Using Low-Cost Optimization Technologies to Reduce the Carbon Footprint

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McIlvaine Hot Topic: Greenhouse Gas Strategies for Coal Fired Plants

NeuCo
The Optimization Standard™

NeuCo's Mission

- To maximize the impact generating assets have on the bottom-line, using real-time asset optimization solutions to improve:
  - **Availability**
    - Maximum reliable capacity whenever needed
  - **Efficiency**
    - Producing this capacity at the lowest possible cost
  - **Emissions**
    - Lower emissions and costly reagents

What is Optimization?

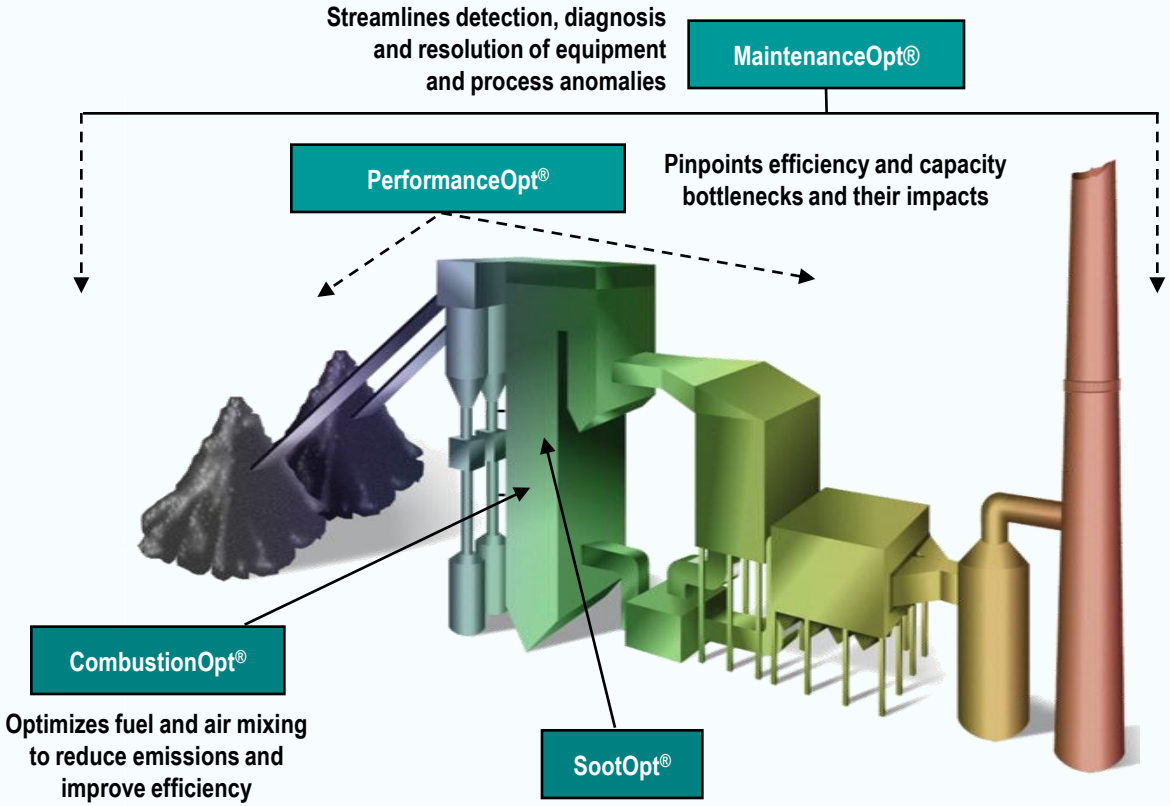
- The **process** of turning reams of complex data into **action**able knowledge that delivers **bottom line** benefit

Data Sources

ERPs (e.g. SAP)
CMMSs (e.g. Maximo)
Monitors (e.g. Optimax)
Analyzers (e.g. Zolo)
Detectors (e.g. SmartSignal)
Historians (e.g. OSI)
DCSs (e.g. ABB)

- An Optimizer Must:
  - **ACT:** continuously identify actions that can improve asset performance
  - **QUANTIFY:** the benefits & missed opportunities
  - **INFORM:** users about what actions were taken and why

Optimization Applications



Emissions Regulations Increasing

- 29 states covered under regional initiatives
- First RGGI auction occurred last week
  - Strong response despite issues with cap vs. actual CO_2
- New Midwest Accord adding states
- 14 states w/GHG emissions targets
- Near-term Federal legislation likely
  - Both Presidential candidates support cap & trade
  - Several pending bills before House and Senate
  - Wide range of reductions and time-tables
  - May be coupled with multi-pollutant bill
  - Legislative need to address CAIR/CAMR gaps

Addressing GHGs With Optimization

- No commercial emissions control systems for CO_2
  - Improving efficiency only proven option
- Optimization suite can improve efficiency & reduce CO_2 by 1.5-2%
- Achieve lowest-cost CO_2 reductions
- Co-benefits
  - Reduced NOx and/or reagent costs
  - Improved control over CO and opacity
  - Increased reliability and commercial availability

Potential Annual CO_2 Benefits for One 500 MW Coal-Fired Unit

CO_2 $/ton	Heat Rate Improvement			
	-0.50%	-1.00%	-1.50%	-2.00%
$2.50	$60,925	$121,851	$182,776	$243,701
$7.50	$182,776	$365,552	$548,328	$731,103
$10.00	$243,701	$487,402	$731,103	$974,805
$15.00	$365,552	$731,103	$1,096,655	$1,462,207
$20.00	$487,402	$974,805	$1,462,207	$1,949,609
$25.00	$609,253	$1,218,506	$1,827,759	$2,437,012

CombustionOpt

- Provides real-time closed-loop optimization of fuel and air mixing
  - Manipulates relevant fuel & air injection points
- Neural network and model predictive control technologies
- Improves NOx, heat rate, steam temp, CO, MW, and opacity

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Unit 3: CombustionOpt Home

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Optimization Advice

Issue/Action	Actual	Target	Prior...	Fuel Svngs ($/mo)...	NO
MVs Disabled(percent)	85.19	100	Low	7,315	

What's Going on Now and Why

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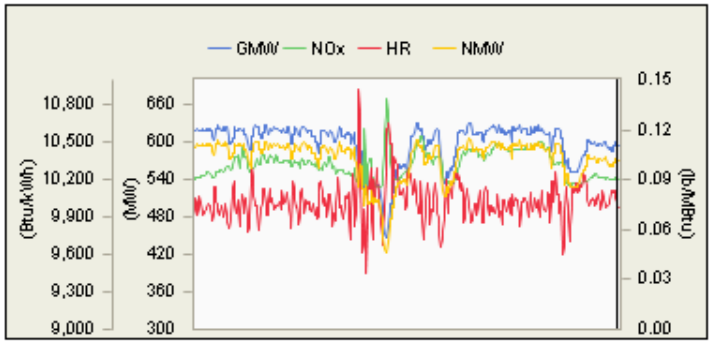
Analysis...

MV Name	Pre-Move	Post-Move
AUXDPR AA SEL BIAS	-5	-5
AUXDPR AB SEL BIAS	9.75	9.5
AUXDPR BC SEL BIAS	-0.145	-0.333
AUXDPR CD SEL BIAS	-4.5	-4
AUXDPR DE SEL BIAS	-5	-5
AUXDPR EF SEL BIAS	-4.875	-4.875
AUXDPR FF SEL BIAS	9.809	9.765
FEEDER A SEL BIAS	1.07	0.57
FEEDER B SEL BIAS	5	5

