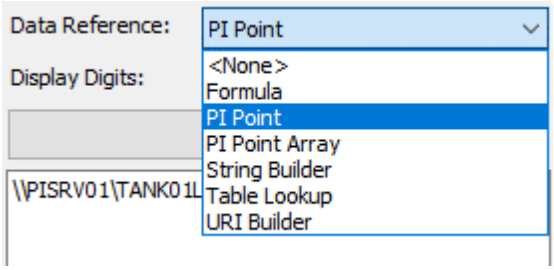
- To enter an UOM, select the UOM from the corresponding UOM Class (here: UOM class= Ratio, UOM= percent). Alternatively, enter the first characters (such as *per*), then select from the list of matching UOMs.



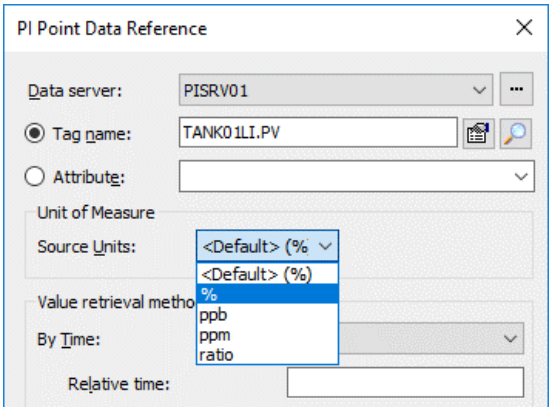


Level Attribute

- With the Attributes tab selected, select the *Level* attribute, change its data reference to PI Point, and then click on the *Settings* button.



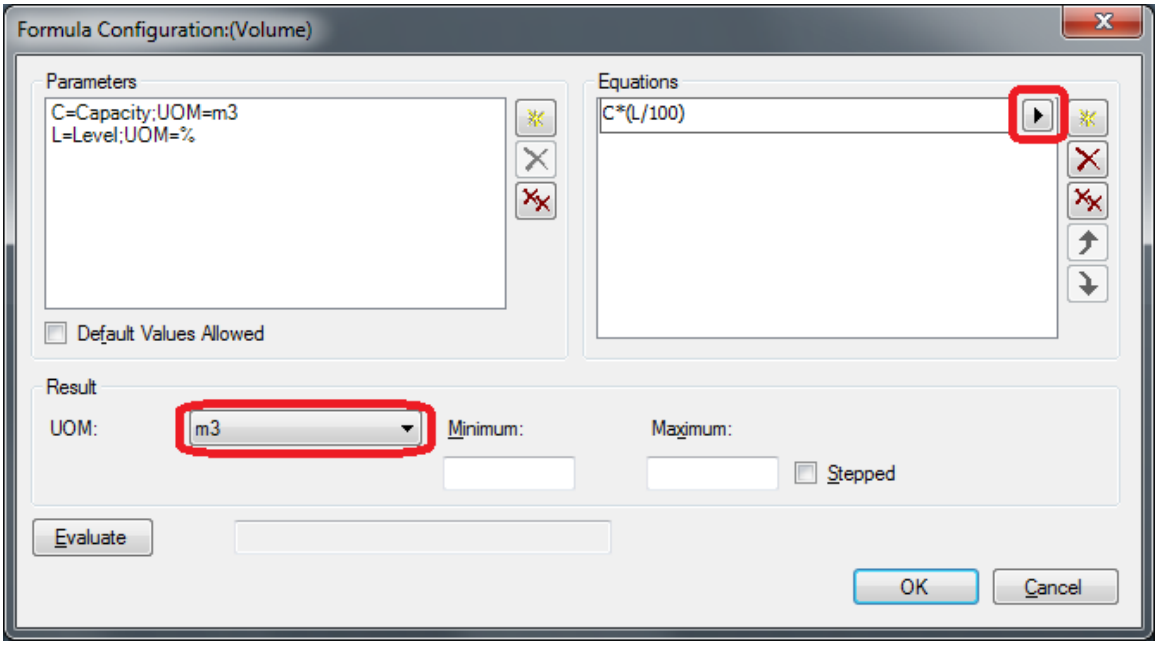
- Select the correct Data Archive at the top and enter TANK01LI.PV (or use the tag search ( )). Change the Source Units from "<Default> (%)" to "**%**".



Note: Make sure you always assign a unit of measure (UOM) rather than just keeping the default. This prevents that the PI Point value is misinterpreted in case the attribute UOM is changed later in time.

Volume Attribute

- Select the *Volume* attribute and set Data Reference to *Formula.*
- Clicking on *Settings* to bring up the Formula Configuration window.
- Use the formula data reference to calculate the volume using the level (%) and the capacity (m3).
- Use the new button ( ) to add parameters to use in the formula.
- Expand the list of functions from the equations section ( ) to pick the operators/functions to use in the formula.



Units of Measures in Formulas

You can perform unit conversions by setting the units of measure (UOM). Units of measure can be explicitly set for the parameters as well as for the result. Do this from the parameters configuration section by choosing the appropriate UOM from the *Unit of Measure* drop down. Do this also in the *Result* section at the bottom left.

Note: It is recommended that you **always** assign the units explicitly! If you leave units selector at “<default> then no unit conversion takes place. If the default UOM of an attribute is changed later on, then no corresponding conversion will happen and results will not be correct!

- Press the Refresh button on the toolbar and then the Check In button or select it from the menu: *File* > *Check In* to save these changes.
  The following table will help you to evaluate whether the calculation is correct.

Tank01 Level	Volume (US Gallon)	Volume (m3)
0 %	0 US Gallon	0 m3
20 %	4,000 US Gallon	ca. 15 m3
40 %	8,000 US Gallon	ca. 30 m3
60 %	12,000 US Gallon	ca. 45 m3
80 %	16,000 US Gallon	ca. 60 m3
100 %	20,000 US Gallon	ca. 75 m3

About Saving Modifications

The AF Server uses a sandbox concept for modifications. It holds the changes until they are published to the end users. When Check In is pressed, the changes made in your active session are published as the single public version that others can now see.

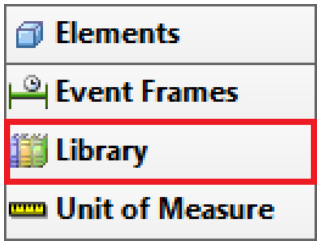
Until you check in, other users will not be able to edit a checked out object. The checked out icon will be shown ( ). As for the user currently editing an object in AF, the object icon will signify some changes were made to the object, that are not yet published ( ). The “Undo all changes to the Database” button ( ) next to the check in button will reset your sandbox changes and set your sandbox back to the database state as it was before you started working.

- To explore the *Display Digits* setting, change Capacity from 20,000 -> 200,000. Once you have entered the modified value, the value will be shown as **2E+05 US Gal**. This is because the value cannot be displayed with just five digits (Display Digits = -5), and the display is switched to scientific format. 2E+05 has to be interpreted as 2.0 * 10 ^ 5 (= 200,000). Change Capacity back to 20,000.

To familiarize with scientific format, open Windows Calculator and switch to Scientific View. Enter 200,000 and change to scientific display (F-E button).

3.2.5 Creating AF Tables

Building the table is similar to building a table in other programs that have simple table building capabilities.



In the PSE, first navigate to the *Library* section from the Navigator Panel. Right-click on the *Tables* item to select *New Table*, or click on the New Table button from the toolbar.

Under the *General* tab, change the name of the table to **"**Material Properties".

Select the *Define Table* tab and add two (2) rows by right-clicking in the blank area to select *Insert* or by selecting the starburst "Insert a row" button ( ) on the right-hand side. Define the table as follows:

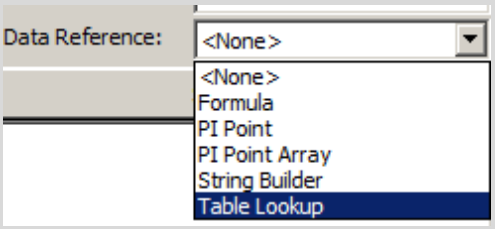
Column Name	Value Type	Unit Of Measure
MaterialID	String	<None>
Density	Double	kg/m3 (Density)

Under the *Table* tab, enter the following fictitious chemicals:

MaterialID	Density
AQ4500	2100 kg/m3
HC1500	3422 kg/m3
WX1200|Old Recipe	8943 kg/m3
WX1200|New Recipe	9213 kg/m3

About Tables

Tables are held in the AF database to provide contextual information through the *Table Lookup* data reference. Tables can provide information about the equipment or process entities or they can be used to store tag names or other configuration information to be used in AF.



Tables can be created internally (like in this exercise), imported from an external relational or tabular data source, or linked dynamically to an external relational data source. In this way, Tables can expose information in maintenance, production planning, or equipment databases for use by PI client applications.

3.2.6 Creating AF Enumeration Sets

About Enumeration Sets

An enumeration set is an ordinal list of sequential integer values, which are mapped to names. It allows AF attributes to refer to a common term instead of a number. This is analogous to the Data Archive digital state sets used by Digital points. It is not needed to rebuild the digital state sets or maintain them in AF. Enumeration sets are just a meaningful way to display information, perform data validation and maintain data consistency across the AF structure.

Hierarchical enumeration values (new in AF 2017 R2):

Enumeration values can be nested in hierarchy. The hierarchy can have as many levels as needed. In our case, WX1200 is produced with different recipes, which result in different physical characteristics and so in different density values. In a different level below the WX1200 value we can distinguish between the old and new recipe.

From the Navigator Panel, select the *Library* section.

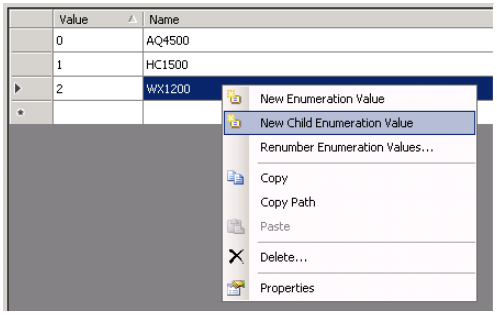
Right-click on the *Enumeration Sets* item to create a *New Enumeration Set*, or click the New Enumeration Set button from the toolbar and name the new set *MaterialID*.

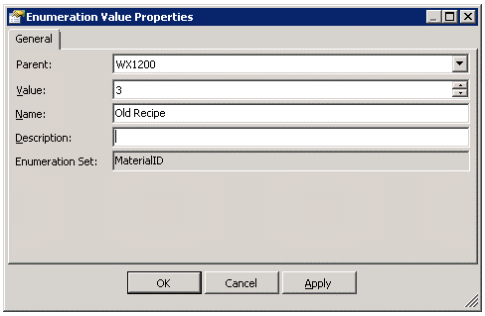
Enter the material IDs from the table below as the names of that set:

Value	Name
0	AQ4500
1	HC1500
2	WX1200

To distinguish WX1200 produced with either the old or new recipe, we will add two child values in a level below WX1200:

Value	Name
3	WX1200|Old Recipe
4	WX1200|New Recipe





Note: Hierarchical enumeration value feature is available since AF 2017 R2

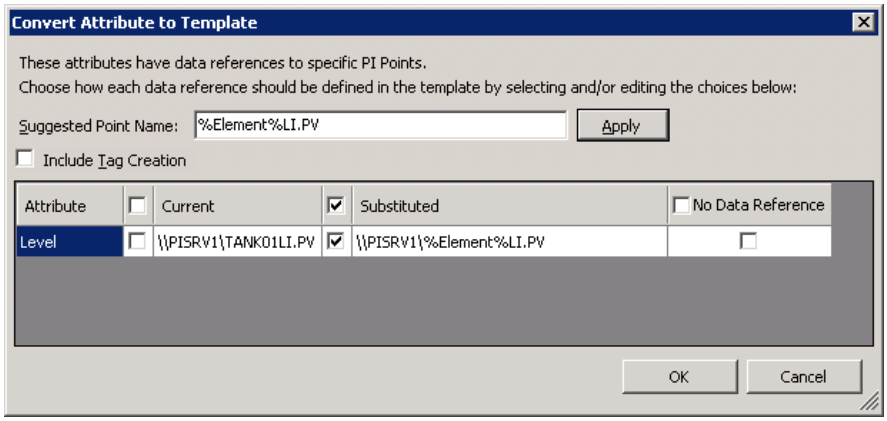
Check In to save newly created objects to the AF database.

3.2.7 Creating AF Element Templates

Select Tank01 from the *Elements* section in the Navigator Panel and right-click on it to select *Convert* > *Convert to Template* (note this does not delete or change the element, but does set it to a new template). When converting you have to decide, how the PI Point Data Reference for the Level attribute should be set. Select ***Substituted***, which will set the PI point name according to a naming pattern rule.

The default naming rule is %Element%.%Attribute%.%ID%.

Under *Suggested Point Name*, enter **%Element%LI.PV** and click *Apply*.



If you create elements for another tank based on the template, the substitution parameters in the point reference (enclosed with %) for the *Level* attribute will be replaced according to the name of the new element:

Naming Pattern: %Element%LI.PV	
Element Name	**PI Point Name**
Tank02	Tank02LI.PV
Tank03	Tank03LI.PV
Tank04	Tank04LI.PV
etc.	

Substitution parameters will be explained later.

Locate your new element template from the *Library* > *Templates* > *Element Templates* section and change its name to “Tank”.

Under the *Attribute Templates* tab, add four (4) new attribute templates by clicking the New Attribute Template button from the toolbar.

Attribute Name	Default UOM	Value Type	Data Reference	Display Digits
Product	<None>	Enumeration Sets > MaterialID	<None>	NA
Density	kg/L (Density class)	Double	Table Lookup	-5
Mass	kg (Mass class)	Double	Formula	-6
Tank Name	<None>	String	String Builder	NA

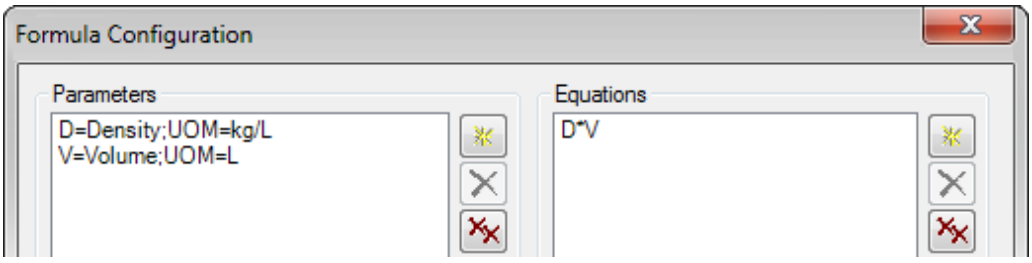
When you create the **Product** attribute, enable the *Configuration Item* Property.

Configure the *Table Lookup* data reference for the *Density* attribute using the following:

Table	Result Column	Where
Material Properties	Density	MaterialID = @Product

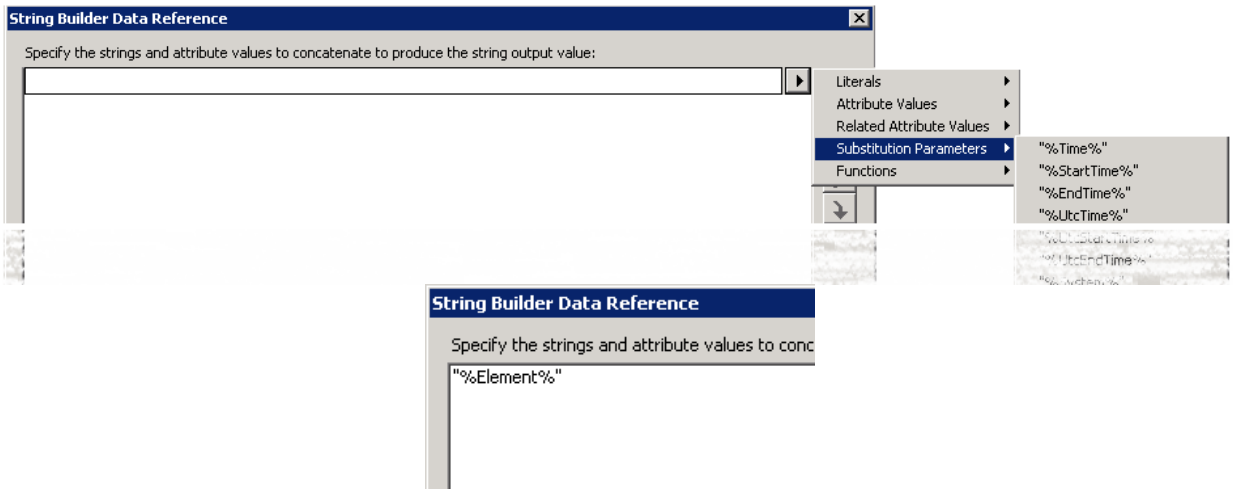
Configure the *Formula* data reference for the *Mass* attribute using the following:

Parameters			Equations
Variable	**Attribute**	**Unit of Measure**	
D	Density	kg/L	D * V
V	Volume	L	



To configure the *String Builder* data reference for the *Tank name* attribute:
Select *String Builder* from the *Data Reference* dropdown selection and click on the Settings…

Click on the Add New String button, click on to get further selection options, then select “%Element%” from Substitution Parameters:



Check In the changes.

Go back to the *Elements* section, select the *Tank01* element and look at its attributes.

Pick material “HC1500” for the *Product* attribute enumeration list and then click on Refresh.

Note the value of the Density attribute. Check the correct tank name.

Note: Elements should always be created from a template, even if at the moment of creation only one asset would make use of that template. This ensures consistency in the creation and management of AF elements.

However, for elements that would act only as organizing assets (folders) and that have no attributes, a template is not required.

3.2.8 Creating New Elements from Templates

Create a new element called “Tank02” based on the *Tank* element template and assign to its attributes the values found in the table below.

Attribute Name	Value
Capacity	30,000
Product	AQ4500

Commit these changes to the AF database (Check In).

The Power of Templates

The term template suggests a cookie-cutter way to create new objects with consistency. AF element templates do this and more for elements. They ensure similar equipment stay alike in AF.

When changes (in default values, attribute definition, or structure) are made to the template, the elements created using that template are automatically updated.

Note: If changes were made at the element’s attribute level, a change to the attribute template will not replace the modifications made by the user. That is, if you uniquely set values or configuration strings in the data references of unique elements’ attributes, they will not be overwritten by a modification of those attributes’ default values at the element template level.

Attributes derived from a template have a *Reset to Template* option on their right-click menu to remove any unique value or configuration string definition for this attribute and reset it to the default values established at the template level.

This allows to create, but also to maintain many elements with the template, knowing that changes are applied to all appropriate related elements.

Templates also allow the AF database to grow into an analysis tool when ready to do so. It is possible to add calculations and analytics into the template at any time since that information will be propagated to all of the elements automatically. It is not necessary to have the complete analysis at the time of template creation.

In this example we created a template from an existing element, but it is possible to go directly to the Library to create a new template by right-clicking Element Templates and selecting New Template or by clicking the New Template button from the toolbar.

AF Templates have an Allow Extensions check box under the General tab. Checking this box allows for additional attributes to be created at the element level, outside of the element template. Obviously, this will no longer guarantee all elements have the same set of attributes.

Templates may be the most powerful and unique feature in AF. Very few applications would not benefit of the use of templates when building AF elements.

3.2.9 Moving Elements under a Parent Element

Elements can be moved under other elements (then called Parent Elements) in order to represent a logical hierarchy to be used by your applications

Tip

When dragging and dropping elements under a parent, *make sure that parent element was first saved to the database* (check-in)! If the parent element was not checked in before moving another element under it (child element), the move operation might cause the child element to be deleted because AF doesn't yet know the parent element exists.

Moving Elements Around

You can move elements around in the *Viewer* using the mouse and keyboard. This will result in creating an element reference, or making a copy of the element or simply moving it.

Dragging an element while pressing the…	Action
Ctrl Key	Copies the original element under another parent element. The original and the copy will not be linked.
Shift Key	Moves the element.
No key	Creates an Element Reference. The element will now exist in two places in the hierarchy. In this case, the element icon has a "link" designator ( ), like in the case of a file shortcut.

Create a new element not based on any template named "Montreal". Check-in the changes.

Select both tanks using the mouse and *drag and drop* them while holding the *Shift key* on the keyboard in order to move those elements under the Montreal element so they become child elements of that location.

Select the *Parent-Child Reference Type* for each tank element. The different reference types will be discussed in the next chapter.

Tip: When moving an object, be deliberate with the *shift key, drag and drop* manipulation. It is safer to right click the element, copy it to the new location and then delete the original.

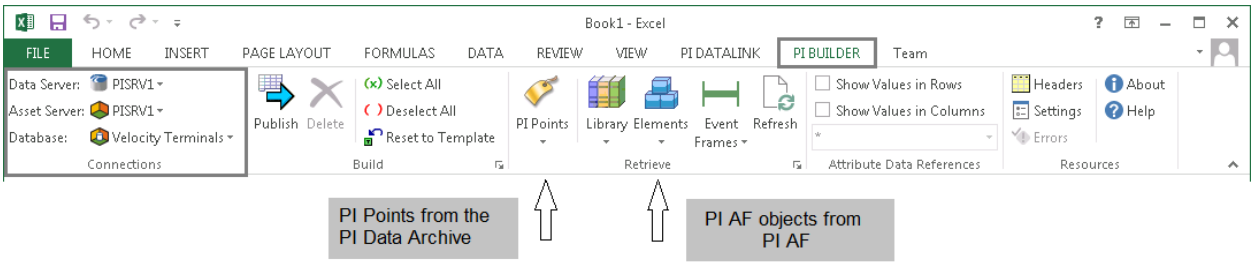
3.2.10 Creating AF Objects in Bulk Using the PI Builder Add-in

PI Builder is an add-in to Microsoft Excel 2007 and later allowing rapid creation and edition of AF objects and PI points in bulk.

Open Microsoft Excel, and select the *PI Builder* ribbon menu.

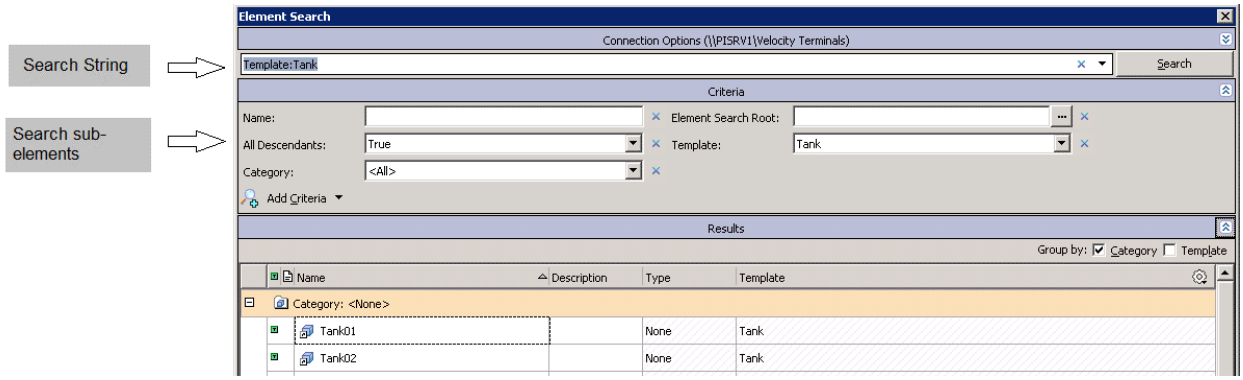
In the *Connections* section, select the Asset Server (AF Server: PISRV01) and the AF database (AF Startup).

To connect to your AF database click on *Database.*

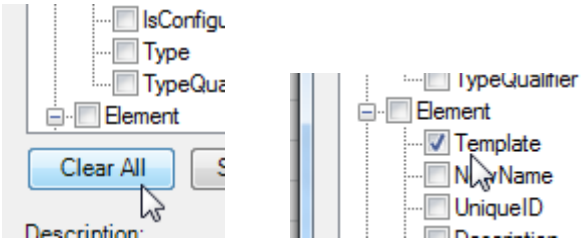


Import the tank elements from AF. To do this, select *Elements* > *Find Elements* from the PI Builder ribbon menu, then select the Tank Template to search and find both tanks.

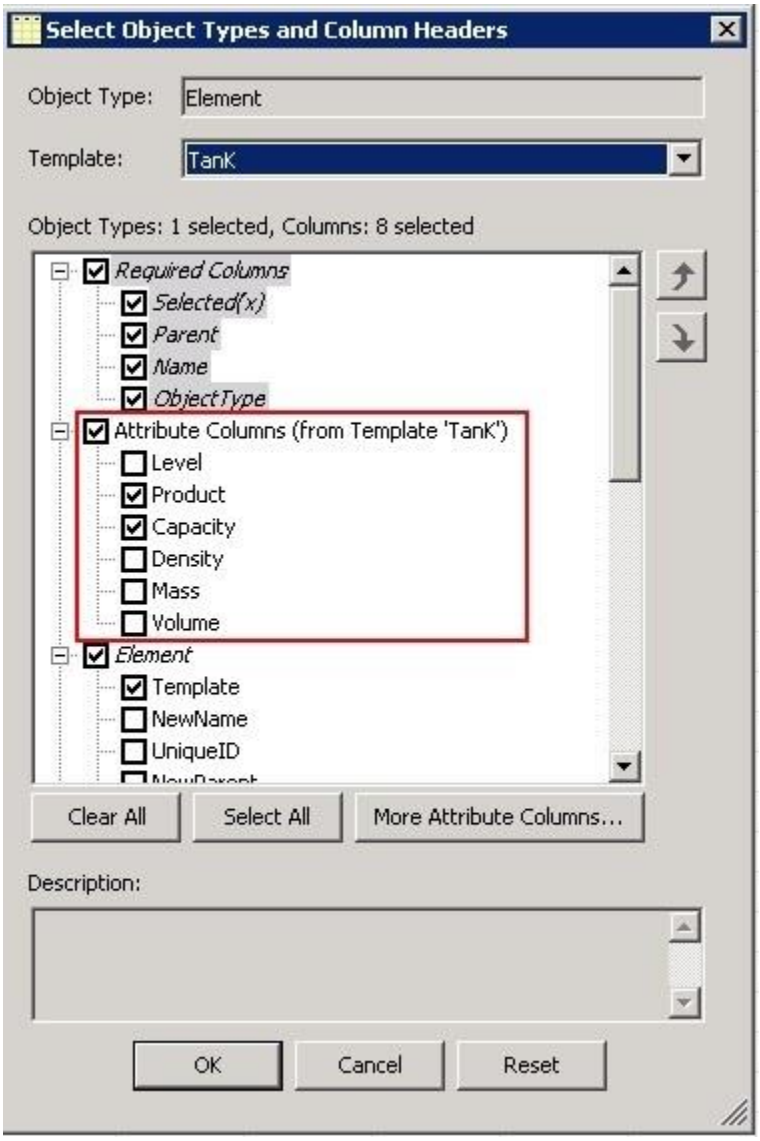
Make sure to search child elements.



Select to import the *Template* configuration of the element.



Select *capacity* and *product* attributes to import their configuration and values.



Once you click OK, the objects imported from AF on the spreadsheet should look like the following:

	A	B	C	D	E	F	G
1	**Selected(x)**	**Parent**	**Name**	**ObjectType**	**Template**	**|Capacity**	**|Product**
2	x	Montreal	Tank01	Element	Tank	20000	AQ4500
3	x	Montreal	Tank02	Element	Tank	30000	HC1500
4							

Use Excel functionalities (find-replace, Ctrl+H) to create records for two (2) additional tanks (Tank03 and Tank04).

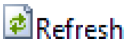
Make sure the Data Archive name is correct for the Level attribute definition.

Verify the Product name matches one of the valid material from the Material Properties AF table.

Name	|Capacity	|Product
Tank03	10000	HC1500
Tank04	10000	WX1200|Old Recipe

The records are now ready to be exported to AF; which will create two new tanks.

Click on the "*Publish*" button from the ribbon menu ( ).

Confirm your work by going to PSE > Elements and pressing the 

button or the F5 key on the keyboard.

Note: To rename an element, simply right-click on it in *PI System Explorer* > *Elements* and select *Rename*. Or use the *NewName* column in the PI Builder in Excel.

Because AF keeps relationships using the elements' GUID, elements can be renamed without breaking relationships between elements or elements and their attributes or their templates. GUIDs are also used in the relationships of elements in data references as well.

3.2.11 Attribute Traits

Attribute traits hold characteristic information for their parent attribute. These can be limits, forecast values, geolocation information, reason codes, asset health, and analysis start triggers. They can either be defined as a fixed value or in combination with a Data Reference such as e.g. PI Point or Table Lookup. Attribute traits are child attributes.

Limit attribute traits: limits typically represent the expected range of a process variable. Following limit traits are defined:

- Minimum and Maximum (very lowest/highest possible value)
- LoLo and HiHi (very low/high value for an abnormal situation, typically initiates an alarm)
- Lo and Hi (low/high value that needs attention, typically initiates a warning)
- Target (aimed-for value such as setpoint)

Forecast attribute traits: forecasts contain predicted values, which allow to compare actual value with the parent attribute. It typically comes from a future PI point.

Location attribute traits: use location attributes to define longitude, latitude, and altitude information for an asset. You can use this information to identify the location of the asset on a map. Used by Integrator for ArcGIS.

Reason attribute traits: use reason attribute traits on event frames and transfers to enable users to select a reason code for excursions, downtime, and other events. The reason attribute trait must be an enumeration set that is previously defined, or a system enumeration set delivered with PI AF.

Analysis start-trigger traits: When users configure analytics to generate event frames, they can optionally elect to store the name of the start trigger in the value of an attribute (string) and mark that attribute with the analysis start trigger trait. This enables clients like PI Vision to indicate the start trigger that created that particular event frame.

Health attribute traits: use health attribute traits on elements and models to enable users to set a numeric health score and a health status (for example, healthy, out of service, in maintenance, warning, or error). The HealthStatus attribute trait uses values from the Health Status enumeration set, which is delivered with PI AF. Administrators can modify the Health Status enumeration set as required.

3.2.12 Directed Activity – Adding value limits for the tank level

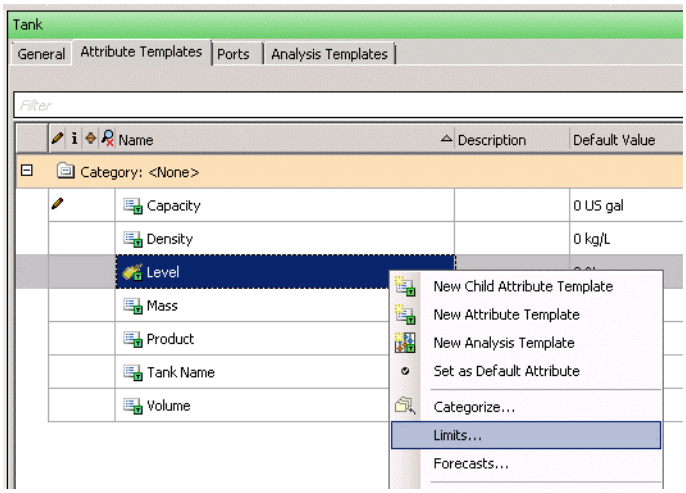
In this part of the class, you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

Problem Description

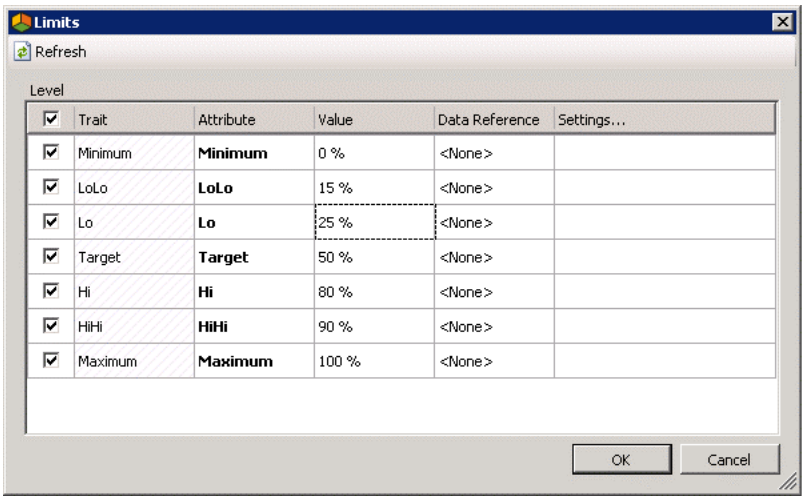
You would like to use attribute traits to maintain limits for the normal operation of the tanks. For all tanks the limits are the same.

Approach

1. In the PSE Navigator, select Library and open the Tank element template in PI System Explorer.
2. Select *Limits…* from the context menu of the *Level* attribute:



3. Set the limit traits as follows and click on OK.



3.2.13 Units of Measure (UOM)

The units of measure (UOM) feature allows automatic unit conversions for data values. AF considers the technical unit for a measurement and allow to display it with a different unit.

For example, suppose AF attributes of a tank represents the diameter and the height and have a UOM of meters. AF considers the selected unit of measure. This provides the option to show the diameter and height in other units than in meters, e.g. to show it in inches. Another consideration is in attributes with a formula. It is possible to calculate the tank volume in liters based on the physical dimensions provided in meters. AF does the automatic conversion for you.

The relations between UOMs are defined with simple or formula conversion methods.

There is **one** repository with all **units of measurement** (UOMs), which is shared by all AF Databases. In other words, the UOMs defined for one AF database maybe used in any other AF database.

Unit of Measurements are organized in **UOM classes**. UOM classes represent measurable properties, such as temperature, length, time, and mass. To facilitate region specific use of UOMs, the UOMs are associated with a **UOM group**, which can either be *Metric* or *US Customary* (additional UOM groups can be defined).

Click on *Unit of Measure* in the PSE Navigator to edit UOMs, UOM classes and UOM groups.

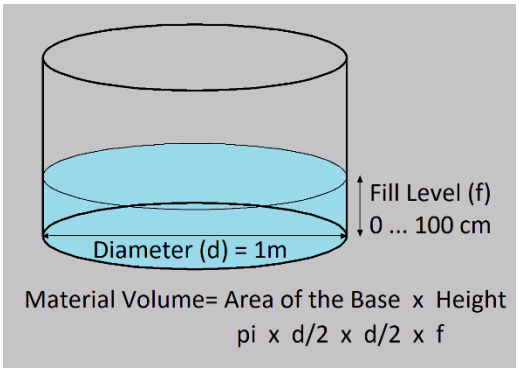
3.2.14 Directed Activity – Exploring how UOMs are organized and how they are used

In this part of the class you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

Activity Objectives

- Understand the organization for UOMs, the UOM classes and the UOM groups and their relationships.
- Apply unit of measures for a calculation of liquid in a container

Problem Description



A container at your plant has a shape of a cylinder. The diameter is 1 m, the height of the liquid inside (PI point: sinusoid) varies and is measured in number of centimeters (range 0 … 100 cm). Use a formula to calculate the reactor volume in liters. Apply units of measures properly.

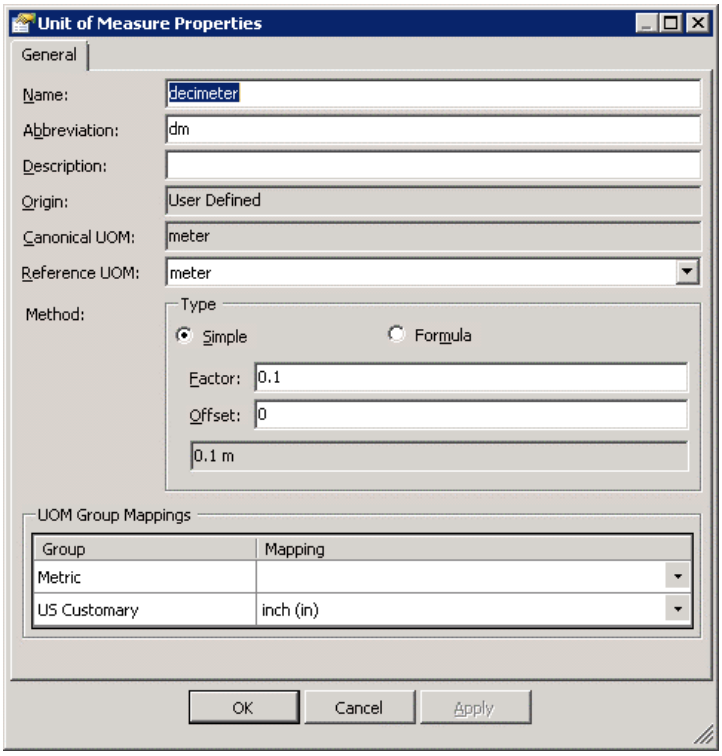
- 1 meter (m) = 10 decimeter (dm) = 100 centimeter (cm)
- The volume of a body in liter is calculated from dimensions in decimeter (1 liter = 1dm x 1dm x 1dm).

Units of Measure, UOM classes and UOM groups

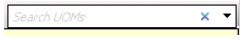
1. Navigate to Unit of Measure and from the list of UOM classes, locate the UOM class for *Length* and display its properties. What is the canonical UOM?
2. From the list of UOMs for *Length*, open the Properties for centimeter. What is the conversion between meter and centimeter? What is the corresponding unit for the US Customary UOM group?

Note: Per default, attributes are displayed in the PI System Explorer with the unit of measure in which they were defined. With Tools > Options you can change that the attribute is displayed with a unit from the selected UOM group.

3. Add new UOM for decimeter (1 decimeter = 0.1 meter), click on OK and Check In.



4. Locate the UOM class for *Area* and display its properties. Note that the base units is Length ^ 2. Locate the UOM class for *Volume* and display its properties. Note that the base units is Length ^ 3.
5. Use the Conversion Calculator at the right hand side and convert 1 m^3 (cubic meter) into liters.
6. (bonus) Use the *Search UOMs* control at the top right and search for units starting with **sec.** What is the difference between the two units you get?



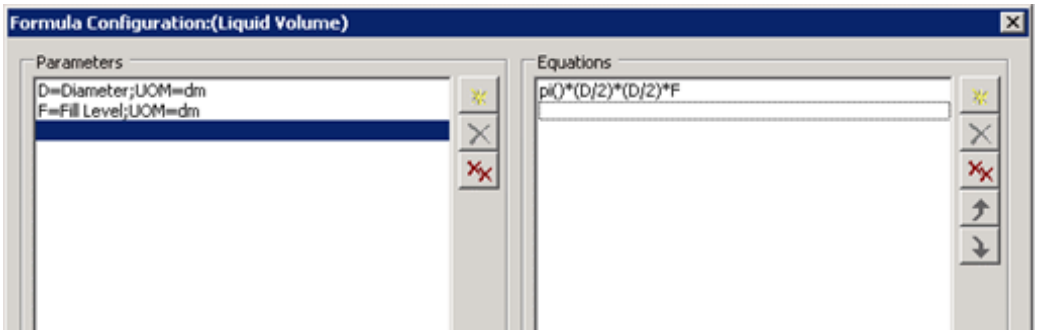
7. (bonus) How many kW has the motor of your car? Convert into horsepower.

Container Element with attributes for Diameter, Fill Level and Liquid Volume

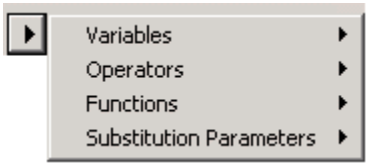
1. Select the *Demo* AF database, select Elements in the Navigator.
2. Locate the **Container01** element (below UOM Demo).
3. Add an attribute for the **Diameter**, set the default UOM to meter (from UOM class *Length*), Value Type= Double, and set value to 1
4. Add an attribute for the **Fill Level**, set the default UOM to meter (from UOM class *Length*), Value Type= Double.

   Set Data Reference to PI Point. Click on Settings to define tag name SINUSOID, and under Unit of Measure set the Source Units to cm.
   Values for SINUSOID are in range 0 … 100, in which range will the values for Fill Level attribute be? Answer: 0 m ….. _____ m
5. Add an attribute for the **Liquid Volume**, set the default UOM to liter (from UOM class *Volume*), Value Type= Double.

   Remember that you get the proper value in liters, when you multiply the values in decimeters. Set data Reference to Formula and define it as follows:



   Hint: you get pi() from the Functions drop-down



6. Select Tools > Options and set Display UOM Group = US Customary. Click Refresh to display UOMs from the US Customary group. Revert the setting back to <None>.
7. (bonus) Remove the Read Only flag for the Fill level attribute and enter maximum fill level of 1m. What is the Liquid Volume? Confirm result by using the Windows calculator.

Name	Value	Unit Of Measure	Value Type	Data Refere…	Settings…
Category: <None>					
Diameter	1 m	meter	Double	<None>	
Fill Level	1 m	meter	Single	PI Point	\\PISRV1\SINUSOID;UOM=cm;ReadOnly=False
Liquid Volume	785.398163397448 L	liter	Double	Formula	D=Diameter;UOM=dm;F=Fill Level;UOM=dm;[pi()*(D/2)*(D/2)*F];UOM=L

4. Modeling and Organizing the Assets

4.1 Starting to Build a AF Structure

In a AF database, assets can be organized or structured into hierarchies. According to its definition a hierarchy is “a system of persons or things arranged in a graded order” (*thefreedictionary.com*). Logical hierarchies of assets or people are common in companies from any industry. They are used to convey the place/location of each entity in the company. Since the AF system is probably not the only enterprise system in your company, other systems in place might already make use of asset hierarchies (maintenance systems, etc.).

Those systems will often have an option to export the hierarchy information into a flat file (.csv, .txt, .xml, etc.). The content of this file can then be opened in Microsoft Excel and be used as a starting point to build the hierarchy in AF using the PI Builder add-in.

Note: The whole company does not need to be modeled in AF for you to be able to get value out of it. In fact, the AF structure build-up is often project-driven. This means to begin with, a small structure containing your pumps might be built for use in PI ProcessBook displays. As more and more applications start making use of AF, the structure will continuously grow to include more and more of your assets.

That being said, it is still a good idea to define the various hierarchy levels that will be represented in the AF structure (divisions, locations, production lines, process, etc.) before gradually adding the assets to that hierarchy.

4.2 Styles of Approach for Designing Assets

There are several styles for designing asset models in AF.

Note: Even if the following approaches will result in a complete asset model, there will always be more information to add in the future. That is fine and is in fact a relief, since it means the AF model does not need to be perfect and complete the first time.

4.2.1 Bottom-up

Often a Data Archive is already in place so one approach is to group the assets by similar Data Archive points. These “similar object” groups become AF element templates, and the “objects” become AF elements. Any foreign data that is available is imported. Next, analytics that may seem useful are added, and finally consumers such as PI ProcessBook displays or PI Datalink reports.

The *bottom-up* approach has the advantage of being a clear, reality-based path to follow. The Data Archive points are known and analytics can be added on top of them.

However, a clear disadvantage is that this approach lacks vision. This approach does not guarantee the result to be useful since the asset model was not built with a particular goal in mind.

4.2.2 Top-down

Another approach is to start by asking theoretical questions:

- ✓ What is the goal of the asset model?
- ✓ What do the consumers need from AF?
- ✓ What are the business requirements?
- ✓ What analytics will be desirable?
- ✓ What sort of foreign data might be useful?

After answering these questions, the element templates and elements can be sketched, and organized in a hierarchy. Next, AF attributes can be added for the desired data points, even if the source for the data is not known yet. The first stage is simply to add the placeholders for that data, i.e. non-configured attributes. If these attributes are confirmed to be the ones needed, then the analytics can be added, the Data Archive tags can be mapped, and the model can be fully implemented.

This *top-down* approach has the advantage of planning for the usefulness of the AF model. Confidence that the model will be well designed and reusable is assured. This advantage cannot be understated and usually outweighs all of the following disadvantages. One disadvantage is that the design can drift away from reality and be incredibly hard to implement while having little benefit over an easier alternative, which is hard to tell beforehand. Another inherent disadvantage is that much of the available raw data that is not “necessary” will be ignored from the model.

4.2.3 Design top-down, then work bottom-up

The preferred approach will be a compromise: begin top-down, identifying goals and trying to identify a “good” design for everything, then quickly move to a mix of this theory and bottom-up experimentation. If a piece of data looks useful, add it to the model because it is rarely a mistake to do so.

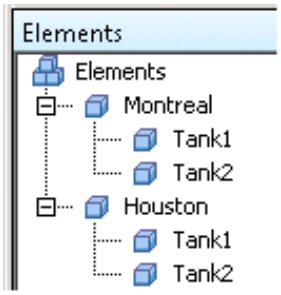
This planned approach combines the advantages of top-down and bottom-up: assurance that the model will be useful, yet a good grounding in reality and completeness during construction. The steps of this approach are:

- Define the assets.
- Design the element templates and inheritance tree.
- Add attribute templates.
- Configure the attributes to point to foreign data or Data Archive points, all with proper units of measure.
- Add calculations/analytics.
- Test the model using consumers (sample reports, displays, etc.).

4.3 Organizing AF Elements in Hierarchies

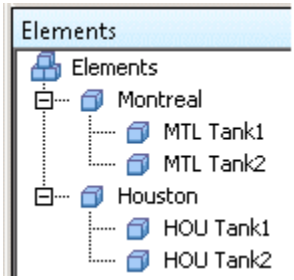
Avoid same names for different devices

If you have multiple devices in different environments, do not assign the same name to them, as this can cause confusion. The following structure is possible but not recommended:



not recommended

To avoid this situation, either assign unique names (such as Tank1, Tank2 in Montreal and Tank3 and Tank4 in Houston) or make the names unique by adding a location code:



Different Views for the assets

Once a hierarchical structure has been built in AF and the assets have been defined, it is possible to organize the assets underneath that structure. Depending on the type of hierarchy that was created, the equipment will be organized by geographical locations, by enterprise divisions, by type of equipment, etc. However, having one kind of asset organization does not imply another type cannot also be used in the same AF database.

AF has this ability to let the system manager organize their assets in multiple different ways. It is then possible to have different “views” of the same information but without duplicating that information. This can be done using Element References ( ).

4.3.1 Directed Activity – Familiarize with multiple asset views

In this part of the class you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

Activity Objectives

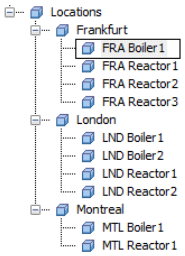
- Understand how to organize assets in different views in order to accommodate different AF user groups in the company.

Problem Description

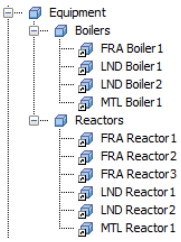
In the **Demo AF database** there is a branch for Asset Views. The main view is organized according to the geographical location of the devices, a second view is maintained based on the equipment types, and in a further view is a general inventory list. You would like to locate the first boiler in Frankfurt in all the views.

Approach

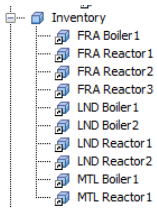
Open the Demo database in AF. Expand both the Locations, the Equipment and the Inventory branch and locate the first boiler in Frankfurt in all the views. Explore that the same information is represented in two locations of the asset tree.



The main view for the boiler is according to its location. FRA Boiler1 is defined below Frankfurt.

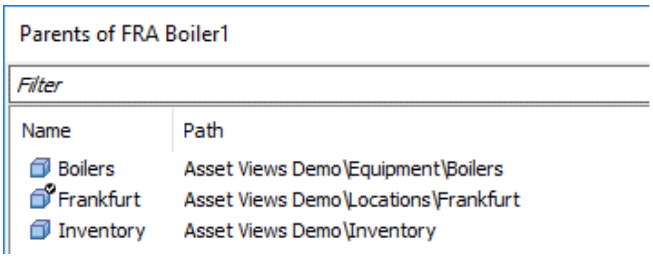


Another view organizes the devices according to their types. FRA Boiler1 is included by an element reference.



There is one more view that contains all devices in a common list. FRA Boiler1 is included by an element reference.

1. Select the Demo database in AF. Select Elements in the Navigator and explore the **Asset Views** branch. Locate FRA Boiler1 in all the three views.
2. Open the General tab for the FRA Boiler1 element.
   Click on the Parents link: Find: Parents
   The three positions in the element tree are listed by their corresponding paths. The icon for the element itself has a little checkmark in the top right corner ( ).



3. Select the element under Locations - Frankfurt and enter an element description. Check-In the change. Then select one of the element references in the other views and verify the modified description in there.

4.3.2 Element Reference Types

Whenever you create a new element or element reference in the asset tree, you are asked to define the reference type related to its parent element.

Composition

The c*omposition* relationship binds two elements together so that whenever one is changed or calculated, the other is too. Deleting the parent element deletes the child as well.

For example, a valve attached to a tank may be represented as a separate element in AF, but is really a part of the tank asset and cannot exist outside of it. Removing the tank from a site removes the valve as well.

Typically, an element having a composition relationship with its parent would not be referenced elsewhere by itself.

Parent-Child

With a *Parent-Child* reference, the child can have multiple parents. The child element can thus be part of multiple hierarchies.

Parent-Child is the default for a new child element creation. When you use that reference type substitution parameters in the element attributes are resolved according to the hierarchy the element is in.

Weak Reference

A *Weak* element reference is like a Parent-Child element reference, but a weak referenced element cannot exist on its own.

Weak is applied for element references when you have a main view (e.g. master view organized according to geographical location) and you create additional views for your assets (e.g. organized according to business function). Different to a parent-child reference the element reference in an additional view will not exist on its own when removed in the master view.

4.3.3 Directed Activity – Understanding Reference Types (optional)

In this part of the class you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

Activity Objectives

- Understand the use of different reference types in context with what happens when you delete an element.

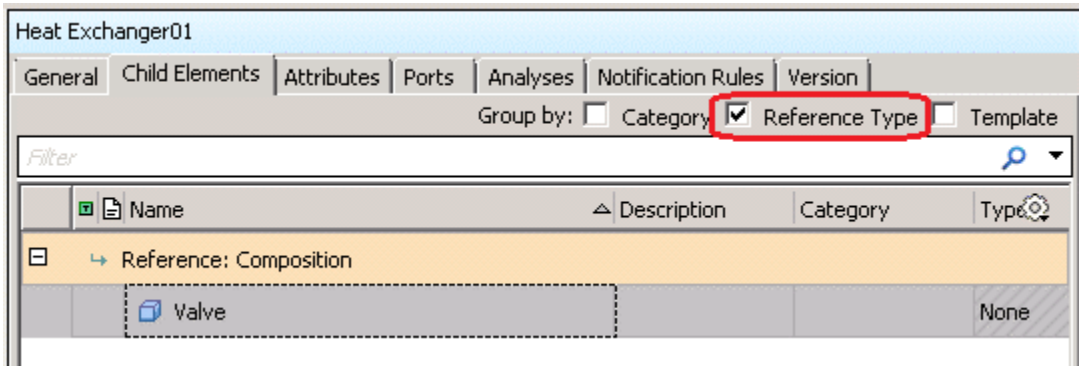
Approach

Open the Demo database in AF. Expand the Reference Types Demo. Explore the reference types between the elements in the structure below.

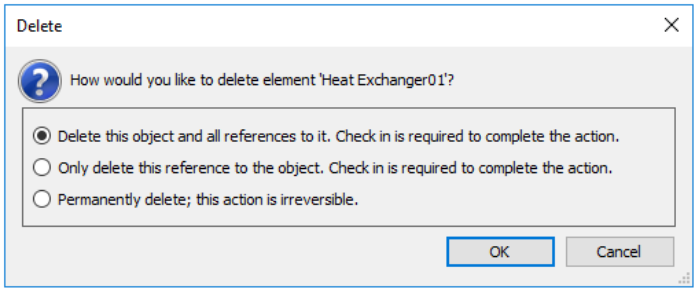
Composition

The **HeatExchanger01** in Production Line B has a valve that is an integral part of the exchanger that can not exist on its own. Therefore, the relation between the valve and the exchange is *Composition*.

1. Select Heat **Exchanger01** and click the Child Elements tab on the right. Check the Reference Type option:



2. Select Heat **Exchanger01** and select *Delete…* from the element context menu. Select Delete option to delete the object and all references to it.



3. Check-In and Refresh. Result: the **valve** element and all the **valve** element references disappear (this is independent from whether the valve element reference has a strong or weak reference to the parent element)

Weak Reference

Pump01 is located as a child under Production Line A - Pumps. This is the main view for Pump01. An element reference for Pump01 is below the Secondary View element, which is an additional view. For this view, the reference Type between **Secondary View** and **Pump01** element reference is *Weak Reference*.

1. Select **Pumps** and click the Child Elements tab on the right. The child element **Pump01** has a Parent-Child reference with its parent.
2. Select **Secondary View** and click the Child Elements tab on the right. The **Pump01** element reference has a Weak Reference with its parent.
3. Select **Pumps** and select *Delete…* from the element context menu. Select Delete option to delete the object and all references to it. Check-In and Refresh. Result: the element reference for **Pump01** below **Secondary View** disappears, because by deleting **Pumps** and **Pump01** you have deleted the last strong parent.

Typically you will be using Weak References for element references as you usually have one main, primary view and further views are additional, secondary ones. However, the next part of the exercise is to explore the use of Parent-Child with element references.

Parent-Child

Pump02 is located as a child under Production Line A - SiteABC. However, this is not considered as the only view for this pump, because an element reference for Pump02 is also below the **Strong Families** element, which is another view that is considered with the same importance Reference Type between **Strong Families** and **Pump02** element reference is *Parent-Child*.

1. Select **Site ABC** and click the Child Elements tab on the right. The child element **Pump02** has a Parent-Child reference with its parent.
2. Select Strong Families and click the Child Elements tab on the right. The **Pump02** element reference has a Parent-Child reference with its parent.
3. Select **Site ABC** and select *Delete…* from the element context menu. Select Delete option to delete the object and all references to it. Check-In and Refresh. Result: the element reference for **Pump02** is promoted to an element. It changes from an element reference icon to an element icon. (Sometimes the PSE does not show that properly even after a Refresh. Switch to another database and back to the Demo database for a complete refresh.)

4.3.4 Exercise – Organizing the Tanks for Velocity Terminals

This solo or group exercise is designed to maximize learning in a specific topic area. Your instructor will have instructions and will coach you if you need assistance during the activity.

Exercise Objectives

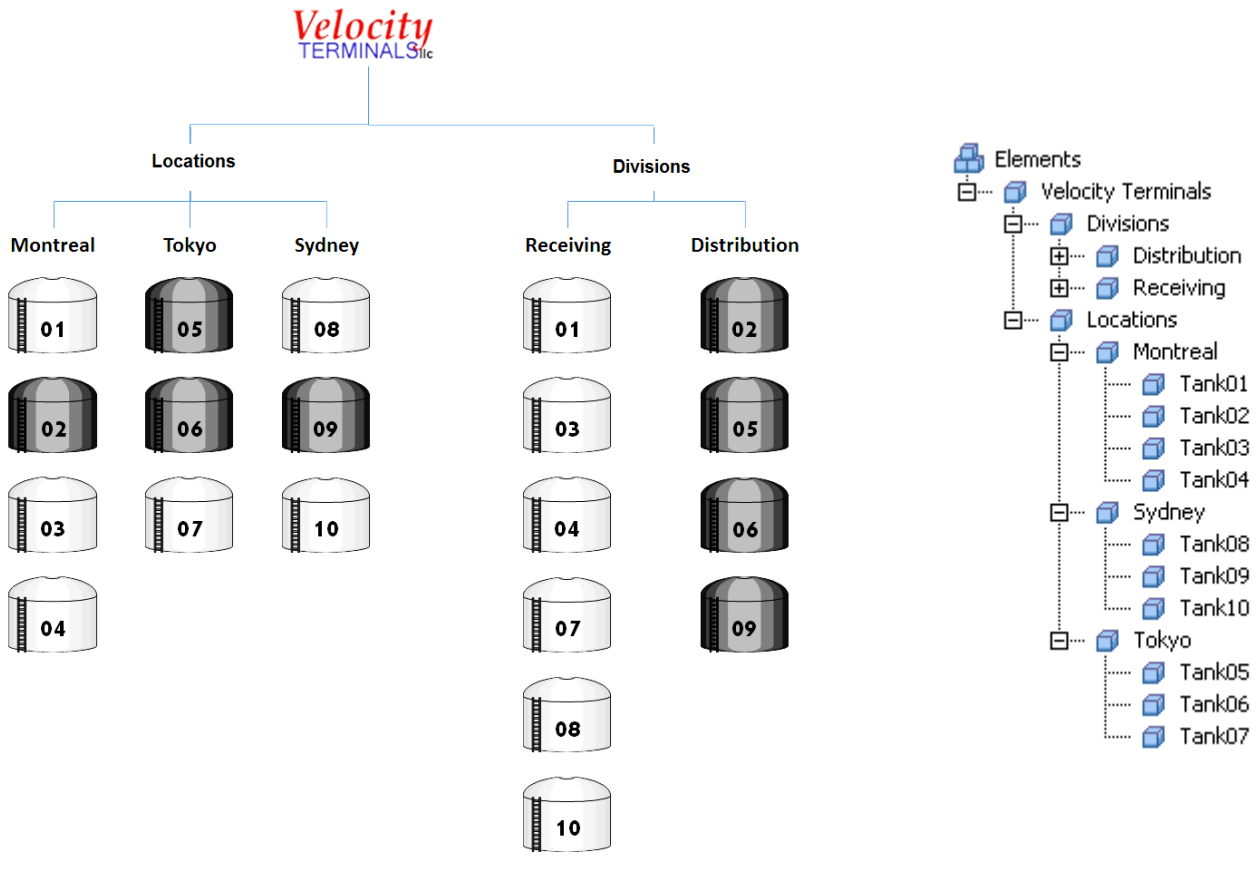
- Build additional elements with PI Builder.
- Create parent elements to build a hierarchy.
- Organize the elements into hierarchies with drag & drop.

Problem Description

Now that four (4) of your tanks are defined and organized under their site (Montreal, Canada), you now want to model and organize the tanks for other sites in your company, Velocity Terminals. The sites are:

- Montreal, Canada
- Tokyo, Japan
- Sydney, Australia

You also want the ability to view the company's tanks as part of a separate hierarchy containing the receiving and distribution divisions. After searching on the enterprise portal, you find the following documents:



Model the extra tanks in AF using the VelocityTerminals_Assets.xlsx worksheet located in the Class folder.

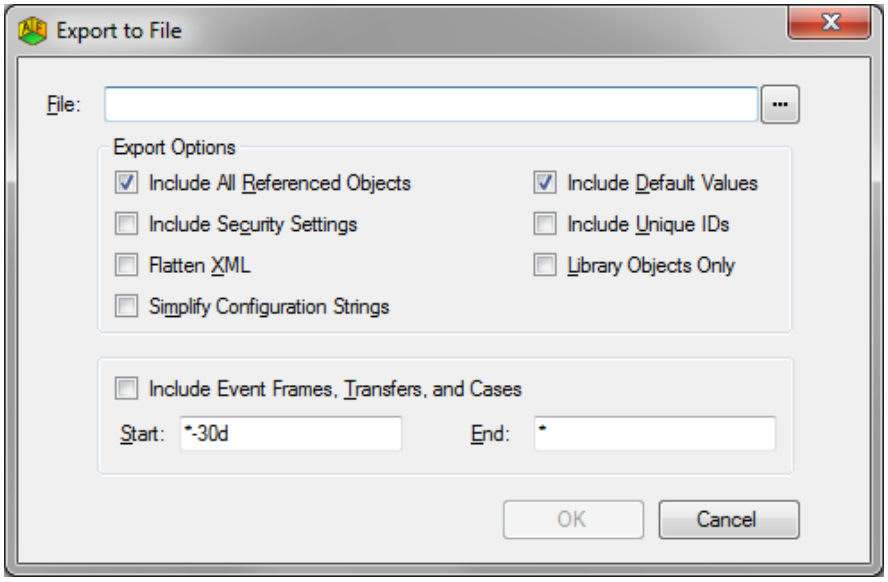
1. To create the elements for the tanks Sydney and Tokyo, open the spreadsheet. Use PI Builder *Publish* ( ) function to create the new elements in your AF database.
2. Using PSE, create new elements, not based on any template, to model the locations and divisions.
3. Use the drag and drop techniques discussed previously to move the tanks into their appropriate hierarchies (Shift Key = Move Element).
4. To create the element references under the Divisions, drag the tank elements into the corresponding element under Divisions (No key pressed = Create Element Reference).

Note: Make use of Element References. Use *Parent-Child* references under the locations and *Weak* references under the divisions.

4.4 Using the Import and Export Feature in PSE

From PSE, it is possible to use an Import and Export feature to export an entire AF database or just a AF object to an XML file. With the Import functionality, it is possible to import this AF object into another AF database. This can also be used to back up a AF structure before performing potential destructive actions.

It is possible to export almost any AF object by simply right clicking that object and selecting the Export to File... option. To export the whole AF hierarchy along with all the necessary information to rebuild it completely, simply use the *File > Export to File* option.



In order to be able to rebuild the structure as is, it is required to check the *Include All Referenced Objects*, so that Templates, Tables, UOMs, etc. are also exported to the .xml file.

4.4.1 Directed Activity – Export and Import a Database

In this part of the class, you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

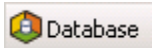
Activity Objectives

- Learn how to export an XML file from an AF Database and import into another AF Database.

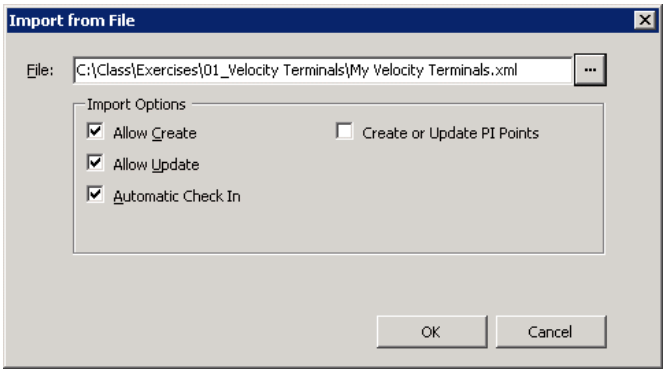
Problem Description

The AF structure for Velocity Terminals has been created in an AF database dedicated to training and checkout. We would like to release it to production in a different AF database. To do that, we will export contents of the **AF Startup** database and import it into another AF database called **Velocity Terminals**.

Approach

- With **AF Startup** database opened**,** select *File* > *Export to File* from PSE menu.
- Click on the icon and change settings to save the XML file as C:\Class\Exercises\01_Velocity Terminals\My Velocity Terminals.xml. Click on Save button (Note: this will not actually create the XML file!)
- Check the *Include All Referenced Objects* option. Click on OK.
- (optional) Use the editor and inspect the .XML file: locate units of measures, the Tanks templates, the table, the elements created for the VT Tanks etc.
- Click on the 

button and select the **Velocity Terminals** database.
- Select File > Import from File from PSE menu and select the file that was saved recently.



- Verify that objects in production database have been created successfully.

5. Visualizing Data

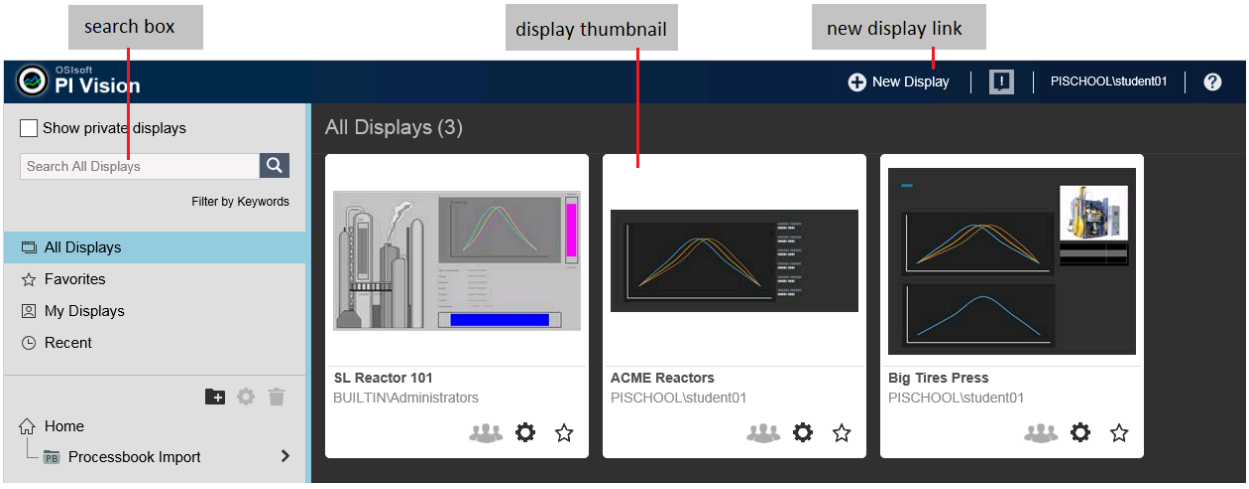
5.1 Visualizing AF Data in PI Vision

PI Vision is a modern and intuitive web-based visualization tool allowing ad hoc analysis through rapid display creation. PI Vision allows you to:

- Search for PI data on desktop or mobile platforms.
- Visualize PI data as symbols, such as trends, tables, values, and gauges.
- Configure multi-state symbols to create visual alarms for critical process states.
- Design, format and save displays for easy retrieval and further analysis.
- Analyze and compare process events.
- Monitor process data in displays.
- Share displays with other members of a group or anyone with access to PI Vision.
- View PI ProcessBook displays.

Note: Before version 2017 the previous name for PI Vision was PI Coresight.

PI Vision homepage:



PI Vision makes use of an efficient search engine to let you browse through the organization's AF structure and rapidly find the information you are interested in. As you begin looking at and analyzing some data, PI Vision will find related information that might also be of interest to you.

If you have added a new database in AF and would like to access with PI Vision, you have to update the list of allowed AF Databases in PI Vision:

Open the PI Vision Administration Page, then select AF Servers tab in the Configuration section. You may have to expand the structure under the AF Server name to see available databases. To add an AF database, select the checkbox next to the AF database name and click on Save.

5.1.1 Directed Activity – Visualizing Velocity Terminal Data in a PI Vision Display

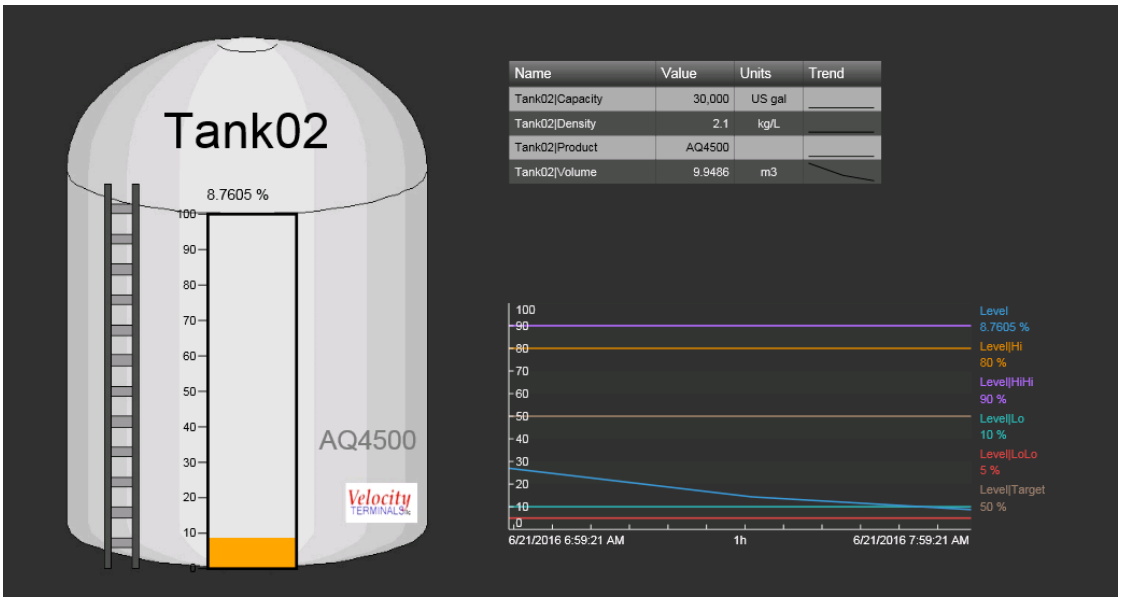
In this part of the class you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

Activity Objectives

- Create a PI Vision display with tank data (AF database: Velocity Terminals)
- Incorporate objects with current data (trend, table, value object, gauge)
- Incorporate a picture
- Asset swap in PI Vision displays

Problem Description

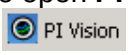
Your manager has asked to visualize the tank data in a PI Vision display (name: *Velocity Terminals Tank*) in the following way:



The display is setup for one of the tanks and should allow to swap between all tanks at Velocity Terminals.

Approach

1. Click on the desktop link to open **PI Vision**. The link is http://pisrv01/PIVision.

   There is also a bookmark 

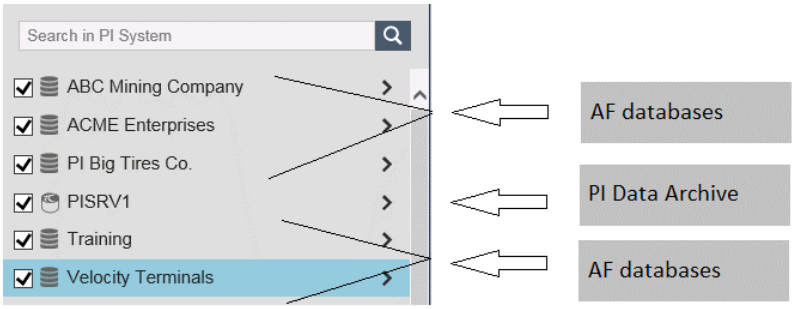
for PI Vision under the favorites.

   The homepage provides an overview with thumbnails of the displays, which have been prepared for the training.

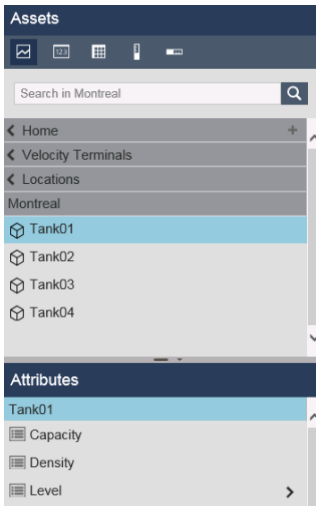
2. To create a new display, click on the link

Note: you are in *Modify* Display operation: the operation icon background is orange and the canvas border is orange. To switch to *Monitor* Operation (you can do that in any non-empty display) click on the operation icon, the canvas border will disappear and the operation icon background switches to blue . You can toggle back and forth between the two operation modes.

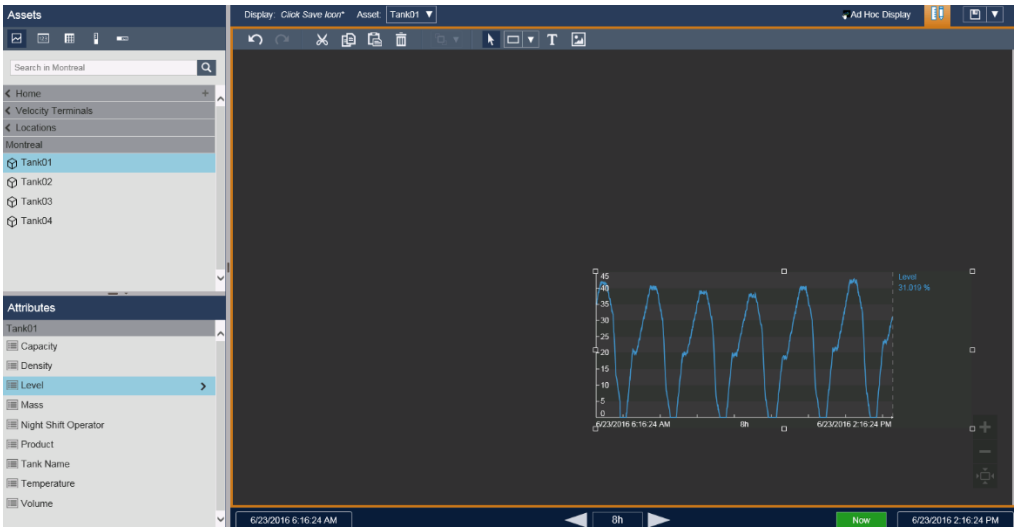
3. The search pane displays search paths for elements in the AF databases and for tags in Data Archive.



