Palo Verde Data Validation and Reconciliation

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Agenda

- Project Introduction
- DVR Modeling and Tuning Process
- Date Selection
- Data Review
- Turbine Efficiencies
- Main Steam Pressure Drops
- TSM Updates
- Model Tuning Process

Project Introduction

- Plant identified consistent difference in gross generation between units
- DVR modeling employed to identify the cause of the generation difference

		Unit 1	Unit 2	Unit 3
Gross Generation	MWe	1407.7	1412.2	1404.7
Difference	MWe	-4.5	0.0	-7.5

DVR Development

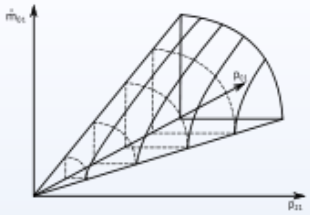
Design Documentation

- Thermal Kit
- Thermodynamic Computer Model
- Plant Drawings
- Thermal Power Calculation (and uncertainty calculation)
- Some Isometrics for pressure drop calculations
- Specification Sheets

Instruments

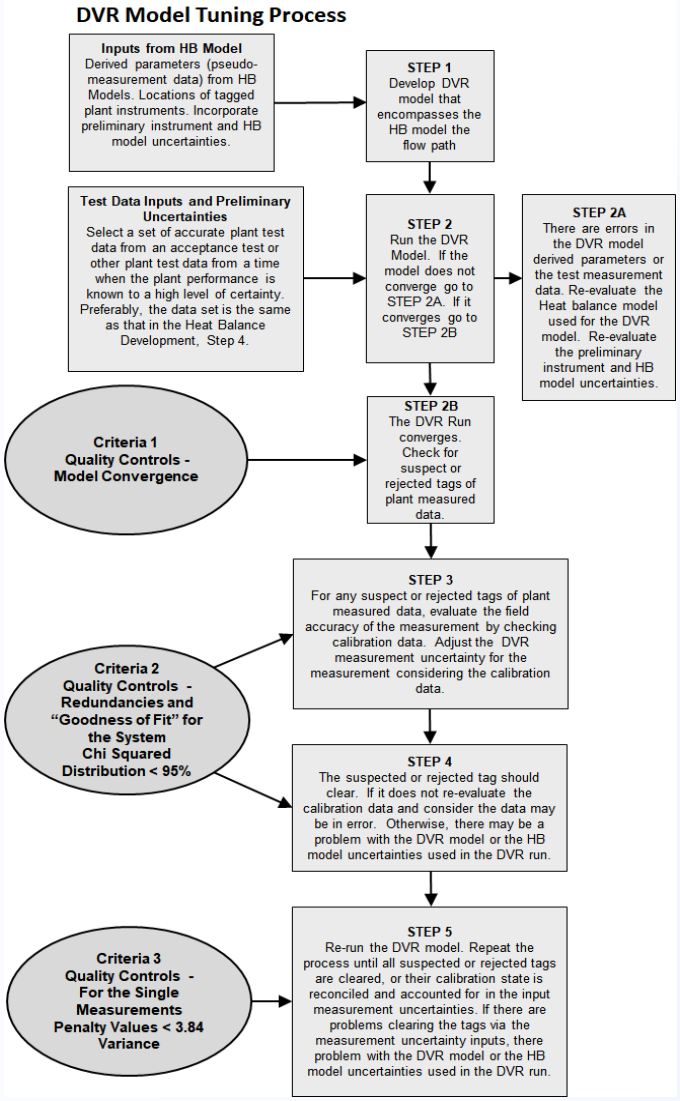
- Determine all instrument inputs to plant computer
- Develop base or starting point uncertainty of all instruments
- For important instruments use formal uncertainty calculations

