Optimization of Emissions Reduction Equipment (SCR)

Jeff Williams

SmartProcess

Business Development Manager

Where ideas become solutions.

Emerson Global Users Exchange '08

Presenters

- Jeff Williams
- John Hayden

Agenda

- Overview
- SCR Optimization
- SCR project Case study

SmartProcess®

Availability

- Reduced Tube leaks
- Less EFORS from sootblower problems

Environmental Management

- NOx / SO2 cap compliance
- NOx / CO / CO_2 minimization
- Opacity Reductions

Generation Management

- Fleet / Economic Evaluation
- Real-Time Performance
- Heat Rate Improvements
- LOI reductions

Operational Flexibility

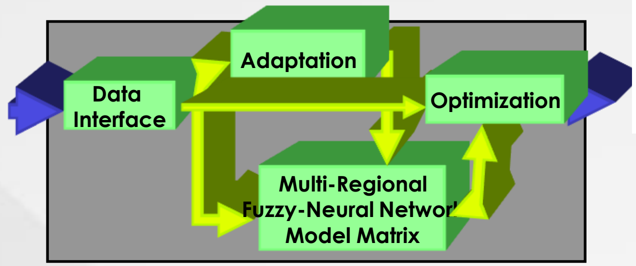
- Dispatch Response
- Ramp Rate Improvements
- Start-up guidance

History - Of SmartProcess Performance and Optimization Experience – Post 1990

Low NOx Dispatch system for LADWP

Power Industry first multivariable advanced fuzzy logic feedforward model based steam temperature control

Industry first Multivariable Model matrix with adaptation and Optimization engines



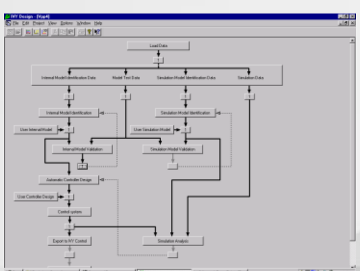
Developed and Beta Tested First Immunological Self-Learning system – Patent Pending

Embedded Model Based Control in Ovation® expert control system via APC.

Steam Temperature LDC

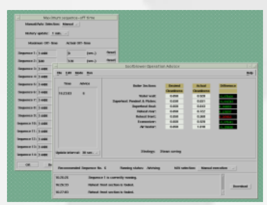
1993 1996 1998 1999 2000 2001 2003 2004 2005 2006

First Dynamic state space models with neural network component – NeuCOP from NeuralWare – Later Aspen



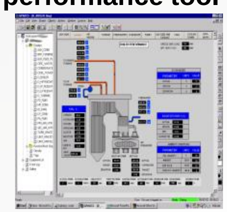
Acquired By Emerson

Named Power Industry Center of Excellence for Emerson



Power Industry first software based intelligent sootblowing combining expert system and neural networks

Industry First Object based Plant performance tool

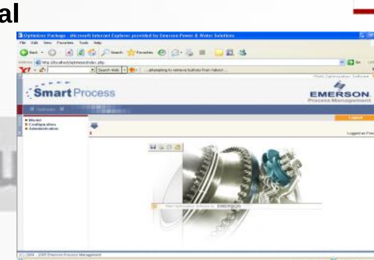


Industry First Cyclone Boiler Optimizer

SmartProcess powers ISA/POWID facility of the year

Released first browser based interface

SmartEngine



Industry First Fleet wide optimization using portal technology

SmartProcess Firsts For Power

- 1st Dynamic Combustion Optimizer
- 1st Advanced Steam Temperature application
- 1st Intelligent Sootblower Optimizer
- 1st OPC based Performance Monitor (GPA)
- 1st Cyclone Optimizer
- 1st Fleet Optimizer
- 1st Open Web Enabled Economic Optimizer, Combustion Optimizer, and Intelligent Sootblower

