



# PI World 2020 Lab

# PI System: From Data Exploration to Notification

Operational IntelligenceCopyright Copyright & Trademark © Copyright 1995-2020 OSIsoft, LLC 1600 Alvarado Street San Leandro, CA 94577

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### PI System software

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

Software	Version
PI Data Archive	2018 SP3
PI Asset Framework (PI AF) server	2018 SP3
PI Asset Framework (PI AF) client (PI System Explorer)	2018 SP3
PI Analysis & PI Notifications Services	2018 SP3
PI Vision	2019
PI Integrator for Business Analytics	2018 R2 SP1
PI DataLink	2019 SP1 (5.5.1)

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

## 1. Lab Overview

### 1.1 Objective

In this lab, we use analytical features of PI System to evaluate and then implement an idea for improving plant operation. First, we'll use Asset Analytics to add descriptive features to gain process insight from the raw measurement data. The PI Integrator for Business Analytics will be used to provide data to Power BI where we'll perform multidimensional analysis allowing us to validate our idea and quantify its value. Using DataLink, we develop a simple predictive model for real-time operationalization in Asset Analytics. Then finally, we'll use PI Notification to recommend a process action based on the result of this prediction.

### 1.2 Gathering Domain Knowledge – PI Vision



The data we are using was taken from a years' operation of two liquid feed dryers. These are large cylindrical vessels (right), filled with molecular sieve pellets. They are used to continuously remove moisture from a hydrocarbon stream in an oil refinery. The liquid feed stream must be completely dry before it combines with a strong acid which serves as a catalyst for the chemical reaction. Even small amounts of water entering the reaction create a highly corrosive environment that will damage and compromise the equipment metallurgy.

The dryers are designed to be redundant, cycling between two operating states. The "Drying" state is when dryer is actually removing moisture from the liquid fed to the reactor. Once saturated, the dryer is switched to a "Regenerating" state. In this state, a hot vapor stream is used to remove

water from the molecular sieve pellets inside the dryer. Thus, the dryers are cycled back and forth between operating states to continuously remove moisture from the feed before it combines with the strong acid catalyst for the chemical reaction.

### The Feed Drying Process – Before

Solidify your process knowledge by looking at the process measurement data in PI Vision.

- 1. From the desktop icon, open 'PI Vision' application.
- 2. From the PI Vision display thumbnails, double-click on the '**Drying Process Before'** tile to open the display shown below.



In the display above, Dryer A is in its "Drying" state while Dryer B is in its "Regenerating" state. The moist liquid feed flows into the top of Dryer A, water is adsorbed in the molecular sieve pellet bed and the dried liquid flows out the bottom and on to the reactor. Meanwhile, a small amount of the feed is heated, vaporized and sent to Dryer B, which is in its "Regenerating" state. The hot vapor stream raises the temperature of Dryer B's bed, driving water out of the molecular sieve and thus preparing it for its next drying cycle once Dryer A is saturated.

The process measurements available for this lab are shown in the display's value and trend objects.

Shown as values are:

Feed Flow - the moist, undried, liquid feed, (barrels per day)

Flow to Vaporizer - a small amount of feed which gets vaporized to regenerate molecular sieve pellets (barrels per day)

Vapor Temp. - vapor temperature, (Deg. F)

Show as values and trends are:

**Outlet Temp.** - Dryer A **orange** - temperature of stream leaving Dryer A, (Deg. F).

**Outlet Temp**. - Dryer B yellow – temperature of stream leaving Dryer B, (Deg. F).

Notice, there is no variable in the display showing the dryer's current state. However, the Outlet Temperature trend in the middle of the display shows the dryer outlet temperatures peaking in an alternating fashion as they rise and fall with each regeneration. These temperature patterns will be the basis for everything we do in this lab.

3. Select the **'Outlet Temperatures'** trend and using the time scroll at the bottom adjust display end time to find a time when Dryer A is in its "regenerating" state. This will occur when Dryer A's outlet temperature, the orange trace is peaking. An example of this operation is shown below, everything works the opposite way.



### **1.3** Process Improvement Idea – PI Vision

After several years of service, the molecular sieve beds will reach their end-of-life and need to be replaced. The replacement of both beds will occur at the next planned refinery shutdown. The most efficient way to manage the condition of these beds is to treat them equally throughout their service life. The condition each bed sees could be measured by the amount of time they operate in a particular state, however a more equitable metric is one based on the volume of moist hydrocarbon feed they see during the drying cycle. The feedrate to this process can vary greatly so times of high throughput are more taxing than times when the feedrate is low.

Our idea for process improvement is to provide more visibility and proactive management of the dryers' molecular sieve beds. We would like to display an indication of dryer state and to provide a running total of barrels processed by each dryer for the life of this load of molecular sieve. This will show how well we are managing the beds over time. As additional assistance, we would like to provide an estimate of how long the next regenerating cycle will take for a dryer currently in its "Drying" state. AF Notifications can send an email reminder to the process operator whenever the estimated regeneration duration exceeds a prescribed time.

### The Feed Drying Process – After

Take a look at the implementation of our idea. During the lab, you'll be going through the steps to make this happen.



- 1. Click the **PI** vision display. This will return you to the display thumbnails.
- 2. Double-click on the 'Drying Process After tile to open the display shown below.



The same process measurements are shown however, we have added several others to add visibility into the dryer's current state, the total barrels of hydrocarbon feed it has dried and a prediction of the time required for the next regenerating cycle.

Additional values are:

Dryer State - multi-stated value, "Drying", "Regenerating", or "Standby"

**Drying Cycle Barrels** – total barrels of feed through Dryer during current "Drying" cycle (barrels).

**Next Regeneration Cycle Duration** – predictive model results estimating duration of next regenerating cycle (hrs.)

Additional trends are:

**Lifetime Barrels** - Dryer A **Teal** – total barrels of feed through Dryer A during "Drying" cycles (barrels).

**Lifetime Barrels** - Dryer B **Cyan** – total barrels of feed through Dryer A during "Drying" cycles (barrels).

### The AF Model

Of course, everything we do in this lab is based on an AF database. For this lab we use one named 'Dryers'. Familiarize yourself with the Dryers by completing the following steps.



- 1. From the Windows taskbar, open PI System Explorer **Explorer** and be sure you're connected to the **'Dryers'** database and that the **Elements** view is selected in the lower left-hand corner.
- 2. Select the **Dryer A** element and the **Attributes** tab at the top. Take a look at the various attributes configured for each dryer. (We won't be using all of them for this lab.)

Elements	Dryer A						
Elements	General (	Child El	ements Attributes Ports Analyses Notification R	ules Version			
Dryer B	Filter						
Lienen Sea dies		•	Name	△ Value			
		Catego	ry: Asset Specifications				
		T	🗉 Dryer	Dryer A			
		Category: Dryer Bed Condition					
	5	•	🍼 Lifetime Barrels	1803270 bbl			
		Category: Dryer Management					
		•	ntering the segmentation Cycle Time Forecast	11.6 h			
		•	ntrying Cycle Barrels	6477.9 bbl			
	0	•	🍼 My Dryer Regeneration Cyde Time Forecast	11.616			
			E Regeneration Cycle Model Intercept	9.6722			
			E Regeneration Cycle Model Slope	0.0003			
			🎺 Regeneration Notification Trigger	1			

3. With **Dryer A** element still selected, click the **Analysis** tab at the top. Here are the Asset Analytics we'll be using to help implement our improvement idea.

lements	Dryer A	
Elements	General Child Elements Attributes Ports Analyses Notification Rules	Version
International In		
武 Element Searches	😝 🖻 🚯 🖻 Name	Backfilling
	🕥 🔳 📙 Dryer Notification	0
	🔗 🔳 🛛 f🕸 Dryer Regeneration Cycle Time Forecast	0
	🖉 🖻 💾 Dryer Regeneration Events	0
	🔗 🖬 f🐼 Dryer State - Best	0
	🔗 🖬 🏾 f🐼 Dryer State - Better	0
	🕜 🖬 f 🔅 Dryer State - Good	0
	🕜 🖬 💾 My Dryer Notification	0
	🔗 🔳 🏾 f🐼 My Dryer Regeneration Cycle Time Forecast	0
	😥 🔳 f 😣 My Dryer State	
	👩 🗉 🏾 ft🕸 Total Barrels Dried	0

Both **Dryer A** and **B** elements have been derived from the **Dryer** template. The lab exercises will be done in this template so everything we do will be applied both dryers.

 Select the Library view in the lower left-hand corner of PI System Explorer. Under the Templates branch of the hierarchy, expand Element Templates to expose the Dryer template we are using for this lab. Click on the Dryer template and select the Analysis Template tab at the top.

Dryer
General Attribute Templates Ports Analysis Templates Notification Rule Templates
🔕 🖻 Name
H Dryer Notification
f⊗ Dryer Regeneration Cycle Time Forecast
Dryer Regeneration Events
f⊗ Dryer State - Best
f🕸 Dryer State - Better
f@ Dryer State - Good
H My Dryer Notification
f  My Dryer Regeneration Cycle Time Fo
ft My Dryer State
f@ Total Barrels Dried

We will be configuring an email notification to proactively remind process operators when it may be time to switch dryers. Notification rules are also configured in asset templates.

5. Select the **Notification rule Template** tab at the top of the Dryer template.



## 2. Exploration and Data Engineering

### 2.1 Objective

There are two objectives for this exercise. First, we'll calculate the operating state of each dryer based on patterns in its outlet temperature. Status tags named 'Dryers:My State A' and 'Dryers:My State B' have been created to store your results. This will require some trial and error to configure a rule that accurately identifies the state of each dryer and that works well for all of 2019. You will be using the **Preview Results** and **Backfill/Recalculate** features of Asset analytics to test and evaluate your results.

The second objective will be to calculate the total volume of hydrocarbon feed each dryer sees during "Drying" cycles only. We will review the Asset Analysis configuration for the calculation of two totals:

Lifetime Barrels – accumulated volume of feed during all drying cycles in 2019 (barrels)

**Drying Cycle Barrels** – total volume of feed during each drying cycle (barrels)

### 2.2 Define and Label Dryer Operating States – Asset Analytics

Take a closer look at the dryer outlet temperature patterns in PI Vision.

1. Open PI Vision from the desktop.



2. Click the logo on the upper left-hand corner of the PI vision display. This will return you to the display thumbnails.

- 3. From the PI Vision display thumbnails, double-click on the **'Drying Process Before'** tile to open this display.
- 4. Expand the 'Outlet Temperatures' trend by double-clicking on it.



This trend clearly shows the heating and cooling of the dryer's molecular sieve bed during the regenerating cycle. We will use Asset Analytics to develop a rule, based on this outlet temperature pattern, to identify each operating state and record it in a PI Tag. Sometimes rule development requires several tries to get it right. This will be the case here as we work through the process to develop the best rule for providing the labelling required for the rest of our analysis.

### **Good Operating State**

Configure an Asset Analytic that defines dryer's "Regenerating" cycle when be when its outlet temperature goes above 170 Deg. F.





- 1. From the Windows taskbar, open PI System Explorer **Explorer** and be sure you're connected to the 'Dryers' database.
- In the lower left-hand corner of PI System Explorer, select the Library view. Under the Templates branch of the hierarchy, expand Element Templates to expose the Dryer template we are using for this lab. Click on the Dryer template.
- 3. To access the Asset Analytics defined for this template, click on the **Analysis Templates** tab at the top of the window.

Library	Dryer
Dryers     Templates     Oryer     Templates     Oryer	General Attribute Templates Ports Analysis Templates Notification Rule Templates
Event Frame     New Analysis     Model Templates	Template Dryer Regeneration Cycle Time Forecast
Transfer Templates	H Dryer Regeneration Events
🕀 🗝 Enumeration Sets	ftø Dryer State - Best
	f() Dryer State - Better
Table Connections	f⇔ Dryer State - Good

- Click on the New Analysis Template icon and change the name of your new Analysis Template to 'My Dryer State'. By default, you have created a new Expression type analysis. This is what we need.
- 5. Uncheck **Enable analysis when created from template** to prevent automatically enabling this analytic. We have some testing to do first.



By default, new Analysis Templates are configured to automatically start when elements created from this template. In many cases you will want to test your analysis first. Unchecking the 'Enable analysis

## Tip when created from template' option will give you complete control as to when your analysis is run.

6. Copy and paste the following equation into the **Expression** field for **Variable1** of the **My Dryer State.** 

```
// State based on dryer outlet temperature.
If 'Outlet Temperature' >= 170
Then (If PrevVal('My Operating State','*')="Regenerating"
    Then NoOutput()
    Else "Regenerating")
Else (If PrevVal('My Operating State', '*') = "Drying"
    Then NoOutput()
    Else "Drying")
```

This analysis simply changes the dryer state value to "Regenerating" whenever a temperature value greater than 170 is observed. Once it falls below 170, the state is "Drying". Values are only posted upon a change in state.

7. The Dryer template has already been configured to have an attribute named 'My Operating State' which point to the PI tags 'Dryers:My State A' and 'Dryers:My State B' for Dryer elements Dryer A and Dryer B, respectively.