DVR Development and Tuning Process



Special Considerations

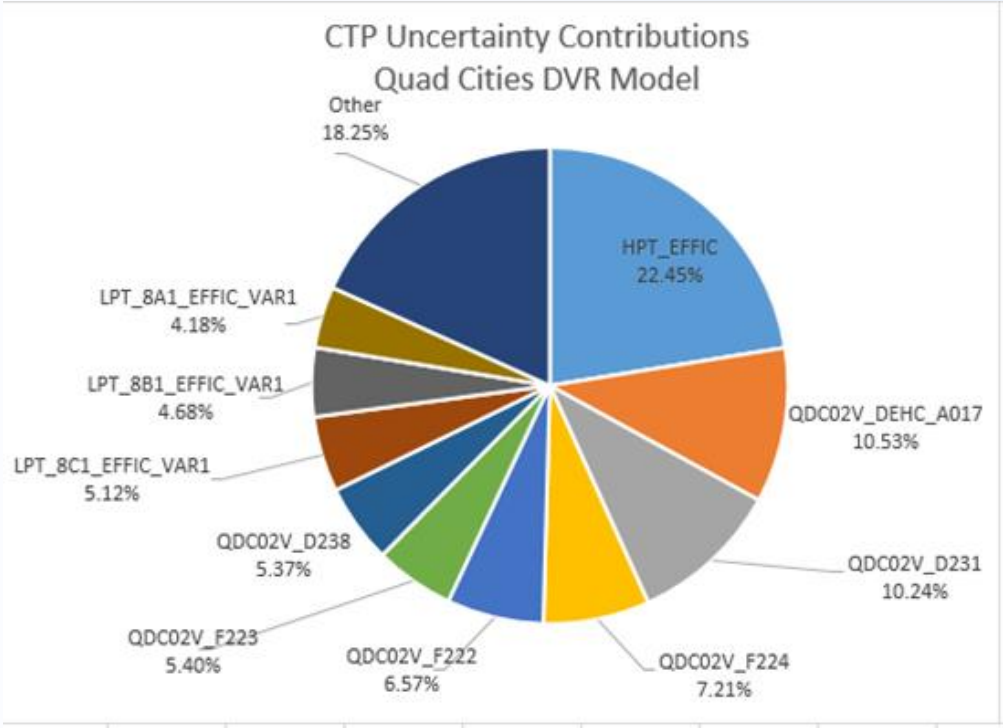
- Design vs. Data?
- Exhaust Loss Curve (last stage turbine efficiency)– Can be developed using the data reconciliation process.
- Control Valve Pressure Drop Curve – Either develop based on plant data or vendor curve. May decide not to use (at reduced redundancy)
- Stodola's ellipse – for turbine stage pressures
- Pressure Drop Calculations for important areas
  - Throttle Pressure
  - HP Exhaust to MSR Inlet
  - MSR outlet to LP inlet
  - Some piping areas to prevent phase change issues from affecting model

