

# Turbine Efficiency Pump Performance

# Using AF



# CPS Energy

- San Antonio's Municipal Gas & Electric
- Diversified with Coal, Gas, Solar & Wind



# Business Decision

- Enterprise Asset Customer – “Downtown decision”
- Comes with “All You Can Eat Buffet”
- Now, what do we do?
- Test Crew – needs help!



# HP & IP Turbine Efficiency

- AF Jump Start Workshop
- Developed HP Turbine Efficiency tool
  - One set of data inputs
  - But, some units had 2, 3 or 4
- Take two – Developed Data Preparation Modules
  - Average points, unit conversions, time averaging, validation
  - Each unit has separate data preparation module
  - Outputs to standardized attributes & PI Tags
    - Braunig1.Throttle Pressure Abs Avg
    - Braunig2.Throttle Pressure Abs Avg
- One HP-IP turbine template; multiple elements



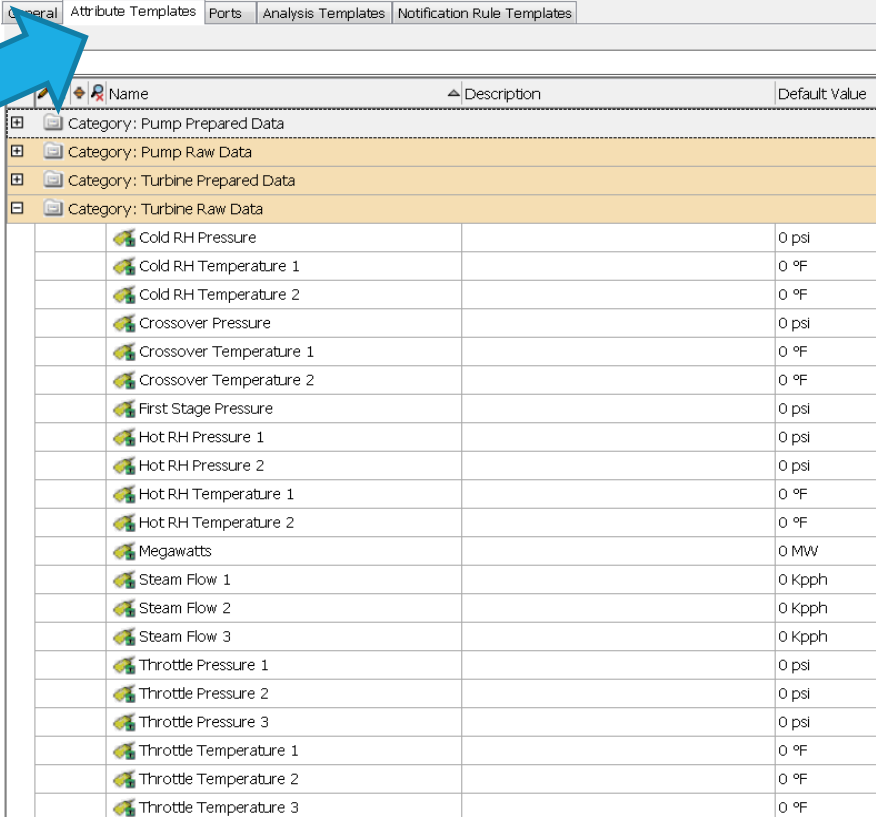
# Turbine Calculations (Engineer Talk)

- Turbine efficiency is a function of inlet condition (Temp, Press) and outlet conditions (Temp, Press)
- Efficiency =  $(\text{Input Enthalpy} - \text{Output Enthalpy}) / (\text{Input Enthalpy} - \text{“Ideal” Output Enthalpy})$
- AF has Steam Property calculations built in (enthalpy, entropy, etc.)
- So... next step is to build ONE HP and IP turbine template



# Data Preparation: Turbine Raw Data

- Some points are single (e.g. Cold RH Pressure)
- Some have two (e.g. Hot RH Pressure)
- Some have 3 (e.g. Steam Flow)
- As many as 4 (not shown)
- No two units are the same!