To the right of the **Expression** field, under **Output Attribute**, click the **Map** link and assign the **'My Operating State'** template attribute.

Also note that the **Example Element** for this template has be set to **Dryer A**. These means that all evaluations and preview calculations will be done using Dryer A data. You can change to another element by clicking the link and selecting a different one, e.g. Dryer B.

You can rename the variable of your analysis from 'Variable1' to 'MyStateRule', (spaces are not allowed in variable names).

0	۸	Name	Description:
	н	Dryer Notification	Categories:
	f69	Dryer Regeneration Cycle Time Forecast	Analysis Type:      Expression      Rollup      Event Frame Generation      SQC
	н	Dryer Regeneration Events	Enable analyses when created from template
	f@	Dryer State - Best	
	f(s)	Dryer State - Better	
	f69	Dryer State - Good	
	н	My Dryer Notification	
	f69	My Dryer Regeneration Cycle Time Fo	
	<b>f</b> (3)	My Dryer State	
	fø	Total Barrels Dried	
_		w variable	E1 Evaluate
Nan	ne	Expression	Output Attribute
Myst	tateR	<pre>// State based on dryer outlet temperature. If 'outlet Temperature' &gt;= 170 Then (If PrevVal('My Operating State','*')="Reg Then NoOutput() Else "Regenerating") Else (If PrevVal('My Operating State', '*') = ' Then NoOutput()</pre>	My Operating State

8. Preview the results of this analytic using the Preview Results feature of Asset Analytics. Right-click on the '**My Dryer State**' analytic in the Analysis list. Select **Preview Results**.

0	Na	ame			Description:	
	нα	Pryer Notification			Categories:	
	f⊗ C	Pryer Regeneration Cy	cle Tir	ne Forecast	Analysis Type:      Expression      Rollup      Event Frame Generation      So	QC
	нα	oryer Regeneration Eve	ents		Enable analyses when created from template	
	f(x) C	Oryer State - Best				
	f⊗ E	Oryer State - Better				
	f⊗ C	Pryer State - Good				
	H N	ly Dryer Notification				
	fØ N	ly Dryer Regeneration	n Cycle	Time Fo		
	£60 N	ly Dryer State				
	f⊗ T	otal Barrels Dried		New	v	
-			X	Delete		
Examp	le Elem	ent: <u>Dryer A</u>	à	Preview Results		
Add	a new v	ariable	S.	Backfill/Recalculate	T Evaluate	
Nan		Expression		Backfill/Recalculate Status	Output Attribute	=
T Vali		// State based	⇔∎	Go to Template		
		If 'Outlet Ter		Reset to Template		
		Then (If Prev)		Convert to Template	egenerating"	
MySt	tateRul	e Then Not Else "Re		Сору	My Operating State	
		Else (If Prev)		Paste	"Drying"	
		Then Not Else "Dr		Check In		
		cise of	5	Undo Check Out		222
			1	Check Out		
				Audit Trail Events		

9. In the Preview Results window, set the **Start Time** to 11/10/19 and the **End Time** to 11/15/19. Click **Generate Results** to run the analysis for this time range. Select the **Multiple** option for the Value Scale.

Start Time: 11/10/19		End Time: 11/	/15/19	Generate Resul
Trigger Time	Variable1	Outlet Temperature (deg F)	My Operating State	Evaluation
11/10/2019 12:00:00 AM	-	89.2	Drying	^ (100%)
11/10/2019 12:06:00 AM	-	89.2	Drying	
11/10/2019 12:12:00 AM	-	89.2	Drying	Progress
11/10/2019 12:18:00 AM		89.2	Drying	
11/10/2019 12:24:00 AM	-	89.2	Drying	0ms
11/10/2019 12:30:00 AM	-	89.2	Drying	Min
11/10/2019 12:36:00 AM	-	89.2	Drying	
11/10/2019 12:42:00 AM	-	89.2	Drying	( 3.8ms
1/10/2019 12:48:00 AM	-	89.2	Drying	Max
			169	t Tempera perating S 9 Avg Trigge 48ms Total
11/10/2019 12:00:00 AM	Multip		12:00:00 AM <	> 1201
	0,			Evaluation
				Export Results

Note

We are not saving results to PI tags yet. The Preview is just giving us a way to check the results for errors within the Asset Analytics environment. The Preview shows a table and trend of analysis result over the specified time range. The results table list the value of each variable for each calculation interval. In the trend, the stepped blue trace shows the dryer's operating state and the red trace is the dryer outlet temperature. There appears to be something indecisive at the beginning of the regeneration cycles. We would expect to see one step indicating the switch from the "Drying" to "Regenerating" state regeneration cycle and we are getting several before there is a clear indication that the dryer is in the "Regenerating" step.

10. Investigate the problem by zooming in on the trend to get more a more detailed view of the data. Draw a box around the areas of interest until you determine the problem. Use the **Revert** button to return to the original trend.



11. Further investigate these result in Excel. Click the **Export Results** button in the lower right-hand corner of the Preview and download the data to a .CSV file on your desktop. Open the file in Excel and scroll down the rows. The problem is more clearly illustrated below.

	А	В	с	D
1	Trigger Time	Variable1	Outlet Temperature (deg F)	My Operating State
536	11/12/2019 5:24	-	167.6	Drying
537	11/12/2019 5:30	-	168.4	Drying
538	11/12/2019 5:36	Regenerating	170.7	Regenerating
539	11/12/2019 5:42	Drying	169.8	Drying
540	11/12/2019 5:48	-	169.5	Drying
541	11/12/2019 5:54	-	169.5	Drying
542	11/12/2019 6:00	-	169.6	Drying
543	11/12/2019 6:06	-	169.6	Drying
544	11/12/2019 6:12	-	169.7	Drying
545	11/12/2019 6:18	-	169.8	Drying
546	11/12/2019 6:24	-	169.8	Drying
547	11/12/2019 6:30	-	169.9	Drying
548	11/12/2019 6:36	-	169.9	Drying
549	11/12/2019 6:42	Regenerating	170	Regenerating
550	11/12/2019 6:48	-	170.1	Regenerating
551	11/12/2019 6:54	-	170.1	Regenerating
552	11/12/2019 7:00	-	170.1	Regenerating
553	11/12/2019 7:06	Drying	169.4	Drying
554	11/12/2019 7:12	-	169.9	Drying
555	11/12/2019 7:18	Regenerating	172.5	Regenerating
556	11/12/2019 7:24	-	210.7	Regenerating
557	11/12/2019 7:30	-	256.3	Regenerating
558	11/12/2019 7:36	-	293.8	Regenerating

Apparently, the output temperature oscillates around 170 Deg. F at the start of the regeneration cycle before it rises consistently. We must try a better approach.

### **Better Operating State**

Configure an Asset Analytic that defines dryer's regeneration cycle starts when the rolling hourly average of its outlet temperature goes above 170 Deg. F. This should solve the oscillation outlet temperature problem.

1. Select the **My Dryer State** analysis and, using copy and paste, replace the **Expression** for **MyStateRule** with the one shown below.

```
// State based on rolling one-hour average of dryer outlet temperature.
If TagAvg('Outlet Temperature','*-1h','*') >= 170
Then (If PrevVal('My Operating State','*')="Regenerating"
Then NoOutput()
Else "Regenerating")
Else (If PrevVal('My Operating State', '*') = "Drying"
Then NoOutput()
Else "Drying")
```

Feeling more confident, we will test this analysis using the Backfill\Recalculate feature of Asset Analytics. We will run the backfill from the '**Dryer A**' element which will publish results into the PI Tag, '**Dryers:My State A**', which we have previously configured. We'll check things over in PI Vision when we're done.

2. To run our analysis from the **Dryer A** element, we must first check in our changes to the Dryer template. Click **Check In** at the top of PI System Explorer.

-						
🕝 Back	Ð	🚽 Check In	🖓 🖌 🛃 Refresh 🛛 🗃 New Template 👻			Search Element Templates
Dryer						
General	Attri	ibute Temple Sav	all changes to the Database ptification Rule Templates			
				Name:	My Dryer State	
1 1	N	lame	/	Description:		
H	4	Dryer Regenera	on Events	Categories:		
f⊌	0	Dryer State - Be	t	Analysis Type:	Expression      Rollup     Ever	nt Frame Generation 🛛 🔿 S
fix	9	Dryer State - Be	ter	Enable an	alyses when created from template	
f∺	9	Dryer State - Go	bd			
н	1	My Dryer Notifi	ation			
fix	9	My Dryer Reger	eration Cycle Time Fo			
્રીષ્ટ	9	My Dryer State				
fix	9	Total Barrels Dri	d	/		
·		nent: <u>Dryer A</u> variable	=			Evaluate
Name			Expression			Output Attribute
MyStat	teRu	lle	<pre>// State based on rolling one-hour average o If TagAvg('Outlet Temperature', '*-1h', '*') &gt; Then (If PrevVal('My Operating State', '*')=" Then NoOutput() Else (If PrevVal('My Operating State', '*') Then NoOutput() Else "Drying")</pre>	= 170 Regenerating"	: temperature.	My Operating State

- 3. Select the **Elements** view in the lower left-hand corner of PI system explorer. Click on the **Dryer A** element and go to its **Analysis** tab at the top.
- 4. Enable the 'My Dryer State' analysis by selecting it and clicking the **Enable Analysis** button at the top. You will see a green checkmark appear once the analysis is running.

Dryer A	4						
Gener	al Child El	ements	Attributes	Ports	Analyses	Notification Rules	Version
	- 12		Name				Backfilling
Enable An	alysis	н	Dryer Notifi	ication			Ø
		,f⊗	Dryer Reger	neration	Cycle Time	Forecast	Ø
		н	Dryer Reger	neration	Events		9
0		f(s)	Dryer State	- Best			0
		ſ⊗	Dryer State	- Better			0
9		fø)	Dryer State	- Good			Ø
		н	My Dryer N	otificatio	on		<b>Ø</b>
0		ſ⊗	My Dryer Re	egenerat	tion Cycle T	ime Forecast	Ø
		f(x)	My Dryer St	tate			0
0		fø)	Total Barrels	s Dried			<b>Ø</b>

 Right-click on the 'My Dryer State' analysis in the Analysis list. Select Backfill\Recalculate. In the dialog, enter a Start Time of 1/1/19 and an End time of 12/31/19. Check 'Permanently delete existing data and recalculate'. Click Start to backfill the results.

🔕 Backfilli	ng or recalculation for My Dryer State	×			
Start Time:	1/1/19				
End Time:	12/31/19				
<ul> <li>Leave</li> <li>Perman</li> </ul>	d we do with existing data? existing data and fill in gaps nently delete existing data and recalculate calculate dependent analyses				
Ready to recalculate from 1/1/2019 12:00:00 AM to 12/31/2019 12:00:00 AM					
	Start Cancel				

6. Once the green checkmark show up in the **Backfilling** column, disable the analysis by clicking the **Disable Analysis** button at the top.

Gener	al Child El	ements	Attributes	Ports	Analyses	Notificatio	on Rules	Version	
Disabl	le Analysis		Name				Backfilli	ng	
		f(s)	Dryer State -	Better			0		
$\bigcirc$		f⊗	Dryer State -	Good			0		
0	T	н	My Dryer Not	tificatio	n		0		
0		f60	My Dryer Reg	enerati	ion Cycle T	ime Fo	0		
0	T	fø)	My Dryer Stat	te			0		
0	T	f⊗	Total Barrels	Dried			0		



7. Open PI vision from the desktop. Launch a new PI Vision by clicking the provided link in the upper right-hand corner of the browser. Under Assets, navigate the Dryers AF Database and select Dryer A. Make sure a trend selected as the default visualization object (upper left-hand corner). Drag attribute My Operating State onto the blank PI Vision display to create a trend of this value. Select attribute Outlet Temperature and

drag it on top of the trend to add its trace. Change the start and end times of the display to be 1/1/19 and 1/1519, respectively.



- 8. Scroll the display through the year and visually inspect the results. Using an average value of the Outlet Temperature works much better for defining the start and end times of each regeneration cycle.
- Return to the Assets pane, navigate the Dryers AF Database and select Dryer B. Select this dryer's attribute Outlet Temperature and drag it on top of the trend to add its trace. Scroll the display to set the time range to someplace around 2/9/19 to 2/22/19.



Upon further review, it appears there are times when the dryer is neither in a Drying or Regenerating state. We can define a third state, Standby, to account for this time. Minimize the PI Vision window.

### **Best Operating State**

Configure an Asset Analytic that defines all three states of the dryer's operation, "Drying", "Regenerating" and "Standby".

- 1. Return to the **Library** view in PI System Explorer. Select the **Dryer** Element Template ad click on the **Analysis Templates** tab at the top of the window.
- 2. Select the **My Dryer State** analysis and, using copy and paste, replace the **Expression** for **MyStateRule** with the one shown below.

```
// Check for Regeneration State.
If TagAvg('Outlet Temperature','*-1h','*') >= 170
Then (If PrevVal('My Operating State','*')="Regenerating"
Then NoOutput()
Else "Regenerating")
// Check for Standby State.
Else (If 'Outlet Temperature' >= 120
Then (If PrevVal('My Operating State', '*') = "Standby"
Then NoOutput()
Else "Standby")
// Must be Drying state.
Else (If PrevVal('My Operating State', '*') = "Drying"
Then NoOutput()
Else "Drying"))
```

3. Check in your changes by clicking **Check In** at the top of PI System Explorer.

Feeling even more confident, we will backfill the results into the PI Tags for both dryers.