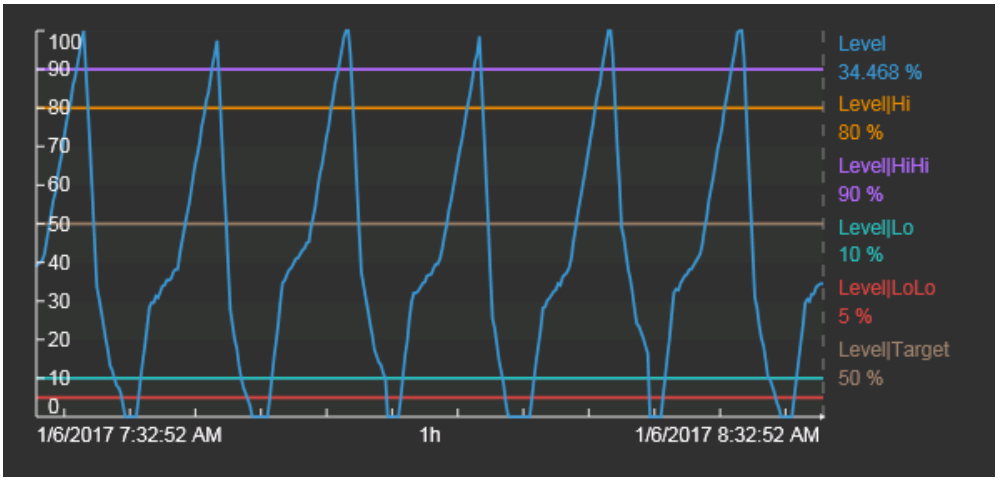
4. Expand the asset structure to navigate to the Tank01. Select AF database *Velocity Terminals* and penetrate to Locations > Montreal > Tank01. Select Tank01 to get the attributes for that tank.



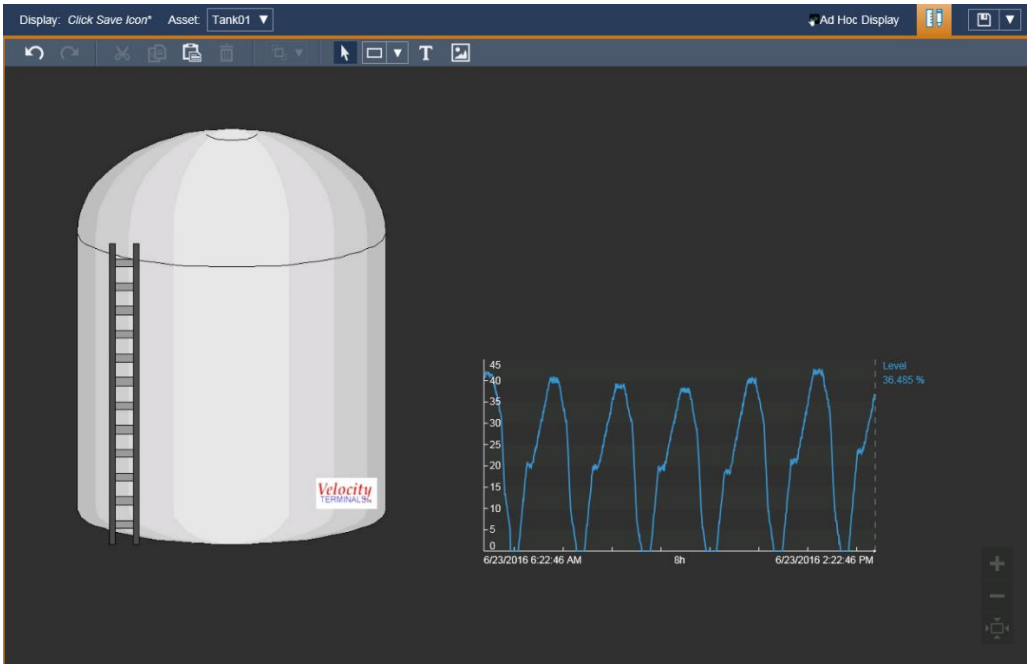
5. Select *Level* attribute and drag it to the display canvas on the left hand side.



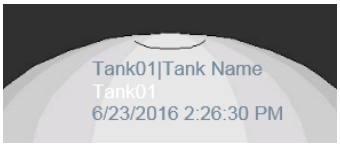
6. Click on the > of the Level attribute to expand the structure and display the traits. Drag *Hi*, *HiHi*, *Lo*, *LoLo* and *Target* into the trend. Select *Format Trend* from the right mouse button menu.
Under *Single or Multiple Scales* select *Show Single Scale.*
Under *Scale Range* select *Use database settings.*
Click into the canvas to close the *Format Trend* settings.
Click on the time selector at the bottom and switch time display range to one hour.



7. Click on Image icon and drag a rectangle in the display canvas. Under the *Browse..* selection navigate to *VT Tank.jpg* under C:\Class\Exercises\01_Velocity Terminals



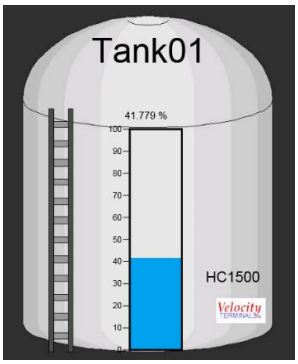
8. From the object list, select the Value object . Drag Tank Name to the top of the tank picture.



9. From the right mouse button menu of the Value object, select Format Value. Uncheck Label, UOM and timestamp. Change Value color to black.

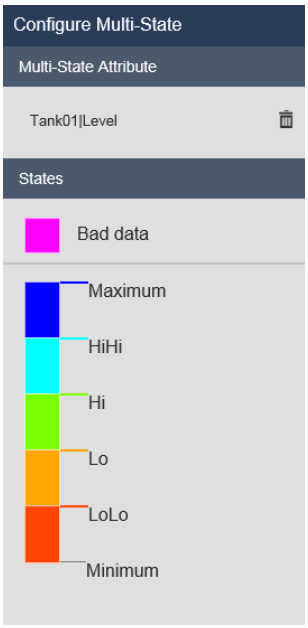
10. Accordingly, position a value object for the Product attribute in the right bottom corner

11. From the object list, select the Vertical Gauge object . Drag Level to the center of the tank picture. Use Format Gauge to change the appearance.



12. From the right mouse button of the gauge object, select *Add Multi-State.* Change the colors as following:

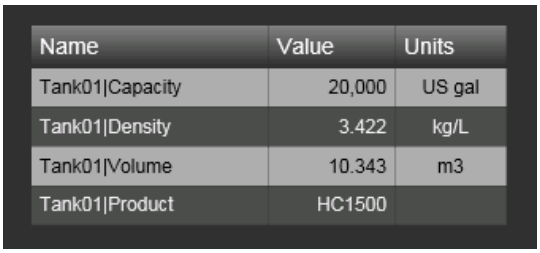
Bad data:	magenta
HiHi – Maximum:	blue
Hi – HiHi:	light blue
Lo – Hi:	light green
LoLo – Lo:	orange
Minimum – LoLo:	red



13. Click on < for Tank01 to collapse the structure again.

    From the object list, select the Table object . Select *Capacity*, *Density*, *Product* and *Volume* (keep Ctrl-key pressed). Then drag them above the trend. You get a table with a header row and four rows for the four attributes you had selected.

Select *Table Columns…* from the right mouse button menu and uncheck Description, Trend, Minimum and Maximum.



Name	Value	Units
Tank01|Capacity	20,000	US gal
Tank01|Density	3.422	kg/L
Tank01|Volume	10.343	m3
Tank01|Product	HC1500	

14. Click on the Save icon on top right corner. Save display as Velocity Terminals Tank.
15. Use the Asset selector

to switch to another tank, Tank02.
16. Use the time control at the bottom to change the display ranges. Use the left arrow to step through past time periods.
17. Position the cursor in the bottom area of the trend and drag it to switch the time range.

18. To revert to the last hour from now, click on the *Now* button, then select the 1h from the time range selector.
19. Note: the display name has an asterisk at its end to indicate there have been changes.

Click on the Save icon to change these changes. To save the modified display under another name select Save As from the dropdown next to the Save button and save under another name.

20. Add a symbol from the library to your display. The library is opened by clicking the symbol on the left hand side: .

5.2 PI ProcessBook Element Relative Display

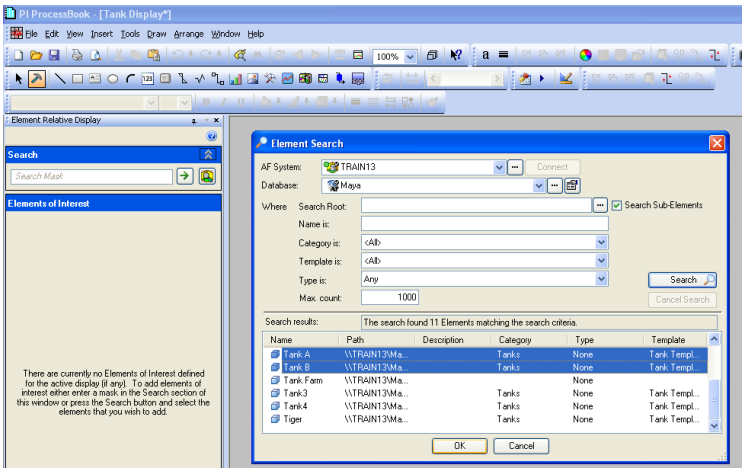
Open PI ProcessBook and use the File > New menu to create a *.PDI (standalone display document) named “Tank Monitoring”.

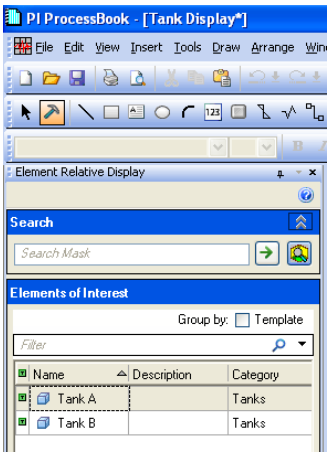
From the *View* menu, select *Element Relative Display* and note the panel, which appears on the left.

There is a PSE icon ( ), select it and select your AF Server-AF System-Database from the resulting *Element Search* dialog.

Make sure to check the *Search Sub-Elements* check box and then click the Search button and select the four (4) tanks.

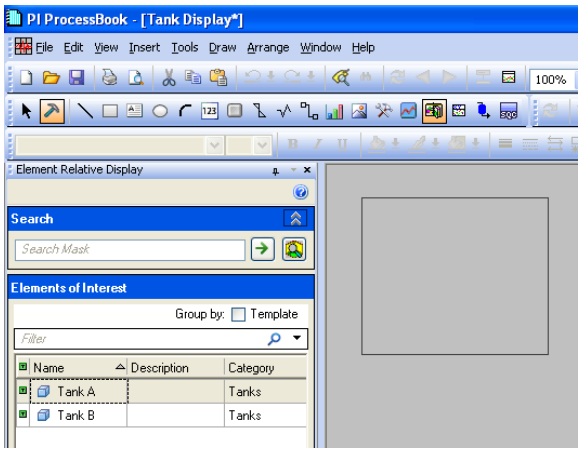
The tanks will be added as Elements of Interest.

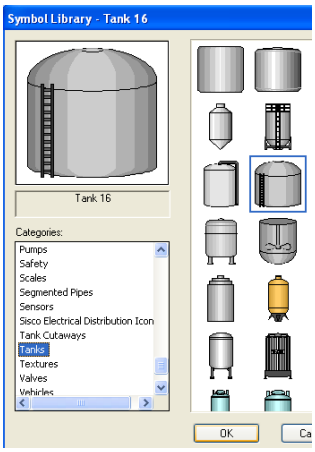




Select from the menus *Tools* > *Build* and then *Draw* > *Symbol Library*.

Now, from the drawing area of the screen, add a new symbol from the symbol library by dragging out a square of approximately 1 ½ inch on the screen, as shown below.





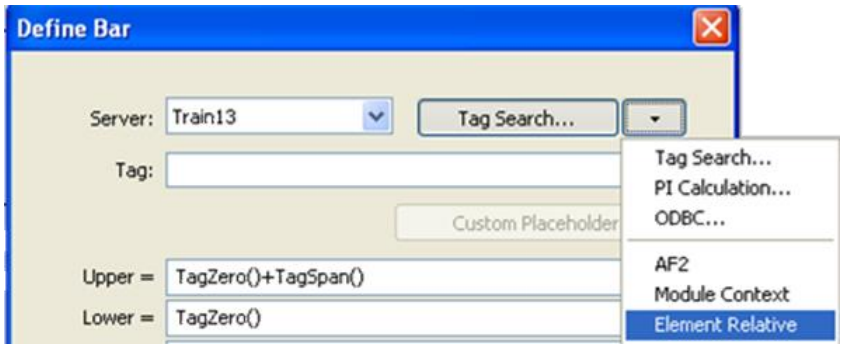
This brings up the Symbol Library window.

Select a tank symbol from the Tanks category to add to the display.

Make sure you are still in Build mode (if not click again on the hammer ( ) icon).

Add a Bar next to the tank to represent its level by selecting *Draw* > *Bar* and then dragging out a bar shape on the screen.

From the Define Bar window, open the pull/down fly-out menu next to the *Tag Search* button and select *Element Relative.*



The selected tank should appear with its attributes.

Select *Level* and use the down arrow to push it into the Selected Attributes list, then click OK.

Add a dynamic value by selecting *Draw* > *Value* and clicking just below the tank symbol on the drawing area.

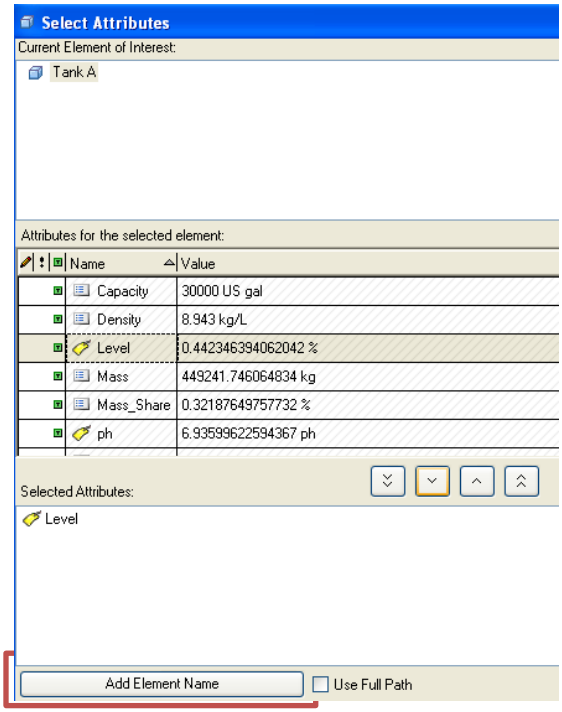
Still using the Element Relative option, select the *Level* attribute again.

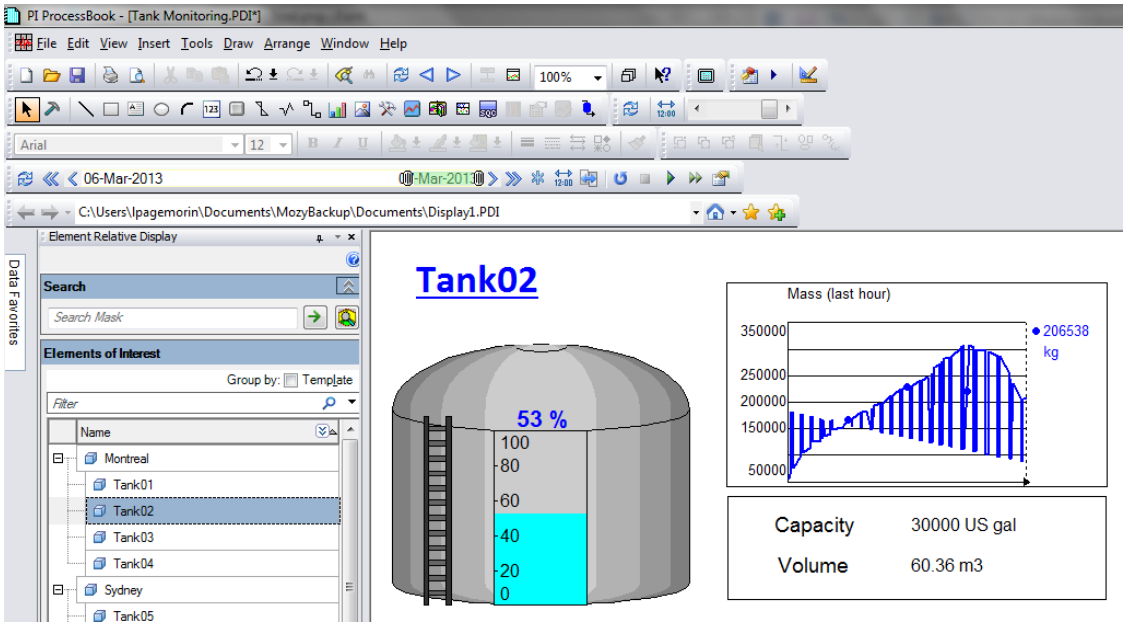
Add a trend by selecting *Draw* > *Trend* and dragging out a rectangle the size of the trend wanted.

Still using the Element Relative option, select the *Mass* attribute to be shown on that trend.

Add another *Value* symbol above the tank, but this time select to *Add Element Name* by clicking this button at the bottom of the Select Attributes window (refer to the picture on the right).

(Optional) Add two other value symbols to display the *Capacity* and the *Volume* attributes.





Switching to Run mode from *Tools* > *Run*.

Select a different tank from the left panel to confirm the PI ProcessBook display is now element relative; meaning the information shown depends on which tank is selected on the side pane.

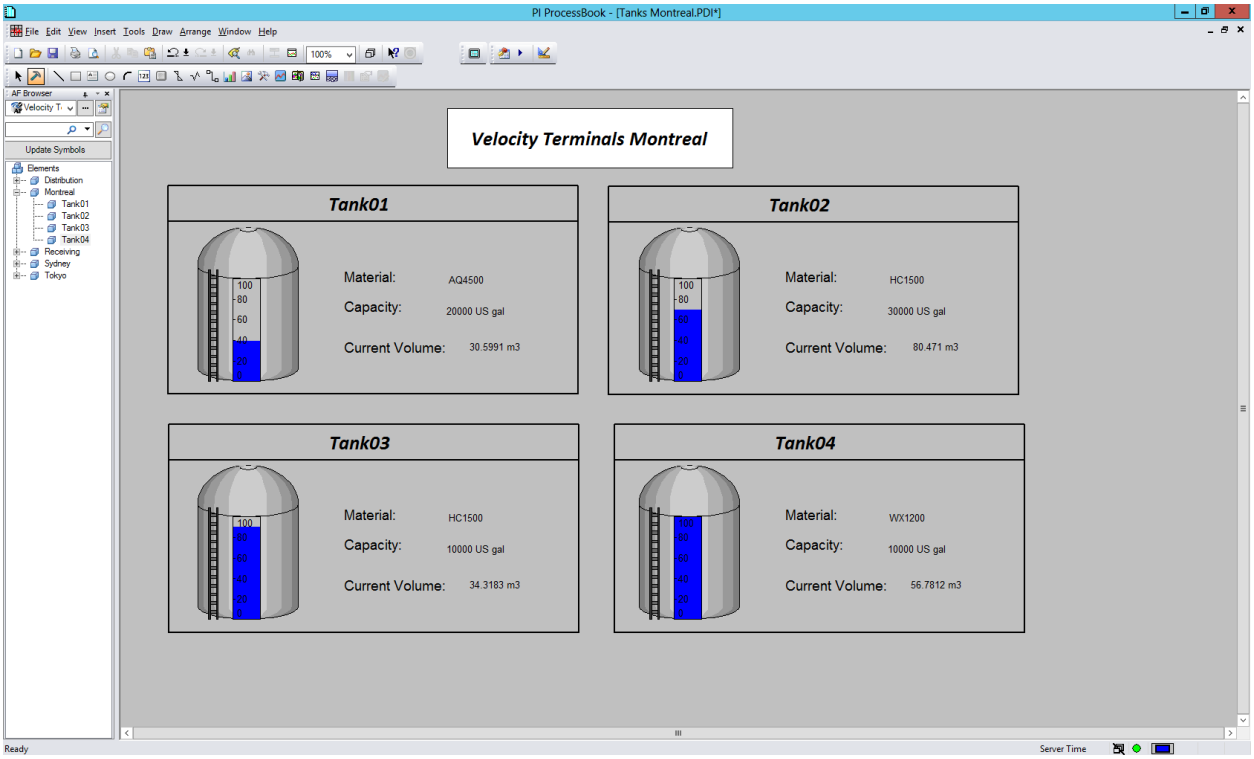
Leveraging the AF structure and templates allows creation of reusable PI ProcessBook displays to represent similar equipment.

Note the Mass attribute shown on the trend symbol has a history displayed, even though the attribute was created moments ago. Formula results are not stored in the Data Archive, rather they are calculated on demand when data is requested by a client.

AF has the power to transform PI System data into information.

5.3 AF-based symbols in PI Processbook (optional)

With Element Relative displays, switching between tanks is made easy, but what if you don't want to switch between the tanks. You want to have all tank information in one display, e.g. information for all Montreal tanks in one display?



To support that capability, Processbook has AF-based symbols which can be assign to an AF asset element template or element.

5.3.1 Directed Activity – Assigning Symbols to Templates or Elements

In this part of the class you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

Activity Objectives

- Demonstrate assigning symbols to template.

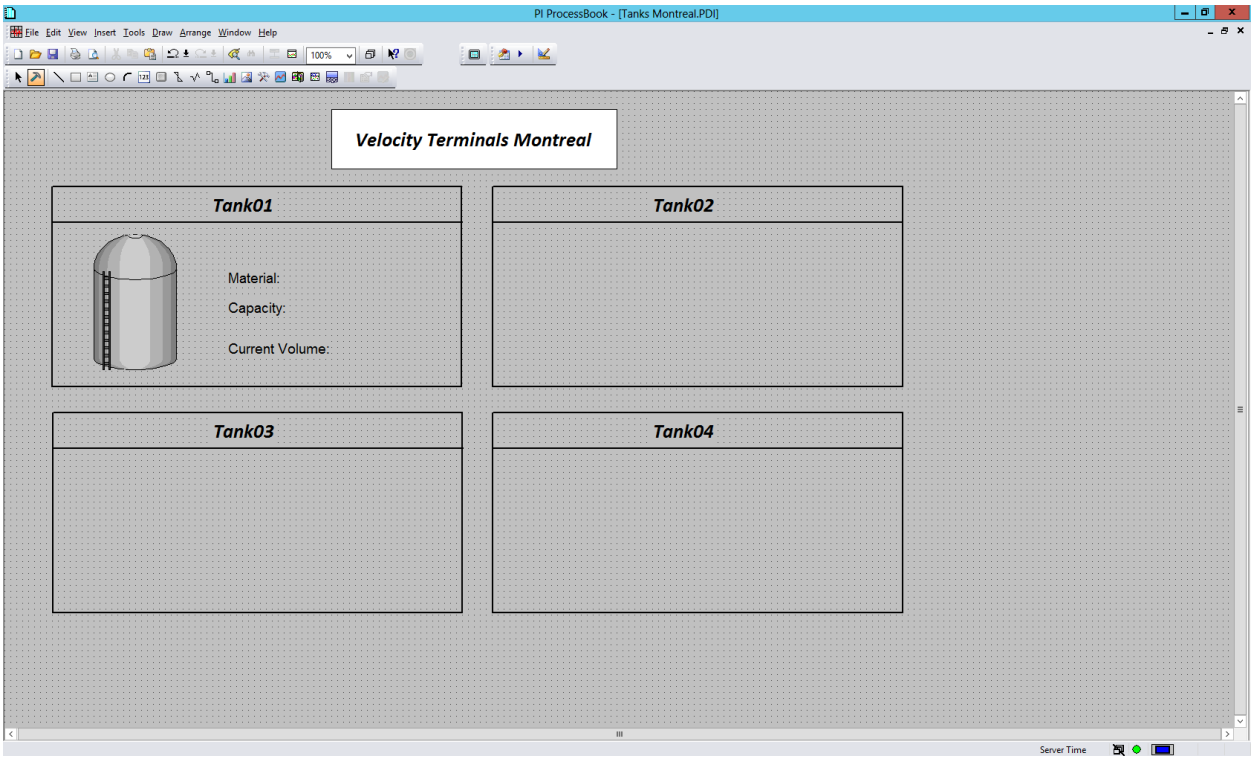
Problem Description

The four tanks at Montreal are experiencing problems. Your manager does not want to switch displays to compare tank properties. He would like to see the four tanks on one display for troubleshooting purposes.

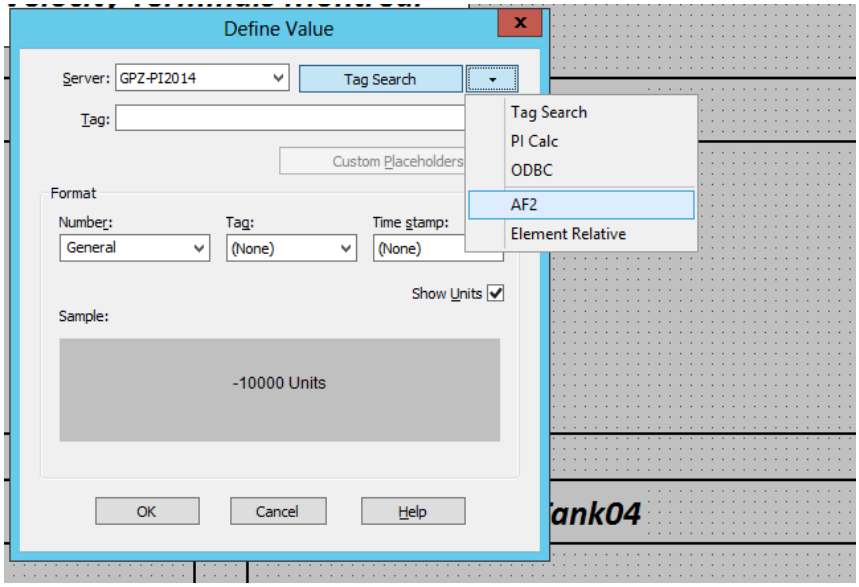
Approach

Let us create a PI Processbook group of symbols for one of the tanks, which we will associate with the tank template in AF. Then it is easy to duplicate this for the other tanks.

Open PI ProcessBook and open the display *Tanks Montreal.PDI* (located in the class\exercises folder):

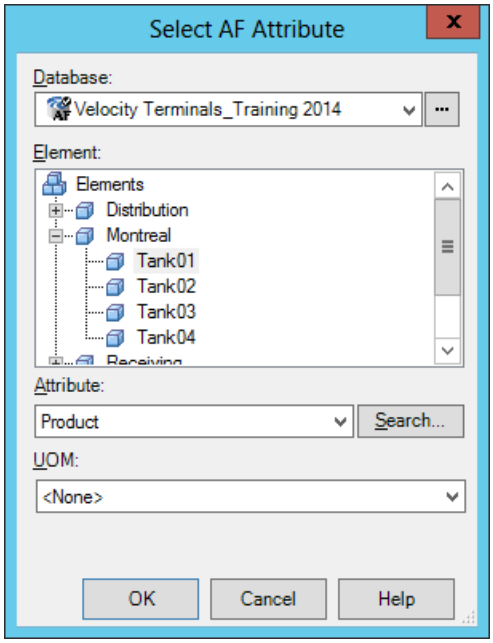


In the area for Tank01, add value objects for Material, Capacity and the Current Volume. In Build Mode, click on Draw > Value and click into the display to position the symbol on the right hand side of the text Material. In the Define Value dialog box, click on the drop down arrow and select AF2:



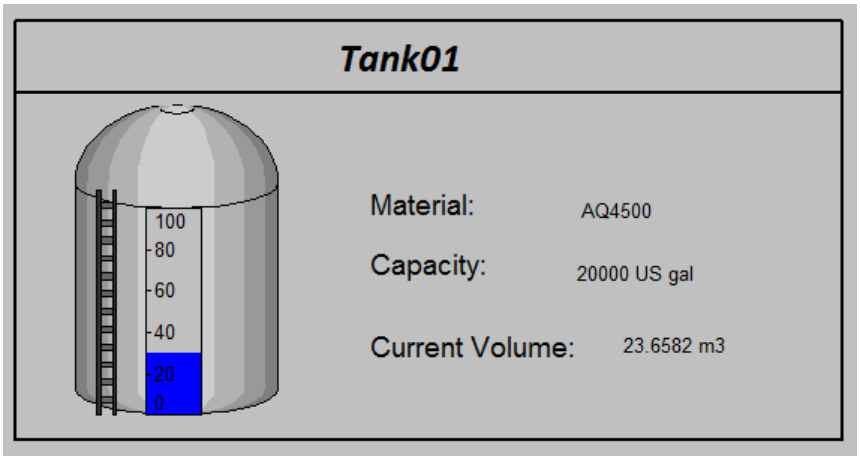
Note: The AF2 dataset provides access to the AF database allowing you to configure a PI ProcessBook symbol with an AF attribute.

In the *Select AF attribute* dialog, click on Tank01 in the AF asset tree and select *Product* Attribute, UOM= <none>:

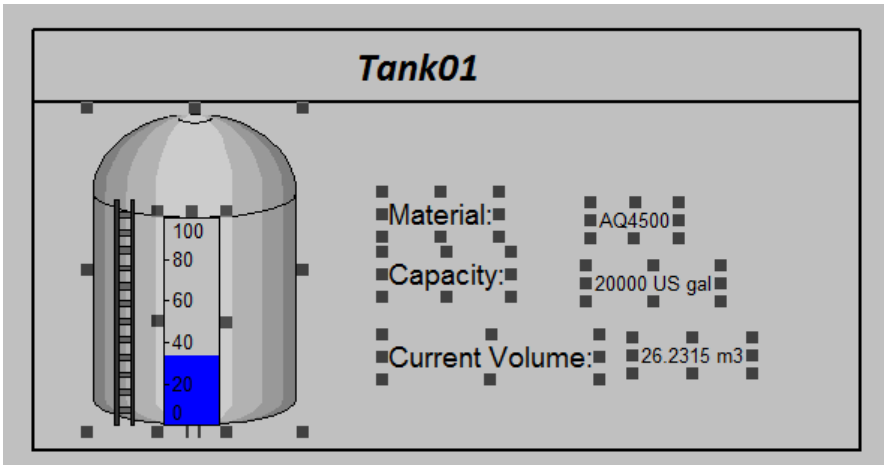


Repeat the same for attributes *Capacity* (attribute: *Capacity*, UOM=US Gallon) and *Current Volume* (attribute: *Volume*, UOM=cubic meter).

In Build Mode, click on Draw > Bar, position the cursor on the tank symbol and click to open a rectangle for a vertical bar. In the Define Bar dialog box, click the drop down arrow and select AF2. In the *Select AF attribute* dialog, click on Tank01 in the AF asset tree and select Attribute *Level*, UOM= %.



Now select the objects in the bottom rectangle (the tank, the bar, the texts and the value objects) and select Arrange > Group to combine them into one object.



From the context menu select *Assign Symbol to Template…* and select the Tank template.

Note: if the *Assign Symbol to Template…* menu item is greyed out, select another object in the display, then reselect the group symbol. The menu item should now be available for selection.

Click on View > AF Browser. To duplicate the tank symbol for the remaining tanks, select Tank02 in the AF Browser and drag it into the corresponding space in the display. Repeat for Tank03 and Tank04.

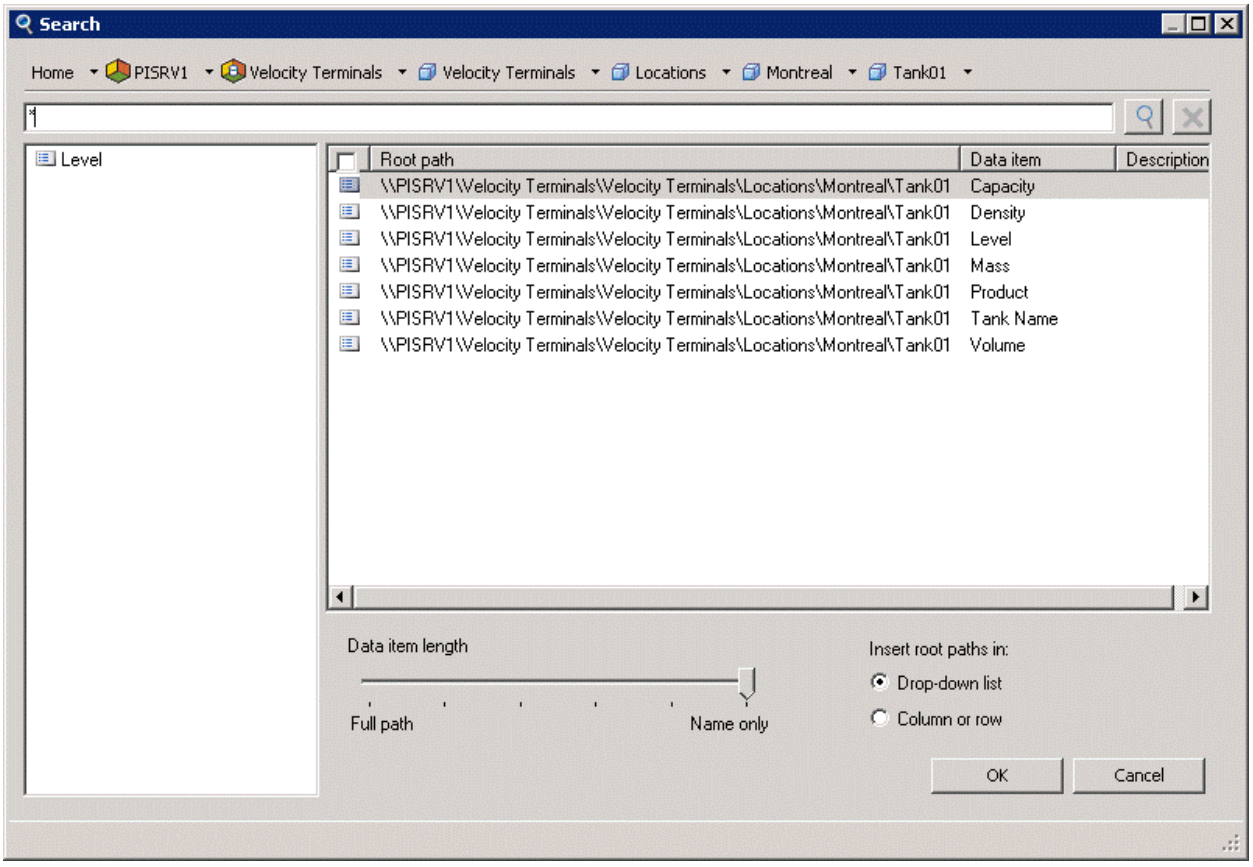
5.4 PI Datalink

PI Datalink is a Microsoft Excel add-in that allows you to import data from your PI System into a spreadsheet. Combined with the computational, graphic, and formatting capabilities of Microsoft Excel, PI Datalink offers powerful tools for gathering, monitoring, analyzing, and reporting PI System data.

5.4.1 PI Datalink Support for AF

With PI Datalink 2013+, it is possible to create reports that will leverage the AF model, allowing reports to be reusable across similar assets. PI Datalink 2013+ benefits from the new integrated search engine, allowing searches for tags and assets all at once.

PI Datalink 2014 introduces support for Event Frames, which will be discussed later in the class.



5.4.2 Directed Activity – PI Datalink Basics: Access Sampled Tag data

In this part of the class, you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

This exercise is a brief introduction into PI Datalink. It familiarizes with recommended steps to create a spreadsheet with dynamic data from the PI system.

Activity Objectives

- Use the Sampled Data function to get interpolated data for a tag in specified time intervals.
- Understand how to reference spreadsheet cells to specify parameters for Datalink functions.

Problem Description

You would have a report with interpolated tag values from tag TANK01LI.PV. The list should cover the last 4 hours and list values in 15 minute intervals.

Approach

1. Open AF Class Datalink Exercises spreadsheet located in the c:\class\exercises\01_Velocity Terminals folder.
2. Select the PI DataLink ribbon. Explore the different groups of PI Datalink functions (see also the list on the next page). Which is the function that you have to use?

   _____

Group	Function Name	Function	Example
Single Value	Current Value	Retrieve the current or most recent value of a data item	What is the current outside air temperature?
	Archive Value	Retrieve a data item value for a specified point in time	What has been the tank level this morning at 8:00 AM?
Multiple Value	Compressed Data	Retrieve data item values for a specified time range	What are the values stored in the archive for the pressure sensor for yesterday?
	Sampled Data	Retrieve evenly-spaced, interpolated data item values for a specified time range	What is the generated Wind turbine power, listed for every full hour on the last Sunday?
	Timed Data	Retrieve interpolated data item values that match with an array specified of time stamps	What are the CO2 level values for the tank at those times yesterday when there is value in the archive for the pressure sensor?
Calculation	Calculated Data	Retrieve calculated data item values. The calculation performs an aggregation over a time period (like minimum, maximum, average etc.)	What are the hourly averages for the reactor's internal temperature for yesterday?
	Time Filtered	Calculate the amount of time over which a performance equation evaluates as true for a specified time range.	How long has the motor been in the "Running" state yesterday?

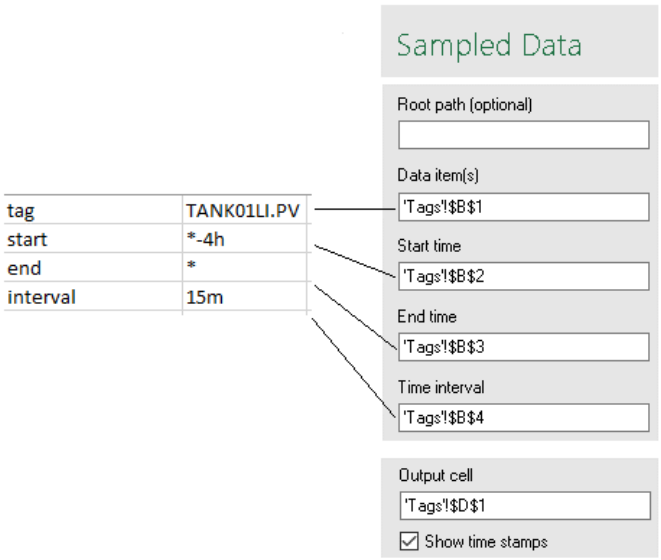
3. Select the Spreadsheet tab named **Tags**.
4. Enter the tag name **TANK01LI.PV** into cell B1.
5. Put the cursor in cell D1. This is where we want to have the result from the Datalink function.

> **Note**: before selecting a PI Datalink function, select the cell in the spreadsheet where the result from the Datalink function should be output! This should be a free area in your spreadsheet, so that existing contents is not overwritten!

6. Select **Sampled Data** function from Multiple Value group. Result: you get the Sampled Data parameter window on the left hand side. Put the cursor into *Data Item(s)* to select this parameter.

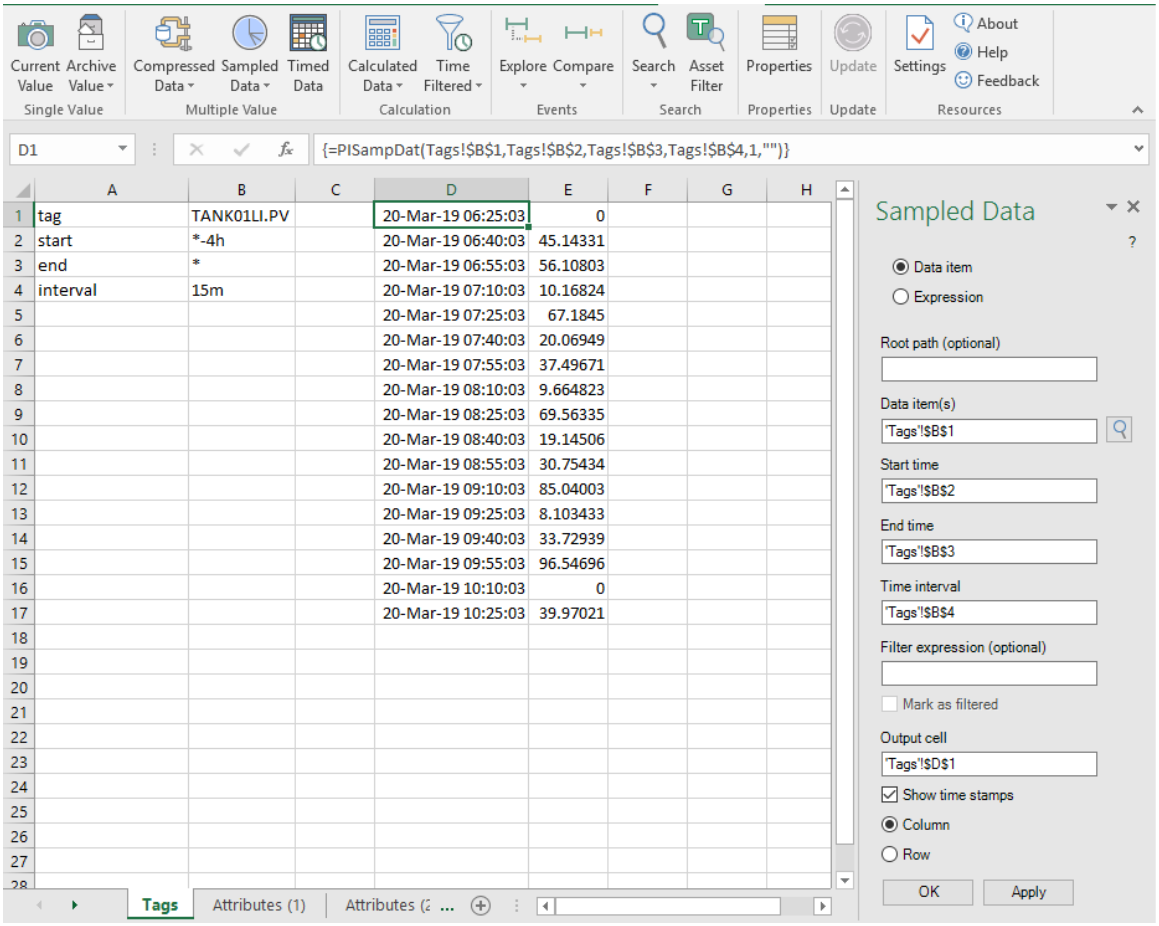
> **Note**: click on the upper half of the icon. If you select the lower half, you select the function along with pre-defined parameters.

7. With *Data Item(s)* selected, click cell B1 to reference the tag TANK01LI.PV. Result: the parameter is set to **'Tags'!$B$1**
8. Put the cursor into *Start time* to select the parameter, then click cell B2.
9. Put the cursor into *End time* to select the parameter, then click cell B3.
10. Put the cursor into *Time interval* to select the parameter, then click cell B4.
11. Check *Show time stamps.*



12. Click on *OK* button. Result: data is returned into cell area D1 … E17.

> Note: if you click *Apply* instead of OK, the Sampled Data parameter window is not closed.



	A	B	C	D	E	F	G	H
1	tag	TANK01LI.PV		20-Mar-19 06:25:03	0			
2	start	*-4h		20-Mar-19 06:40:03	45.14331			
3	end	*		20-Mar-19 06:55:03	56.10803			
4	interval	15m		20-Mar-19 07:10:03	10.16824			
5				20-Mar-19 07:25:03	67.1845			
6				20-Mar-19 07:40:03	20.06949			
7				20-Mar-19 07:55:03	37.49671			
8				20-Mar-19 08:10:03	9.664823			
9				20-Mar-19 08:25:03	69.56335			
10				20-Mar-19 08:40:03	19.14506			
11				20-Mar-19 08:55:03	30.75434			
12				20-Mar-19 09:10:03	85.04003			
13				20-Mar-19 09:25:03	8.103433			
14				20-Mar-19 09:40:03	33.72939			
15				20-Mar-19 09:55:03	96.54696			
16				20-Mar-19 10:10:03	0			
17				20-Mar-19 10:25:03	39.97021			
18								
19								
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22								
23								
24								
25								
26								
27								

5.4.3 Directed Activity – PI Datalink Basics: report with data from AF

In this part of the class, you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

This exercise repeats the previous exercise, but instead of referring to a tag, an attribute in AF (with PI Point Data Reference) is referenced.

Activity Objectives

- Understand how to specify an AF attribute in PI Datalink functions.

Problem Description

The report from the previous exercise should be built by referring to the Level attribute of Tank01 in AF.

Approach

There are two ways to do that:

- refer to the Level attribute with the full AF path in one parameter for the Datalink function
- refer to the Level attribute with the path and the attribute name in two parameters

Full AF Path

1. Select the Spreadsheet tab named **Attributes (1)**.
2. Put the cursor into cell B1, then click on the lower part of the Search icon and select *In a row*. Result the Datalink Search window appears. You can either search for tags or for information in AF. Select the AF Server PISRV01. Result: PISRV01 is shown in the search path above.
3. Click on Velocity Terminals database, then penetrate further on to elements Velocity Terminals – Locations – Montreal.
4. Enter **Level** into the search field and click on the magnifier glass at the right side. Result: four Level attributes are listed, one from each of the four tanks in Montreal, Tank01 … Tank04.
5. Drag the slider for *Data item length* to the left position, which is *Full Path*.
6. Select the line for Tank01 is the list above, then click on OK. Result: the full path appears in cell B1:
   \\PISRV01\Velocity Terminals\Velocity Terminals\Locations\Montreal\Tank01|Level

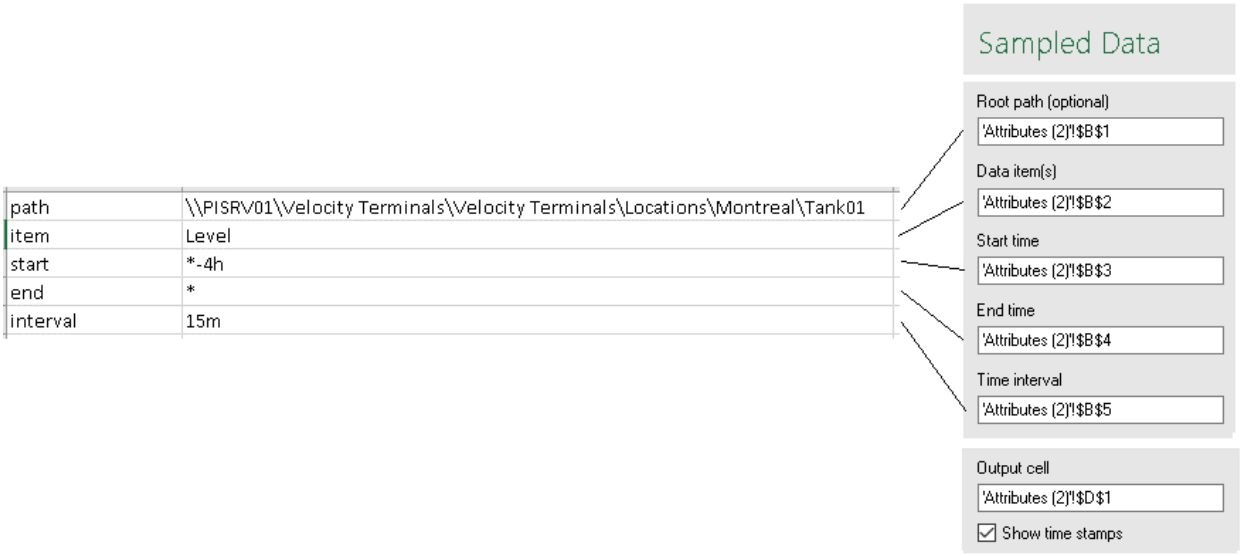
Note: the | character separates the path from the attribute name.

13. Select **Sampled Data** function from Multiple Value group. Result: you get the Sampled Data parameter window on the left hand side. Put the cursor into *Data Item(s)* to select this parameter.
14. With *Data Item(s)* selected, click cell B1 to reference the cell with the full path.
15. Set parameters for *Start time, End time* and *Time interval* and check *Show time stamps.*

16. Check *Show time stamps.* Click on *OK* button. Result: data is returned into cell area D1 … E17.

Path and Item (attribute name) in two parameters

1. Select the Spreadsheet tab named **Attributes (2)**.
2. Put the cursor into cell B1, then click on the lower part of the Search icon and select *In a row*. Result the Datalink Search window appears.
3. Run the same search as in the previous exercise (it is probably still preset) and get the same four Level attributes listed as before.
4. Drag the slider for *Data item length* to the right position, which is *Name Only*.
5. Select the line for Tank01 is the list above, and select *Insert root paths in: Column or Row*. Click on OK. Result: the path appears in cell B1, the attribute name appears in cell B2.
6. Put the cursor in cell D1. This is where we want to have the result from the Datalink function.
7. Select **Sampled Data** function from Multiple Value group. Result: you get the Sampled Data parameter window on the left hand side. Put the cursor into *Root path* to select this parameter.
8. With *Root path* selected, click cell B1. Result: the parameter is set to **'Attributes (2)'!$B$1**
9. Set parameters for *Start time, End time* and *Time interval* and check *Show time stamps.*



10. Click on *OK* button. Result: data is returned into cell area D1 … E17.

5.4.4 Directed Activity – PI Datalink: switch asset context in a report with data from AF

In this part of the class, you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

PI Datalink search window allows the possibility to generate drop-down lists in Excel to allow a report to be applicable to multiple similar assets. This exercise repeats the previous exercise, but shows how to create a cell with a drop-down selection to switch the asset context.

Activity Objectives

- Create a Datalink report that can be switched between different assets.

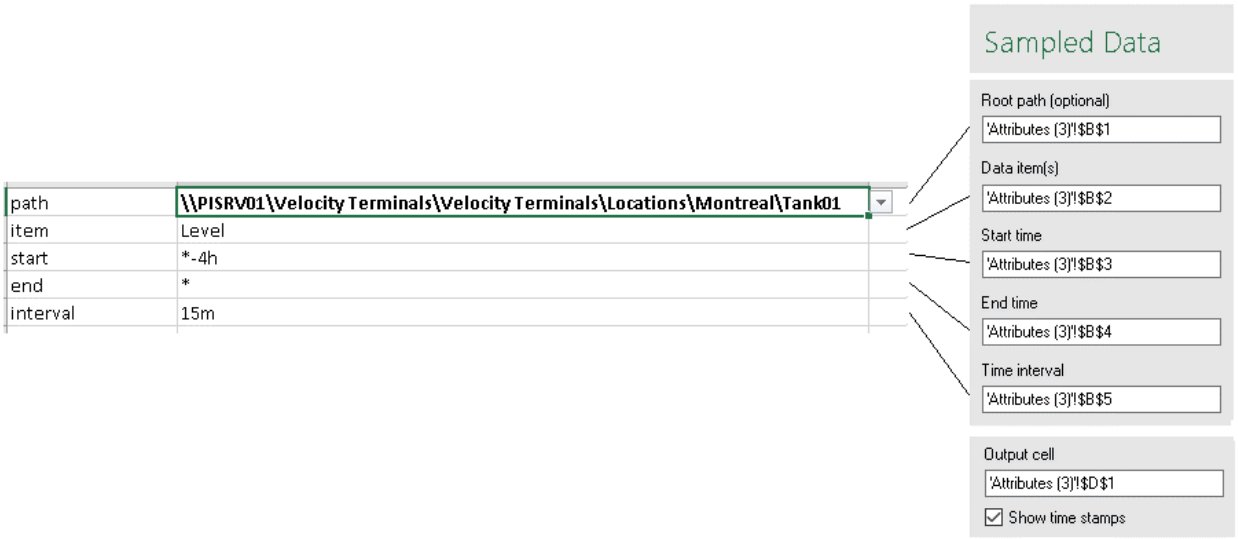
Problem Description

The report from the previous exercise, which gives values for the Level attribute of a tank, should be enhanced to allow the switch between the twelve tanks.

Approach

1. Select the Spreadsheet tab named **Attributes (3)**.
2. Put the cursor into cell B1, then click on the lower part of the Search icon and select *In a column*. Result the Datalink Search window appears.
7. Expand the search for tanks in all locations. You can do that by click on Locations in the search above. Enter **Level** into the search field and click on the magnifier glass at the right side. Result: twelve Level attributes are listed, one from each of the twelve tanks, Tank01 … Tank12.
3. Drag the slider for Data item length to the right position, which is Name Only.
4. Select the all lines in the list above (you can click on the checkbox in the header line for that), and select *Insert root paths in: Drop-down list*. Click on OK. Result: the path appears in cell B1, the attribute name appears in cell B2.
5. If you click cell B1 you get a drop-down selector icon for one for your 12 tanks.
6. Put the cursor in cell D1. This is where we want to have the result from the Datalink function.
7. Select Sampled Data function from Multiple Value group. Result: you get the Sampled Data parameter window on the left hand side. Put the cursor into Root path to select this parameter.

8. With Root path selected, click cell B1. Result: the parameter is set to 'Attributes (2)'!$B$1
9. Put the cursor into Data Item(s) to select this parameter. With Data Item(s) selected, click cell B2.
10. Set parameters for *Start time, End time* and *Time interval* and check *Show time stamps*.
11. Check Show time stamps.



12. Click on OK button. Result: data is returned into cell area D1 … E17.
13. If you switch the tank selection in cell B1, the report will retrieve data for the selected tank.

5.4.5 Exercise – Tank Level Report

This solo or group exercise is designed to maximize learning in a specific topic area. Your instructor will have instructions and will coach you if you need assistance during the exercise.

Objectives

- Exercise the searching in PI Datalink.
- Get familiar with PI Datalink function to retrieve archive data.

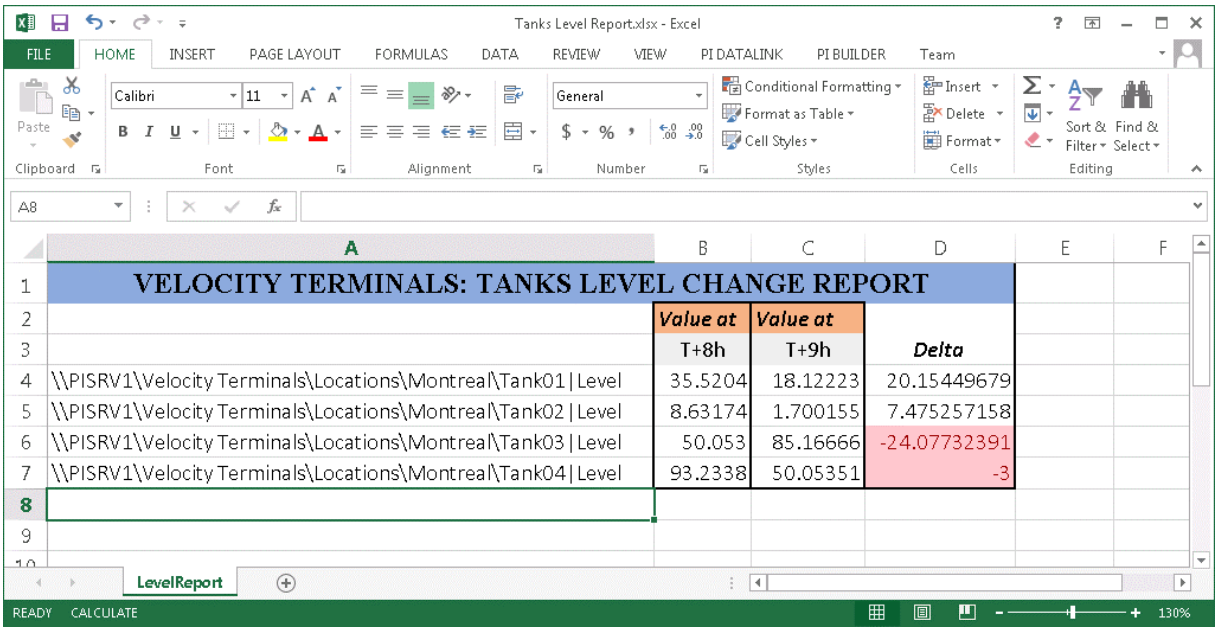
Problem Description

The production supervisor needs an Excel report displaying the change in the level of tank in Montreal between 8:00 AM and 9:00 AM today.

Approach

Select the Spreadsheet tab named **LevelReport.**

Use the *Archive Value* function to retrieve the level at 8:00 AM and at 9:00 AM today. Once you have the level in two columns, you can calculate the difference using Excel. Watch and follow along while the instructor creates this PI Datalink report. Use Excel *conditional formatting* (Excel Home tab, Styles group) to highlight a negative change.



5.4.6 Exercise – Building an Element Relative PI Datalink Report

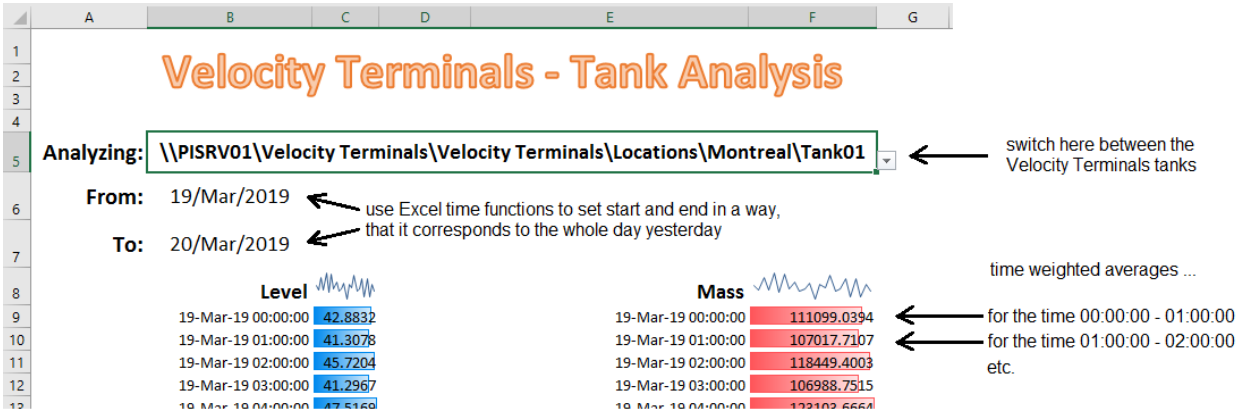
This solo or group exercise is designed to maximize learning in a specific topic area. Your instructor will have instructions and will coach you if you need assistance during the exercise.

Objectives

- Experiment with PI Datalink's Asset Relative feature.
- Follow the steps needed to create a report applicable to similar assets.

Problem Description

Create a small report that has the hourly averages for the level and mass present in one of the Velocity Terminals tanks for the previous day. The report should have the data for one tank, but should allow switching to another tank.



Approach

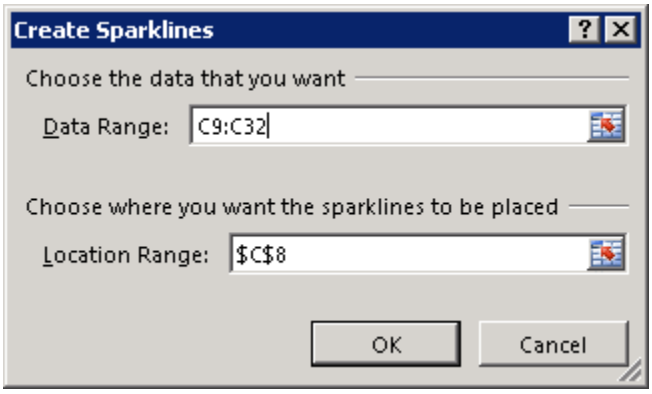
Select the Spreadsheet tab named **Tank Analysis Report.**

Which Datalink function allows to aggregate data such as getting the average over a period of time?

_____

Hint: Cell C8 and F8 were prepared to show spark lines. Here is how the spark line has been added for the **Level** data:

- Select the cells with the data (just select the values, not the timestamps)
- From the Excel Insert ribbon, select Sparkline
- Select the output cell (C8)



(Accordingly for the **Mass** spark line)

6. Adding Analytics to the Assets

PI Asset Framework provides several options to enhance the data with calculations that are carried out on top of the values in the PI Data Archive. These calculations transform raw process data into decision making information that is provided by the PI System.

AF Calculation Option	Examples
Value Retrieval Methods (defined in PI Point data Reference)	Get interpolated value for a PI Point from a particular point in time (e.g. from 2 hours ago), get aggregated data for a PI point for a defined time period (e.g. maximum from the last 24 hours)
Formula Data Reference	Ad-hoc calculation (add volumes from two tanks)
Asset Analytics (Expression, Rollup, Event Frame Generation, SQC)	Expression: perform all kind of simple and complex calculations such as summaries, consumptions, metric data, KPIs etc. Rollup: aggregate/summarize data over several levels in the asset hierarchy (e.g. maximum temperature for all reactors, overall production in all production lines) EF Generation: monitor process for special conditions and capture in event frames (e.g. downtimes, process excursions) SQC: online statistical calculations

For a decision on what calculation options to use, consider the following aspects:

- What load will the calculation place on the PI System?
- Do I need to keep the history for the calculation?
- Will the calculation be applied to multiple assets?
- How complex is the calculation?

For related information refer to the Comparison table at the end of the next chapter.

Beside options in AF, there are further options in the PI System: Performance Equations (PE) points and Totalizer tags (tag-based analytics in PI Data Archive (*)),Calculated Data function and PI Expressions (PI Datalink), PI Calculation datasets (PI Processbook) and PI Advanced Computing Engine (PI ACE).

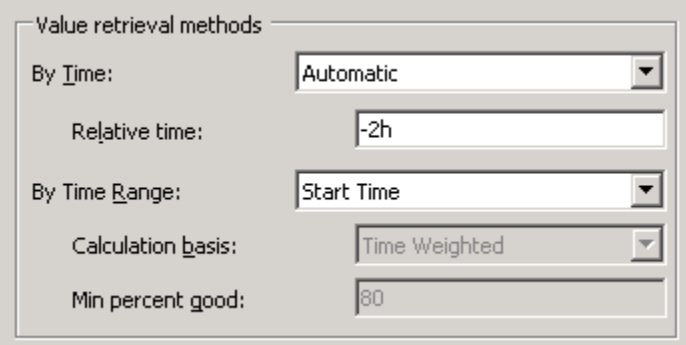
(*) Note: Rather than using tag-based analytics in PI Data Archive, OSIsoft strongly recommends that users upgrade to asset analytics that support event frames, formula data references, and other newer features of PI Asset Framework.

6.1 AF Calculation Options Overview

This section is an overview of calculation options in the PI System, all options are explained individually in more detail later.

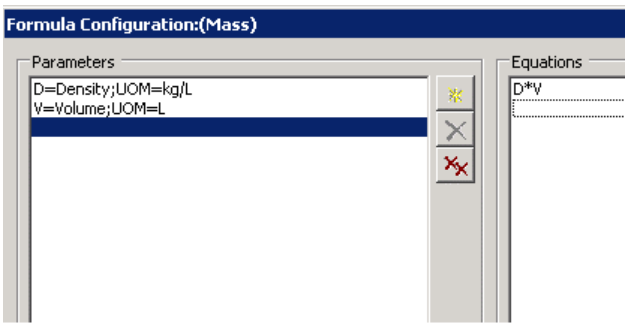
Value Retrieval Methods

- Configurable option within the PI Point Data Reference
- By default the current value of a tag is displayed
- By Time: get data from another point in time
  (e.g. value from 2 hours ago)
- By Time Range: get aggregated data
  (e.g. maximum value from last 15 minutes, total amount of material based on the inflow)



Formula Data Reference

- Ad-hoc calculation, no history saved
- Calculation is defined in one or multiple equations
- Equation syntax based on variables,
  operators (+, *, …) and functions (sin, cos, abs, sqrt,…)
- Examples: volume based on capacity and level, value of your stock based on amount of goods and current prize

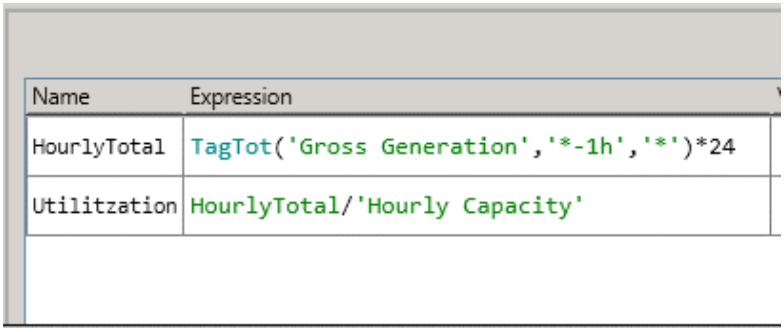


Asset Analytics (Analyses)

- Analysis Types: Expression, Rollup, Event Frame Generation, SQC

Expression Analyses:

- Calculation defined based on attributes, variables, operators and functions
- Functions include Performance Equation (PE) functions (e.g. FindEq, TimeGE, TagMax, Tag Avg,…)
- Results stored in attributes (Analysis Data Reference, PI Point Data Reference)



Note: This is for a first orientation. Expression Analyses as well as the other analysis types will be explained in more detail later on.

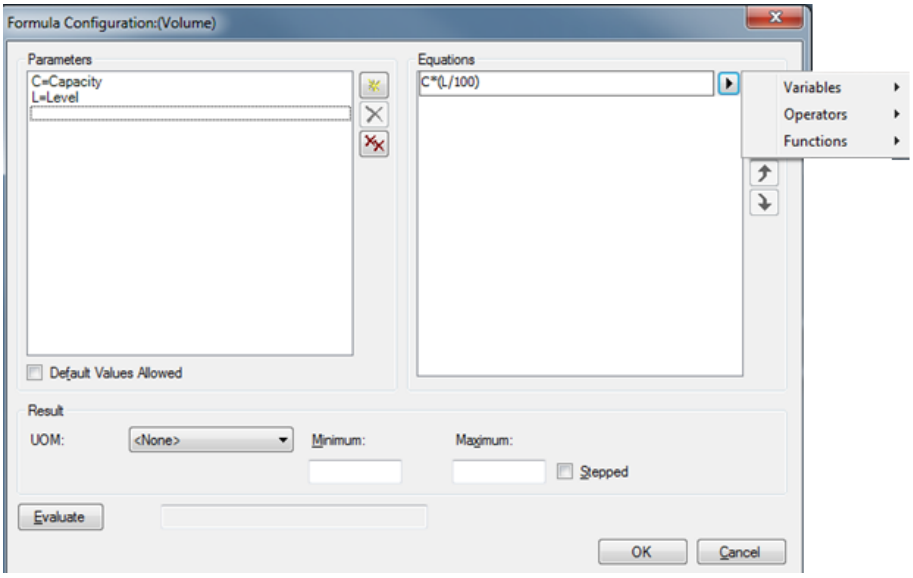
Comparison

To help you with the selection for the best calculation option, use the following table.

	Value Retrieval Methods	**Formula Data Reference**	**Expression Analysis** (Output to non PI Point Attribute)	**Expression Analysis** (Output to PI Point Attribute)
Creation Method	Configuration	Expression	Expression	Expression
Functions	No	Limited	PE	PE
Historization	No	No	No	Yes
Recalculation/ Backfilling	No	No	No	Yes
Calculation Load	Server	Client	Client	Server
Time Awareness	Relative	No	Yes	Yes

6.2 Formula Data Reference

Formula Data References allows the creation of simple custom calculations. Calculations can be in the form of a single formula or a sequence of calculations. The calculations are executed on demand, and the results are not archived anywhere. The functions available are limited and they are not time-weighted.



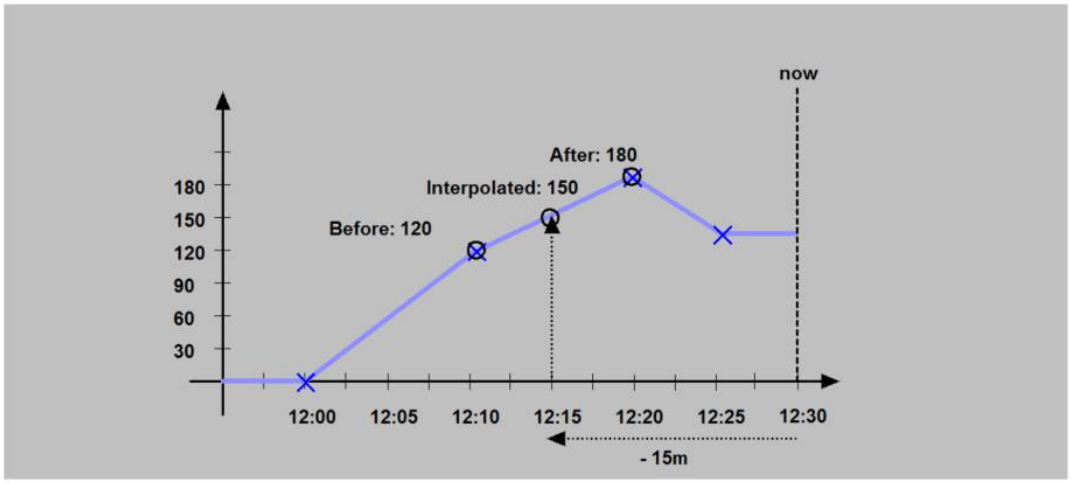
6.3 Value Retrieval Modes

By default, the PI Point Data Reference retrieves the current value of a particular point. The value retrieval methods of the PI Point Data Reference can be configured so that the value will be either

- the value of a point at a specific time (**By Time** retrieval mode)
- the result of a calculation on the point's value over a time range, e.g. an average
  (**By Time Range** retrieval mode).

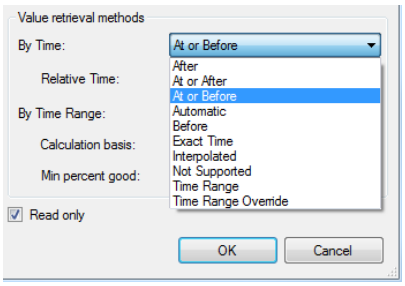
For full information refer to "Configure value retrieval by time" and "Configure value retrieval by time range" in Chapter "PI point data references" in the *PI System Explorer User Guide*, version 2015, p. 140 and 141.

By Time - Retrieving a value other than the current one.



After | At or After | At or Before | Automatic | Before | Exact Time | Interpolated

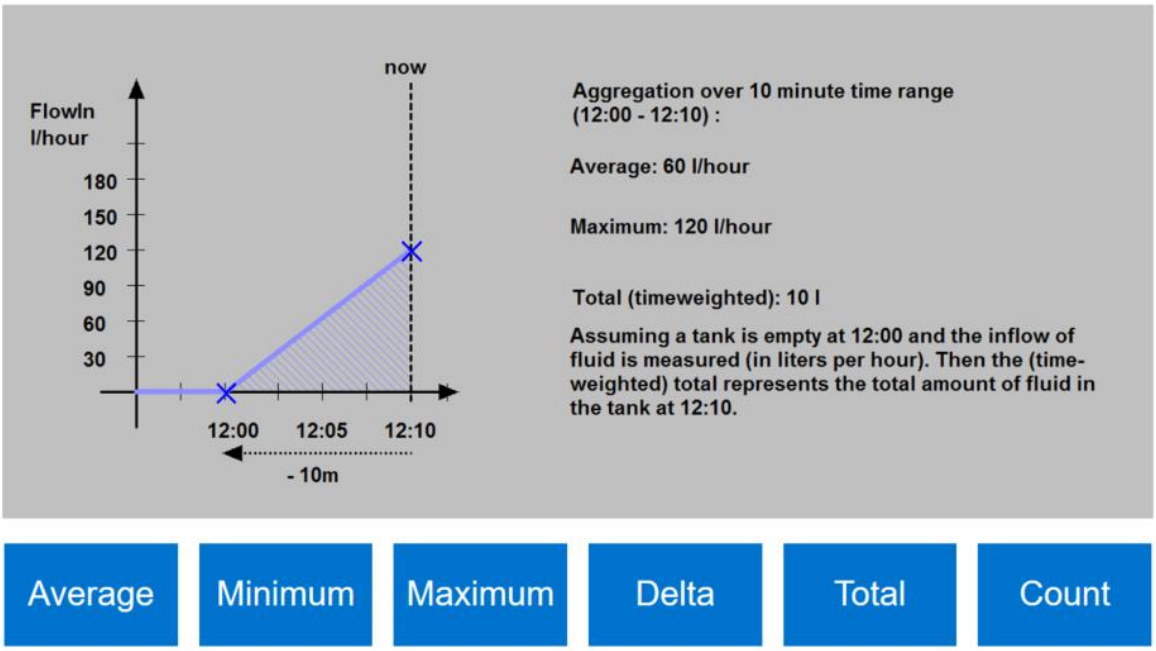
By Time mode options are **After**, **At or Before**, **At or After**, **Automatic**, **Before**, **Exact Time** and **Interpolated**. To get a value other than the current value these options are used in context with the **Relative Time** field. Relative time expressions have to be in the PI System Time format (see examples below).



By Time	Relative Time	Meaning
At or After	-15m	Returns the recorded value from 15 minutes before the current time. If no value exists at that time, the next recorded value is returned.
After	-2h	Returns the first recorded value after the point in time that is two hours ago. If a value exists exactly at that time, it is not returned.
Exact	-2h	Returns the recorded value from two hours before the current time. If no value exists at that time, “No Data”-error is returned.
Interpolated	T+6h	Returns an interpolated time for 6:00:00 of the current day.