Solutions for Improved Plant Performance

SmartProcess®

Fleet Optimization

Economic Optimization

Combustion Optimization

Unit Response Optimization

Sootblower Optimization

Steam Temp. Optimization

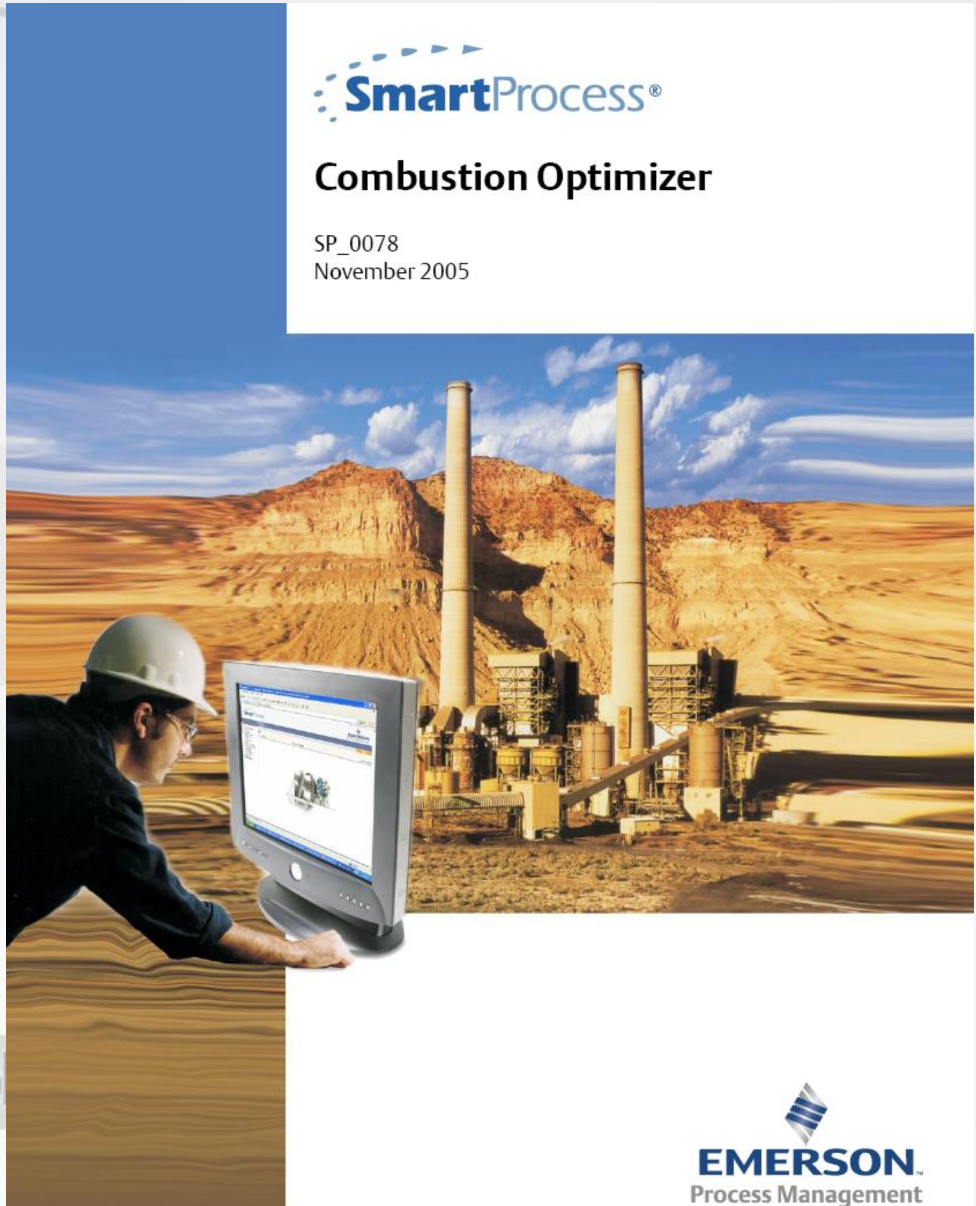
SCR Optimization

Performance Monitoring

LoopMetrics

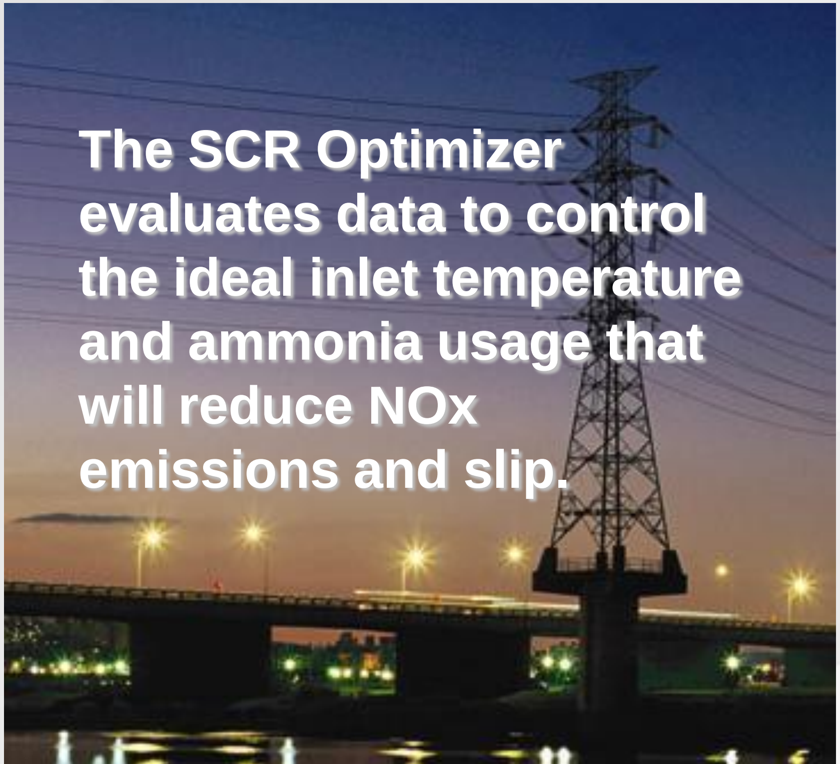
Complete system

- Site Assessment
- Project Start
- Development of Plant Integration Plan and Design of control modifications