- 4. In the lower left-hand corner of PI System Explorer, select the **Management** view. Here is where you manage all the Asset Analytics configured for an AF Database. This includes enabling, disabling and backfilling calculations.
- 5. Select the '**My Dryer State**' analyses for the **Dryer A and B** elements. On the right-hand side under **Operations**, click **Enable**.

Ana	lyses							
2 tot	tal analys	ies s	electe	d (2 on th	is page)		1 - 20 of 20 < >	Operations
	Status	0	A	Element	Name	Template	Backfilling	Enable Disable selected analyses
	0		н	Dryer B	Dryer Notification	Dryer Notification	0 ^	Enable   Disable automatic recalculation for
	0		н	Dryer A	Dryer Notification	Dryer Notification	0	selected analyses
	0		f(x)	Dryer A	Dryer Regeneration Cycle Time Forecast	Dryer Regeneration Cycle Time Forecast	0	Queue   Cancel backfilling or recalculation f
	0		f69	Dryer B	Dryer Regeneration Cycle Time Forecast	Dryer Regeneration Cycle Time Forecast	0	selected analyses
	0		н	Dryer B	Dryer Regeneration Events	Dryer Regeneration Events	0	
	0		н	Dryer A	Dryer Regeneration Events	Dryer Regeneration Events	0	
	0		f69	Dryer B	Dryer State - Best	Dryer State - Best	0	
	0		f6)	Dryer A	Dryer State - Best	Dryer State - Best	0	
	0		f60	Dryer B	Dryer State - Better	Dryer State - Better	0	
	0		f60	Dryer A	Dryer State - Better	Dryer State - Better	0	
	0		foo	Dryer B	Dryer State - Good	Dryer State - Good	0	
	0		f60	Dryer A	Dryer State - Good	Dryer State - Good	0	
	0		н	Dryer A	My Dryer Notification	My Dryer Notification	0	
	0		н	Dryer B	My Dryer Notification	My Dryer Notification	0	
	0		f(v)	Dryer B	My Dryer Regeneration Cycle Time Forecast	My Dryer Regeneration Cycle Time Forecast	0	
	0		féa	Dryer A	My Dryer Regeneration Cycle Time Forecast	My Dryer Regeneration Cycle Time Forecast	0	Pending Operations
1	0		f00	Dryer A	My Dryer State	My Dryer State	0	No pending operations
1	0		f69	Dryer B	My Dryer State	My Dryer State		
	0		560	Dryer B	Total Barrels Dried	Total Barrels Dried	0	

6. Once the *spears* appears in the **Status** column the analyses are up and running. Again under **Operations**, click on **Queue**. This exposes the backfilling configuration dialog.

Configure the **Start** and **End** times to be '1/1/19' and '12/31/19', respectively. Check '**Permanently delete existing data and recalculate**'. This will allow the backfill service to overwrite the results we stored for Dryer A in the previous step. And finally, click **Queue** start backfilling results for the two dryers.

Operations	
Enable   Disabl	e selected analyses
Enable   Disabl	e automatic recalculation for selected analyses
Queue Cance	backfilling or recalculation for selected analyses
Start 1/1/1	9
End 12/31	/19
	we do with existing data? xisting data and fill in gaps
Perman	ently delete existing data and recalculate
Rec	alculate dependent analyses
	Queue
data withi	ion will permanently delete all the n the time range. For event frames sult in loss of annotations and Igements.

- 7. Once Appear under the **Backfilling** column, disable the analysis by clicking **Disable**.
- 8. Reopen the PI vision display. You should see that the state tag has correctly identified the "Standby" state.



### 2.3 Calculate Dryer Utilization Metrics – Asset Analytics

We have successfully defined a rule for determining dryer operating states and populated PI Tags with these values. Now we can add two analyses to measure the utilization of the molecular sieve beds. The first will calculate the volume, in barrels throughput, for each drying cycle. The second will be a running total for all drying cycles since the start of 2019, when this load of molecular sieve was first put into service. As you will see, these calculations are only possible because we first created the required process context in the PI System, i.e. the dryer operating state values.

- 1. Return to the **Library** view in PI System Explorer. Select the **Dryer** Element Template and click on the **Analysis Templates** tab at the top of the window.
- 2. Select the Total Dried Barrels analysis.

😳 🖪 Name		Description: Total barrels dried for lifetime and current drying cycle.		
f(x) Dryer State - Be	st	Categories:		
f(e) Dryer State - Be	tter	Analysis Type:      Expression      Rollup      Event Frame Generation      SQC		
f👀 Dryer State - Go	od	Enable analyses when created from template		
H My Dryer Notifi	cation			
f(<) My Dryer Reger	neration Cycle Time Fo			
f(<) My Dryer State				
f⊗ Total Barrels Dri	ed			
Add a new variable	Expression	Utout Attribut		
PreviousFeedFlowEvent	<pre>// Find timestamp of last archive event for Proce PrevEvent('Feed Flow', '*')</pre>			
CycleTotal	<pre>// Calculate total feed processed during this dry If Not(BadVal(PrevVal('Feed Flow','*'))) And Not( Then (If 'Best Operating State'="OryIng" Then 'Drying Cycle Barrels' + TagTot('Feed Else 0) Else NoOutput()</pre>	BadVa1('Feed Flow'))		
<pre>// Calculate total of feed processed during life of drying bed. // Calculate total of feed processed during life of drying bed. if Not(BadVal(PrevVal('Feed Flow', '*'))) And Not(BadVal('Feed Flow')) Then (If 'Best Operating State' = "Drying" Then 'Lifetime Barrels' + TagTot('Feed Flow', PreviousFeedFlowEvent, '*') Else Nooutput()) Else Nooutput()</pre>				

The Total Dried Barrels analysis generates two results which are stored into PI Tags referenced by the AF Attributes **Drying Cycle Barrels** and **Lifetime Barrels**. This is a three-step analysis that breaks down as follows;

Assign a variable, **PreviousFeedFlowEvent** to contain the timestamp of the last archive value of the **Feed Flow** attribute (BPD).

// Find timestamp of last archive event for Process Flow.
PrevEvent('Feed Flow', '\*')

Calculate **Drying Cycle Barrels**. Check for bad values of either the previously archived or current value of the **Feed Flow**, the endpoints of the incremental total. If good values are returned, add the incremental total to the **Drying Cycle Barrels** attribute when the dryer is in a Drying state. Otherwise reset its value to zero. If either value of the Feed Flow is bad, do nothing.

// Calculate total feed processed during this drying cycle.
If Not(BadVal(PrevVal('Feed Flow','\*'))) And Not(BadVal('Feed Flow'))

### Then (If 'Best Operating State'="Drying"

Then 'Drying Cycle Barrels' + TagTot('Feed Flow', PreviousFeedFlowEvent,'\*') Else 0)

### Else NoOutput()



In this calculation we are converting a flow rate in barrels/day to a volume, barrels. The 'TagTot' function handles this conversion AND also handles cases where values stored in the PI Archive are not evenly time spaced.

Calculate **Lifetime Barrels**. Check for bad values of either the previously archived or current value of the **Feed Flow**, the endpoints of the incremental total. If good values are returned, add the incremental total to the **Lifetime Barrels** attribute when the dryer is in a Drying state. Otherwise do nothing. If either value of the Feed Flow is bad, do nothing.

```
// Calculate total of feed processed during life of drying bed.
If Not(BadVal(PrevVal('Feed Flow','*'))) And Not(BadVal('Feed Flow'))
```

Then (If 'Best Operating State' = "Drying" Then 'Lifetime Barrels' + TagTot('Feed Flow', PreviousFeedFlowEvent,'\*') Else NoOutput())

Else NoOutput()

5. Open PI Vision from the desktop.



- 6. Click the **PI** vision display. This will return you to the display thumbnails.
- 7. From the PI Vision display thumbnails, double-click on the '**Total Barrels Dried**' tile to open this display.



## 3. Contextualization and Data Preparation

### 3.1 Objective

In this exercise we will configure Event Frames to prepare useful process information for each dryer regeneration cycle. The Event Frame attributes we choose are ones we will find useful for qualifying our idea and for building the model to estimate the duration of the next dryer regeneration cycle.

### 3.2 **Prepare Dryer Regeneration Features - Event Frame Template**

Event Frames produce records, stored in the PI System, containing the start time, end time and duration of significant processing periods, like dryer regeneration cycles. We can add other values, pertaining to the regeneration cycles, to the Event Frame records using Asset Analytics. Here, we will add the following attributes of interest.

- Average Outlet Temperature, Deg. F.
- Maximum Outlet Temperature, Deg. F.
- Average Regenerating Temperature, Deg. F.
- Maximum Regenerating Temperature, Deg. F.
- Drying Cycle Barrels, barrels
- Drying Cycle Duration, hrs.
- Regen Cycle Vapor, barrels

There are two steps in configuring Event Frames. The first is creating an Event Frame template which defines the naming pattern and attributes. The second is configuring the Asset Analytic to trigger the start and end of the Event Frame period. In this example, we will also generate values for several of the attributes in the above list using Asset Analytics. This is a very powerful feature, as you will see.

An Event Frame template has been created for you to use. After walking through its configuration, we will configure an analytic to generate the event Frames themselves.

 In PI System Explorer, select the Library view. Under the Templates branch of the hierarchy, expand Event Frame Templates and select the My Dryer Regeneration Cycle template. The Naming Pattern is specified under the General tab. Event Frame

names use substitution parameters. Click the *line* at the far right-hand of the name field to get some hints.

General Attribut	te Templates	
Name: Description:	My Dryer Regeneration Cycle My Dryer Regenerations	
Base Template: Categories:	<none> Severity: None</none>	
Naming Pattern:	%ELEMENT% My Regeneration Cycle %STARTTIME:MM-dd-yy HH:mm%	
Find:		yy-MM-dd HH:mm:ss.fff% E:yyyy-MM-dd HH:mm:ss.fff%

2. Select the Attribute Templates tab at the top to see the list of attributes. Expand the

attribute configuration dialog by clicking the along the right-hand boarder of PI System Explorer. Select the **Avg Outlet Temp** attribute.

My I	Dryer Regeneration Cycle			
Gen	neral Attribute Templates			
				Group by: 🗹 Category 🗌 Template
Filt	er	<del>-</del> م	Name:	Avg Outlet Temp
	✓ i  Name	△ De <i>Opt</i>	Description:	
	Category: Asset Analytic Calculations		Properties:	<none> ~</none>
	🔤 Drying Cycle Barrels	Total fe	Categories:	Asset Attribute Aggregations
1	🖫 Drying Cycle Duration	Time in '	Default UOM:	Fahrenheit ~
1	E Regen Cycle Vapor	Total re	Value Type:	Single v
Ð	Category: Asset Attribute Aggregations		Default Value:	0.0 deg F
	Avg Outlet Temp		Display Digits:	1 PI Point
	Kang Regen Temp		Data Reference.	
1	Kax Outlet Temp		_	Settings
	Kan		.\Elements[.] Out	et Temperature;TimeRangeMethod=Average

There are two attribute categories for this template, **Asset Analytic Calculations** and **Asset Attribute Aggregations**. Let's take a look at the second group first.

3. Click through the list of **Asset Attribute Aggregations**. These values will be calculated when the Event Frame ends and are derived from the attributes defined in the associated element. In this case, the Dryer A and Dryer B elements. They all have a PI Point Data Reference since their values will come from a PI Point aggregation.

The following table shows the expression syntax used to define these attributes.

Attribute	Settings
Avg Outlet Temp	.\Elements[.] Outlet Temperature;TimeRangeMethod=Average
Avg Regen Temp	.\Elements[.] Regenerant Temperature;TimeRangeMethod=Average
Max Outlet Temp	.\Elements[.] Outlet Temperature;TimeRangeMethod=Maximum
Max Regen Temp	.\Elements[.] Regenerant Temperature;TimeRangeMethod=Maximum

- 4. Click on any one of the attributes in the **Asset Analytic Calculation** list. Notice there are no settings specified and they have no Data Reference specified. These are merely placeholders to contain the result of an Asset Analytics calculation which occurs upon the end or close of the Event Frame. We will configure this calculation next section.
- 5. Under **Element Templates**, return to the **Dryer** template and select **Analysis Templates** tab at the top.
- Make a copy of the Dryer Regeneration Events analysis by right-clicking on it and selecting Copy. Then, right-click again and select Paste. Select the copied analysis, Dryer Regeneration Events1 and rename it to My Dryer Regeneration Events.
- 7. Change the Event Frame Template this analysis will use to be **My Dryer Regeneration Cycle.** This is done from the Event Frame Template dropdown shown below.