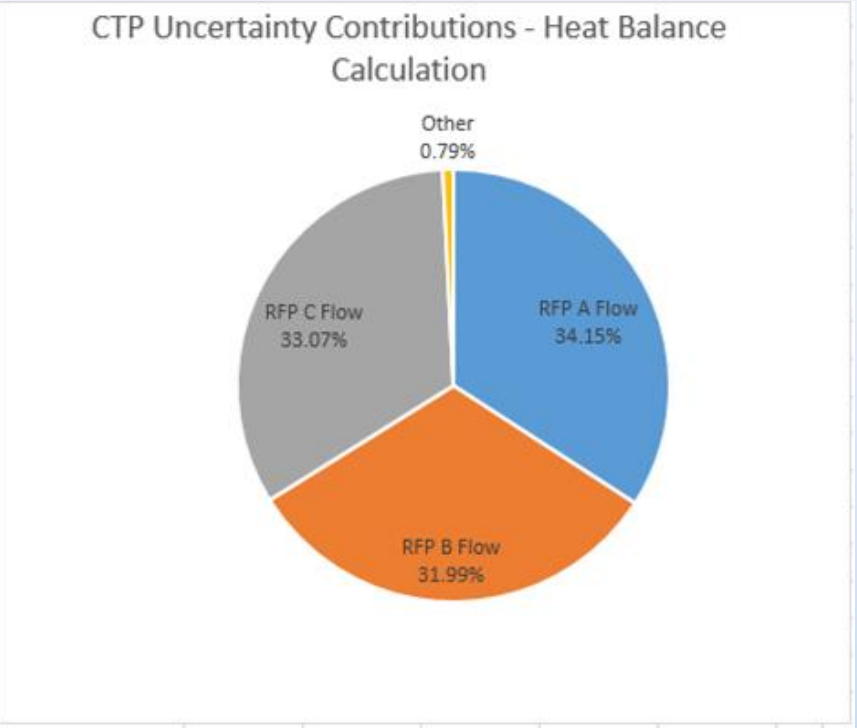


Once Initial Tuning is completed

- Run the model through plant data that cover the entire operating range of CW inlet temperature
- Evaluate measured and reconciled key plant parameters to insure there are no unexplained relationships.
- Identify any parameters that may have an overbearing influence on the results.
- Account for Cycle Isolation issues.
- Identify measurement points the need to be addressed
  - Removed from model because they are so intermittent or bad
  - Adjust uncertainty to stabilize model over data range
  - Suggest instrument calibrations to allow proper model execution

The overall goal of the tuning process is to ensure that the influences on the Core Thermal Power are relying on as many instruments as possible. Compare the two charts.





Major Error Contributors to Core Thermal Power (Generic Plant)

Item #	MWth Error Contributor	% Accuracy	Error in Total MWth	% of the Total MWth Uncertainty
1	DVR Turbine Efficiency Model Errors (in MWe)	1	10.6 MWth	41.6
2	Megawatts Generation	0.25%	0.8 MWth	3.0
3	Other Final Feedwater Flow Measurements	2%	5.6 MWth	21.8
4	Final Feedwater Temperature	2 Deg F	0.9 MWth	3.5
5	Other Flows (main steam and, condensate flows)	5%	3.5 MWth	13.9
6	Main Steam Quality	0.5 %	1.4 MWth	5.7
7	Main Steam Pressure	1%	0.3 MWth	1.4
8	Reheat Temperatures	2%	0.60 MWth	2.44
9	Generator Efficiency	0.175%	0.4 MWth	1.5
10	Condenser Pressure	5%	0.4 MWth	1.6
11	Miscellaneous		1.0 MWth	3.6
	Total		25.5 MWth	100.0
	CTP Value: 3334.85 MWth		0.76 % MWth	

The effect on % MWth error for each additional measurement will depend on the uncertainty for that measurement and how highly correlated the measurement is to the MWth calculation.

Date Selection

- Selected dates for model development based on unit and component performance
  - Unit 1: January 25, 2017
  - Unit 2: March 2, 2017
  - Unit 3: February16, 2017