- Execution of Plant Integration Plan
- Data Collection & Conditioning
- Model Design & Validation
- Installation of Model
- Advisory Mode Operation
- Closed-Loop Mode Operation
- Benchmark & Documentation



Where ideas become so

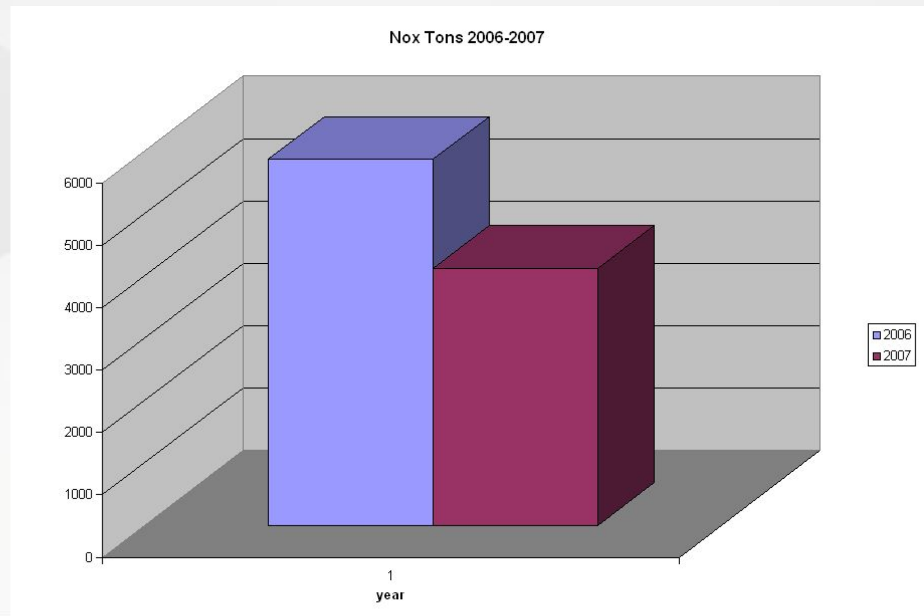
SCR Optimizer



The SCR Optimizer evaluates data to control the ideal inlet temperature and ammonia usage that will reduce NOx emissions and slip.