श						
A Name     A Name     Dryer Regener     MyDryer Rege     ft0 Dryer State - E     ft0 Dryer State - C     My Dryer Reg     ft0 Total Barrels D	neration Events letter Good neration Events ried	Name: My Dryer Description: Categories: Analysis Type: Despr Enable analyses whe Streate a new notification	n created from temple	ste	me Generation 🔿 SQC	
Seneration Mode: Expla		Ay Dryer Regeneration Cycle				÷
Add 🗸						Evaluate
Name PreviousRegenEvent	Expression FindEq('Best Operating State','*','-7d', "Regenera	ting")	True for	Severity	Output Attribute	× (8)
PreviousDryingEvent	<pre>// Search backwards for last "Drying" event time, FindEq('Best Operating State', PreviousRegenEvent,</pre>	prior to last "Regenerating" e	Y			8
Start triggers     StartTrigger	<pre>// Use Operating State as Event Frame trigger. By // Event Frame will end when Operating State retur 'Best Operating State'="Regenerating"</pre>		Set (optional)	None ~		
<ul> <li>Outputs at close</li> </ul>			1	1		1
RegenCycleVapor	<pre>// Total flow to vaporizer during tis regeneration TagTot('Regenerant Vapor Flow', EventFrame("StartT</pre>				Map	8
DryingCycleBarrels	<pre>// Drying Cycle Barrels in previous Drying cycle. TagMax('Drying Cycle Barrels', PreviousDryingEvent,</pre>			Map Avg Outlet Ten	8	
DryingCycleDuration // Duration in hours of previous Drying cycle. /TimeEq('Best Operating State', PreviousDryingEvent,'*',"Drying") /3600					Map Avg Regen Ten	0
					Max Outlet Ter	mp tings
heduling:     Event-Trig gger on Any Input	gered O Periodic				📲 Regen Cycle V	apor

- 8. Click the **Map** link for each Output at Close expression and match it with its corresponding Attribute in the Event Frame Template. Be careful the order is not the same.
- 9. Review the **Start Trigger expression**. When this condition it TRUE, the Event Frame starts. Once it becomes FALSE, the Event Frame ends.

StartTrigger	<ul><li>// Use Operating State as Event Frame trigger. By default,</li><li>// Event Frame will end when Operating State returns</li></ul>
	// to "Standby" or "Drying".
	'Best Operating State'="Regenerating"

Two of the values we want included in the Event Frame are calculated with respect to the Drying cycle that immediately precedes a Regeneration Cycle. To find out when the last

Drying cycle started, we use two Variable expressions to perform a two-step backward search into the PI Archive to retrieve timestamps of these events.

Name	Expression
PreviousRegenEvent	<pre>// Search backwards for last "Regenerating" event time. FindEq('Best Operating State','*','-7d', "Regenerating")</pre>
PreviousDryingEvent	<pre>// Search backwards for last "Drying" event time, // prior to last "Regenerating" event. FindEq('Best Operating State',PreviousRegenEvent, '-7d', "Drying")</pre>

10. We use **Output Expressions** to calculate the needed aggregations the remaining values for our Event Frame Template. These expressions leverage the Event Frame Start and End times, as well as, the timestamp variable retrieved above. They are evaluated when the Event Frame closes and are posted as values to the "placeholder" attributes we have configured in the Event Frame Template.

Name	Expression
RegenCycleVapor	<pre>// Calculate total flow to vaporizer during tis regeneration cycle. TagTot('Regenerant Vapor Flow', EventFrame("StartTime"), EventFrame("EndTime"))</pre>
DryingCycleBarrels	<pre>// Drying Cycle Barrels in previous Drying cycle. TagMax('Drying Cycle Barrels', PreviousDryingEvent, '*')</pre>
DryingCycleDuration	<pre>// Duration in hours of previous Drying cycle. TimeEq('Best Operating State', PreviousDryingEvent,'*',"Drying") /3600</pre>

11. Click the **Evaluate** button to preview the results and make sure there are no errors. If it all looks good, **Check In** your changes.

Add 🗸						Eva	aluate
Name	Expression	True for	Severity	Value at Evaluatio	Value at Last Trigg	Output Attribute	
Variables							
PreviousRegenEvent	<pre>// Search backwards for last "Regenerating" event time. FindEq('Best Operating State','*','-7d', "Regenerating")</pre>			2/17/2020 10:36:0	2/17/2020 10:36:0		8
PreviousDryingEvent	<pre>// Search backwards for last "Drying" event time, // prior to last "Regenerating" event. FindEq("Best Operating State", PreviousRegenEvent, '-7d', "Drying")</pre>			2/16/2020 6:00:00	2/16/2020 6:00:00		8
Start triggers							
StartTrigger	<pre>// Use Operating State as Event Frame trigger. By default, // Event Frame will end when Operating State returns // to "Standby" or "Drying". "Best Operating State = "Regenerating"</pre>	Set (optio	None v	False	False		
Outputs at close							
RegenCycleVapor	<pre>// Calculate total flow to vaporizer during tis regeneration cycle. TagTot('Regenerant Vapor Flow', EventFrame("StartTime"), EventFrame("EndTime"))</pre>			Use Preview	Use Preview	Regen Cycle Vapor	8
DryingCycleBarrels	<pre>// Drying Cycle Barrels in previous Drying cycle. TagMax('Drying Cycle Barrels', PreviousDryingEvent, '*')</pre>			9301.1 bbl	9301.1 bbl	Drying Cycle Barrels	
DryingCycleDuration	<pre>// Duration in hours of previous Drying cycle. TimeEq('Best Operating State', PreviousDryingEvent,'*',"Drying") /3600</pre>			29.4	27.6	Drying Cycle Duratic	on 🛛

### 3.3 Generate Regeneration Data for Analysis - Event Frames

Generate the Event Frames to capture the data needed to analyze the dryer regenerations for 2019.

1. Return to the **Management** view in PI System Explorer. Select the '**My Dryer Regeneration Events**' analyses for the **Dryer A and B** elements. On the right-hand side under **Operations**, click **Enable**.

Anal	lyses								
2 tot	tal analys	ses se	lecte	d (2 on th	is page)		1	1 - 22 of 22 < > Operations	
	Status	0		Element	Name	Template	Backfilling	Enable Disable selected analyses	
	0		н	Dryer B	Dryer Notification	Dryer Notification		Enable   Disable automatic recalculation for selected	analur
	0		H	Dryer A	Dryer Notification	Dryer Notification			
	0		f60	Dryer A	A Dryer Regeneration Cycle Time Forecast	Dryer Regeneration Cycle Time Forecast	0	Queue   Cancel backfilling or recalculation for selecte analyses	d
	0		foo	Dryer B	Dryer Regeneration Cycle Time Forecast	Dryer Regeneration Cycle Time Forecast	0	unaryaca.	
	0		н	Dryer B	Dryer Regeneration Events	Dryer Regeneration Events			
	0		H	Dryer A	Dryer Regeneration Events	Dryer Regeneration Events			
	0		foo	Dryer B	Dryer State - Best	Dryer State - Best	0		
	0		fto	Dryer A	Dryer State - Best	Dryer State - Best	0		
	0		fto	Dryer B	Dryer State - Better	Dryer State - Better	0		
	0		f60	Dryer A	Dryer State - Better	Dryer State - Better	0		
	0		f60	Dryer B	Dryer State - Good	Dryer State - Good	0		
	0		f60	Dryer A	Dryer State - Good	Dryer State - Good	0		
	0		н	Dryer A	My Dryer Notification	My Dryer Notification	0		
	0		н	Dryer B	My Dryer Notification	My Dryer Notification	0		
	0		f60	Dryer B	My Dryer Regeneration Cycle Time Forecast	My Dryer Regeneration Cycle Time Forecast	0		
	0		fee	Dryer A	My Dryer Regeneration Cycle Time Forecast	My Dryer Regeneration Cycle Time Forecast	0		
1	0		н	Dryer A	My Dryer Regeneration Events	My Dryer Regeneration Events		Pending Operations	
1	0		н	Dryer B	My Dryer Regeneration Events	My Dryer Regeneration Events		No pending operations	
	0		509	Dryer A	My Dryer State	My Dryer State	0		
	0		f60	Dryer B	My Dryer State	My Dryer State	0		
	0		foo	Dryer B	Total Barrels Dried	Total Barrels Dried	0		

2. Once the *spears* appears in the **Status** column the analyses are up and running. Again under **Operations**, click on **Queue**. This exposes the backfilling configuration dialog.

Configure the **Start** and **End** times to be **'1/1/19'** and **'12/31/19'**, respectively. Check **'Permanently delete existing data and recalculate'**. This will allow the backfill service to overwrite the results we stored for Dryer A in the previous step. And finally, click **Queue** start backfilling Event Frames for the two dryers.

Operati	ons
Enable	Disable selected analyses
Enable	Disable automatic recalculation for selected analyses
<u>Queue</u>	Cancel backfilling or recalculation for selected analyses
Start	1/1/19
End	12/31/19
	should we do with existing data? eave existing data and fill in gaps
• P	ermanently delete existing data and recalculate
	Recalculate dependent analyses
	Queue
dat this	calculation will permanently delete all the a within the time range. For event frames s will result in loss of annotations and nowledgements.

- 3. Once the *solution* appears under the **Backfilling** column, disable the analysis by clicking **Disable**.
- 4. Select the **Event Frames** view in the lower left-hand corner of PI System Explorer. Launch the **Event Frame Search** from the top menu.

🔕 \\PI	SRV01\Di	yers - Pl	Syster	n Explore	er (Adminis	
File	Search	View	Go	Tools	Help	
🙆 Data	Event Frame Search					
Event F	Transfer Search					
🛪 Event	Event Frame Attribute Search					
Transfer Attribute Search						
🗶 Trans	er bearene			6		

5. Set the **Search** to **'Ending After'** and the **Template** to **'My Dryer Regeneration Cycle'**. Click **Search** to find the Event Frames matching this criteria.

Event Frame Search								>
emplate: "My Dryer Regeneration Cycle"							× •	Search
			Criteria					
Search: Ending After 🗸								
earch start: 1/1/1970 12:00:00 AM 📑 🕨 🗹 All De	escendants							
Name:		Analysis Name:				×		
Hement Name:			<all></all>		~	x		
		Category:	CALL		*	<u>^</u>		
Template: My Dryer Regeneration Cycle			Results					
😽 Add Qriteria 🔻							up by: 🗌 Categor	
😽 Add Qriteria 🔻	Duration	Start Time 🔺	Results End Time	Description	Template	Grou Primary Element	ıp by: 🗌 Categor	y 🗌 Templa
Add Orteria	Duration 1:12:00	Start Time 4	End Time	Description My Dryer Reg	1//////////////////////////////////////	Primary Element	ip by: 🗌 Categor	
Add Criteria -		1/1/2019 5:06	End Time	My Dryer Reg	My Dryer Reg	Primary Element Dryer A	ip by: 🗌 Categor	
Add Qitteria           Image: Constraint of the second sec	1:12:00	1/1/2019 5:06 1/1/2019 8:30	End Time	My Dryer Reg My Dryer Reg	My Dryer Reg My Dryer Reg	Primary Element Dryer A Dryer B	ip by: 🗌 Categor	
Add Criteria     Add Criteria     Add Criteria     Add Criteria     All     Cover A My Regeneration Cycle 01-01:19 05:06     ☐ Criver B My Regeneration Cycle 01-01:19 08:30     ☐ Criver B My Regeneration Cycle 01-01:19 23:54	1:12:00 9:36:00	1/1/2019 5:06 1/1/2019 8:30 1/1/2019 11:5	End Time 1/1/2019 6:18 1/1/2019 6:06	My Dryer Reg My Dryer Reg My Dryer Reg	My Dryer Reg My Dryer Reg My Dryer Reg	Primary Element Dryer A Dryer B Dryer A	ap by: 🗌 Categor	
	1:12:00 9:36:00 10:48:00	1/1/2019 5:06           1/1/2019 8:30           1/1/2019 11:5           1/2/2019 12:4	End Time 1/1/2019 6:18 1/1/2019 6:06 1/2/2019 10:4 1/2/2019 10:4	My Dryer Reg My Dryer Reg My Dryer Reg My Dryer Reg	My Dryer Reg My Dryer Reg My Dryer Reg My Dryer Reg	Primary Element Dryer A Dryer B Dryer A Dryer B Dryer B Dryer B	µp by: □ Categor	
Add Gitteria           Add Gitteria           Image:	1:12:00 9:36:00 10:48:00 10:06:00 10:54:00	1/1/2019 5:06 1/1/2019 8:30 1/1/2019 11:5 1/2/2019 12:4 1/3/2019 12:4	End Time 1/1/2019 6:18 1/1/2019 6:06 1/2/2019 10:4 1/2/2019 10:4 1/3/2019 11:4	My Dryer Reg My Dryer Reg My Dryer Reg My Dryer Reg My Dryer Reg	My Dryer Reg My Dryer Reg My Dryer Reg My Dryer Reg My Dryer Reg	Primary Element Dryer A Dryer B Dryer A Dryer B Dryer A	ap by: 🗌 Categor	
Add Gitteria           Add Gitteria           Image: Compare and the second secon	1: 12:00 9: 36:00 10: 48:00 10: 05:00 10: 54:00 10: 12:00	1/1/2019 5:06 1/1/2019 8:30 1/1/2019 11:5 1/2/2019 12:4 1/3/2019 12:4 1/3/2019 2:00	End Time 1/1/2019 6:18 1/1/2019 6:06 1/2/2019 10:4 1/2/2019 10:4 1/3/2019 11:4 1/4/2019 12:1	My Dryer Reg My Dryer Reg My Dryer Reg My Dryer Reg My Dryer Reg My Dryer Reg	My Dryer Reg My Dryer Reg My Dryer Reg My Dryer Reg My Dryer Reg My Dryer Reg	Primary Element Dryer A Dryer B Dryer B Dryer B Dryer A Dryer B	ap by: 🗌 Categor	
Add Cytteria           Image: Comparison of the compa	1:12:00 9:36:00 10:48:00 10:06:00 10:54:00	1/1/2019 5:06           1/1/2019 8:30           1/1/2019 11:5           1/2/2019 12:4           1/3/2019 12:4           1/3/2019 12:4           1/3/2019 2:00           1/4/2019 3:06	End Time 1/1/2019 6:18 1/1/2019 6:06 1/2/2019 10:4 1/2/2019 10:4 1/3/2019 11:4	My Dryer Reg My Dryer Reg My Dryer Reg My Dryer Reg My Dryer Reg My Dryer Reg	My Dryer Reg My Dryer Reg My Dryer Reg My Dryer Reg My Dryer Reg My Dryer Reg	Primary Element Dryer A Dryer B Dryer A Dryer B Dryer A Dryer B Dryer A	ap by: 🗌 Categor	

6. The default Event Frame search does not show attributes in the results. Click the at the upper right-hand corner of the results grid and click **Select Attributes** to bring up the dialog below.