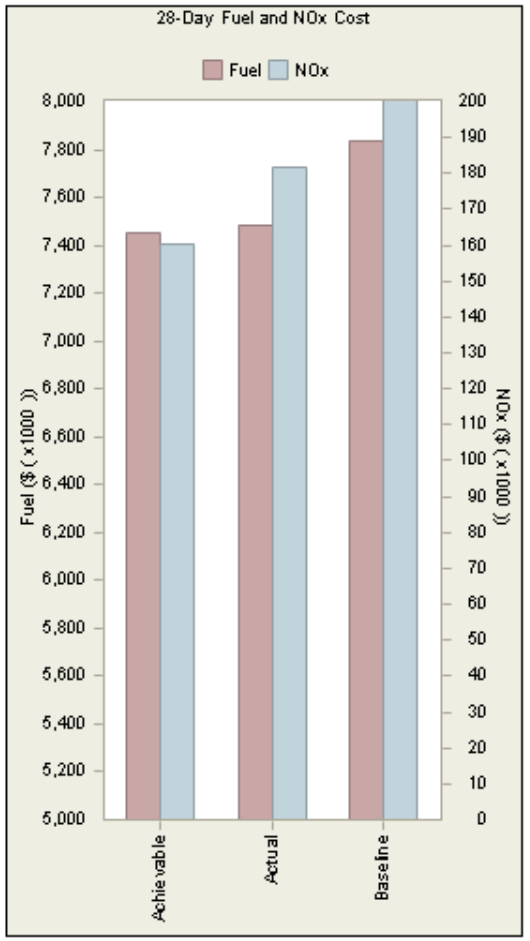
Objectives	Actual	Predicted	Target	Delta Cost
NOx (lb/MBtu	0.0917	0.0865	Down	
RH Spray Flo	50.16	46.85	< 25 (klb/h	
Heat Rate (Bt	10035.1	9998.1	Down	
Mill 3A dP (in	7.94	7.92	< 7.5 (inH	
Sum of Fdr Bi	0.04	0.03	0	
Mill 3F dP (in	7.00	6.95	< 7.5 (inH	
Mill 3C dP (in	6.07	6.07	< 7.5 (inH	
O2 1 & 2 (per	3.39	3.43	> 2.5 (perc	
Mill 3B dP (in	5.33	5.33	< 7.5 (inH	

Unit Status Online

MV Clusters	Enabled	Total
Aux Air	7	7
Fuel Air	6	6
Feeders	6	6
SOFA Tilts	0	2
SOFA Dmprs	4	4
O2, WB DP	0	2
Total	**23**	**27**



Optimization Benchmarks



Benefits	vs. Achievable	vs. Baseline
Fuel ($)	32,848	350,347
NOx ($)	21,213	41,733

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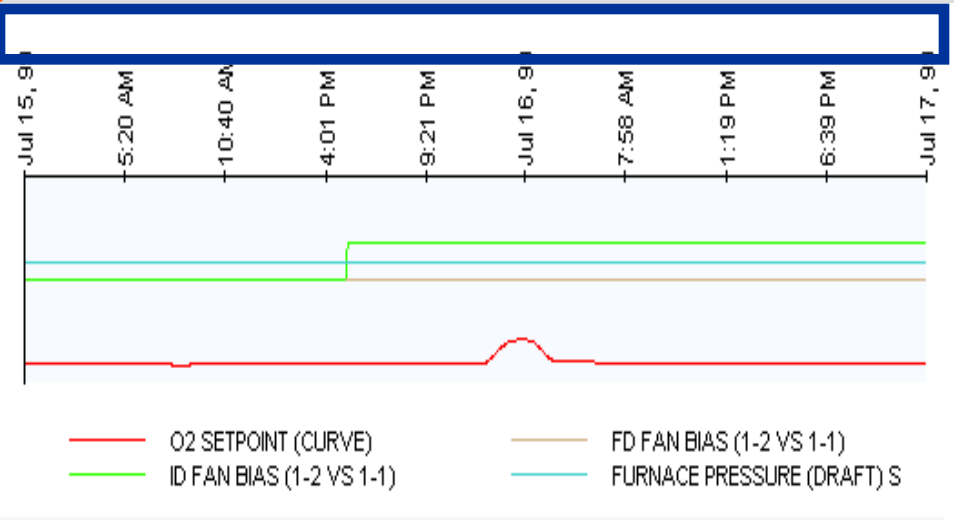
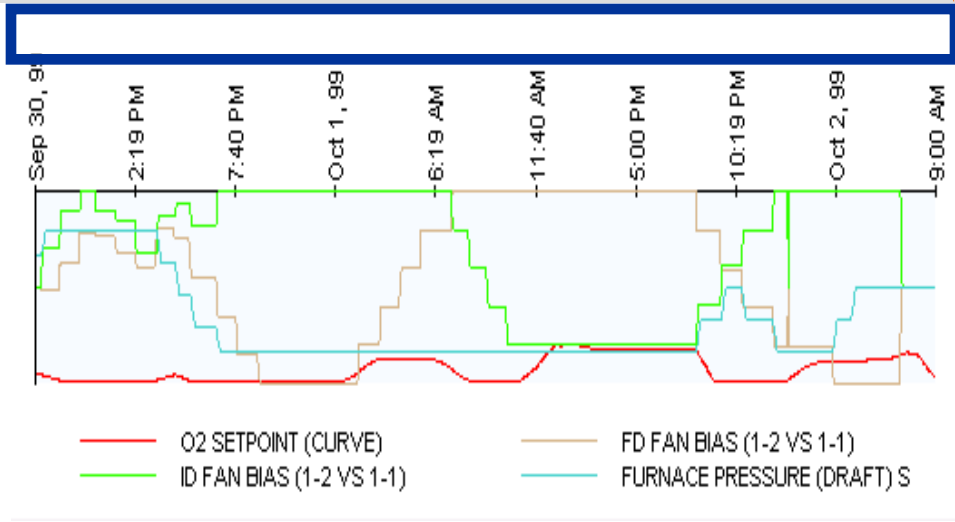
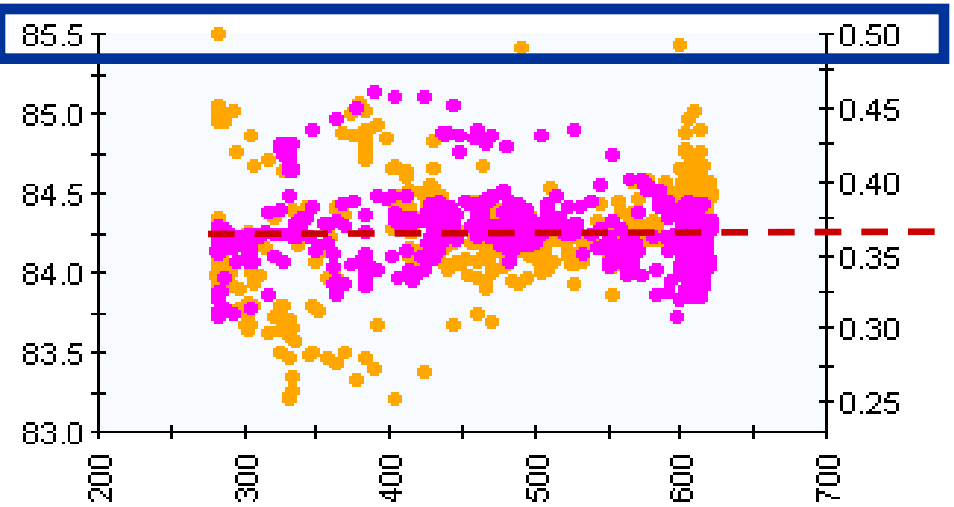
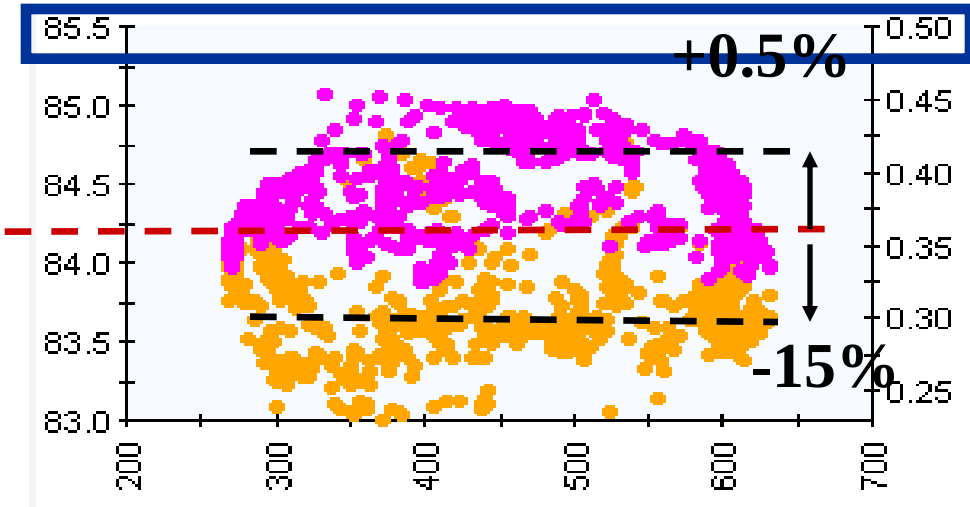
Impact of Combustion Optimization on Operations & Performance