Note: Do not choose the Not Supported, Time Range, and Time Range Override options for **By Time**. These options are for attribute values based on time range calculations (see below**)**

By Time Range – Retrieving the result of an aggregation.



By Time Range options are:

Average (time-weighted), Count, Delta, Maximum, Minimum, Population Standard Deviation, Standard Deviation, Start Time, End Time, Total.

In case of Total, an extra drop-down appears to specify the time units of the rate point or attribute over which the calculation is performed. That is required since the Data Archive always assumes a rate point to be in **units/day**. Selecting the right time units is thus essential to retrieve a correct result.

The options in the **By Time field** for a **By Time Range** retrieval are **Not Supported**, **Time Range** and **Time Range Override**. Depending on what time context the client application is providing the behavior is in the following table.

By Time Setting	**Meaning**
Not Supported	If client application sends a time range, it is considered for the calculation. If client application sends point in time (and not a time range), an error is returned.
Time Range	If client application sends a time range, it is considered for the calculation. If client application sends point in time (and not a time range), the time range specified under **Relative Time** is used.
Time Range Override	The time range specified under **Relative Time** is used in any case.

6.3.1 Directed Activity – Understanding Value Retrieval Modes for Times Ranges (optional)

In this part of the class, you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

Activity Objectives

- Distinguish retrieval modes for time periods: Not Supported, Time Range and Time Range Override

Problem Description

- You are measuring a temperature and would like to get minimum and maximum for the last hour as well as for the time period applied in your PI Vision trend.

Approach

Open the Demo database and select the Value Retrieval Demo element.

1. Display the elements attributes and get their function.

Attribute Name	Value
Temperature	Actual Value from now
Temperature.Min. TimeRangeNotSupported	Temperature Minimum for a time period: The time range is taken from the client (here: PSE). Because the PSE does not supply a time range, a corresponding error (*The attribute requires a time range…*) is displayed.
Temperature.Min. TimeRange.1HR	Temperature Minimum for a time period: If the time range is supplied by client (here: PSE), it is used. Because the PSE does not supply a time range, the specified range is used (1hr).
Temperature.Min. TimeRangeOverride.1HR	Temperature Minimum for one hour time period
(according to the three minimum attributes, there are three corresponding maximum attributes)	

2. (optional) From PSE Tools > Options > Time Context set a time range for PSE of e.g. last five minutes. Discuss the value attribute changes. Reset the time context back (Query Date Time= Latest Available)

Click on the desktop link to open **PI Vision** and select the **Retrieval Modes Demo** display.

1. Display the elements attributes and get their function. Set time period selector to 1h:

Attribute Name	Value
Temperature	Actual Value from now
Temperature.Min. TimeRangeNotSupported	Temperature Minimum for a time period: The time range is taken from the client (here: PI Vision). PI Vision time range is one hour. This means the Temperature Minimum is for a hour time period.
Temperature.Min. TimeRange.1HR	Temperature Minimum for a time period: If the time range is supplied by client (here: PI Vision), it is used. PI Vision time range is one hour. This means the Temperature Minimum is for a hour time period.
Temperature.Min. TimeRangeOverride.1HR	Temperature Minimum for one hour time period
(according to the three minimum attributes, there are three corresponding maximum attributes)	

2. Set the time period selector to 8 hours.

Attribute Name	Value
Temperature	Actual Value from now
Temperature.Min. TimeRangeNotSupported	Temperature Minimum for a time period: The time range is taken from the client (here: PI Vision). PI Vision time range is eight hours. This means the Temperature Minimum is for an eight hour time period.
Temperature.Min. TimeRange.1HR	Temperature Minimum for a time period: If the time range is supplied by client (here: PI Vision), it is used. PI Vision time range is eight hours. This means the Temperature Minimum is for an eight hour time period.
Temperature.Min. TimeRangeOverride.1HR	Temperature Minimum for one hour time period

3. Set the start time to y+22h, set the end time to t. This is the time period of the two hours before midnight today.
(yesterday 22:00:00 – today 00:00:00).

Attribute Name	Value
Temperature	Value from today midnight (today 00:00:00)
Temperature.Min. TimeRangeNotSupported	Temperature Minimum for a time period: The time range is taken from the client (here: PI Vision). PI Vision time range is two hours. This means the Temperature Minimum is for the two hour time period before midnight today.
Temperature.Min. TimeRange.1HR	Temperature Minimum for a time period: If the time range is supplied by client (here: PI Vision), it is used. PI Vision time range is two hours. This means the Temperature Minimum is for the two hour time period before midnight today.
Temperature.Min. TimeRangeOverride.1HR	Temperature Minimum is for the one hour time period before midnight today (yesterday 23:00:00 – today 00:00:00)

6.3.2 Directed Activity – Apply Value Retrieval Modes for Tank Level Attribute

In this part of the class, you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

Activity Objectives

- Use the Value Retrieval mode to get the value of a tag from two hours ago and its average for the last two hours.

Problem Description

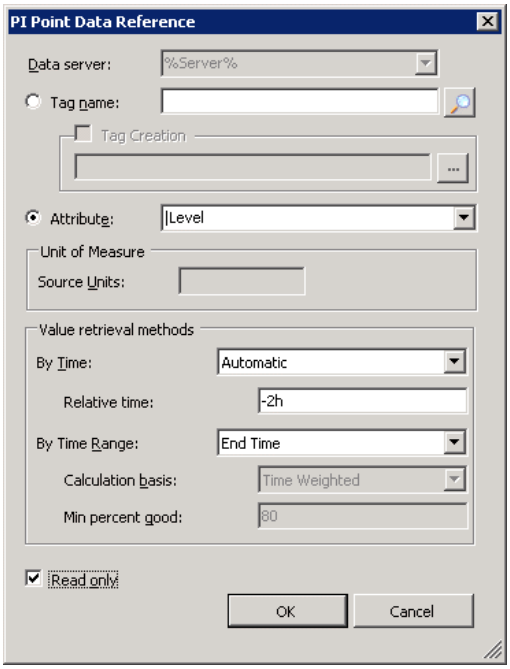
- In addition to the actual material content level in the tanks, the operational personnel would like to see what the level has been 2 hours ago and what the average level has been for the last 2 hours.

Approach

Open the Tank template in the Library of the Velocity Terminals database.
Select Attribute templates tab.

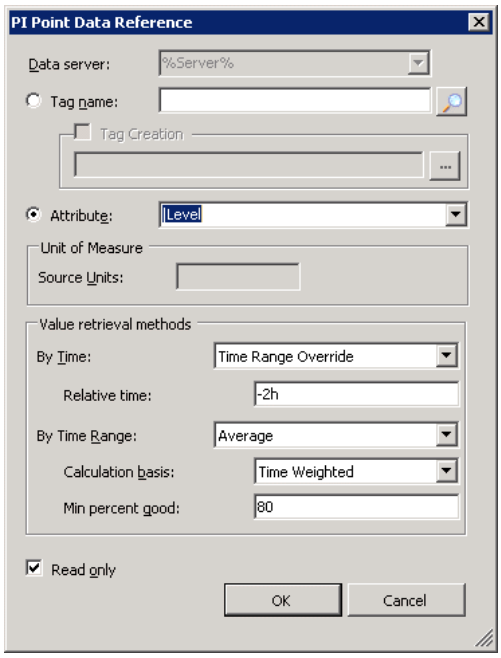
For the value from two hours ago:

1. Select the line with the Level attribute and select New Child Attribute Template from the right-mouse button context menu.
2. Attribute Name = Level.2HoursAgo
   Default UOM = percent
   DisplayDigits=2
   Data Reference = PI Point
3. PI Point Settings:



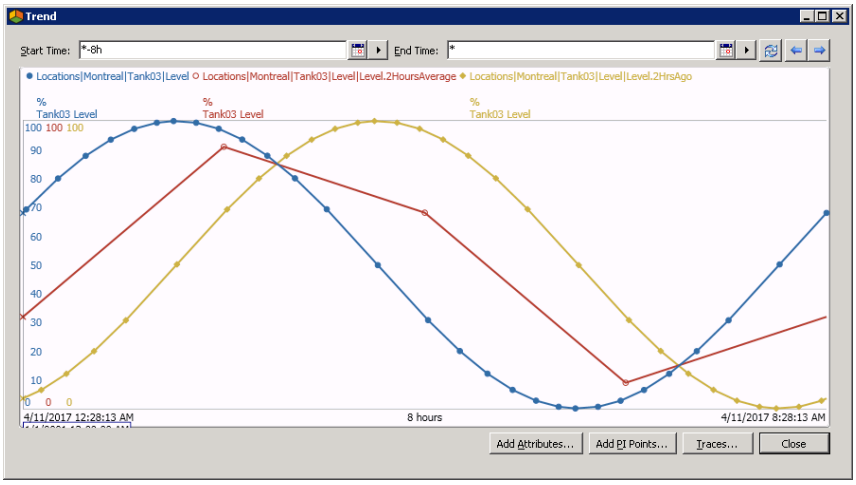
For the average value of the last two hours:

1. Select the line with the Level attribute and select New Child Attribute Template from the right-mouse button context menu.
2. Attribute Name = Level.2HoursAverage
   Default UOM = percent
   DisplayDigits=2
   Data Reference = PI Point
3. PI Point Settings:



Verify the results:

1. Open one of the Velocity Terminals tanks (look at Tank03 because Level for Tank01 and Tank02 changes too often).
2. Select the lines with the Level attribute and the two recently created child attributes and select Trend from the right-mouse button context menu.
3. Set Start Time= *-8h and End Time= * and click on Refresh button.



6.3.3 Directed Activity – Simple Calculations for PI Big Tires Co.

In this part of the class, you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

Activity Objectives

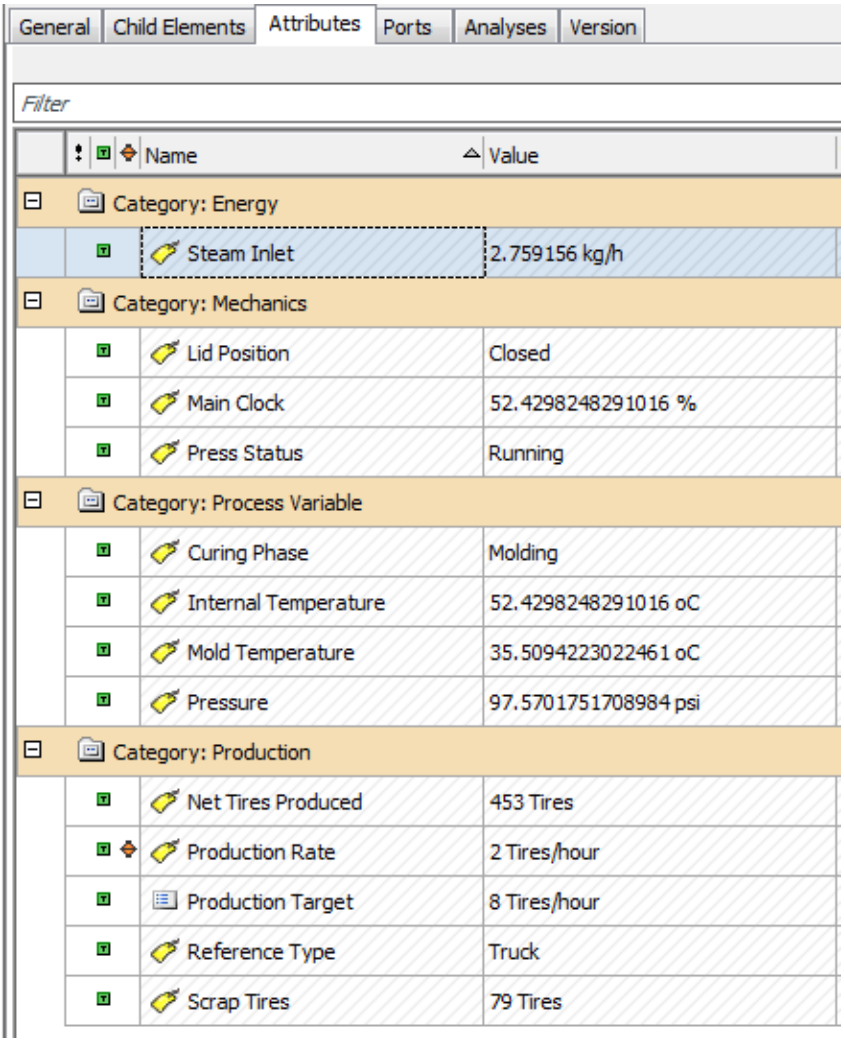
- Use the Formula Data Reference and the Value Retrieval modes to create analytics.

Case study

As a consultant for a tire manufacturing company, PI Big Tires Co., you help create a smarter AF structure; your client wants to have more insight on his operations by taking advantage of the calculation and analytics features provided by the PI System. The tire curing presses are an essential part of the production process and currently there is a lack of key performance metrics; your client wants you to start working on this section of the factory.

Here is how a Tire Curing Press works: raw tires are loaded individually into a Tire Curing Press. Once the tire is loaded, the press closes up and temperature and pressure is applied to cook and mold the tire. After the cooking time has elapsed, the press opens up and the tire is unloaded into a cooling unit where fans blow air until the tire reaches a specific temperature.

Below a screenshot of the current press template. Open PSE, connect to the AF Server and AF database indicated by the instructor and take a minute to familiarize yourself with the template and attributes.

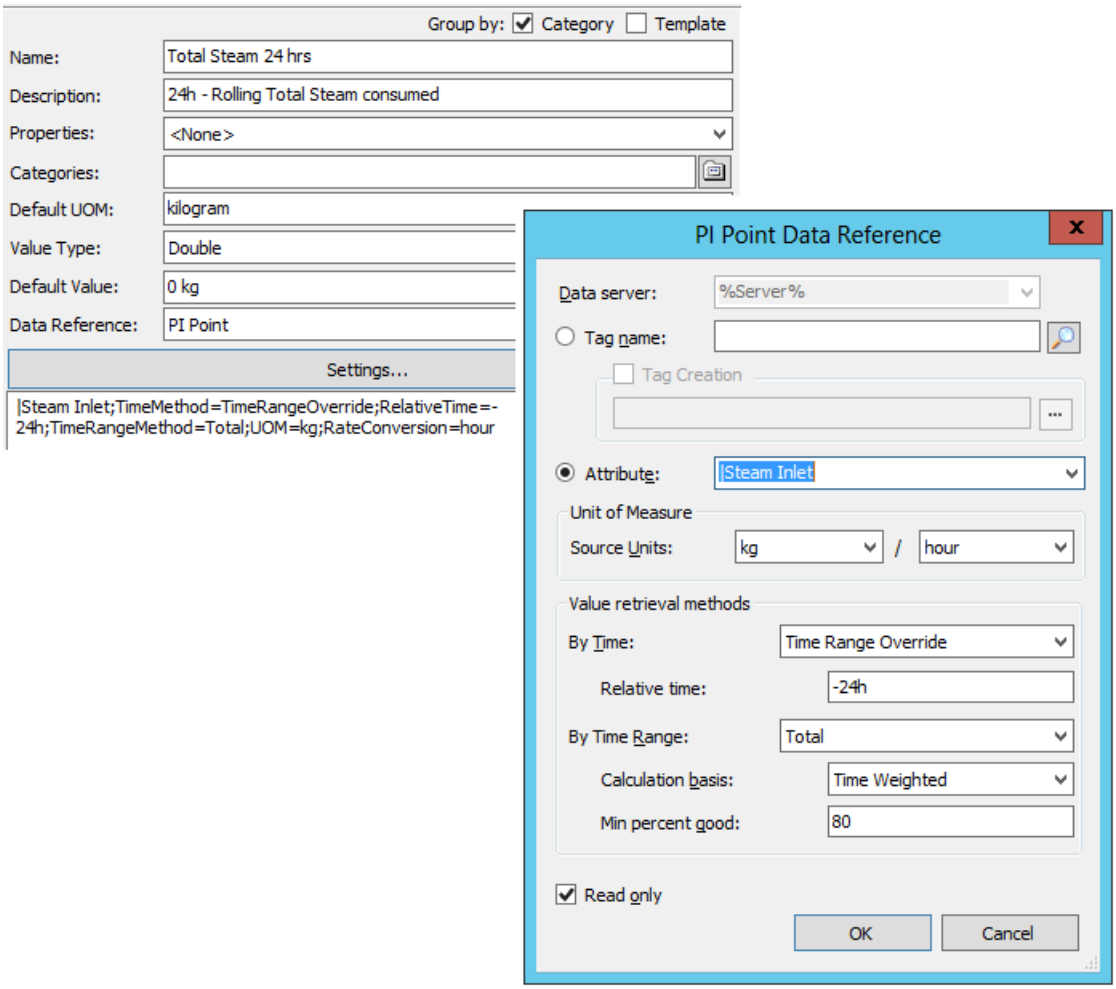


Problem Description

1. The maintenance coordinator would like a new attribute to display the total steam consumed during the last 24 hours. He does not need to archive the result of that calculation in the Data Archive.
2. The cost of a scrap tire is 20 dollars. The quality inspector would like everyone to see in an AF attribute how much money the company has lost in scrap tires. The production supervisor agreed to display this in AF but not to archive the result in the Data Archive.

Approach

1. Create a new attribute on the *press* template and use the value retrieval methods to calculate the total.



2. Create a new attribute and use the formula data reference to calculate the cost of scrap tires.

6.4 PI Analysis Service, Expression Analysis

Asset analytics is a new feature of PI Analysis Service released with AF 2014 (2.6). Asset Analytics allows you to create and manage analyses on top of your AF assets. An analysis is a scheduled calculation that gets input values from attributes in any level of your AF hierarchy and outputs its results to other AF attributes.

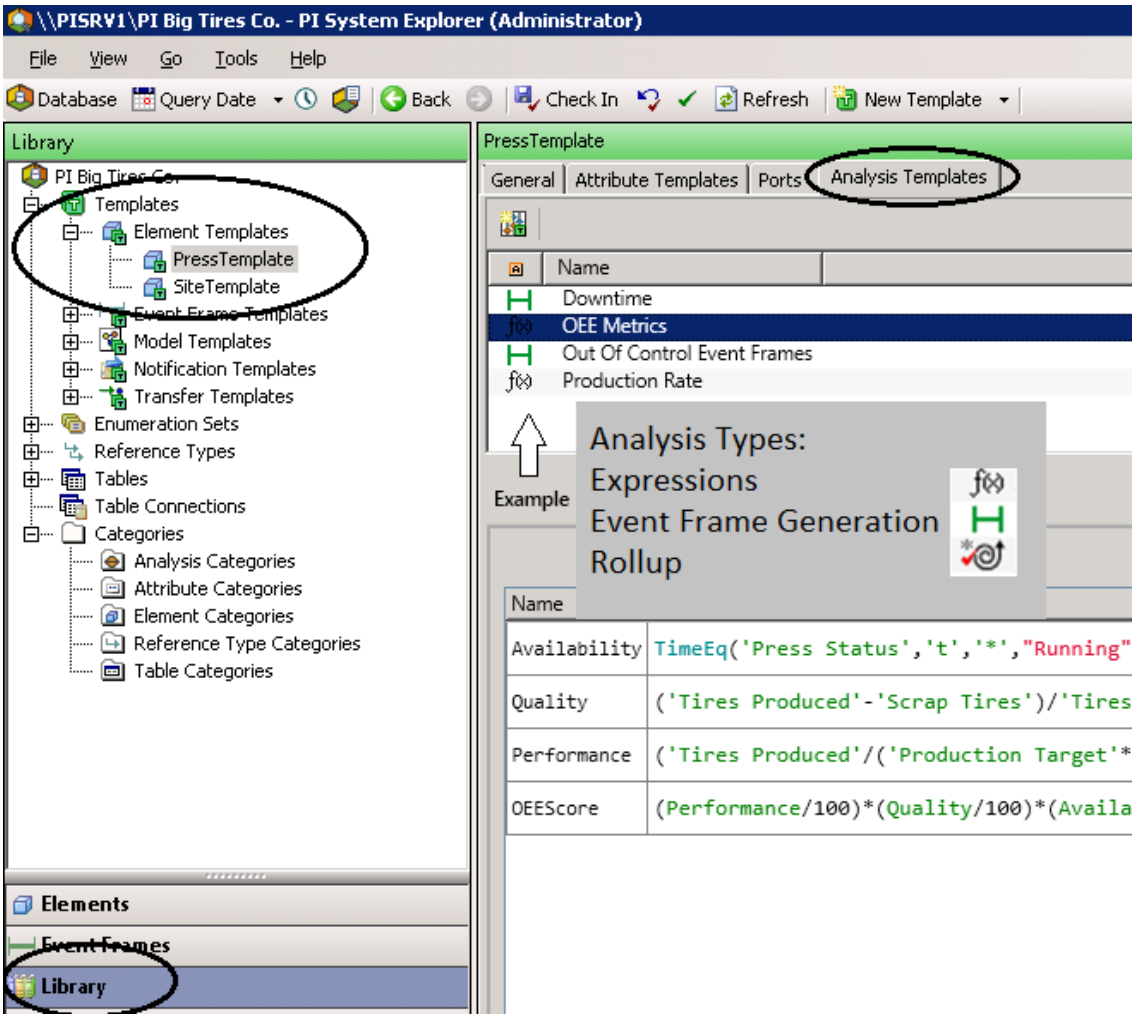
Asset analytics features three types of analysis:

- Expressions: Wide range of functions to create powerful analyses. Expressions use the Performance Equation syntax.
- Rollup: Aggregation calculations for a group of selected attributes.
- Event Frame Generation: Specify conditions to trigger the start and the end of an event.
- SQC: Uses Statistical Quality Control (SQC) methods to monitor that attribute values lie within pre-determined boundaries.

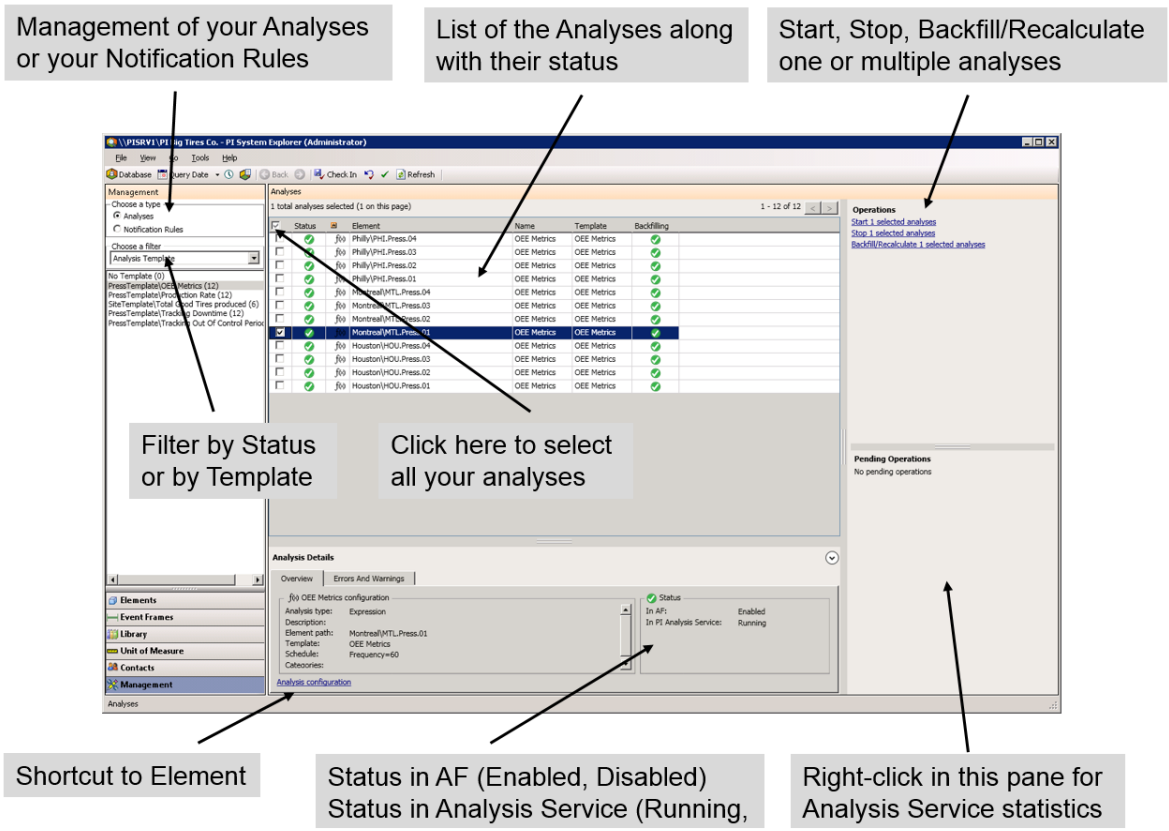
Asset analytics provides the following capabilities:

- Historization: When the output attribute is mapped to a PI Point, the calculation results are archived in the Data Archive.
- Backfilling/Recalculation:
  Backfilling: Run the analysis over an earlier time period to backfill data for the PI Points mapped to its outputs. Example: a new analysis to calculate daily overall consumptions is created on April 1st. With Backfilling the overall consumptions are calculated for a past period such as e.g. January - March and stored in the archive of the output tag.
  Recalculation: In case the values for the inputs of a calculation have changed the recalculation feature allows to update the calculation results accordingly.
- Security: It is possible to configure and manage permissions to limit access to analyses and analysis templates.
- Preview and Test: Calculation results can be previewed before putting the analyses into production.
- Calculation Dependencies: The result of a calculation can be used as an input to another calculation.
- Scheduling options: Calculations can be configured to be executed according to a schedule or they can be event based.

Every analysis is associated with an element and can be created directly on that element by selecting the **Analyses** tab; however, it is recommended that analyses be associated with an element template. In order to do this, select the corresponding Element Template and then use the **Analysis Templates** tab (see figure below).



Analyses can be managed (e.g. start, stop, backfill) directly at the element level under the *Analyses* tab, or by using the *Management* plug-in from the navigator panel. See below a screenshot presenting a short description of the different components of the Management plug-in.


Management of your Analyses or your Notification Rules
List of the Analyses along with their status
Start, Stop, Backfill/Recalculate one or multiple analyses
Filter by Status or by Template
Click here to select all your analyses
Shortcut to Element
Status in AF (Enabled, Disabled)
Status in Analysis Service (Running,
Right-click in this pane for Analysis Service statistics

6.4.1 The Expression Analysis

The *expression analysis* allows you to create and schedule calculations using the Performance Equation (PE) syntax and a broad gallery of functions. Before discussing expression analysis in detail, it is essential to review the syntax for expression analysis (also referred as Performance Equation (PE) syntax).

6.4.2 Syntax for Expression Analysis (PE Syntax)

The syntax for expression analysis is an algebraic syntax used to perform calculations and filter data in multiple client and server products from the PI System suite. Besides PI Analysis Service, the following products use this syntax:

- **Data Archive** through a PE points.
- **PI ProcessBook** through a PI Calculation dataset.
- **PI Datalink** through use of Filter Expressions or PI Expressions.
- **Notifications** through use of a PI PE Trigger Condition.

This syntax has three (3) rules when it comes to writing expressions:

1. AF Attributes or Data Archive tag names and time stamps are written enclosed in **single quotes (')**:

   For example: 'Pressure', 'CDT158', '*-1h', '03-Feb-2013 13:38'

2. Text (strings) or digital states are written enclosed in **double quotes (")**:

   For example: "This is a comment.", "OFF", "Active", etc.

3. Mathematical operators and PE functions are written as is.

   For example: +, -, *, ^, TagTot(), FindGT(), etc.

The expression functions reference guide is available under the PSE help menu.

6.4.3 Directed Activity – Checking Out the Expression Functions Reference

In this part of the class, you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

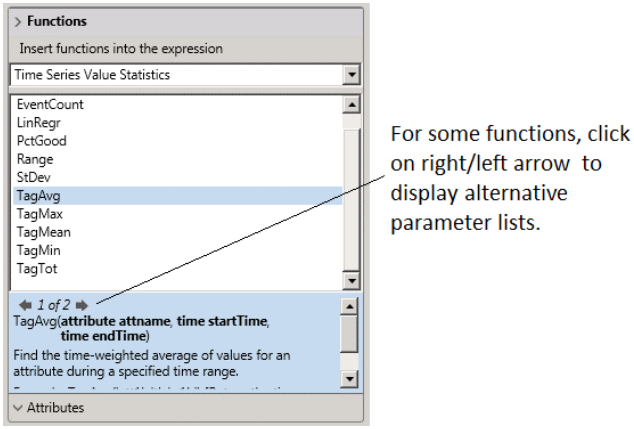
Activity Objectives

- Learn where to find information about analysis expression functions.
- Explore the functions of the Expression Analysis syntax.

Approach

Information about analysis expression functions can be found at:

1. **Analyses tab (Elements and Element Templates)**: Select the *Demo* AF Database and locate the Analysis Demo element. Select the Analyses tab. Expression Functions are listed at the right hand side. Use the drop-down for segregation according to functionality.



2. **PI System Explorer Help**: Asset Analytics > Expression functions reference

With the instructor, examine the highlights of Expression Analysis syntax and its available functions.

- What function would you use to calculate the time-weighted average of an attribute over the last 8 hours? _____.
- You want to find the total time that an attribute was greater than 100.What function would you use? _____.

Note: Each function presented in the reference guide features examples that can be copied over to notepad or to other PI System products directly.

6.4.4 Exercise – Applying Expression Analysis Syntax

This solo or group activity is designed to maximize learning in a specific topic area. Your instructor will have instructions and will coach you if you need assistance during the activity.

Exercise Objectives

- Learn to apply the Expression Analysis Syntax to different calculation and filtering problems.

Problem Description and Approach

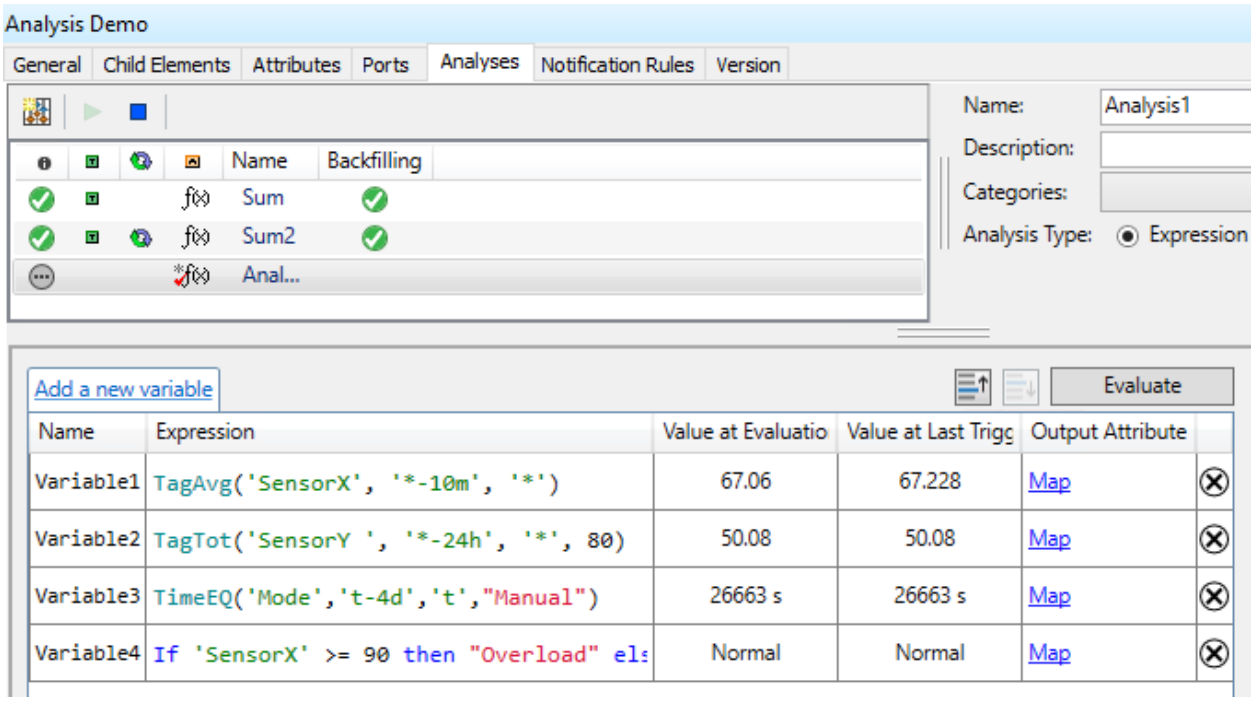
You may want to construct your equations in Notepad or another text editor rather than in the space below so you can cut and paste from the help file.

Problem	Your solution…	Hints
Get a ten-minute “rolling” average of the **SensorX** attribute		**TagAvg()**
Get the time-weighted total for the **SensorY** attribute over the last 24 hours, but only if at least 80% of the values used in the calculation are considered “good”.		**TagTot()**
The amount of time the **Mode** attribute was “Manual” during the past four days.		**TimeEQ()** The amount of time returned is in seconds.
Display “Overload” when the **SensorX** attribute is greater or equal than 90 , “Normal” when between 10 and 90 (**excluding** the boundary values), and “Empty” when lower or equal than 10.		**If... then… else**

Try to do this exercise on your own before referring to the exercise solutions section at the end of the book.

Familiarize with the function entry (optional)

1. Open the Demo database and select the Analysis Demo element.
2. Select the Analyses tab
3. Click on the New Analysis icon.
4. Enter the expressions in the Expression tab.



5. The analysis is not needed any more, so you can click on Check-out to undo the entry.

6.4.5 Directed Activity - Overall Equipment Effectiveness (OEE) Metrics

In this part of the class you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

Activity Objectives

- Create and configure an expression analysis.
- Create an analysis template.
- Backfill an analysis.
- Manage an analysis via the Analyses plugin.

Problem Description

Management would like to track the productivity of the tire curing presses by using Overall Equipment Effectiveness (OEE). In short, OEE, developed in the mid 1990's, enables the monitoring of plant floor productivity and improvement of the efficiency of a manufacturing process. OEE is composed of three different metrics: Availability, Performance and Quality.

Metric	Description	Formula
Availability	Percentage of time that an equipment is up and running	Operating Time / Planned Production Time
Performance	Actual yield to the target yield	Total pieces / Target
Quality	Percentage of good units that are produced	Good pieces / Total Pieces
OEE	*Availability*Performance*Quality*	

For this exercise, OEE metrics will be calculated daily.

Approach

The metrics represent a ratio, which can be in the range 0 … 1. We could also represent this as a percentage in the range 0 … 100. We will use units for ratio and percentage to convert the figures accordingly.

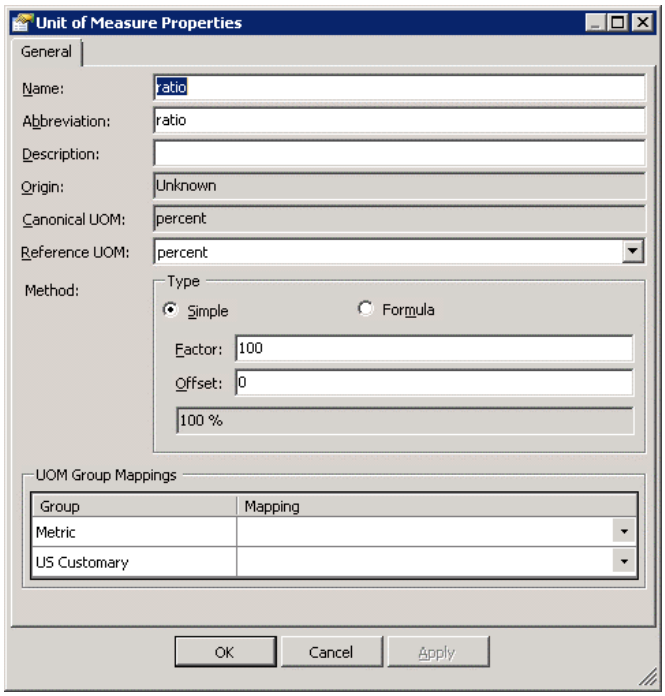
Each press has a status attribute. A press is considered to be operating whenever it is in the running status; any other status indicates that the press is out of order.

Follow the instructor as he or she performs the steps to create an analysis to calculate the availability of the presses. You will later be working on your own.

Adding a unit of measure for the ratio

There is already a UOM class for ration, which has percent in it. Let us add another unit of measure for the ratio.

With Unit of Measure selected in PI System Explorer Navigator, navigate to the UOM class *Ratio*. Add a new unit of measure named **ratio**:

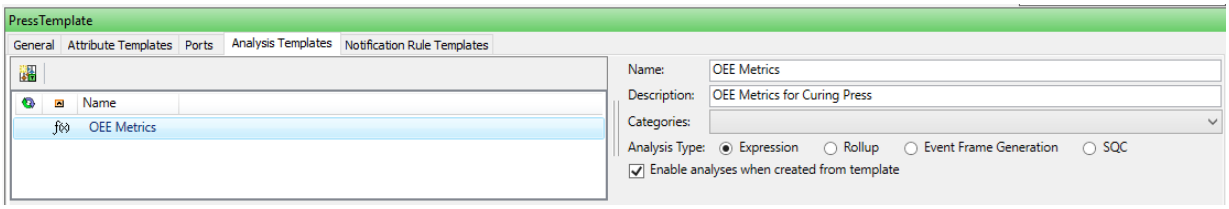


Note: A ratio of 1 means 100%.

Adding an Analysis Template

As indicated previously, it is recommended to configure the analyses directly at the template level. So let's open the press element template and click on the *Analysis Templates* tab. In this window (see figure below) you will be able to set up analyses that will be automatically created when a new instance of the corresponding element is added to the AF structure.

First, enter a name and a meaningful description for the analysis (e.g OEE Metrics), and then select the expression analysis type using the radio buttons.



Note: We have selected to enable the analysis right-away when it is created from the template. Uncheck the option if you are not confident that your analysis does the right calculation. The analyses can be started at a later time for the related elements.

Entering an Expression

The next step is to enter the expression, which is the equation that will be executed. An expression can be written in a single row or multiple rows. Asset analytics allows you to assign the result of a row to a variable; this variable can be used later in another row.

Tip: Take advantage of the variables to simplify complicated expressions; testing and debugging will be much easier since you will be able to evaluate smaller expressions one at a time.

Let us use the first row to calculate the OEE availability. Start by giving a name to the variable, for example *Availability*. The pane on the right lists descriptions of all available functions that you can use to build your equation.

How can we get the time the press was running today?

_____.

In what way will the time be returned?

_____.

Let us assume the press should run all time. How can we get the number of seconds until now since midnight?

_____.

The ratio between these two times will be in range 0…1.
To assign the appropriate engineering unit, use the function *Convert*.

Note: The Convert function converts a value from its current unit of measure (UOM) to a specified UOM. For a value with no UOM, assign the specified UOM.

Example:
Convert ('Outside Air Temperature', "degC")

So the complete expression is:

```
Convert(TimeEq('Press Status','t','*',"Running")/DaySec('*'),"ratio")
```

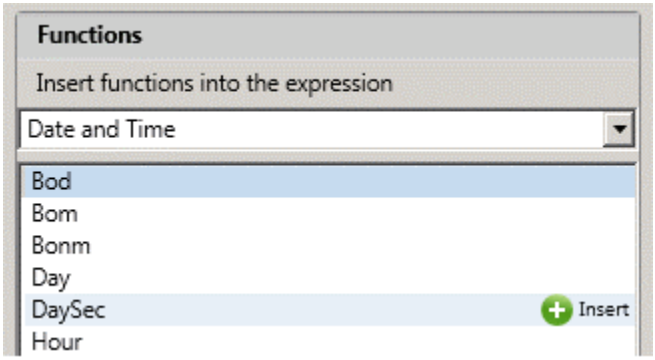
Here are some tips concerning entry of expressions:

- **Tip1**: Auto completion (aka. IntelliSense) is available to assist you with the syntax.

- **Tip2:** If you enter something that is syntactically incorrect, a curly underline will occur:

```
TimeEq('Press Status','t','*',"Running")/DaySec('*')100
```

- **Tip3:** If you click on *Functions* in the right hand side, the pane will list all available functions. The drop-down on the top allow to filter function groups (e.g. *Date and Time*). Select a function and click on the green Plus icon to add it into the expression (you don't have to type it)

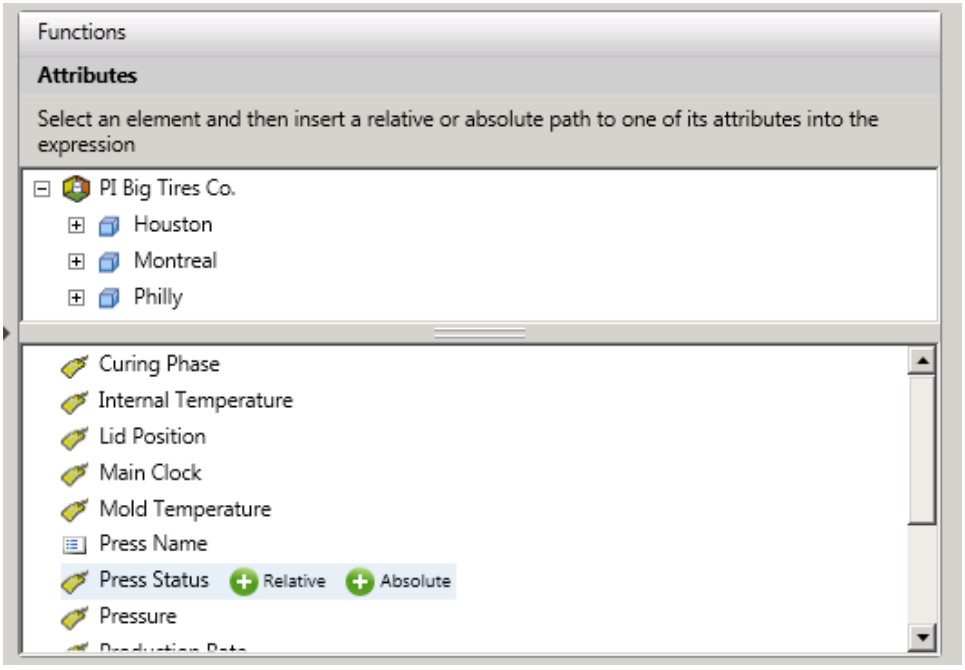


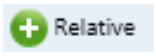
- **Tip4**: You can add comments to explain what you are doing. Comments start with two forward slashes (//). To start a new line use Shift-Enter.

Name	Expression

Availability	`// Is the ratio between the time the press is running`
	`// and the full time it is supposed to operate.`
	`// The press is supposed to run all time`
	`Convert(TimeEq('Press Status','t','*',"Running")/DaySec('*'),"ratio")`

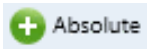
- **Tip5:** If you click on *Attributes* in the right hand side, the pane will list all available attributes. The upper part allows to navigate in the asset tree. Select an attribute and click on either one of the green Plus icons to add it into the expression (you don't have to type it)





Insert Relative:

The attribute is inserted without the path in the element tree:
This refers to the attribute in its actual element context.



Insert Absolute:

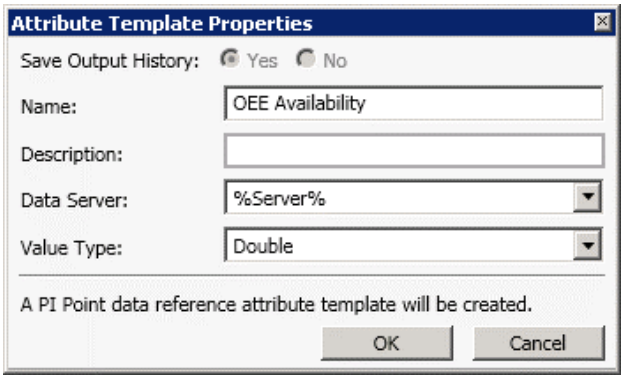
The attribute is inserted along with the absolute element path. This refers to the attribute in the specified element path.

You can pick attributes from other elements by navigating in the asset tree shown above. An example for use of an absolute path is when the attribute has a general meaning, e.g. the outside air temperature at a location:

```
'\Houston|OutsideAirTemperature'
```

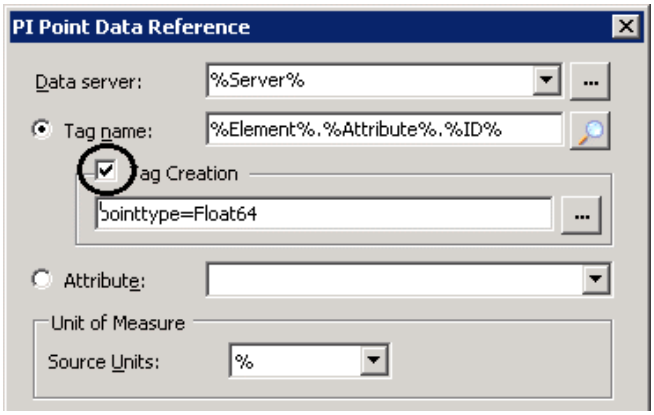
Mapping the output to an attribute

The output of an expression can be mapped to either an existing or a new attribute. In order to map it to an existing attribute click to *Map* and select the corresponding attribute. We will be mapping the result of the availability calculation to a new attribute, so select *New Attribute Template,* which will open the *Attribute Template Properties* window. Set the name to OEE Availability.



Switch to the Attributes Templates tab and select the OEE Availability attribute. Set Default UOM to percent. Assign a new attribute category *OEE* Metrics. Under Settings, you can now select a PI Point as an output. If an appropriate PI Point does not exist, you can enable automatic point creation; simply check the *Tag Creation* checkbox under *Settings*.

Tip: In case the output attribute's data reference is a point, calculation results will be stored in the Data Archive; therefore you will be able to trend them in PI Vision or PI ProcessBook. Moreover, points also provide improved performance for AF.

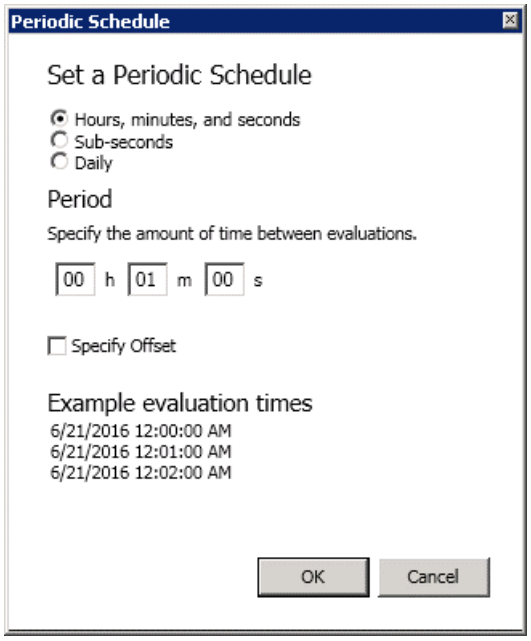


Note: When automatic tag creation is enabled, you can use substitution parameters to name the points. *%Element%.%Attribute%.%ID%* is the default for asset analytics output points. Substitution parameters will be presented later in the class.

Scheduling an expression

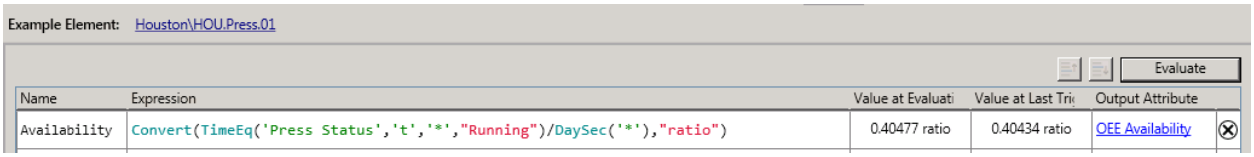
Now that the calculation has been written, it is time to schedule it. Two scheduling options are available: periodic and event-triggered.

- Event-triggered scheduling is event driven: the calculation is executed whenever one or multiple input attributes receive a new value. You get to choose which input attributes trigger the calculation.
- Periodic scheduling is clock-based and in the configuration window, you can specify a period and an offset. Let us schedule the OEE calculations to be executed every minute (00h 01m 00s).



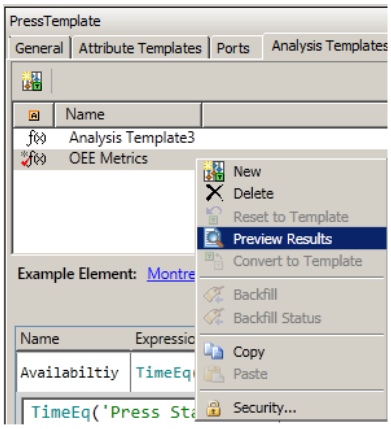
Testing an expression

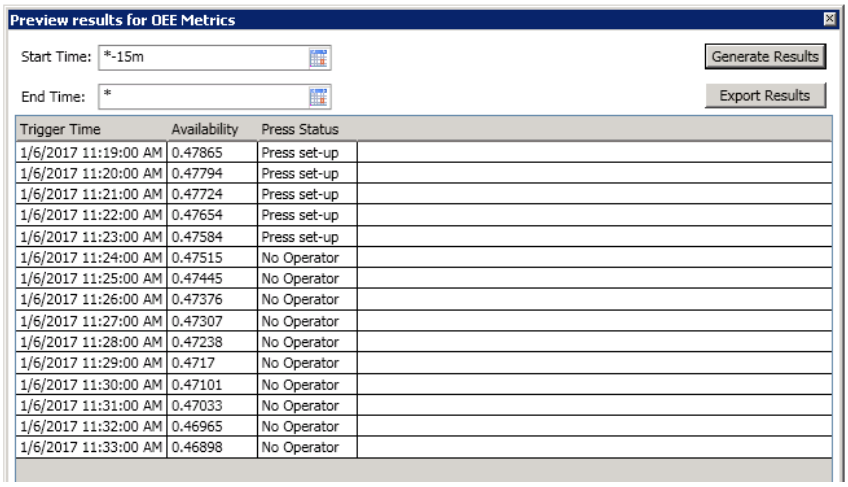
Now that the calculation has been written and the scheduling is defined, it is time to test it. The *Evaluate* button executes the expressions against values at evaluation (i.e. now) and against values at Last Trigger (in our case when the current minute has started). This will help you determine whether the results makes sense. Since we are working from a template, you will have to click on *Example Element* before you can test the expression**.**



Another great way to validate your expression is to run it against archived values; we call this feature "preview results". Right click the analysis name and select *Preview Results* (see screenshot below).

Tip: You can export the results table to a spreadsheet or you can copy selected rows from the results table into other applications.





Checking in an Expression

To the left of the analysis name the following icon is showing . This indicates that the analysis has been modified and it needs to be checked-in for the changes to take effect. Go ahead and click on .

Upon Check In, the Analysis Service will create the points for the output attribute and start the analyses for all presses.

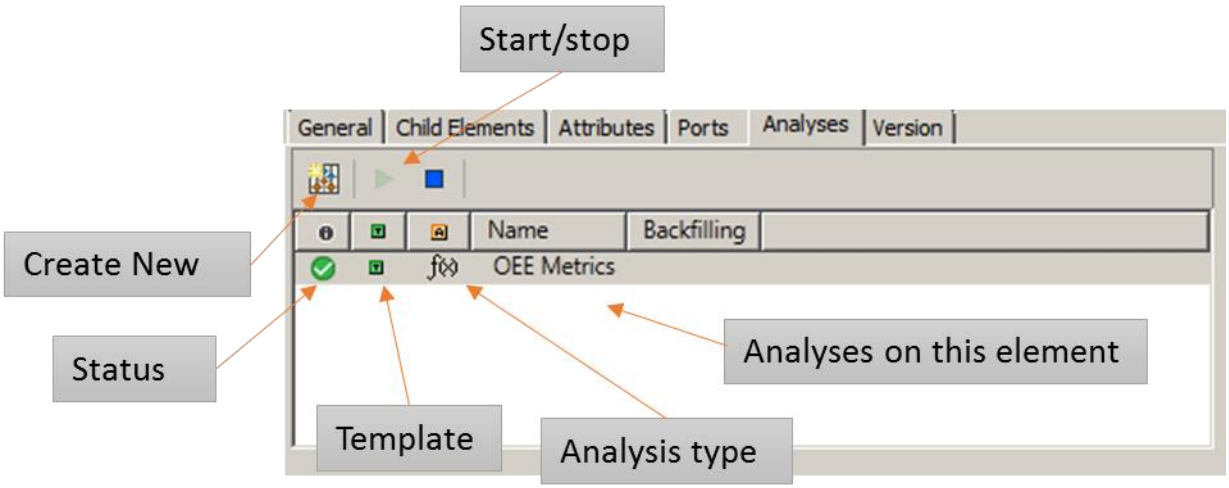
If you go to the *Elements* plugin and navigate to one of the presses you will notice under the *Attributes* tab that the analysis' output attribute (OEE Availability) is referring to a tag that has been created based on the settings in the template. In case the attribute value is *"Pt Created"* click on the Refresh button (after the full minute has elapsed) so you get a calculated value. In case the attribute would be showing "PI Point not found", select *Create or Update PI Point.*

Tip: By right clicking the parent element (i.e. Montreal) and selecting **Create or Update Data Reference,** PI Points for all presses will be created; so you do not have to do it one by one.

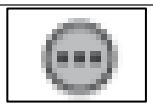
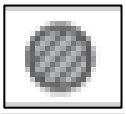
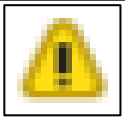
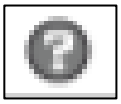
Managing Analyses (Start, Stop, Backfill)

The *Analyses* tab allows you to manage the analysis. You can even create new analyses for a particular element, however, as we said before, we recommend using analysis templates.

Analyses should start-up automatically unless there is an error with the configuration. You can use the play ( ) and stop ( ) buttons to either start or stop an analysis. Below a screenshot of the management analysis pane.



An analysis can be in one of several states. The icon to the left of the analysis name indicates its status. See the table below for the meaning of each icon.

Icon	Meaning
	New analysis
	Starting or stopping
	Running
	Disabled
	Error
	Warning
	Unknown status

Since the analysis has been started, the OEE Availability attribute should now be showing results. You may have to wait for a few minutes or refresh the screen to see updates.

6.4.6 Exercise – OEE Metrics – Performance and Quality

This solo or group exercise is designed to maximize learning in a specific topic area. Your instructor will have instructions and will coach you if you need assistance during the exercise.

Exercise Objectives

- Create and schedule an expression analysis.

Problem Description

Create analyses to calculate the remaining two OEE metrics: performance and quality. After doing this you will be able to compute the OEE score.

Approach

Using the analysis template you just created (OEE Metrics), add two more expressions to calculate the quality and performance metrics.

Quality

The quality is calculated as net production of good items / net production count. The total number of tires produced on the day (this includes the scrap tires) is tracked under *Tires Produced*, the daily bad quality items are tracked under the *Scrap Tires* attribute.

Expression:

_____.

Performance

Performance is calculated as the net production count / expected production count. The daily production count is tracked via the AF Attribute *Tires Produced*; the production target is expressed in **tires/hour** under the AF attribute *Production Target.*

Hint: Since the production target is expressed in tires/hour, you will have to find the expected production count by multiplying the *Production Target* by the number of hours elapsed during the current day.

Useful functions: hour('*') and minute('*')

Expression:

_____.

OEE Score

Calculated as the product of **Availability*****Performance*****Quality**. Expression:

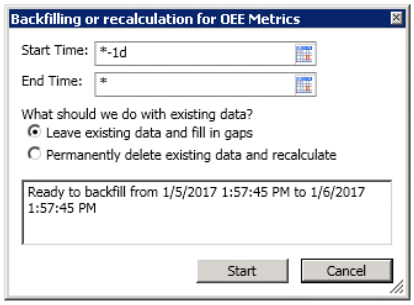
_____.

Tip: Every variable of an expression can be mapped to an output attribute.

6.4.7 Backfilling/Recalculation

An analysis writes new data to its output attributes starting from the moment it is created. It is however also possible to calculate the data for past periods of time. There are two related options for that, which control how existing data should be handled.

Example: you create a new analysis on March, 1st 2017 to calculate the heat energy consumption, which is added from various sources. The designated output attribute with the total consumption will have values for the time from that date onwards. To get values for January and February 2017 as well you can use the backfill feature.



The two options are:

1. *Leave existing data and fill gaps*: existing data is retained and only missing data is back filled.
2. *Permanently delete existing data and recalculate:* existing data will be deleted before the new data are backfilled.

Notes:

- The option for existing data handling is new with AF 2016 R2. In previous AF versions data were never deleted. This had to be carried out manually before the backfill.
- Backfilling/recalculation requires that the output attributes have been mapped to PI Points**.**
- Backfilled data is added into the archive files. With PI Data Archive versions before 2012 an upfront intervention could be required to make backfilling to work properly (e.g. PI archives reprocessing)
- For an event-frame-generation analysis, data is automatically deleted and recalculated (which is the only mode allowed). Be aware that annotations on those event frames will be lost.

6.4.8 Directed Activity - Backfilling OEE Metrics

In this part of the class, you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

Activity Objectives

- Learn how to backfill a calculation.
- Get familiar with the *Analyses* plug-in and perform some administration tasks.

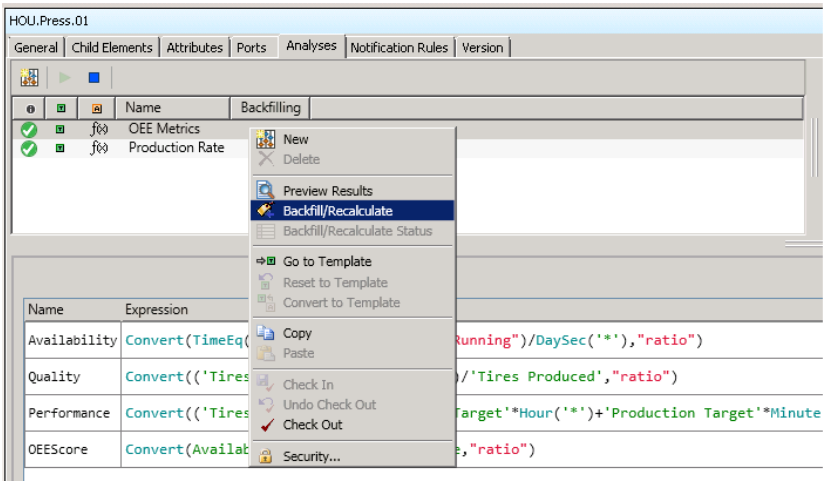
Problem Description

Management is very happy seeing real-time updates for the OEE score so they want more details. They have asked you to trend the OEE score for the last week for all presses belonging to the Houston site where they recently acquired innovative technology.

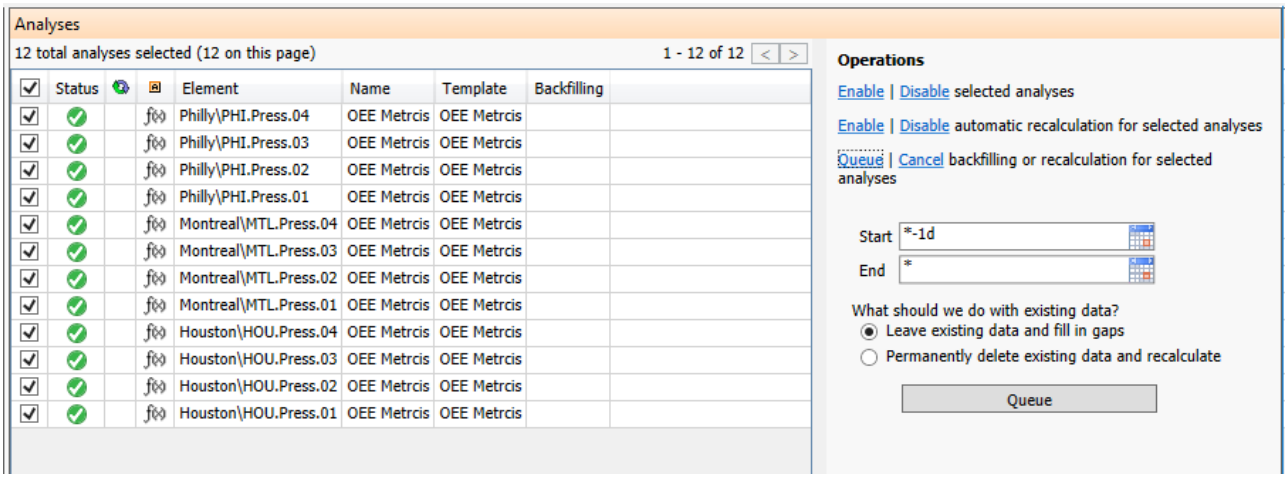
Approach

First, make sure that the OEE Metrics analyses are running and showing no errors. In order to do this, you can take advantage of the *Management* plugin under the *Navigator* pane.

To backfill an analysis, one option is to browse to the corresponding element and then right click the desired analysis and select *Backfill/Recalculate*.



However, since we want to backfill an analysis belonging to multiple elements, it would take too many clicks to complete this task element by element. The *Analyses* plug-in offers the possibility to perform backfills in bulk. All you need to do is select the analyses, click on *Queue backfilling for selected analyses* under the *Operations* pane. Next, enter the start time and end time then hit *Queue*.



6.4.9 Improving analyses for robustness and readability

We have seen how to write an analysis to calculate OEE KPIs. There are some options to make the calculations more robust and improve readability. The following screenshot provides an example how to avoid divisions by zero and how to distribute the calculation into more steps to achieve that.

Name	Expression
OperatingTime	`// number of seconds since midnight when press was running` `TimeEq('Press Status','t','*","Running")`
PlannedProductionTime	`// press should run all time, so get the seconds since midnight` `DaySec('*')`

Availability	`//calculate the ratio, avoid division by zero`
	`If PlannedProductionTime=0`
	`then 0 else Convert(OperatingTime/PlannedProductionTime,"ratio")`

GoodPieces	`// subtract scrap from total number of produced tires` `'Tires Produced'-'Scrap Tires'`
TotalPieces	`// total number of tires` `'Tires Produced'`

Quality	`// calculate the ratio, avoid division by zero`
	`IF TotalPieces=0`
	`THEN 0 else Convert(GoodPieces/TotalPieces,"ratio")`

Target	`// how many tires should have been produced since minutes?` `'Production Target'*Hour('*')+'Production Target'*Minute('*')/60`

Performance	`// calculate the ratio, avoid division by zero`
	`if Target=0`
	`then 0 else Convert(TotalPieces/Target,"ratio")`

Score	`Convert(Availability*Quality*Performance,"ratio")`

The following two articles provide more related information :

Tips and Tricks for Asset Based Analytics
https://pisquare.osisoft.com/community/all-things-pi/af-library/blog/2016/08/30/tips-and-tricks-for-asset-based-analytics

KB01520 - Asset Analytics Tips and Tricks
https://techsupport.osisoft.com/Troubleshooting/KB/KB01520

6.5 The Rollup Analysis

The rollup analysis allows you to perform aggregations or summary calculations based on attributes associated with an element. The power of rollup analyses lies in their ability to perform aggregations on an element's children.

As an example, you might need to calculate the total energy consumption for a group of motors in a paper mill. To do this, you create a rollup analysis on the parent element (the paper mill) that sums the energy consumption attributes from its child elements the motors.

When designing and building a AF hierarchy, the use of categories is going to pay off when you start using the rollup analysis type. This is because when configuring a rollup analysis, the attributes to be included in the calculation are selected by name or category.

6.5.1 Directed Activity – Comparing Sites using Rollups

In this part of the class you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

Activity Objectives

- Configure and test a roll-up calculation.

Problem Description

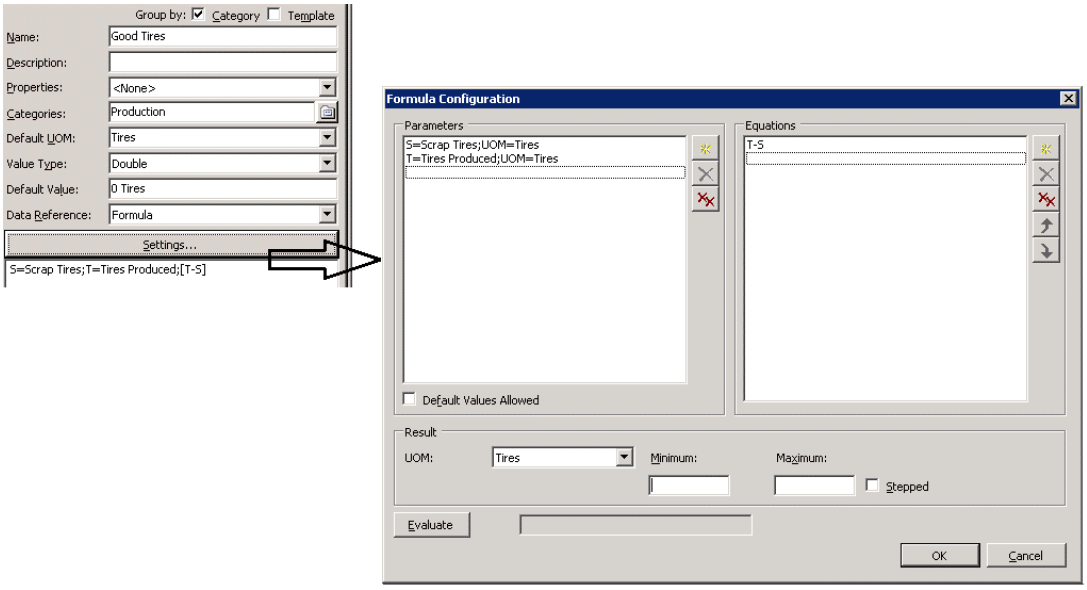
Management of our fictitious tire company would like to start comparing the performance of the tire presses across all sites in the organization; the first metric they would like you to develop is the total production of good tires.

Approach

Each press has an attribute for the current day's total production and another one for the current day's scrap tires; however, no attribute holds the count of good tires produced, so you will have to come up with one.

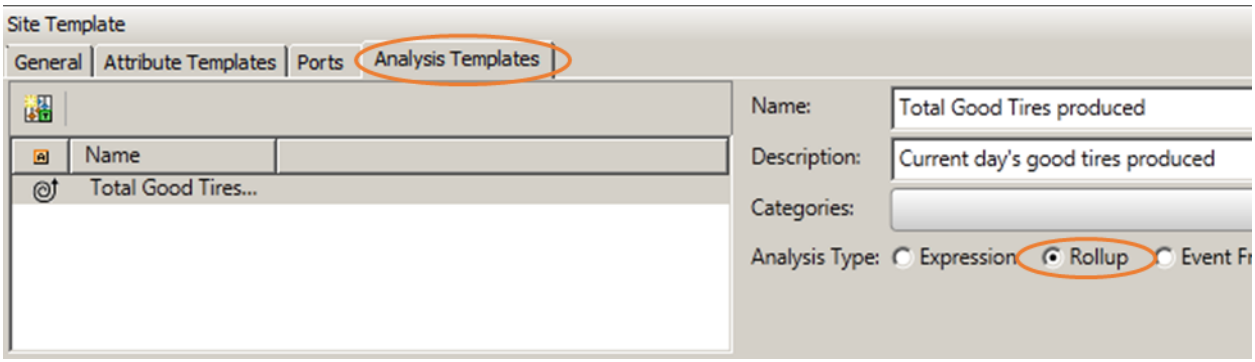
Let us start by creating the *Good tires production counter* attribute. Since you do not want to archive the results of this intermediate calculation, you can use a AF Formula Data Reference.

Under the *press template,* add the new attribute and calculate the difference between the *Tired produced* (represents the total production) and the *Scrap tires*. This new attribute should belong to the production category.



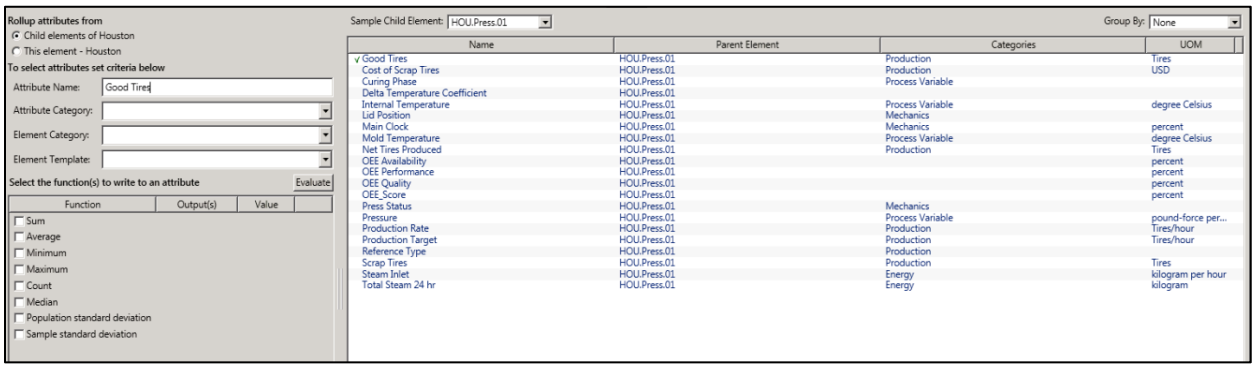
Creating a roll-up analysis

Now it is time to shift focus to the parent elements, the sites. Select the Houston site and go to the *Analysis* tab, give a meaningful name to your analysis and select the *Rollup* analysis type.



A list of all available attributes is displayed on the right pane. It is now necessary to select from that list the ones that will participate in the rollup calculation. You can narrow down your search by filtering by element category or template. You can then type-in the attribute name or category. The matching results will show a checkmark (✓).

Note: A rollup identifies input attributes each time it is executed, hence it automatically includes any new attributes that meets the selection criteria. You do not need to update the rollup configuration when you create a new element.



Selecting the roll up function

Now that you have selected the attributes for the rollup, it is time to specify the function or type of summary calculation the rollup analysis will run. There are six available summary functions:

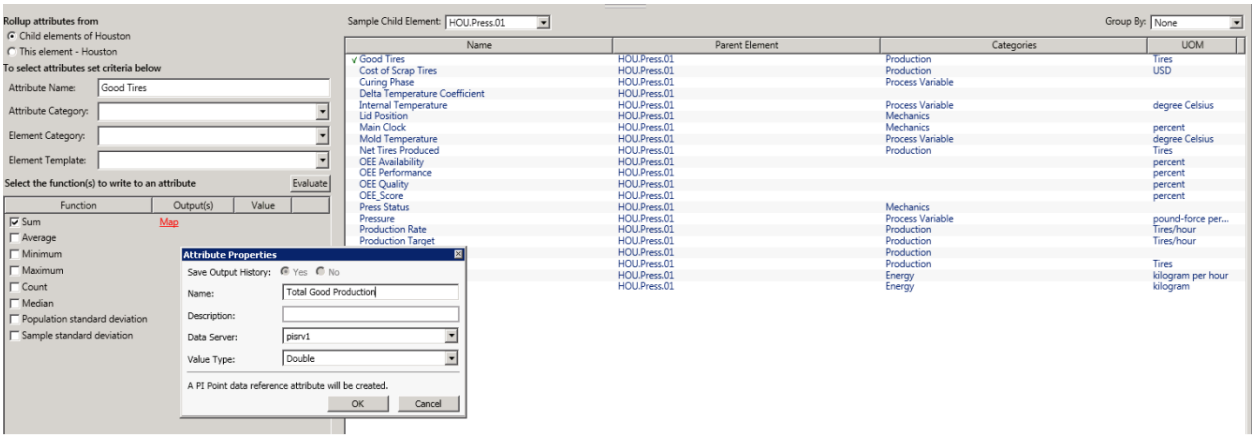
- Sum
- Average
- Minimum
- Maximum
- Count
- Median

Since we want to calculate the total number to tires produced on a particular site, the summary function to select is *Sum***.**

Tip: You can select multiple functions in a rollup calculation, each one mapped to a specific output attribute.