Add Attributes from T	emplate:	My Dry	er Regeneration Cyc	e					
) Add Attributes from E	vent Frame:	Dryer A My	Regeneration Cycle 0	1-01-19 05:06			2	1	
Others:		Enter a sen	Enter a semicolon separated list of names to use as attribute columns:						
Attribute Templates:						Attributes:			
1y Dryer Regeneration	Cyde		Group by:	Category	Γ	I Avg Outlet Temp			
Filter				<del>ب</del> م	»	Avg Regen Temp		1	
lame 4	Description		Category		>	Drying Cycle Barrels Drying Cycle Duration		1	
🔏 Avg Outlet Temp	]		Asset Attribute Aggr	egations		Max Outlet Temp		1	
🐔 Avg Regen Temp	-		Asset Attribute Aggre	egations		Max Regen Temp     Access Curde Vaner		-	
🔚 Drying Cycle Barrels	Total feed d	ried durin	Asset Analytic Calcul	ations		Regen Cycle Vapor		1	
🔚 Drying Cycle Dur	Time in "Dry	ing" state	Asset Analytic Calcul	ations					
Kax Outlet Temp			Asset Attribute Aggre	egations					
🐔 Max Regen Temp			Asset Attribute Aggre	egations					
🔄 Regen Cycle Vapor	Total regen	erant use	Asset Analytic Calcul	ations					

7. Click to select all attributes. Click **OK**. Then click OK in the Event Frame Search dialog. This brings all Event Frame records into PI System Explorer. We are now ready to extract this data from PI for analysis.

## 4. Data Analysis and Qualification

## 4.1 Objectives

The previous sections of this lab have so far provided us with the data set necessary to start to formulate a model to predict the behavior of the regeneration times for the dryers. In the following section we will be taking the event frame Dryer Regeneration Cycle data and analyzing this set of data to find relationships between the parameters we have and the resulting regeneration times.

The objective of this section is to analyze the Dryer Regeneration Cycle event frame data using various tools at our disposal including Power BI and Excel, and to qualify which variables are important to take into account for our predictive model. We will also be demonstrating how the PI System can enable data analysis and qualification within these tools through the use of the PI Integrator for Business Analytics as well as the PI DataLink Add-In for Excel.

In the following section we will:

- Export the Dryer event frame data into a .CSV file using the PI Integrator for Business Analytics
- Import the .CSV Dryer data into Power BI and examine the relationships between the dryer operating states to confirm the initial problem assessment
- Examine the Dryer Event Frame data in Excel using PI DataLink and decide on a variable to use for predicting Dryer Regeneration Time
- Utilize basic charting and best fit line functionality within Excel to generate a linear model to predict Dryer Regeneration Time

In addition to providing you with hands-on experience using the PI Integrator for Business Analytics and Power BI, the main reason we are going through the trouble of bringing in this data into Power BI is to confirm our initial hypothesis that there is in fact an imbalance in the use of these two dryers. Remember that the overall goal of this analytics project is to formulate a model to predict and standardize the dryer phases in order utilize the dryers in a more balanced way. It is extremely beneficial from a financial and maintenance standpoint to have these dryers end of life around the same time, and the goal of looking at the dryer phases in Power BI is to confirm that they are not currently being used evenly. From a bigger picture perspective, it is helpful to do this sort of 'sanity check' in the middle of a larger analytics project to confirm that the problems you are trying to solve are in fact real, and that the project is worth taking to the next stages of completion.

# 4.2 Problem Assessment – PI integrator for Business Analytics and Power BI

From the Windows taskbar, open PI System Explorer and review the 'Dryers' database. We will be using the PI Integrator for Business Analytics to create an event frame view publication based on the event frames built upon this asset model. The publication target will be a .CSV file posted in the subdirectory C:\PI World\ (this

is also the 'PI World' folder shortcut on the desktop). This .CSV file will provide the data for populating our dataset and analyzing in Power BI.

- 1. Open the PI Integrator for Business Analytics from the desktop shortcut.
- 2. Click **Create Event View** on the top menu. Name your view '**My Dryer Regenerations**' and click **Create View**.

Create New Event View	х
Event View Name	
My Dryer Regenerations	
Access Permissions 0	
PI Integrator Service	*
Cancel Create	View

- 3. On the Select Data page, select the **Dryers** database. Select one of the listed event frames under the **Source Events** Section on the left. Drag and drop this event into the **Search Shape** area in the middle of the screen under **Event Shape**.
- 4. On the event frame that was just dragged to the center, click on the Edit pencil icon to the right to bring up the Edit Filters option. Adjust the filter to use the 'Dryer Regeneration' event frame template rather than the Event Frame Name.

Edit Filters	×
Event Frame Name     Dryer A Regeneration Cycle 01-01-19 05:00	
Event Frame Template Search Derived Templates      Dryer Regeneration Cycle      Add Filter	¥
Cancel	Save

5. With the same event frame highlighted on the left section under **Source Events**, notice the attributes associated with these event frames just below in the **Attributes** Section.

Attributes Filter	×
Select All	
🗬 Avg Outlet Temp	0
Avg Regen Temp	0
III Drying Cycle Barrels	0
I Drying Cycle Duration	0
I Max Outlet Temp	0
I Max Regen Temp	0
III Regen Cycle Vapor	0

 Click and drag each of these attributes to the center of the screen under the 'Dryer Regeneration Cycle' parent that was just created in the middle of the screen. Your event shape should now look like the one below:

바방 Search Shape	
<sup>H</sup> 령 Event Shape	
▲ ™∄ Dryer Regeneration Cycle	# ×
Avg Outlet Temp	ø x
Avg Regen Temp	ø x
Drying Cycle Barrels	# X
Drying Cycle Duration	# X
A Max Outlet Temp	ø ×
A Max Regen Temp	ø ×
📰 Regen Cycle Vapor	# X

7. With the shape selected and the filters set, you should see 100+ event frames matching the criteria listed in the **Matches** area on the right.

✓ Matches

Found 100+ Matches

- ▶ 11성 Dryer A Regeneration Cycle 01-01-19 05:00
- ▶ Ind Dryer B Regeneration Cycle 01-01-19 08:30
- ▶ 바녕 Dryer A Regeneration Cycle 01-01-19 23:54
- ▶ Ing Dryer B Regeneration Cycle 01-02-19 12:42
- Ind Dryer A Regeneration Cycle 01-03-19 00:48
- ▶ 14:00 Pryer B Regeneration Cycle 01-03-19 14:00
- Ind Dryer A Regeneration Cycle 01-04-19 03:06
- 8. Click on the **Next** button on the upper right corner to proceed to the **Modify View** page.
- The Modify View page shows a preview of the first 100 rows of data from the first 100 event frames matching the Event Shape. Set the time range, 1/1/19 5:00 AM to 12/31/19 12:00 AM, to match the available PI data for the lab. Click Apply.

Start Time		End Time		
1/1/19 5:00 AM		12/31/19 12:00 AM	00	Apply

10. Highlight the **Event Frame Duration** column to bring up the **Column Details** pane on the right. Adjust the **Data Type** to '**Single**' to get the additional digits for duration.

Olumn Details
Name
Event Frame Duration
Reset Name to Default
Data Content 🛛 😧
Hour
Time Context
Event Frame Duration
Data Type
Single 🔹
Remove Column
Apply Changes

- 11. Click **Next** to proceed to the **Publish** page.
- 12. Select **CSV File** as the Target Configuration and click **Publish**, then **Confirm** to publish the data as a .CSV file.

Select Data > Modify View > Publish		
Target Configuration	Overwrite Options	Summary
CSV File v	The selected target only supports overwriting old data	Shape and Matches
		There are 100+ Matching Instances
Run Mode		Timeframe and Interval
Run Once		• Your Start Time is 2019-01-01T05:00:00.000Z
Run on a Schedule		Your End Time is 2019-12-31100:00:00.000Z     Your Time Interval gets an interpolated measurement Every 1     minute
		Publish

13. The file name will be the name of the asset view, **My Dryer Regenerations**, and it will be in the subdirectory, C:\PI World (this is also the 'PI World' folder shortcut on the desktop). This target was configured using the Administration pages of the PI Integrator for Business Analytics.

### Assessment of Dryer Regeneration Data in Power BI

Now that we have the years' worth of dryer regeneration event data in .CSV file format, we can easily ingest it into Power BI for further analysis. Within Power BI, we will be plotting the dryer states (Drying, Standby, Regenerating) for each dryer as a function of time (using weeks as our unit of time). This type of analysis lends itself very well to the capabilities of Power BI and illustrates the benefits of using the PI Integrator for BA to shape the data.

- 1. From the desktop, open the Power BI Report 'Regeneration Analysis.pbix'
- 2. Alternatively, if you'd like to build out the Power BI Report yourself, follow these steps:
  - I. From the desktop, open the '**Power BI Desktop**' application.
  - II. Import the 'Dryer Regenerations.csv' file. Click on the 'Get Data' option at the top of the application and choose the 'Text/CSV' file option. Click on 'Connect'



- III. Choose the **'Dryer Regenerations.csv'** file in the **C:\PI World** location and click **'Open'**
- IV. Click 'Load' to import the dataset into Power BI.

File Origin Delimiter			Data Type Detection				
65001: Unicode (UTF-8) * Tab		-	<ul> <li>Based on first 200 rows</li> </ul>		*	D	
ld	Dryer Regeneration Cycle	Event Frame Start Time	Event Fram	ne End Time	Event Frame Duration	TimeStamp	A
1	Dryer A Regeneration Cycle 01-01-19 05	:00 1/1/2019 5:00:00 AM	1/1/20	019 6:18:00 AM	1.3	1/1/2019 6:18:00 AM	^
2	Dryer B Regeneration Cycle 01-01-19 08	30 1/1/2019 8:30:00 AM	1/1/20	019 6:06:00 PM	9.6	1/1/2019 6:06:00 PM	
3	Dryer A Regeneration Cycle 01-01-19 23	54 1/1/2019 11:54:00 PM	1/2/201	19 10:42:00 AM	10.8	1/2/2019 10:42:00 AM	
4	Dryer B Regeneration Cycle 01-02-19 12	42 1/2/2019 12:42:00 PM	1/2/2019 10:48:00 PM		10.1	1/2/2019 10:48:00 PM	
5	Dryer A Regeneration Cycle 01-03-19 00	:48 1/3/2019 12:48:00 AM	1/3/201	19 11:42:00 AM	10.9	1/3/2019 11:42:00 AM	
6	Dryer B Regeneration Cycle 01-03-19 14	:00 1/3/2019 2:00:00 PM	1/4/201	19 12:12:00 AM	10.2	1/4/2019 12:12:00 AM	
7	Dryer A Regeneration Cycle 01-04-19 03	06 1/4/2019 3:06:00 AM	1/4/20	019 1:00:00 PM	9.9	1/4/2019 1:00:00 PM	
8	Dryer B Regeneration Cycle 01-04-19 15	24 1/4/2019 3:24:00 PM	1/5/20	019 2:30:00 AM	11.1	1/5/2019 2:30:00 AM	
9	Dryer A Regeneration Cycle 01-05-19 04	:30 1/5/2019 4:30:00 AM	1/5/20	019 1:12:00 PM	8.7	1/5/2019 1:12:00 PM	
10	Dryer B Regeneration Cycle 01-05-19 15	00 1/5/2019 3:00:00 PM	1/5/201	19 11 24:00 PM	8.4	1/5/2019 11:24:00 PM	
11	Dryer A Regeneration Cycle 01-06-19 01	36 1/6/2019 1:36:00 AM	1/6/20	019 9:54:00 AM	8.3	1/6/2019 9:54:00 AM	
12	Dryer B Regeneration Cycle 01-06-19 15	24 1/6/2019 3:24:00 PM	1/5/201	19 11:30:00 PM	8.1	1/6/2019 11:30:00 PM	
13	Dryer A Regeneration Cycle 01-07-19 01	54 1/7/2019 1:54:00 AM	1/7/201	19 10:24:00 AM	8.5	1/7/2019 10:24:00 AM	
14	Dryer B Regeneration Cycle 01-07-19 12	42 1/7/2019 12:42:00 PM	1/8/201	19 12:42:00 AM	12	1/8/2019 12:42:00 AM	
15	Dryer A Regeneration Cycle 01-08-19 03	:06 1/8/2019 3:06:00 AM	1/8/20	019 3:12:00 AM	0.1	1/8/2019 3:12:00 AM	
16	Dryer A Regeneration Cycle 01-08-19 03	24 1/8/2019 3:24:00 AM	1/8/201	19 12 24:00 PM	9	1/8/2019 12:24:00 PM	
17	Dryer B Regeneration Cycle 01-08-19 14	48 1/8/2019 2:48:00 PM	1/9/201	19 12:54:00 AM	10.1	1/9/2019 12:54:00 AM	
18	Dryer A Regeneration Cycle 01-09-19 04	18 1/9/2019 4:18:00 AM	1/9/20	019 3:00:00 PM	10.7	1/9/2019 3:00:00 PM	
19	Dryer B Regeneration Cycle 01-09-19 17	05 1/9/2019 5:06:00 PM	1/10/20	019 7:00:00 AM	13.9	1/10/2019 7:00:00 AM	
20	Dryer A Regeneration Cycle 01-10-19 09	:00 1/10/2019 9:00:00 AM	1/10/20	019 6:42:00 PM	9.7	1/10/2019 6:42:00 PM	~
3						>	