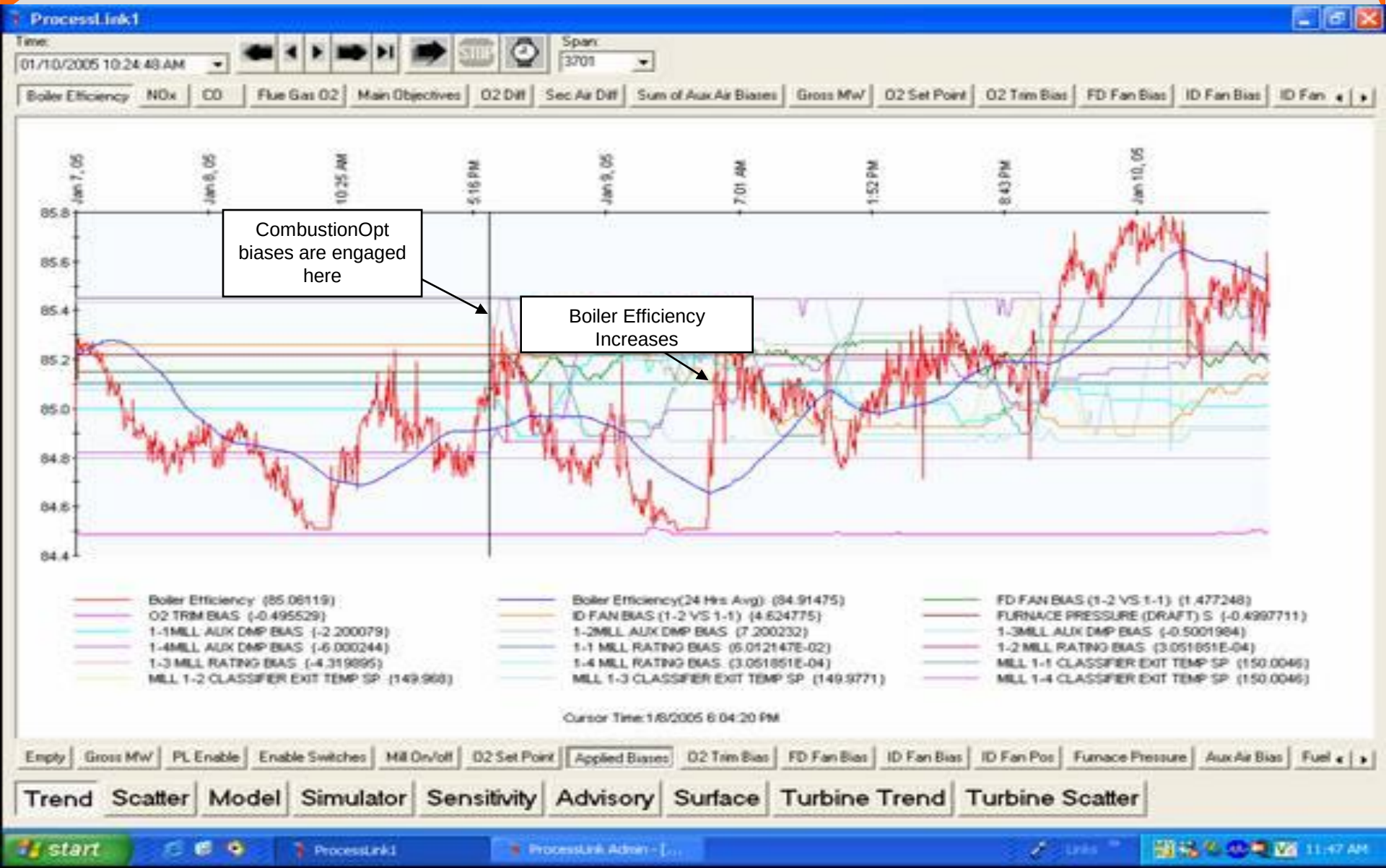






Boiler Efficiency NOx

Same 600 MW Unit Five Years Later



SootOpt

- Provides real-time closed-loop optimization of unit performance by manipulating all relevant sootblowing controls
- Expert systems, neural networks & model predictive control
- Improves reliability, heat rate, steam temp & emissions

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Unit 3: SootOpt Home

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Optimization Alerts

Issue/Action	Actual	Target	!!!
Some SH boiler IKs 1A, 1, 2 are below minimum required ops	1	0	!!!
Some RH boiler IKs 11-14 are over expected ops	1	0	!!!

Optimization Analysis

Last Evaluation: 8/22/2008 11:22:07 AM, Goal: Reduce APH 3A Gas In Temp, Zone: SH_Economizer, Device: SH12_72

Blower Select: Model

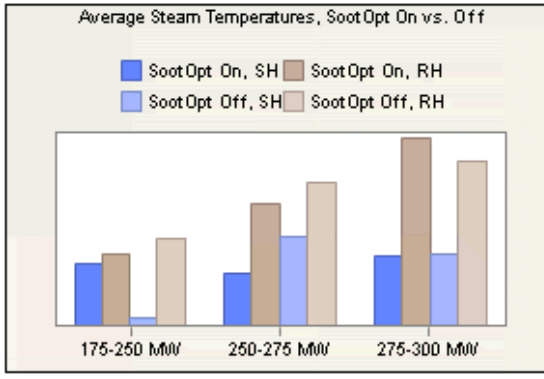
Zone Selection:

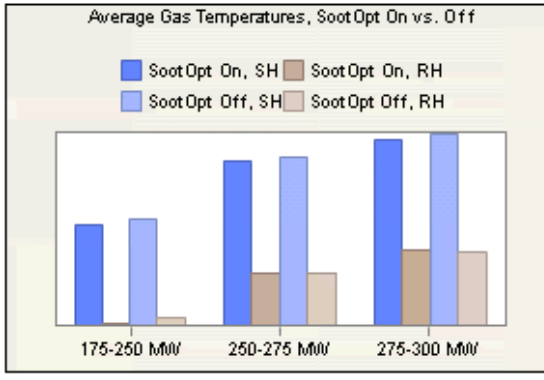
Goal	Zone	Eligible	Applica...
Lower RH Steam Temp	RH_Platen	✗	✓
Lower RH Steam Temp	RH_Furnace	✗	✓
Reduce APH 3A Gas In Temp	SH_Convection	✗	✓
Reduce APH 3A Gas In Temp	SH_Economizer	✓	✓
Reduce APH 3A Gas In Temp	SH_Platen	✓	✓
Reduce APH 3A Gas In Temp	SH_Furnace	✗	✓
Reduce APH 3B Gas In Temp	RH_Furnace	✗	✓
Reduce APH 3B Gas In Temp	RH_Platen	✗	✓

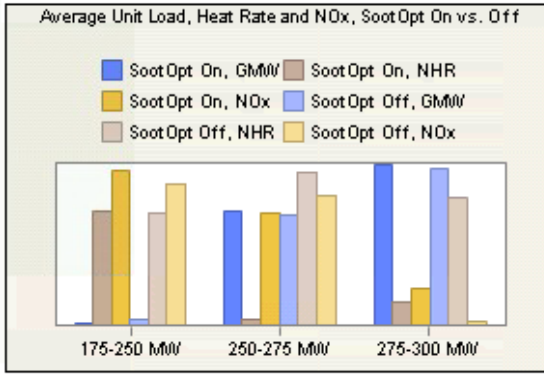
Blower Selection:

Blower	Eligible	Idle	Rank
SH11_71	✓		
SH12_72	✗		
SH13_73	✗		
SH14_74	✓		

Optimization Benchmarks







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Baldwin 3 SootOpt ON-OFF Comparison