Mapping the output to an attribute

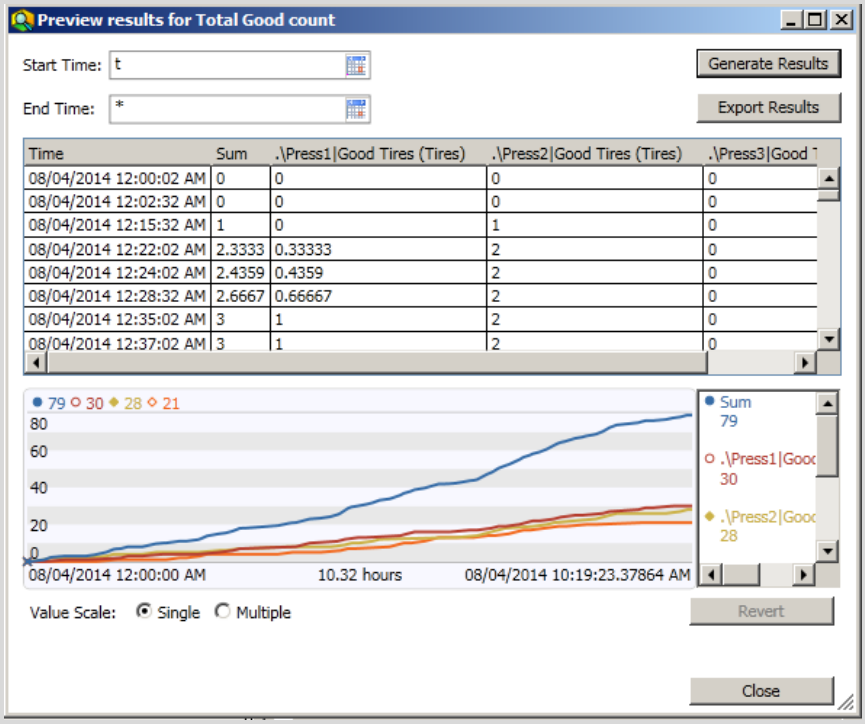
Once the function is selected, you can map the output to an attribute. In case the output attribute does not exist yet, you will be prompted to create a new one. Let us create a new output attribute and name it *Total Good Production*.



Scheduling the roll-up calculation

Finally, it is time to schedule the calculation. The same two scheduling options presented for the expression analysis type are available for rollups: event-triggered and periodic. For this exercise, it makes sense to update the result every time a new good tire is produced, hence, select event-triggered scheduling.

Tip: Before starting the analysis it is a good idea to click on the evaluate button to preview the result. Furthermore, you can right-click on the analysis name and select *Preview Results*; this will show you a trend with the result of the calculation had it run for a previous period of time. These two actions will help you validate your rollup calculation.



The calculation is ready to be started! Check-In your changes.

Note: If the PI point of the Total Good Production attribute is not created use *Create or Update PI Point* function from the attributes right-mouse button context menu.

Check the status of the calculation for any errors and validate that the output attribute is updating.

6.5.2 Group Question – One Site, Multiple Sites

The following questions are intended to reinforce key information, or to discover a new insight. Your instructor may choose to have you try to answer the questions on your own or have the group answer them together out loud.

Objectives

- Convert an analysis to an analysis template.

Questions

The rollup calculation has been deployed to the Houston site only. What feature of AF can you use to deploy it to the remaining sites? _____

What steps would you take to achieve this?

1. _____.

Note1: In the **Convert Attribute to Template** dialog box, enable the **Include Tag Creation** checkbox. This is needed because no tags have yet been created to store the results of the Analysis.

Note2: set the PI Point naming pattern for **Total Good Tires Produced** attribute to follow the default pattern, which is %Element%.%Attribute%.%ID%

2. _____.

Bonus Question

How to display the three (3) Total Good Production Counters in one list?

_____.

6.5.3 Exercise – Perform an advanced attribute search (optional)

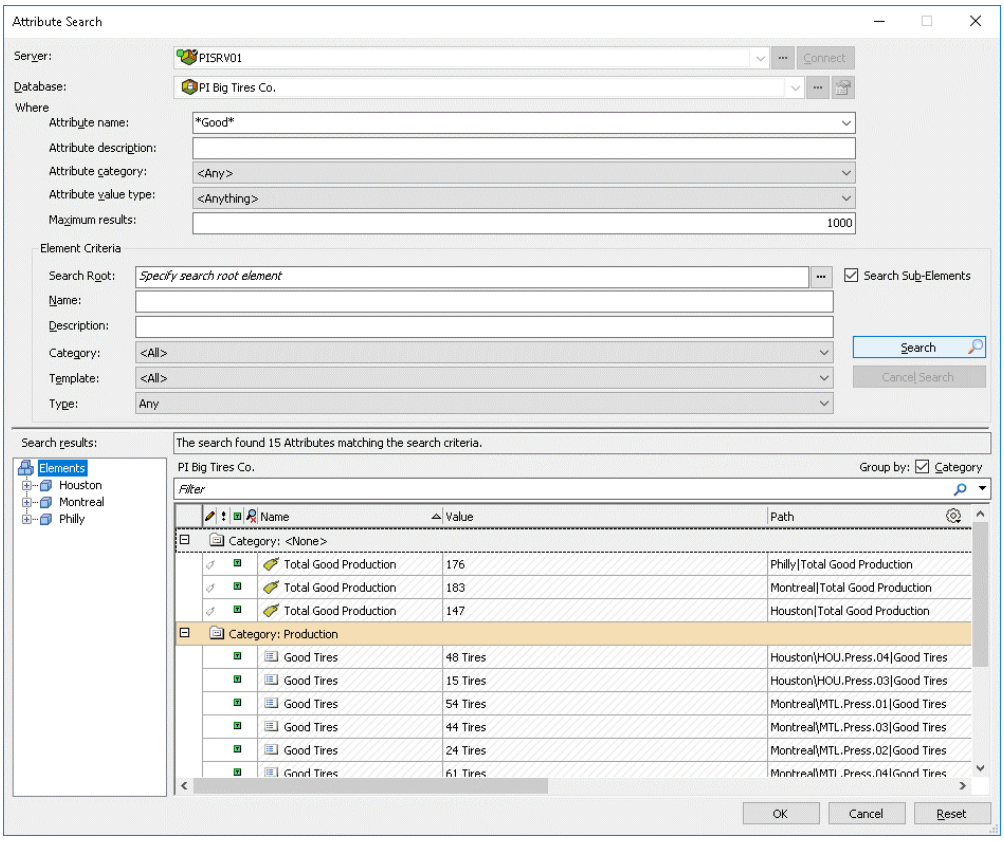
This solo or group activity is designed to maximize learning in a specific topic area. Your instructor will have instructions and will coach you if you need assistance during the activity.

Exercise Objectives

- You have recently created attributes in several places of your asset hierarchy that contain the string “Good”. Use the attribute search to get all their values in one list.

Approach

1. From the PSE menu, select Search – Attribute Search…
2. Enter ***Good**** into the attribute name field. Make sure the *Search Sub-Elements* option is selected. Click Search. Result: attributes containing string “Good” are returned. Click on OK.



3. Click on the name of the Search to populate the Search Results at the right hand side.

6.6 Visualizing Calculation Results in PI Vision

6.6.1 Directed Activity – Visualize OEE Metric calculation results

In this part of the class, you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

Activity Objectives

- Duplicate an existing PI Vision display for the tire presses
- Visualize the OEE Metric calculation results.

Approach

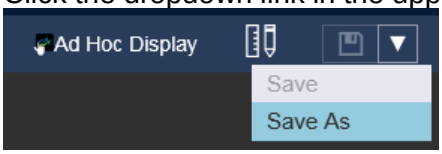
Save the existing PI Vision display for PI Big Tire Presses under another name.

Add Good Tire Production Counter into the existing trend.

Add a trend for the OEE Metrics

Duplicate a PI Vision Display

1. From the PI Vision overview page, open the *Big Tires Press* display.
2. Click the dropdown link in the upper right corner to open the Save As menu.

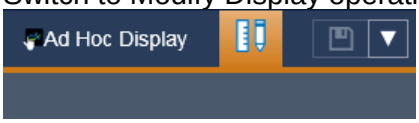


3. Enter *Big Tires Press Training* as display name and click on Save.

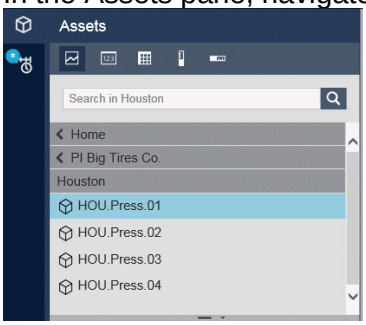
Note: If you have added a database in AF and would like to access with PI Vision, you have to update the list of allowed AF Databases in PI Vision. For more information see Visualizing AF Data in PI Vision above).

Add data into a trend

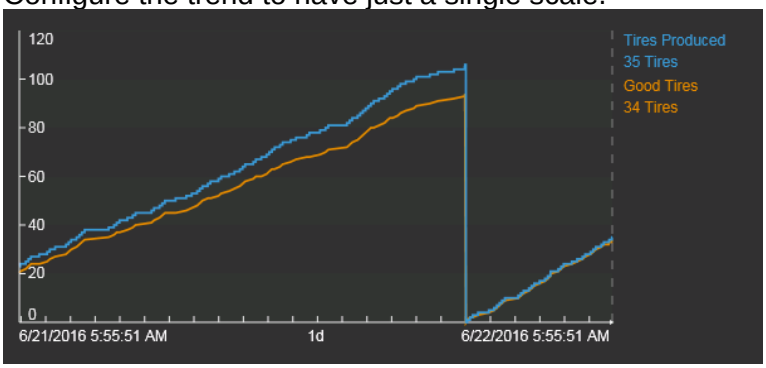
1. Switch to Modify Display operation:



2. In the Assets pane, navigate to HOU.Press.01



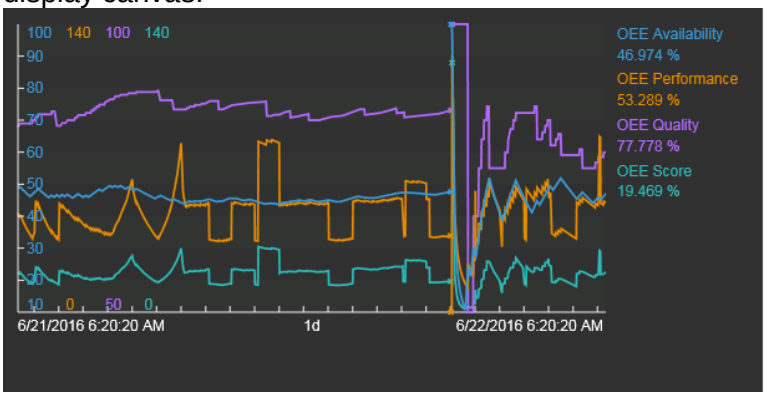
3. From the Attributes pane, drag the *Good Tires* attributes into the trend with the *Tires Produced* counter.
4. Configure the trend to have just a single scale.



Add a trend for OEE Metrics

1. Verify that trend has been selected in the symbol gallery.

2. From the Attributes list, select the OEE Metric category and drag it into the display canvas.



7. Tracking Important Events

Events are important process or business time periods that represent something happening that affects your operations. In the PI System, events are known as event frames. Thanks to Event Frames, you can analyze your PI data in the context of these events rather than by continuous time periods. Instead of searching by time, Event Frames enables users to easily search the PI System for the events they are trying to analyze or report on.

With Event Frames, the PI System helps you capture, store, find, compare and analyze the important events and their related data.

Event Frames represent occurrences in your process that you want to know about, for example:

• Downtime tracking	• Environmental monitoring excursions
• Process excursions	• Product tracking batches
• Equipment startups and shut downs	• Operator shifts

The following table presents some of the features and advantages of Event Frames:

Flexibility	✓ Reference multiple elements within the same event. ✓ Support multiple overlapping events on a AF element. ✓ Capture any event; a “batch” is just one type of capturable event.
Powerful search	✓ Search by time range, type of event or event frame attribute. ✓ Most common search attributes can be configures as indexed attributes to speed up end-user searches
Scalability	✓ Event Frames are extremely scalable.

A Event Frame is defined by three characteristics:

1. Name.
2. Start time and end time: defines the event’s time range.
3. Context: event attributes and related assets.

7.1 Tracking Production Downtime Periods

7.1.1 Directed Activity - Downtime Tracking

In this part of the class you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

Activity Objectives

- Create an event frame template.
- Configure an event frame trigger.

Problem Description

PI Big Tires Co. has been falling behind their production schedule because, for various reasons, the tires presses are frequently down. To improve the situation they want to use Event Frames in AF to track the downtime periods for all their presses in Houston, Montreal and Philadelphia.

The Maintenance engineer has asked you to trace the root cause for every downtime. The curing press can be in one of five states, which have different criticality.

Press Status:

Running ✓

Press set-up !

Planned Maintenance !

Maintenance !!

No Operator !!!

They want to have a record of the investigations performed by the maintenance team. Therefore it should be possible to acknowledge and save individual comments for each Downtime Event Frame.

Approach

1. For the first press in Houston, inspect the history of the Press Status value and create one event frame manually. Set the name, the Start and End Time, and the element reference. Define an event frame attribute to track the Press Status value at the beginning of the downtime (i.e. the reason code of the problem).
2. Create a corresponding event frame template (convert the event frame created in the previous step into a template).
3. Define a naming pattern for new event frames from that event frame template.
4. Add an analysis for the first press in Houston that monitors the Press Status. Distinguish the different Press Status values and associate them with corresponding severities.
5. Use an Output Expression to get and store the event frame duration to ease future analysis of the event frame data with Excel Power Pivot.
6. Preview the analysis to assess whether the triggers were set correctly.
7. Start the analysis.
8. Backfill the analysis for the time since midnight today.
9. Include the analysis into the press template to apply the analysis to all presses.
10. Backfill the analyses for all presses for the time since midnight today.

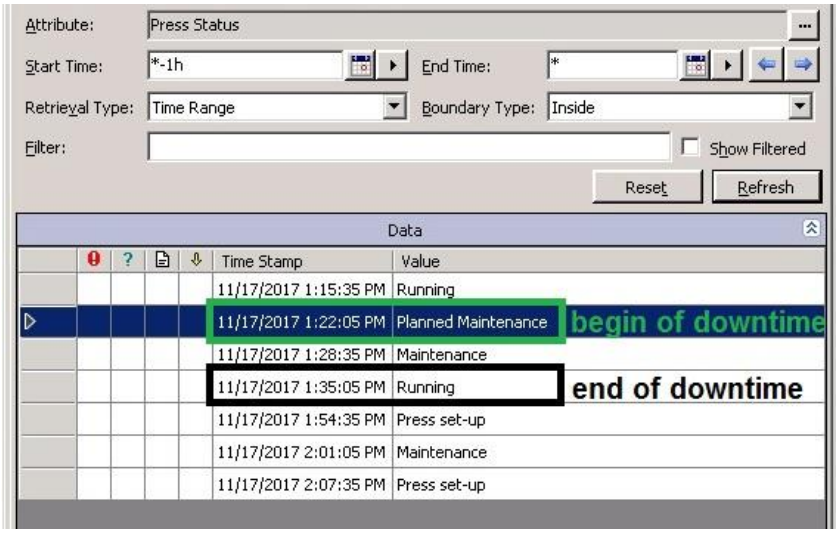
The instructor will show these steps and ask you to follow along in directed activities.

7.1.2 Manual Event Frame Generation

To begin with, we will create a single event frame manually to have an example of what we would like to capture for the period of a press downtime.

To begin with, let us identify a downtime period for the first press in Houston, **HOU.Press.01,** based on the **Press Status** values.

1. Select *Elements* from the navigator panel and select *Attributes* tab for **HOU.Press.01**.
2. Select the line for Press Status. Select *Time Series Data…* from the right-mouse button context menu and display the values for the last two hours.
3. Identify a period, when there was a downtime. It starts with a value that is different from **Running** and ends with a value of **Running** again. In our case below, the press was not running after 1:22:05 PM because of Planned Maintenance, and was not running again before 1:35:05 PM because of another Maintenance.

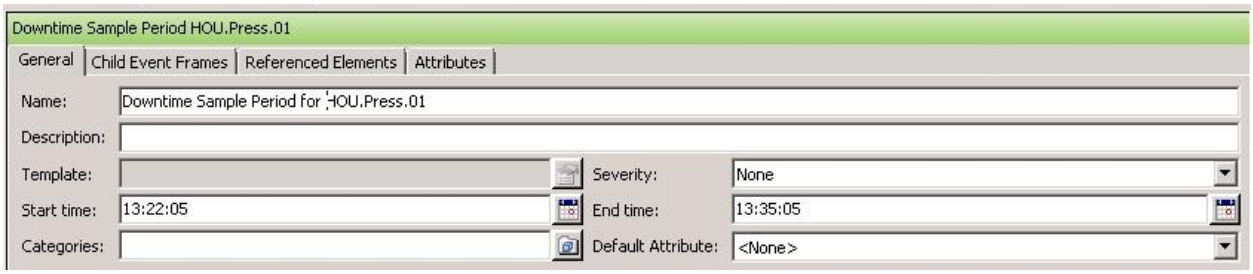


Fill in the information for your case in the table below and close the window.

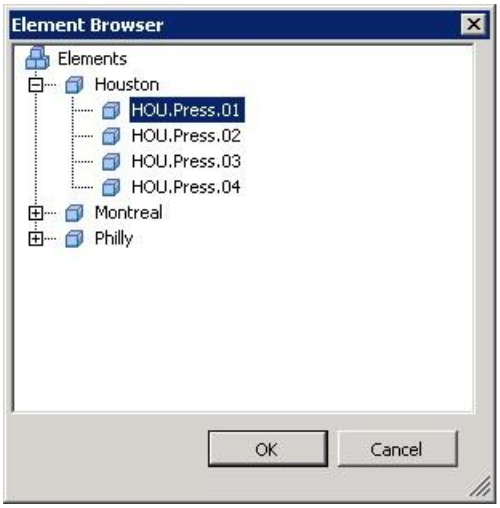
	Example above:	Your case:
Start Time	13:22:05	
End Time	13:35:05	
Time in seconds	780	
Reason for the downtime	Planned Maintenance	

4. Select *Event Frames* from the navigator panel and click on the

button. Select <none> for Event Frame Template.
5. For name, enter **Downtime Sample Period for HOU.Press.01.** Enter Start and End Times in hh:mm:ss. As you do not specify a date, PSE will assume it is for today.

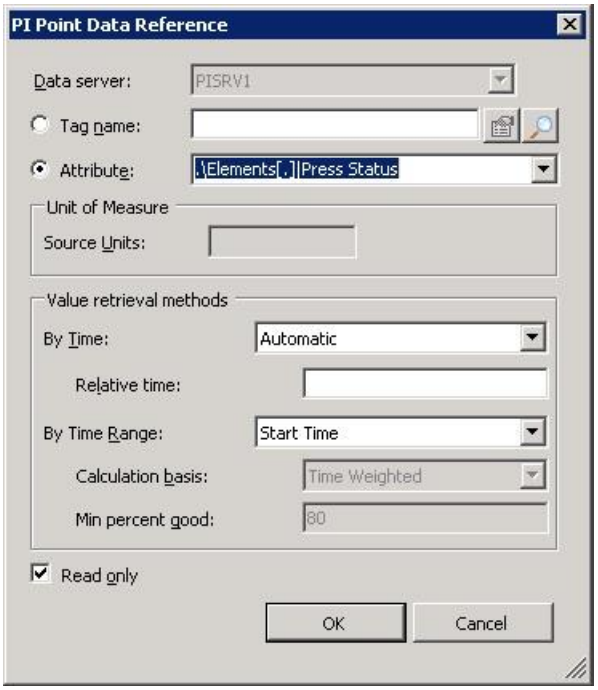


6. On the *Referenced Elements* tab, select the blue *Add Element Reference* link, click on the ... button in the Single section.
7. In the Element Browser navigate to Houston -> HOU.Press.01 and click on OK.



Event Frame Attribute for the Downtime Reason Code

8. Let us track the reason, why the press had a downtime. It is the value of the **Press Status** attribute at the start of the problem.
   On the Attributes tab, click on the blue *New Attribute* link. For the attribute name, enter **Reason Code.** For value type, select **Press Status** from enumeration sets. For *Data Reference* select *PI Point*. Click on *Settings.*
9. The dropdown offers the attributes of HOU.Press.01, select ***.\Elements[.]\|Press Status*.** For *By Time Range* select *Start Time.* Click on OK.



You will get the Press Status value for the beginning of the event frame period as it has been recorded before.
Note: If the value type was reset, switch it back to Press Status.

Event Frame Attributes

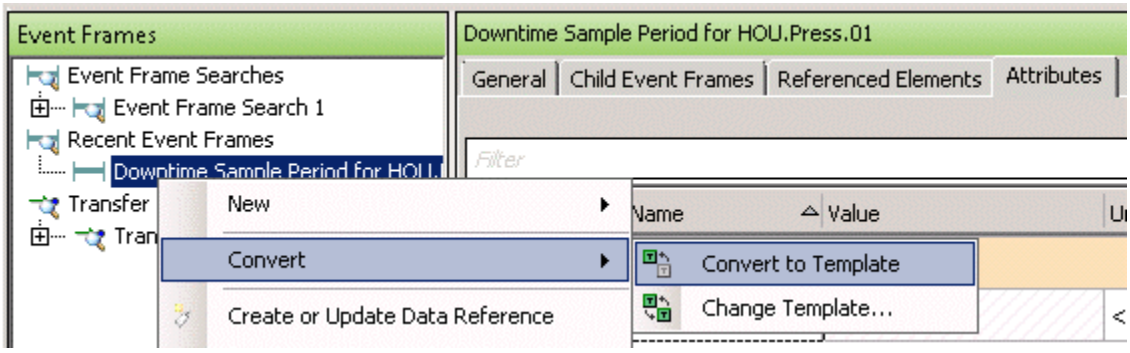
The generic format for attributes of event frames is **.\Elements[.]|Attribute**.

The attribute reference starts with *.\Elements[.]|* to indicate the primary element of the event frame's Elements collection. .\ is the current reference, *[.]* is the default object of the collection. The pipe character (|) is used to separate the element from the attribute name.

Create a new Event Frame template based on our manually created event frame.

Now, that we have defined what we would like to record for press downtimes, let us make a template out of it.

1. Check In your changes
2. Select the event frame you created, and from the right mouse button menu, select *Convert* > *Convert To Template*.



3. For the Reason Code, keep **.\Elements[.]|Press Status;TimeRangeMethod=StartTime**
   Click on OK.

4. Check In your changes

7.1.3 Finalize the event frame template

Let us have a look at the event frame template that has been created and adjust and finalize it.

1. Select *Library* from the navigator panel and expand the structure Templates > Event Frame Templates and select *Downtime Sample Period for HOU.Press.01Template*. Rename to **Press Downtime**.
2. The *Naming Pattern* field enables you to dynamically build the name of the event frames produced from the template so that each event frame will have a unique, identifiable name. Use the arrow on the right ( ) for a list of available substitution parameters. The most common ones are presented in the following table:

%ELEMENT%	Referenced element. Asset where the event happened.
%..\ELEMENT%	Name of the parent element of the referenced element. To retrieve further ancestors, use the `..\` notation, such as `%..\..\Element%`.
%TEMPLATE%	Name of the event frame template.
%STARTTIME:yyyy-MM-dd HH:mm:ss.fff%	Event start time and format.

3. What naming pattern should we set so the downtime events are called something like the following?

   DownTime HOU.Press.01 (Houston) 2015-12-24 23:22:21

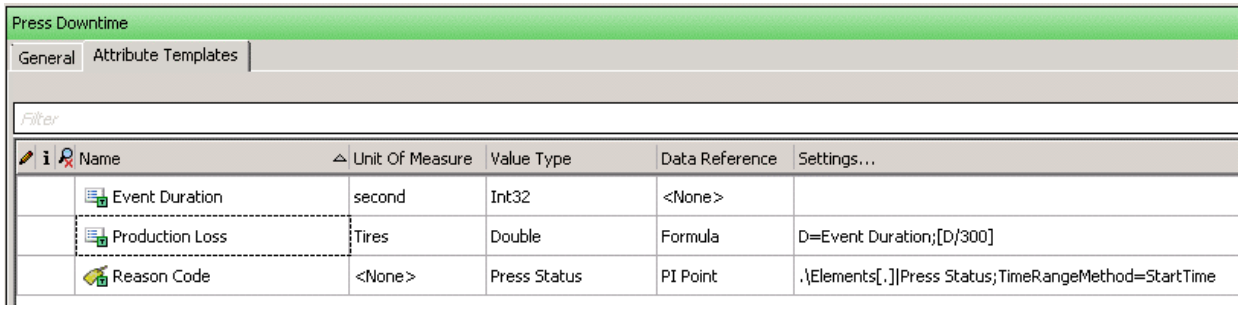
   _____

Note: In case the **Naming Pattern** field is not set, event frames created with asset analytics will be named NameOfTheAnalysis – Starttime (i.e. Press Downtime – 20140725 11:20:00).

4. To track, whether the event frames was read by an operator, enable the

option

5. Open the Attribute Templates tab. The **Reason Code** attribute we have defined before is listed here.
6. Add an **Event Duration** attribute (default UOM: second, value type: Int32). The attribute value will be set by the analysis, which we will create in the next step.
7. Producing one tire takes approximately 5 minutes. Based on the duration of the press downtime the number of tires can be calculated that could have been produced in case the press would have been running.
   Add a **Production Loss** attribute (default UOM: tires, value type: Double), set Data Reference to *Formula*. To get the amount of production loss, divide the duration in seconds by 300:



8. Check in the changes.

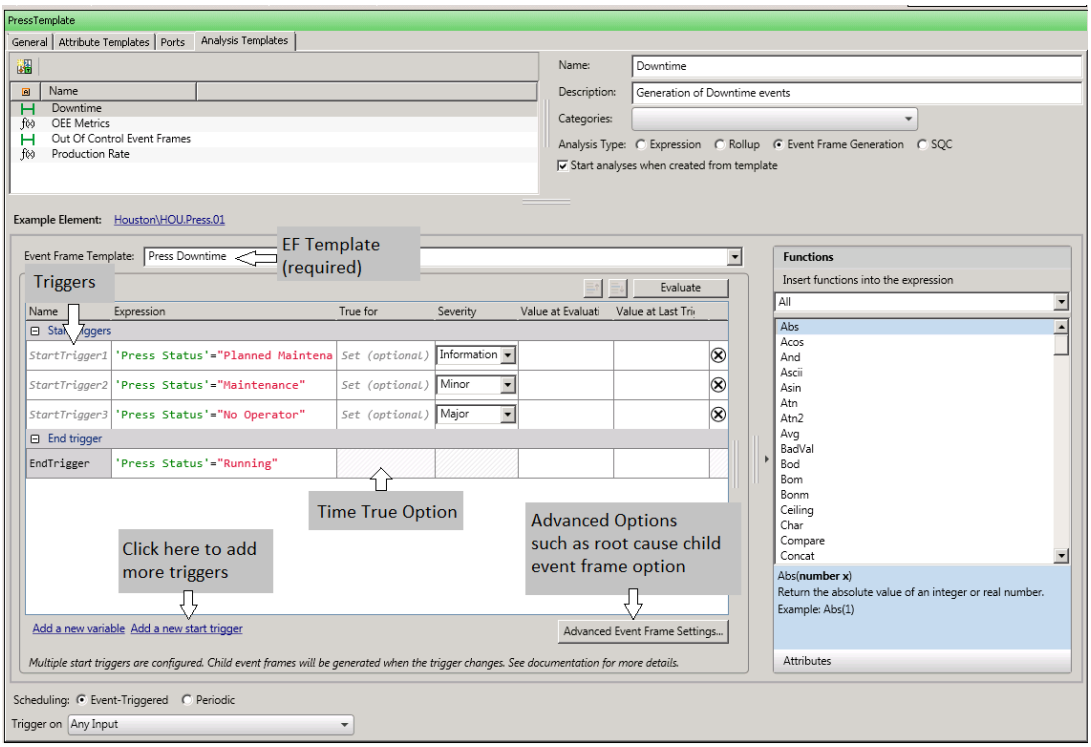
7.1.4 Creating an EF Generation Analysis

Let us create an EF generation analysis to track the downtime events in our curing presses. Create it directly under *Houston's press1*. Once we validate that this is working fine we will convert the analysis into a template for deployment to all the presses in our company.

Event frame analyses are configured in a similar way to expressions and rollup analyses. Browse to Houston's press1 and under the *Analyses* tab select *Event Frame Generation***.** Give a meaningful name and description to your analysis.

An event frame analysis is based on an event frame template, go ahead and select the template from the dropdown list.

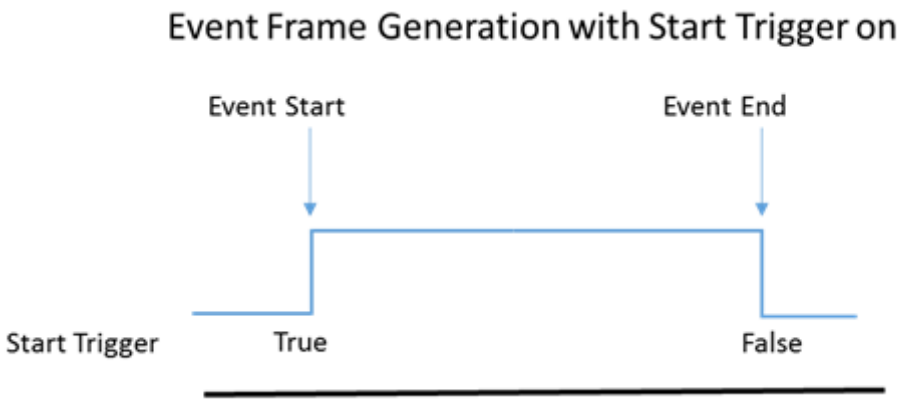
Tip: Before you create an EF generation analysis, be sure an event frame template is available for it.



Triggering Conditions (Start Trigger Only)

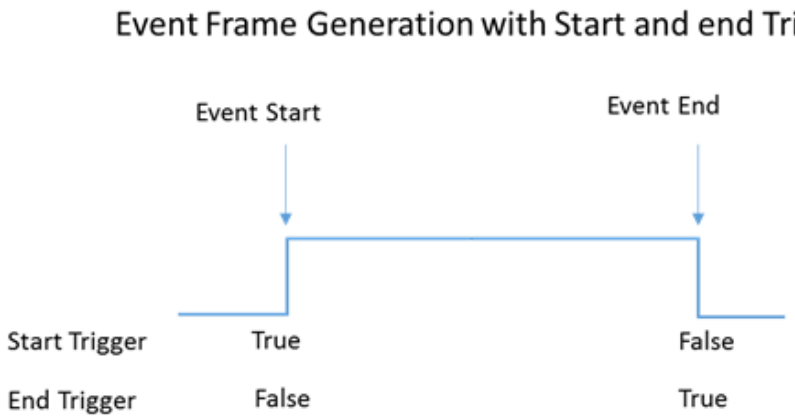
It is time to enter the conditions that will trigger the start and end event: StartTrigger and EndTrigger. These conditions are entered as expressions using the PE syntax presented earlier.

When a single condition triggers both the start and the end of an event frame, only the *StartTrigger* expression is needed. When the expression evaluates to *TRUE* the event frame is started, and when it evaluates to *FALSE* the event frame is closed. For example a tank's level rising above a threshold might start an overflow event, the event would end when level is below the threshold.



Triggering Conditions (Start and End Trigger)

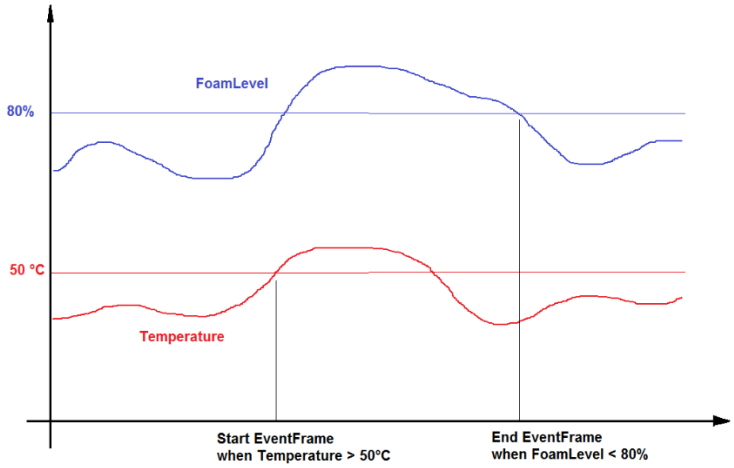
You can specify an EndTrigger expression when the start and end conditions are different:



In the case with Start and End Triggers, the end of the event is dependent on the End Trigger condition only. So after the event has started, the event ends when the End Trigger becomes true, independent from whether the Start Trigger is True or False.

Tip: If using start and end triggers, make sure the expressions never evaluate to TRUE at the same time since this may lead to event frames with zero second durations. Try to configure your event frames to use only a StartTrigger expression.

For example, if the temperature rises in your reactor the foam level rises accordingly. When the temperature drops again, the foam level drops as well, but with some delay in time.
You would like to capture the time, when temperature is too high until foam level is back to normal:



Name	Expression
StartTrigger	'Temperature'>50
EndTrigger	'FoamLevel'<80

Defining Triggering Condition for the Press Downtime

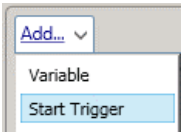
Since AF 2016 it is possible to define several start trigger conditions and associate them with different event frame severities. This meets our requirement to have event frames with different severity based on the reason why the press was down. Let us look at the first situation, when the press stopped running because of a *Planned maintenance* or a *Press set-up*.

The expression to start the event in that case is:

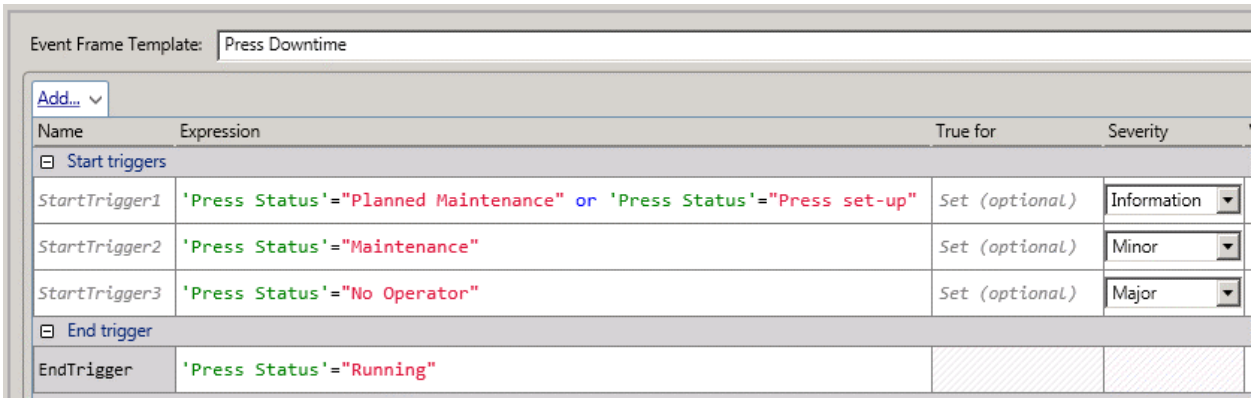
_____.

Assign an *Information* severity level.

To enter start and end triggers, click on blue *Add…* link and select corresponding option from the dropdown.



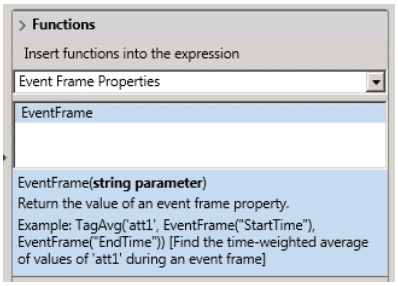
Enter the start and end trigger expressions and assign the severity levels as follows:



Tip: Use the StartTrigger *True for* option to require the start trigger remain true for a set time interval before creating the event frame. This is useful for attributes with continuous, non-stepped data to prevent spikes in the input data from generating unwanted event frames.

Store the duration in the corresponding event frame attribute

Since AF 2017 R2 there is an *EventFrame* function, which allows to get event frame properties such as the event frame duration in an easy way.



To store the event frame duration in the **Event Duration** attribute of the event frame:

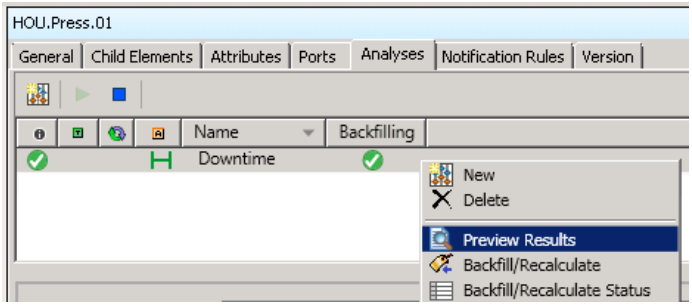
1. To enter an output expression, click on blue *Add…* link on top of the triggers section and select *Output Expression* option from the dropdown.
2. For the expression, enter `EventFrame("Duration")`
3. Click on the blue *Map* link at the right hand side, and select the **Event Duration** attribute.

Scheduling an Event Frame Analysis

The last thing to do is to schedule the event frame analysis. As with expressions and rollups, two scheduling options are available: Event-Trigger and Periodic. For this exercise, schedule it as Event-Triggered.

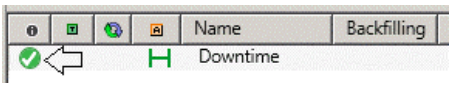
7.1.5 Previewing Event Frame analysis results and starting the analysis

You can now use the *Preview Feature* to validate whether the events that would be generated are as expected. Select the Downtime analysis in the list of analyses. From the right mouse context menu, select *Preview Results*.



If the results are OK, click on

changes. Result: the analysis will start running:

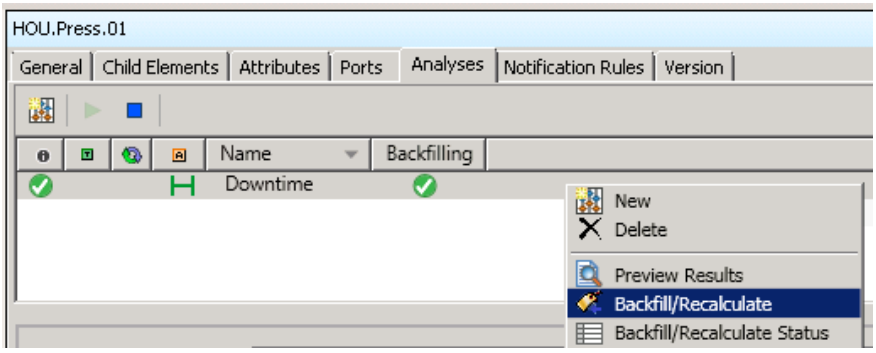


7.1.6 Backfilling Event Frame analysis

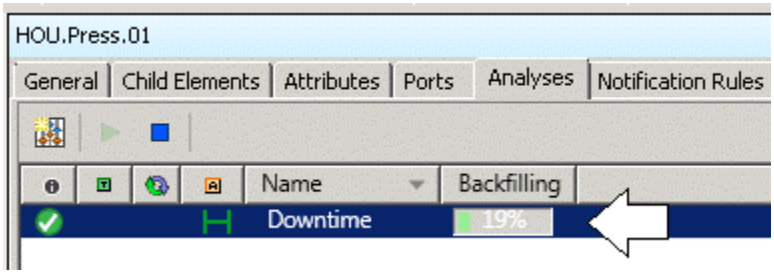
The analysis we have created will monitor the Press Status from now on. However, with the Backfill function of analysis, it is possible to also backfill past periods in time! This means that the archived values for Press Status will be examined and event frames with dates in the past will be created accordingly.

To backfill the time since midnight:

1. Select the Downtime analysis in the list of analyses. From the right mouse context menu, select *Backfill/Recalculate*.



2. For Start Time, enter a t (=today midnight), for End Time enter a * (=now). Click on Start button. The *Backfilling* column will show the progress of the backfill activity.

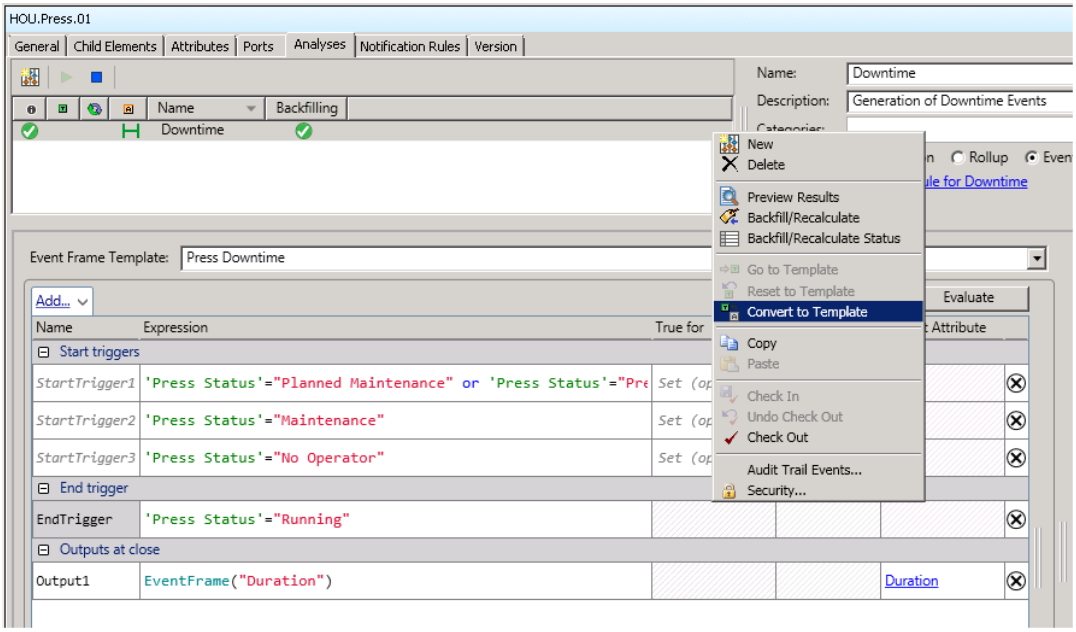


3. After backfilling is completed, switch to the General tab and click on the blue *Event Frames* link. You will get a list with all event frames linked with that element.
4. (optional) Verification: what is the start time of the first event frame?
5. (optional) Scroll through the list and locate the manually created event frame. There will be a further corresponding event frame with same start and end time that was created by the analysis. Select the manually created event frame and select ***Delete…*** from the right mouse button context menu. This event frame is not required any more.

7.1.7 Converting an Analysis into a Template

It is very common that customers create and test an analysis directly on an element (e.g. Houston's Press01) before adding it to a template (e.g. Press template). Analyses can be added to a template so you do not need to configure them once again at the template level. Just right click the analysis and select *Convert to Template* as seen in the figure below. Then check-in.

Note: *Convert to Template* does not create an element template; it just adds an analysis to an already existing one.



Note: The analysis will be added to all assets created from the element template. Analyses will be started automatically after the Check-in.

7.1.8 Exercise – Backfilling Event Frames

This solo or group exercise is designed to maximize learning in a specific topic area. Your instructor will have instructions and will coach you if you need assistance during the exercise.

Exercise Objectives

- Define and save a search that returns the downtime analyses for all presses.
- Backfill the analyses in bulk.
- Understand the backfill options.

Problem Description

Downtime events are now being tracked in real time for all presses in our company. Management does not want to wait for new events to start analyzing the causes of production loss; they want you to create the event frames for all presses since today midnight.

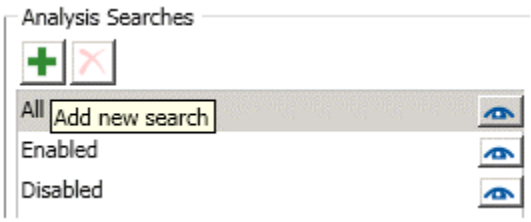
Approach

Use the *Management* plugin in the *Navigator Panel* to backfill multiple event frames.

Initially, all analyses in that AF database will be listed.

To work with a specific set of analyses (all the downtime analyses for all presses), you can define and save a search that will filter just those analyses:

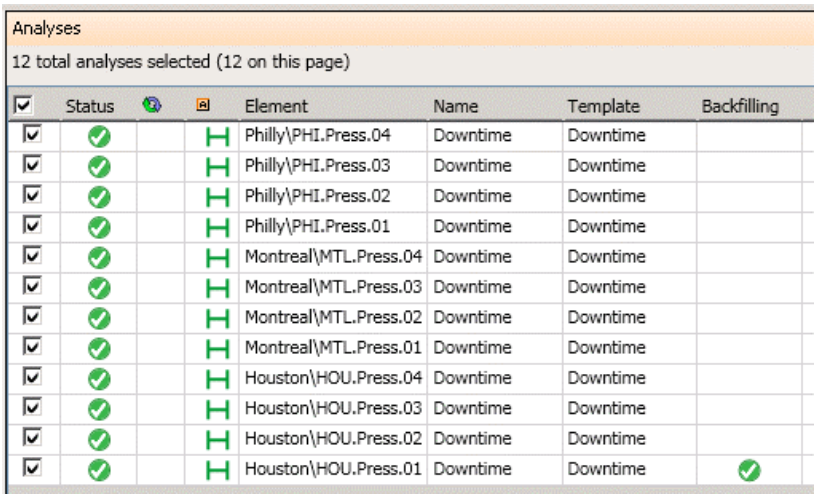
1. Click on the green sign to add a new search:



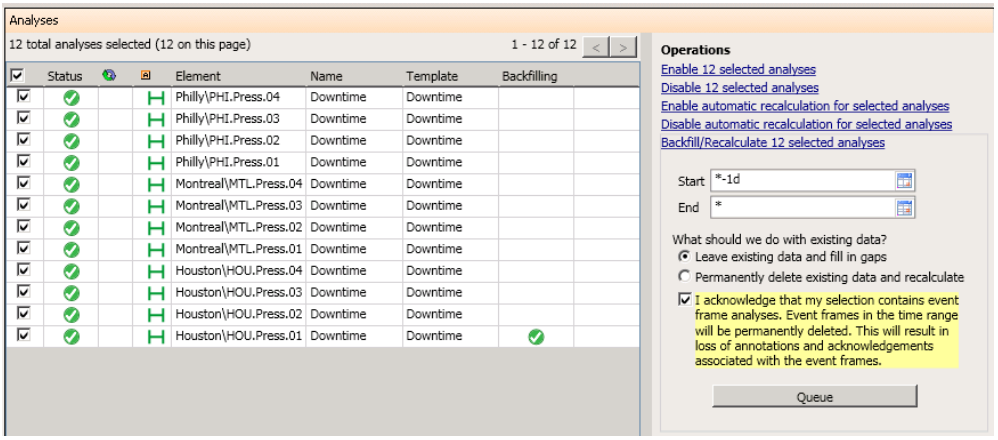
2. For the search name, enter *Press Downtime Analyses* and select **Template** under the Add Criteria dropdown.
3. From the Template dropdown, select Press Template\Downtime and click on OK. Result: the list of analyses on the right hand side lists twelve analyses (four from each location).

To perform a backfill for all Presses:

1. Click on the checkbox on top of the list to select all presses.



2. Click on blue *Backfill/Recalculate 12 selected analyses* link. Acknowledge that existing event frames in the time range will be deleted, then click on *Queue* button.



Note with regard to the required acknowledgement: For an event-frame-generation analysis (different to the backfill case in context with non event-frame-generation analyses), data is automatically deleted and recalculated. This is the only mode allowed. Be aware that annotations on those event frames will be lost.

Automatic Recalculation: (AF 2017 R2 and later)

In case you expect that data from your inputs will be late-arriving or be out-of-order, you can request automatic recalculation for an analysis. The Management list allows to set this option for multiple analyses within one command. To set the option on an individual analysis base, use Advanced Options on the Analyses tab of an element or an element template.

7.2 Consuming Event Frames

Event Frames are stored in the AF Server. Visualization clients, such as PI Vision and PI Datalink access the AF Server to retrieve the events and their related data providing you with powerful tools to analyze important events.

Note: PI ProcessBook, PI BatchView, and PI Manual Logger do not support event frame visualization.

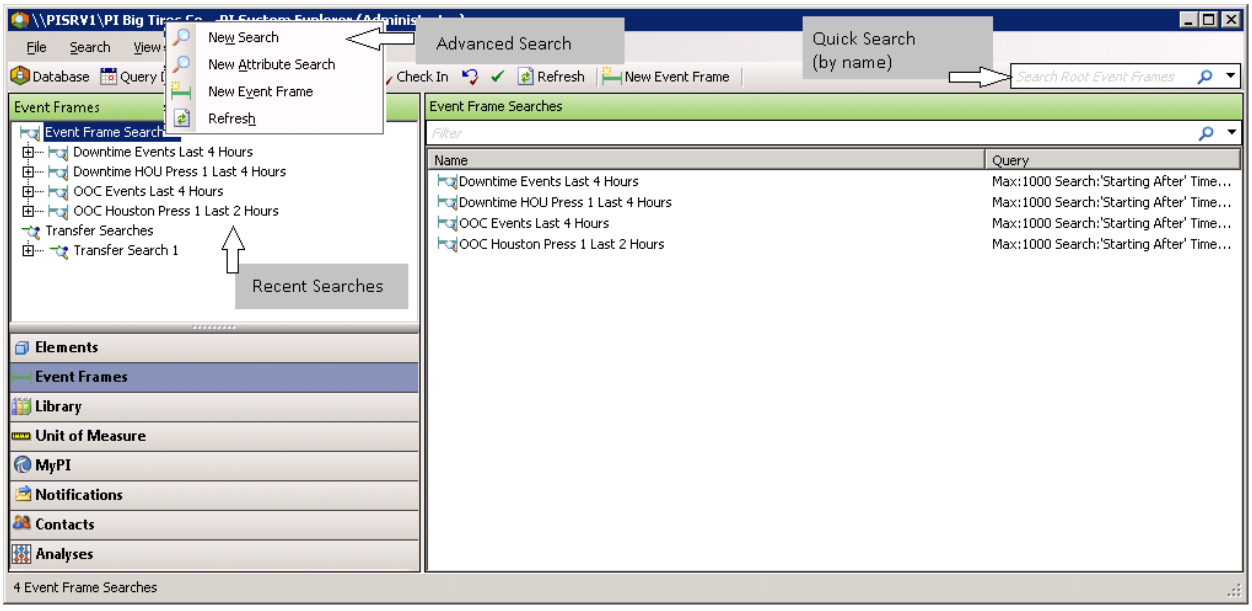
7.2.1 Event Frames in PSE

In this section, we will be exploring how to consume event frames in PI System Explorer (PSE). As an administrator, you can use PSE to search for events and analyze them. The results are presented in a practical table format that features a Gantt chart and columns for the attributes. Moreover, this is a quick way of verifying the creation of event frames.

In order to access event frames in PSE, click on the *Event Frames* plugin under the navigator panel.

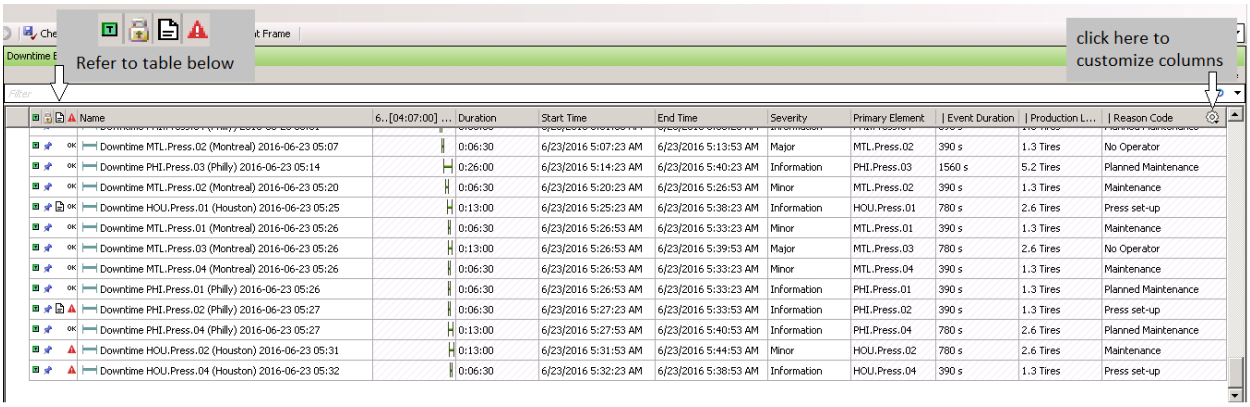
Note: Unlike elements, it is not possible to browse events. You actually have to search for them.

The following screenshot presents the main features of the *Event Frames* plugin:



Event Frame Search Results

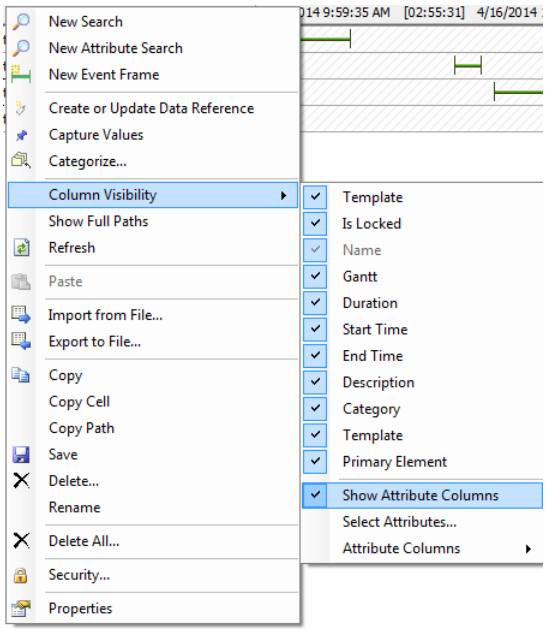
Event frames are listed with their information such as the event frame name, a Gantt diagram, the event duration, the severity, and the start and end time:



Displaying the Event Frame attributes

By default, the event attributes are not displayed in the result window.

By right-clicking and selecting *Column Visibility,* you will be able to choose the attributes you want to display.



Tip: To change the column visibility you can also click on the Settings icon in the header row of the search results.

Column (Meaning)	Column (Header Icon)	EF Row Information	Meaning
Is Template			Hover with the mouse over this column to get the event frame template.
		<empty>	Event frame is not based on an event frame template.
Is Locked			Captured Values: values for the event frame attributes are saved in AF (see note below).
		<empty>	Values for the event frame attributes are not saved in AF (see note below).
Is Annotated			Event Frame is annotated. Hover with the mouse over the icon to get the annotation(s). Use EF right mouse button menu option *Annotate…* to enter new annotations.
		<empty>	Event Frame is not annotated. Use EF right mouse button menu option *Annotate…* to enter new annotations.
Is Not Acknowledged			Event Frame can be acknowledged. Use EF right mouse button menu option *Acknowledge…* to acknowledge the EF.
			Event Frame is acknowledged. Hover with the mouse over the icon to get acknowledgement info (by whom?, when?).
		<empty>	Event Frame cannot be acknowledged. Whether an event frame can be acknowledged is defined in the corresponding event frame template (General tab)

Note: You capture values to save the values for event frame attributes in a table in the PI AF database. This can improve performance since PI AF does not execute any data references. If you add new attributes to event frames with captured values, you should recapture those values to ensure that values are also captured for the new attributes.

7.2.2 Directed Activity - Downtime Event Frame Searches, Acknowledgement and Annotation

In this part of the class, you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

Exercise Objectives

- Familiarize yourself with the event frame search in PSE.
- Acknowledge and annotate event frames.

Problem Description

You have AF analysis that will capture press downtimes.

Due to a staffing issue in your plant, you want to get the details for any downtimes after 10PM yesterday triggered by a “No Operator” root cause so you can annotate the events, and acknowledge them.

Approach

Use the *Event Frame Search* window to perform the following:

1. Select *New Search* from the right mouse button menu of the Event Frame search root.
2. Enter following criteria: start time: *y+22h*, event frame template: *Press Downtime*, element name: *Hou**, Reason Code= *No Operator* (you have to use Add Criteria to enter that)

   Hint: you can enter the criteria one by one and click on Search every time. If you enter more criteria, then you get less event frames that match your criteria. Click on OK when the returned event frames meet the desired scope.

3. Rename your narrowed down search: *Downtime Events No Operator after 10PM yesterday*

   Background: Once performed, your searches and their criteria are saved. Use *Rename* from the context menu of a search to assign a descriptive name for the search. To further refine an existing search, while keeping the existing search saved, select *New Search* from the context menu of the search and then modify the new one.

4. Add columns for the *Reason Code* and the *Event Duration* attributes. Verify the *Reason Code* is *No Operator* in every case.

5. Select the first event frame and add annotation: “Bob was busy with representative from press manufacturer.”
6. Select all event frames that started before midnight and acknowledge them in one action.

7.2.3 Exercise – Perform multiple Event Frame Searches with different criteria

This solo or group exercise is designed to maximize learning in a specific topic area. Your instructor will have instructions and will coach you if you need assistance during the exercise.

Exercise Objectives

- Perform medium to advanced event frames searches.

Problem Description

Perform the following event frame searches in PSE:

1. Find all downtime events for Montreal's press2 for the last 12 hours.
2. Add columns to show the *Production Lost* and *Reason code*.
3. Narrow down your search to find events that lasted more than 10 minutes.
4. Narrow down your search to find downtime events caused by Press set-up.

Approach

Use the *Event Frame Search* window to perform your searches. Make sure to add the necessary search criteria.

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7.2.4 Event Frame Reports in Excel with PI Datalink

Explore versus Compare Events functions

You can use PI Datalink (2014 or later) to import event frames from AF into Excel and then create reports for viewing and analyzing those events. Pivot tables and pivot charts are great Excel features for summarizing the data and getting better insight into event frames

Under the PI Datalink ribbon in Excel you will find two functions (buttons) to import event frame data into Excel: The **Explore Events** function and the **Compare Events** function.

The **Explore Events** function returns one event per row, which is useful to analyze events sharing the same EF template.

	A	B	C	D	E
1	Event name	Start time	End time	Primary element	Temp.Max
2	Batch 1222	30/01/2015 12:23:07	30/01/2015 14:05:07	RE100	89.56497955
3	Batch 1317	30/01/2015 13:18:37	30/01/2015 14:19:37	RE200	73.08377075
4	Batch 1327	30/01/2015 13:28:07	30/01/2015 14:04:07	RE300	92.61405945
5	Batch 1410	30/01/2015 14:11:07	30/01/2015 14:47:07	RE300	101.1487427

Here: maximum temperature of event frame named *Batch 1222* has been highlighted above in yellow (89.56).

In case an event frame has child events, it is possible to also list child elements in further lines below the parent event. In the example below, there are nine child event frames (Material Add 1, Agitate, ,…):

	A	B	C	D	E	F
1	Event name	Child 1	Start time	End time	Primary element	Temp.Max
2	Batch 1222		30/01/2015 12:23:07	30/01/2015 14:05:07	RE100	89.56497955
3	Batch 1222	Material Add 1	30/01/2015 12:24:37	30/01/2015 12:35:07		12.45047569
4	Batch 1222	Agitate	30/01/2015 12:35:07	30/01/2015 12:41:37		13.08228683
5	Batch 1222	Material Add 2	30/01/2015 12:41:37	30/01/2015 12:56:37		14.34287834
6	Batch 1222	Agitate	30/01/2015 12:56:37	30/01/2015 13:07:37		16.33535957
7	Batch 1222	Heat	30/01/2015 13:07:37	30/01/2015 13:14:07		41.38076401
8	Batch 1222	Dwell	30/01/2015 13:14:07	30/01/2015 13:34:37		89.26969147
9	Batch 1222	Agitate	30/01/2015 13:34:37	30/01/2015 13:39:37		89.56497955
10	Batch 1222	Cool	30/01/2015 13:39:37	30/01/2015 13:53:37		89.56497955
11	Batch 1222	XFER_OUT	30/01/2015 13:53:37	30/01/2015 14:05:07		47.95473671
12	Batch 1317		30/01/2015 13:18:37	30/01/2015 14:19:37	RE200	73.08377075
13	Batch 1317	Material Add 1	30/01/2015 13:20:07	30/01/2015 13:25:07		19.77932739
14	Batch 1317	Agitate	30/01/2015 13:25:07	30/01/2015 13:32:37		19.77932739
15	Batch 1317	Material Add 2	30/01/2015 13:32:37	30/01/2015 13:42:07		19.32192421
16	Batch 1317	Agitate	30/01/2015 13:42:07	30/01/2015 13:46:07		18.90079117
17	Batch 1317	Heat	30/01/2015 13:46:07	30/01/2015 13:55:37		72.09648132
18	Batch 1317	Dwell	30/01/2015 13:55:37	30/01/2015 14:06:37		73.08377075
19	Batch 1317	Agitate	30/01/2015 14:06:37	30/01/2015 14:08:37		71.17395782
20	Batch 1317	Cool	30/01/2015 14:08:37	30/01/2015 14:13:37		60.78569031
21	Batch 1317	XFER_OUT	30/01/2015 14:13:37	30/01/2015 14:19:37		3.42448926
22	Batch 1327		30/01/2015 13:28:07	30/01/2015 14:04:07	RE300	92.61405945

Here: the maximum temperature of child event frames *Material Add 1* and *Agitate* have been highlighted in green (12.45 and 13.08).

The second function, **Compare Events**, allows you to compare hierarchical events, in other words, events with child events. The compare events function shows attributes from both the parent event and the child event(s). In the following example maximum temperature for the complete production batch as well as for the first child event frames *Material Add 1* and *Agitate* is returned:

	A	B	C	D	E	F	G
1	.|Event name	.|Start time	.|End time	.|Primary element	.|Temp.Max	.\Material Add 1|Temp.Max	.\Agitate[1]|Temp.Max
2	Batch 1222	30/01/2015 12:23:07	30/01/2015 14:05:07	RE100	89.56497955	12.45047569	13.08228683
3	Batch 1247	30/01/2015 12:48:07	30/01/2015 13:49:07	RE400	113.7231445	35.76528931	43.35900879
4	Batch 1317	30/01/2015 13:18:37	30/01/2015 14:19:37	RE200	73.08377075	19.77932739	19.77932739
5	Batch 1327	30/01/2015 13:28:07	30/01/2015 14:04:07	RE300	92.61405945	21.78729439	23.9196682
6	Batch 1410	30/01/2015 14:11:07	30/01/2015 14:47:07	RE300	101.1487427	21.77057076	22.690979

7.2.5 Directed Activity – Creating Downtime Event Frame Reports with PI Datalink

In this part of the class, you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

Activity Objectives

- Learn how to import event frame data into excel.

Problem

Management wants to answer the following questions about the downtime events:

- What is the most offending cause of downtimes?
- How much production are we losing because of downtime events?

The best way to find an answer to these questions is by creating an Excel report which imports the event frames into an Excel spreadsheet. Excel offers some useful business intelligence tools that will help us aggregate the data so management can make decisions.

Approach

We will be using PI Datalink to import the event frame information and then use Excel PowerPivot and PowerChart to analyze the downtime events.

Building the DownTime Analysis Report

For this exercise, you will be using a template: *Press DownTime Analysis.xlsx,* located in the class\exercises folder. The template contains two sheets; we will be importing the event frames data into the *Raw Data* sheet, which will be read from the *Report* sheet via a pivot table and a pivot chart.

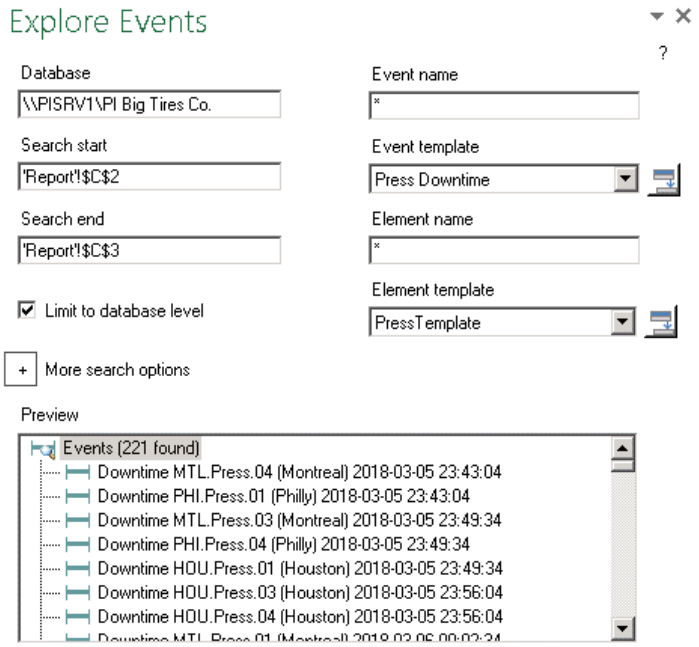
Since we want to analyze the downtime events which are all based on the same EF template, we will be taking advantage of the *Explore function* in PI Datalink. Go to the *Raw Data* sheet, set the cursor into cell A2 and click on the *Explore function* in the PI Datalink ribbon

Configuring the Explore Events Function

The *Explore Events* pane will show up. This pane offers several fields for you to refine your event frames search. Moreover, it features a results preview section.

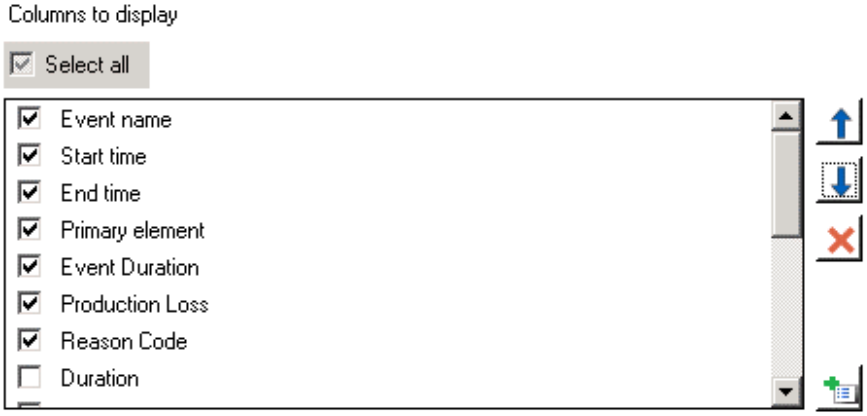
For the *Search start* and *Search end* fields point to the corresponding cells on the *Report sheet* (see figure).

Keep * for event name and element name.



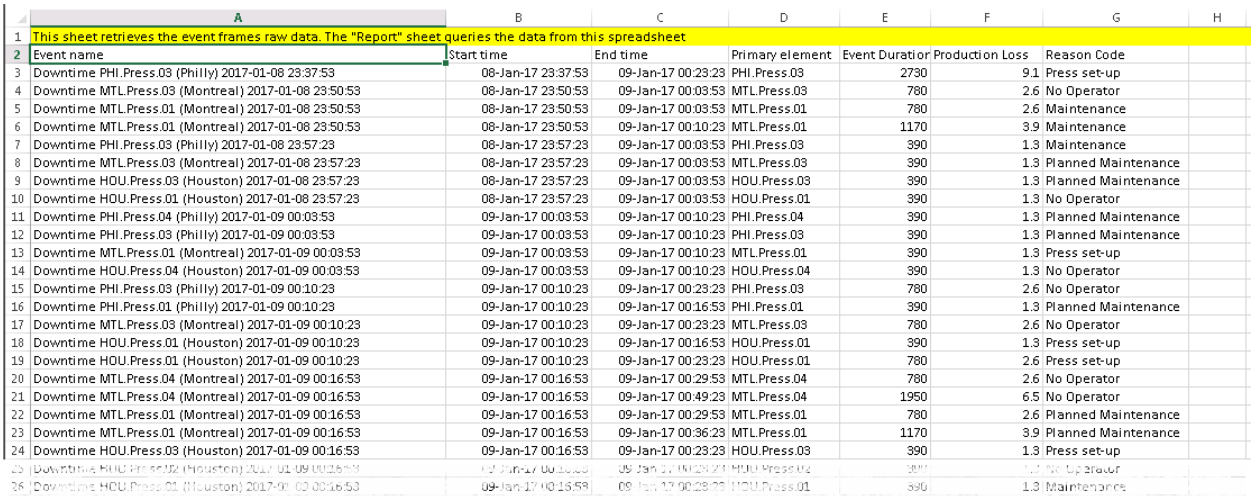
Note: It is expected you will not get Event Frames that are not yet finished. To exclude Event Frames that are not finished, click on *More Search Options* and select *entirely in range* under the search mode.

Select the seven columns to display; you can as well set the column order. The columns are actually the event frame attributes. The following columns are needed for the analysis:



Make sure you selected *Event Duration* attribute (gives you the number of seconds), and **not** *Duration (would give you the time in a format hh:mm:ss, such as e.g. 0:06:30).*

Hit OK to display all event frame information in the *Raw Data* sheet.



	A	B	C	D	E	F	G	H
1	This sheet retrieves the event frames raw data. The "Report" sheet queries the data from this spreadsheet							
2	Event name	Start time	End time	Primary element	Event Duration	Production Loss	Reason Code	
3	Downtime PHI.Press.03 (Philly) 2017-01-08 23:37:53	08-Jan-17 23:37:53	09-Jan-17 00:23:23	PHI.Press.03	2730	9.1	Press set-up	
4	Downtime MTL.Press.03 (Montreal) 2017-01-08 23:50:53	08-Jan-17 23:50:53	09-Jan-17 00:03:53	MTL.Press.03	780	2.6	No Operator	
5	Downtime MTL.Press.01 (Montreal) 2017-01-08 23:50:53	08-Jan-17 23:50:53	09-Jan-17 00:03:53	MTL.Press.01	780	2.6	Maintenance	
6	Downtime MTL.Press.01 (Montreal) 2017-01-08 23:50:53	08-Jan-17 23:50:53	09-Jan-17 00:10:23	MTL.Press.01	1170	3.9	Maintenance	
7	Downtime PHI.Press.03 (Philly) 2017-01-08 23:57:23	08-Jan-17 23:57:23	09-Jan-17 00:03:53	PHI.Press.03	390	1.3	Maintenance	
8	Downtime MTL.Press.03 (Montreal) 2017-01-08 23:57:23	08-Jan-17 23:57:23	09-Jan-17 00:03:53	MTL.Press.03	390	1.3	Planned Maintenance	
9	Downtime HOU.Press.03 (Houston) 2017-01-08 23:57:23	08-Jan-17 23:57:23	09-Jan-17 00:03:53	HOU.Press.03	390	1.3	Planned Maintenance	
10	Downtime HOU.Press.01 (Houston) 2017-01-08 23:57:23	08-Jan-17 23:57:23	09-Jan-17 00:03:53	HOU.Press.01	390	1.3	No Operator	
11	Downtime PHI.Press.04 (Philly) 2017-01-09 00:03:53	09-Jan-17 00:03:53	09-Jan-17 00:10:23	PHI.Press.04	390	1.3	Planned Maintenance	
12	Downtime PHI.Press.03 (Philly) 2017-01-09 00:03:53	09-Jan-17 00:03:53	09-Jan-17 00:10:23	PHI.Press.03	390	1.3	Planned Maintenance	
13	Downtime MTL.Press.01 (Montreal) 2017-01-09 00:03:53	09-Jan-17 00:03:53	09-Jan-17 00:10:23	MTL.Press.01	390	1.3	Press set-up	
14	Downtime HOU.Press.04 (Houston) 2017-01-09 00:03:53	09-Jan-17 00:03:53	09-Jan-17 00:10:23	HOU.Press.04	390	1.3	No Operator	
15	Downtime PHI.Press.03 (Philly) 2017-01-09 00:10:23	09-Jan-17 00:10:23	09-Jan-17 00:23:23	PHI.Press.03	780	2.6	No Operator	
16	Downtime PHI.Press.01 (Philly) 2017-01-09 00:10:23	09-Jan-17 00:10:23	09-Jan-17 00:16:53	PHI.Press.01	390	1.3	Planned Maintenance	
17	Downtime MTL.Press.03 (Montreal) 2017-01-09 00:10:23	09-Jan-17 00:10:23	09-Jan-17 00:23:23	MTL.Press.03	780	2.6	No Operator	
18	Downtime HOU.Press.01 (Houston) 2017-01-09 00:10:23	09-Jan-17 00:10:23	09-Jan-17 00:16:53	HOU.Press.01	390	1.3	Press set-up	
19	Downtime HOU.Press.01 (Houston) 2017-01-09 00:10:23	09-Jan-17 00:10:23	09-Jan-17 00:23:23	HOU.Press.01	780	2.6	Press set-up	
20	Downtime MTL.Press.04 (Montreal) 2017-01-09 00:16:53	09-Jan-17 00:16:53	09-Jan-17 00:29:53	MTL.Press.04	780	2.6	No Operator	
21	Downtime MTL.Press.04 (Montreal) 2017-01-09 00:16:53	09-Jan-17 00:16:53	09-Jan-17 00:49:23	MTL.Press.04	1950	6.5	No Operator	
22	Downtime MTL.Press.01 (Montreal) 2017-01-09 00:16:53	09-Jan-17 00:16:53	09-Jan-17 00:29:53	MTL.Press.01	780	2.6	Planned Maintenance	
23	Downtime MTL.Press.01 (Montreal) 2017-01-09 00:16:53	09-Jan-17 00:16:53	09-Jan-17 00:36:23	MTL.Press.01	1170	3.9	Planned Maintenance	
24	Downtime HOU.Press.03 (Houston) 2017-01-09 00:16:53	09-Jan-17 00:16:53	09-Jan-17 00:23:23	HOU.Press.03	390	1.3	Press set-up	
25	Downtime HOU.Press.02 (Houston) 2017-01-09 00:16:53	09-Jan-17 00:16:53	09-Jan-17 00:29:23	HOU.Press.02	390	1.3	No Operator	
26	Downtime HOU.Press.01 (Houston) 2017-01-09 00:16:53	09-Jan-17 00:16:53	09-Jan-17 00:29:23	HOU.Press.01	390	1.3	Maintenance	

Just by looking at this spreadsheet, it is very difficult to identify the most offending downtime cause or the production lost. By using an Excel tool, *Pivot tables*, we will be able to automatically extract, organize, and summarize the event frame data. PivotTables, and their graphical companions, Pivot Charts, are very versatile and easy to create. No formulas needed!