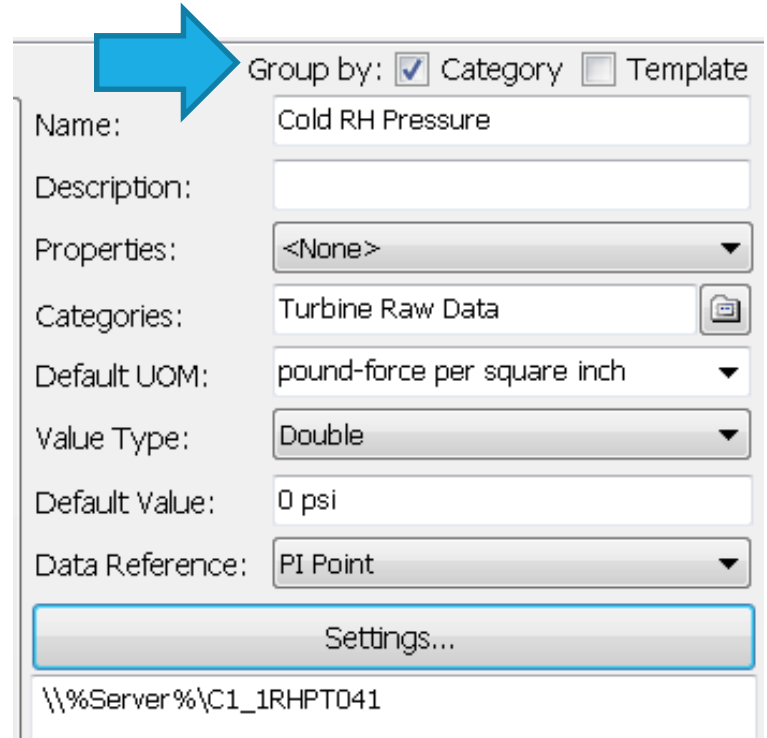


Name	Description	Default Value
Category: Pump Prepared Data		
Category: Pump Raw Data		
Category: Turbine Prepared Data		
Category: Turbine Raw Data		
Cold RH Pressure		0 psi
Cold RH Temperature 1		0 °F
Cold RH Temperature 2		0 °F
Crossover Pressure		0 psi
Crossover Temperature 1		0 °F
Crossover Temperature 2		0 °F
First Stage Pressure		0 psi
Hot RH Pressure 1		0 psi
Hot RH Pressure 2		0 psi
Hot RH Temperature 1		0 °F
Hot RH Temperature 2		0 °F
Megawatts		0 MW
Steam Flow 1		0 Kpph
Steam Flow 2		0 Kpph
Steam Flow 3		0 Kpph
Throttle Pressure 1		0 psi
Throttle Pressure 2		0 psi
Throttle Pressure 3		0 psi
Throttle Temperature 1		0 °F
Throttle Temperature 2		0 °F
Throttle Temperature 3		0 °F



# Data Preparation: Turbine Raw Data (Details)

- Group by Category (more on that later)
- Name – follow a naming convention
- Description – not necessary
- Properties – skip
- Categories – more on this later
- Default Unit of Measure (UOM)
- Value Type: Double is “standard”
- Default Value: skip
- Data Reference: PI Point
- Settings: This maps PI Point to AF



A screenshot of a data configuration dialog box. A large blue arrow points to the 'Group by:' field. The dialog box contains the following fields and values:

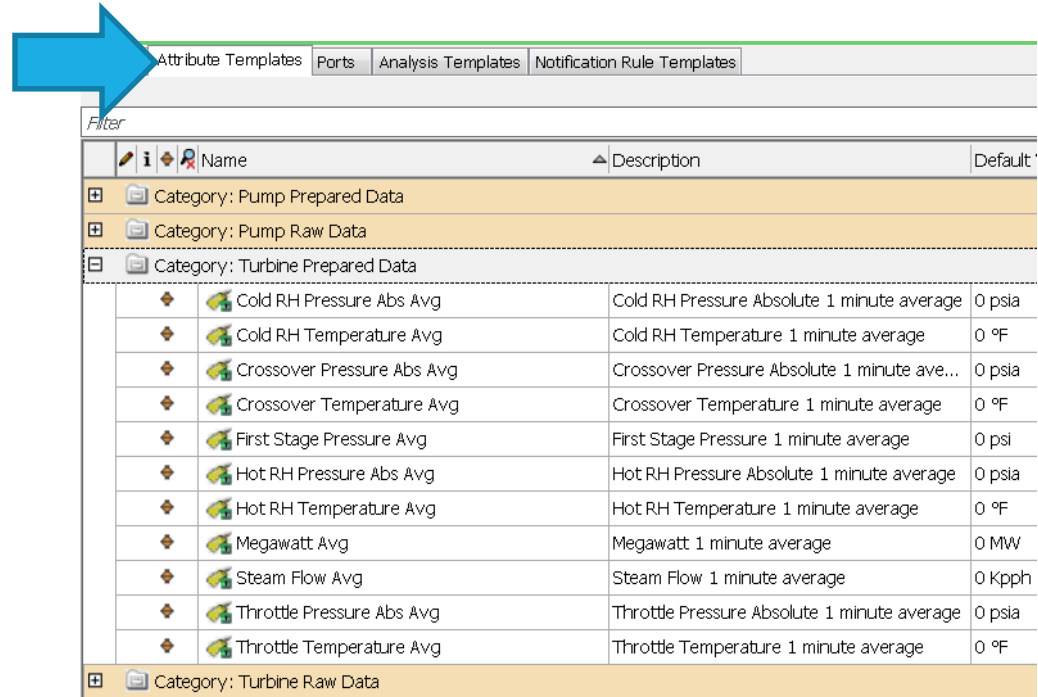
- Group by:  Category  Template
- Name: Cold RH Pressure
- Description: (empty)
- Properties: <None>
- Categories: Turbine Raw Data
- Default UOM: pound-force per square inch
- Value Type: Double
- Default Value: 0 psi
- Data Reference: PI Point

At the bottom, there is a 'Settings...' button and a path field containing: \\%Server%\C1\_1RHPT041



# Data Preparation: Turbine Prepared Data

- Follow a naming convention!
- For turbines, absolute pressure is important
- HP Turbine requires 4 inputs and an “X-axis”
- IP Turbine requires 4 inputs and an “X-axis”
- All of these require calculations...
- Where do the calculations happen?



The screenshot shows a software interface with a tabbed menu at the top containing 'Attribute Templates', 'Ports', 'Analysis Templates', and 'Notification Rule Templates'. A blue arrow points to the 'Attribute Templates' tab. Below the tabs is a 'Filter' input field. The main area displays a table with columns for 'Name', 'Description', and 'Default'. The table is organized into categories: 'Category: Pump Prepared Data', 'Category: Pump Raw Data', 'Category: Turbine Prepared Data', and 'Category: Turbine Raw Data'. The 'Turbine Prepared Data' category is expanded, showing a list of parameters with their descriptions and default values.

Name	Description	Default
Category: Pump Prepared Data		
Category: Pump Raw Data		
Category: Turbine Prepared Data		
Cold RH Pressure Abs Avg	Cold RH Pressure Absolute 1 minute average	0 psia
Cold RH Temperature Avg	Cold RH Temperature 1 minute average	0 °F
Crossover Pressure Abs Avg	Crossover Pressure Absolute 1 minute ave...	0 psia
Crossover Temperature Avg	Crossover Temperature 1 minute average	0 °F
First Stage Pressure Avg	First Stage Pressure 1 minute average	0 psi
Hot RH Pressure Abs Avg	Hot RH Pressure Absolute 1 minute average	0 psia
Hot RH Temperature Avg	Hot RH Temperature 1 minute average	0 °F
Megawatt Avg	Megawatt 1 minute average	0 MW
Steam Flow Avg	Steam Flow 1 minute average	0 Kpph
Throttle Pressure Abs Avg	Throttle Pressure Absolute 1 minute average	0 psia
Throttle Temperature Avg	Throttle Temperature 1 minute average	0 °F
Category: Turbine Raw Data		