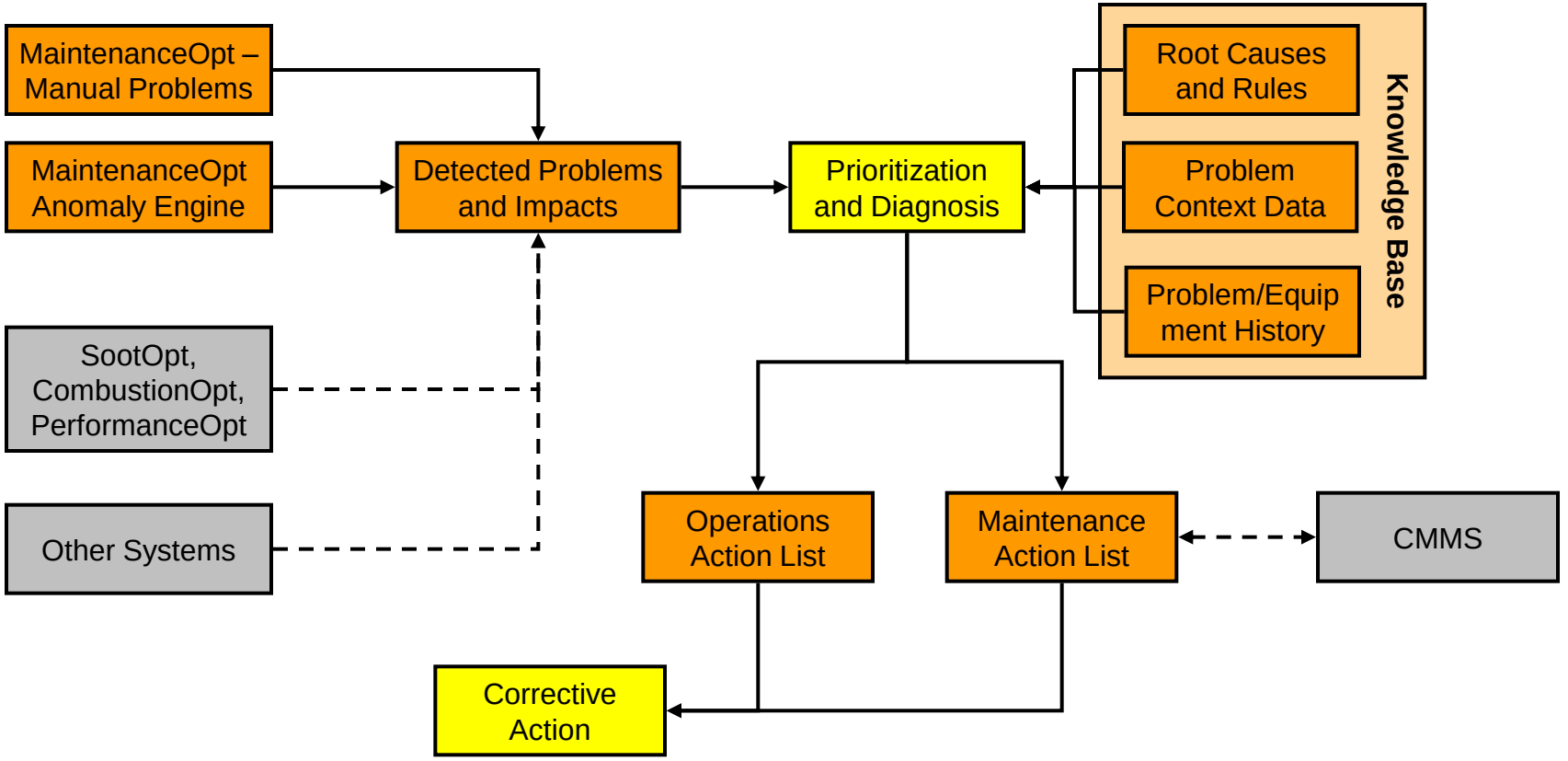
	Soot Off	Soot On	
	Requests per 24hr	Requests per 24hr	Change Percent
PlatSH	15.02	9.03	-39.85
RH	12.84	8.72	-32.09
SecSH	11.66	5.05	-56.70
PriSH	9.99	7.42	-25.76
Econ	7.93	8.09	1.92
Total	**57.44**	**38.31**	**-33.30**
	Avg	Avg	
NOx, lb/MBTU	0.0896	0.0830	-7.36
HR, BTU/kWh	10344.27	10288.96	-0.53

- SootOpt's boiler cleanliness optimization not only reduces heat and emissions, but also results in substantially fewer unnecessary cleaning actions
- Waterwall erosion due to boiler cleaning is the biggest source of tube ruptures
- Tube ruptures represent by far the largest contribution to forced outages and EFOR degradation

MaintenanceOpt

- Diagnostics clearinghouse for plant anomalies
  - Reports criticality, cause & remedial actions
  - Prioritize and manage problems/resolutions based on impact on profitability
  - Diagnose problem and identify actions based on heuristics and data relevant to root cause analysis
- Neural network detectors & a customized heuristic knowledge-base
- Improves reliability, capacity & heat rate
- Integrates with CMMS to feed work orders and track status

MaintenanceOpt – How It Works



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Unit 1: MaintenanceOpt Home

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Optimization Benchmarking provides a variety of perspectives for both efficiency and capacity benefits

Optimization Advice

Issues to screen (10)		84
Problems to diagnose (6)	35,222	155,887
Problems to resolve (1)		
Outage (1)	10,609	31,997
De-rate (0)	0	0
No de-rate (0)	0	0
Operations (0)		

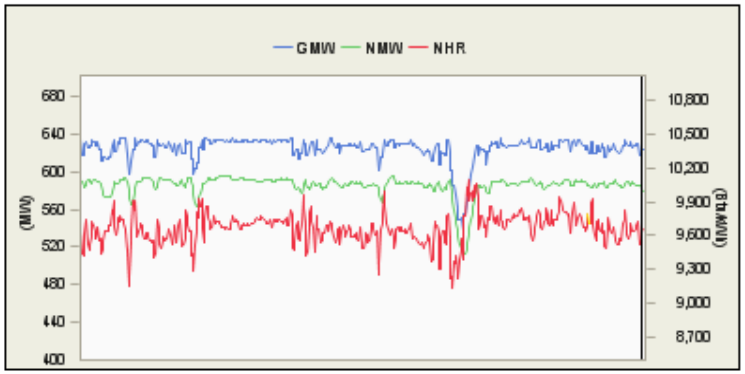
Symptoms/problems categorized by workflow stage and equipment category

What's Going on Now and Why

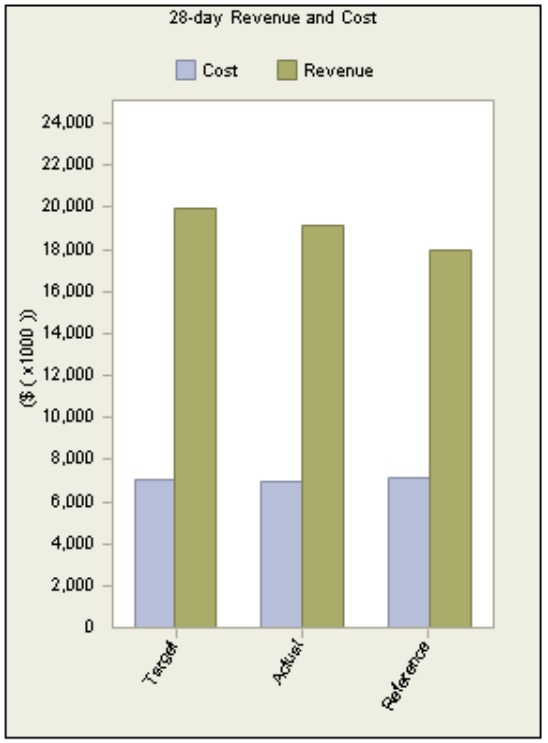
Priority of Problems

Equipment	To Diagnose			To Resolve		
	Low	Med	High	Low	Med	High
FWH 1F1			1			
Main Conde...			1			
Aux Conden...			1			
Main Conde...	1					
HP Turbine					1	
Boiler		1				

Description	Tagname	Expected	Actual	Priority



Optimization Benchmarks



Benefits	vs. Target	vs. Reference
Cost ($)	-97,355	240,647
Revenue ($)	831,203	1,168,811

Responsiveness	Average Age (days)	Target Age (days)
Problems Escalated (13)	0	1
Problems Diagnosed (0)	–	1.5
Problems Resolved (1)	0	4

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Unit 1: MaintenanceOpt Analysis

2 days | 12/17/2007 02:00:00 PM

Action List | Tools

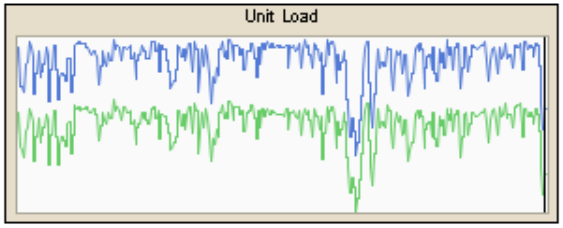
Issues to screen | Problems to diagnose | Problems to resolve