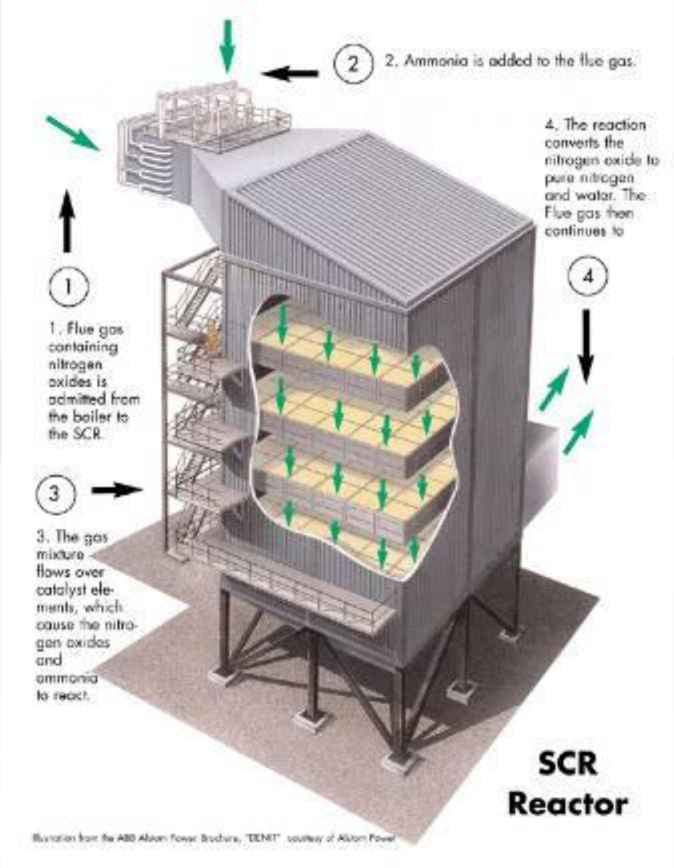
Take your SCR technology a step further.

- Results
  - Improves efficiency
  - Maintains optimum temp
  - Extends 1st stage catalyst life



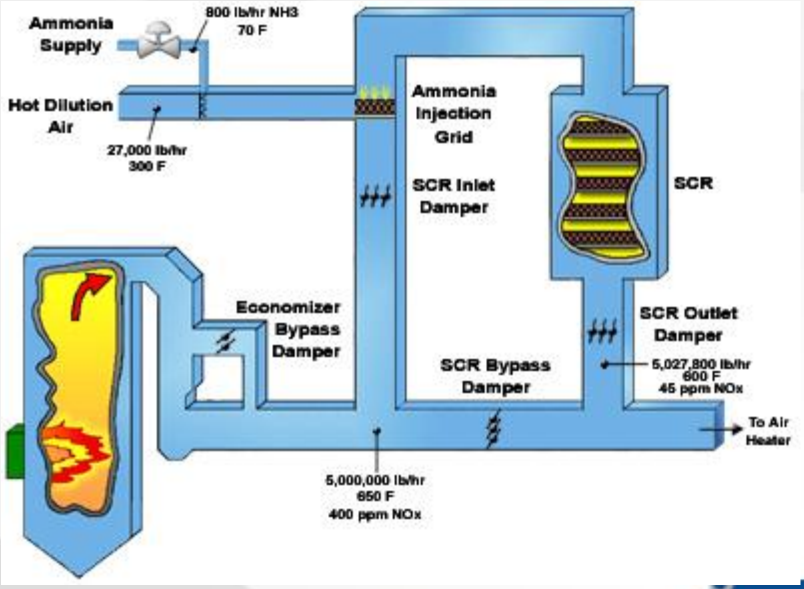
SCR Optimization Factors

- SCR’s operate most efficiently at 600-670˚F
- There are a number of layers
- Excess ammonia spray saturates the catalyst bed and escapes the reactor (slip)
- NOx inlet variability causes uneven reactions