V. Add a column to the dataset to assign the week number. Click on the

**'Data'** View **I** rather than the **'Report'** view **I** on the top left of the application to see the tabular dataset we just imported. Click on the **'New Column'** action on the top toolbar.



VI. In the formula bar with the new column highlighted, type the following and click the check box to commit :

Week = WEEKNUM('Dryer Regenerations'[TimeStamp])



VII. Add a column to the dataset to note which dryer is involved in each

event. Click on the '**Data'** View rather than the '**Report'** view on the top left of the application to see the tabular dataset we just imported. Click on the '**New Column'** action on the top toolbar. In the formula bar with the new column highlighted, type the following and click the check box to commit :

**Dryer** = LEFT('Dryer Regenerations'[Dryer Regeneration Cycle], 7)


VIII. Add a new measure to calculate the total time each dryer is in the '**Drying**' stage. Click on the '**New Measure**' action on the top toolbar.



IX. In the formula bar with the new measure column highlighted, type/paste the following and click the check box to commit :

**Drying Time** = CALCULATE(SUM('Dryer Regenerations'[Drying Cycle Duration]), FILTER(ALLEXCEPT('Dryer Regenerations','Dryer Regenerations'[Dryer],'Dryer Regenerations'[Event Frame Duration]),'Dryer Regenerations'[Week]<=MAX('Dryer Regenerations'[Week])))

X. Add a new measure to calculate the total time each dryer is in the '**Regenerating**' stage. Click on the '**New Measure**' action on the top toolbar. In the formula bar with the new measure column highlighted, type/paste the following and click the check box to commit:

**Regenerating Time** = CALCULATE(SUM('Dryer Regenerations'[Event Frame Duration]),FILTER(ALLEXCEPT('Dryer Regenerations','Dryer Regenerations'[Dryer],'Dryer Regenerations'[Event Frame Duration]),'Dryer Regenerations'[Week]<=MAX('Dryer Regenerations'[Week])))

XI. Add a new measure to calculate the total time each dryer is in the **'Regenerating'** stage. Click on the **'New Measure'** action on the top toolbar. In the formula bar with the new measure column highlighted, type/paste the following and click the check box to commit:

**Standby Time** = CALCULATE(DISTINCTCOUNT('Dryer Regenerations'[Week])\*168-SUM('Dryer Regenerations'[Event Frame Duration])-SUM('Dryer Regenerations'[Drying Cycle Duration]),FILTER(ALLEXCEPT('Dryer Regenerations','Dryer Regenerations'[Dryer],'Dryer Regenerations'[Event Frame Duration]),'Dryer Regenerations'[Week]<=MAX('Dryer Regenerations'[Week])))

XII. Switch back to the '**Report**' View . We now want to build out three charts displaying each of the Dryer States as a function of Week for each dryer. Your report will eventually look like the one below:



XIII. Create a Line Chart for Drying Time by Week and Dryer. Choose the Line Chart Visual and populate the fields as shown:

6	Q
Axis	
Week	~ ×
Legend	
Dryer	$\sim \times$
Values	
Drying Time	$\sim \times$

XIV. Create a Line Chart for Standby Time by Week and Dryer. Choose the Line Chart Visual and populate the fields as shown:

	10,001	•
8	Q	
Axis		
Week		$\sim \times$
L		
Legend		
Dryer		$\sim \times$
Values		
Standby Time		V.V

XV. Create a Line Chart for Regenerating Time by Week and Dryer. Choose the Line Chart Visual and populate the fields as shown:

Axis	
Week	××
Legend	
Dryer	××
Values	
Regenerating Time	$\sim \times$

XVI. Create four Card visualizations to calculate the average hours of Drying and Regenerating times for each cycle in each dryer. For the Average Drying time card, populate the Fields with the Drying Cycle Duration item and choose to display the Average value. In the dropdown, choose 'New Quick Measure.' Choose the 'Filtered Value' Calculation. Drag the Dryer item into the Filter field and filter on Dryer A.

Average of Drying Cycle $\checkmark$		Average of Drying Cycle	
Drillthrough Cross-report	Remove field Rename Sum	e Drillthrough	Remove field Rename
Off O-	Average	e Cross-report Off O	Sum V Average
Keep all filters On — Add drillthrough fields I	Minimum Maximum Count (Distinct) Count Standard deviation Variance Median	T Keep all filters T On• K Add drillthrough fields I	Minimum Maximum Count (Distinct) Count Standard deviation Variance Median
	Show value as		Show value as
	New quick measure		New quick measure

Calculation	Fields		
Filtered value	▼ ,O Sei	arch	
Calculate a value with a filter applied. Learn i	ore	Dryer Regenerations	
Base value ①		Outlet Temp	
		Regen Temp	
Average of Drying Cycle Duration	× Σ Ανο		
Filter 🛈		er Regeneration Cycle	
	T Dec	ing Cycle Barrels	
Dryer	× 1	ing Cycle Duration	
Dryer A	-	ing Time	
	Σ Eve	nt Frame Duration	
	> 🖽 I	Event Frame End Time	
	▶	Event Frame Start Time	
	Σld		
	Σ Ma	x Outlet Temp	
	∑ Ma	x Regen Temp	
	-	en Cycle Vapor	
	-	enerating Time	
		TimeStamp	
	TS We	ek	

- XVII. Repeat this process three more times for the average hours Dryer and Regeneration times for each cycle in each dryer.
- XVIII. Once complete, your report should look similar to the one below:



 Let's take a moment to analyze the 2019 Dryer Operating States Power BI report above. From this report, we can quickly see that there is a clear imbalance between the two dryers in terms of utilization. On average, Dryer A has longer drying cycle times than Dryer B. Conversely, Dryer B has longer Regenerating cycle times on average.



Plotting this data in Power BI, a Business Analytics tool, makes it easy to see the cumulative use of each dryer throughout the year using weeks as the unit of time. The plots above are cumulative slices of data rather than the simple 2-d (x,y) plotting that excel is capable of. This is why we are using Power BI at this step of the project.

With this visual, we can confirm that the problem we are trying to solve does in fact exist and it is worth moving forward with the project.

## 4.3 Model Development – PI DataLink

In the previous section, we illustrated the use of the PI Integrator for BA to publish data into Power BI for analysis. In this section, we will illustrate how PI Datalink and Excel can also be used to analyze our Dryer dataset and how we can use basic Excel functionality to generate a linear model to predict regenerating times for each dryer, which we can use for our simple predictive model.

At this point in the Analytics project, it's important to get assistance from Subject Matter Experts (SMEs) who understand the process we are modeling – to ensure we end up with helpful and meaningful results. Our SME in this case has indicated that the **Drying Cycle Barrels** variable that we have – which corresponds to the number of barrels dried in the previous drying cycle – will be the best one to predict preceding regeneration cycle time.



For a brief discussion/explanation on why we decided on Drying Cycle Barrels as our predictive variable to inform regeneration time, see the Appendix section 7.1.

- 1. On the desktop, open up the Excel file '**PI World Dryer Regen Duration.xlsx**'
- 2. There are three sheets in the 'PI World Dryer Regen Duration.xlsx' file.
  - a. The first sheet titled 'Dryer A' has also been built out for you. Since we've chosen the Drying Cycle Barrels as our dependent variable for our linear prediction model, we are focusing on that variable here. The event frame search has brought in the Duration and Drying Cycle Barrels data for the year 2019. We've also filtered out any event frames with a prior Drying Cycle Duration of less than 10 hours you can see how this can be done in the Event Frame search in the next step. This purpose of this filter is to remove any "false starts" in the

data, when a drying cycle is shorter than typical. This would result in a skewed prediction and we will account for this in our regeneration prediction forecast.

This sheet plots the Regeneration Cycle duration as a function of the Drying Cycle Barrels variable – the number of barrels the dryer processed in the previous drying cycle.

This scatter chart has a linear best-fit line indicating the relationship that the Drying Cycle Barrels variable has on the Regeneration Cycle Time. We will be using this equation of the derived linear regression line as our model to predict Regeneration Cycle Duration.



This is clearly a rather simple predictive model that could be more advanced, but for the purposes of this lab we are focusing on the methodology of starting analytics and data science projects with the common tools at our disposal to get us started and familiarized with the basics.



b. The second sheet titled 'My Dryer B' has not yet been built out for you. To give you experience importing event frame data into Excel using PI DataLink, follow the steps below to build out the same charts as 'Dryer A' and to develop our linear regression model for Dryer B. If you'd prefer to use a pre-built sheet for Dryer B, it is the last sheet in the workbook titled 'Dryer B'. i. Bring in all the event frame data for the year 2019 using PI DataLink. Make sure you're in the '**PI DataLink'** ribbon add-in to Excel. Click on '**Explore'** tool in the events tool section of PI DataLink.



- ii. Enter the following parameters for your event frame search such that it looks like the one below and click **Apply**:
  - 1. Database: \\PISRV01\Dryers
  - 2. Event Name: \*
  - 3. Search Start: 1/1/2019
  - 4. Search End: 12/31/2019
  - 5. Event Template: Dryer Regeneration Cycle
  - 6. Element Name: Dryer B
  - 7. Element Template: \*
  - 8. **+More Search Options>Attribute Value Filters**: 'Drying Cycle Duration' > 10
  - 9. Select Columns to Display:
    - Event Name
    - Drying Cycle Barrels
    - Duration

Explore Events						~
Database	_		-			?
\\PISRV01\Dryers			Event name			
Search start			Event	emplate		_
1/1/2019				emplate Regeneration Cyc	de v	3
Search end					ue •	<u> </u>
12/31/2019			Dryer E	nt name		
		1	-	nt template		1
Limit to database level			*	it template	~	7
<ul> <li>More search options</li> </ul>						
Event category			Search	mode		
•	~ 📑		active i	n range	~	3
Minimum duration			Sort or	der		
			start tim	e ascending	~	3
Maximum duration			Severit	v		
			$\sim$	•	~	3
Attribute value filters						
Attribute 0	perator		Value			
Drying Cycle Durat 🗸 >		×	10			
× .		×				
×		~				
×		V				
Acknowledgment filters						
Acknowledged				Limit to annotate	ы	
Unacknowledged						
Preview						
Events (183 found)	ation Cycle 01-	01-1	19 08:30	)	^	
Dryer B Regener	ation Cycle 01-	02-1	19 12:42			
Dryer B Regener						
Dryer B Regener	ation Cycle 01-	05-1	19 15:00	)		
Dryer B Regener						
Davar D Davanar					*	
Columns to display						
Select all						
Event name		_			^	1
Drying Cycle Barrels						
Duration						+
Start time						×
Event template						
Primary element						
Primary element path		_			~	1
Number of child event leve	de .		Outpu	cell		
Number of child event level	×5		<u> </u>	A'ISAS1		
-						
				ОК	Apply	

iii. Add a column to the end of the dataset (should be column D) to convert the duration into hours. To do this, simply multiply the imported duration by 24 and change the format of the cells in that column to be of type **Number** with two decimals.