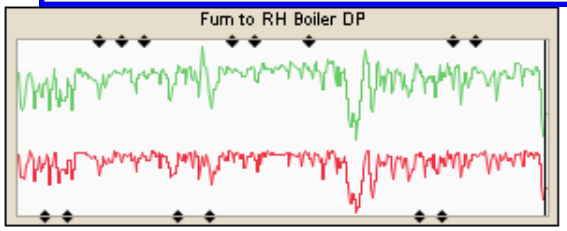
Src	Issue	Actual	Target	Pri	Risk	Cost ($/mo)...	Revenue ($/mo)...
C'Opt	1A1 Main Quality 6h Avg < min threshold	25.72	35	Low		NA	–
M'Opt	High Boiler DP (Furnace to Reheat)(inH2Og)	4.16	3.4	Low		NA	NA
M'Opt	Auxiliary Power Increase(MW)	41.8	36.9	Low		NA	NA
M'Opt	High Boiler DP (Furnace to Econ)(inH2Og)	10.72	9.41	Low		NA	NA
C'Opt	1A5 Main Quality 6h Avg < min threshold	0.25	35	Med		NA	–

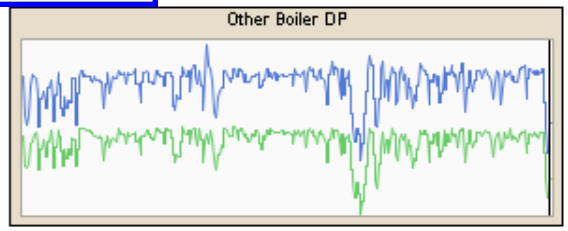
Optimization Advice shows currently triggered symptoms as well as recommended actions and predicted impacts.

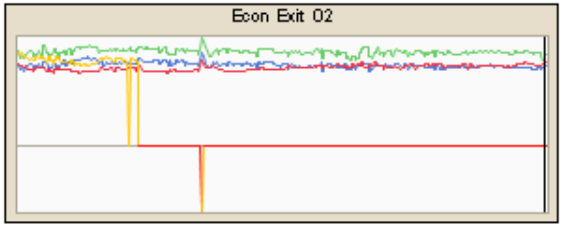
View Log

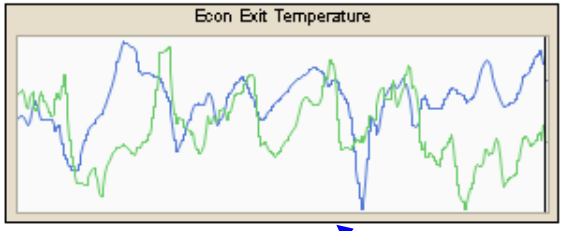
Context Data | Attachments | Problem History | Equipment History

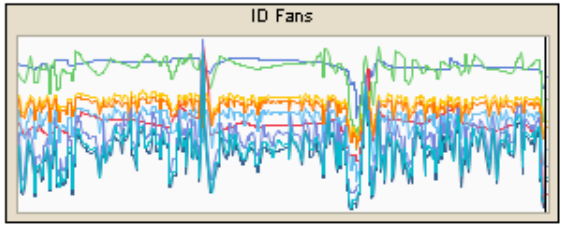












General	Value

Econ Exit	Value

Context data relevant to the highlighted problem

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Session Documents Help

Unit 1: MaintenanceOpt Analysis

2 days | 12/17/2007 02:00:00 PM

Action List | Tools

Issues to screen | Problems to diagnose | Problems to resolve

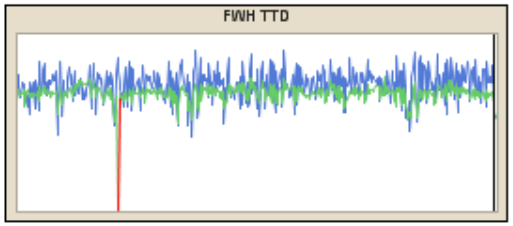
Src	Issue	Actual	Target	Pri	Risk	Cost ($/mo)...	Revenue ($/mo)...
P'Opt	Low Condenser 1A Efficiency(%)	54.61	98	Low		6,882	22,121
P'Opt	Low Hot Reheat Temp(degF)	961.67	963.8	Med			
C'Opt	MVs Disabled(percent)	44.64	100	Med			
P'Opt	Low Condenser 1B Efficiency(%)	54.77	98	High			5
P'Opt	Low Aux Condenser Efficiency(%)	69.62	85	High			6
P'Opt	High FWH 1F1 TTD(degR)	5.63	5.66	High			

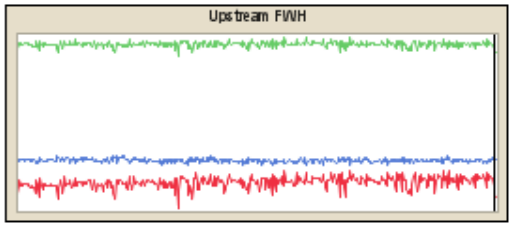
Optimization Advice shows currently triggered symptoms as well as recommended actions and predicted impacts.

Show Impacts | Show Causes

View Log | Add Issue

Context Data | Attachments | Problem History | Equipment History





FWH (F)	Actual	Achievable
TTD	5.47	5.4
TR	39.28	39.36
DCA	4.86	4.95

Upstream FWH (F)	Actual
TTD	15.82
TR	34.16
DCA	9.41

Temperature (F)	Actual
Emergency Drain	0
FWH Tube Outlet	398.35
FWH Outlet Minus Downstream Inlet	0
FWH Shell Inlet	814.58
FWH Tube Inlet	357.8
FWH Drain Outlet	361.5
Turbine Extraction	635.57

Flow (klb/h)	Actual
FW Flow Rate through Heater	1,493.82
FWH Extraction Flow	51.92
Primary Flow Rate Difference	0

Cleanliness (%)	Actual	Achievable
Condenser	53.05	85
FWH	62.52	70

Other Data	Actual
Level Normal Drain Valve Position	50 %
Emergency Drain Valve Position	0 %
Heater Level	9.37 in
Heater OOS Status	1
Heat Rte Impact (Btu/kWh)	0.01