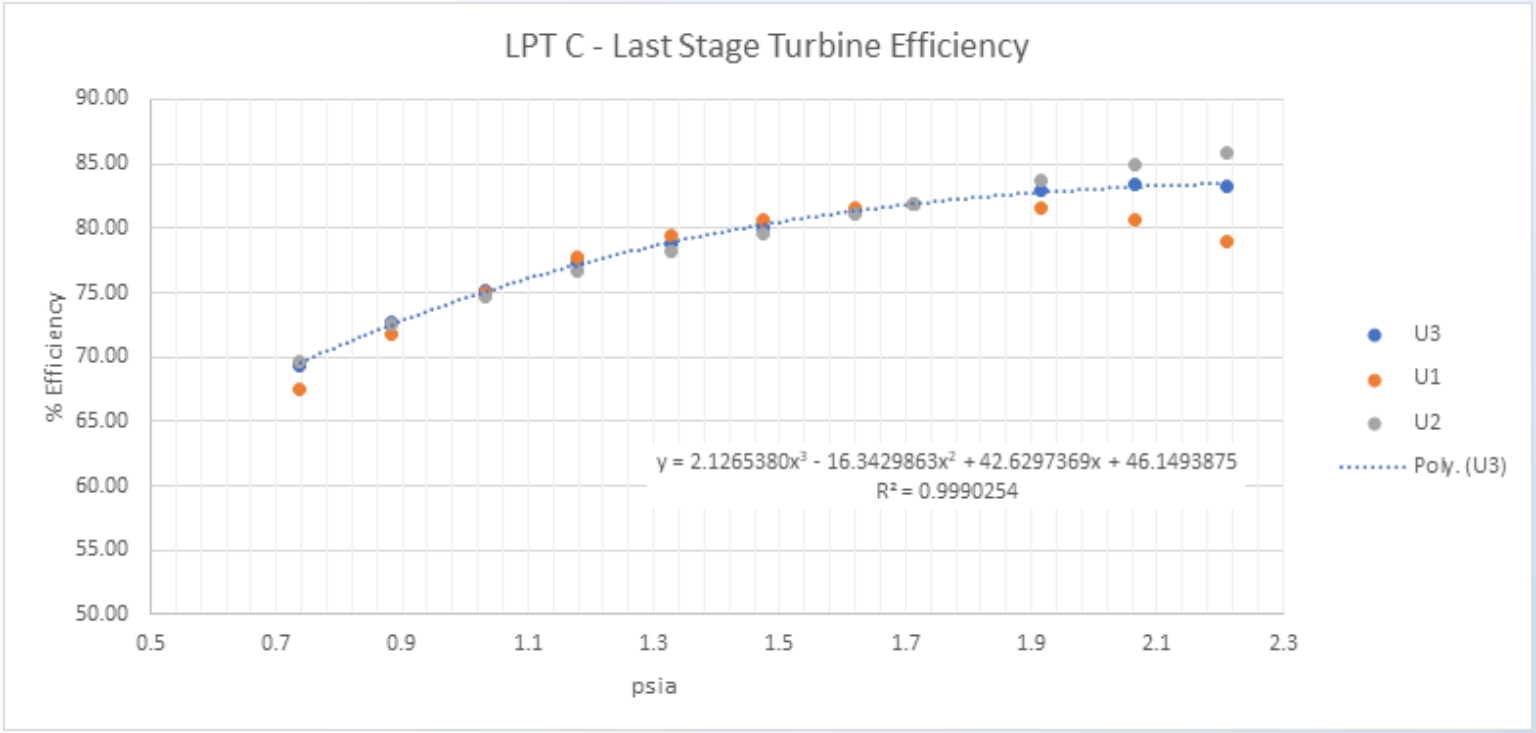
		Unit 1	Unit 2	Unit 3
Condenser A Pressure	inHgA	1.75564	1.82469	1.77757
Condenser B Pressure	inHgA	2.16399	2.14154	2.16965
Condenser C Pressure	inHgA	2.84976	2.82121	2.82136
Average	inHgA	2.256	2.262	2.256

DVR Data Results

		Unit 1	Unit 2	Unit 3
Gross Generation	**MWe**	**1407.7**	**1412.2**	**1404.7**
Core Thermal Power	MWe	1.0	0.0	4.1
Steam Generator Blowdown	MWe	0.0	0.0	-0.1
Condenser Pressure	MWe	1.2	0.0	0.8
Auxiliary Steam Flow	MWe	-1.4	0.0	-1.4
Feedwater Heater #7 TTD	MWe	0.2	0.0	-0.5
Feedwater Heater #6 TTD	MWe	-0.1	0.0	0.2
Feed Pump Suction Temp	MWe	-0.1	0.0	-0.2
Miscellaneous (Cycle Isolation)	MWe	0.5	0.0	1.0
Turbine Efficiencies	MWe	5.9	0.0	5.8
Adjusted Gross Generation	**MWe**	**1414.9**	**1412.2**	**1414.2**

Turbine Seasonal Impacts

- Data identified seasonal differences in Exhaust Losses between the units
- Results in larger unit differences during summer