7.2.6 Directed Activity – Summarize Event Frame Data with Excel Pivot Chart functions (optional)

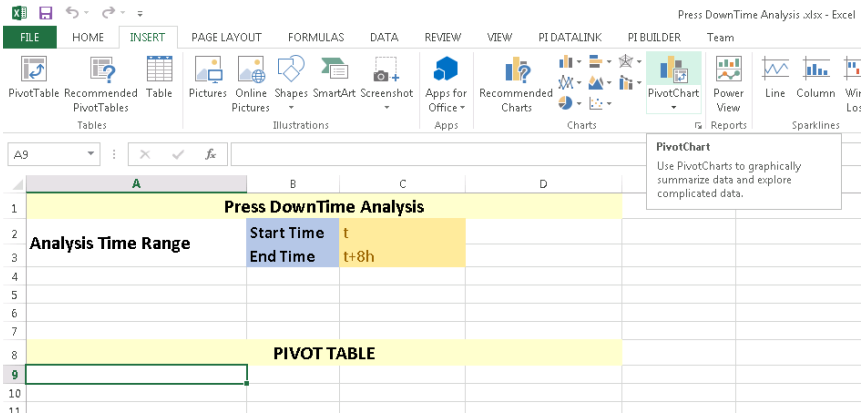
In this part of the class, you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

Activity Objectives

- Use Excel functionalities to summarize event frame information.

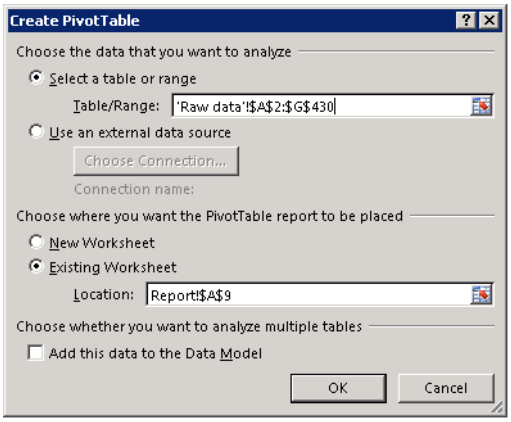
Creating a PivotChart and a PivotTable

Go to the *Report* sheet, select the *Insert* ribbon and select the *PivotCharts option* to create a PivotTable and a PivotChart.

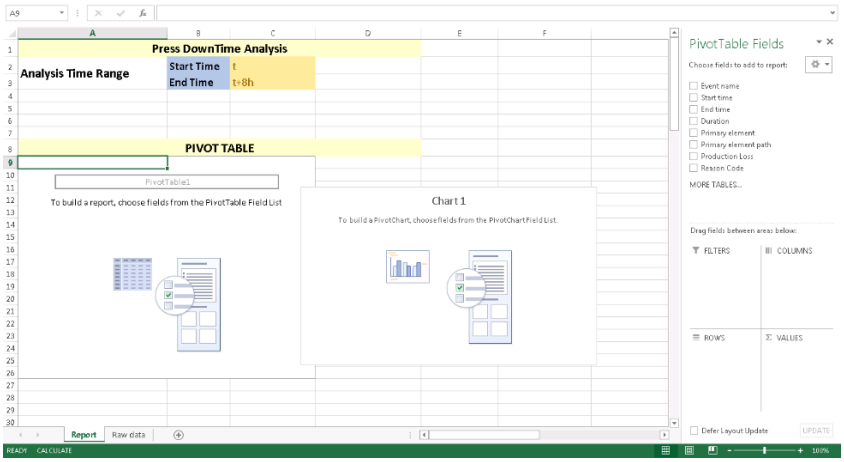


As input for the PivotTable select the cell range in the *Raw Data* sheet where the ExploreEvents function has returned the data (including the header line).
Then choose to place the PivotTable and PivotChart in the *Report* sheet.

Tip: if you want to correct the source area later in time, select all cells of your PivotTable (or choose the Analyse ribbon), then from the Analyse Ribbon, select **Change Data Source**.

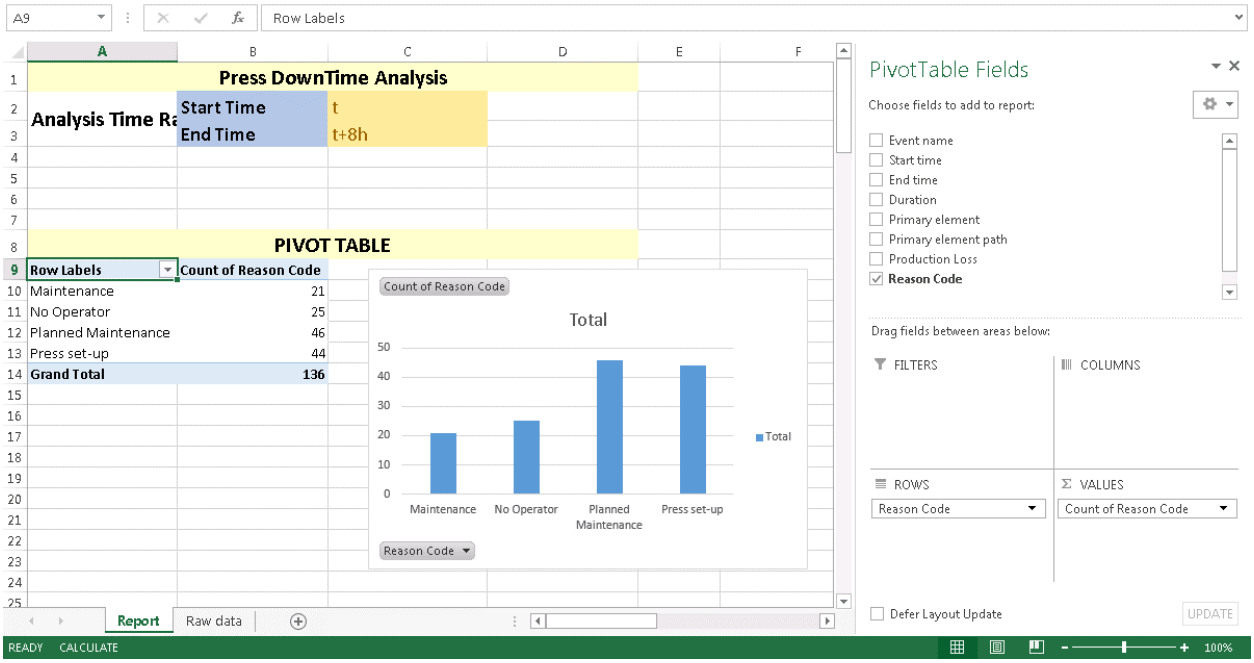


The PivotChart field list should now be shown in your Excel worksheet and a range of the worksheet should be designated where the pivot table will be located, as shown below.

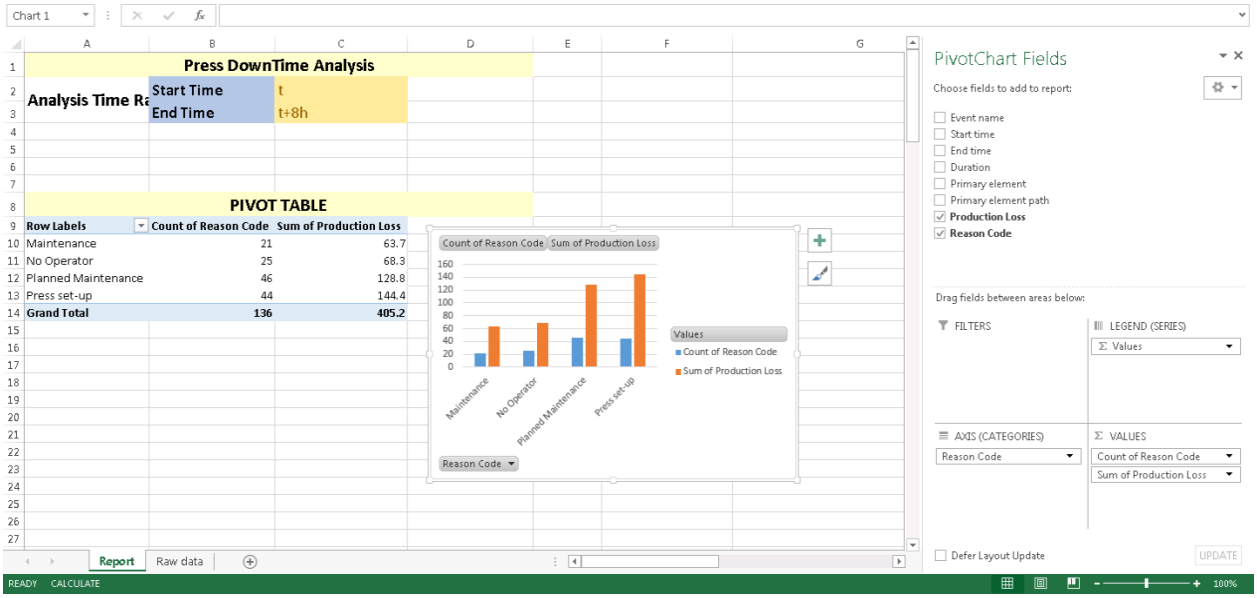


Select the PivotTable, and review the PivotTable Field list. These fields come from the column names of the *Raw Data* sheet.

To perform a downtime analysis for our Event Frames based on the corresponding reason code, select the **Reason Code** line and drag into the *Values* area. The applied Aggregation for the reason codes is COUNT, because these are non-numeric values. Select the **Reason Code** line again and drag into the *Rows* area:



Select the **Production Loss** line and drag into the *Values* area. The aggregation applied for these numeric values is SUM. Your PIVOT table is extended by another row, which summarizes corresponding production losses, based on the reason codes:

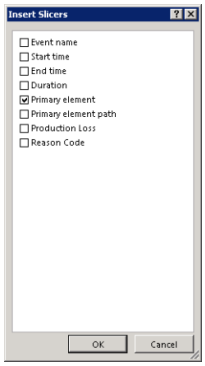


Tip1: if the PivotTable Fields pane was closed and you want to have it available again, select a cell of your PivotTable. From the right-mouse button menu, select **Show Field List**.

Tip2: to change the aggregation that is applied to your data, select the dropdown icon on the field, and choose Value Field Settings… to select another aggregation type.

Let us enhance our Pivot table for analysis depending on individual press selections.

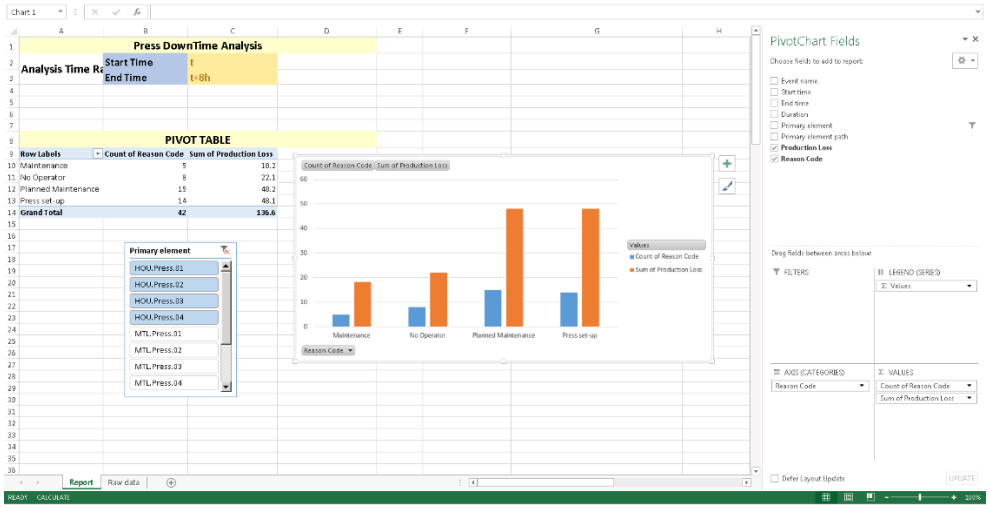
Which column of our data represents a press ?



Select a cell in the Pivot table, and select the Analyze ribbon from the Pivot Table tools. Click on insert slicer, select primary element and click on OK.

The slicer for the primary element is added. It allows selecting any combination of one or more presses for our analysis. Check various combinations (use Shift- and Ctrl-key for selections in the slicer):

- all presses
- PHI. Press01 only
- all “Number 01”- presses (i.e. HOU.Press.01, MTL.Press.01 and PHI. Press01)
- all presses in Houston



The PivotTable and the PivotChart will update to show you what reason code is causing most of the downtime events. In the screenshot above, it is clear that during the observed period of time, planned maintenance has caused most of the production losses for the Houston Presses.

7.3 Tracking Production Excursion Periods

7.3.1 Group Exercise – Tracking a Controller out of Control

This group exercise is designed to maximize learning in a specific topic area. Your instructor will have instructions, and will coach you if you need assistance during the exercise.

Exercise Objectives

- Review steps to create an event frame analysis, starting from the creation of the event frame template up to the analysis configuration and testing.

Problem Description

The process control team is concerned about the number of scrap tires and want to investigate the production conditions in more detail. They are asking for a list with those periods of time, when the internal temperature exceeds 25 C during the loading Phase and the lid has closed.

In order for the process control team to start fixing the problem they'd like to keep track of these undesired events by monitoring how the internal temperature and pressure behaves for the rest of the cycle, until the press lid opens. Moreover, they care to know the maximum temperature and pressure during each of these events.

It was observed that pressure and internal temperature behavior 3 minutes before the problem starts can provide them useful information to understand why there is an excursion from the normal production process.

PI Big Tires company calls these events "Out of control events". The event names should reference the concerned press, the start time and the kind of tires currently produced. Examples:

OOC HOU.Press.02 2018-02-21 10:25:00 (Winter-Tire Production)
OOC MTL.Press.02 2018-02-21 08:41:30 (Motorcycle-Tire Production)

Approach

As a group of 2 – 3 students, go through the table below to discuss common understanding of the steps required to monitor the tire production cycles and detect out-of-control situations. In an out-of-control situation the internal press temperature is too high during the Loading phase of the Press.

Hint to get the kind of tires currently produced:
Sine AF 2017 R2, the event frame naming pattern allows to use values from event frame attributes. If an event frame has an attribute called ProductType, %@ProductType% in the naming pattern will give you the value of that event frame attribute.

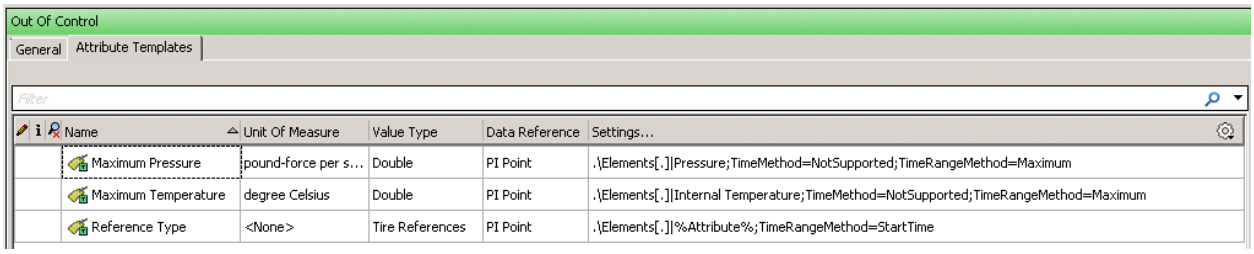
Fill in the open positions in the table below.

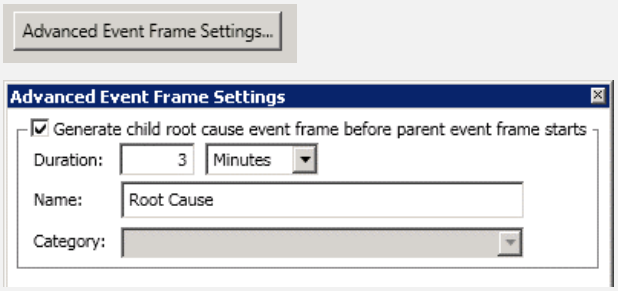
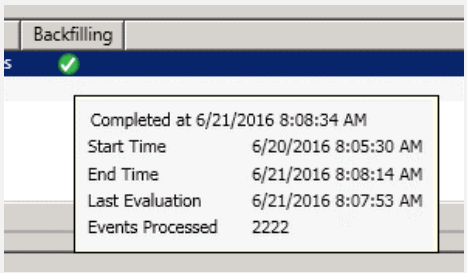
Design event frame template	Template Name	1. Naming Pattern:
	Attributes	1. Name: _____. 2. Name: _____.
	Attribute Configuration	Attribute for Maximum Pressure: UOM: _____ DR Setting _____ Attribute for Maximum Temperature UOM: _____ DR Setting _____ Attribute for Reference Type UOM: _____ DR Setting _____
Create Event Frame Analysis on an element	StartTrigger	
	EndTrigger	
	Scheduling	
	Child Root Cause Event Frame	□ Generate child root cause event frame
	Testing	□ Evaluate □ Preview Results
	Backfilling	Backfill Last 24 hours
Validating Event Frames via PSE	Event Frame Search	Define the Search Criteria to get the out-of-control events for HOU.Press.01 for the last two hours.
	Event Frame Attributes	Add attributes in the Event Frame Search results to get maximum Internal Temperature and Maximum Pressure
Convert analysis to template	Element template	□ Analysis in template.
	Analysis plugin	□ Analyses started □ Analyses status □ Backfill all presses (optional)

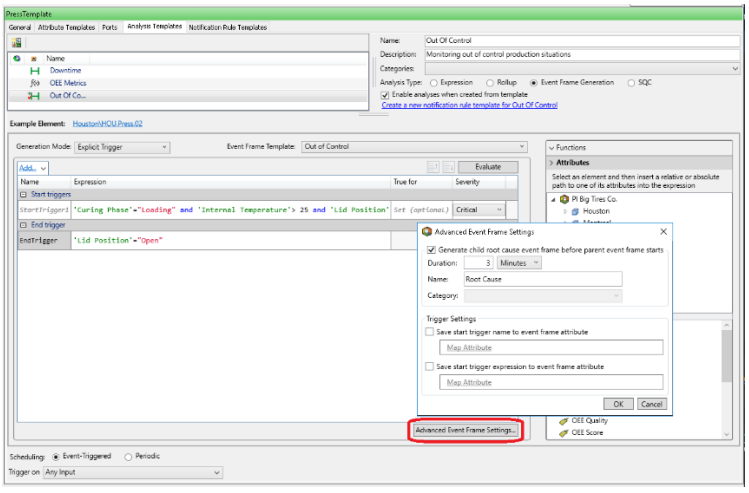
7.3.2 Directed Exercise: Review the Steps for Out Of Control Events

The following information is provided to discuss your solutions with the instructor. You will also perform the steps in a directed activity.

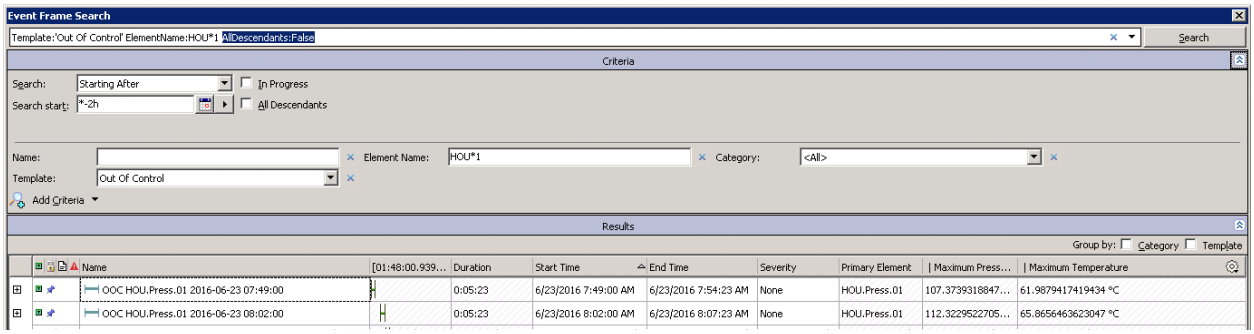
Design event frame template	Template Name	Naming Pattern: **OOC %Element%** **%STARTTIME:yyyy-MM-dd HH:mm:ss%** **(%@Reference Type%-Tire Production)** Enable the **Can Be Acknowledged** option**.**
	Attribute 1	Name: **Maximum Pressure** UOM: **PSI** Data Reference Configuration: **.\Elements[.]|Pressure;** **TimeRangeMethod=Maximum**
	Attribute 2	Name: **Maximum Temperature** UOM: **ºC** Data Reference Configuration: **.\Elements[.]|Internal Temperature;** **TimeRangeMethod=Maximum**
	Attribute 3	Name: **Reference Type** UOM: **<none>** Value Type: **Tire References** Data Reference Configuration: **.\Elements[.]|%Attribute%;** **TimeRangeMethod=StartTime**



<table>
<tr><td rowspan="7">Create Event Frame Analysis on an element</td><td>StartTrigger</td><td colspan="2">'Curing Phase'="Loading" and 'Internal Temperature'>25 and 'Lid Position'="Closed"</td></tr>
<tr><td>EndTrigger</td><td colspan="2">'Lid Position'="Open"</td></tr>
<tr><td>Severity</td><td colspan="2">Critial</td></tr>
<tr><td>Child Root Cause Event Frame</td><td colspan="2">☑ Generate child root cause event frame
 
</td></tr>
<tr><td>Scheduling</td><td colspan="2">Event –Triggered any input</td></tr>
<tr><td>Testing</td><td>☑ Evaluate</td><td>☑ Preview Results</td></tr>
<tr><td>Backfilling</td><td colspan="2">Backfill Last 24 hours, then verify the backfill status:
 
</td></tr>
</table>



Validating Event Frames via PSE	**Event Frame Search and Event Frame Attributes**	**Enter the following Search Criteria for Event Frame Search:** **1. Starting After *-4h** **2. Template= Out Of Control** **3. Element Name=** HOU*1 **4. Uncheck** All Descendants **(otherwise the root cause events will also be returned in separate lines)** **Click on Search button.** **To display the event frame attributes, click on the ⚙ button to customize the columns for the Search results. Click on *Select Attributes…* Add Maximum Pressure, Maximum Temperature and Reference Type**



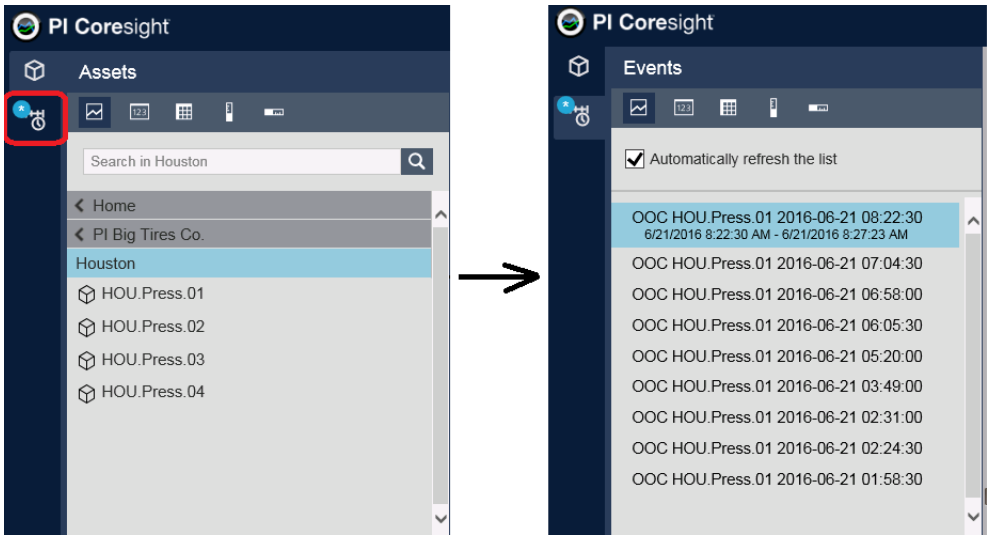
Click on OK. Rename the default name of the Search (*Event Frame Search X*) to *OOC Houston Press 1 Last 4 hours*.

Record the start time and end time and the two maximum values for two selected event frames (do not select event frames that are not yet finished). In the next exercise, we will see how information for these Event Frames are presented in PI Vision.

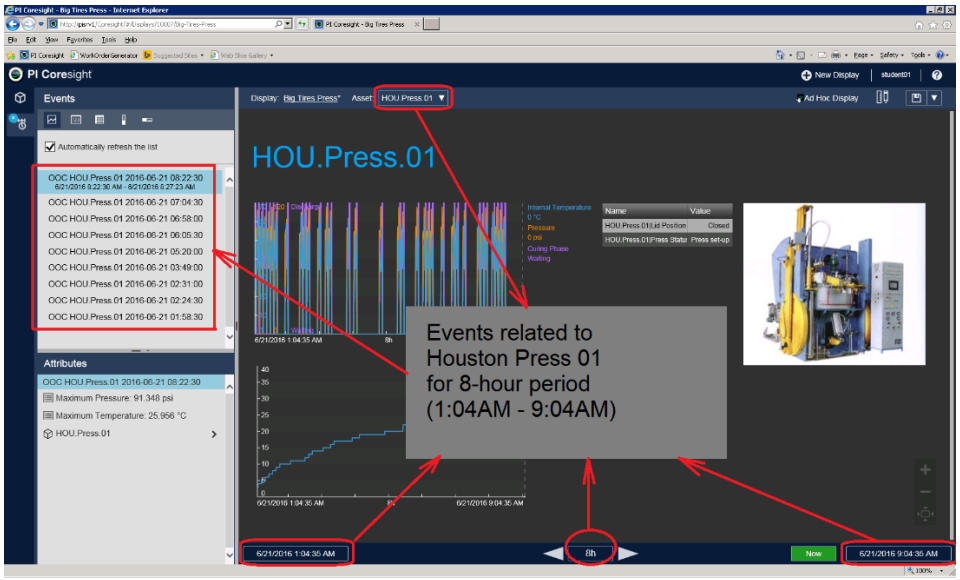
Convert analysis to template	**Element template**	☑ Analysis in template.
	Analysis plugin	☑ Analyses started ☑ Analyses status ☑ Backfill all presses (optional)

7.4 Event Frames in PI Vision

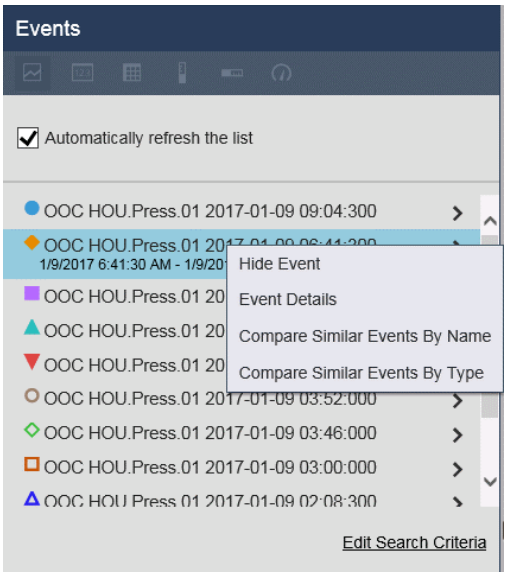
PI Vision discovers events related to assets on the display and it lists them in a dedicated *Events* tab. The time range and duration of the display determine for which period of time the events are listed. In case any event frames exist in that period, the icon for the event frames has a little blue dot on the top left edge. Click on the icon to switch from Assets pane display to Events pane display:

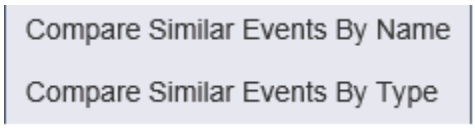


Any event frame for the asset, where the start and/or the stop time falls into the time period is listed:



If you select one of the event frames and click the right mouse button, you have three options:

Apply Time Range: Applies time range of the selected event to all symbols on the display.	
Event Details: Opens a dedicated screen to analyze, acknowledge and annotate events	
Compare Similar Events By Name / By Type: Opens another Browser tab to compare process data across multiple events on a single "overlay" trend.	



By Name	When comparing events by name, the Event Comparison screen displays up to 11 events with the same name, Event Frame template, and referenced asset.
By Type	When comparing events by type, the Event Comparison screen displays up to 11 events based on the same Event Frame template and same referenced asset.

When you change the time range for your display, the events list will be refreshed automatically. Uncheck button for *Automatically refresh the list* to avoid searches whenever you make a change for the time range of the display.

7.4.1 Directed Activity – Visualizing Events Using PI Vision

In this part of the class, you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

Activity Objectives

- Explore the process data for Houston.Press.01 during out-of-control periods
- Analyse the out-of-control event details

Approach

- Switch the display time range to show data for several out-of-control periods.
- Display the details of a particular out-of-control Event to get related asset information.

Change the Display Time Range

1. From the PI Vision overview page, open the *Big Tires Press* display.
2. Switch to the Events list display
3. To just get OOC events, edit search criteria and filter for event type = Out Of Control
4. Set the time range to the last two hours: enter *-2h* into the field for the start time. The *Now* button on the left hand side should still be in green, so that the end time is current time.
   Because the time range is reduced from one day to two hours, the list of events will become smaller (*Automatically refresh the list* must be enabled).
5. Select one of the out-of-control events and select *Apply Time Range* from the right mouse button menu. Display time range is adjusted to the time range of the event. Repeat for other events.

Get Event Details

1. From the right mouse button menu of a selected event, select *Event Details*.
2. Explore related attributes for the Houston Press 01. Get minimum and maximum for the pressure and the internal temperature.
3. Click on the Back control to return to the Press display.

7.4.2 Directed Activity – Comparing Similar Events Using PI Vision

In this part of the class, you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

Activity Objectives

- Display process data from multiple events in one trend (overlay trend) for comparison
- Use PI Vision functions to highlight particular event frames and to hide selected event frames for improved comparison experience.

Approach

Open a second browser tab for event comparison.

Customize the display by highlighting and hiding event frames.

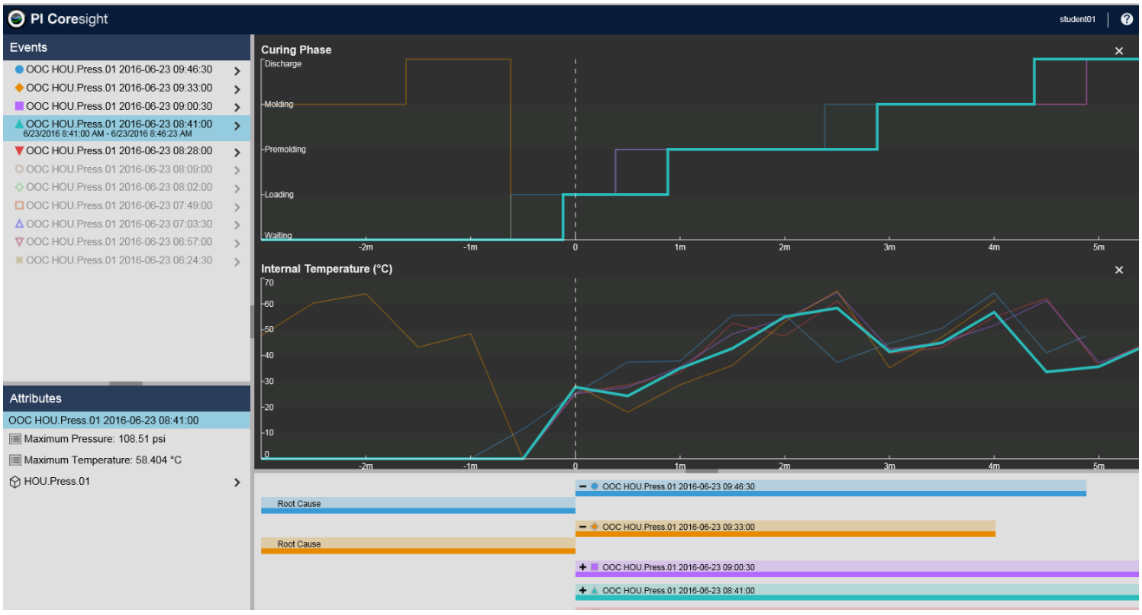
1. If needed, adjust the time range so that you get the event frames you recorded before. Increase or decrease the start time (from *-2h* to *-3h* or to *-90m*). When the time range is changed, the list of events will become smaller or greater (*Automatically refresh the list* must be enabled).
   The *Now* button on the left hand side should still be in green, so that the end time is current time.
2. Select *Compare Similar Events By Type* from the right mouse button menu.
   An additional browser tab will be added for the *Event Comparison*.

Event Comparison can display data for up to 11 trends (including the one selected).

3. Select an event frame to hide it. Select an event frame and select *Hide Event* from the right mouse button menu to remove it from the display. (You can do that in the Events list pane or in the Gantt Chart pane)

4. Remove all trends except Internal Temperature and Pressure.

   To remove a trends, click on the ✕ icon.
   Add a trend for the *Curing Phase*. To add the trace, expand attribute structure below the HOU.Press.01 element and drag the *Curing Phase* attribute



5. (optional) Save the display.

8. Taking Full Advantage of AF Functionalities

8.1 AF Object Security

Beginning with AF version 2.7, a security model similar to Data Archive security was implemented. This model relies on Windows integrated security for authentication, but provides its own authorization to AF objects using **AF Identities** and **Mappings**.

In AF version 2.6 and before, permissions in AF were set based on Windows user and groups.

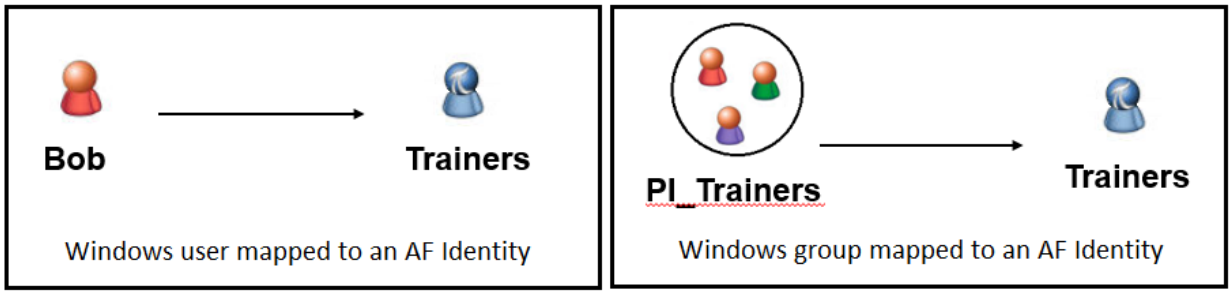
8.1.1 AF Identities and Mappings

An **AF identity** represents a set of access permissions on the AF server. Each AF mapping points from a Windows user or group to an AF identity.

Built-In AF Identities are Administrators, Engineers and World

According to the specific security requirements, AF identities are created on the AF Server, and the permissions for the AF server resources (such as an element collection or objects) are granted for these AF Identities.

With **AF Mappings**, Windows users and groups are mapped to the AF Identities:

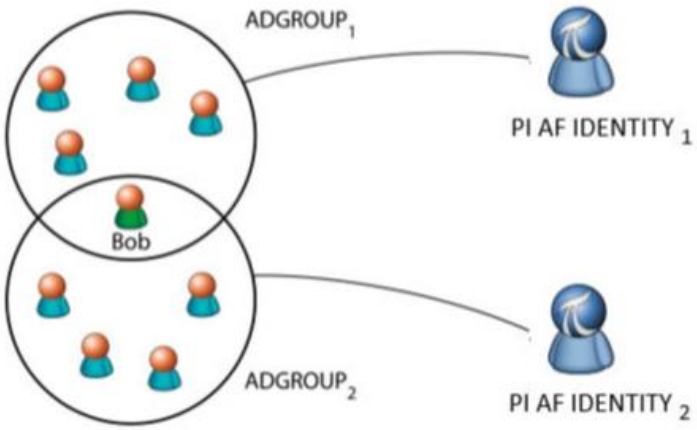


Note: It is preferable to define the AF Mappings for Active Directory (AD) groups instead of individual windows users. Since it is inefficient to maintain individual user accounts directly, it is recommended that the mapping on a user basis be the exception.

Members of the Windows groups that are mapped to an AF identity are automatically granted the access permissions for that AF identity.

For example, the Active Directory (AD) group Engineering Team is mapped to Engineers, so all the members in that AD group have read/write permission for the Elements collection.

In case of multiple identities user is granted permissions based on all AF Identities to which he or she is mapped. In example below, Bob has all permissions from PI AF Identity 1 and PI AF Identity 2.

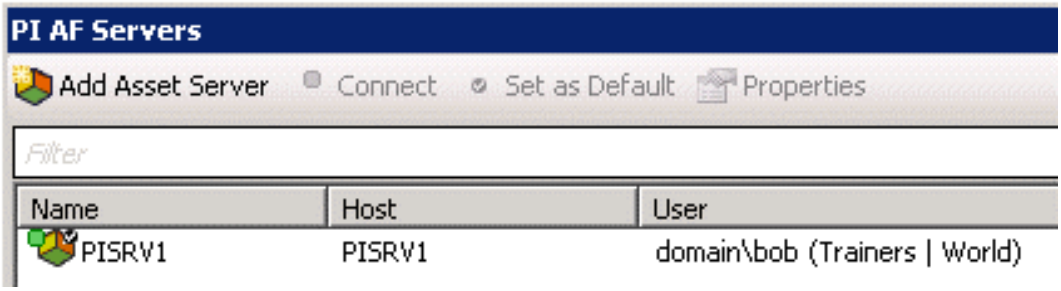


Built-in AF Identities:

AF Identity	Description
Administrators	By default, this identity has all access permissions to every collection and object on the AF server, including all databases. It cannot be modified or deleted. It is recommended that access to this identity is restricted to only a few users.
Engineers	This identity has the same privileges as *Administrators*, with the exception of the *Admin (a)* permission. This identity is also not allowed to delete AF databases. It is recommended that this identity be restricted to those users who are defining the asset database. Additional identities should be created to narrow the scope of access within AF.
World	This identity has read access permissions to every collection and object on the AF server. More information see below.

World Identity:

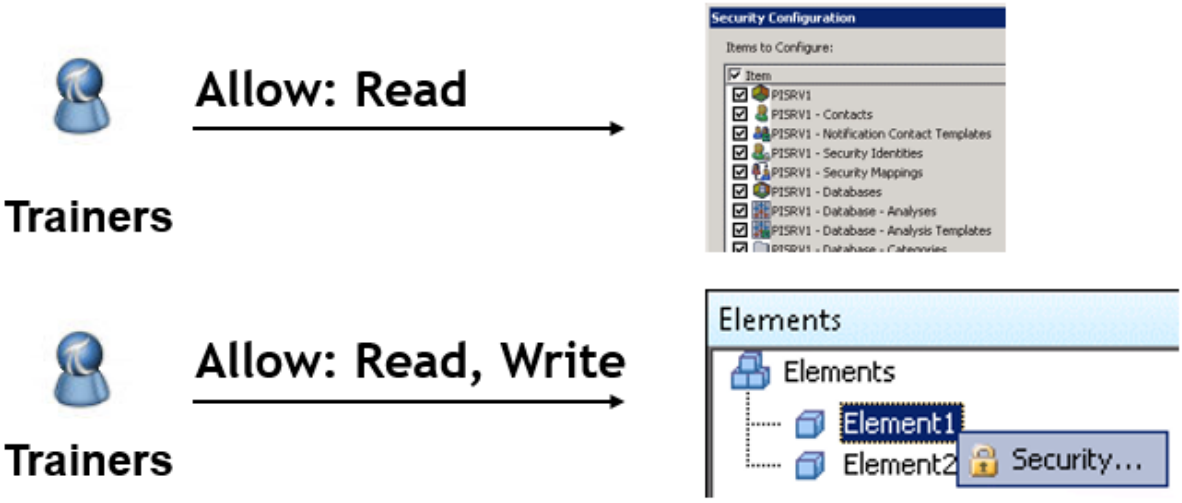
By default, World identity is mapped to the Windows Everyone users group:



By default, World Identity has Read permissions on all items. World identity cannot be modified or deleted. However, Mappings for World can be removed and Permissions for World can be removed.

8.1.2 AF access rights

Access permissions can be granted for all AF Objects. Examples:



The following table describes the access permissions you can assign to AF identities for all objects in the AF hierarchy.

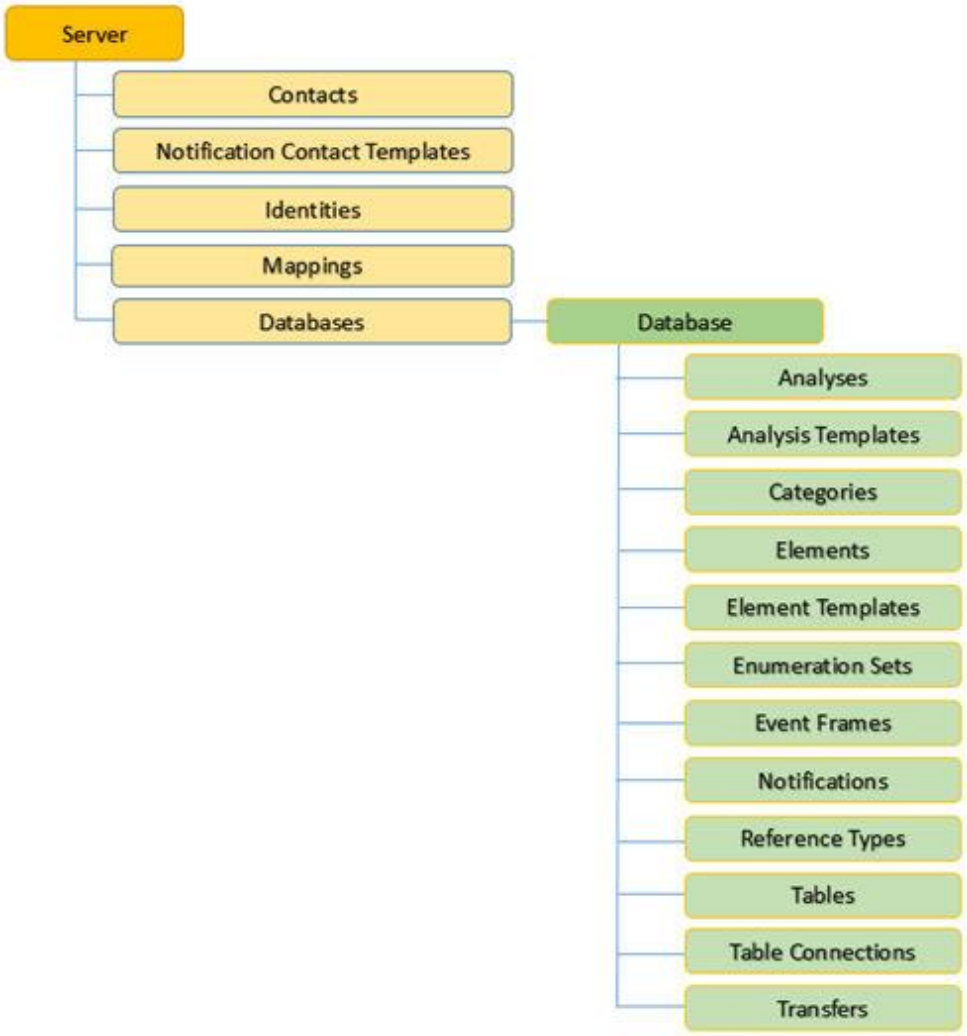
Access right	Abbreviation	Definition
Read	r	Enables a user to view the object.
Write	w	Enables a user to create and modify an object. The exception is that event frames and transfers also require Write Data permission on the element template from which they are created. Additionally, if users do not have Write permission on the AF database, they cannot modify any object within the database, regardless of the specific permission on that object.
Read/Write		Enables a user to read and write to the associated object.
Read Data	rd	Enables a user to read element's attribute values (non-configuration items).
Write Data	wd	Enables a user to modify element's attribute values (non-configuration items). Additionally, this permission controls whether a user can create or modify event frames.
Subscribe	s	Enables a user to subscribe and unsubscribe to a notification.
SubscribeOthers	so	Enables a user to subscribe and unsubscribe other users to a notification.
Delete	d	Enables a user to delete an object.
Execute	x	Enables a user to perform most actions on an analysis case. Only used in Pimsoft SigmafineTM data reconciliations. The PI Analysis Service does not use this permission. The Write permission is required to modify, run, and stop asset analyses.
Admin	a	Enables a user to modify the security settings, or owner, of an object. Also allows to force an Undo Check Out on an object that is checked out to another user, as well as to lock and unlock an event frame..

Setting permissions can be done for individual AF objects or for collections of objects. When you create new objects, except for child elements, the collection security is used as the default security. When you create a child element, the security descriptor of the parent element becomes its default security.

8.1.3 AF Security Hierarchy

The following chart shows the structure of the AF objects in a AF Server. Each securable AF object (element, event frame, and notification, and so on) throughout the hierarchy has an associated security descriptor that contains the access permissions information for that object.

All AF objects of the same type belong to a collection. For example, every AF element in a database belongs to the Elements collection for that database. Each collection also has an associated security descriptor that contains access permission information.

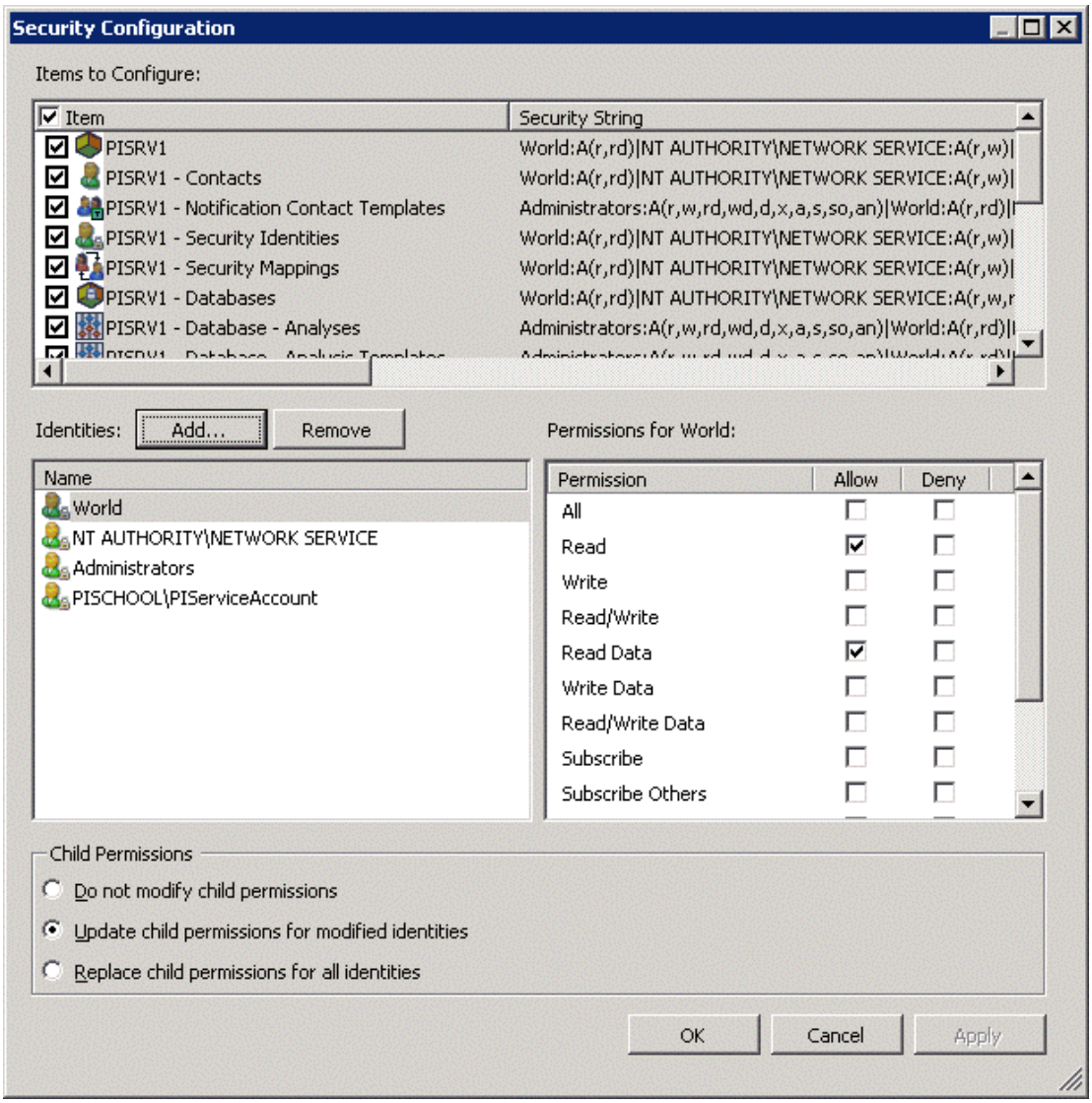


8.1.4 AF Server Security

Setting the security for a AF server

To open *Security Configuration* window for AF Server: On the toolbar, click the **Database** button. In the *Select Database* window, click the **Edit Security** button.

Alternatively, click the AF Server Properties button to open the AF Server Properties window, then click the blue **Security** link below the Aliases field. The *Security Configuration* window displays the defined access rights and allows to change them.



The **Items to configure** list for the AF Server contains the following items:

- AF Server
- Contacts Collection
- Notification Contact Templates Collection
- Identities Collection
- Mappings Collection
- Databases Collection (entire AF hierarchy)
- Analyses Collection (entire AF hierarchy)
- Analysis Templates Collection (entire AF hierarchy)
- Categories (entire AF hierarchy)
- Elements Collection (entire AF hierarchy)
- Element Templates Collection (entire AF hierarchy)

…

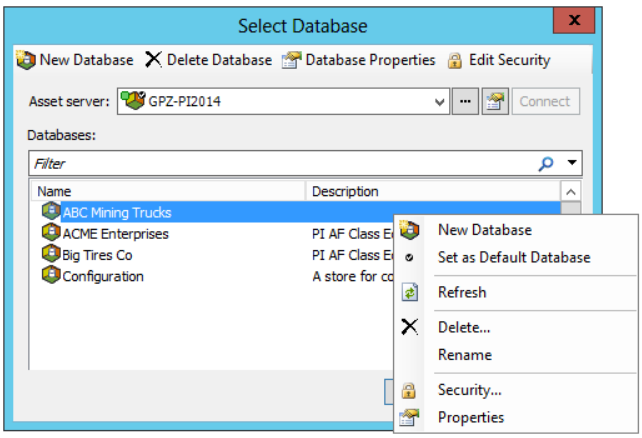
The Security Configuration allows adding, removing or changing the permissions for AF Identities.

- You can uncheck/check items to control the scope of the changes you are going to apply.
- You can modify permissions for one of the AF identities that is listed, or add or remove identities, as needed.
- The child permissions option defines the handling concerning permission inheritance.

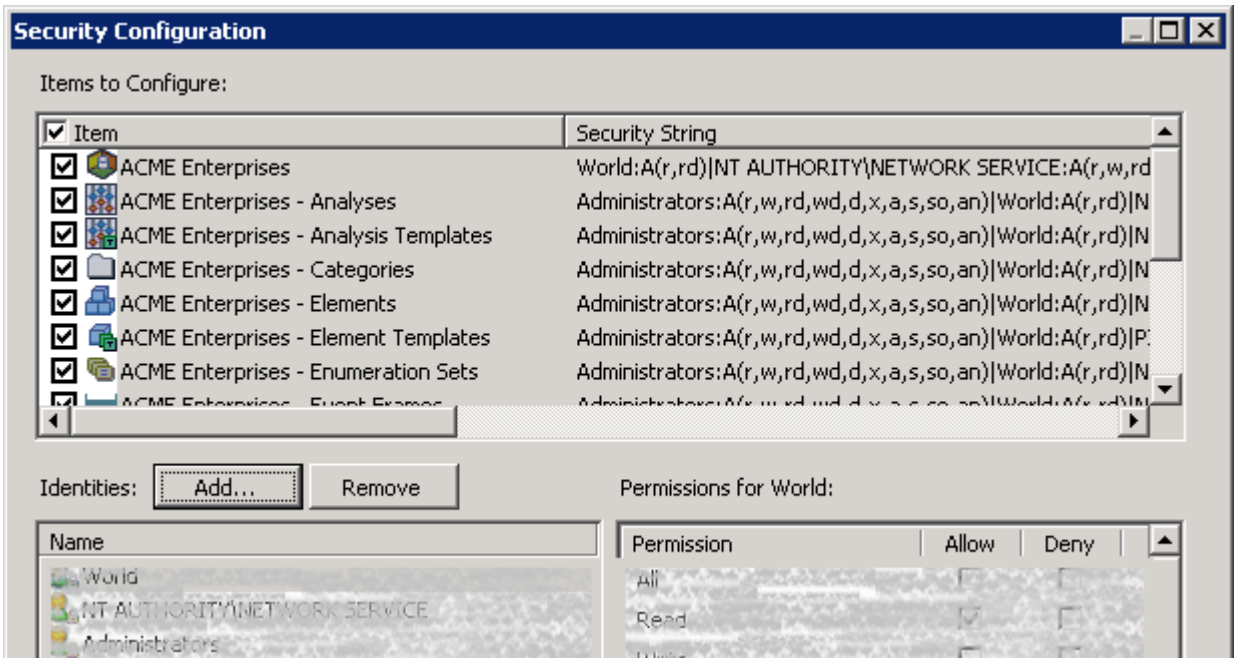
Setting the security for an AF database

To open *Security Configuration* window for an AF database:

On the toolbar, click the *Database* button. In the *Select Database* window, right-click a database in the **Databases** list and select **Security**.



In the **Items to Configure** list of the *Security Configuration* window, the selected database and every collection is checked.



The **Items to configure** list for the AF Database contains the following items:

- AF Database
- Analyses Collection
- Analysis Templates Collection
- Categories
- Elements Collection
- Element Templates Collection

…

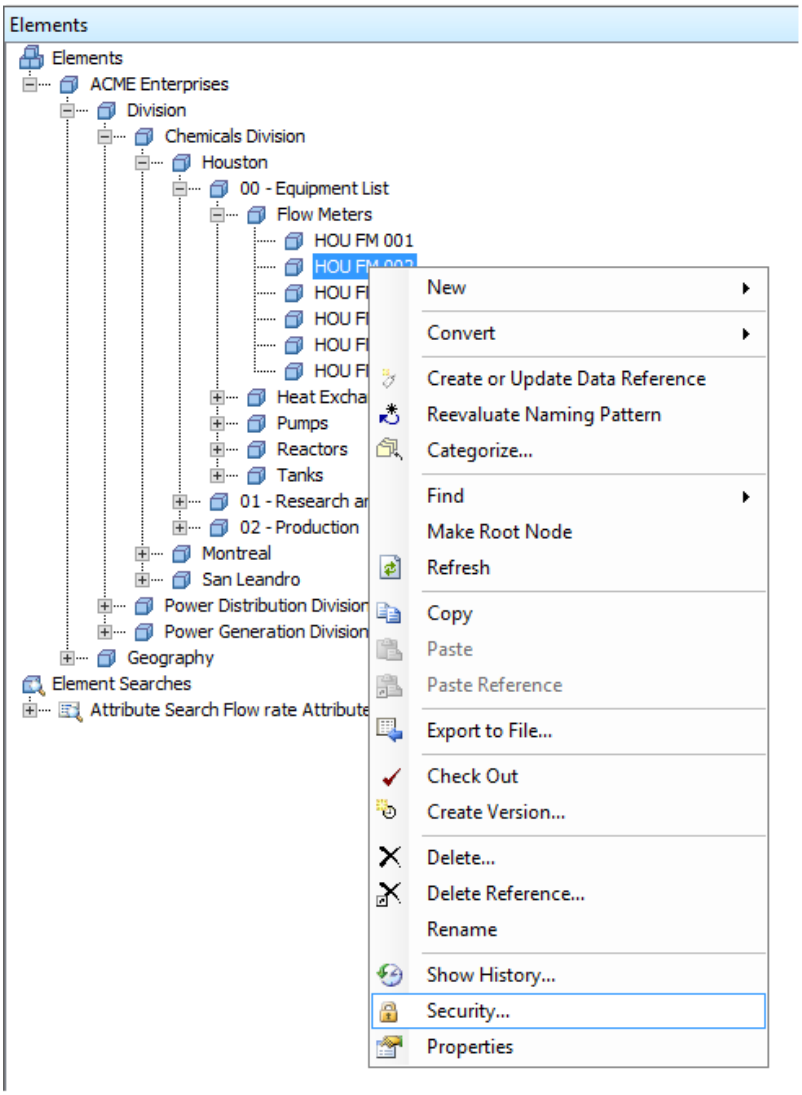
The Security Configuration allows adding, removing or changing the permissions for AF Identities. You can uncheck/check items to control the scope of the changes you are going to apply. You can modify permissions for one of the AF identities that is listed, or add or remove identities, as needed. The child permissions option defines the handling concerning permission inheritance.

Setting the security for an AF collection

You can configure access permissions to collections (Elements collection, Event Frame collection, Templates collection...) at several points in the AF hierarchy. You can set them at the server level or at the database level. If set at the server level, the permissions assigned to identities on the server are also assigned to the same identities in every database.

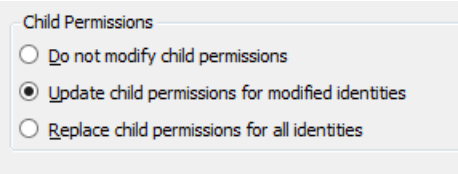
AF Object Security

You can set specific access permissions for an identity that differ from the default settings inherited from elsewhere in the AF hierarchy on any object (or object group) and collection in a database.



Permissions inheritance

When you change the access permissions for an element, the following applies for access permissions of child elements:

Reference Type	Behavior
Composition	Access permissions for child and parent are always the same.
Weak	Access permissions are never inherited.
Parent – Child	When access permissions are set on a parent, the Child Permission settings in the Security Configuration window depend on option used 

Option	Description
Do not modify child permissions	Prevents access permissions that have been set for the current object or collection from being replicated to child collections and objects in the AF hierarchy. Default for AF server 2.5 and earlier
Update child permissions for modified identities	For each selected item on the Items to Configure list in the Security Configuration window, replicates the access permissions for all child collections and objects for each identity on the Identities list whose access permissions have been modified. Default for AF server 2.6 and later.
Replace child permissions for all identities	For each selected item on the Items to Configure list in the Security Configuration window, replaces all child permissions for every identity on the Identities list with the parent access permissions. Hint: Before you apply this option, review access permission settings for all items on the Items to Configure list to avoid unintentionally overwriting custom permissions that may have been applied elsewhere in the collection hierarchy!

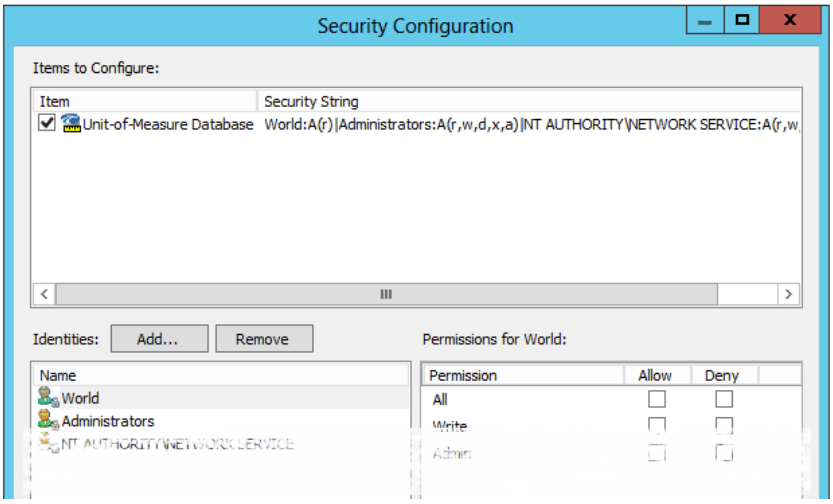
UOM Database security

The AF Unit of Measure (UOM) database is shared across all AF databases. You cannot set permissions for individual UOMs or UOM classes. Permissions can only be set for the entire UOM database.

To open UOM *Security Configuration* window:

In the Navigator pane, select **Unit of Measure.**

On the toolbar, click the **UOM Security** button.



Security Tips

Administrator privileges at the server level, provides access to every object regardless of their security settings.
If you want to edit an element, you need *write* permissions on the Elements collection and on the particular element.
Library objects, such as templates, enumeration sets, UOMs and reference types always have *read* permission regardless of their security settings
Deny settings override any granted allow permissions

8.1.5 Directed Activity – AF Objects Security

In this part of the class, you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

Exercise Objectives

- Create AF Identity and use it for a mapping to a Windows user account.
- Assign Permissions for an AF database and for AF elements.

Problem Description

Sheila, the new intern (student04@PISCHOOL.INT) has been hired at Velocity Terminals. To prevent unauthorized read access and unintended changes, the engineering supervisor has to change the security for the AF database:

Because of confidentiality, only designated Windows users should be able to read the data for Velocity Terminals. Beside Administrators and Engineers, just the intern should be able to read the data.

Sheila should not be able to see tanks in Sydney or Tokyo. Of course, if the intern browses to the Distribution or Receiving divisions he should only see the tanks belonging to Montreal.

She will be doing some research on Tank01; hence, she should be able to edit this tank's data and configuration.

Note: In order to avoid negative impact on the Velocity Terminals production database, perform the steps on the ***AF Startup*** AF database!

Approach

1. Click on the AF Server Properties button ( ) to open the *AF Server Properties* window. Identities and Mappings tabs: Add a new **Interns** AF Identity and map the **student04** account to it.

2. Click on the Database button (Database), select *Security* for **AF Startup** database:
   - To remove the permissions for the **World** Identity:
     Select World identity, then click on Remove button.
   - To add *Read* and *Read Data* permissions for the **Interns** Identity:
     Click on Add... button, select the Interns identity.
     Uncheck Allow All, then enable Read and Read Data
     Select *Update child permissions*-Option and click on Apply button.

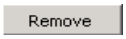
3. For the Tank01 element in Montreal…

   - To add Read/Write and Read/Write Data permissions for the Interns Identity:

     Select Security… from Tank01 element.
     Select the Interns identity.
     Enable Read/Wríte and Read/Write Data
   - Select *Do not Modify Child Permission*-Option, click on

button.

4. For the Tokyo and the Sydney element…
   - Remove all permissions for the Interns Identity:

     Select Security… from Sydney element
     Select the Interns identity.
     Click on 

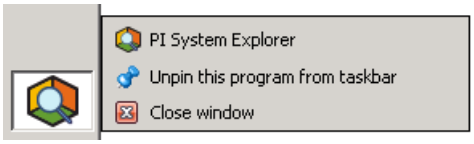
button
     Select *Update child permissions*-Option and click on

button. (accordingly for Tokyo).

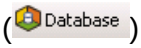
Verification

1. Maximize PI System Explorer (PSE).

2. Open a second PI System Explorer (PSE) instance for connection with the intern's account:

   With Shift key pressed, right-click the System Explorer icon in the Windows taskbar and select Run as a different user. Supply student04 credentials. (optional, for improved distinction) If needed, resize the window and bring it in front of the first PSE window.

3. On second PSE: click the Database button (

). In *Select database* window, click on the

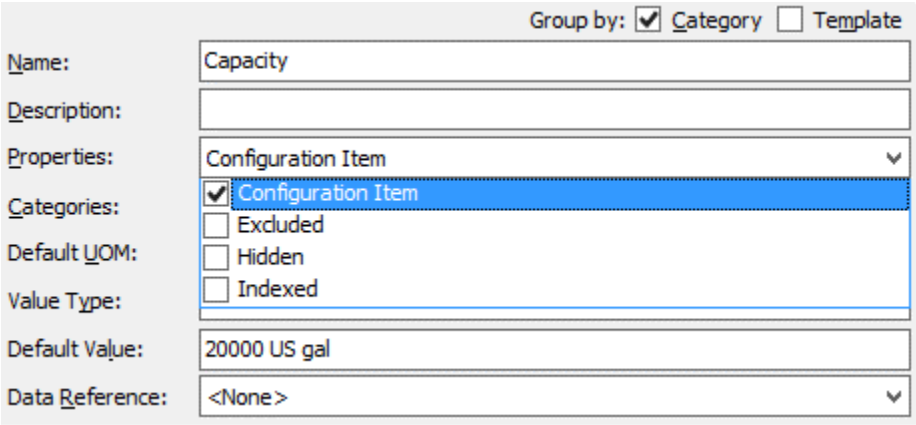
button next to the AF Server name.

4. The current connection is with pischool\student04. Note the effective identity permissions for pischool\student04 are (Interns | World)

5. Click on OK. Select the AF Startup database and verify the permissions on the tanks. Attempt to change descriptors for Tank01 and Tank02.

8.2 AF Attribute Properties

When attributes are created, there are four associated properties (configuration item, excluded, hidden, indexed). You have the option to set those properties for each element attribute. In case of an element derived from a template, the properties of the attributes cannot be changed any more except for the Exclude property:



Configuration Item	You assign the **Configuration Item** property to an attribute with a constant value that represents inherent properties of an asset (e.g. a device serial number). In PI System Explorer, configuration attributes are marked with a pencil icon (✎). When you change the attribute value of a configuration item PI System Explorer automatically checks out the attribute. To commit the change you need to Check In.
Indexed	**Indexed** attributes are attributes that are optimized for fast search results and fast value retrieval. You can only index attributes whose values are stored in the AF database. This means that you cannot index attributes that get their values from PI point data references or from linked table references.
Excluded (new in AF Server 2015)	In situations where not all attributes in an element template apply, attributes that are not applicable can be excluded. **Example**: only some of the tanks have a second container coating. Set the attribute for the material of the second coating to **Excluded** property for the tanks with a single coating.
Hidden (new in AF Server 2015)	The **Hidden** property is useful if an attribute is being used to hold an intermediate result, such as a table lookup result that can then be retrieved by a PI point data reference, or is being used solely to populate a tag name in a substitution parameter.

8.2.1 Directed Activity – Use of attribute properties

In this part of the class you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

Activity Objectives

- Assign properties for attributes for specific use cases.

Problem Description

The Capacity attribute for a tank is considered as a constant that represent an inherent property for the tanks at Velocity Terminals. The value will always be the same except for a change of the equipment itself. Capacity changes should require a Check-Out and Check-In sequence in AF.

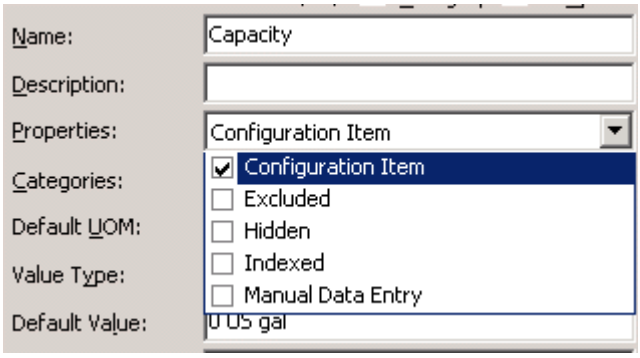
Only the first tank in every location of Velocity Terminals (Montreal, Sydney, Tokyo) has a dedicated night shift operator. Add attributes with the operator names, which should only exist for tanks Tank01, Tank05 and Tank08.

The tag name convention for process values at Velocity Terminals is the abbreviation ".PV" at the end of the tag name. The abbreviation should be defined in an AF attribute, but the attribute should not appear in PI Visualization Tools or in PI System Explorer Searches.

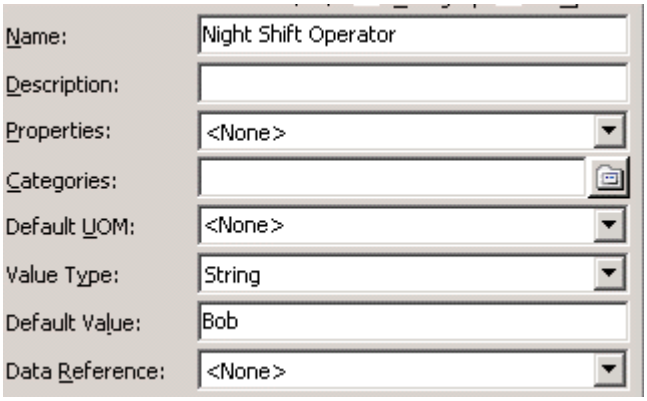
Approach

Open the **Velocity Terminals** database in AF and navigate to the Tank template in the Library. (Do not use the AF Startup database any more.)

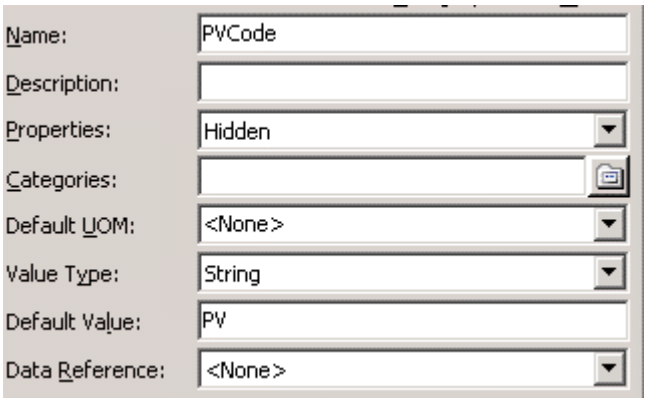
Select the *Capacity* attribute and enable the *Configuration Item* property



Add a *Night Shift Operator* attribute with Value Type String and Default Value *Bob*.



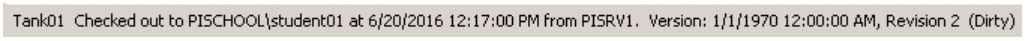
Add a *PVCode* attribute with Value Type String, enable the Hidden property and enter the Default Value *PV*.



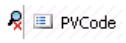
Check-In the new attributes.

Switch to elements and select *Tank01*. Change the *Capacity* from 20,000 to 22,000. Notice, that the Tank01 element has been checked out. It is marked accordingly in the Asset tree

. If you select the element PI System Explorer status line displays details of the checked out element:



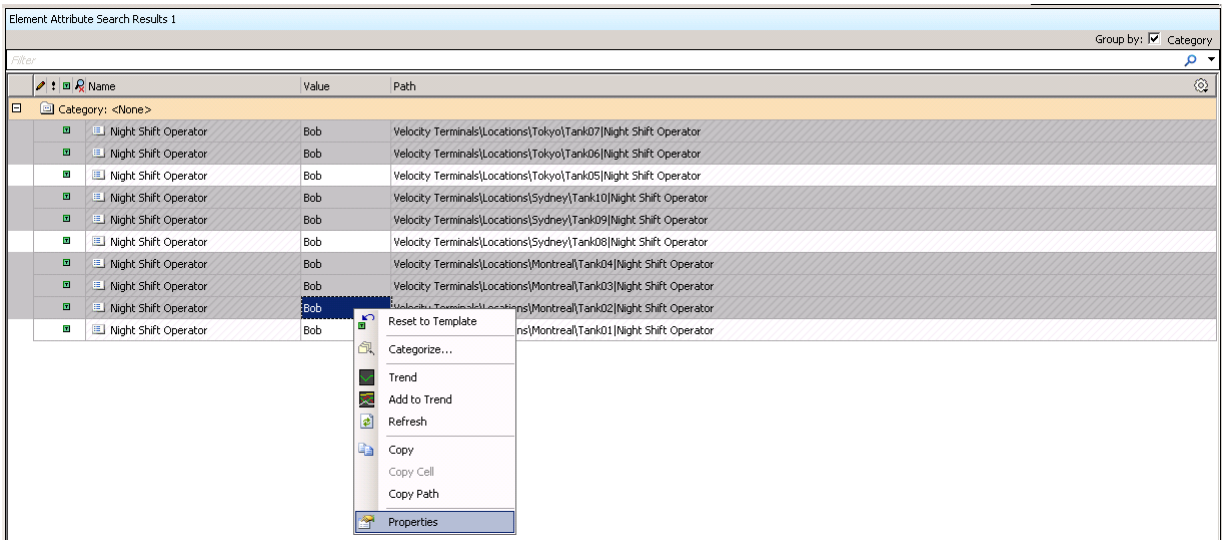
Click on Undo Checkout button in the toolbar to revert to the initial setting.