Context data relevant to the highlighted problem

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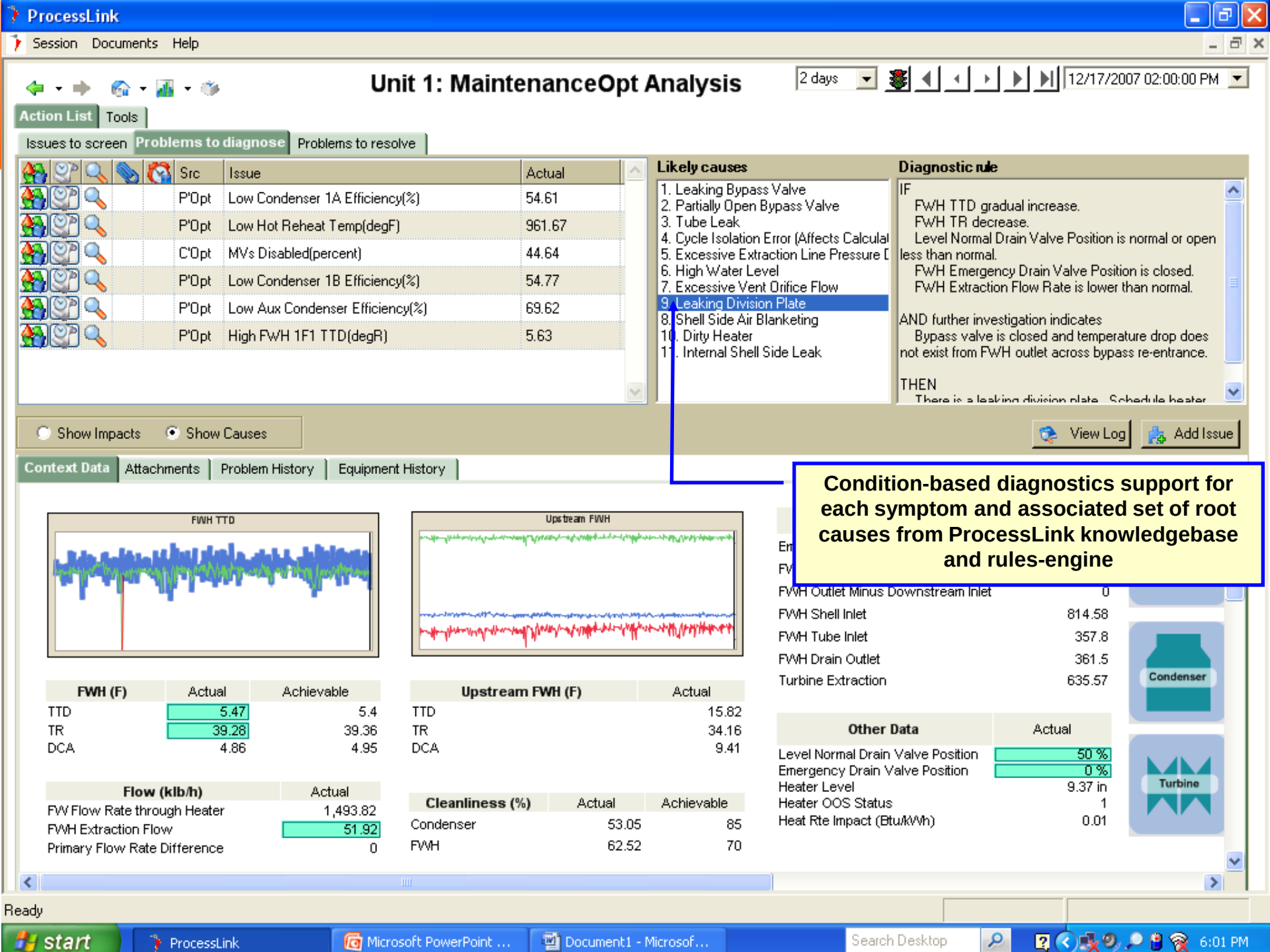
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Unit 1: MaintenanceOpt Analysis
2 days
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Action List Tools
Issues to screen Problems to diagnose Problems to resolve
Src Issue Actual
P'Opt Low Condenser 1A Efficiency(%) 54.61
P'Opt Low Hot Reheat Temp(degF) 961.67
C'Opt MVs Disabled(percent) 44.64
P'Opt Low Condenser 1B Efficiency(%) 54.77
P'Opt Low Aux Condenser Efficiency(%) 69.62
P'Opt High FWH 1F1 TTD(degR) 5.63
Likely causes
1. Leaking Bypass Valve
2. Partially Open Bypass Valve
3. Tube Leak
4. Cycle Isolation Error (Affects Calcula
5. Excessive Extraction Line Pressure D
6. High Water Level
7. Excessive Vent Orifice Flow
9. Leaking Division Plate
8. Shell Side Air Blanketing
10. Dirty Heater
11. Internal Shell Side Leak
Diagnostic rule
IF
FWH TTD gradual increase.
FWH TR decrease.
Level Normal Drain Valve Position is normal or open less than normal.
FWH Emergency Drain Valve Position is closed.
FWH Extraction Flow Rate is lower than normal.
AND further investigation indicates
Bypass valve is closed and temperature drop does not exist from FWH outlet across bypass re-entrance.
THEN
Show Impacts
Show Causes
View Log
Add Issue
Context Data Attachments Problem History Equipment History
FWH TTD
Upstream FWH
FWH (F) Actual Achievable
TTD 5.47 5.4
TR 39.28 39.36
DCA 4.86 4.95
Upstream FWH (F) Actual
TTD 15.82
TR 34.16
DCA 9.41
Flow (klb/h) Actual
FW Flow Rate through Heater 1,493.82
FWH Extraction Flow 51.92
Primary Flow Rate Difference 0
Cleanliness (%) Actual Achievable
Condenser 53.05 85
FWH 62.52 70
FWH Outlet Minus Downstream Inlet 0
FWH Shell Inlet 814.58
FWH Tube Inlet 357.8
FWH Drain Outlet 361.5
Turbine Extraction 635.57
Other Data Actual
Level Normal Drain Valve Position 50 %
Emergency Drain Valve Position 0 %
Heater Level 9.37 in
Heater OOS Status 1
Heat Rte Impact (Btu/kWh) 0.01
Condenser
Turbine
Condition-based diagnostics support for each symptom and associated set of root causes from ProcessLink knowledgebase and rules-engine
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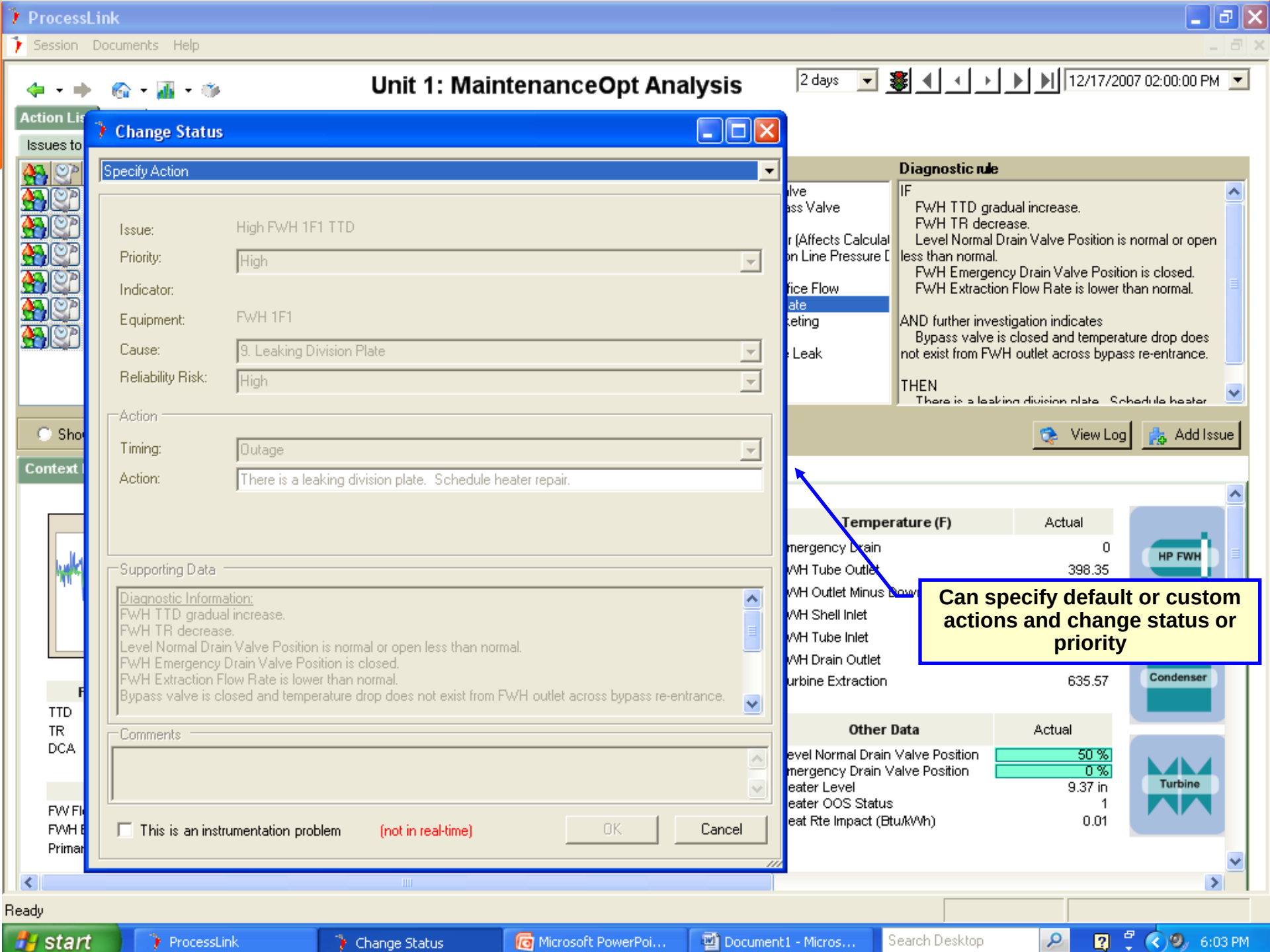
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Unit 1: MaintenanceOpt Analysis
2 days
12/17/2007 02:00:00 PM
Change Status
Specify Action
Issue: High FWH 1F1 TTD
Priority: High
Indicator:
Equipment: FWH 1F1
Cause: 9. Leaking Division Plate
Reliability Risk: High
Action
Timing: Outage
Action: There is a leaking division plate. Schedule heater repair.
Supporting Data
Diagnostic Information:
FWH TTD gradual increase.
FWH TR decrease.
Level Normal Drain Valve Position is normal or open less than normal.
FWH Emergency Drain Valve Position is closed.
FWH Extraction Flow Rate is lower than normal.
Bypass valve is closed and temperature drop does not exist from FWH outlet across bypass re-entrance.
Comments
This is an instrumentation problem
(not in real-time)
OK
Cancel
Diagnostic rule
IF
FWH TTD gradual increase.
FWH TR decrease.
Level Normal Drain Valve Position is normal or open less than normal.
FWH Emergency Drain Valve Position is closed.
FWH Extraction Flow Rate is lower than normal.
AND further investigation indicates
Bypass valve is closed and temperature drop does not exist from FWH outlet across bypass re-entrance.
THEN
View Log
Add Issue
Temperature (F)
Actual
0
398.35
635.57
Other Data
Actual
50 %
0 %
9.37 in
1
0.01
HP FWH
Condenser
Turbine
Can specify default or custom actions and change status or priority
Ready
start
ProcessLink
Change Status
Microsoft PowerPoi...
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PerformanceOpt