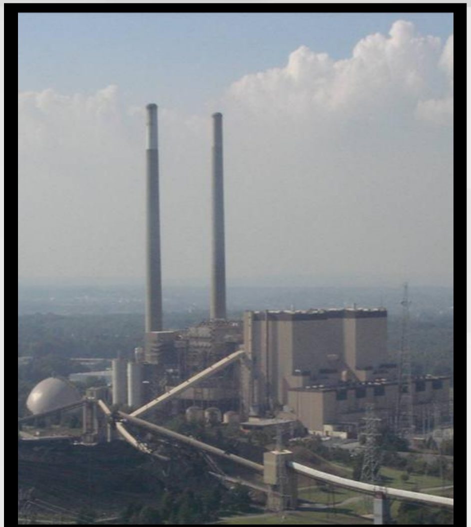


SCR Optimization

- Control temperature via Bypass and O2 bias
- Minimize NOx variability
- Model reactor, predict flow requirement for zero slip



SmartProcess® Improves Emissions and Temperature Control at CPSG's Brandon Shores Power Station



Application

Unit #1 a 680-megawatt coal-fired generating unit with a B&W boiler and GE turbine

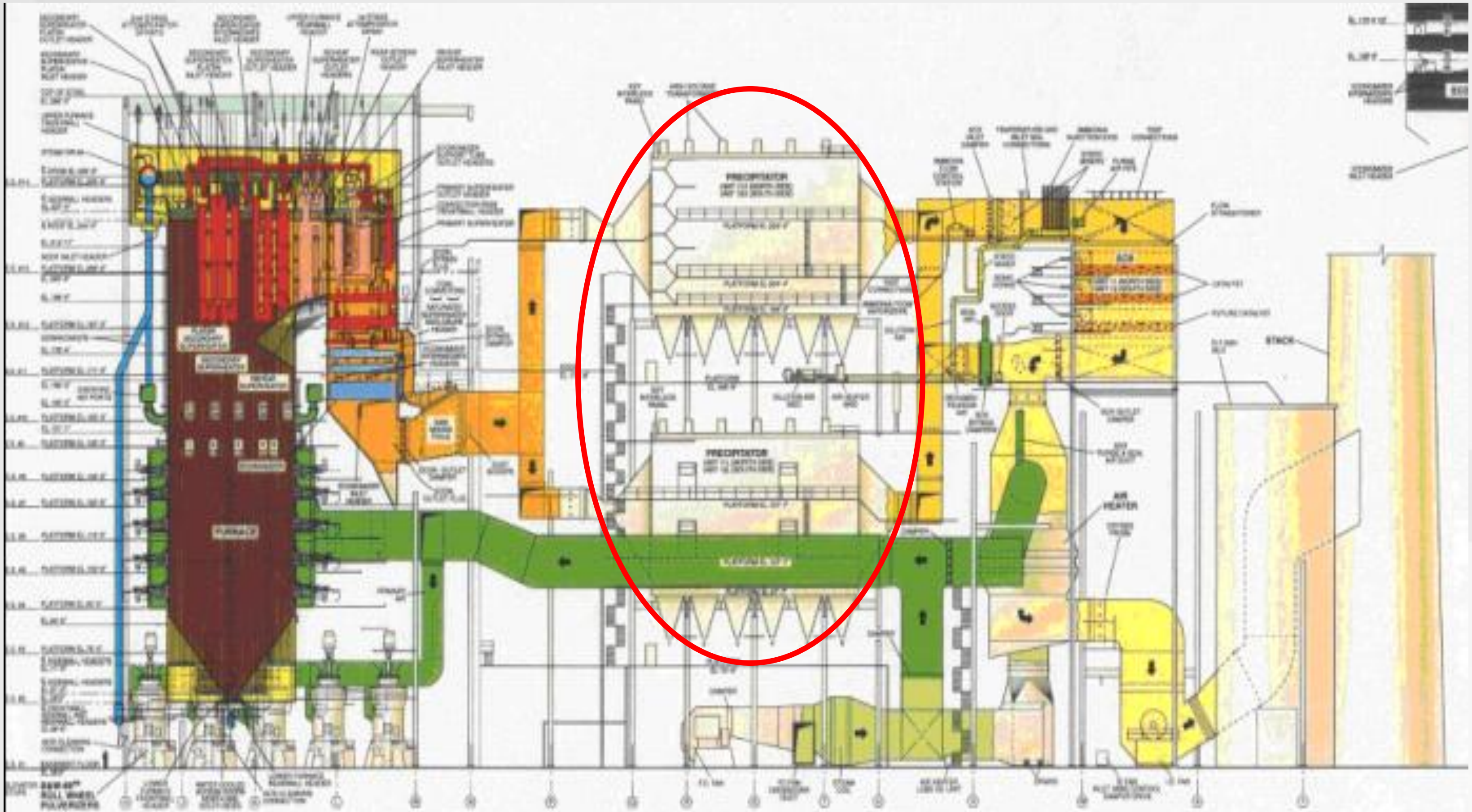
- CHALLENGE
  - Optimize temperature control
  - Reduce emissions of NOx
  - Improve ammonia utilization and reduce slip
- SOLUTION
  - SmartProcess SCR Optimization
- RESULTS
  - 120 hour improvement in 90% removal rate hours
  - 250 tons of additional NOx reduction
  - Minimize the impact of varying conditions of coal quality, cleanliness of boiler, mill selection, and daily operation levels