# Data Preparation: Customized Calculations

- Analysis Templates
- Note organization
- Scope of variables
- Output Attributes
- Equations
- Data validation

Example Element: [CPS Energy Power Generation\Calaveras Power Station\Sommers Plant\Sommers1\DataPrep](#)

Name	Expression	Ver	Output Attribute
Megawatts	<code>TagAvg('Megawatts', '*-60s', '*')</code>		<a href="#">Megawatt Avg</a>
StmFlow1min1	<code>TagAvg('Steam Flow 1', '*-60s', '*')</code>		<a href="#">Map</a>
StmFlow1min2	<code>TagAvg('Steam Flow 2', '*-60s', '*')</code>		<a href="#">Map</a>
StmFlow1min3	<code>TagAvg('Steam Flow 3', '*-60s', '*')</code>		<a href="#">Map</a>
StmFlow1min	<code>If BadVal(StmFlow1min1) and BadVal(StmFlow1min2)</code>		<a href="#">Steam Flow Avg</a>
FirstStg21min	<code>TagAvg('First Stage Pressure', '*-60s', '*')</code>		<a href="#">First Stage Pressure Avg</a>

```
If BadVal(StmFlow1min1) and BadVal(StmFlow1min2) and BadVal(StmFlow1min3) Then Avg(StmFlow1min1, StmFlow1min2, StmFlow1min3)
Else If BadVal(StmFlow1min2) and BadVal(StmFlow1min3) Then Avg(StmFlow1min1, StmFlow1min2)
Else If BadVal(StmFlow1min1) and BadVal(StmFlow1min3) Then Avg(StmFlow1min1, StmFlow1min3)
Else If BadVal(StmFlow1min1) and BadVal(StmFlow1min2) Then Avg(StmFlow1min1, StmFlow1min2)
Else If BadVal(StmFlow1min1) Then Avg(StmFlow1min2, StmFlow1min3)
Else If BadVal(StmFlow1min2) Then Avg(StmFlow1min1, StmFlow1min3)
Else If BadVal(StmFlow1min3) Then Avg(StmFlow1min1, StmFlow1min2)
Else Avg(StmFlow1min1, StmFlow1min2, StmFlow1min3)
```



# Steam Turbine Template: Turbine Raw & Prepared Data

- Output from Data Prep...
- Are inputs for Steam Turbine Template!
- Calculation Limit
- Categories

General   Attribute Templates   Ports   Analysis Templates   Notification Rule Templates			
Filter			
	Name	Description	Default Value
Category: Turbine Efficiency			
	Calculation Limit	Do Not Calc if MW below Limit	100 MW
	Cold RH Pressure Abs Avg	Cold RH Pressure Absolute 1 minute average	0 psia
	Cold RH Temperature Avg	Cold RH Temperature 1 minute average	0 °F
	Crossover Pressure Abs Avg	Crossover Pressure Absolute 1 minute ave...	0 psia
	Crossover Temperature Avg	Crossover Temperature 1 minute average	0 °F
	First Stage Pressure Avg	First Stage Pressure 1 minute average	0 psi
	FW Flow Avg	FW Flow 1 minute average	0 Kpph
	Hot RH Pressure Abs Avg	Hot RH Pressure Absolute 1 minute average	0 psia
	Hot RH Temperature Avg	Hot RH Temperature 1 minute average	0 °F
	HP Turbine Efficiency	HP Turbine Efficiency	0 %
	IP Turbine Efficiency	IP Turbine Efficiency	0 %
	Megawatt Avg	Megawatt 1 minute average	0 MW
	Steam Flow Avg	Steam Flow 1 minute average	0 Kpph
	Throttle Pressure Abs Avg	Throttle Pressure Absolute 1 minute average	0 psia
	Throttle Temperature Avg	Throttle Temperature 1 minute average	0 °F

# Steam Turbine Template: Calculations

- Analysis Templates
- Organization
- Scope of variables
- Output Attribute to PI Tags
- Steam Property Calcs
- Calculation Limit