- Identifies performance bottlenecks, their efficiency & capacity impacts & actionable advice
- 1st Principles model of unit with continual background simulations
- Improves efficiency, reliability, heat rate & capacity
- Prioritization based on monetized impacts
- Integrated with the other optimizers
  - Coal quality information to CombustionOpt
  - Boiler cleanliness information to SootOpt
  - Accurate problem impact assessments to MaintenanceOpt

ProcessLink

Session Documents Memory Help

Deseret: PerformanceOpt Home

1/17/2007 08:48 AM (7 days)

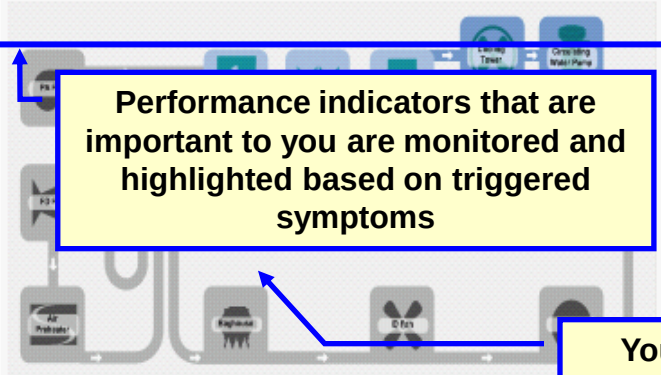
Optimization Advice

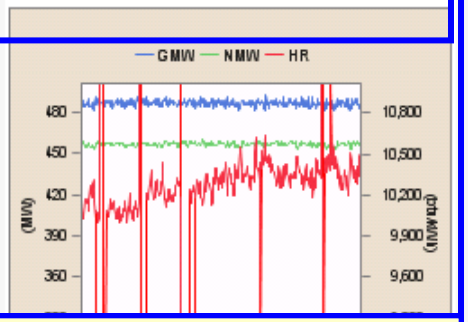
Symptom			
FWH 3 TTD Degradation			
FWH Ext Pressure Sensor 1A-1B Devi			
FWH 4 DCA Degradation			
FWH 6 DCA Degradation	0.00		0.00
FWH 4 TTD Degradation			

Optimization Benchmarking provides a variety of perspectives for both efficiency and capacity benefits

Optimization Advice shows currently triggered symptoms as well as recommended actions and predicted impacts.

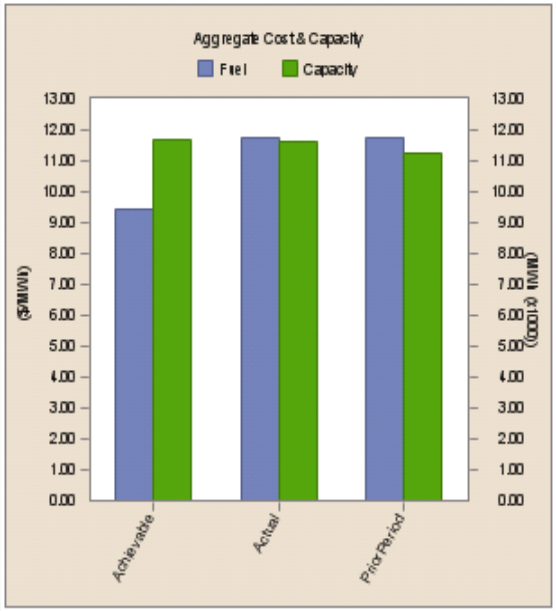
Controllable Losses			
Throttle Pressure (psig)			
Throttle Temperature (degF)			
Upper (1st) SH Spray Flow (klb/h)			
Lower (2nd) SH Spray Flow (klb/h)	58.8	34.1	24.7
Reheat Temperature (degF)	1,012	1,000	12
Reheat Spray Flow (klb/h)	11.6	11.2	0.4
Final Feedwater Temperature (degF)	428	424	4
Condenser Backpressure (inHg)	2.71	2.68	0.02
Hotwell Subcooling (deltaF)	-0.1	0.0	-0.1
Air Heater Gas Inlet Temperature (degF)	697	673	24
AH Cold End Average Temperature (degF)	176	190	-14
Air Heater Gas Inlet O2 (%)	3.0	2.7	0.3
Air Heater Leakage (%)	33	10	23
Auxiliary Power (MW)	27.9	29.0	-1.1



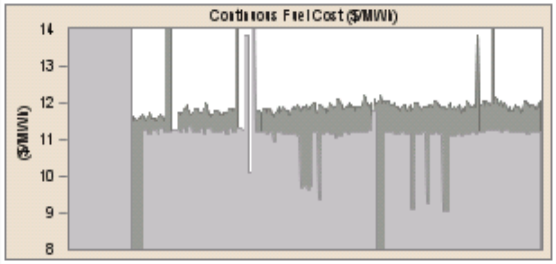


Performance indicators that are important to you are monitored and highlighted based on triggered symptoms

You can click on any of these equipment icons to go to the page containing data about that piece of equipment



Potential benefits	$	$/MWh
Fuel	26,766.94	2.3
		MWh
Capacity		42.37



Potential additional benefits ($)

Daily Weekly Monthly

ProcessLink 10.129.94.19

Session Documents Help

Unit 1: PerformanceOpt Analysis

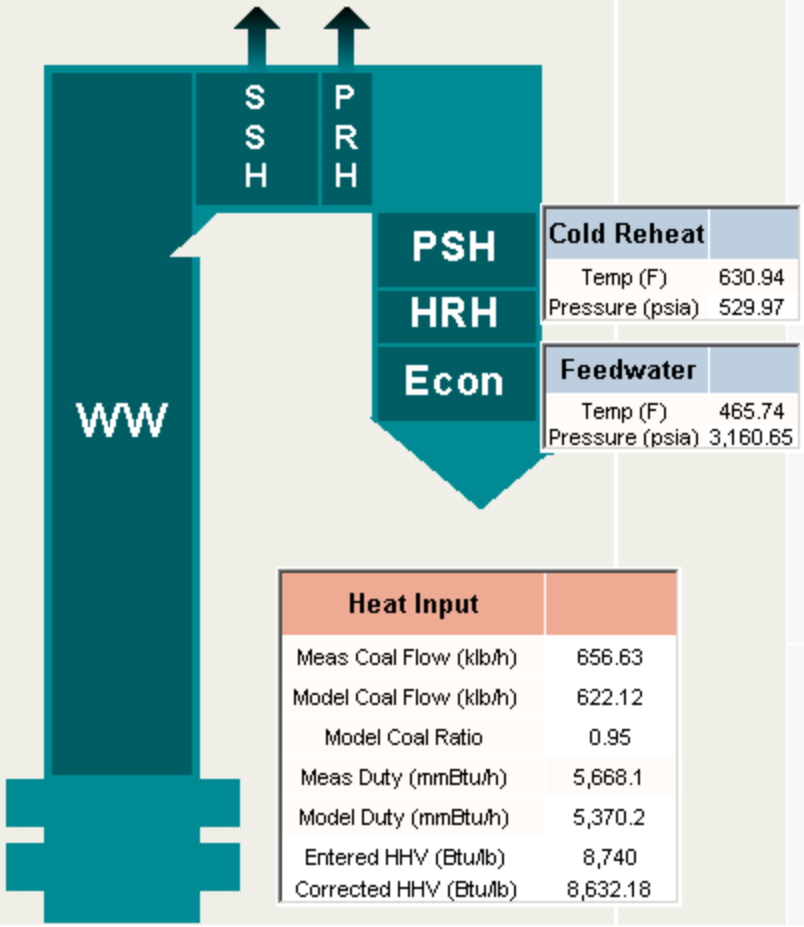
1 day 06/26/2007 11:30:5

Equipment | Trend

Boiler | Steam Turbine | Condenser | Condensate Pump | CW Pump | FWH AB | FWH CD | BF Pump | FWH FG | Air Heater