Turbine Efficiencies

		Unit 1	Unit 2	Unit 3
HPT Efficiency	%	83.43%	84.20%	83.78%
LPT Group 1 Efficiency	%	95.98%	96.31%	95.98%
LPT Group 2 Efficiency	%	95.12%	95.45%	95.10%
LPT Group 3 Efficiency	%	95.49%	96.15%	95.48%
LPT Group 4 Efficiency	%	90.85%	91.20%	90.80%
LPT Group 5 Efficiency	%	89.08%	89.35%	89.09%
LPT Group 6 Efficiency	%	68.64%	69.22%	68.72%
Average LTP Group Efficiency	%	89.19%	89.61%	89.20%
Electrical Generation Impact	MWe	-5.91	0	-5.76

Turbine Efficiencies

		Unit 1	Unit 2	Unit 3
HPT Efficiency	**%**	-0.77%	-	-0.42%
LPT Group 1 Efficiency	%	-0.33%	-	-0.34%
LPT Group 2 Efficiency	%	-0.33%	-	-0.35%
LPT Group 3 Efficiency	%	-0.66%	-	-0.67%
LPT Group 4 Efficiency	%	-0.34%	-	-0.40%
LPT Group 5 Efficiency	%	-0.27%	-	-0.26%
LPT Group 6 Efficiency	%	-0.58%	-	-0.50%
Average LTP Group Efficiency	%	-0.42%	-	-0.41%
Electrical Generation Impact	MWe	-5.91	-	-5.76

Turbine Construction Differences

- Unit 2 LPT Retrofit done by OEM in 2003
  - Suspected generation shortfall following retrofit
  - Some discrepancy over post retrofit performance test
- Recommended improvements for Unit 1 and Unit 3 LP retrofit turbines
  - Improved seal and partition design in final two stages
  - Optimized moisture removal features on all applicable stages

Pressure Drop Correction Factors

- Steam pressure drops were inconsistent
- Often the pressure drop was overestimated