- iv. Once the event frame data is brought into the **'Dryer B'** sheet, we can now use Excel's charting functionality to plot the Regeneration Cycle duration as a function of each variable.
- v. Within Excel, click on the **Insert** ribbon at the top and choose the **Scatter** plot



- vi. Right click on the scatter plot and click 'Select Data.' On the Select Data window, the range of values for Duration (Hours) will be the dependent y-axis on this chart and the Drying Cycle Barrels variable will be on the x-axis.
- vii. On this chart, click to Add a Chart Element of a Linear Trendline. Format the trendline to Display Equation on chart and to Display R-squared value on chart. Once complete, you should have a chart that looks like the one below:



We now have a linear regression model for each dryer using the variable of Drying Cycle Barrels, or the number of barrels dried during the preceding drying cycle, that we will use to predict the proceeding Regeneration Cycle Duration in the next section.

#### **Dryer A**

Y = 0.0003X + 9.6722

Where Y = Regeneration Duration and X = Drying Cycle Barrels

#### Dryer B

Y = 0.0006X + 9.5749

Where Y = Regeneration Duration and X = Drying Cycle Barrels

# 5. Operationalization and Notification

## 5.1 Objective

The purpose of this last section of this analytics project is to operationalize the linear model we derived in the previous section to generate a prediction for dryer regeneration time. In the following section we will:

- Create a forecasting analytic using AF Analytics to predict dryer regeneration times
- Create a notification to alert operators when dryer regeneration times are predicted to be 11 hours or more

### 5.2 Forecast Deployment – AF Analytics

From the Windows taskbar, open PI System Explorer and be sure you're connected to the 'Dryers' database.

First off, we will be using an AF Table to store the coefficients of our linear regression lines from the previous section.

1. Navigate to the **Library** and the **Dryer Data** under **Tables**. The table and the coefficients for each Dryer's equation have been built for you. Take a moment to confirm that these are correct.

	Dryer	Regeneration Duration Forecast Slope	Regeneration Duration Forecast Intercept
•	Dryer A	0.0003	9.6722
	Dryer B	0.0006	9.5749

We will be creating an AF Analytic for the forecast equation at the template level for the dryers.

- 1. Navigate to the Library and the Dryer template under Element Templates.
- 2. Click on the **Analysis Templates** Tab and click on the **New Analysis Template** option.



Name your new Analysis Template '**My Dryer Regeneration Cycle Time Forecast.**' This analysis has already been build out under the name '**Dryer**  **Regeneration Cycle Time'** but we want you to be able to build out the expression on your own. By default, you have created a new **Expression** type analysis. This is what we need.

3. We will be creating a multi-line analysis utilizing the multi-variable capability of AF Analytics. The first step in our analysis is to find the last drying event. We will be making use of new AF Analytics functions that allow for array calculations. Let's us the **RecordedValuesByCount** function to grab the past 10 states of the dryer. Create a variable called **PastTenStates** and input the following formula:

#### RecordedValuesByCount('Best Operating State','\*',10)

This operation will create an array of 10 values consisting of the past 10 states the dryer has had. To view the output of the operation, click on **Evaluate** and hover your mouse over the **Blue Information Symbol** next to the evaluation.

Example Element: Dryer A								
Add a new variable							Evaluate	1
Name	Expression Va				Value at Last Trigger	Output Attribute		۲
PastTenStates	<pre>// Array containing last 10 archived values and their timestamps. RecordedValuesByCount('Best Operating State','*',10)</pre>			Drying,, Drying]	[Drying,, Drying]	Map	8	
PastDryingStates	<pre>// Array of only "Process" states and their timestamps. FilterData(PastTenStates,\$val="Drying")</pre>	To access the values, use a or For example, PastTenStates[1		[Drying,, Drying]	[Drying,, Drying]	Map	8	
LastDryingEvent	<pre>// Time of most recent "Process" event. TimeStamp(PastDryingStates[1])</pre>	Total number of values: 10	Value	/30/2020 11:06:00 AM	1/30/2020 11:06:00 AM	Map	8	
HrsIntoDryingCycle	TimeEq('Best Operating State', LastDryingEvent, '*', "Drying")/3600	1/30/2020 11:06:00 AM 1/30/2020 12:54:00 AM	Drying Regenerating	7.6438	7.6	Map	8	
	If 'Best Operating State' = "Drying" And HrsIntoDryingCycle >= 5 Then 'Regeneration Cycle Model Slope' * 'Drying Cycle Barrels' + 'Reg Else 0	1/29/2020 11:36:00 PM	Standby Drying Regenerating	11.3	11.3	Forecasted Regeneration Cycle Duration	8	
		1/28/2020 10:18:00 PM 1/28/2020 6:54:00 AM 1/27/2020 8:42:00 PM 1/27/2020 7:36:00 PM 1/27/2020 3:00:00 AM	Standby Drying Regenerating Standby Drying					•

4. We now want to filter this array to only capture the states where the dryer is in "Drying" mode. Create another variable called PastDryingStates and input the following formula:

```
FilterData(PastTenStates,$val="Drying")
```

This operation will create an array of filtered values consisting of the past "**Drying**" phases and their associated timestamps.

To access the values, use a one-based index. For example, PastDryingStates[1] will return Drying.					
Total number of values: 4					
Timestamp	Value	ł			
1/30/2020 11:06:00 AM	Drying	l			
1/29/2020 10:12:00 AM	Drying	l			
1/28/2020 6:54:00 AM	Drying	ŀ			
1/27/2020 3:00:00 AM	Drying				

5. Let's grab the most recent drying event. Create a new variable called **LastDryingEvent** and input the following:

#### TimeStamp(PastDryingStates[1])

This operation grabs the timestamp of first value in the **PastDryingStates** array, or the most recent drying phase's associated timestamp.

6. We want the analysis to check how long the dryer has been in the drying state. Create a new variable called **HrsIntoDryingCycle** and input the following:

```
TimeEq('Best Operating State', LastDryingEvent, '*',
"Drying")/3600
```

This operation will output (in hours) the length of time that the dryer has been in the drying phase.

7. Finally, we want to input our forecasting equation. Create a new variable called **ForecastedRegenCycleDuration** and input the following:

```
If 'Best Operating State' = "Drying" And HrsIntoDryingCycle >= 10
Then 'Regeneration Cycle Model Slope' * 'Drying Cycle Barrels' +
'Regeneration Cycle Model Intercept'
Else 0
```

This operation first checks that the dryer is in the drying phase and if it has been in the drying phase longer than 10 hours. If those conditions are met, it then applies the coefficients from our linear regression model stored in the **Dryer Data** table previously created. Otherwise, if the initial conditions aren't met, then the forecast is not performed. Remember – we only want this prediction to be made when the dryer is in the current drying phase.



Why did we add the condition in the previous equation to check if the Drying Phase has been longer than 10 hours?

Remember that during our modeling, we filtered out event frame data where any Drying Cycle Durations shorter than 10 hours. It's important to account for these filters in your prediction logic.

8. The Dryer template has already been configured to have an attribute named 'My Forecasted Regeneration Cycle Time Forecast' which point to the PI tags 'Dryer A.My Dryer Regeneration Cycle Time Forecast.%ID%' and 'Dryer B.My Dryer Regeneration Cycle Time Forecast\_%ID%' for Dryer elements Dryer A and Dryer B, respectively.

To the right of the **Expression** field, under **Output Attribute**, click the **Map** link and assign the '**My Forecasted Regeneration Cycle Time Forecast**' template attribute for the **ForecastedRegenCycleDuration** variable.

Also note that the **Example Element** for this template has be set to **Dryer A**. These means that all evaluations and preview calculations will be done using Dryer A data. You can change to another element by clicking the link and selecting a different one, e.g. Dryer B.

- 9. Check in your changes by clicking **Check In** at the top of PI System Explorer.
- 10. We now have our complete analysis which is forecasting the duration of the regeneration cycle using the Drying Cycle Barrels of the preceding drying phase as a predictor. Your complete analysis should look like the one below, and should evaluate like the one below:

General A	Attribute Templates Ports	Analysis Templates Notification Rule Templates								
			Name:	My Dryer Regeneration Cycle Time Forecast						
0 ×	Name									
н	Dryer Notification		Categories:							
\$60	Dryer Regeneration Cycle	ration Cycle Time Forecast		Analysis Type:   Expression   Rollup   Event Frame Generation   SQC						
н	Dryer Regeneration Events		Enable an	Enable analyses when created from template						
f0)										
f60			13							
fø										
	My Dryer Regeneration ( Total Barrels Dried	Cycle Time Forecast								
	lement: <u>Dryer A</u>							valuate		
		Expression			Value at Evaluation	Value at Last Trigger	Output Attribute	Evaluate		
Add a ne	ew variable	Expression // Array containing last 10 archived values and their timestamps. RecordedValuesByCount("Best Operating State", **,10)			Value at Evaluation (Drying,, Drying)	Value at Last Trigger      [Drying,, Drying]	Town of the second seco	Evaluate		
Add a ne Name PastTen	ew variable	<pre>// Array containing last 10 archived values and their timestamps.</pre>					Output Attribute			
Add a ne Name PastTen PastDry	ew variable IStates	<pre>// Array containing last 10 archived values and their timestamps. RecordedValuesByCount('Best Operating State','*',10) // Array of only "Process" states and their timestamps.</pre>			[Drying,, Drying]	<ul> <li>[Drying,, Drying]</li> </ul>	Cutput Attribute Map Map	¢		
Add a ne Name PastTen PastDry LastDry	ew variable IStates /ingStates	<pre>// Array containing last 10 archived values and their timestamps. RecordedValuesByCourt('Best Operating State','*',10) // Array of only "Process" states and their timestamps. FilterData(PastTenStates,Sval="Drying") // Time of most recent "Process" event.</pre>			<ul> <li>[Drying,, Drying]</li> <li>[Drying,, Drying]</li> </ul>	<ul> <li>[Drying,, Drying]</li> <li>[Drying,, Drying]</li> </ul>	Cutput Attribute Map Map	(		

# 11. You can use the **Preview Results** feature of AF Analytics to confirm that the Analysis is functioning. Right-click on your analysis and click on **Preview Results**.

	End Time	s •							C	ienerate Resu
Trigger Time	PastTenStates	PastDryingStates	LastDryingEvent	HrsIntoDryingCycle	ForecastedRegenCycleDuration	Best Operating State	Regeneration Cycle Model Slope	Drying Cycle Barrels (bbl)	Regeneration Cycl	Evaluation
/24/2020 8:12:00 PM	[Regenerating,, Regenerating]	[Drying, Drying, Drying]	1/23/2020 7:42:00 PM	17	0	Regenerating	0.0003	0.0	10.4 ^	(100%)
24/2020 10:36:00 PM	() [Regenerating,, Regenerating]	[Drying, Drying, Drying]	1/23/2020 7:42:00 PM	17	0	Regenerating	0.0003	0.0	10.4	$\square$
24/2020 10:42:00 PM	IDrying,, Drying]	[Drying,, Drying]	1/24/2020 10:42:00 PM	0	0	Drying	0.0003	34.4	10.4	Progress
25/2020 12:24:00 AM	IDrying,, Drying]	[Drying,, Drying]	1/24/2020 10:42:00 PM	1.7	0	Drying	0.0003	619.8	10.4	
25/2020 5:12:00 AM	IDrying,, Drying]	[Drying,, Drying]	1/24/2020 10:42:00 PM	6.5	11.137	Drying	0.0003	2302.9	10.4	0.8ms
25/2020 7:12:00 AM	IDrying,, Drying]	[Drying,, Drying]	1/24/2020 10:42:00 PM	8.5	11.344	Drying	0.0003	2994.5	10.4	Min
/25/2020 11:24:00 AM	[Drying,, Drying]	[Drying,, Drying]	1/24/2020 10:42:00 PM	12.7	11.784	Drying	0.0003	4458.6	10.4	
25/2020 1:18:00 PM	IDrying,, Drying]	[Drying,, Drying]	1/24/2020 10:42:00 PM	14.6	11.983	Drying	0.0003	5124.0	10.4	( 12ms
25/2020 1-24-00 PM	IStandby Standby	1 IDoving Doving Doving1	1/2//2020 10-/2-00 PM	14 7	0	Standby	0.0003	0.0	10, ~	Max
<ul> <li> <ul> <li></li></ul></li></ul>	1	1	Λ		Λ			1	No Data • HrsIntoDryir 3.9	1.4ms Avg
:06:40 AM							/		ForecastedR     0	Avg Trigo
2:50:00 AM									<ul> <li>Best Operati</li> </ul>	Avg ing
2:50:00 AM 2:33:20 AM 2:16:40 AM				/					Drying	(126ms
2:33:20 AM				7 days				1/31/2020 5:56:50 PM		126ms Total 78

- 12. In the lower left-hand corner of PI System Explorer, select the **Management** view. Here is where you manage all the Asset Analytics configured for an AF Database. This includes enabling, disabling and backfilling calculations.
- 13. Select the **'My Dryer Regeneration Cycle Time Forecast'** analyses for the **Dryer A and B** elements. On the right-hand side under **Operations**, click **Enable**.
- 14. Once the *spears* in the **Status** column the analyses are up and running. Again under **Operations**, click on **Queue**. This exposes the backfilling configuration dialog.

Configure the **Start** and **End** times to be **'\*-7d'** and **'\*'**, respectively. And finally, click **Queue** start backfilling results for the two dryers.