	Current	Ach
Net Heat Rate	9,865.13	9,
Gross MW	587.76	5

Steam	SH	RH
Flow (klb/h)	4,048.68	3,599.09
Temp (F)	1,000.21	950.58
Pressure (psia)	2,506.41	529.97



Cold Reheat	
Temp (F)	630.94
Pressure (psia)	529.97

Feedwater	
Temp (F)	465.74
Pressure (psia)	3,160.65

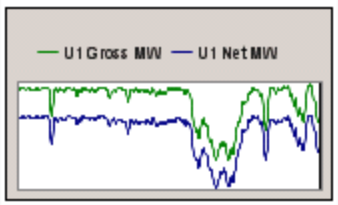
Heat Input	
Meas Coal Flow (klb/h)	656.63
Model Coal Flow (klb/h)	622.12
Model Coal Ratio	0.95
Meas Duty (mmBtu/h)	5,668.1
Model Duty (mmBtu/h)	5,370.2
Entered HHV (Btu/lb)	8,740
Corrected HHV (Btu/lb)	8,632.18

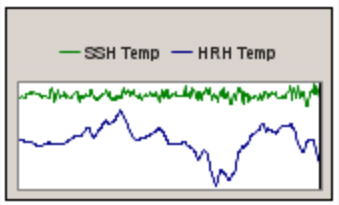
Efficiency Losses	MBtu/h	%
Dry gas loss	311.05	5.79
Water from H2 in fuel	215.68	4.02
Water from H20 in fuel	204.03	3.8
Moisture in air loss	5.24	0.1
Unburned carbon loss	27.38	0.51
Sensible Q in refuse	8.92	0.17
Radiation loss	5.1	0.09
Total losses	777.42	14.48

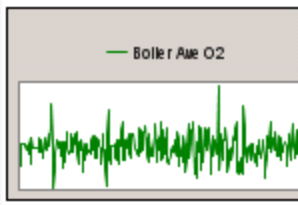
Efficiency Credits	MBtu/h	%
Dry Air Credit	60.45	1.13
Moisture in Air Credit	1.04	0.02
Sensible Heat in Fuel	0	0
Total Credits	61.49	1.15

Unit 1 Performance	Actual	
Gross MW	587.76	5
Net MW	548.43	5
Gross HR	9,131.82	9,0
Net HR	9,865.1	9,
Boiler Eff - I/O (%)	87.93	8
Boiler Eff - Losses	85.7	

Zone	Q (MBtu/h)	Clean (%)	T Out (deg F)	Clean (exp)	T Out
Economizer	485.03	99.14	570.2	83.45	540
Water Wall	2,057.12	76.94	689.8	76.89	680
Primary SH	443.01	70.05	725.6	83.45	726
Secondary SH	1,088.8	94.25	1,000.2	85.45	995
Reheater	641.67	71.06	950.6	81.45	975







ProcessLink - [Prototype BaldwinUnit1 UnitAdvisor Form (ProcessLink.Applications.Documents.Forms.Form viewer)]

Session Documents Help

Unit 1: UnitAdvisor

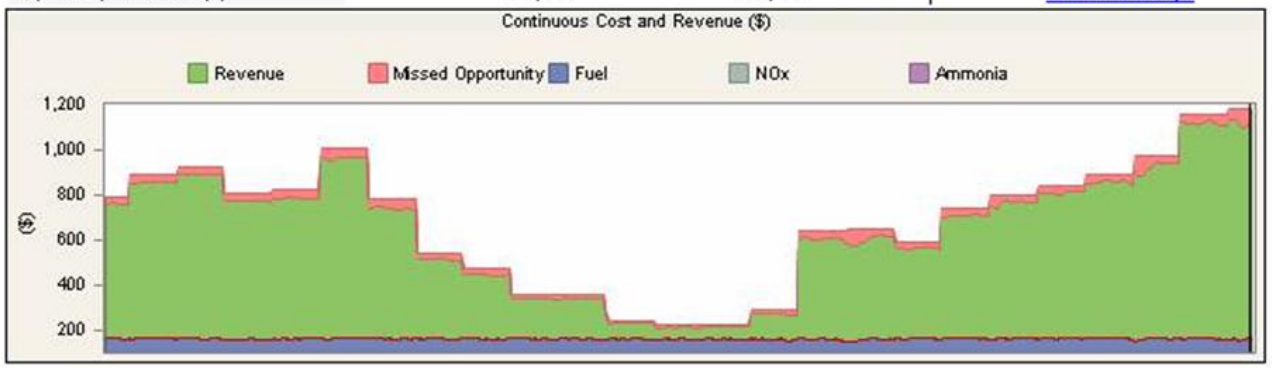
10/8/2007 06:36 PM (1 day)

Optimization Advice

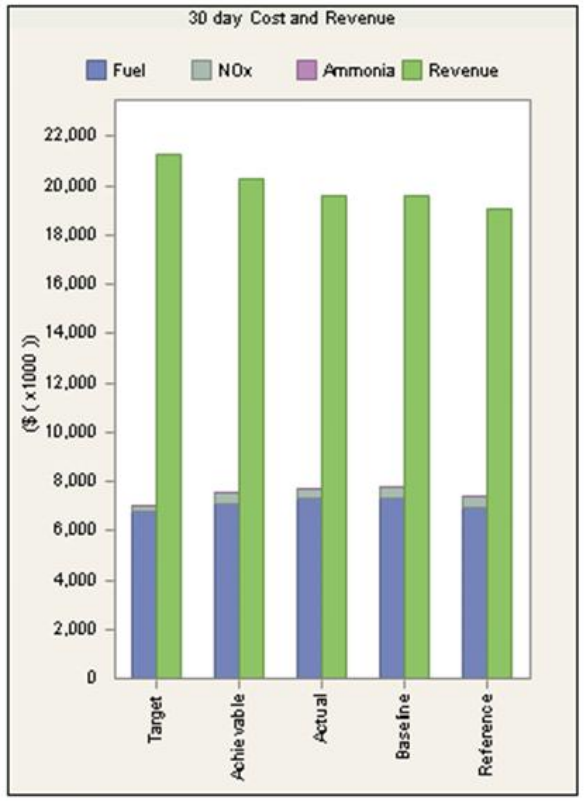
Issue/Action	Timing	Risk	Cost ($/mo)	Revenue ($/mo)
Low Hot Reheat Temp			18,391	300,438
Low Condenser 1B Efficiency			28,950	98,020
Low Condenser 1A Efficiency			25,267	85,693
Main Condenser 1B Backpressure De...			8,224	55,043
Main Condenser 1A Backpressure De...			7,199	46,274
Issues to screen (10)			17,368	104,852
Problems to diagnose (7)			81,132	496,545
Problems to resolve (1)			10,808	36,490

What's Going on Now and Why

KPIs	Actual	Expected	Delta	Primiary Optimizers
NOx (lb/MBtu)	0.065	0.070		CombustionOpt; SootOpt
Ammonia (lb/h)	455	460		CombustionOpt; SootOpt
Heat Rate (Btu/kWh)	10,567	10,000		PerformanceOpt
CO2 (ton)	2,121	2,020		PerformanceOpt
Opacity Excursions (%)	30	35		CombustionOpt; SootOpt
Availability (%)	92	100		MaintenanceOpt
Revenue ($)	1,965,427	1,950,000		MaintenanceOpt
Capital Expenditures ($)	850,000	850,000		MaintenanceOpt



Optimization Benchmarks



Benefits	vsTarget	vsAchieve	vsBase	vsRef
Fuel	487,964	177,709	22,423	-349,650
NOx	---	12,214	5,144	---
NH3	---	8,004	6,223	---
Revenue	1,674,427	702,810	---	523,931

Ready

Optimization: Won't Solve the Problem but Part of GHG Solution

- Achieve lowest-cost CO_2 reductions
- Demonstrate proactive commitment
- Simultaneously achieve operations improvements:
  - Reduced NOx and/or reagent costs
  - Improved control over CO and opacity
  - Increased reliability and commercial availability
- Newer regulations (based on tons and not lb/mmBtu rates) mean that every incremental heat rate improvement results in fewer tons of CO_2, SO_2, and Mercury