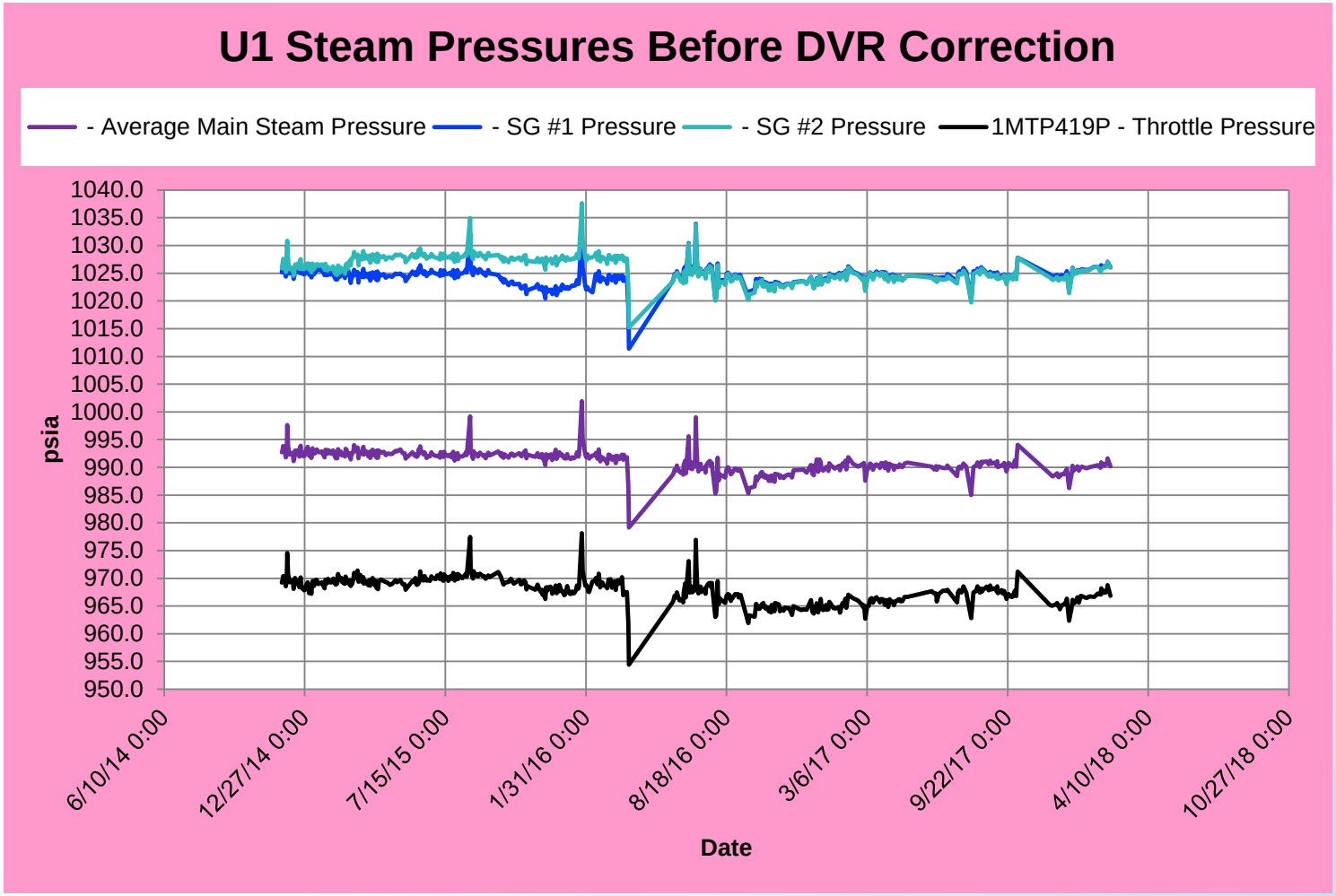
Plant Data Pressure Drops

	Unit 1	Unit 2	Unit 3
SG to MS	34.6	25.6	38.3
MS to Throttle	40.0	27.1	27.1

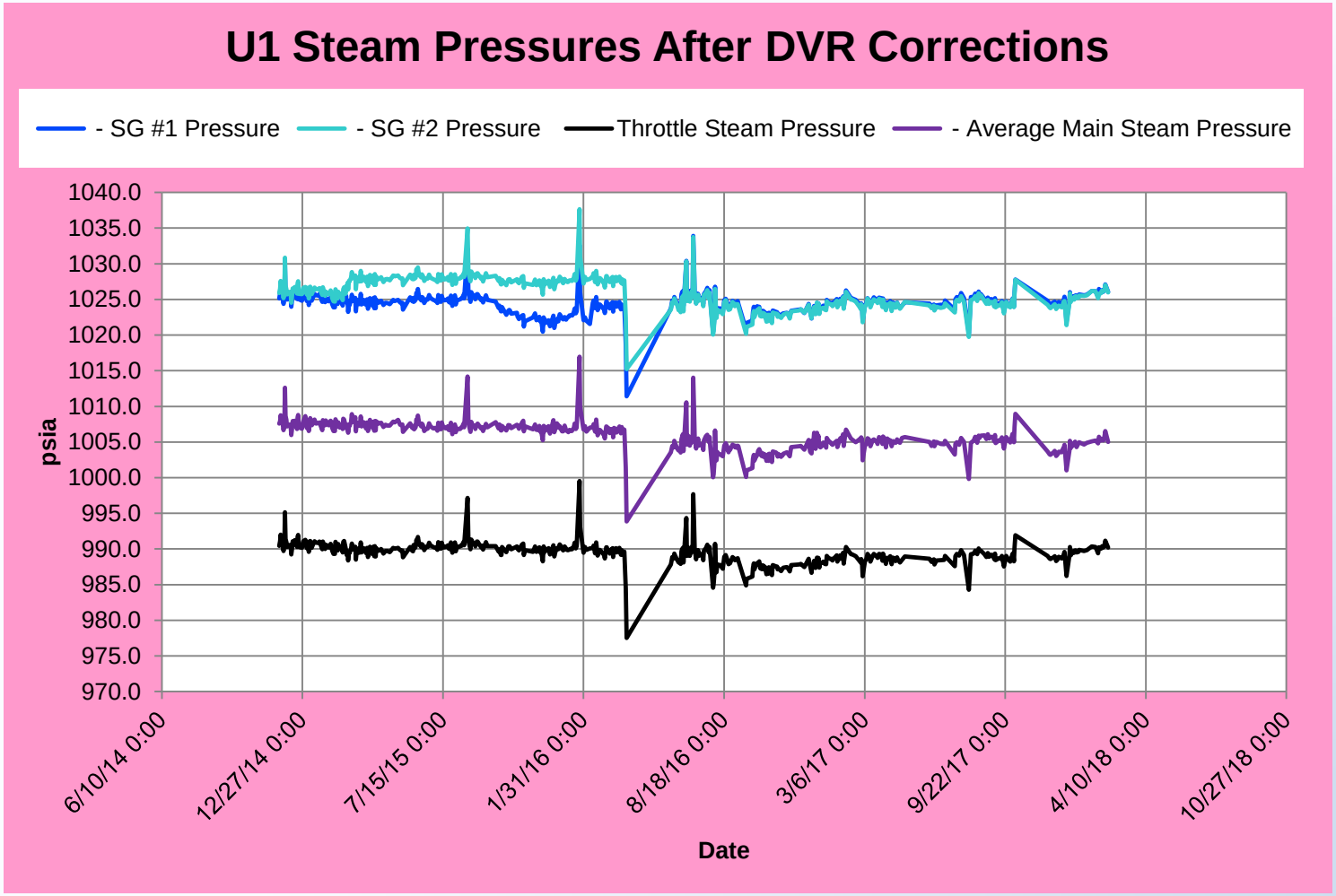
Reconciled Data Pressure Drops

	Unit 1	Unit 2	Unit 3