General | Attribute | **Analysis Templates** | Notification Rule Templates

Name: HP Turbine Efficiency C  
Description: HP Turbine Efficiency C  
Categories:  
Analysis Type:  Expression  Roll  
 Start analyses when created from ter

Example Element: [CPS Energy Power Generation\Calaveras Power Station\Spruce Plant\Spruce1V1 Main Turbine](#)

Name	Expression	V:	V:	Output Attribute	
ThrottleH	Steam_HPT('Throttle Pressure Abs Avg', 'Throttle Temperature Avg')			Map	⊗
ColdRHH	Steam_HPT('Cold RH Pressure Abs Avg', 'Cold RH Temperature Avg')			Map	⊗
ThrottleS	Steam_SPT('Throttle Pressure Abs Avg', 'Throttle Temperature Avg')			Map	⊗
ColdRHHisen	Steam_HPS('Cold RH Pressure Abs Avg', ThrottleS)			Map	⊗
TurbineEffici	if 'Megawatt Avg' > 'Calculation Limit' THEN (100*(Thrott			HP Turbine Efficiency	⊗
	if 'Megawatt Avg' > 'Calculation Limit' THEN (100*(ThrottleH - ColdRHH) (ThrottleH - ColdRHHisen) ELSE 0				



# HP/IP Turbine At-A-Glance

- Data Preparation Steps
  - What input data is required? – goal setting
  - Locate point(s) for each input – find the PI points
  - Create AF points, mapped to PI points
  - Do numerical averaging (60 second averages)
  - Do other intermediate calcs (e.g. convert psig to psia)
  - Do averaging for multiple points, with data validation
- Create HP/IP Turbine Template
- Create HP\IP Turbine Element (specific unit & data prep element)

## Visualization



# Next Project: Pump Performance

- All centrifugal pumps have similar characteristic curves
- Pump affinity equations will work for most pumps
- Required data
  - Inlet temperature & pressure
  - Outlet temperature & pressure
  - Pump flow
  - Pump speed (rpm) – may be constant
  - Design pump speed



# Pump Performance - Nuances

- Boiler Feed Pumps – sort of easy
- Condensate Pumps – suction pressure in  $\text{inHg}_{\text{abs}}$
- Boiler Feed Booster Pumps – ratioed speed
- Some points are single, some have 2, some have 3 (need to average and use data verification)



# Asset Framework Nuances

- When list of points gets longer, organization is more important
- Rule of thumb: keep it all visible on one page
- Categories – very useful!



Pump Prepared Data

6 points for Booster BFP

6 points for Cond Pumps

6 points for Main BFP

Other Categories

DataPrepSommers1

General Attribute Templates Ports Analysis Templates Notification Rule Templates

Filter

Name	Description	Default Value
Category: Pump Prepared Data		
Booster BFP Disch Press Avg		0 psi
Booster BFP Disch Temp Avg		0 °F
Booster BFP Flow Avg		0 Kpph
Booster BFP Speed Avg		0 rpm
Booster BFP Suct Press Avg		0 psi
Booster BFP Suct Temp Avg		0 °F
Cond Pump Disch Press Avg		0 psi
Cond Pump Disch Temp Avg		0 °F
Cond Pump Flow Avg		0 Kpph
Cond Pump Speed Avg		1180 rpm
Cond Pump Suct Press Avg		0 psi
Cond Pump Suct Temp Avg		0 °F
Main BFP Disch Press Avg		0 psi
Main BFP Disch Temp Avg		0 °F
Main BFP Flow Avg		0 Kpph
Main BFP Speed Avg		0 rpm
Main BFP Suct Press Avg		0 psi
Main BFP Suct Temp Avg		0 °F
Category: Pump Raw Data		
Category: Turbine Prepared Data		
Category: Turbine Raw Data		



Prepared Data (collapsed)