### 5.3 **Proactive Solution – PI Notifications**

Now that we have a working analysis whose output will tell us the predicted duration for each regeneration phase, we want to be able to take this one step further – to notify operators when to end the drying phase for one dryer and begin regeneration (switch which dryer is active). Remember, the ultimate goal here is to balance the use of each dryer such that they will have a similar end of life – significantly reducing replacement costs and required downtime.

In this last section we will:

- Create an Event Frame analysis to store an event any time the expected Regeneration forecast is greater than or equal to 11 hours.
- Create a notification rule to send an e-mail to the <u>student01@pischool.int</u> account any time the expected Regeneration forecast is greater than or equal to 11 hours.

#### Analysis for Event Frame Generation

- An Event Frame template has been created for you to use. After walking through its configuration, we will configure an analytic to generate the Event Frames themselves. In PI System Explorer, select the Library view. Under the Templates branch of the hierarchy, expand Event Frame Templates and select the Regeneration Time Notification template. The Naming Pattern is specified under the General tab.
- 2. Select the Attribute Templates tab at the top to see the list of attributes.

Expand the attribute configuration dialog by clicking the along the righthand boarder of PI System Explorer.

- 3. You can see that this particular template will store the Forecasted Regeneration Cycle Time and the Last Drying Cycle Time. Just like in the previous event frame, these are merely placeholders to contain the result of an Asset Analytics calculation which occurs upon the end or close of the Event Frame. We will configure this calculation in the next steps.
- 4. In PI System Explorer, navigate back to the **Dryer** element template in the **Library** under **Element Templates**. Click and navigate to the **Analysis Templates** tab.
- 5. Create a new Analysis Template by clicking . Rename it 'My Dryer Notification'. Set the Analysis Type to Event Frame Generation. Uncheck Enable analysis when creating from template. Assign the Event Frame Template to Regeneration Time Notification. Note that the Example Element has been assigned to Dryer A by default.
- 6. Similar to our **My Dryer Regeneration Cycle Time Forecast**, we will be using AF Analytics array functions to grab the timestamp of the latest drying event.
  - a. We will be creating a multi-line analysis utilizing the multi-variable capability of AF Analytics. The first step in our analysis is to find the last drying event. We will be making use of new AF Analytics functions that allow for array calculations. Let's us the **RecordedValuesByCount** function to grab the past 10 states of the dryer. Create a variable called **PastTenStates** and input the following formula:

RecordedValuesByCount('Best Operating State','\*',10)

This operation will create an array of 10 values consisting of the past 10 states the dryer has had. To view the output of the operation, click on **Evaluate** and hover your mouse over the **Blue Information Symbol** next to the evaluation.

 We now want to filter this array to only capture the states where the dryer is in "Drying" mode. Create another variable called PastDryingStates and input the following formula:

FilterData(PastTenStates,\$val="Drying")

This operation will create an array of filtered values consisting of the past "**Drying**" phases and their associated timestamps.

c. Let's grab the most recent drying event. Create a new variable called **LastDryingEvent** and input the following:

TimeStamp(PastDryingStates[1])

This operation grabs the timestamp of first value in the **PastDryingStates** array, or the most recent drying phase's associated timestamp.

7. Add a Start Trigger with the following logic:

```
'My Dryer Regeneration Cycle Time Forecast' >= 11
```

8. Add an End Trigger with the following logic:

'My Dryer Regeneration Cycle Time Forecast' >= 11

This event frame will be captured and begin and end when the predicted regeneration cycle duration is greater than or equal to 11.

- To write to the Forecasted Regeneration Cycle Time and the Last Drying Cycle Time attributes of the Event Frame template, we will be using Output Expressions.
  - a. Add an output expression called **CurrentForecast** and input the following expression

```
TagVal('My Dryer Regeneration Cycle Time Forecast',
EventFrame("StartTime"))
```

This expression will output the value of the predicted regeneration time at the start time of the event frame.

Map this output expression to the **Forecasted Regeneration Cycle Time** attribute of the Event Frame Template

b. Add an output expression called **LastDryingCycle** and input the following expression

#### LastDryingEvent

This will write the value of the **LastDryingEvent** variable you created previously.

Map this output expression to the **Last Drying Cycle Time** attribute of the Event Frame Template.

10. Your complete My Dryer Notification Event Frame should look like this:

<u>Add</u> ~						Evalu	ate
Name	Expression	True for	Severity	Value at Evaluation	Value at Last Trigger	Output Attribute	
Variables				21			
PastTenStates	RecordedValuesByCount('Best Operating State','*',10)			<ol> <li>[Drying,, Drying]</li> </ol>	[Drying,, Drying]		(
PastDryingStates	<pre>FilterData(PastTenStates,\$val="Drying")</pre>			(Drying,, Drying)	[Drying,, Drying]		0
LastDryingEvent	TimeStamp(PastDryingStates[1])			1/31/2020 2:00:00 PM	1/31/2020 2:00:00 PM		0
Start triggers							
StartTrigger1	'My Dryer Regeneration Cycle Time Forecast' >= 11	Set (optional)	None	v True	True		
End trigger							
EndTrigger	'My Dryer Regeneration Cycle Time Forecast' >= 11			True	True		Ø
Outputs at close							
CurrentForecast	<pre>TagVal('My Dryer Regeneration Cycle Time Forecast', EventFrame("StartTime"))</pre>			Use Preview	Use Preview	Forecasted Regeneration Cycle Time	¢
LastDryingCycle	LastDryingEvent			1/31/2020 2:00:00 PM	1/31/2020 2:00:00 PM	Last Drying Cycle Start time	Q

- 11. Click the **Evaluate** button to preview the results and make sure there are no errors. If it all looks good, **Check In** your changes.
- 12. Return to the **Management** view in PI System Explorer. Select the '**My Dryer Notification**' analyses for the **Dryer A and B** elements. On the right-hand side under **Operations**, click **Enable**.
- 13. Once the *spears* in the **Status** column the analyses are up and running. Again under **Operations**, click on **Queue**. This exposes the backfilling configuration dialog.

Configure the **Start** and **End** times to be **\*\*-7d'** and **\*\*'**, respectively. And finally, click **Queue** start backfilling Event Frames for the two dryers.

#### Create a Notification Rule

The next step from here is to create a **New Notification Rule Template** from this **My Dryer Notification** Event Frame.

- Under the Analysis Details on the top right of PI System Explorer, click on the blue hyperlinked text that says "Create a new notification rule template for My Dryer Notification"
- 2. Call this new notification rule template "My Dryer Notification"
- 3. Under the Subscriptions section, click on View/Edit Subscriptions
- 4. Expand **student01** and drag the **E-mail** endpoint under **student01** into the **Subscriptions** section. Click OK and **Check In**.

#### **Configure Notification Message Formatting**

- 1. Click on the blue **Manage Formats** link in the **Subscriptions** section. Select the line with **Global Default Email** (color changes to light blue) and click on the Duplicate icon above. Rename the duplicated format as **My Dryer Notification Email**.
- 2. Change the subject of the e-mail to: Subject Event Frame:Name - High Regeneration Time Forecasted
- 3. Remove the items for Server, Database, and Severity.
- 4. Add an informative message to tell the operators the predicted regeneration time and instruct them to switch dryers. It should like similar to this:

Target:Path is currently in the DRYING phase with a PREDICTED REGENERATION TIME of Forecasted Regeneration Cycle Time:Value At Start Time hours.

Please Switch Dryers.

- 5. At the bottom of the design window, add a link to the '**Drying Process After**' PI Vision Display.
  - a. Click on the Insert Link option and enter the URI of the PI Vision page showing the drying states: <u>https://pisrv01/PIVision/#/Displays/10/Drying-Process----After</u>. Click Continue.
  - b. Enter PI Vision Drying Process in the Text to Display field.
  - c. Set the time context for the PI Vision link:
    - i. Enter a new Key for starttime with a value of "-7d'.
    - ii. Enter a new Key for endtime with a value of '\*'.
    - iii. Your create link window should look like below when completed:

Create a Link						
Link to	○ Web		Restart Co	onfiguration		
Display link as	● Text ○ Screenshot					
Text to display	PI Vision Drying Process					
PI Vision address	https://pisrv01/PIVision/					
Display name	/Displays/10/Drying-ProcessAfter					
Parameters						
Key		Value				
starttime		*-7d		×		
endtime		×		×		
Add New Parameter						
Preview	https://pisrv01/PIVision/#/Displays/10/Drying-ProcessAfter?starttime=*-7d&iendtime=*					
			OK	Cancel		

#### d. Click OK and Check In.

6. Your message configuration window should look like the one below when complete:

My Dryer Notification - Message - My Dryer Notification Email	
😝 Name Is Default	
Global Default Email Asset server	
ஞ My Dryer Notification Email 🗸	
Design       HTML Preview         W       W	
Attachments	Ž Test Send ₊
Event:       Event Frame:Name         Name:       Notification Rule:Name         Start Time:       Event Frame:Start Time         Target:       Target:Path         Send Time:       Notification Rule:Send Time         Target:Path       is currently in the DRYING phase with a PREDICTED REGENERATION TIME of Forecasted Regeneration Cycle Time:Value At Start Time         Target:Path       is currently in the DRYING phase with a PREDICTED REGENERATION TIME of Forecasted Regeneration Cycle Time:Value At Start Time         Please Switch Dryers.       Please Switch Dryers.         Pl Vision:Hyperlink:Pl Vision Drying Process	ne

- 7. Click on the **Test Send** button and enter in the <u>student01@pischool.int</u> email address.
- 8. Open up **Outlook** from the Desktop or the Taskbar. You should have received the test e-mail. Open the e-mail and confirm the formatting and that the PI Vision link works.

#### **Confirming Notifications**

- 1. Return to the **Management** view in PI System Explorer. Select the '**My Dryer Notification**' analyses for the **Dryer A and B** elements. On the right-hand side under **Operations**, click **Enable**.
- 2. Once the *spears* in the **Status** column the analyses are up and running. Again under **Operations**, click on **Queue**. This exposes the backfilling configuration dialog.

Configure the **Start** and **End** times to be **'\*-7d'** and **'\*'**, respectively. And finally, click **Queue** start backfilling Event Frames for the two dryers.

0	н	Dryer A	My Dryer Notification	My Dryer Notification
0	н	Dryer B	My Dryer Notification	My Dryer Notification
0	fi)	Dryer B	My Dryer Regeneration Cycle Time Forecast	My Dryer Regeneration Cycle Time Forecast
0	f(<)	Dryer A	My Dryer Regeneration Cycle Time Forecast	My Dryer Regeneration Cycle Time Forecast

You should be receiving e-mails after the analysis has been running for some time and the conditions for the Dryer Notification are met. Below is an example of what your e-mails will look like with the link to the PI Vision page:



# 6. Summary

### 6.1 Revisit Learning Objectives

Thank you for completing this lab with us! In this lab we:

- Explored features of several OSIsoft products in one lab.
- Learned how to interact with the PI System.
- Discovered how its features can work in concert to take an improvement idea and impact an actual operating problem.
- Transitioned PI Users into PI *Power* Users, enabling them to make a larger contribution in addressing process problems based on an improved understating of available tools and their domain expertise.

# 7. Appendix

## 7.1 Predictive Model Development and Variable Selection

There is a hidden sheet in the '**PI World Dryer Regen Duration.xlsx'** Excel file on the lab VM desktop that has been built out for you. If you right click on the sheet ribbon and click **Unhide > 'Regen** Variables' you will be able to see this sheet. This sheet plots event frame duration (or the Regeneration cycle duration) as a function of key variables.

The purpose of this sheet is to identify an appropriate variable to use that will be a good predictor of the time it takes the dryer to regenerate. The variables we have are:

- Average Regen Temp (the average temperature of the dryer throughout the regeneration phase)
- Regen Vapor Flow (the total flow of regeneration vapor throughout the regeneration phase)
- Drying Cycle Duration (the duration of the drying phase preceding the regeneration phase)
- Drying Cycle Barrels (the amount of barrels processed during the drying phase preceding the regeneration phase)



Avg Regen Temp and Regen Vapor Flow appear to be good indicators of Regen Duration – meaning there definitely appears to be a correlation between these

variables and the regeneration duration. Would these variables be a good choice for predicting the regeneration time?

**The answer is of course, no.** The reason being is that these variables are collected during the regeneration phase itself, and thus cannot be used to predict the duration of the regeneration phase. This is important to know for this analytics project and this lesson can be taken to other analytics projects as well.

Having the domain knowledge on the process to know which variables are appropriate to use for modeling and forecasting is extremely important.

A common story we hear from analytics and data science projects is that the end results often propose "obvious" answers or suggestions. This highlights the importance of working with, or including Subject Matter Experts throughout the course of your analytics projects.

So that leaves us with two variables: Drying Cycle Duration and Drying Cycle Barrels. Drying Cycle Duration seems like a potentially good candidate, however the drawback with simply using duration as our predictor is that the flow or the speed of the barrels processed during the drying phase is extremely variable and unknown. For example, one drying phase might have a shorter duration but process more feed because of a higher flow than another drying phase. Given that knowledge, the **Drying Cycle Barrels is the best option we have to use as a variable for our predictive model for regeneration duration**.

Tip





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