Notice that the *PVCode* attribute is marked as hidden 

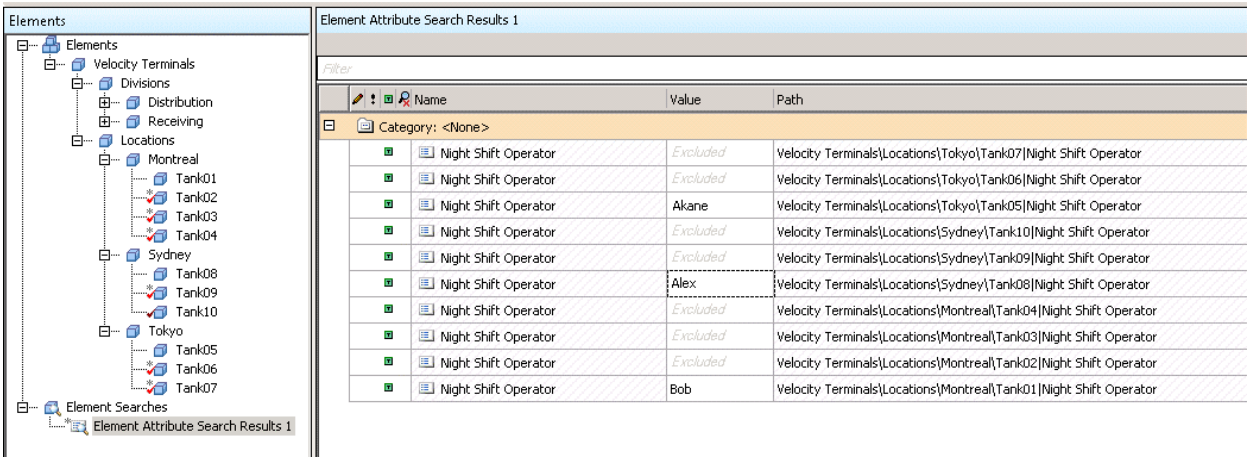
. Perform an attribute search (search > Attribute Search) for all attributes in Montreal that start with P*. PVCode is not returned.

Perform an attribute search for the *Night Shift Operator* attributes under Locations.

Select the lines for tanks without a Night Shift Operator (Tank02, Tank03, Tank04, Tank06, Tank07, Tank09, Tank10):



Select Properties and set **Excluded**. Click on OK. The change applies to all the selected attributes. Change the names for the first tanks in Tokyo (Akane) and Sydney (Alex):



Click on Check-In. Then click on Refresh. Now the search returns only the non-excluded attributes for Tank01, Tank05 and Tank08.

Select the tank elements individually and observe what is displayed for the *Night Shift Operator.*

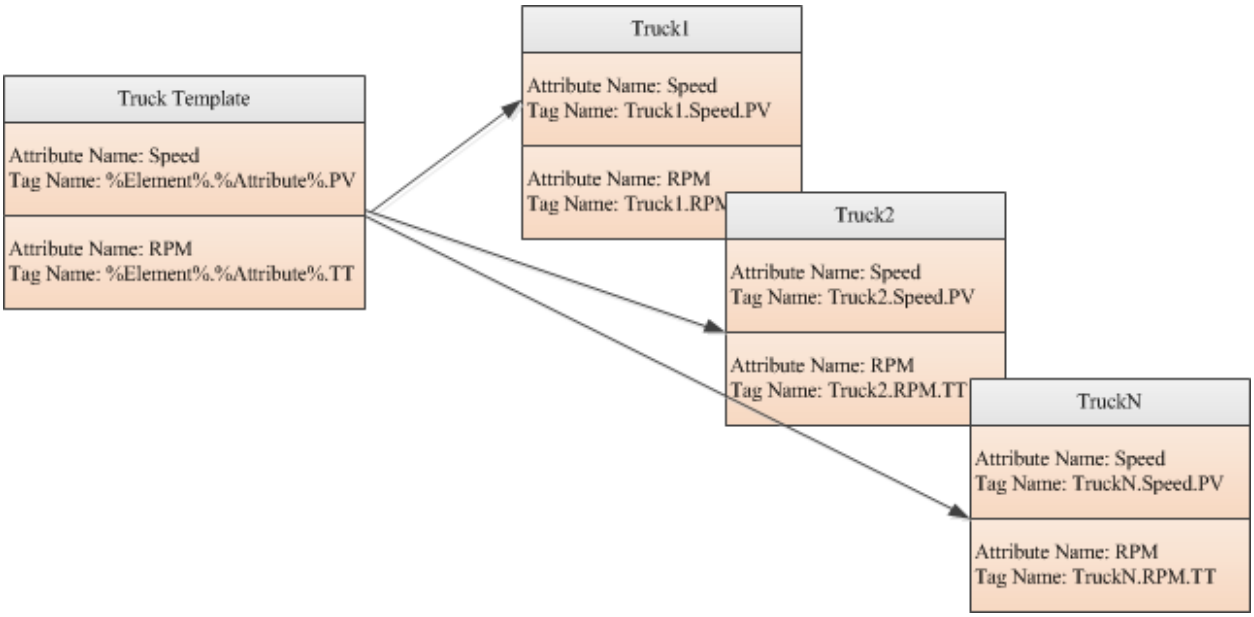
Under Tools > Options select the *General* tab and uncheck the Show Excluded Attributes option. Click OK. Select the tanks individually again and observe what is displayed now for the *Night Shift Operator.*

8.3 AF Advanced Template Design

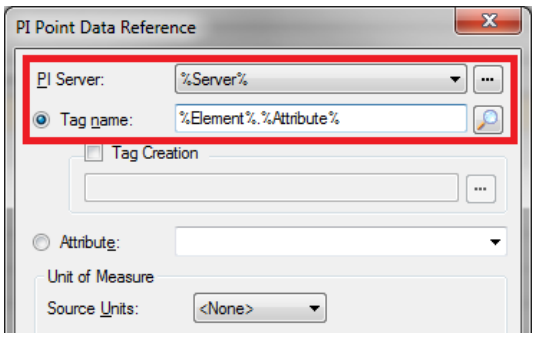
8.3.1 Substitution Parameters in an Attribute Template

Substitution parameters are variables that you place in attribute templates for PI point data references. AF resolves a substitution parameter when elements are created. As an example, the substitution parameter *%Element%* would resolve to the attribute's element name.

For example, in a truck template, the tag for the speed attribute is configured as *%Element%.%Attribute%.PV*. Once Truck1 is created from this template, AF would try to find a tag named *Truck1.Speed.PV*.



Notice the default configuration for a PI Point Data Reference attribute template: *\\%Server%\%Element%.%Attribute%.*



Substitution parameters can also be applied in Table Lookup and String Builder Data References.

8.3.2 Defining the Substitution Parameters

AF supports numerous substitution parameters, which can be used in attribute templates. The following table lists the ones most commonly used.

Parameter Name	Substitution
%Attribute%	Name of the attribute that holds this data reference.
%Description%	Description of the attribute that holds this data reference.
%Element%	Name of the element in which the attribute resides. For event frames, this refers to the name of the primary-referenced element.
%..\Element%	Name of the parent element of the element in which the attribute resides. To retrieve further ancestors, use the ..\ notation, such as %..\..\Element%.
%Server%	Name of the default Data Archive for the computer on which you create the attribute. The default Data Archive for the computer on which PSE is running. **Note**: The %Server% parameter does not resolve to the computer on which the AF database resides. The %Server% parameter can resolve to a different Data Archive depending on the default in AF Client.

The following table lists the substitution parameters that are useful for event frames naming patterns.

Parameter Name	Substitution
%EventFrame%	Name of the event frame in which the attribute resides.
%..\EventFrame%	Name of the parent event frame of the event frame in which the attribute resides. To retrieve further ancestors, use the ..\ notation such as %..\..\EventFrame%.
%StartTime%, %EndTime%	Local start or end time, if obtainable from the time context.
%UtcStartTime%, %UtcEndTime%	Coordinated universal (UTC) start or end time if it can be obtained from the time context.

See also Appendix A: Substitution Parameters at the end of the book. A helpful document for the use of substitution parameters is the **Guide to Substitution Syntax in AF-EF Data References**. It can be obtained from PI Square at https://pisquare.osisoft.com/thread/11188, copy is in the documentation class folder

8.3.3 Directed Activity – Substitution Parameters and Automatic Tag Creation

This solo or group activity is designed to maximize learning in a specific topic area. Your instructor will have instructions and will coach you if you need assistance during the activity.

Objectives

- Use AF attributes substitution parameters.
- Demonstrate automatic tag creation.

Problem Description

A new pressure transducer has been installed on every tank at Velocity Terminals. You have to add a pressure attribute to the tanks in your AF structure; however, the PI tags have not been created. Your colleague from instrumentation tells you that the tag configuration should be similar to a test tag he created a few weeks ago called MyPressureTag.

Velocity Terminals would like you to use a meaningful naming convention for the PI tags created as part of this project; they would like the tags to be named something like:

Montreal-Tank01.Pressure.PV

Since our company has sites globally, it is better to use International units for pressure (Bar)

Approach

Add a new attribute to the *Tank* template, name it *Pressure* and use *Bar* as the default UOM.

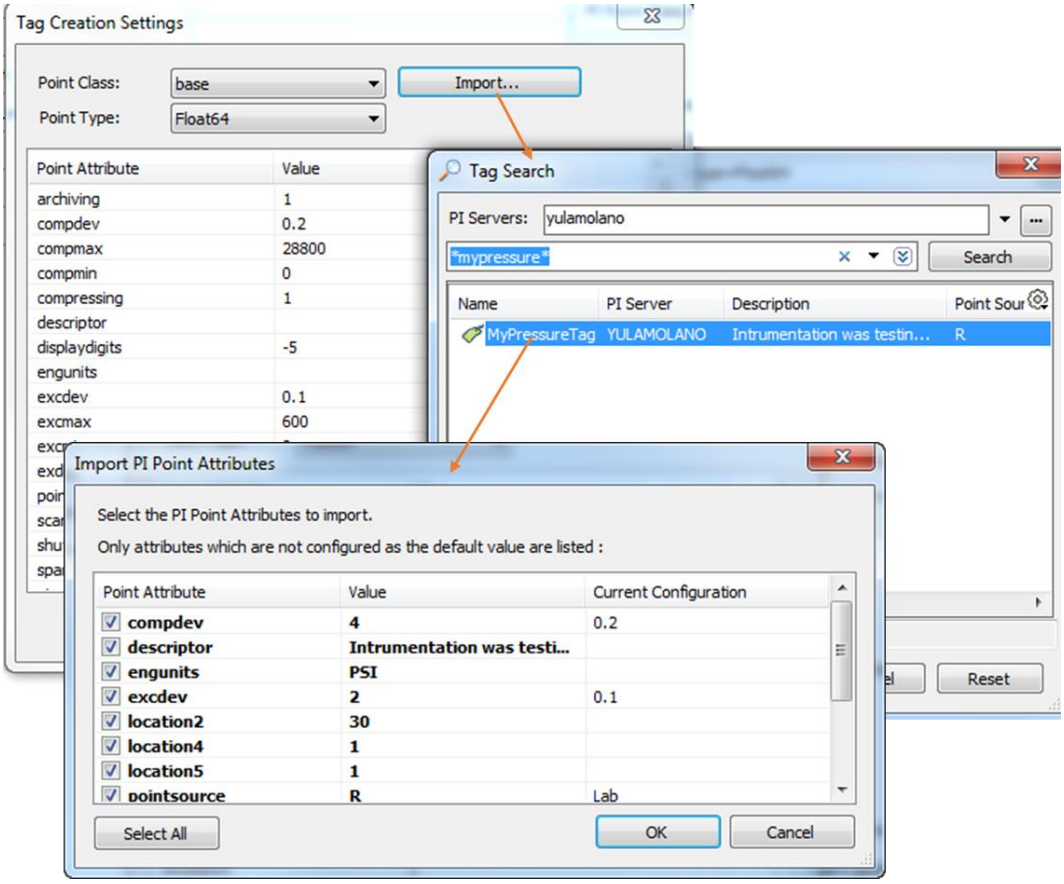
Select *PI Point* as the *Data Reference,* and click on *Settings* to configure it.

Under *Tag Name,* what should you write?

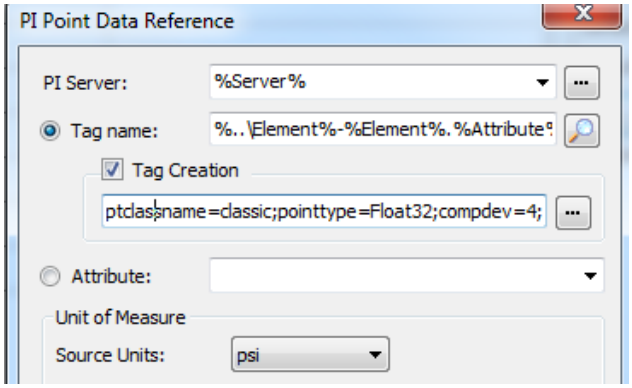
_____.

Since the tags have not been created, check *Tag Creation* and then the ellipsis (…). As your friend at instrumentation has already configured a tag to collect the pressure data, you may go ahead and import its settings (See figure below).

Tip: You could configure the tag settings (PointSource, InstrumentTag,Location codes, etc.) from the *Tag Creation Settings* dialog window; however, importing the settings of a working tag will save you some time.



You probably noticed that the tag's engineering units (engunits) were PSI. Since you want to display the attribute in AF in bars, you can take advantage of the on-the-fly-unit-conversion feature of AF. Select psi as the *Source Units*.



Check your tanks: what value is showing for your existing tanks?

_____.

What do you do to create the tags for the already existing tanks?

_____.

8.3.4 Advanced Substitution Parameters

Not only can substitution parameters resolve to the name of a AF object like an attribute, but also to the value of an attribute.

Imagine the Velocity Terminals example again. Imagine the tag names are always built the same way following this tag naming convention:

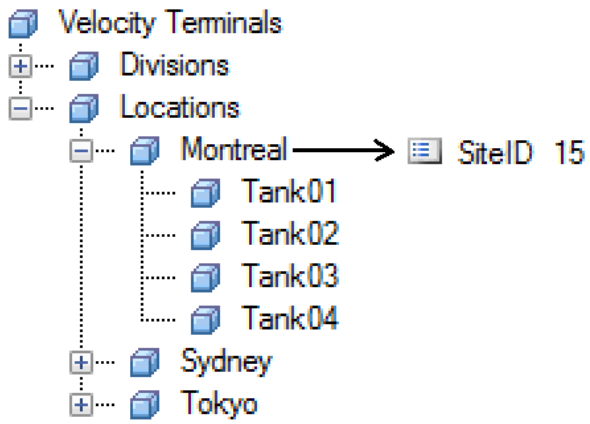
15Tank01**TS**.PV

LocationCode*EquipmentName****MeasurementType****.DataType*

Where

LocationCode	=	Code for the location (ex.: Montreal is 15)
Equipment Name	=	Equipment name (ex.: TANK01)
MeasurementType	=	Measurement type (ex.: TS for temperature sensor)
Data Type	=	Type of data (ex.: PV for process value)

This could lead us to determine that the Tank01's temperature would have its tag named *15TANK01TS.PV*. With that in mind, substitution parameters make it possible to configure the temperature attribute at the template level in such a way that any newly created tank in the AF hierarchy would automatically see its temperature mapped to the correct Data Archive tag. The idea here is to have all the required information somewhere in the structure so the attribute can reconstruct the tag name depending on where it is in the hierarchy. A solution to the above tag naming convention would simply be to add an ID attribute under the city name element.



Then, the level attribute could be built using the following configuration string:

\\%Server%\%@..\|SiteID%%Element%TS.PV

Reading a Substitution Parameter

The above *%@..\|SiteID%* substitution parameter can be read as: "Give me the value of the parent-element's SiteID attribute." In order to better understand the configuration string above, refer to the following table:

Symbol	Definition	Examples
%[…]%	Consider the expression as a substitution parameter.	**%**Element**%**, **%**Attribute**%**
.	Navigate a level down.	%@.\<ChildElement>|<Attribute>%
..	Navigate a level up.	%**..\..**\Element%, %**..**|Attribute%
\	References an element.	%..****Element%
|	References an attribute.	%..**|**Attribute%, %@**|**<Attribute>%
@	References the value of the object instead of its name.	%@..\..|<Attribute>%

8.3.5 Directed Activity – Using Substitution Parameters in a Template Attribute

In this part of the class, you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

Exercise Objectives

- Assemble substitution parameters to automatically map Data Archive tags to AF attributes.

Problem Description

Velocity Terminals will buy other facilities in the next few months where multiple tanks are present. They are going to implement the same tag naming convention at those new locations and will want to save time when adding those extra assets to the actual AF hierarchy.

They want to use the substitution parameters to speed up the creation of additional assets in AF. To demonstrate that this is feasible, you are asked to add a new temperature attribute template to the Tank's template so that it uses substitution parameters to automatically find the correct PI tag.

Looking again on the Velocity Terminals portal, you find the below table in a spreadsheet:

Site	SiteID
Montreal	15
Sydney	23
Tokyo	44

Approach

1. Create an attribute under each location to display its ID (hint: you may want to use the site template along with a table and a table lookup data reference).
2. Add a temperature attribute to the tank template. Use substitution parameters so that the tag names are automatically built according to the expected tag naming convention.
3. Validate the new configuration string by browsing the tanks.

Extra Bonus point

Add an (hidden) attribute to the tank template that displays the PI Point name of tank temperature. Use String Builder to assemble the tag name. Apply the Hidden attribute.

Note: When referring attribute values there are differences between substitution parameters used in PI Point Data References and the syntax in the String Builder.
%@..\|SiteID% works in the PI point reference but has to be '..\|SiteID' instead for the String Builder.
For more information refer to "String Builder data references" in Chapter "Configuration of data references" in the PI System Explorer User Guide, version 2015, p. 124 ff.

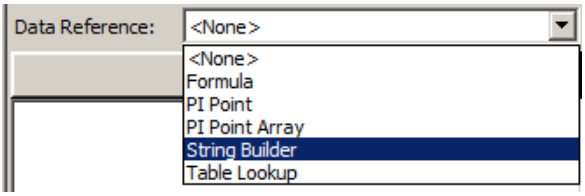
8.3.6 The String Builder Data Reference

The *String Builder* data reference allows you to use substitution parameters and functions to manipulate values and output a string.

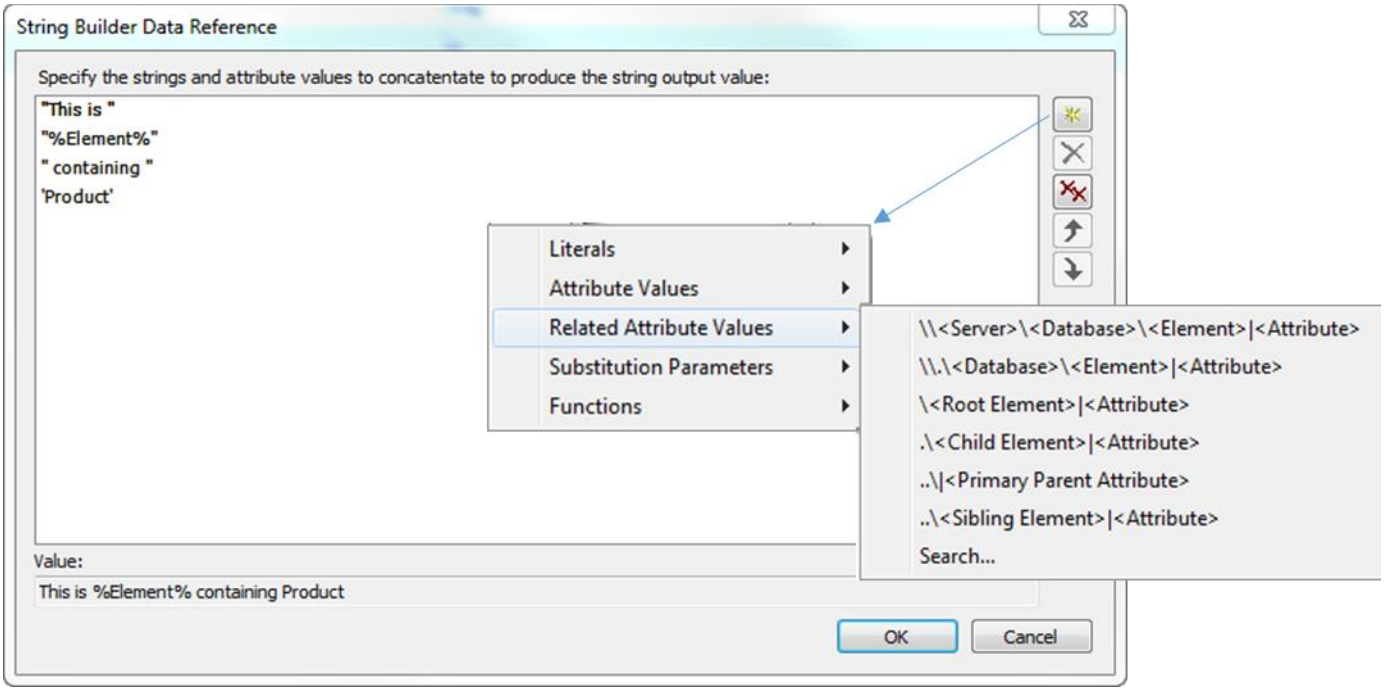
Below some cases where the *String Builder* data reference is useful:

- ✓ Concatenate strings (Element Name + Attribute Name + Value).
- ✓ Format dates and numbers.
- ✓ Build paths to elements and attributes.
- ✓ Parse comments from operators stored in PI tags.
- ✓ Display element information as an attribute.

Note: Since this data reference supports substitution parameters, when used in a template, value substitutions takes place at run time.



String Builder allows you to manipulate strings located anywhere in your hierarchy by using the *Related Attribute Values* contextual menu (see figure below).



8.3.7 Exercise– Using the String Builder Data Reference

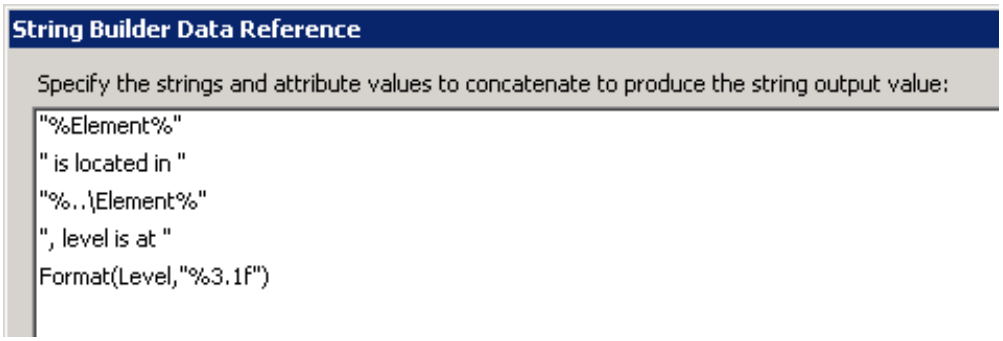
This solo or group exercise is designed to maximize learning in a specific topic area. Your instructor will have instructions, and will coach you if you need assistance during the exercise.

Create a new attribute with information in a string like the following:

```
Tank01 is located in Montreal, level is at 99.8%
```

Approach

1. From the Navigator Panel, select the *Library* section. Open the **Tank** element template.
2. Add the **Tank Level Information** attribute, value type= String, Data Reference= String Builder.
3. Use the String Builder Data Reference dialog box to construct the string



Note 1: to display the level value in the requested format (one digit after the decimal point), use the *Format (real,format)* function in String Builder. Format follows Performance Equation (PE) style syntax, e.g.: `"%3.1f".` The number before the decimal indicates the minimum total number of characters to output, pre-padding with blanks, the number after the decimal indicates the number of digits to display after the decimal point.

Note 2: You can construct an expression on a single line, using semicolons to separate its terms. But you can also place each term on its own line, which eliminates the semicolons and makes the expression structure more apparent (see above).

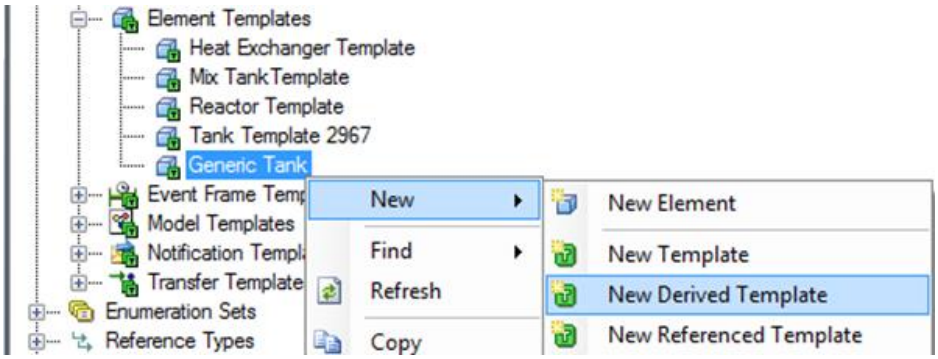
4. Switch to one of the tank elements and verify the attribute string as desired. If required, correct the String Builder definition.
5. Click on Check-In

8.3.8 Template Inheritance and Base Template

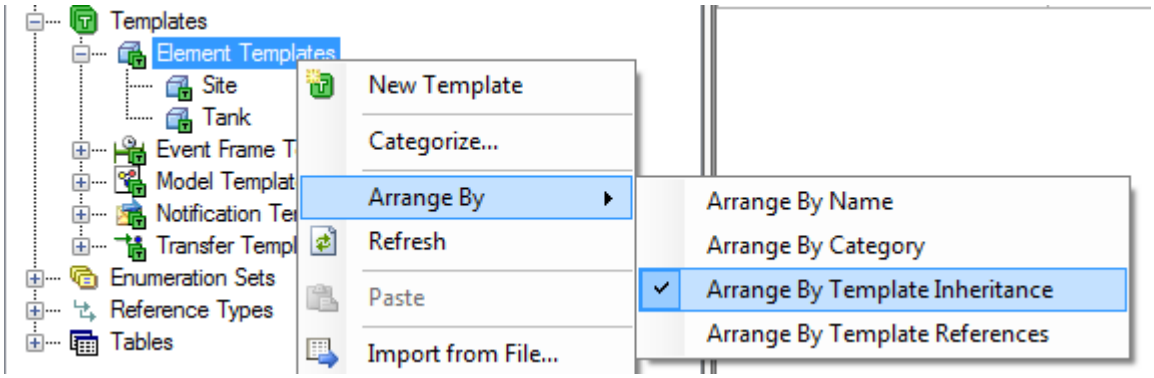
A powerful feature of the element template is the ability to set a base template. Once a base template is created, it can be used to create a number of derived templates. When an element is created from a derived template, the element contains all attributes from both the base template and the derived template.

- An element created from the Tank element template has three attributes: Diameter, Height and Fill Level.
- An element created from the Mixing Tank element template has five attributes: Diameter, Height, Fill Level, Mixer Speed and Mixer Blade Size

A base template is best used when you are modeling elements that have a set of attributes in common with a few attributes that differ. For example, if you have a set of tanks, some with two valves and some with one valve, you can create an element template for the one-valve models and use that as the base template for the two-valve models. Set the base template of an element template in the *General* tab; alternatively, you can set the base template at creation time by right clicking the base template and select *New Derived Template*.



To view the template inheritance tree from the PSE Library, simply organized the templates by inheritance.



8.3.9 Directed Activity – Working with derived element templates

In this part of the class, you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

Activity Objectives

- Create a derived template for a special tank that has an additional sensor for CO2 measurement
- Use a derived template to accommodate a different PI Point reference for the Level attribute in a special tank.

Two modifications were done on Tank10, which means that the tank deviates from the normal ones on the following details:

- There is an additional sensor for CO2 measurement. The tag name is: **Tank10CO2.PV**

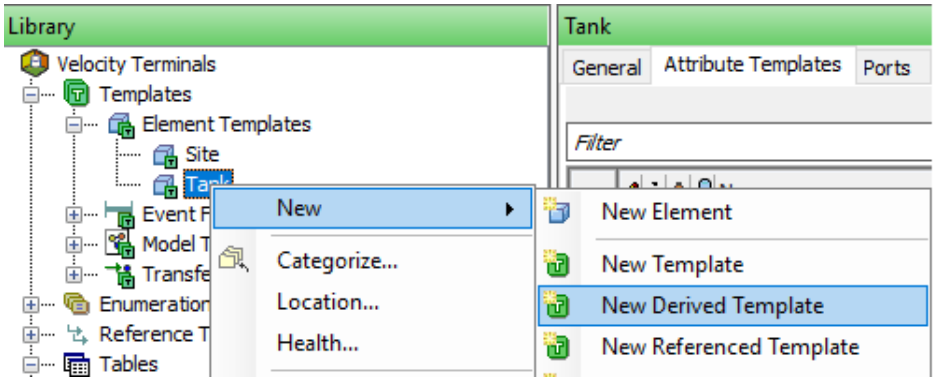
- The name for the Level sensor is different now. Instead of Tank10LI.PV the name is **Tank10LEVEL.PV**

  This means the name does not follow the normal name pattern %Element%LI.PV. Instead the name pattern is %Element%Level.

Approach

Create an element template for a Special Tank that has an additional sensor and a different naming pattern for the Level attribute.

1. Open the Tank template in the Library of the Velocity Terminals database.
2. From the Tank template context menu and select *New Derived Template*



3. Rename the new element template to **Special Tank**.

Additional Attribute for CO2 (PI Point: Tank10CO2.PV)

4. On the *Attributes Templates* tab, add a new attribute template **CO2**:

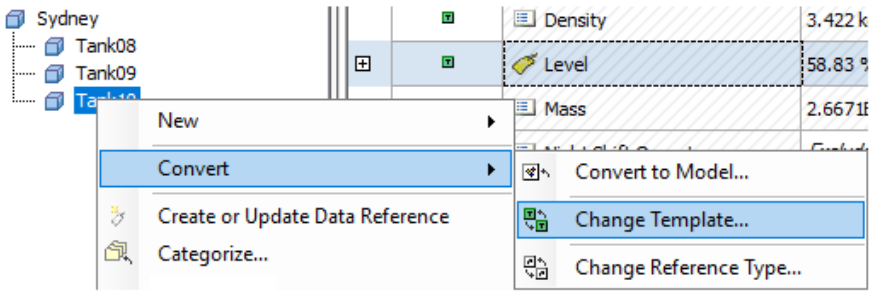
   Default UOM = percent (Ratio)
   Value Type= Double
   DisplayDigits=2
   Data Reference = PI Point

5. Click on *Settings…* to enter the PI Point name. Use substitution parameters to define a standard naming pattern based on the element and the attribute name. Make use of the PVCode attribute string. What do you write?

   _____

6. Change the Source Unit from **<Default> (%)** to **%.**

7. In the Navigator, switch to Elements. Select Tank10 and change the template from **Tank** to **Special Tank**.



8. Verify the Tank10 has the CO2 attribute, the value is from PI Point Tank10CO2.PV.

Attribute Overwrite for Level (PI Point: Tank10LEVEL.PV)

9. On the *Attributes Templates* tab, add a new attribute template **Level** :

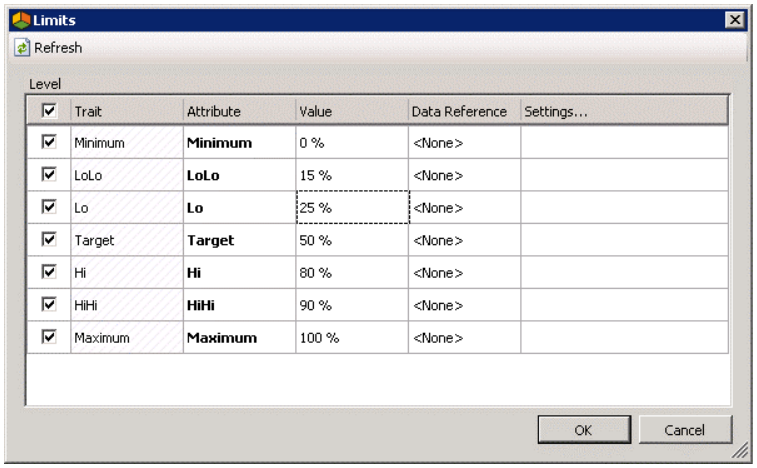
   Default UOM = percent (Ratio)
   Value Type= Double
   DisplayDigits=2
   Data Reference = PI Point

10. Click on *Settings…* to enter the PI Point name. Use substitution parameters to define the different naming pattern based on the element and the attribute name. Make use of the PVCode attribute string.

What do you write?

_____

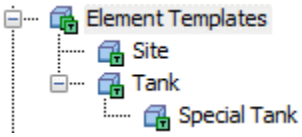
11. Change the Source Unit from **<Default> (%)** to **%.**
12. To define the limits, select the Level attribute and click on *Limits…*in the context menu. Set the limits in the same way as for the normal tank:



13. In the Navigator, switch to Elements. Select Tank10 and verify the PI Point for the Level attribute of Tank10 is Tank10Level.PV
14. Check-In your changes.

Show element templates based on inheritance

15. Open the Element Templates in the Library of the Velocity Terminals. From the context menu, select *Arrange By > Arrange By Template Inheritance*. Result: Special Tank is shown below Tank.



8.3.10 Exercise – ABC Mining Company and Advanced Template Design (optional)

This solo or group exercise is designed to maximize learning in a specific topic area. Your instructor will have instructions, and will coach you if you need assistance during the exercise.

Exercise Objectives

- Design Templates for AF, which use template inheritance.
- Create elements, which use PI Point Data and Formula Data References from these templates.

Problem Description

You are installing a Data Archive and AF Server for ABC Mining Company and you are currently focusing on their truck fleet.

ABC Mining Company has eight (8) mining trucks:

ID	Model	License Plate Number	Gas Tank Capacity
SP1	Mining Car	CA HYK427	210 US Gallons
SP2	Mining Car	CA HRZ648	210 US Gallons
SP3	Mining Car	CA HBB139	210 US Gallons
SP4	Super Carry	CA HAR990	317 US Gallons
SP5	Super Carry	CA HEED21	317 US Gallons
SP6	Super Carry	CA HQB932	317 US Gallons
SP7	Mine Runner	CA HOT263	500 US Gallons
SP8	Mine Runner	CA HEE563	500 US Gallons

All of the mining trucks have some common measurements:

Measurement	Units	Data Archive Tag
Tripmeter (miles since last fill up)	Mile	SP1.Trip, SP2.Trip … SP8.Trip
Gas Tank Level	Gallon	SP1.GasLvl, SP2.GasLvl … SP8.GasLvl
Oil Level	liters	SP1.OilLvl, SP2.OilLvl … SP8.OilLvl
Tire Pressure	psi	SP1.TireP, SP2.TireP … SP8.TireP

These measurements are sent back to the scheduling department with real-time updates via radio.

The Super Carry trucks and the Mine Runner vehicles capture additional data:

Measurement	Units	Data Archive Tag
GPS – Longitude	Seconds (“)	SP5.GPSLong… SP8.GPSLong
GPS – Latitude	Seconds (“)	SP5.GPSLat… SP8.GPSLat

The GPS readings are in **Seconds (“)** (from the Plane Angle UOM Class, where there is a relation between degree, minutes and seconds). The degrees and minutes are assumed.

ABC Mining Company wants the **Fuel Efficiency** in miles per gallon (MPG) (double) for every delivery vehicle.

Your task is to configure the templates, elements, and attributes required to support ABC Mining Company truck fleet monitoring system.

Approach

1. Use *Import from File…* to import the **Truck Identification** and the **Truck Model Specifications** tables. The XML files are located C:\Class\Exercises\03_ABCMiningCompany

2. Create an element template **General Truck** for the trucks without GPS.

3. Create an element named **SP1** based on the template just created.

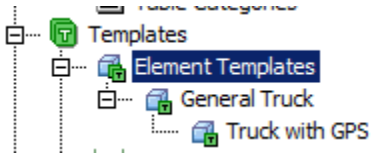
4. Create another element, named **SP2,** based on the template just created.

5. Define the attributes for the four measurements (Tripmeter, Gas Tank Level, Oil Level, Tire Pressure) in the **General Truck** template. Verify in SP1 and SP2 that data is received from the right points.

6. Define the attributes for the data you can read out of the **Truck Identification** table (License Plate, Model).

7. Define the attributes for the data you can read out of the **Truck Model Specifications** table based on the model of the truck (Gas Tank Capacity, Nominal Oil Level, Nominal Tire Pressure).

8. Create a derived element template **Truck with GPS** for the trucks with GPS (Super Carry, Mine Runner)



9. Define the attributes for the GPS measurements (GPS Latitude, GPS Longitude) in the **Truck with GPS** template.

10. Use PI Builder to create elements for the remaining trucks in bulk. Verify the attributes for the trucks are correct.

	A	B	C	D	E
1	**Selected(x)**	**Parent**	**Name**	**ObjectType**	**Template**
2			SP1	Element	General Truck
3			SP2	Element	General Truck
4	x		SP3	Element	General Truck
5	x		SP4	Element	Truck with GPS
6	x		SP5	Element	Truck with GPS
7	x		SP6	Element	Truck with GPS
8	x		SP7	Element	Truck with GPS
9	x		SP8	Element	Truck with GPS

11. Categorize the attributes by grouping them in categories and display them in those groups by checking the Group by: ☑ Category checkbox in the upper right corner of the attribute Configuration Panel.

Category	Attributes
Gas Tank	Gas Tank Capacity, Gas tank Level
Identification	License Plate, Model
Oil	Actual Oil Level, Nominal Oil Level
Tire Pressure	Actual Tire Pressure, Nominal Tire Pressure
Trip Data	Trip Meter

12. Add a new UOM class **Fuel Efficiency** that has unit-of-measure MPG as its canonical unit.

13. Add an attribute for the **Fuel Efficiency**, Data Reference= Formula. For the Fuel Efficiency calculation, the mileage since fill-up and the current gas level are reported, so the mpg (miles per gallon) can be calculated.
Hint: Formula: Tripmeter / (Gas Tank Capacity – Gas Tank Level)

14. (Optional) Also produce the Range calculation in miles for each vehicle (fuel efficiency * remaining fuel).

15. (Optional) Add a further unit-of-measure *Liter per 100 km* (abbreviation: *l/100km*) with following formulas:
    MPG = 235 / l/100km
    l/100km = 235 / MPG
    Display the Fuel Efficiency in liters per hundred kilometers ***(****L/100 km****).*** In order to convert from MPG, the Formula option will be used when specifying the conversion).

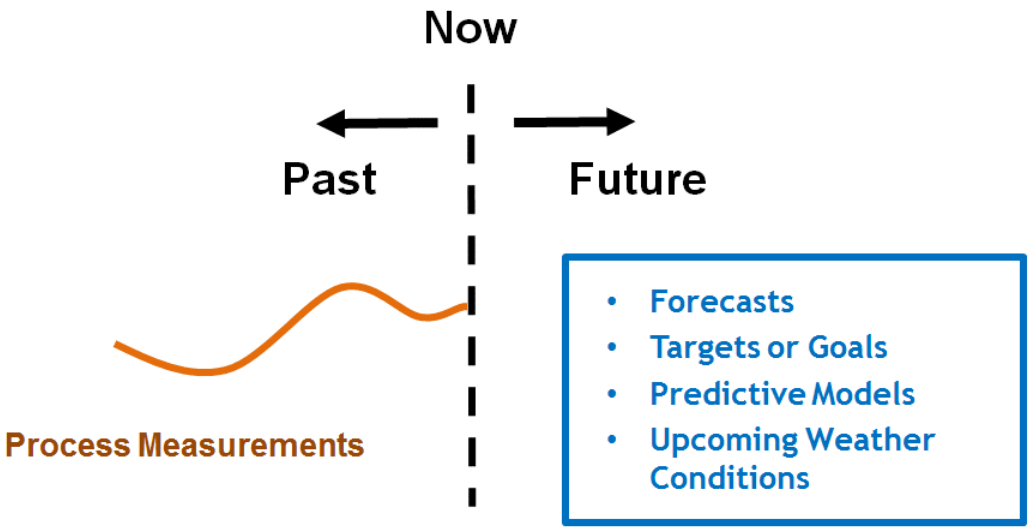
Try to do this exercise on your own before referring to the exercise solutions section at the end of the book.

About Attribute Categories

Categories can be used to group AF objects like elements, attributes, or tables together to facilitate the administration of those objects. To add an attribute to a category, simply select one or more categories from the Categories field of the attribute's Configuration Panel, or alternatively write the category name. If that category does not exist yet, a prompt will be shown to ask if this category should be created.

8.4 AF and Future Data (optional)

Data Archive 2015 introduces the ability to store future data, which allows to handle data with timestamps up until January 2038. January 1970 remains the past limit for all tags.



Future tags should be used when storing data that is not collected sequentially in chronological order. For example, process or operational data should be kept in historical tags because it is measured and collected in real time. On the other hand, forecasts or any form of predictive data over an arbitrary time range are perfectly suited for future tags.

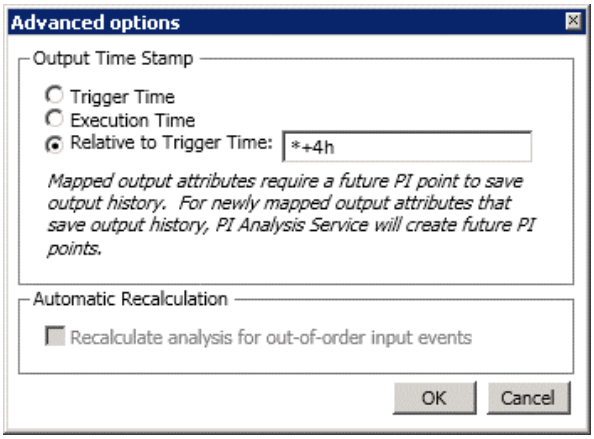
Future data and analyses

You can use future data as input to an analysis. You can also use an analysis to produce future data by specifying a future time stamp for the output from an analysis.

8.4.1 Advanced Configuration Options (new with Analysis Service 2015)

For any scheduled analysis, the default timestamp for output values is the trigger time. For periodic scheduling, the trigger time is the scheduled evaluation time, and for event-triggered scheduling, the trigger time is the time that a specified attribute changes values.

Using Advanced Option, you can specify the timestamp of analysis output values.



Option	Behavior
Trigger Time	Default value. The clock time that a schedule specifies or that an input value changes.
Execution Time	The clock time at which the analysis calculates the value.
Relative to Trigger Time:	A time specified by a PI time expression. Enter a valid time expression, such as a time relative to the trigger time or a fixed time. A relative time in the future will create events with timestamp in the future. For mapped output points this requires a future PI point (available for Data Archive 2015).
Automatic Recalculation	In case you expect that data from your inputs will be late-arriving or be out-of-order, you can request automatic recalculation for an analysis. The Management list allows to set this option for multiple analyses within one command.

When can the *Relative to Trigger Time* option be useful?

You need a daily summary for the raw material consumption in the plant for 24 hour periods (yesterday midnight – midnight today). Asset Analytics is used to calculate the sum. However, due to the operation in the plant it is not possible to have all the required input data ready with a delay of 10 - 15 minutes. With a scheduled daily execution at 12:15AM for the analysis the *Relative to Trigger Time* option is set T (today midnight) so the output result gets stamped at midnight (even though the summary is done 15 minutes later).

8.4.2 Directed Activity – AF Attributes with future data (optional)

In this part of the class, you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

Activity Objectives

- Create attributes which refer to tag with future data.
- Use Asset Analytics to calculate forecast data.
- Explore the display of AF attribute values with future timestamps in PI Processbook.

Problem Description

The amount of material, which is delivered by the trucks of the ABC Mining Company from the mine to the train station for further transportation, is tracked in order to compare it against a target production plan. The cumulative daily total of material that has been delivered by the mine trucks is reported into tags *SP?.Load* every 4 hours. The production management department of the ABC Mining Company calculates expected loads for next four hours, which are provided in tags *SP?.LoadSim.*

Your task is to calculate the cumulative material for end of the coming four-hour period. These calculations should be stored into future tags *SP?.DeliveryPlan* in order to do a comparison on a per truck basis between the actual delivered material and the corresponding forecasted deliveries.

Approach

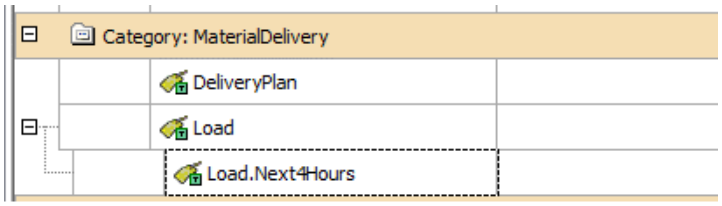
Follow the instructor as he or she performs steps to simulate plan data creation and to create AF attributes in the *General Truck* template that will lead to the corresponding visualization in a PI Processbook display.

Plan Data Creation

Using AF Analytics, we will calculate a new forecast for the load delivery every four hours by adding the expected load for the next four hours to the current load of the truck.

Attribute Creation for General Truck template

- In System Explorer, select the Library section, and open the General Truck template in the Element Templates section.
- Select the Attribute Templates tab on the right hand side. To segregate these three attributes from the remaining ones, add an attribute category of Material Delivery.
- Configure the attributes per the table below. The *Load.Next4Hours* attribute should be a child element for the *Load* attribute:



Attribute Name	Default UOM	Value Type	Data Reference	Setting
Load	ton (Mass)	Double	PI Point	%Element%.%Attribute%
Load.Next4Hours	ton (Mass)	Double	PI Point	%Element%.LoadSim
Delivery Plan	ton (Mass)	Double	PI Point	%Element%. DeliveryPlan

For the attribute category set to **Material Delivery** in all cases.

Load:

The actual cumulative truck load (on a per Day basis)

Load.Next4Hours:

The expected load for the next 4 hours

Delivery Plan:

The forecasted cumulative truck load (on a per day basis)

Calculate the expected load for the next 4 hours

- In System Explorer, select the Library section, and open the General Truck template in the Element Templates section.

- Select the Analysis Templates tab on the right hand side and create new analysis template *Load Delivery Forecast* (Expression type).

  The following calculation rules apply:

Calculation Time	Calculation	Result Timestamp
00:00:00	Initial Forecast for the day is the expected load for the next four hours	04:00:00
04:00:00, 08:00:00, etc. until 16:00:00	Forecast is the actual Load plus the expected load for the next four hours	08:00:00, 12:00:00, etc. until 20:00:00
20:00:00	As the accumulation is on a per day basis, the value is reset to 0 at midnight.	00:00:00

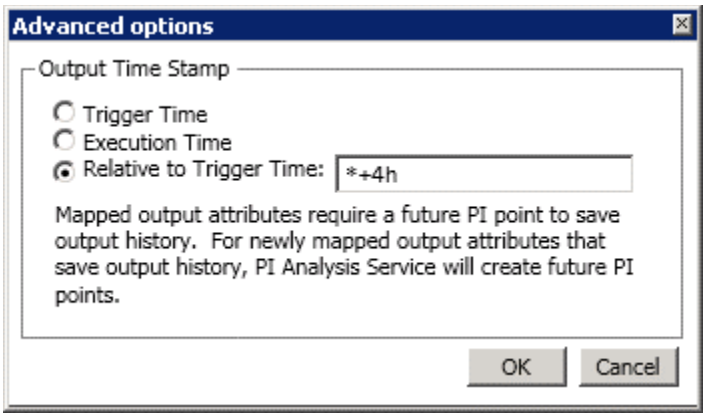
  How does your expression look like?

  _____.

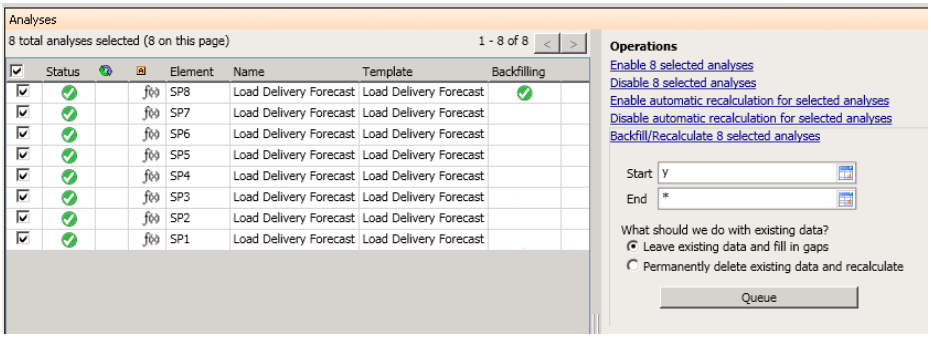
- Set Output Attribute to *Delivery Plan*.

- We want to do our calculation every 4 hours, and the result will be written with a timestamp that is four hours into future. Set Scheduling to *Periodic*. Click *Configure* to set a four-hour interval. Do not specify an offset, so the calculation is performed at the full hour.

  To write the results with a future timestamp, select *Advanced…* and set *Relative to Trigger Time* to **+4h.* Check in.

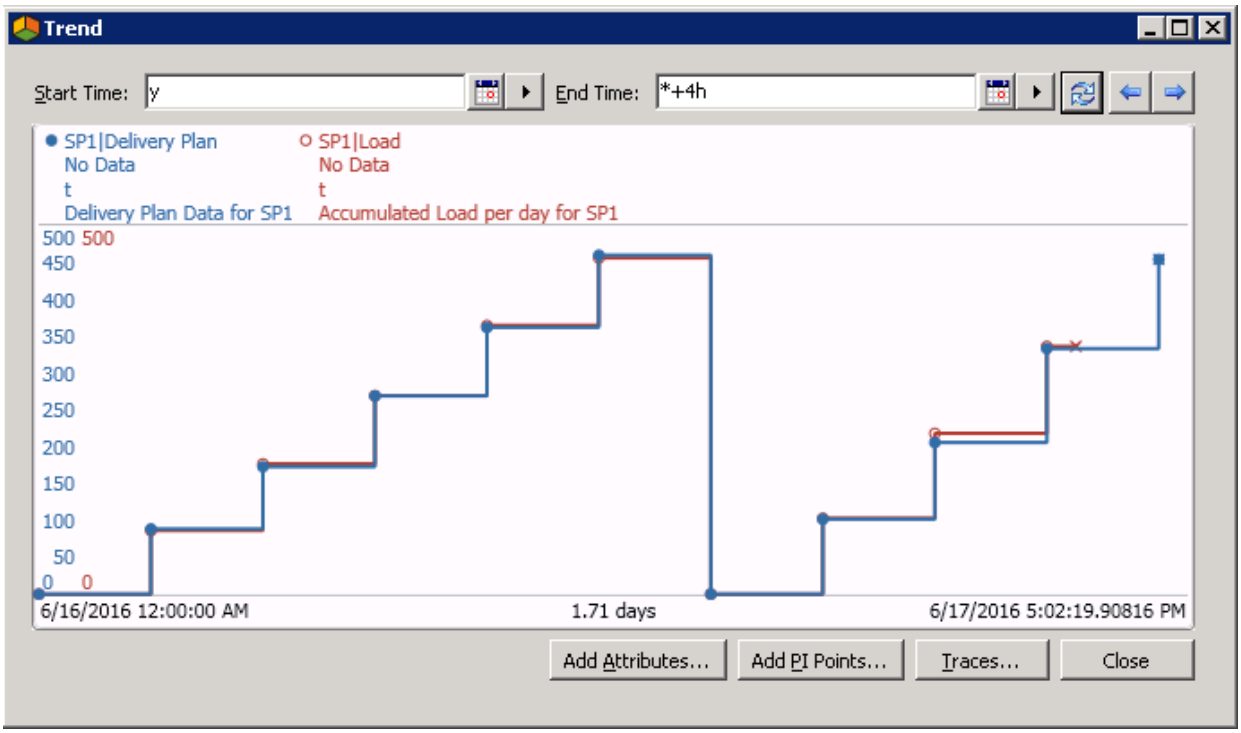


- In the Navigator pane, select Management to list all analyses for the 8 trucks.
- Enable checkbox in the top row to select all analyses. Select *Backfill checked analyses* operation. Set start to y and end to *. Then click on Queue to start the backfill process.



After the backfilling is completed, verify the results as follows:

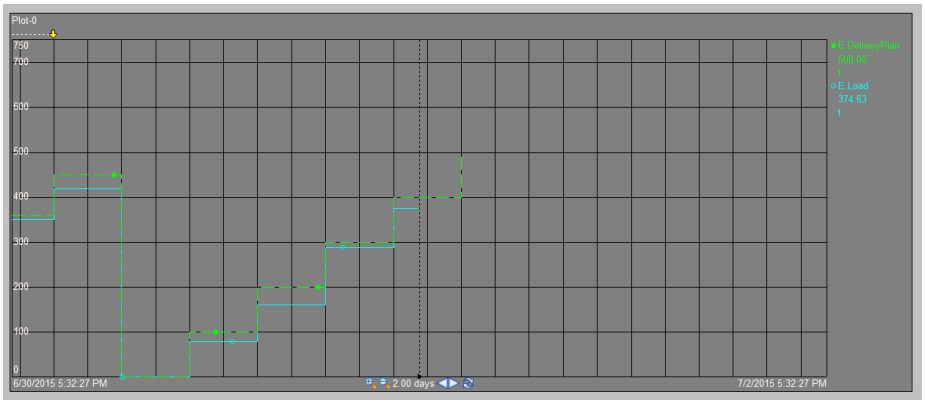
- Open one of the trucks under the Elements of the ABC Mining Company database.
- Select the lines with the *Delivery Plan* and the *Load* attribute and select Trend from the right-mouse button context menu.
- Set Start Time= *y* and End Time= **+4h* and click on Refresh button. Verify the trend curve with the forecast values:



Tip: For some trucks, actual Load and corresponding plan data value can be very close together. You can zoom into the trend by dragging a rectangle. To revert to initial scaling, click on the Refresh button.

8.4.3 Display of Attributes with future and historical data in Processbook (optional)

- Open the *ABC Mining Trucks Material Delivery.PDI* file (located in the class\exercises folder) in Processbook.
- Under View of the Processbook menu, enable *Element Relative Display* to open the *Element Relative Display* window pane.
- Click on the Find and Add New Element Contexts button to open the Element Search dialog.
- Select the *ABC Mining Company* AF database and search for the trucks with the name search pattern *SP**.
- Select the eight trucks *SP1 – SP8* from the search results list and click on OK.
- Select one of the trucks. The trend displays the data for a time period from 24 hours back into the past until 24 hours into the future:



9. Communicating Important Events

Notifications, which is a feature in Asset Framework, allows alerts to users in real time about conditions in their system that need specific attention. Corresponding actions can be taken to be pro-active or to resolve the problem of the current situation. The information is either sent via email or is passed onto a Web Service.

The recipients for the notifications ("subscribers") have the option to acknowledge notifications. In case a situation, that requires action, is not acknowledged in time, notifications can be sent out again.

Examples for the use of notifications are:

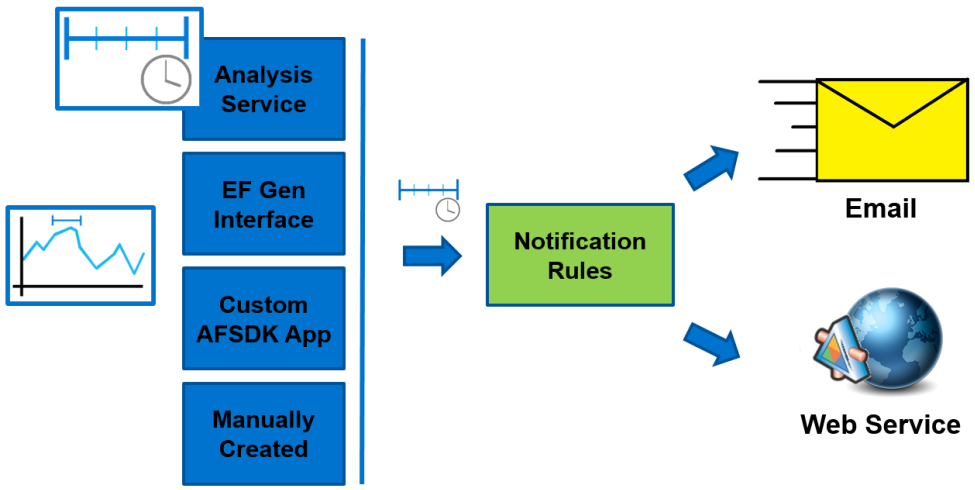
- Temperature is outside the normal range
- Equipment is shutdown
- Runtime counters have elapsed indicating a maintenance is required
- Amount of supply material is below a critical minimum level

Note: Notifications have been revised in the AF 2016 R2 version. In previous versions, there was a different concept for the Notifications, which is now referred to as "Legacy Notifications". When upgrading the PI System to 2016 R2, existing legacy notifications can be migrated to the new concept using a dedicated migration tool.

9.1 Introducing Notifications

With AF 2016 R2, notifications are triggered when new Event Frames are generated in AF. Conditions for the trigger are defined in notification rules.

The event frames generation may be related to different sources. It can be performed by asset analytics, by an Event Frame Generator (EFGen) interface, by a custom AF SDK application or a manual creation.



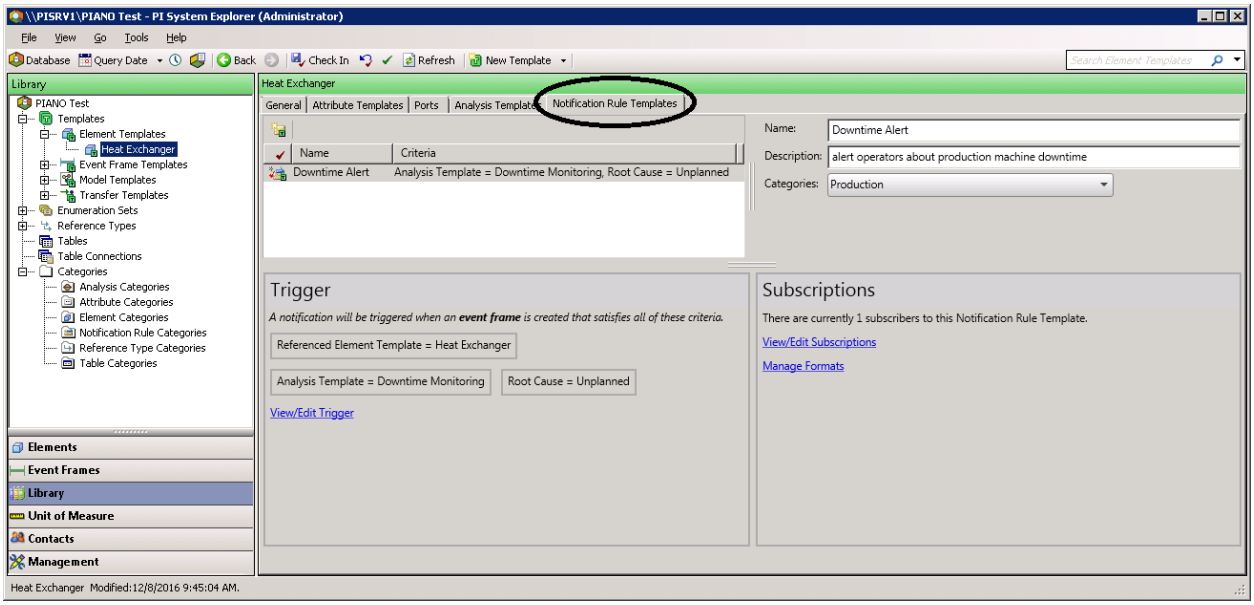
9.1.1 Notification Components

PI Notifications Service

The PI Notifications Service processes event frames defined in the Asset Framework (AF) in real-time and sends out email and web service notifications. The service is installed from the AF Server 2016 R2 Install Kit.

Notification Rule tab (PI System Explorer)

Notification Rules can be defined for individual elements or be created as a template. The User Interface for configuring notification rules in PI System Explorer is in a dedicated tab on elements and element templates:

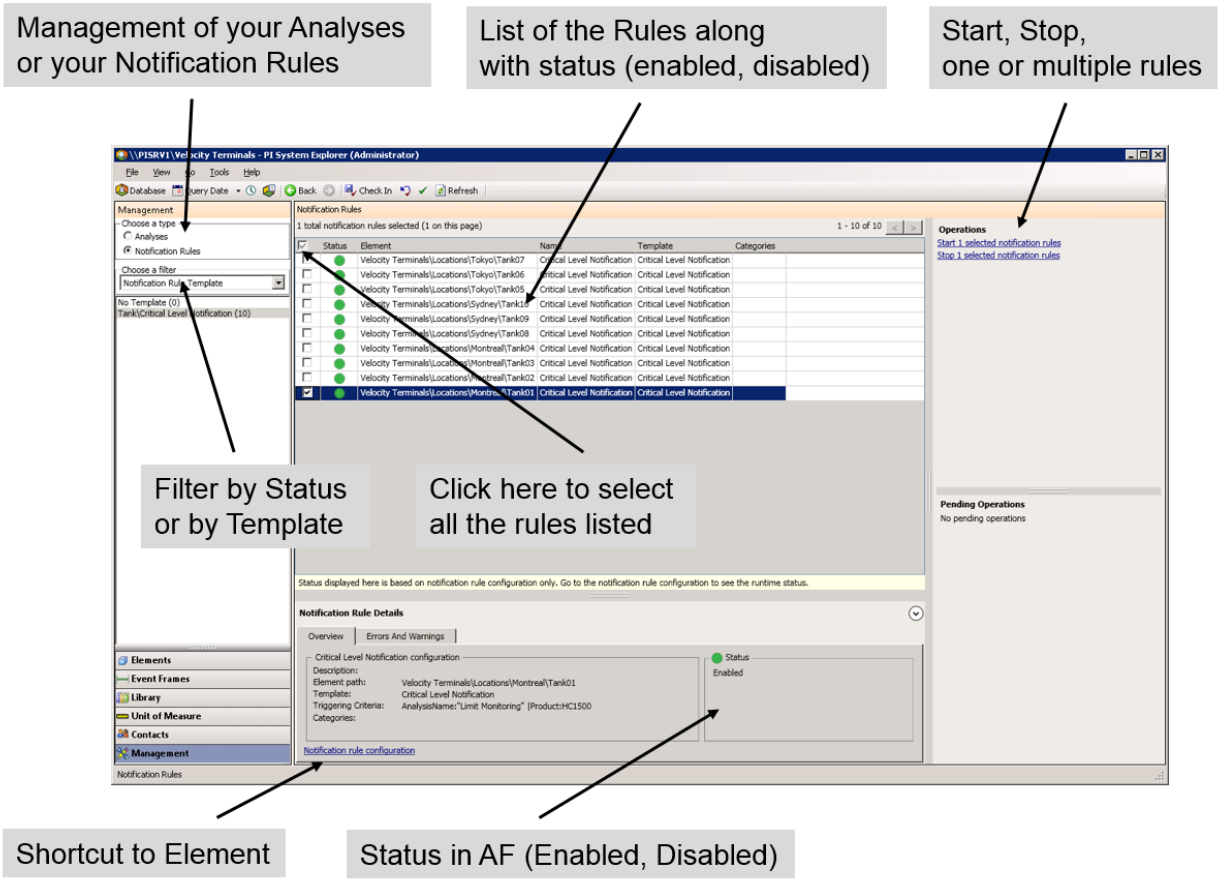


Note: There is no entry for Notifications in the PI System Explorer Navigator (bottom left corner) any more.

The definition includes the trigger criteria, adding subscribers to the notification rule, and formatting the message to suit the needs of your organization.

Management Plug-In (PI System Explorer)

- Allows management of analyses and notification rules on the AF Server.



9.2 Delivering the Events

Notifications *Delivery Channels* provide for the mechanism by which alerts are delivered to subscribers. With the standard installation of Notifications, the following delivery channels are available:

- Email

  Email delivery channel supports sending emails with notification alerts via an SMTP Mail Server.

- Web Service

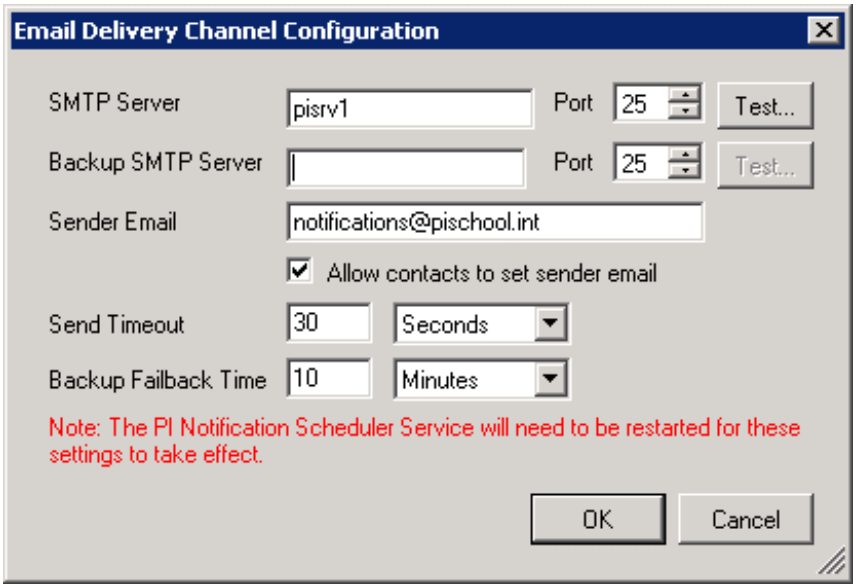
  Web service channel supports providing information to a web service by calling one of its methods.

Note: Legacy Notifications in earlier AF versions also supported OCS and Custom delivery channels. These are not supported with the new Notifications in AF 2016 R2.

9.2.1 Email Delivery Channel

The settings for the Email delivery channel allow you to configure the primary and backup SMTP server to relay the emails as well as the "*From"* email address for the alerts. The IT department should indicate which servers and ports to use for the primary and backup SMTP servers. As for the "Sender Email", this address is not validated and can thus be set to any address desired (i.e.: PINotifications@domain.com). In most cases, the *Allow contacts to set sender email* should not be enabled.

Note: In the Azure-based learning (VLE) setup use notifications@pischool.int.



Once the email delivery channel is setup, most email addresses should be provided by Active Directory (AD). If the AD does not include all email addresses needed, it will be possible to create additional emails within the *Contacts* section of PSE.

9.2.2 Directed Activity – Email Delivery Configuration and Checkout

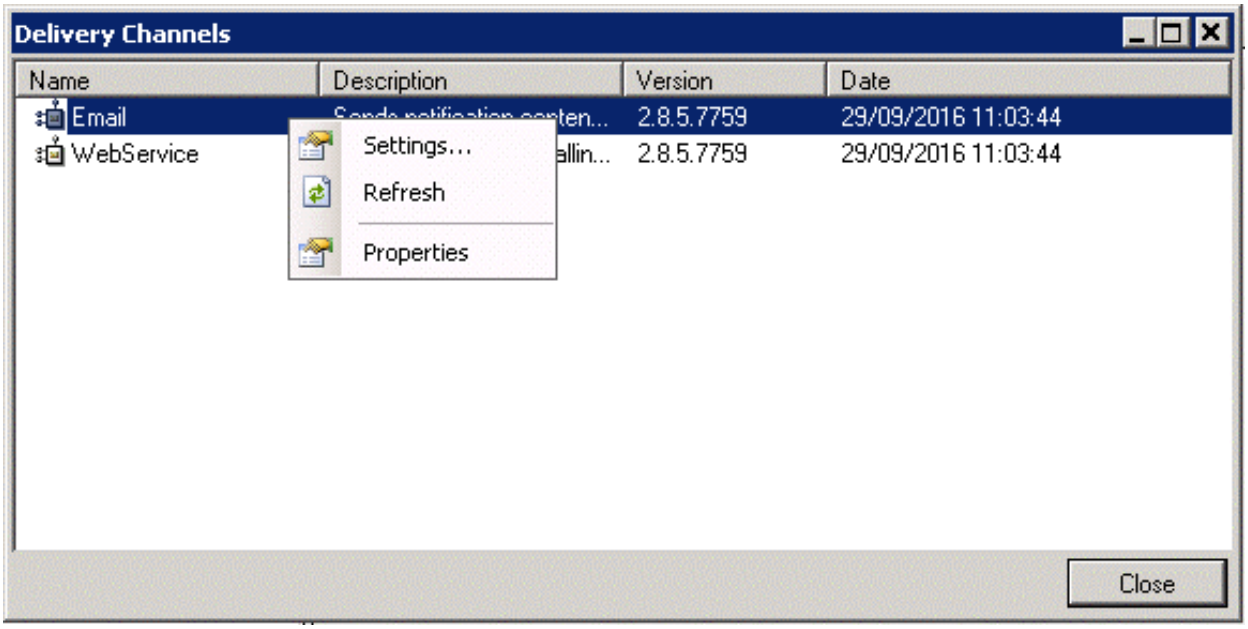
In this part of the class, you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

Activity Objectives

- Understand the required settings for the email delivery.

Approach

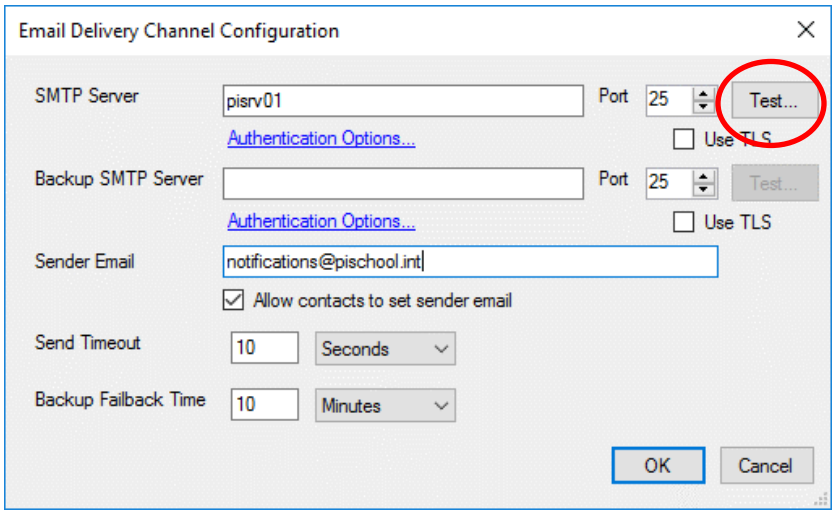
1. From PSE, select Contacts in the Navigator and navigate to *Tools* > *Delivery Channel Plugins*, then from the Email Delivery Channel Plug-In context menu select the *Settings.*



2. In case of the Azure-based learning (VLE) setup, the mail server is installed on PISRV01.

Note: The mail server on PISRV01 is configured just for some user accounts in the pischool.int domain.

3. Click on the *Test…* button to send a test email to **student01@pischool.int**.



4. Start Microsoft Office Outlook and verify reception of the test email.

9.2.3 Web Service Delivery Channel

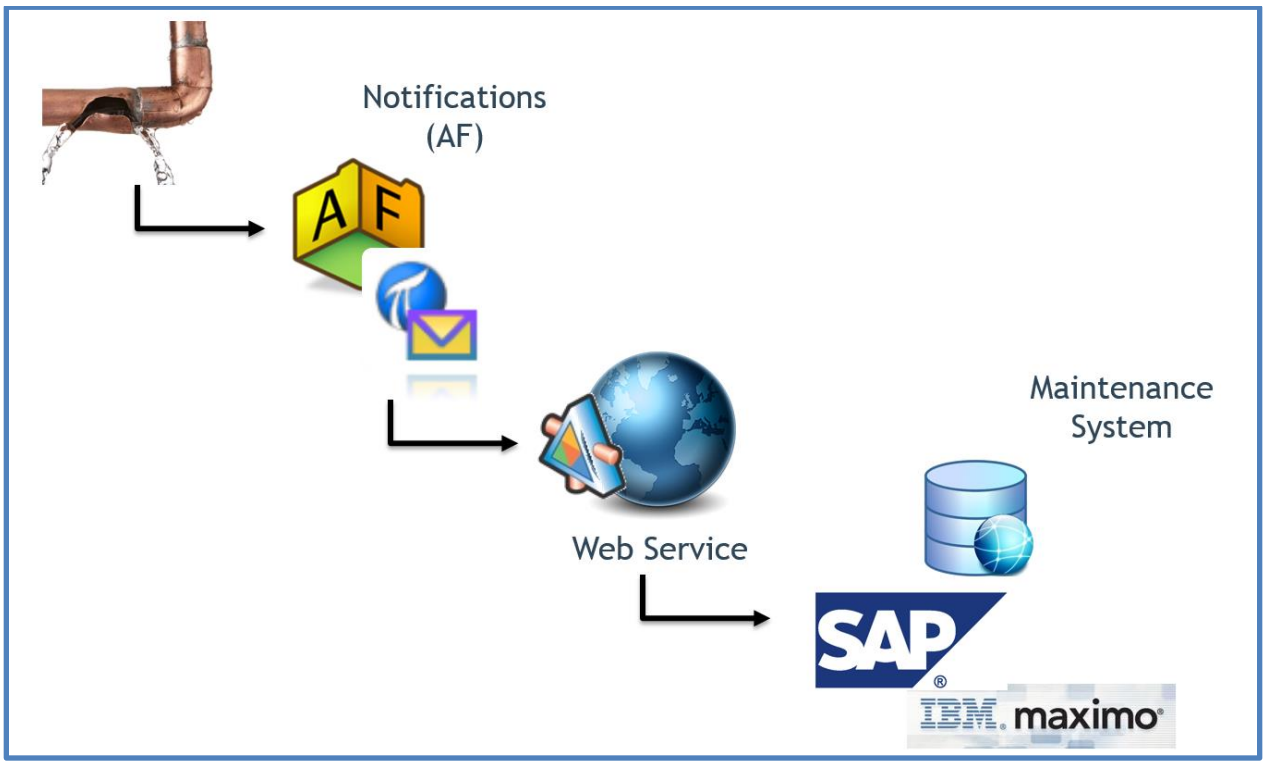
The web service delivery channel allows Notifications to contact and provide information to a web service by calling one of its methods. To use this delivery channel, a web service must thus be available on a web server.