SG to MS	19.2	18.5	18.5
MS to Throttle	19.9	19.8	19.8

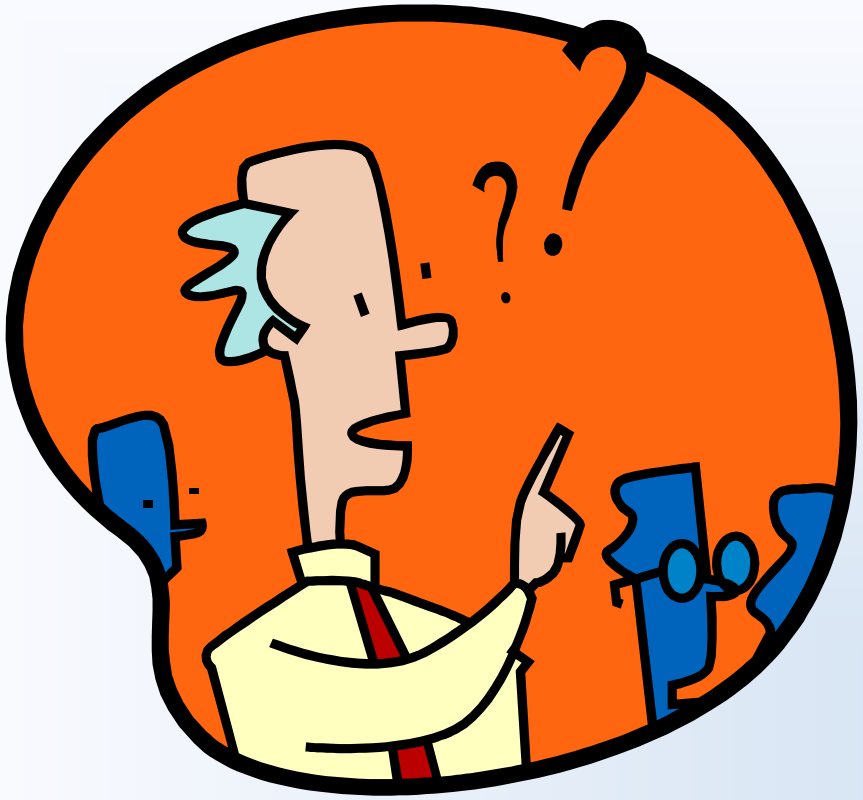
Pressure Drop Correction Factors in TSM



Pressure Drop Correction Factors in TSM



Questions



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