Pump Raw Data

Turbine Categories

DataPrepSommers1

General Attribute Templates Ports Analysis Templates Notification Rule Templates

Filter

Name	Description	Default Value
Category: Pump Prepared Data		
Category: Pump Raw Data		
Booster BFP Discharge Pressure		0 psi
Booster BFP Discharge Temperature		0 °F
Booster BFP Suction Pressure		0 psi
Booster BFP Suction Temperature		0 °F
Cond Pump Discharge Pressure		0 psi
Cond Pump Discharge Temperature		0 °F
Cond Pump Flow 1		0 Kpph
Cond Pump Flow 2		0 Kpph
Cond Pump Flow 3		0 Kpph
Cond Pump Speed 1A		0 rpm
Cond Pump Speed 1B		0 rpm
Cond Pump Suction Pressure		0 inHg
Cond Pump Suction Temperature		0 °F
Feedwater Flow 1		0 Kpph
Feedwater Flow 2		0 Kpph
Feedwater Flow 3		0 Kpph
Main BFP Discharge Pressure		0 psi
Main BFP Discharge Temperature		0 °F
Main BFP Speed		0 rpm
Main BFP Suction Pressure		0 psi
Main BFP Suction Temperature		0 °F
Category: Turbine Prepared Data		
Category: Turbine Raw Data		



# Analysis Templates

Name	Expression	V:	V:	Output Attribute	
Megawatts	TagAvg('Megawatts','*-60s','*')			<a href="#">Megawatt Avg</a>	⊗
StmFlow1min1	TagAvg('Steam Flow 1','*-60s','*')			<a href="#">Map</a>	⊗
StmFlow1min2	TagAvg('Steam Flow 2','*-60s','*')			<a href="#">Map</a>	⊗
StmFlow1min3	TagAvg('Steam Flow 3','*-60s','*')			<a href="#">Map</a>	⊗
StmFlow1min	If BadVal(StmFlow1min1) and BadVal(StmFlow1min2) and BadVal(StmFlo			<a href="#">Steam Flow Avg</a>	⊗
FirstStgZ1min	TagAvg('First Stage Pressure','*-60s','*')			<a href="#">First Stage Pressure Avg</a>	⊗
ThrStmZ1min1	TagAvg('Throttle Pressure 1','*-60s','*')+14.696			<a href="#">Map</a>	⊗
ThrStmZ1min2	TagAvg('Throttle Pressure 2','*-60s','*')+14.696			<a href="#">Map</a>	⊗
ThrStmZ1min3	TagAvg('Throttle Pressure 3','*-60s','*')+14.696			<a href="#">Map</a>	⊗
ThrStmZ1min	If BadVal(ThrStmZ1min1) and BadVal(ThrStmZ1min2) and BadVal(ThrStm			<a href="#">Throttle Pressure Abs Avg</a>	⊗
ThrStmQ1min1	TagAvg('Throttle Temperature 1','*-60s','*')			<a href="#">Map</a>	⊗



# Analysis Templates

- Calculations cannot be grouped by category
- But, more than one Asset Template may be used
- So I put these in a “logical sequence”
- “X-axis” – first stage pressure/ megawatts/ steam flow
- HP turbine inlet steam
- HP turbine outlet steam
- IP turbine inlet steam
- IP turbine outlet steam
- Double (triple) readings come first, then averages



# Summing Up...

- Goal Setting (HP/IP Turbine Efficiency)
- Start Somewhere (Jump Start)
- Goal Refinement
- Go slow to go fast
  - Data Preparation for Turbines
  - Template for Turbines
  - Data Preparation for Pumps
  - Template for Pumps
  - Categorize/ Organize along the way
  - Leave Space for future work



# The Ultimate Win

- Test Crew Past – once 5 (+5)
- Test Crew Present – one guy
- Test Crew Future - AF



# Contact Information

**J. Michael Harris**

[jmharris@cpsenergy.com](mailto:jmharris@cpsenergy.com)

Generation Performance Mgr  
CPS Energy



## Questions

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



State your **name & company**

## Please don't forget to...

complete the Post  
Event Survey



감사합니다

谢谢

Danke

Merci

Gracias

**Thank You**

ありがとう

Спасибо

Obrigado