About Web Services

A web service is a method of communication between two electronic devices over the web. In most cases, it is a service hosted on a web server that provides methods to its clients. Those methods will usually wait for incoming information from one end, then crunch the data, to finally return the data to the same client or pass that information to another one.

There are many web services commercially available, and many development environments offer templates and other tools to develop custom Web services.

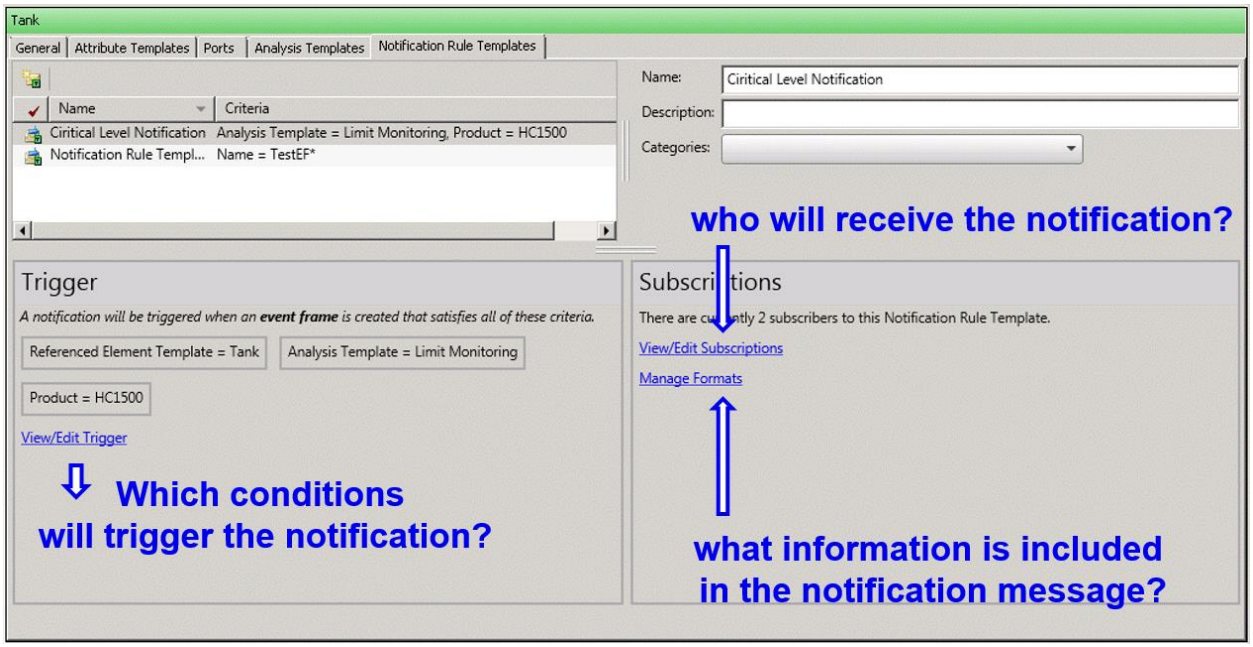
Example: A custom Web Service could process the received information and generate corresponding work orders in a customer Maintenance System:



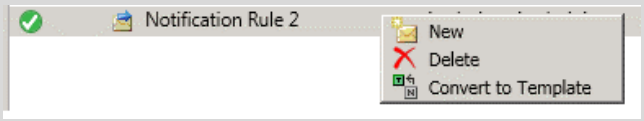
9.3 Configuring Notifications

Configuring a notification rule includes specifying the trigger criteria, adding subscribers to the notification rule, and formatting the message to suit the needs of your organization.

1. Select element or element template on which Notification Rule will be created
2. Create a new Notification Rule:
   a. Define the notification trigger conditions
   b. Add the subscribers
   c. Format the Notification message
3. Test the Notification



Note: If you have created a notification rule for an individual element, you can extend the scope to the corresponding element template by using the *Convert to Template* function.



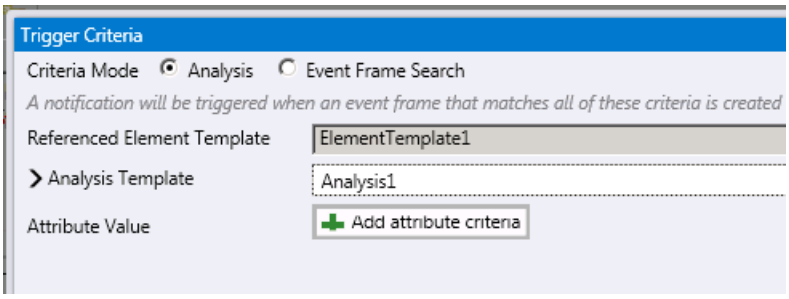
9.3.1 Trigger Conditions

The Notification Rules define the criteria that identify, which event frame generation will initiate a new notification.

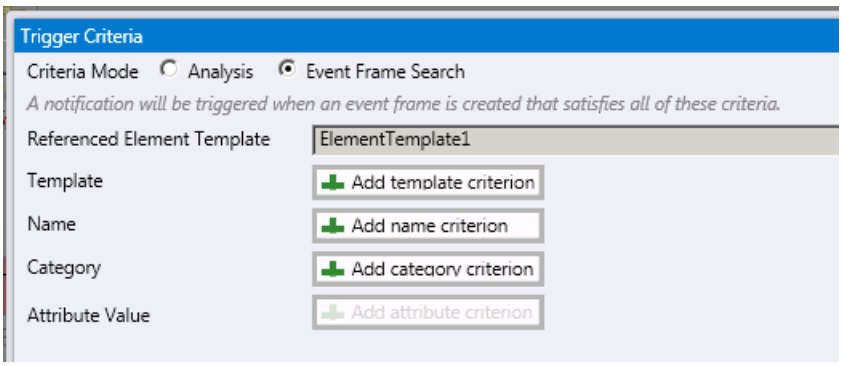
There are two possible trigger criteria modes for the Notification Rules:

- Analysis
- Event Frame Search

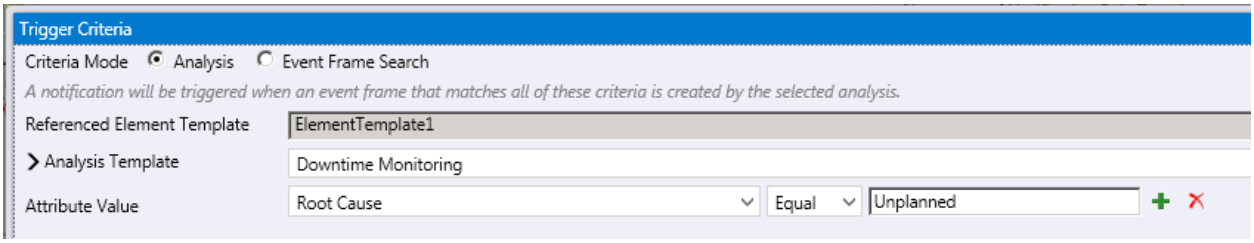
Use the *Analysis* mode to trigger a notification rule on event frames generated by a particular analysis.



Use *Event Frame Search* mode to trigger a notification rule based on event frame name, template and category. In the *Event Frame Search* mode, you can select a configured event frame template, from the drop-down list, and then configure the name and category for the event frames that will trigger your notifications. The name may contain wildcard characters that are supported by event frame search.



For both the modes, you can add additional trigger criteria using event frame attribute values. Criteria can be any specified for any attribute in the event frame template that is specified in the notification rule trigger criteria. For example, if your event frame template defines an event like "downtime" but you only want an email about "unplanned" downtime, you can configure an attribute value condition where a "reason code" attribute on the "downtime" event frame template has a value indicating "unplanned" downtime.



Note: Very often at work, the measure of success is made on how many things are produced. For Notifications, the more alerts that are produced, very often the less successful the use of Notifications becomes. If too many alerts are provided to a recipient, she/he probably won't be able to give each one of them the appropriate attention or response. This will make the implementation useless, as all of the alerts will become noise to the recipients.

9.3.2 Directed Activity –Triggering the Alerts

In this part of the class, you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

Activity Objectives

- Create an analysis for event frame generation and build a corresponding notification rule on it.
- Define notification trigger conditions.
- Add a subscriber who will receive the notification.

Problem Description

We will configure notification for the tanks at Velocity Terminals. This notification will inform whenever tank levels are outside the target operational levels (either too low or too high). The notification is required only for the tanks containing HC1500 because inappropriate quantities for that product is causing issues. If the tank is almost empty, the coating inside can corrode and will need treatment. If the tank is almost full, there is a risk that the material spills and causes environmental damage, which is even more critical.

The emails alerting about the limit violation should include the values of the level as well as the value of the temperature, because this information is needed to assess the condition of the liquid in the tank.

Under the Tank Element Template, we will create an analysis to create event-frames, whenever level is outside the limits. Notification Rules will be created to trigger notifications when new events occur and the material is HC1500.

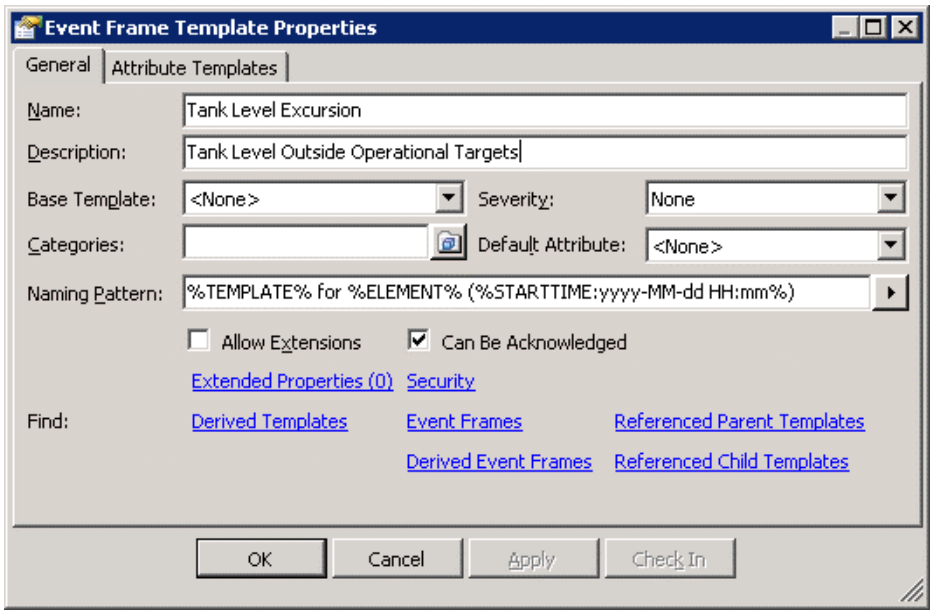
Approach

Event Frame Template

1. Open Velocity Terminals database in PSE, select Library in the Navigator and select *New Template* under Event Frame Templates.
2. For the name enter **Tank Level Excursion**
3. For the description enter **Tank Level Outside Operational Targets**
4. For the naming pattern enter

   %TEMPLATE% for %ELEMENT% (%STARTTIME:yyyy-MM-dd HH:mm%)

Once an event frame is created, what will the event frame names look like?



5. Check the option for *Can Be Acknowledged*
6. Click on OK

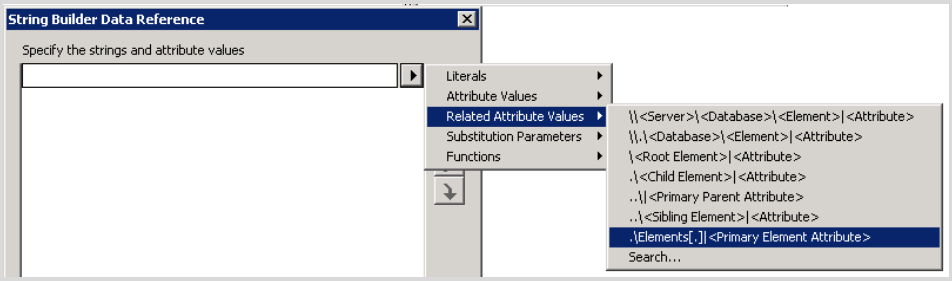
Event Frame Attribute Templates

7. Select Attributes Templates tab. Select New Attribute Template.
8. Add attributes for **Level**, **Temperature**, **Product** and **Level Excursion**

Attribute Name	UOM	Data Reference	Value Type	Settings…	DisplayDigits
Level	percent	PI Point	Double	.\Elements[.]|%Attribute%; TimeRangeMethod=StartTime	2
Level Excursion	<none>	<none>	String		NA
Product	<none>	String Builder	String	.\Elements[.]|%Attribute%;	NA
Temperature	Degree Celsius	PI Point	Double	.\Elements[.]|%Attribute%; TimeRangeMethod=StartTime	2

Tip1: Once you have entered the **Level** attribute you can use the Copy and Paste function to create another PI Point attribute which you can use to edit to create the one for **Temperature**

Tip2: You can enter the setting for the **Product** attribute manually. Alternatively, select an attribute value from the menu and edit accordingly. Make sure the setting matches exactly to the above information.

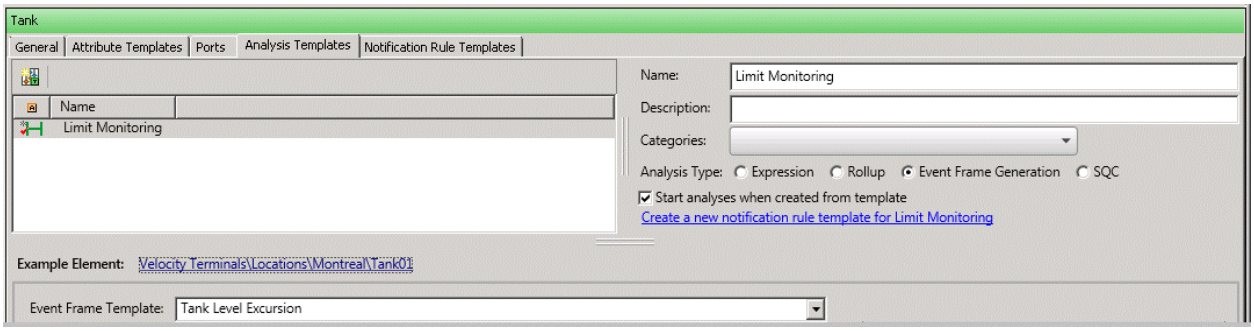


The **Level Excursion** attribute will be used to indicate, whether either the high or the low limit was violated. Setting the value for this attribute will be defined later on when configuring the analysis for the corresponding event frames generation.

9. Check In

Analysis for Event Frame Generation when limits are violated

10. Select Tank from Element Templates
11. Select Analysis Templates tab and click on the blue link to *Create a New Analysis Template.*
12. For the name enter *Limit Monitoring*
13. Select analysis type *Event Frame Generation*
14. For the example element select one of the tanks (e.g. **Tank01**).
15. For the *Event Frame template*, select **Tank Level Excursion**:



16. Rename *Start Trigger 1* to **Too High.** Enter expression:
    `'Level'>'Level|HiHi'`

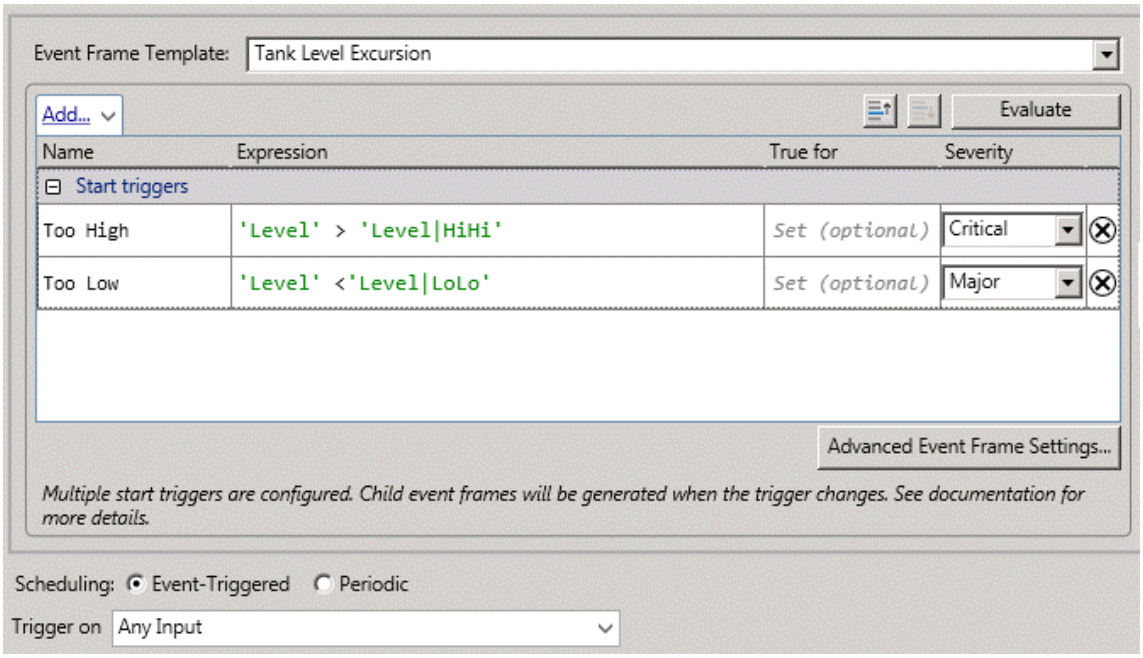
    Set severity to Critical.

17. Add a new Start Trigger, set the name to **Too Low.** Enter expression:
    `'Level'<'Level|LoLo'`

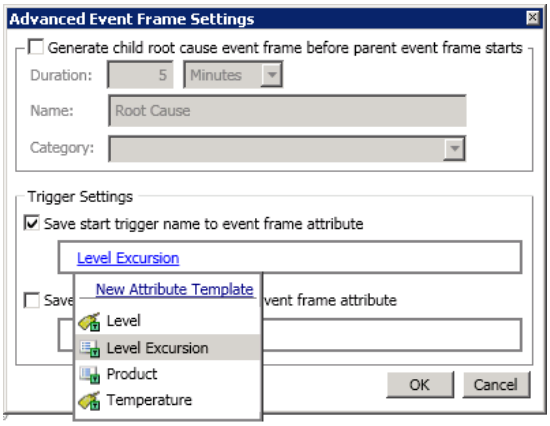
    Set severity to Major.

18. Whenever the level changes, we want to check whether any of the limit was violated. Therefore set *Event-Triggered* for Scheduling.

Note: The scheduling defines how often the triggers will be evaluated. If this option is Event-Triggered the triggers will be evaluated whenever there is a change for the attributes in the Trigger Expressions. This is usually how Analytics are executed if attributes are PI Point data references. Use Periodic in case the attribute is of another data reference (e.g. Table Lookup).



19. Click on *Advanced Event Frame Settings...*Check *Save Trigger name to event frame attribute*. Click on *Map Attribute* and select **Level Excursion** attribute. Click on OK.



Note: the Warning
"The selected attribute template will be converted to a Configuration Item and any existing configuration of the attribute template will be lost."
can be ignored.

20. Check In.

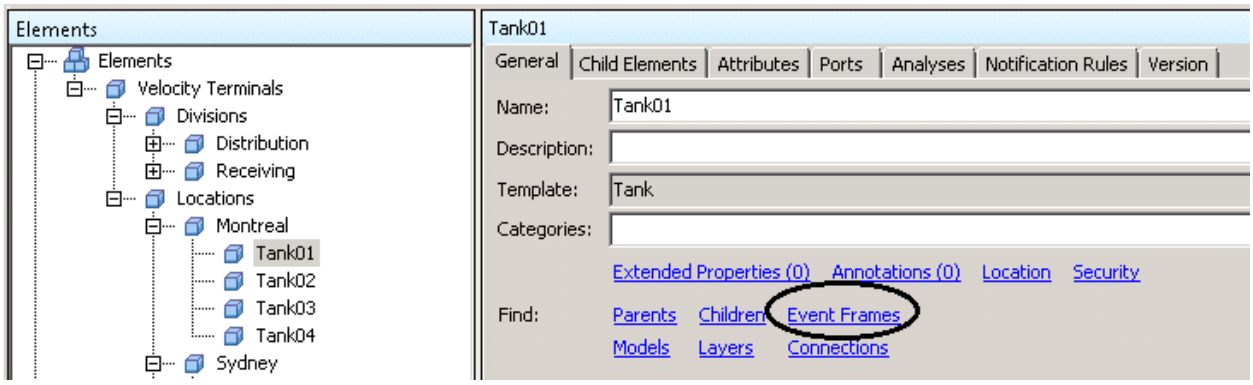
Simulate the level is above the limit

Note: The simulation for the level of Tank01 cycles the value every 10 minute with a violation of the low and high limit. You can either wait some time, so that the required value change occurs automatically, or you can force it with a manual entry. Note that a manual entry may be replaced by a new value from the interface too early to start the event frame

21. Select Elements – Velocity Terminals - Locations - Montreal - Tank01
22. Select **Level** Attribute – Settings
23. Uncheck Read-Only.
24. Select **Product** Attribute and change to HC1500 (we need that for later).
25. Check In.
26. Enter **98** into the Value for the **Level** attribute

Verify generation of event frames when limits are violated

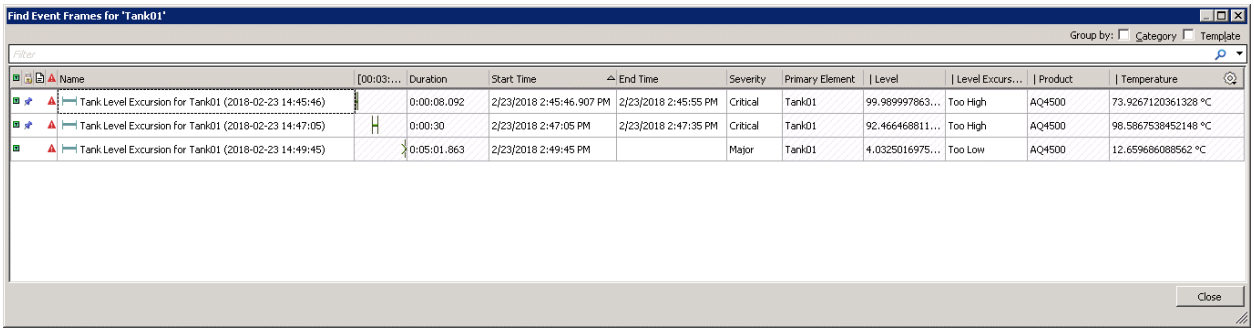
27. Select Elements in Navigator Panel, navigate to Tank01 and select the element.
28. Click on the blue Event Frames link on the General tab.



Tip: You should have an event frame for Tank01. If there is no event frame, the reason might be, that the tank was actually already outside the limits. Re-enter a value.

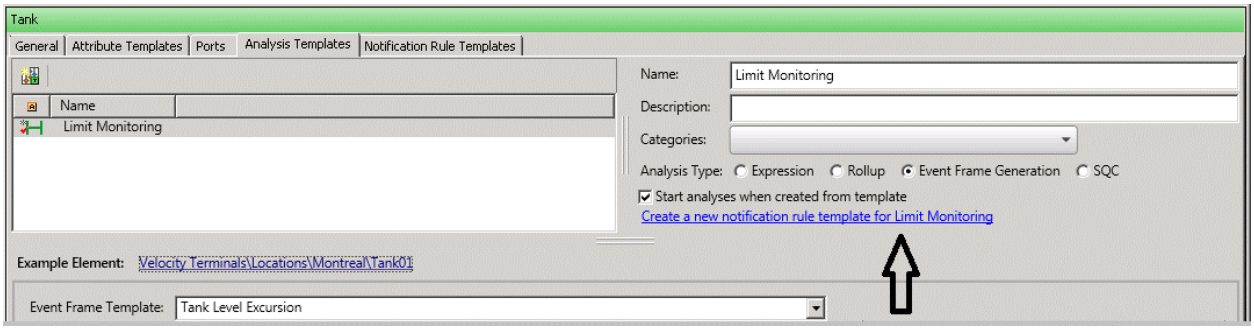
29. Click on the Wheel icon in the header line of the results.

    Click on Select Attributes. Click on icon to add all four (4) attributes from the **Tank Level Excursion** event frame template. Click on OK. The list will be extended by the four selected attributes. Click on OK.



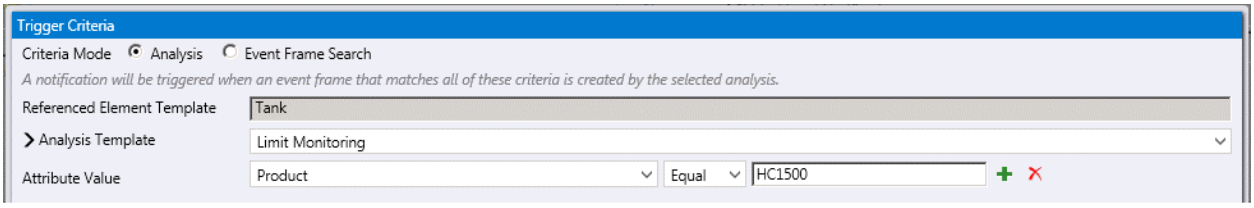
Create a Notification Rule

30. Select Tank from Element Templates. Select *Analysis Templates* tab, select the **Limit Monitoring** Analysis.
31. Click on the blue link to create a new notification rule template

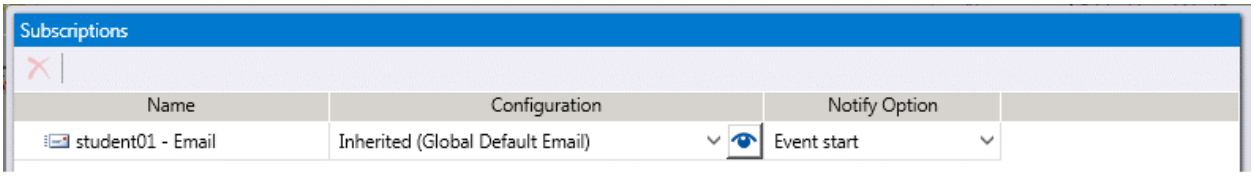


32. On Notification Rule Templates tab change the name to **Critical Level Notification**
33. In the *Trigger* section, select the blue *View/Edit Trigger* link.
34. Select the link to add attribute criteria

35. Add Product Equal **HC1500**. Click on OK.



36. In the *Subscriptions* section, select the blue *View/Edit Subscriptions* link.
37. Expand student01 so that the email occurs and drag it into the Subscriptions section. Click OK. Check In.

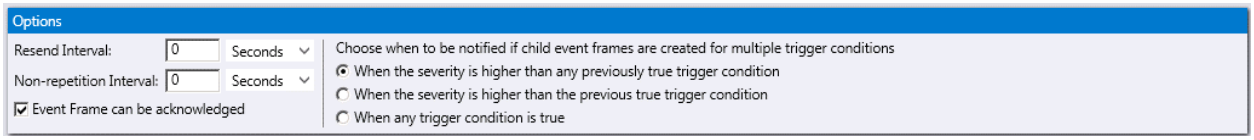


38. Start Outlook for student01.
39. Change the value for the **Level** attribute of Tank01 to 99 and verify that you receive an email.

Note: give the system some time to send out the email. It can even take up one to two minutes before the email arrives.

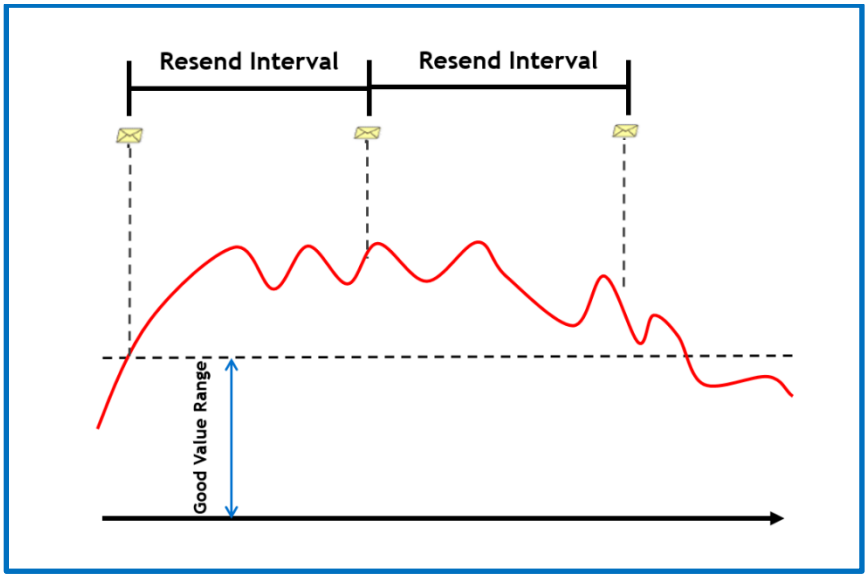
9.3.3 Trigger Criteria Options

When the Trigger Criteria are defined, following options can be set:



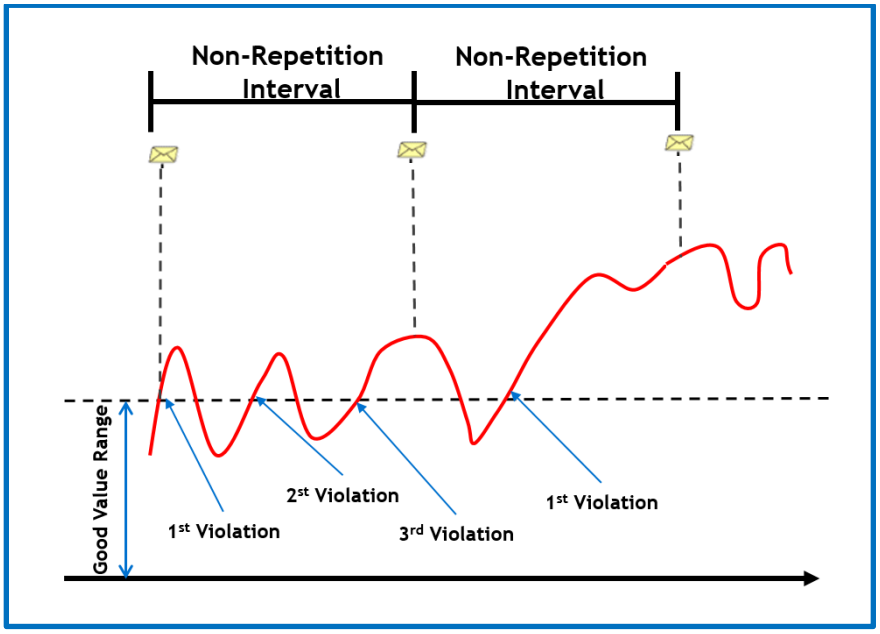
Resend Interval

The time interval after which PI Notifications Service will send additional alerts until the event frame matching the notification rule is acknowledged or closed.



Non-Repetition Interval

The time interval during which PI Notifications Service will not send similar alerts associated with the same notification rule.



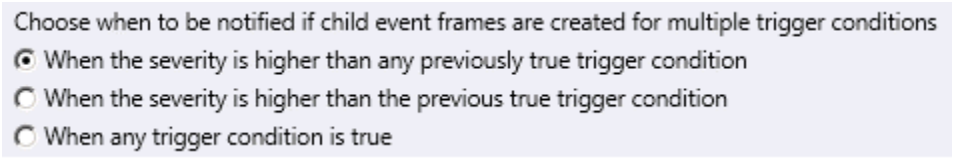
Event Frame Can be acknowledged

Option to enable event frame to be acknowledged; the event frame template is also modified accordingly. This option is automatically selected if the event frame template has been configured for acknowledgement

Severity Option

This option applies only to event frame generation analyses. If you have configured multiple start triggers for your analysis, you may choose to be notified in these ways:

- When the current trigger severity is higher than any trigger severity encountered so far.
- When the current trigger severity is higher than the previous trigger severity.
- Every time a trigger condition is true, regardless of its relative severity to other previous triggers.

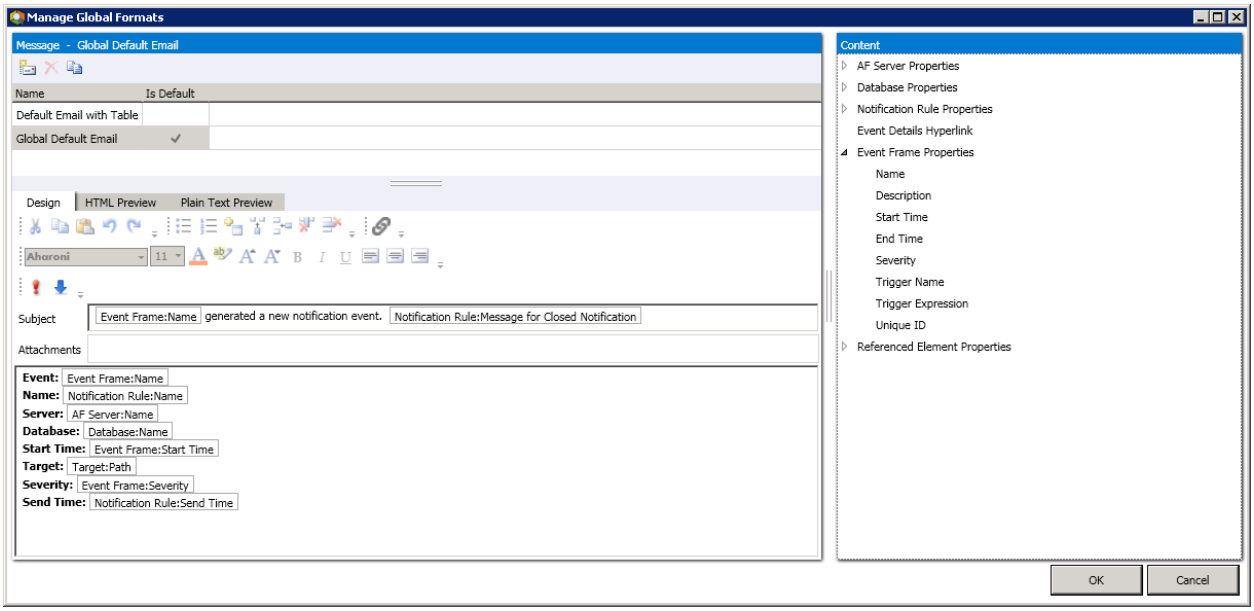


9.4 Formatting the Information to Deliver

The Notifications software includes a complete formatting tool, which enables you to define the formatting, and information that is included in email alerts.

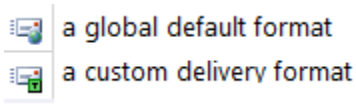
Global Default Formats

The system provides one global format that is used as the default format. You can edit or rename the global format, but cannot delete it. Additional formats can be added. To access global default formats, navigate to *Tools -> Global Formats* .



Custom Delivery Formats

To edit or add specific Custom delivery formats for a particular Notification Rule, select the blue Message Formats link. The formats can be distinguished by their corresponding icons:



9.4.1 Directed Activity – Message Formatting

In this part of the class, you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

Activity Objectives

- Prepare a message-formatting templates for email message delivery.

Approach

1. From PSE, navigate to *Tools* > *Global Format*.
2. Select the line with *Global Default Email* (color changes to light blue), and click on the Duplicate icon above. Rename the new format as “Default Email with Table”.

About Formatting Messages

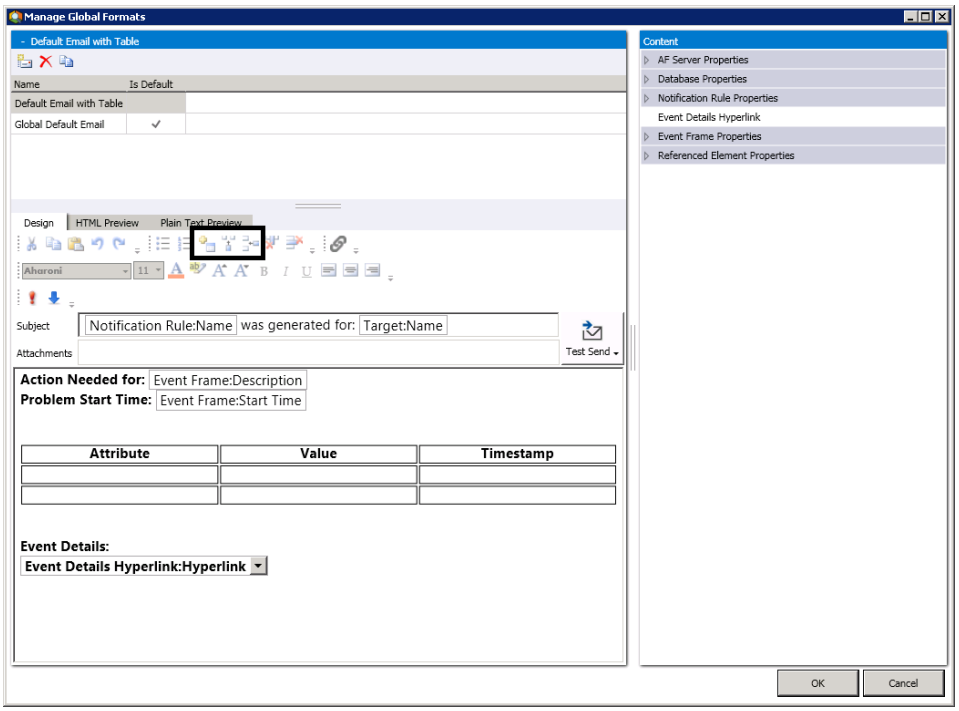
The *Formats* window has a *Content* section on the right side to add extra content to the message. From that Content pane, simply drag and drop, or double-click on the desired content to add it to the message. Only generic content can be added within the Global Formats section. Specific content can be added when configuring the Message tab for a specific notification rule or a notification rule template.

3. Select the Default Email with Table format and modify the formatting so that a table will be available to organize the information related to the notification. (See figure below)

   To add a table, use the controls highlighted in the screenshot above. When you add the Hyperlink, select the option to *send the link as text:*

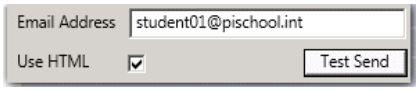
   We will be able to use the link and open a related display in PI Vision. When sending an email to someone outside the organization with no access to PI Vision use the option to *send a screenshot.*

> Note: the mail server used in the AF class VLE environment does not support to include screenshots in the email!



4. To perform a test send click on the

   button.
   For the Email address, enter student01@pischool.int:



5. Click OK.

9.4.2 Directed Activity – Configuring the Tank Level Excursion Notification Messages

In this part of the class, you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

Activity Objectives

- Compose notification messages from message format templates.

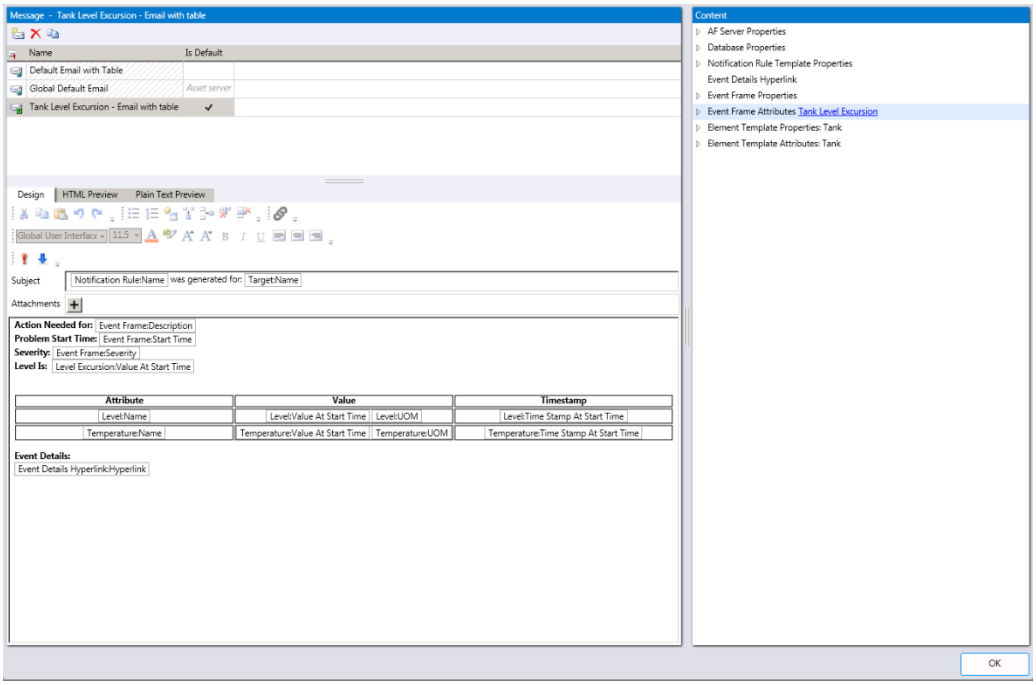
Approach

We want to define a particular format for the emails alerting about limit violations to send to our recipients. The message format includes a table with the values of the level and the temperature. The message should also provide a link into PI Vision allowing an acknowledgement as well as a display for the time after the limit was violated.

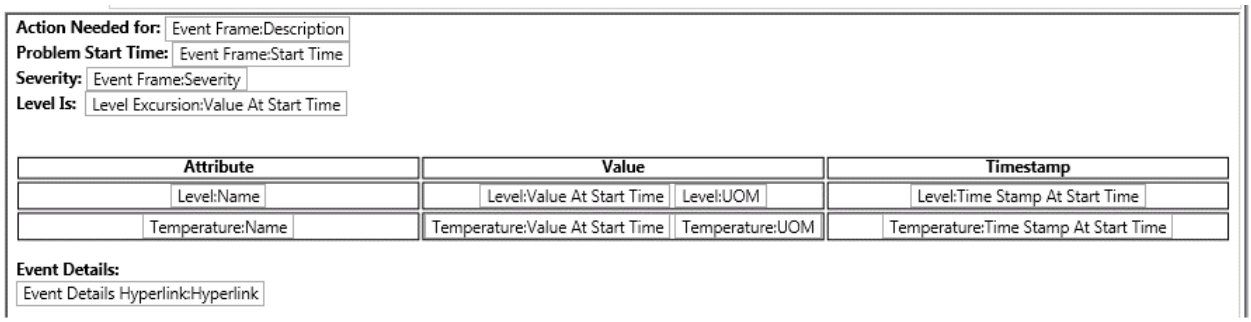
1. Select Tank from Library -> Element Templates, open the *Notification Rule Templates* tab.

Tank Level Excursion – Email with Table

2. Click on the blue *Manage Formats* link in the *Subscriptions* section. Select the line with **Default Email with Table** (color changes to light blue) and click on the Duplicate icon above. Rename the duplicated format as **Tank Level Excursion - Email with Table**.



3. Add the appropriate information to the table by dragging and dropping or double-clicking on the information from the *Content* pane on the right hand side. The second row of the table should include the Level information while the third row should include the Temperature information. If completed, click on OK



4. In the Subscriptions section on the Notification Rule tab Click on the blue View/Edit Subscriptions link.
5. In the line for student01 select **Tank Level Excursion - Email with Table** in the Configuration column. Click on OK. Check In.
6. Verify with Outlook whether the new notification emails have the new requested format.

9.5 Acknowledging Notifications

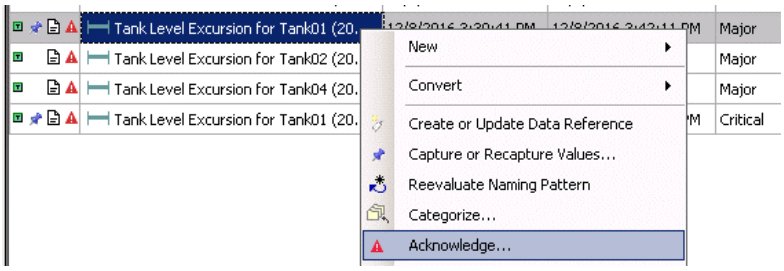
Acknowledgements of Notifications can be used to confirm that important notifications are read and acted on.

Note: A pre-requisite for the Acknowledgement feature is that the *Can be Acknowledged* setting in the event frame template has been checked.

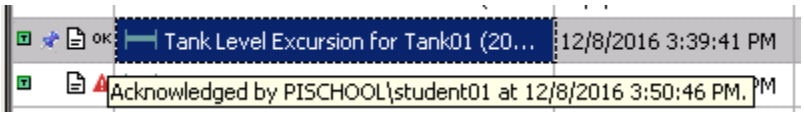
Ways of Acknowledging

Acknowledgment can be performed in two ways:

- Display the event in PI System Explorer (Event Frame Search Result). Select the context menu function *Acknowledge…*



When acknowledged, the red exclamation mark ⚠ changes into an OK. When you hover with the mouse over the OK you get information about who and when the acknowledgement was made.



- Open the corresponding Event details display in PI Vision. Click on the Acknowledgement link for the event frame.
  To display the corresponding event details, either follow the Event Details link in the notification email or use the event search options in PI Vision.

9.5.1 Directed Activity – Commenting and Acknowledging Events

In this part of the class, you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

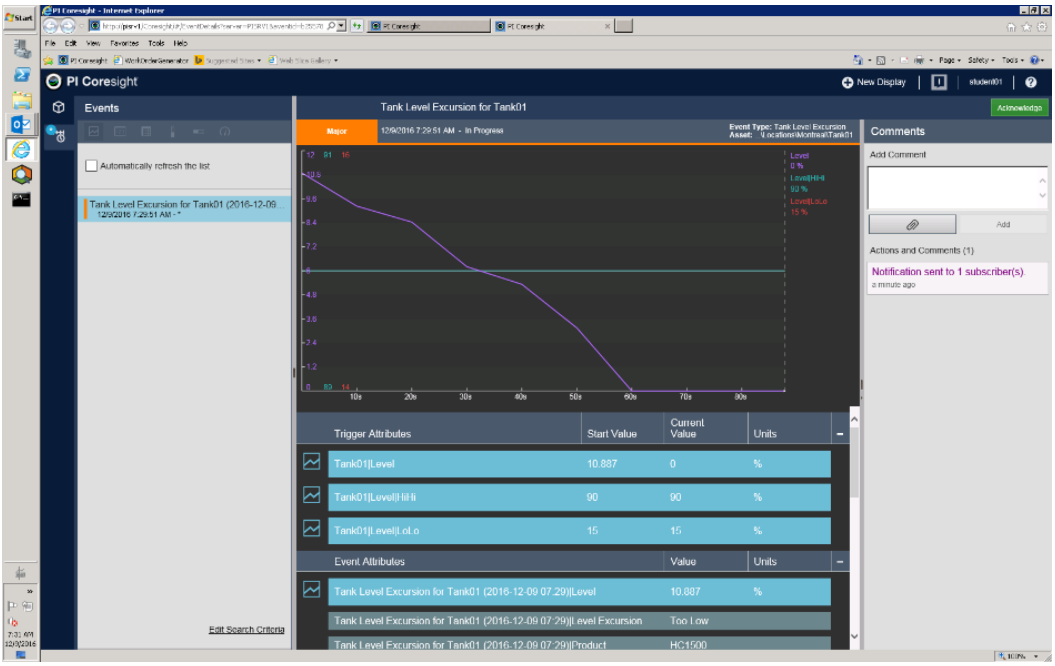
Tank01 in Montreal is critical for the whole operation at that site. If the material level in that tank is not proper, it is the duty of student01 to add a comment on the problem and to acknowledge the notification to document that action has been taken.

Activity Objectives

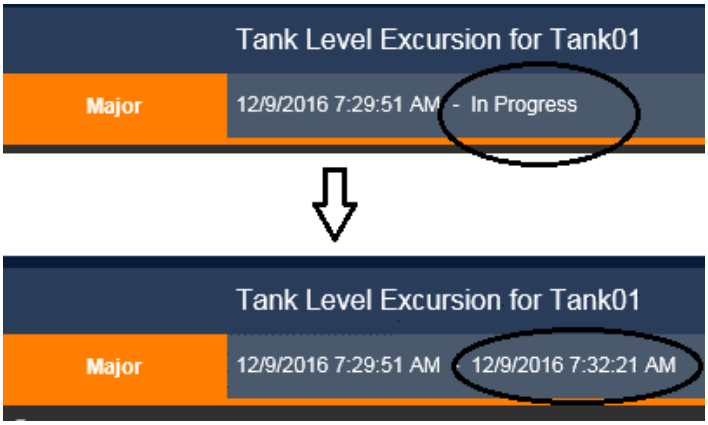
- Read the information in the latest notification email for Tank01 and open the event details in PI Vision
- Enter a comment on the current level status and acknowledge the alert.

Approach

6. In Outlook, open the latest notification email for Tank01.
   (If the email is quite new there is a high chance that the level has not yet returned to normal level since it started to violate the limit.)
7. Click on the blue *Events Details Hyperlink* link. Details page for the event will be displayed in PI Vision.

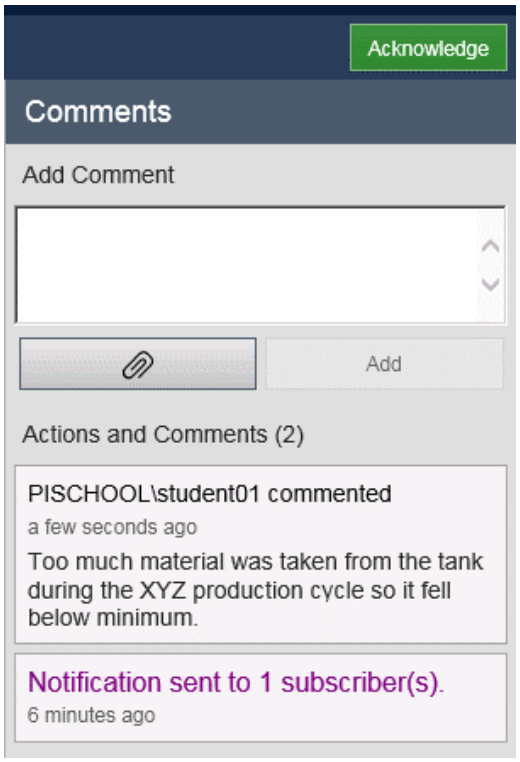


8. If the level is still outside the limits, the event is still ongoing. In that case, the end time is displayed as *In Progress.* In case you continue to observe the display for some time, the time span covered in the trend will increase until the level returned to normal (PI Vision update rate is 15 seconds).

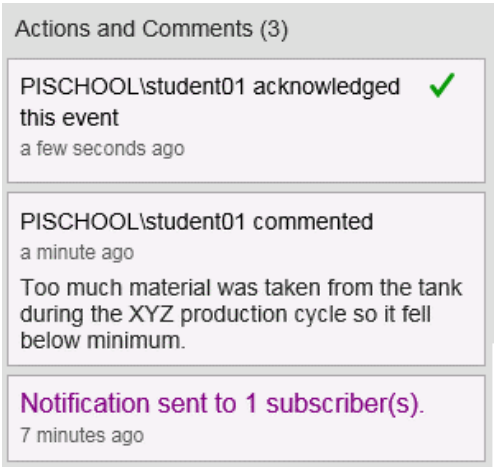


9. Add and remove trend lines by selecting and unselecting them in the list below the trend.

10. Add a text into the comment field and click on the *Add* button to enter.



11. Click on the *Acknowledge* button to acknowledge the event. Information about the notifications being sent, the comment and the acknowledgement are shown in PI Vision.



9.5.2 Directed Activity – Validating the Acknowledgment Process

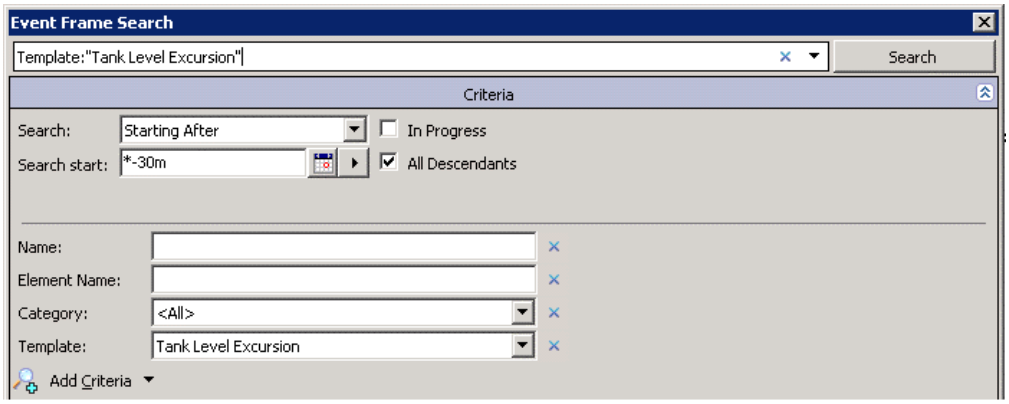
In this part of the class, you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

Exercise Objectives

- Compare the commenting and acknowledgment of notification alerts in PI Vision and PI System Explorer.

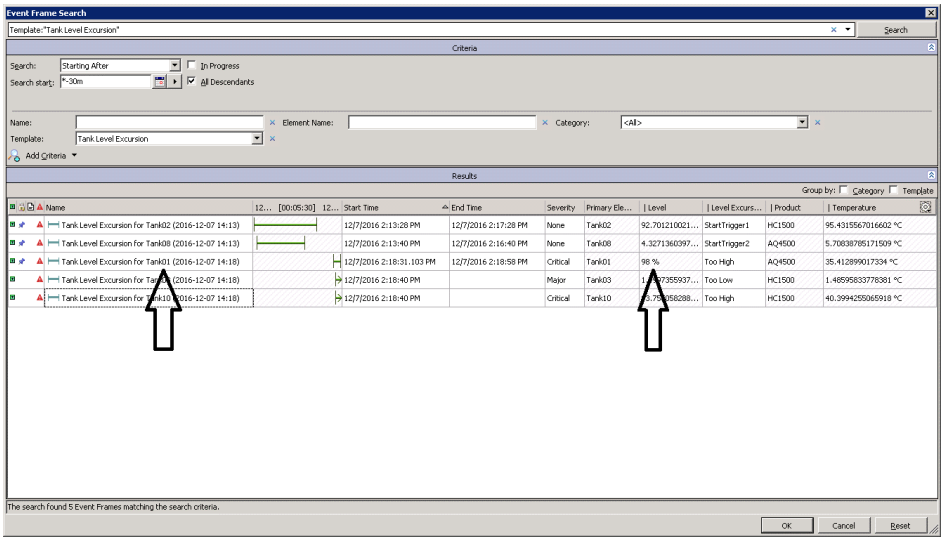
Approach

1. Open the PI System Explorer and select Event Frames in the Navigator.
2. Select *New Search…* from Event Frame Searches context menu
3. Set Search to: *Starting After*
4. Set Search Start to: ***-30m**
5. Set Template to: **Tank Level Excursion**. Click on *Search.*

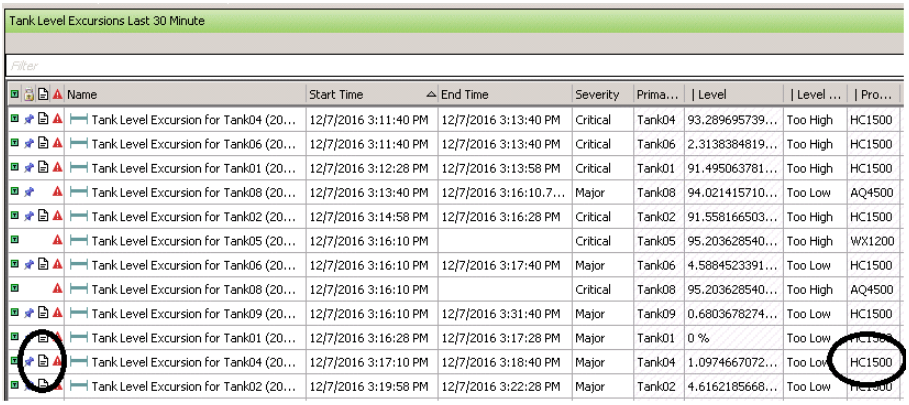


6. Click on the Wheel icon in the header line of the results.

   Click on Select Attributes. Click on icon to add all four (4) attributes. Click on OK. The list will be extended by the four selected attributes. Click on OK.



7. Rename default Search name to **Tank Level Excursions Last 30 Minutes**
8. Verify whether the event frames with Product= **HC1500** have an annotation icon. If you hover over the Annotation icon it displays *Notification sent to 1 subscriber(s)*.



9. Verify that comment and acknowledgement information from the previous exercise is displayed in PI System Explorer.
10. To acknowledge alerts in PI System Explorer, select one or several lines of the event frame list. From the context menu, select *Acknowledge…* The icon in the acknowledgement column changes from Unacknowledged to Acknowledged .

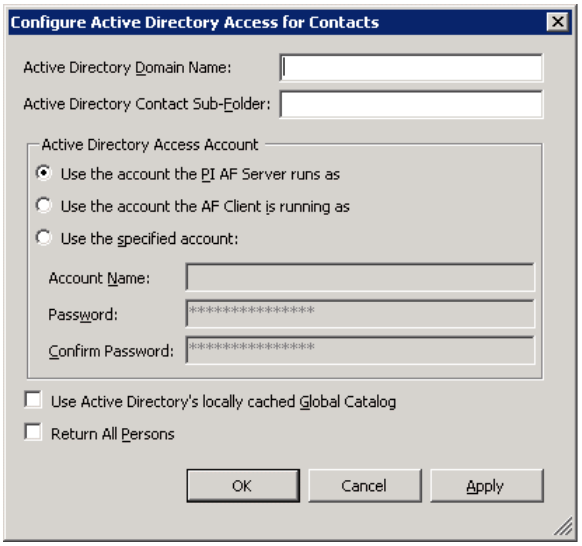
9.6 Adding Contacts

The Contacts section of the navigator panel of PSE allows for the definition of contacts. The contacts will be receiving the notification messages once they are triggered. This section defines the various types of contact objects that can be created and used by Notifications.

9.6.1 Active Directory (AD) access for contacts

Notifications normally gets the contacts and their addresses from the configured domain AD database. This prevents the administrator from having to do the tedious task of entering all of the potential subscribers and their contact information in order to start using Notifications.

Each AF server provides the option to specify the domain and contact sub-folder, as well as the account needed to access Active Directory and retrieve contact names. By default, the account under which the AF server application service is running is used for Active Directory access. The AD access is configurable in the AF Server Properties dialog box (with Contacts being selected in the Navigator, go to *Tools* > *Active Directory Properties*).



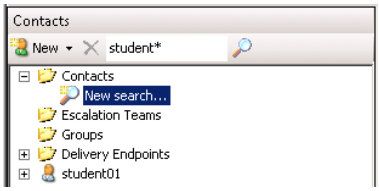
By default, the AF server is installed using a virtual account, NT SERVICE\AFService. However, the AF server service account can be changed. If the AF server service account does not have the necessary permission to read the Active Directory, no contact names will be retrieved in the Contacts list. If your Active Directory security is configured to allow the AF server service account to read the Active Directory, this is the simplest option.

In the *Active Directory Domain Name* text box, enter the full DNS name of the Active Directory domain from which the contact names will be retrieved for the PI Notifications Service Contacts.

In the *Active Directory Contact Sub-Folder* text box, enter the path to the folder containing the list of contacts for this domain. In larger Active Directory domains, contacts may be organized within sub-folders. The use of sub-folders can allow for faster retrieval of a list of Active Directory contacts.

9.6.2 Searching for Contacts

Because the AD database are often very large, contacts information is only available from search results. To search for contacts, click the New search button under the Contacts section or use the search field. The star (*) can be used as a wildcard for that search. In case of the Azure-based learning (VLE) setup a search for student* will return all the student AD users (student01, student02, student03, student04).



9.6.3 Directed Activity – Adding Contact Information

In this part of the class, you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

Activity Objectives

- Create a new contact for Notifications.

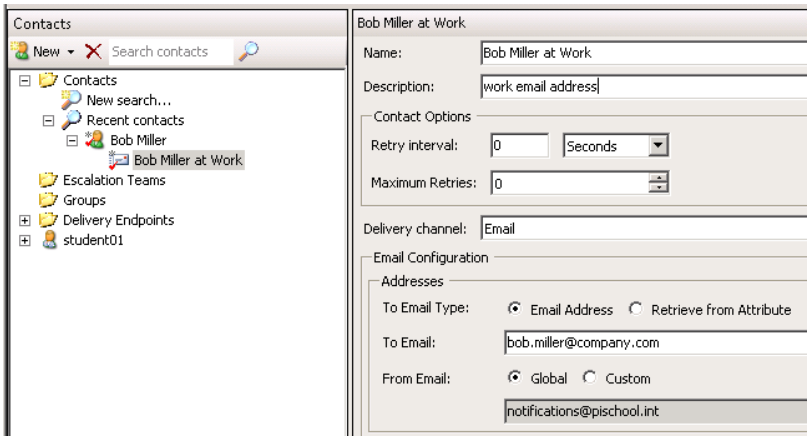
Problem Description

For those who do not have entries in AD you can enter custom contacts one at a time. This may be appropriate for vendors or other contacts not in your company who you may want to receive notifications. Custom contacts are available to all AF databases.

Approach

Adding a custom contact in PSE:

1. To create a custom contact, select *Contacts* from the navigator panel.
2. Select *New* > *New Contact* from the toolbar and enter your name for the contact *Name*.
3. Right click the contact for you and select *New Delivery Endpoint*
4. Enter a delivery endpoint name (e.g. <your name> at Work). From the Delivery Channel dropdown, select Email.
   Fill in your work email address and check in your changes.



5. (optional) Enter a second delivery endpoint for the home email address.

Note: in the Azure-based learning (VLE) setup there are only some email addresses in the pischool.int AD you can actually use for sending emails to. Refer to the corresponding information in the Exercise section at the end of the book.

9.6.4 Notifications Groups

A Notifications Group is an unordered collection of delivery endpoints, which includes Active Directory recipients. If a notification is configured to send a message to a Notifications Group, the message is sent to all members of the group simultaneously.

9.6.5 Notifications Escalation Teams

An escalation team is a delayed delivery group, which receives alerts on a notification only if a specified time period called the *Escalation Period* has elapsed, and the acknowledgement requirement is not satisfied. Acknowledgments will be discussed in a later section, but it is the ability to inform the Notifications server that the alert was acknowledged by a contact.

A notification alert is sent to the first contact on the list. If the notification is not acknowledged within a specified time, then notification messages are sent sequentially to the remaining members of the escalation team until the notification instance is acknowledged.

Building escalation teams is very similar to building groups and so they can be included in the subscribers' area of a notification. Keep in mind that if an escalation team is added to a notification, that does not require acknowledgements, they will never receive alerts.

9.6.6 Subscribing Contacts to Notifications

To maintain subscribers of a notification, navigate to the Notification Rules tab for a selected element or a selected element template, and then click *View/Edit Subscriptions* in the Subscriptions pane.

To add contacts, endpoints or groups to existing notifications, drag and drop them into the Subscriptions list. To remove, select a line with a subscription and click on the *Unsubscribe* icon on the top.

9.6.7 Dynamic Endpoints (since AF 2017 R2)

You can configure an email delivery endpoint as a value of an attribute. This provides an additional flexibility in situations where notification emails can be sent to different recipients without making changes to the notification rule template.

9.6.8 Directed Activity –Sending Notification Alerts to different email addresses depending on the current time

In this part of the class, you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

Exercise Objectives

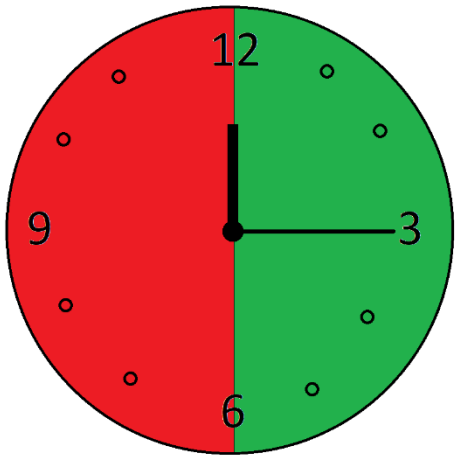
- Create an analysis to define an email address depending on current time.
- Switch email recipient for notification emails

Problem Description

To balance the workload for the people responsible to handle tank level excursions, the notification emails should be sent to different email addresses depending on the actual clock time according to the following rules:

Montreal and Tokyo:
During second half of the hour send emails to:
student02@pischool.int

Sydney:
During second half of the hour send emails to:
student03@pischool.int



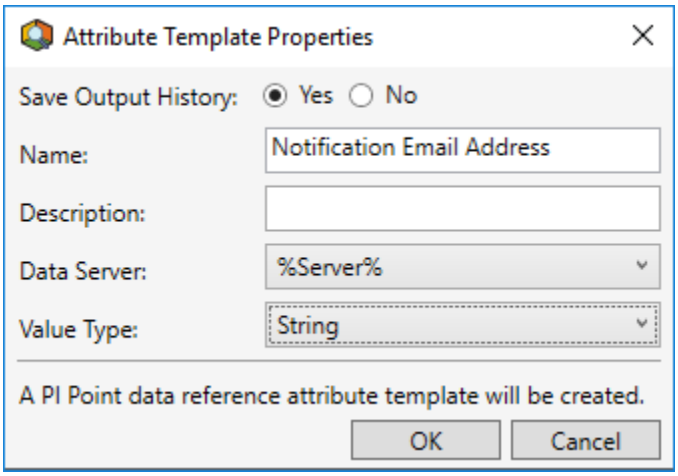
During first half of the hour send emails to:
student01@pischool.int

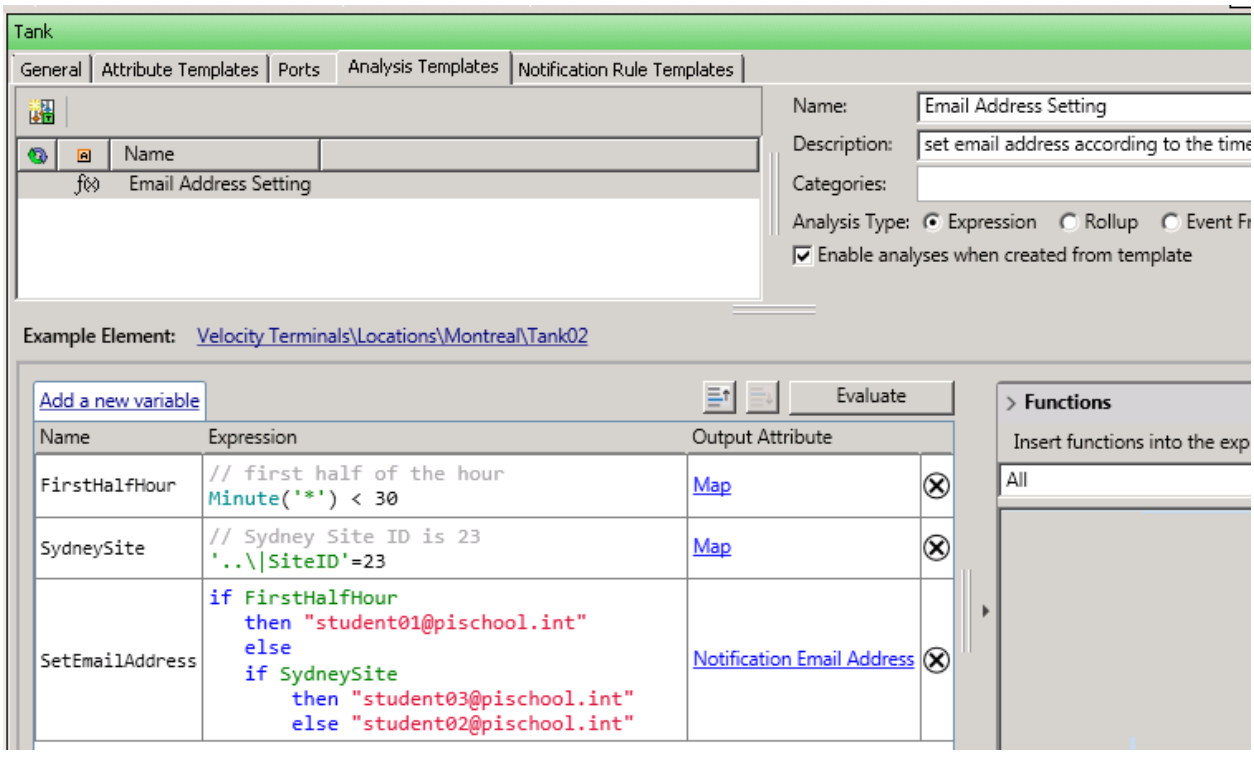
Note: The above rule is likely not a typical real situation, but has rather been selected to allow a convenient check-out during the class training.

Approach

Create an Analysis to set the email address according to the time

1. Open the PI System Explorer and navigate to the **Tank** element template. Create a new analysis, **Email Address Setting.**
   When you map the output, select the option to save output history. Set the value type to string. For scheduling, select period of 30 minutes, no offset.



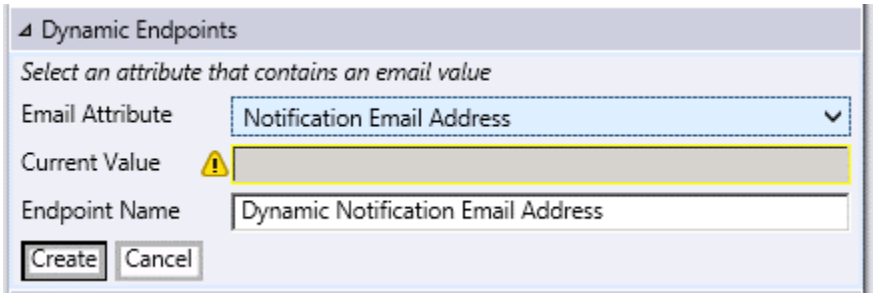


Tips:

- `'..\|SiteID'` refers to the attribute **SiteID** in the parent element of the tank (which is the site)
- To start a new line, use Shift-Enter.
- Do not use blanks for the Variable names.
- To check the analysis, select an example element and run Preview Results.
- To get initial value for the Notification Email Address (is calculated only every 30 minutes), switch to management tab and perform a Backfill for the last hour.

Create a dynamic endpoint that refers to the Notification Email Address attribute and create a related subscription.

1. Select *Library* in the Navigator and open the *Notification Rule Templates* for the **Tank** element template.
2. Click on the blue *View/Edit Subscriptions* link
3. Expand *Dynamic Endpoints* in the *Contacts* section and select **Notification Email Address** from the dropdown of the attribute list. For the Endpoint Name, enter **Dynamic Notification Email Address**. Click the Create button.



Note: the Warning
"Value must be a valid email address at delivery time."
can be ignored.

4. Select the line with the existing subscription and click on the Unsubscribe icon on the top.
5. Expand *Dynamic Endpoints* in the *Contacts* section and drag **Dynamic Notification Email Address** to the Subscriptions list. Click on the dropdown icon in the Configuration column and select **Tank Level Excursion - Email with Table**.
6. Click on OK to exit the *View/Edit Subscriptions* dialog box.
7. Check in the changes.
8. Verify whether email delivery is performed as intended. (requires you keep system running for a while).

9.6.9 Directed Activity –Sending Notification Alerts in Escalation Sequence (optional)

In this part of the class, you will perform a learning activity to explore the different concepts presented in this chapter or section. You may be invited to watch what the instructor is doing or perform the same steps at the same time. Your instructor will have directions.

Exercise Objectives

- Assign several contacts to an escalation team
- Understand and apply options for an escalation team.
- Explore the sequence of notifications for an escalation team.

Problem Description

You want to change the strategy, which people in the organization are informed in case of a level limit violation. In order to avoid a transitional period, you want to suspend the notification emails during the time, when you reconfigure the system.

Two people from the operational personnel, the tank operator and the safety engineer) can handle the situation when the tank level has exceeded a limit. The tank operator should be informed first. In case he does not take action within 5 minutes, the safety engineer should be informed as well. Do not send email to student01 anymore.

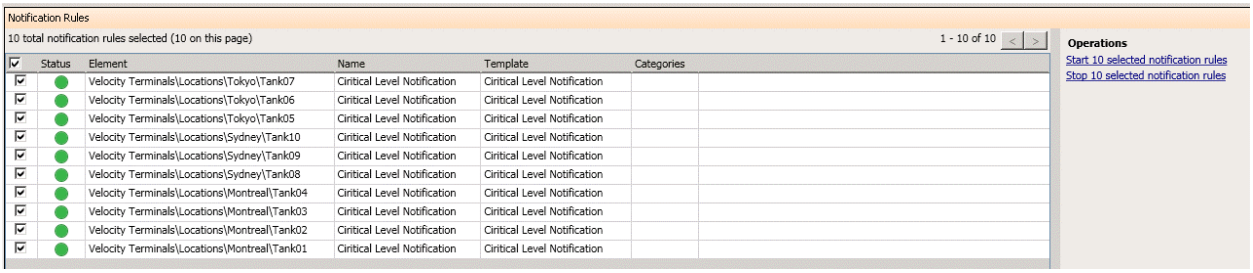
Use the following email addresses:

Tank Operator: student02@pischool.int
Safety Engineer: student03@pischool.int

Note, that if you are executing this exercise in a local language environment, email addresses for local language accounts corresponding to student02 and student03 are not supported.

Approach

1. Open the PI System Explorer and select *Management* in the Navigator. Choose *Notification Rules* type.

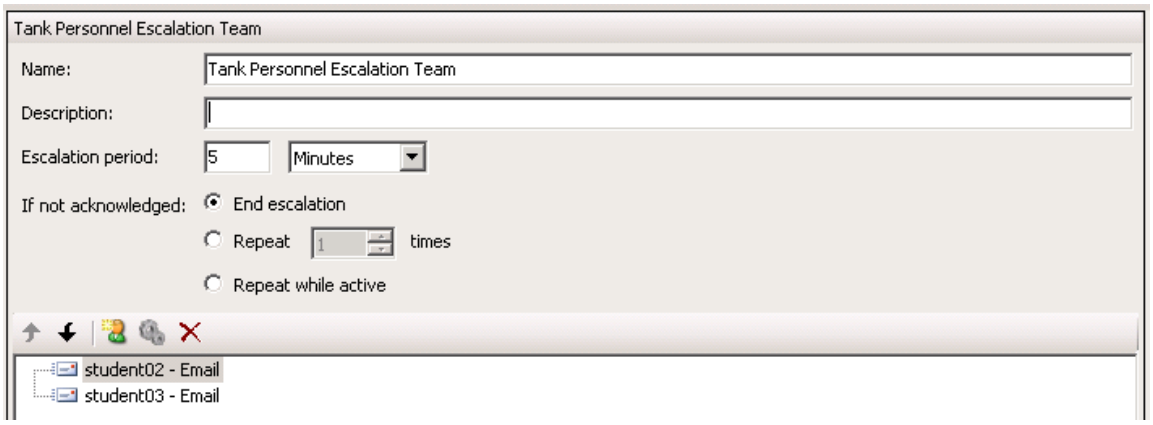


Note: The status displayed here is based on the notification rule configuration only. The status does not give information on whether the notification is running or in error.

2. Enable the check box in the header line to select all notifications for the ten (10) tanks, then click *Disable selected notification rules*.

Tip: By selecting any combination of lines with rules, you can start or stop the selected rules.

3. Select *Contacts* in the Navigator.
4. Create a new escalation team called **Tank Personnel Escalation Team** by right clicking the Escalation Teams folder and selecting *New Escalation Team*.
5. Add the tank operator (student02@pischool.int) as well as the safety engineer (student03@pischool.int) and select a 5 minutes Escalation period. Do not repeat the escalation sequence, if the alert was not acknowledged.



6. Select *Library* in the Navigator and open the *Notification Rule Templates* for the **Tank** element template.
7. Click on the blue *View/Edit Subscriptions* link
8. Expand *Escalation Teams* in the *Contacts* section and drag **Tank Personnel Escalation Team** to the Subscriptions list. Click on the dropdown icon of the team name to expand the team members. Select **Tank Level Excursion - Email with Table** for both.
9. Select the line(s) with the other subscriptions and click on the Unsubscribe icon on the top.
10. Click on OK to exit the *View/Edit Subscriptions* dialog box.
11. Check in the changes.
12. Select *Management* in the Navigator. Start the notifications in the same way as they were stopped before.

Question for different Escalation Option Settings

Assume you have set to repeat the escalation three (3) times, in case it was not acknowledged. How many emails will be sent out, if no action is taken by the operators and the violation is there for more than an hour? When will the last email be sent?

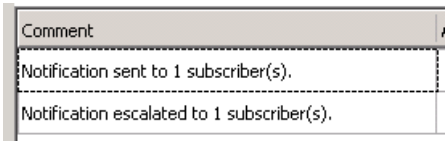
Answers: _____ emails will be sent, the last email is sent _____ minutes after the problem started.

Explore the escalation sequences (optional)

After some runtime (> 30 minutes), several new level limit violations will have happened for Tank01 and Tank02.

Note: The simulation of the tank levels repeats the same pattern all over again. The cycle times depend on the tanks. Tank01: 10 minutes, Tank02: 30 minutes, Tank03…Tank10: > some hours.

1. Select Event Frames in the Navigator.
2. List the event frames for the Search named **Tank Level Excursions Last 30 Minutes** (if still displayed from previous activities, click on the Refresh button in PI System Explorer Toolbar)
3. Select a completed event frame (End Time not empty) for a Low Limit Violation of Tank02. Select *Annotate…* from the context menu. The Annotations lists the email sequence.



Hint: Click on the Wheel icon to show a column with Description information to get more details on the email that was sent.

4. Select a completed event frame for Tank01. Can you describe why no escalation was sent?

9.7 Delivering Notifications via a Web Service

9.7.1 Web Service

The web service delivery channel allows Notifications to contact and provide information to a web service by calling one of its methods. To use this delivery channel, a web service must thus be available on a web server.

About Web Services

A web service is a method of communication between two electronic devices over the web. In most cases, it is a service hosted on a web server that provides methods to its clients. Those methods will usually wait for incoming information from one end, then crunch the data, to finally return the data to the same client or pass that information to another one.

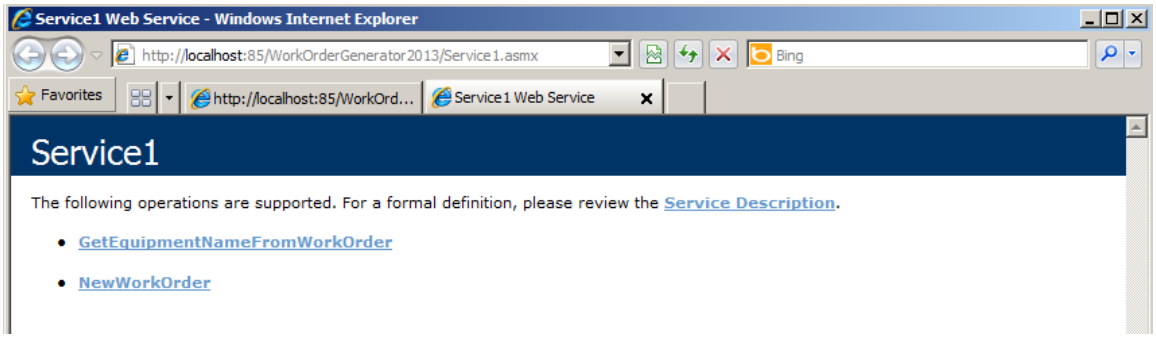
There are many web services commercially available, and many development environments offer templates and other tools to develop custom Web services. Just to have an idea of a Web service, the http://www.webservicex.net/ website offers samples like a Global Weather web service.

The configuration necessary to send information to a web service via Notifications will be done when creating a new *Delivery Endpoint* of type *WebService* from the *Contacts* section of the navigator panel in PSE.

9.7.2 Web Service example: The Work Order Generator

This is a custom web service designed to act as an automatic work order generator. Imagine a notification that would trigger whenever a piece of equipment needs maintenance. Via the web service, the notification would pass all necessary information to the maintenance system so a work order can be generated. For this training, a SQL Server database called “WorkOrderGenerator” will act as the maintenance system. This database is hosted on your local SQL Server instance. The web service itself should be available at the following URL:

http://localhost:85/WorkOrderGenerator2013/Service1.asmx



9.7.3 Directed activity – Validating the Web Service Functionality (Optional)

This solo or group activity is designed to maximize learning in a specific topic area. Your instructor will have instructions and will coach you if you need assistance during the activity.

Exercise Objectives

- Understand the functionality of the sample Web Service for a Work Order Generator

Approach

The *NewWorkOrder* method allows a user or an application to create a new work order entry in the SQL Server database by passing the following information: equipment name, failure type and action to take.

From the web page of the web service, click the *NewWorkOrder* method and enter something for the *EquipmentName*, *FailureType* and *ActionToTake* fields, then click the *Invoke button*. If the following shows up, then work order was successfully generated. Again, remember web services are not meant for user interaction.

<?xml version="1.0" encoding="UTF-8"?>
*<int xmlns="http://localhost/">**1**</int>*

You can go ahead and query the WorkOrderGenerator SQL server database to confirm that the new work order was successfully created in the system.

1. Open the Internet Explorer and got to:
   http://localhost:85/WorkOrderGenerator2013/service1.asmx
   (There is also a link for that under the favorites)
2. Click on *New Work Order*. Enter the parameters:
   a. For the *EquipmentName*, enter **Reactor1**
   b. For the *FailureType*, enter **Pressure Too High**
   c. For the *ActionToTake*, enter **Check Pressure Relief Valve**
3. Click on *Invoke.* Record the Work Order Number that is returned.
4. Re-open the page (click on the favorites link again) and select *GetEquipmentNameFromWorkOrder.* Enter the work order number from the last step and submit.
5. Open SQL Server Management Studio and connect to PISRV01.
6. Expand
   Databases > *WorkOrderGenerator* > Tables > dbo.*WorkOrderGen* table.
7. From the right-mouse button context menu, execute *Select Top 1000 Rows*.
8. Locate the last entry to verify whether the new work order entry has been added.

9.7.4 Directed activity – Creating a WebService delivery endpoint (optional)

This solo or group activity is designed to maximize learning in a specific topic area. Your instructor will have instructions and will coach you if you need assistance during the activity.

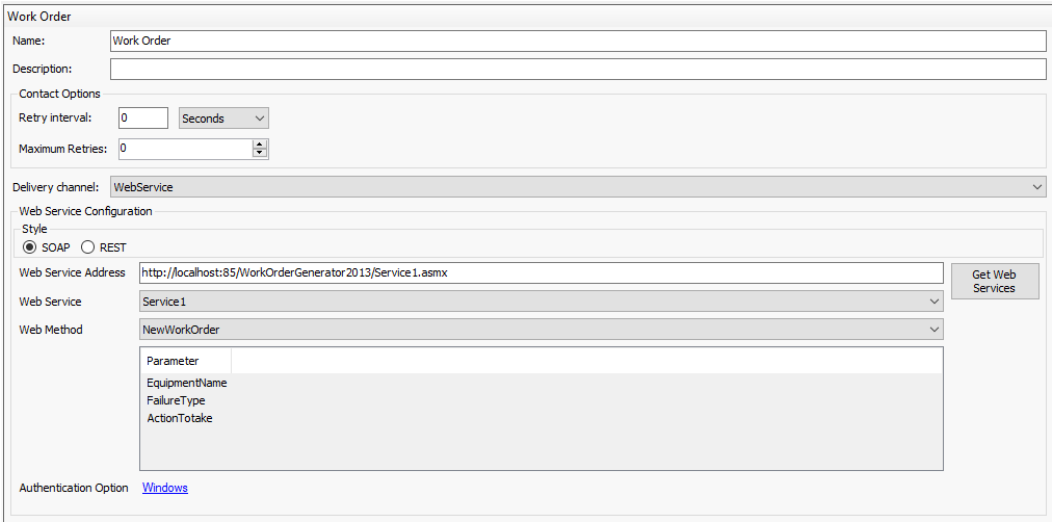
Exercise Objectives

- Familiarize with the creation of a Web Service delivery point for the Work Order Generator.

Approach

To add a custom delivery endpoint in PSE:

1. Select *Contacts* from the navigator panel.
2. Select *New Delivery Endpoint* from the right-click context menu of the *Delivery Endpoints* folder. Enter the name **Work Order** and a description and select Web service delivery channel. Check-In.
3. Enter the web service address http://localhost:85/WorkOrderGenerator2013/service1.asmx and click on Get Web Services
4. Select *NewWorkOrder* from the drop-down options under Web method.



5. Check in.

9.7.5 Directed activity – Automatically Creating a Work Order in the Maintenance System

This solo or group activity is designed to maximize learning in a specific topic area. Your instructor will have instructions and will coach you if you need assistance during the activity.

Exercise Objectives

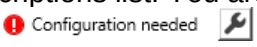
- Set up different types of subscribers to a notification.
- Demonstrate how Notifications can provide PI System information to a work order system.

Problem Description

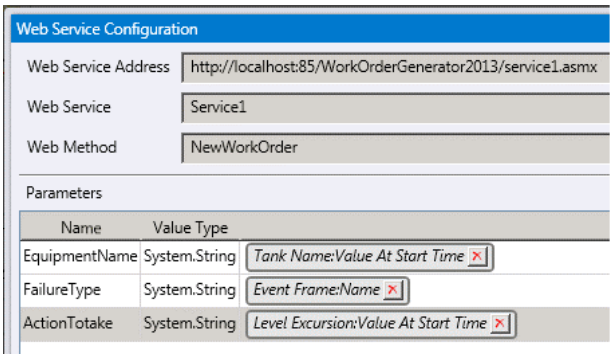
In addition to alerting people by sending emails, you would like to create new entries in the work order database for the critical tank level events.

Approach

To add a subscription for another delivery endpoint in PSE:

1. Select *Library* from the navigator panel and navigate to the **Tank** element template. Open the *Notification Rule Templates* tab.
2. Click on the blue *View/Edit Subscriptions* link in the *Subscriptions* section.
3. Expand Delivery Endpoints in the Contacts section and drag **Work Order** to the Subscriptions list. You are informed that you have to configure the Web Service: 

4. Click on the spanner icon and use drag and drop to set for the three (3) web service methods' parameters:
    a. For the *EquipmentName*, set **Tank name:Value At Start Time** (from Element Template Attributes: Tank)
    b. For the *FailureType*, enter **Event Frame:Name** (from Event Frame Properties)
    c. For the *ActionToTake*, enter **Level Excursion:Value At Start Time** (from Event Frame Attributes: Tank level Excursion)



5. Click on OK.
6. Check In the changes.

To verify the work order entries:

After some runtime, several new level limit violations will have happened for Tank01 and Tank02.

1. Select Event Frames in the Navigator.
2. List the event frames for the Search named **Tank Level Excursions Last 30 Minutes** (if still displayed from previous activities, click on the Refresh button in PI System Explorer Toolbar)
3. Select a new event frame. Select *Annotate…* from the context menu. The Annotations lists that notification has been sent to two (2) subscribers.

4. Open SQL Server Management Studio and connect to PISRV01 and access the dbo.*WorkOrderGen* table contents again. Verify whether new work order entry/entries have been added.

Note: the work order database accepts event frame names with a maximum of 50 characters. If names are too long, no entry is made is made in the table

9.7.6 Exercise – ABC Mining Company Notifications (optional)

This solo or group exercise is designed to maximize learning in a specific topic area. Your instructor will have instructions and will coach you if you need assistance during the exercise.

Exercise Objectives

- Create a new analysis to detect tire pressure problems (implement into general truck template)
- Create a new analysis to detect low gas level problems (implement into general truck template)
- Distinguish the different root causes of truck problems
- Create corresponding notification rules (apply to general truck template)
- Create custom format to provide detail information about the issue in the notification email

Problem Description

ABC Mining Company wants to set up two types of alerts, which will be configured later for sending emails to the manager on duty (student01@pischool.int).

ABC Mining Company management wants to be alerted under the following circumstances:

- Tire Pressure is more than 3 psi below or above the nominal pressure value for more than 5 minutes. Severity for this problem is Critical.
- If any vehicle's gas tank has *less than 50%* gas left, they need to be aware so they can schedule a return to the refueling station.
  Severity for this problem is Major.

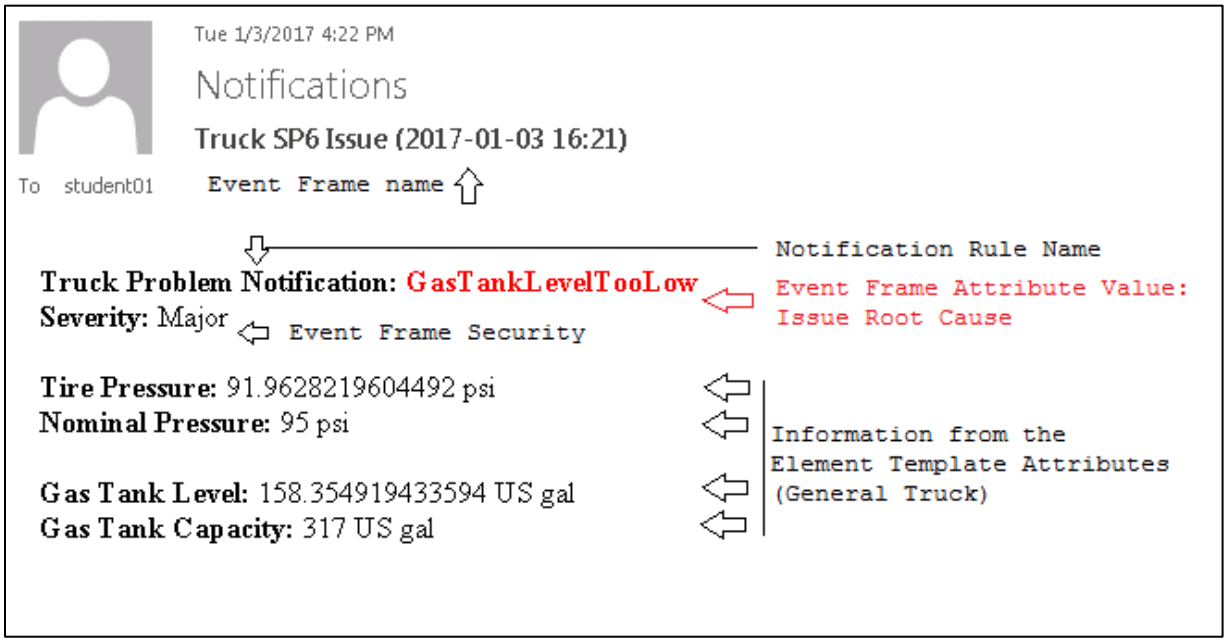
Approach

In order to build the analyses and notification rules that can be applied to all types of vehicles, the target element template must be one common to all vehicles (in this case the base template **General Truck**).

1. Create a new event frame template **Truck Operation Issue** with following attributes: **Actual Tire Pressure**, **Gas Tank Level** and **Issue Root Cause**.
2. Create a new analysis template **Tire Pressure Monitoring.**
3. Create a new analysis template **Gas Tank Level Monitoring.**
4. Create a new notification rule template **Truck Problem Notification** and use the Event Frame Search option to generate notifications whenever there is a new event frame based on the **Truck Operation Issue** template. Subscribe student01 to it.

5. Duplicate the Global Default Email format and change the new format **Truck Problem Email** so it will send emails of the following format:

Use the following information how to set up the email fields:



6. Assign the **Truck Problem Email** format for emails to student01.
7. Check in.

10. AF Best Practices

The following recommendations provide some guidelines on how to best setup your AF asset structure based on experience from existing AF installations.

Be aware that in real life you cannot follow all these recommendations!

- All elements should be based on a template

  Even if the template has no attributes in the beginning

  Easier maintenance

- All elements at the same level should be of the same type

  Enterprise at the first level, Site the second level, Area the third, etc.

  Easier use of relative references from child-elements

- Do not only consider Bottom-Up approach

  Try to achieve a well-designed structure, plan for the usefulness of the AF model

- Categories for elements attributes and analyses

  Organizes large numbers of attributes/elements

  A fast way to search for elements and attributes

- Always set the unit of measure explicitly

  PI Point attributes: set source unit for the tag

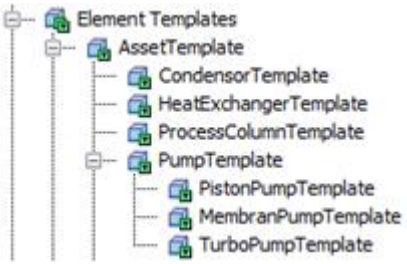
  Formulas: set units for all variables and the result

  Analyses: use the Convert() function

  Avoid defaults

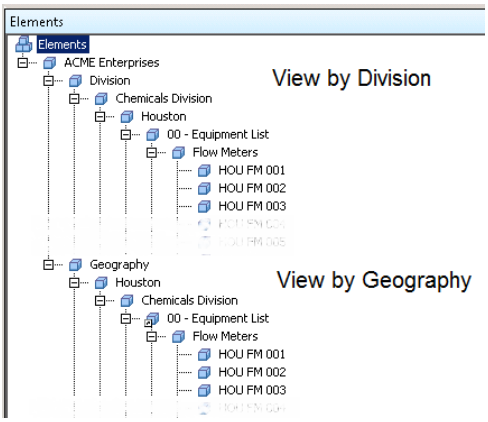
- Use inherited templates

  Allows Flexibility but keeps the standardization



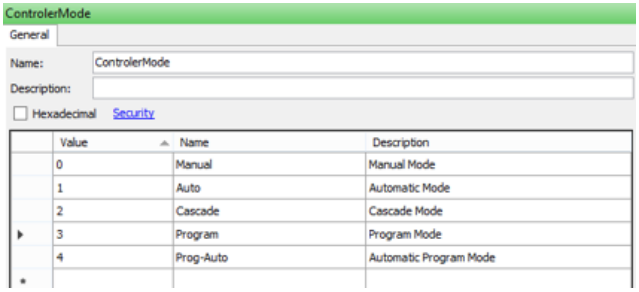
- Build Different Views specific for your users

  Use element references



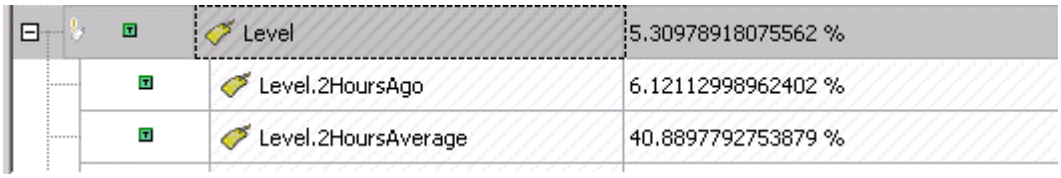
- Use Enumerations

  Limit the choices that
  can be entered in attributes



- Use Hierarchies of Attributes

  Group details or aggregations on a different level



- Use all Data References

  Many options with Table Lookup and for String Builder

- Keep relational data in relational database

  Link AF Tables to results and views

  Use Cache and Parameters

AF Community Library

https://pisquare.osisoft.com/community/all-things-pi/af-library

To improve your AF Skills visit the **AF Community Library** in PI Square!

The library is full of tips and tricks, displays, hierarchies, and templates here. See what others are working, ask for feedback or collaboration, and start exploring how to use PI AF to address your business problems.

To learn more about best practices with AF, explore the **Asset Based Example Kits** that are available from the AF Community Library! The Asset Based PI Example Kits are designed to help you learn how to apply asset- based PI to common, industry-specific business objectives.

11. Final Exercise

11.1 Modeling a Wind Farm in AF

This solo or group exercise is designed to maximize learning in a specific topic area. Your instructor will have instructions and will coach you if you need assistance during the exercise.

Exercise Objectives

- Design a complete AF database.
- Choose the optimum tools to perform the requested tasks efficiently.
- Understand the difference between importing AF tables and linking Microsoft SQL Server tables.
- Explore the AF attribute categories.

Problem Description

You have 50 Wind Powered Turbine units in your wind farm and you have Data Archive tags built for them. The engineers have interesting data in various spreadsheets. You also have maintenance data in a Microsoft SQL Server. You would like to integrate all that data into AF using a common template.

Approach

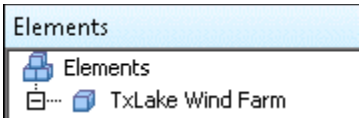
We will create an asset database primarily using the PI Builder tool. Much of the work will be accomplished within Microsoft Excel.

There is a spreadsheet pre-configured for you to use in this exercise: TxLakeWindFarm_WPUs.xlsx

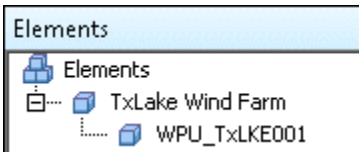
The Data Archive tags used in this exercise are already created.

Modeling the assets

1. Create a AF database TxLake Windfarm to represent the wind farm.
2. A top-level element should be created under which you will create all the wind turbines (i.e. Wind Farm).



3. Configure a Wind Turbine Template and create an element for the first wind turbine based on the template.



4. Create two AF tables: **WPU Models Specifications** (information about the four wind turbine models is obtained from TxLakeWindFarm_WPUModels spreadsheet) and **WPUs Identification** (information about the fifty turbines is obtained from TxLakeWindFarm_WPUs spreadsheet). Both files are located in the C:\Class\Exercises\04_TxLake Wind Farm folder

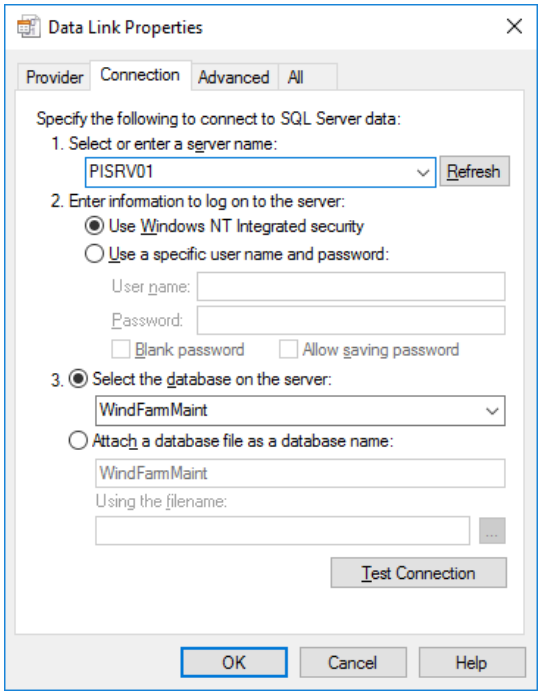
Hint: Information on how to import data from an Excel File into an AF Table can be found in the exercise solution section.

5. Configure the necessary attributes to model the data available in the two tables.
6. Create and configure the necessary attribute templates to model the real-time data coming in the Data Archive tags (TxLakeWindFarm_Tags.xlsx).
7. Open the TxLakeWindFarm_WPUs.xlsx spreadsheet to see how many turbines this wind farm has and then use a blank spreadsheet to create the AF elements using PI Builder. The wind turbines are to be called WPU_TxLKE001, etc. and based on the same template.
8. Validate that the wind turbines were created by opening PSE.

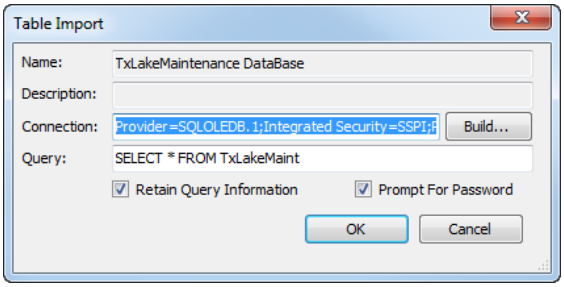
Hint: Because the tag naming convention includes the wind turbine name, it is possible to use substitution parameters in the template to populate the PI Point data references.

Importing SQL Server data

9. Create a new AF table linked to the wind farm maintenance system (Microsoft SQL Server database: WindFarmMaint)



- Under Table Properties, select *Link*. In the dropdown for Connection, select *<Build>*
- Use the *Microsoft OLE DB Provider for SQL Server* driver.
- Enter the Microsoft SQL Server instance name you noted at the beginning of this exercise.
- Use Windows authentication.
- Enter the Microsoft SQL Database name you noted at the beginning of this exercise



- Link to the TxLakeMaint table (*SELECT * FROM TxLakeMaint*).

10. Create and configure the necessary attribute templates to model the data available from the Microsoft SQL Server relational database.
11. Create attribute categories to organize the attributes into logical groupings.

About Attribute Categories

Categories can be used for various AF objects, such as the attributes. Attribute Categories are used to group attributes together so it is easier to look, search or perform aggregations on the attributes of a AF model. Categories are not extensively used in client applications like PI ProcessBook or PI Datalink. However, certain analytics, like the roll-up calculation, take advantage of this feature.

Adding Analytics

12. Add an attribute to show the last hour's average generated power (kW). This is a running average over the last hour on the instantaneous generation attribute (.GenWatts tag). There is no need to archive the result of this calculation.
13. Add an attribute to show the WPU effectiveness or yield (%) with the following formula. The results of this calculation should be historized. The calculation should be executed every minute. Backfill 1 hour worth of data for the first 10 wind turbines.

    *Power / Rated Power * 100*

14. Calculate the Total Power Generated for the whole wind farm in MegaWatts by using a rollup analysis.

Tracking important Events

15. Lake Wind Farm's engineers would like to keep track of high-speed winds; knowing the duration of wind gusts (speeds faster than 90 mph) is essential for performance analysis. Furthermore, engineers need to know what the average rotor speed and the maximum power generated are during a wind gust. Backfill the events for the last hour for all wind turbines.

Visualizing the data (Optional)

16. Complete the PI ProcessBook display TxLakeWindFarm_WPUStatus.pdi and make it Element Relative to monitor the wind turbines of the TxLake Wind Farm.
17. Use PI Vision to visualize the high wind speed events.

12. Exercise Solution Section

12.1 Azure-based learning (VLE) setup

There is a dedicated setup in Azure (cloud based computing service from Microsoft), which is prepared to perform the exercises of this class. The setup consists of the following two machines: PIDC.PISCHOOL.INT (domain controller) and PISRV01.PISCHOOL.INT (application server). The training is carried out on PISRV01.

The Windows domain accounts available for this training are: student01, student02, student03, and student04. For localized environments, the following accounts have to be used:

German: de-student01, de-student02,de-student03, de-student04
Spanish: es-student01, es-student02,es-student03, es-student04
French: fr-student01, fr-student02,fr-student03, fr-student04
Japanese: ja-student01, ja-student02,ja-student03, ja-student04
Korean: ko-student01, ko-student02,ko-student03, ko-student04
Portuguese: pt-student01, pt-student02,pt-student03, pt-student04
Russian: ru-student01, ru-student02,ru-student03, ru-student04
Chinese: zh-student01, zh-student02,zh-student03, zh-student04

The Mail Server is configured to support the following student accounts: student01@pischool.int, student02@pischool.int, student03@pischool.int and student04@pischool.int.

12.2 Exercise Solution: Applying Expression Analysis Syntax

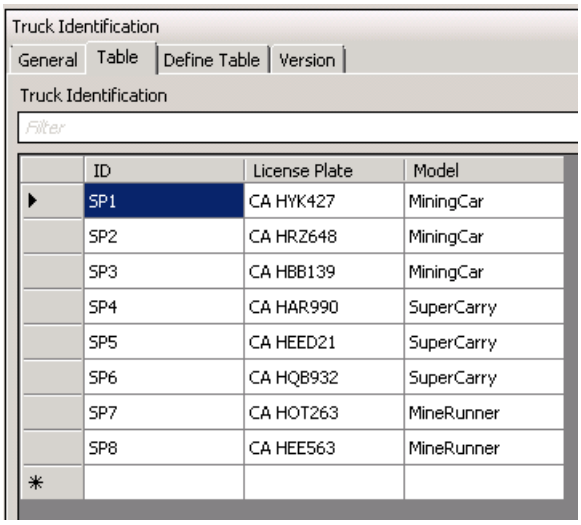
Problem	Solution	Hints
Get a ten-minute "rolling" average of the **SensorX** attribute	TagAvg('SensorX', '*-10m', '*')	The **TagAvg()** function gives the average of a tag over a given time period.
Get the time-weighted total for the **SensorY** attribute over the last 24 hours, but only if at least 80% of the values used in the calculation are considered "good".	IF PCTGood('SensorY', '*-24h', '*')>=80 THEN TagTot('SensorY ', '*-24h', '*') ELSE NoOutput() or TagTot('SensorY ', '*-24h', '*', 80)	**If… Then… Else…** statements can be used in the PE syntax. The **PCTGood()** function gives the percentage of "good" values for a tag. The **TagTot()** function gives the time-weighted total of a tag over a given time period.
The amount of time the **Mode** attribute was "Manual" during the past four days.	TimeEQ('Mode','t-4d','t',"Manual")	**TimeEQ()** The amount of time returned is in seconds.
Display "Overload" when the **Level** attribute is greater or equal than 90 , "Normal" when between 10 and 90 (**excluding** the boundary values), and "Empty" when lower or equal than 10.	If 'SensorX' >= 90 then "Overload" else if 'SensorX' <= 10 then "Empty" else "Normal"	**If… Then… Else…** require the ELSE clause to be present.

12.3 Exercise Solution: ABC Mining Trucks

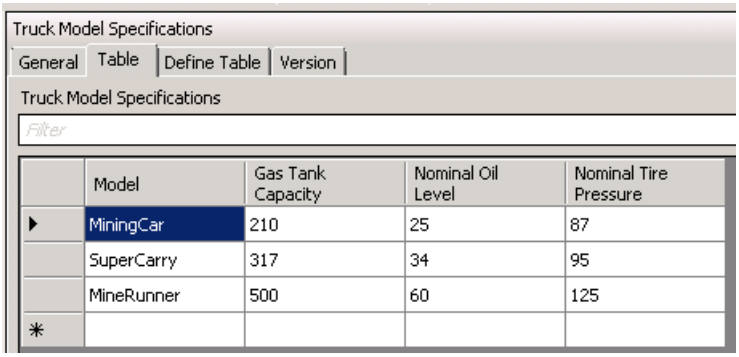
Step-by-Step Solution

1. Create tags required for the exercise from the file ABCMiningCompany_Tags.xlsx located in C:\Class\Exercises\03_ABCMiningCompany (or the location specified by your instructor).
   (not required in case you are using the Azure-based learning (VLE) setup)

2. Create two tables *Truck Model Specifications* and *Truck Identification*.
   To avoid manual entry, tables can be imported from files C:\Class\Exercises\03_ABCMiningCompany\Truck Identification.xml and C:\Class\Exercises\03_ABCMiningCompany\Truck Model Specifications.xml.To import the tables, select File > Import from file. Verify the result under Library > Tables:

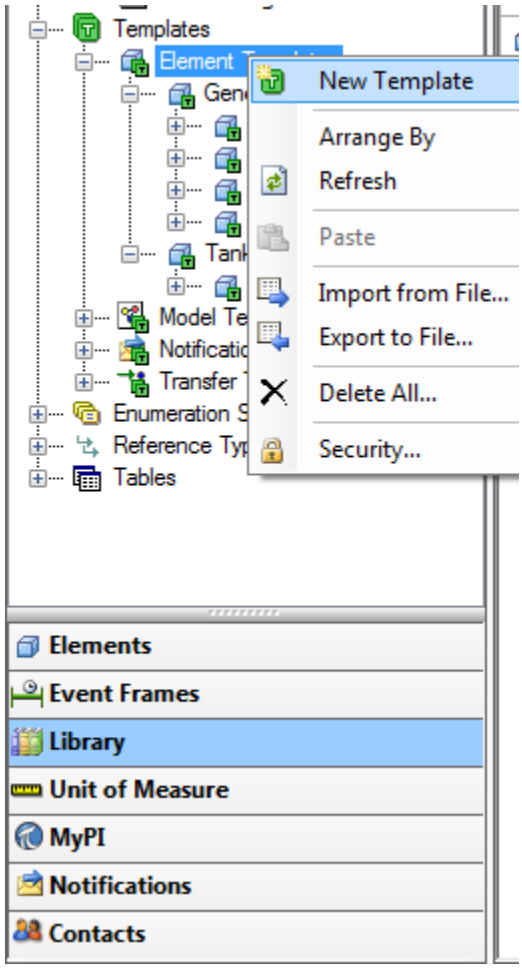


	ID	License Plate	Model
▶	SP1	CA HYK427	MiningCar
	SP2	CA HRZ648	MiningCar
	SP3	CA HBB139	MiningCar
	SP4	CA HAR990	SuperCarry
	SP5	CA HEED21	SuperCarry
	SP6	CA HQB932	SuperCarry
	SP7	CA HOT263	MineRunner
	SP8	CA HEE563	MineRunner
*			

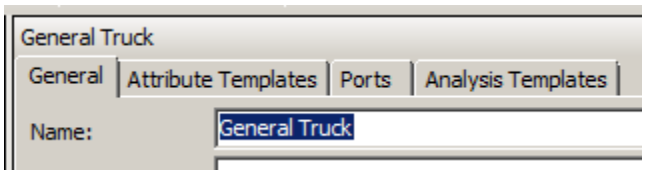


	Model	Gas Tank Capacity	Nominal Oil Level	Nominal Tire Pressure
▶	MiningCar	210	25	87
	SuperCarry	317	34	95
	MineRunner	500	60	125
*				

3. Create the Base Template. From within PSE, select Library > Templates > Element Templates > New Template.

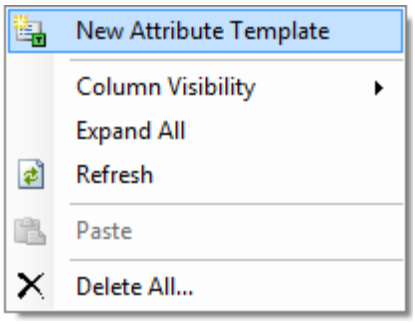


4. Name the template General Truck.

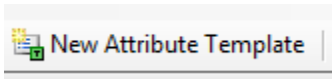


5. Select the Attribute Template tab.

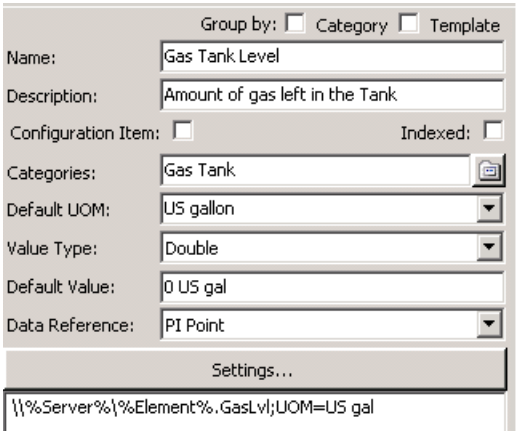
6. In the white space, right-click, then select New Attribute Template or select the New Attribute Template button in the menu.



Or

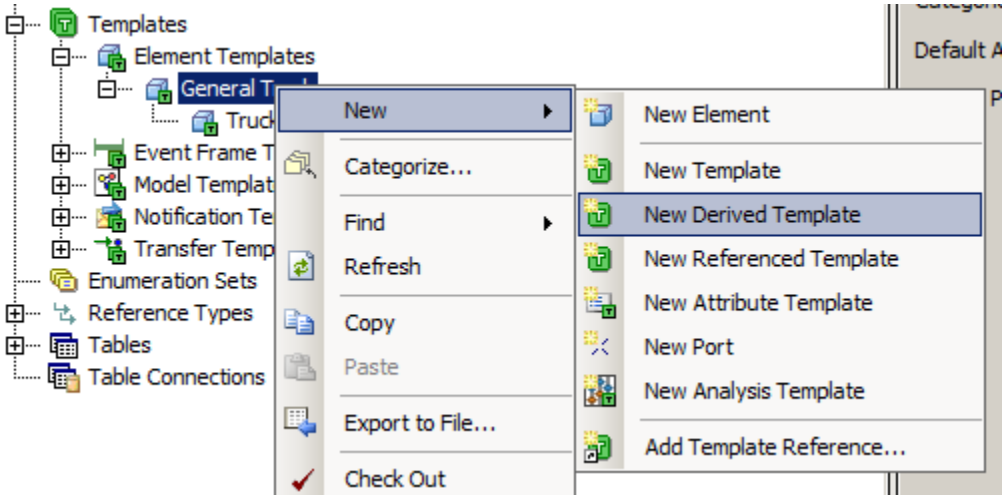


7. Create the attributes standard to all the trucks.

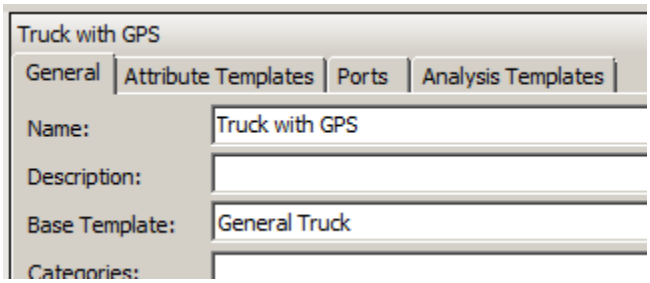


Attribute	Type	Data Reference	UOM	Settings
Actual Oil Level	Double	PI Point	liter	%Element%.OilLvl
Actual Tire Pressure	Double	PI Point	psi	%Element%.TireP
Gas Tank Capacity	Double	Table Lookup	US Gallon	SELECT [Gas Tank Capacity] FROM [Truck Model Specifications] WHERE Model = @Model
Gas Tank Level	Double	PI Point	US Gallon	%Element%.GasLvl
License Plate	String	Table Lookup		SELECT [License Plate] FROM [Truck Identification] WHERE ID = '%Element%'
Model	String	Table Lookup		SELECT Model FROM [Truck Identification] WHERE ID = '%Element%'
Nominal Oil Level	Double	Table Lookup	liter	SELECT [Nominal Oil Level] FROM [Truck Model Specifications] WHERE Model = @Model
Nominal Tire Pressure	Double	Table Lookup	psi	SELECT [Nominal Tire Pressure] FROM [Truck Model Specifications] WHERE Model = @Model
Tripmeter	Double	PI Point	mile	%Element%.Trip

8. Create a derived template for the truck model with GPS Data.



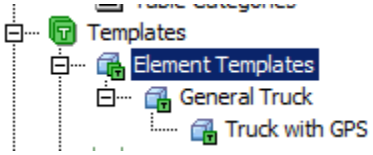
9. The Truck with GPS Data template is derived from the General Truck base template.



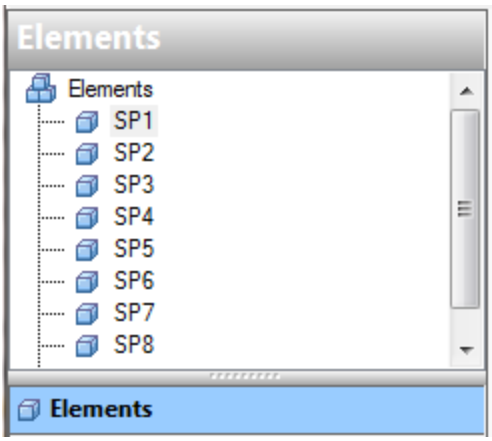
10. Add attribute templates for GPS Latitude and GPS Longitude to the template for the Truck with GPS:

Attribute	Type	Data Reference	UOM	Settings
GPS Latitude	Double	PI Point	seconds	%Element%.GPSLat
GPS Longitude	Double	PI Point	seconds	%Element%.GPSLat

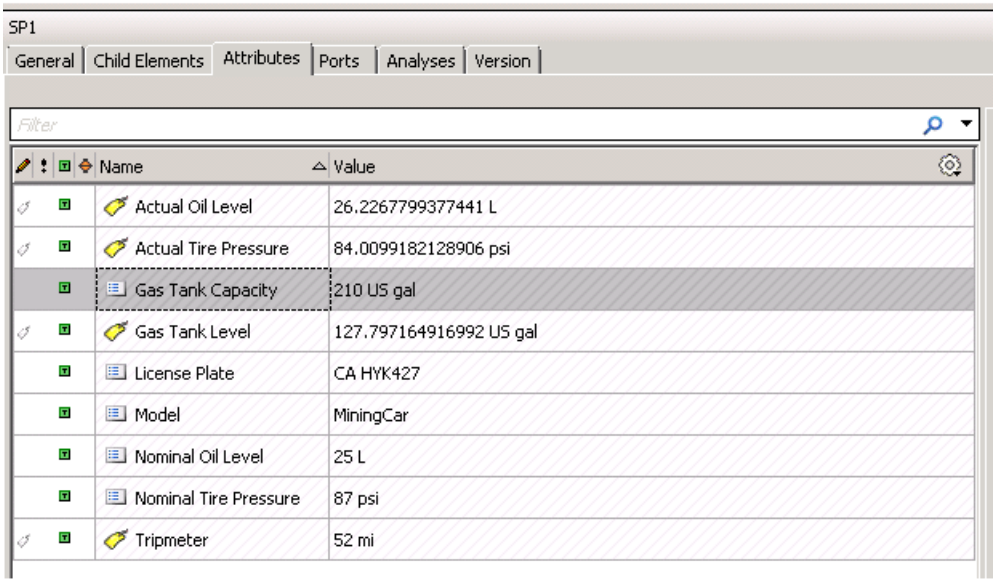
11. Check in and refresh the Browse window, If you right-click Elements Template in the tree on the left hand side, you have the option to arrange templates by template inheritance. That way you will see the relation between the templates. The default is to arrange by name.



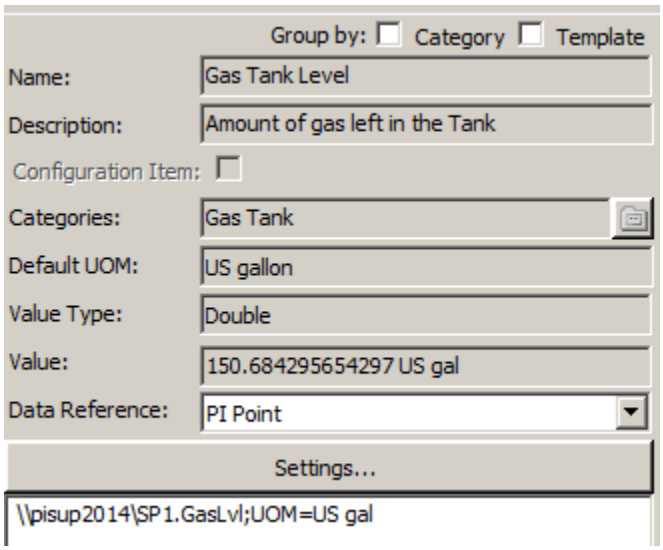
12. Create individual elements for the eight (8) trucks currently operated by ABC Mining. Name them according to the initial table with vehicle listing.



13. Verify all the expected fields are present in the individual elements representing the appropriate model. Truck SP1 is shown below for reference:

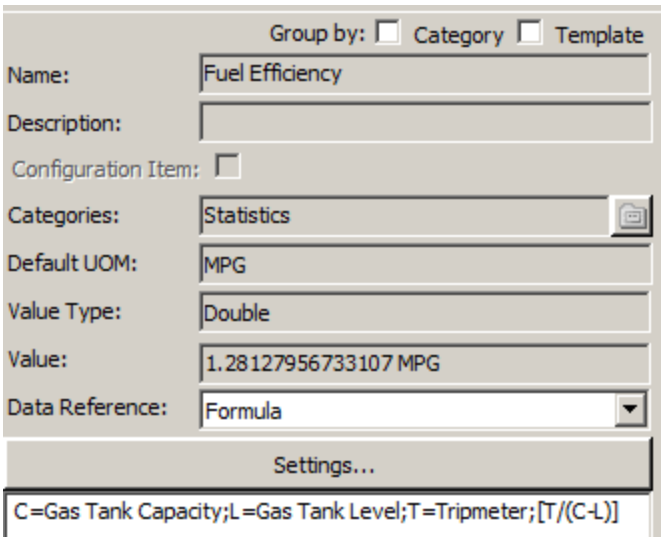


14. Verify all attributes are being updated based on the PI Points. For example, Gas Tank Level is based on %Element%.GasLvl but the tag should be listed as SP1.GasLvl with the appropriate Element ID in place of %Element%

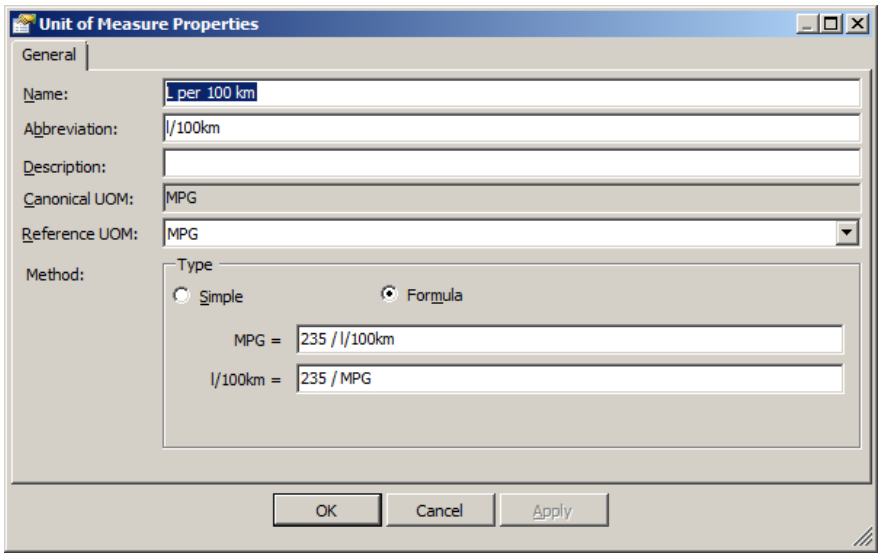


15. Add a new UOM class *Fuel Efficiency* that has unit-of-measure MPG as its canonical unit.

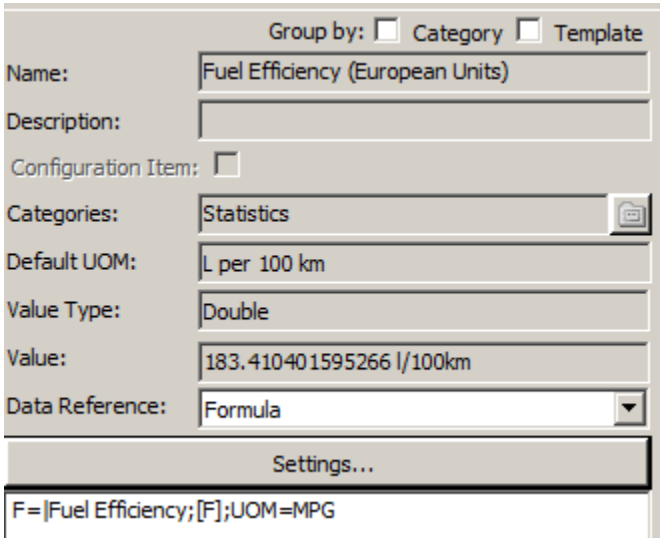
16. Add the Fuel Efficiency calculation to the base template. As mentioned in the hint, the Fuel Efficiency can be calculated using the gas tank level, trip meter, and gas tank capacity. Assign MPG as the Default UOM.



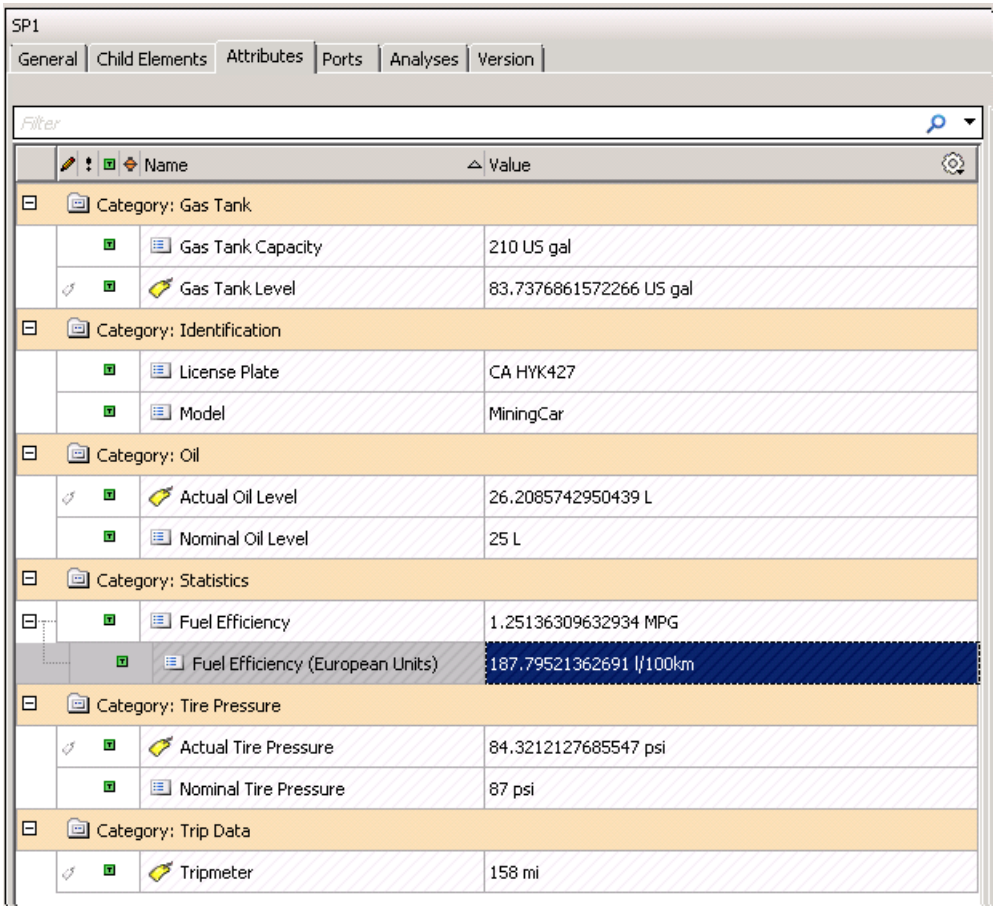
17. Add a further unit-of-measure *Liter per 100 km* (abbreviation: *l/100km*) to UOM class *Fuel Efficiency.*
Enter the formulas as below:



18. Add *Fuel Efficiency (European Units)* as a child attribute for *Fuel Efficiency*. Assign *L per 100 km* as default UOM. Use a Formula Data Reference and refer to the *Fuel Efficiency.* Set Result UOM to *MPG:*

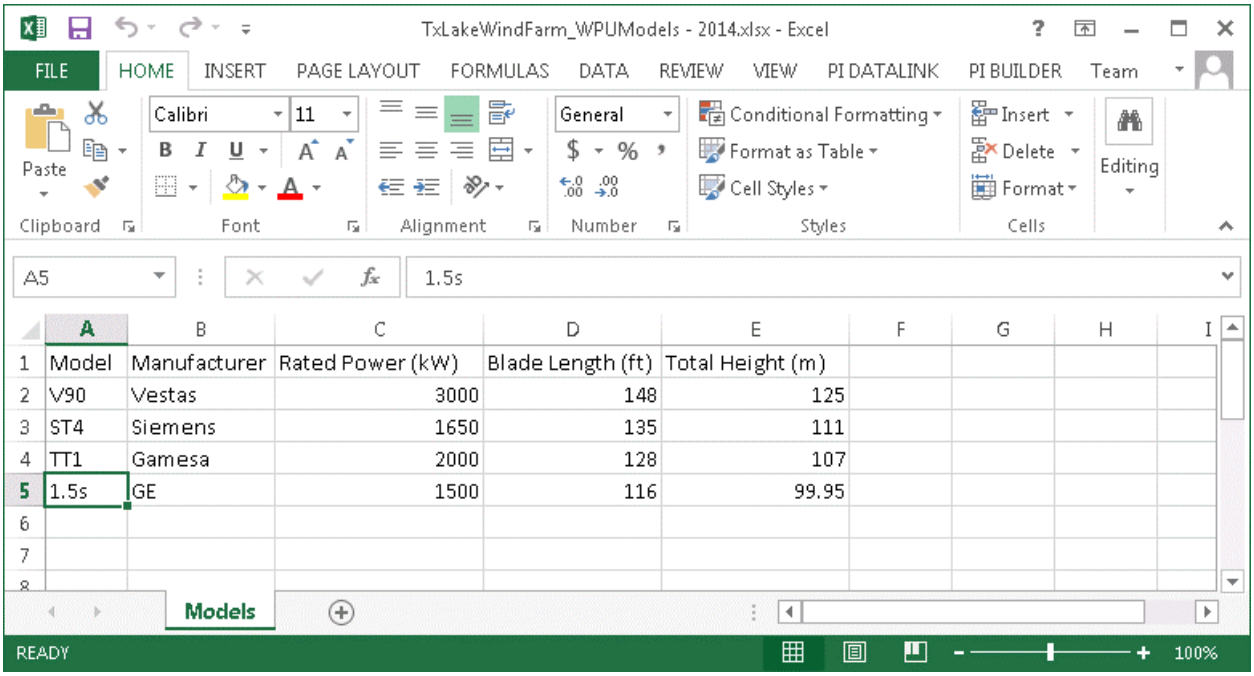


19. After adding this to the base template, check in the template, then verify the elements have the fuel efficiency attribute added.



12.4 Solution: How to import data from an Excel File into an AF Table

The following steps describe how to import data from an Excel file (here: TXLakeWindFarm_WPUModels.xlsx, located in c:\class\Exercises\04_TxLake Wind Farm folder)



Step-by-Step Solution (64-bit PI System Explorer)

In PI System Explorer, navigate to the AF table or create one as described in Create AF tables.

1. In the **Library** pane, expand the **Tables** node, and select **New Table**.
   The table details display in the right pane.

2. Click Import.
   The corresponding window opens.

3. Click Build.
   The Data Link Properties window opens.

4. On the Provider tab, select the provider according to the version of Microsoft Office that you are using and click Next.

   For Office 2007 and higher: select **Microsoft Office 12.0 Access Database Engine OLE DB Provider**.

> Note: though we have Excel 2016 (16.0.4266.1001), do not select **Microsoft Office 16.0 Access Database Engine OLE DB Provider**

5. On the Connection tab, specify the following and click OK.

   Data Source
   The location and file name of the workbook:
   c:\class\Exercises\04_TxLake Wind Farm\TXLakeWindFarm_WPUModels - 2014.xlsx

   User Name
   Login credentials of a user that has been granted read access to the database or workbook. Keep Admin, blank password.

6. On the **Advanced** tab, in the **Access permissions** list, select **Share Deny None.**

7. On the **All** tab, select the **Extended Properties** value and click **Edit Value**.

   The Edit Property Value window opens. Enter: **Excel 12.0**

8. To verify that the spreadsheet is accessible, return to the **Connection** tab and click **Test Connection**.
9. If the settings are valid, a Test connection succeeded message displays.

   To dismiss the window and return to PI System Explorer, click **OK**.

10. To define the data to be returned from the spreadsheet, enter an SQL query in the **Query** field. To dismiss the window, click **OK**.

    Into the query line, enter: SELECT * FROM [Models$]

11. To review the resulting data, examine the **Table** tab. If the query is specified correctly, the tab contains a table displaying the results.

12. To save your changes, right-click the table node and choose **Check In**.

Step-by-Step Solution (32-bit PI System Explorer)

1. Open the .xlsx file in MS Excel and Save as Excel 97-2003 Workbook (.xls).

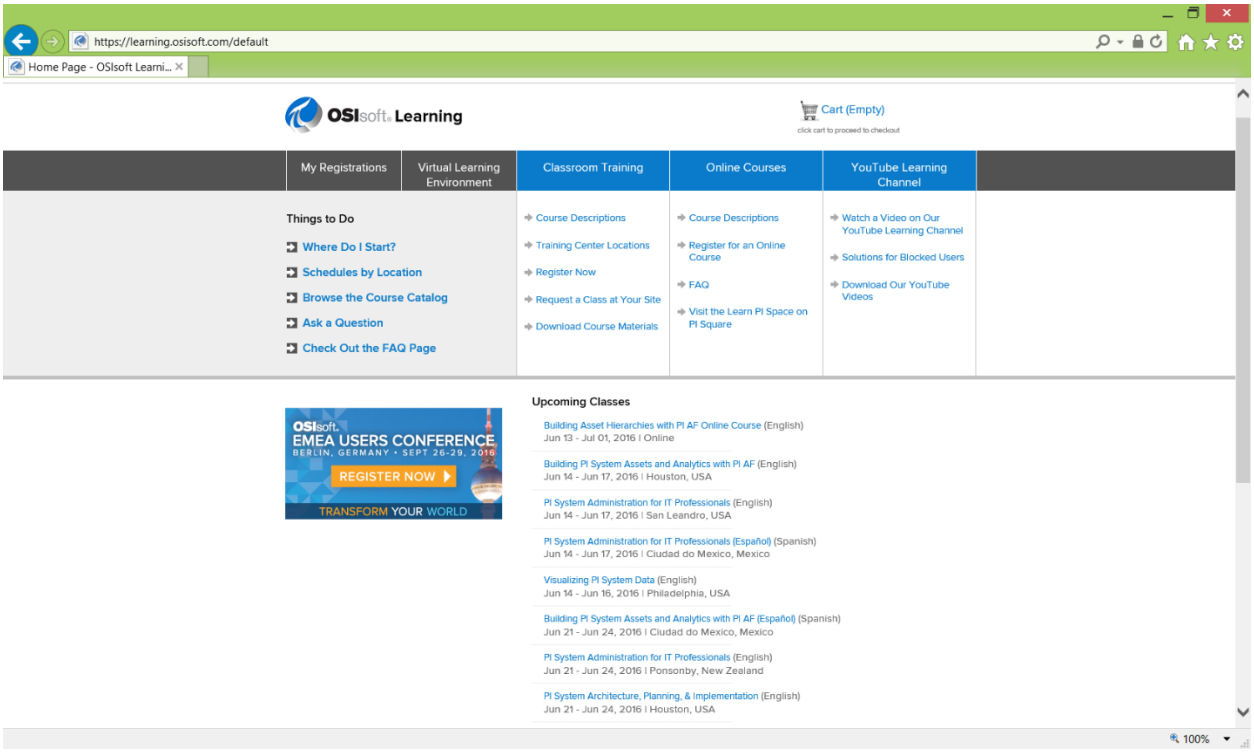
2. Follow the same steps as above.

   As **Provider**, select **Microsoft Jet 4.0 OLE DB Provider**
   Under Extended Properties, for Excel 97 – 2003, enter **Excel 8.0**

13. Resources

13.1 Training Options

The OSIsoft Training page is located at https://learning.osisoft.com.



13.1.1 Instructor Led Training

Instructor led training at our public training site - *Our classic offering - Learn about the PI System at OSIsoft Training Centers with classes in several languages and growing!*

Instructor led training at your site - *Our personalized offering - Learn with customized curriculum and get coaching at your site, at your time, with your data!*

13.1.2 OnLine Training

Small Private Online Courses - *Our latest offering - Learn about the PI System from your own office or home, on your own schedule, with your own data!* For more information go to https://pisquare.osisoft.com/community/Master-PI

On Demand Learning: YouTube Channel - *Learning Anywhere, Everywhere - Learn about the PI system by watching any of our 1000+ free videos on You Tube!* Playlist for various topics are available to help guide you through your training topic.

VLE – Virtual Learning Environment - is a fully functional PI System running in our Microsoft Azure cloud. We have a wide array of defined labs, from PI ProcessBook to AF to developer technologies.

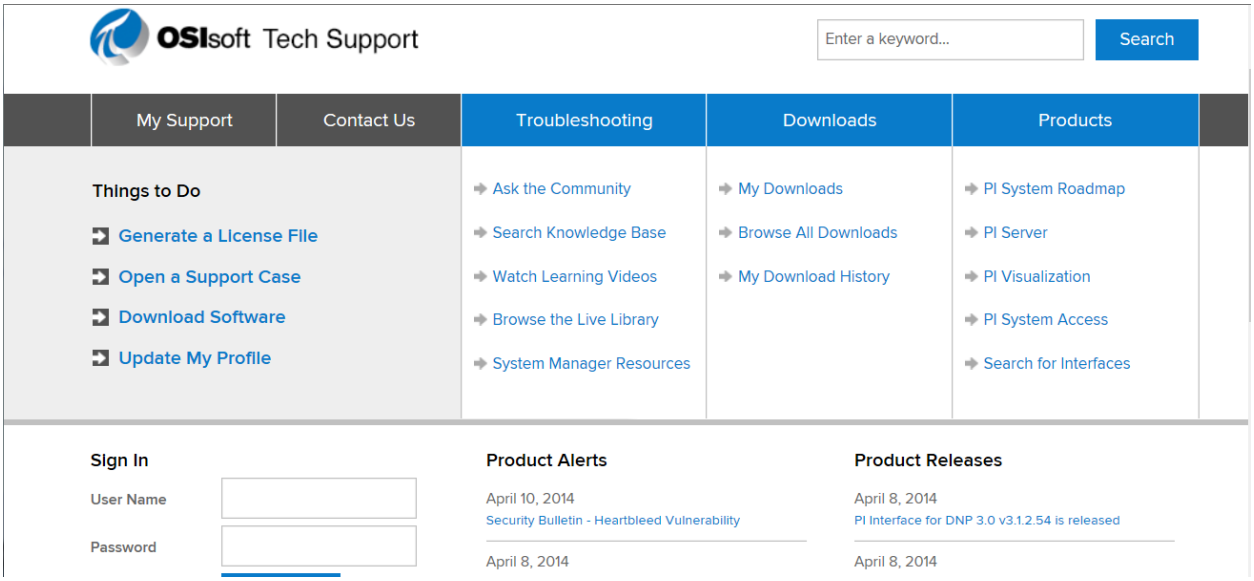
13.2 OSIsoft Community

PI Square is OSIsoft's Community. Here you can make connections with

- other OSIsoft employees and customers;
- PI Dev Club to assist in your development projects;

13.3 Tech Support

We recommend visiting the Tech Support site, http://techsupport.osisoft.com.



From here you have many options.

- You can download anything your company is licensed for using the Download center.
- You can view OSIsoft' s Roadmap to get information about the most current releases and predicated release dates and features for new version or products.
- You can login and view your support calls, both currently open and previously closed.
- You can also search through our Knowledge Base to try and troubleshoot any issues you may be having on your own.

The phone number and email address for OSIsoft Technical Support:

- Phone: (01) 510 297-5828 US or search https://techsupport.osisoft.com/Contact-Us/ for your local contact number.
- E-Mail: support@osisoft.com
- Before you contact Tech Support, collect
    - the name of the product and the version number..
    - Determine the PI version and build numbers using the **Operation > Version** option in SMT.
    - Get computer platform (CPU type, operating system, and version number) as follows:

- On Windows, right-click on My Computer icon and select Properties tab.
- On UNIX, type *uname -a*

- Note the time that the difficulty started, and be prepared to report the contents of the message log at that time. The message log is found in the **Operation > Message Log Viewer** option in SMT.
- You will likely also need the PIPC log covering the applicable time range. This log is located in `\\pipc\dat`.

13.4 Further Questions

For questions about Licensing, if you are in the US, you can find your salesman listed at http://www.osisoft.com **> Contact Us > US Sales**. If you are outside the US you can find your salesman listed at http://www.osisoft.com **> Contact Us > International Sales**.

For questions about existing Support Issues, you should call technical support at 510 297-5828 or visit http://techsupport.osisoft.com **> My Support > My Calls**.

For questions about unresolved training issues, contact your instructor or email learning@osisoft.com.

For all other questions, please contact our Customer Service group via email at customerservice@osisoft.com.

14. Software Versions Used in this Document

The list below describes the software versions used in this version of the course.

Software	Version
Windows Server	2016
Data Archive Server	2018 SP2 (3.4.425.1435)
PI System Management Tools	2018 (3.6.3.30)
AF Server	2018 SP2 (2.10.5.9050)
PI System Explorer	2018 SP2 (2.10.5.9050)
PI Analysis Service	2018 SP2 (2.10.5.9050)
PI Notifications Service	2018 SP2 (2.10.5.9050)
PI Vision	2017 R2 Update 1 (3.3.0.9)
PI Web API	2017 R2 SP1 (1.11.0.640)
PI Datalink	2019 (5.5.0.0)
PI ProcessBook	2015 R2 SP2 (3.6.2.271)
Microsoft Office (64-bit)	2016
Microsoft SQL Server (64-bit)	2014 (12.0.2000.8)

15. Appendix A Substitution Parameters

Defining the Substitution Parameters

The substitution parameters are listed in the following table. The ones in bold are the commonly used “Name” substitution parameters.

Parameter	**Will be replaced by this object’s name:**
%..\Element%	The name of the owning element of the element in which the attribute resides. To retrieve further ancestors, use the ‘..\’ notations, such as %..\..\Element%.
%|Attribute%	Name of the root attribute or attribute template that holds this data reference.
%..|Attribute%	The name of the owning attribute in which the attribute resides. To retrieve further ancestors, use the ‘..|’ notations, such as %..|..|Attribute%.
%@Attribute%	The value of the attribute referenced. To retrieve further ancestors, use the ‘..|’ notations, such as %@..|..|Attribute%.
%\Element%	The name of the root AF Element in which the attribute resides.
%<Environment Variable>%	The matching System Environment Variable’s value. For example %COMPUTERNAME% is replaced with the name of the computer on which the Data Reference is executing.
%Analysis%	The name of the analysis if it can be obtained from the context.
%Attribute%	The name of the attribute that holds this data reference.
%AttributeId%	The attribute ID that holds this data reference.
%Database%	The name of the AF Database in which the attribute resides.
%Description%	The description of the attribute that holds this data reference.
%Element%	The name of the AF Element in which the attribute resides.

%ElementDescription%	The description of the element in which the attribute resides.
%ElementId%	The element ID that holds this data reference.
%EndTime%	The local end time if it can be obtained from the time context.
%Model%	The name of the model if it can be obtained from the context.
%Server%	The name of the default Data Archive of the AF Database in which the attribute resides.
%StartTime%	The local start time if it can be obtained from the time context.
%System%	The name of the PI System in which the attribute resides.
%Time%	The local time if it can be obtained from the time context.
%UtcEndTime%	The coordinated universal (UTC) end time if it can be obtained from the time context.
%UtcStartTime%	The coordinated universal (UTC) start time if it can be obtained from the time context.
%UtcTime%	The coordinated universal (UTC) time if it can be obtained from the time context.
.\	The current reference
[.]	The default object of the parent collection. For example .\Elements[.] |Temperature returns the temperature attribute from the primary element of the current reference's Elements collection.
[@filter=text]	The search string in text (e.g. Tank*) matches the given filter. Supported filters are: @Name, @Index, @Template, @Category, @ReferenceType, @Description, @Type, @UOM.
[@Index=#]	Returns the result at location # from the collection result.

For a complete list refer to "Substitution parameters in data references" in Chapter "Configuration of data references" in the *PI System Explorer User Guide*, version 2015, p. 124 ff.

16. Revision History

Revision	Reviewer	Description
2010	Martin Bryant	Initial version of the Building PI System Assets and Analytics with AF class workbook.
2012	Linda Payne	Revision to include comments from instructors after few classes' delivery.
2012b	Louis-Philippe Pagé-Morin	Revision to include new features of the 2012
2014	Alejandro Molano	AF 2.6 Update, added Asset-Based analytics chapter, Event Frames chapter and EF visualization using PI Coresight and PI Datalink.
2015	Linda Payne, Gerhard Polenz	Replaced Pizza Delivery Vehicles by Mining Trucks Application, updated for Azure-based learning (VLE) setup
2015a	Linda Payne, Gerhard Polenz	Updated for PI Server 2015 Revised chapter AF Object SecurityTerm, added chapter for Future Data
2015b	Gerhard Polenz	Revised exercise 6.2.3 (PIVOT table), Changed chapter 9.6 (Future data now created by AF Analysis), added chapter 12.6. How to import data from Excel
2016a	Gerhard Polenz	2016 Software Upgrade. Coresight related parts rewritten, EF-related exercises revised, attribute traits, attribute properties, multiple Asset views, ACE optional
2016b	Gerhard Polenz	2016 R2 Software Upgrade. Complete re-write of the Notification section
2016c	Gerhard Polenz	new VLE VM security, new student passwords
2017 R2	Gerhard Polenz	2017 R2 Software Upgrade, Coresight->PIVision
2018	Gerhard Polenz	VLE based on Windows 2016 Server (PISRV01), added DisplayDigits, removed PE, Totalizer and ACE chapters