Case Study
SCR Temperature Optimization Project

Plant Information & History

- 375 Acre Site
- Two 680 MW (Gross) Coal Fired Units
- 5000 to 6000 tons of coal burned per typical day per unit. Delivery by barge.
- 400-500 tons fly ash per day produced per unit. Fly ash reuse by ProAsh.
- Selective Catalytic Reduction (SCR) for NOx control.
- 167 Employees including Coal and Ash Handling shared with Wagner Plant.
- Air Quality Control System Project (Sorbent Injection and Baghouse for Hg and SO3 control, Wet Scrubber for SO2 control) under way to meet Healthy Air Act Requirements Jan 1, 2010.
- Unit 1 commissioned in 1984 – GE Turbine & B&W Boiler.
- Unit 2 commissioned in 1991 – GE Turbine & B&W Boiler.

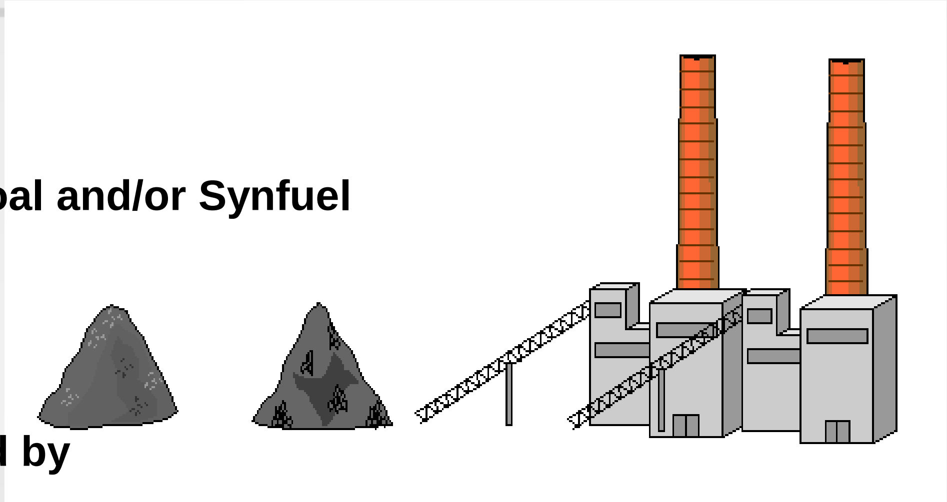
Boiler Design



BRANDON SHORES GENERATING STATION, UNIT 1

Hot-side Precipitator located before the Air Heaters

Types of Coal and Unit Operation



Coal

• **Low Sulfur Eastern Bituminous Coal and/or Synfuel (mined in Kentucky / West Virginia)**

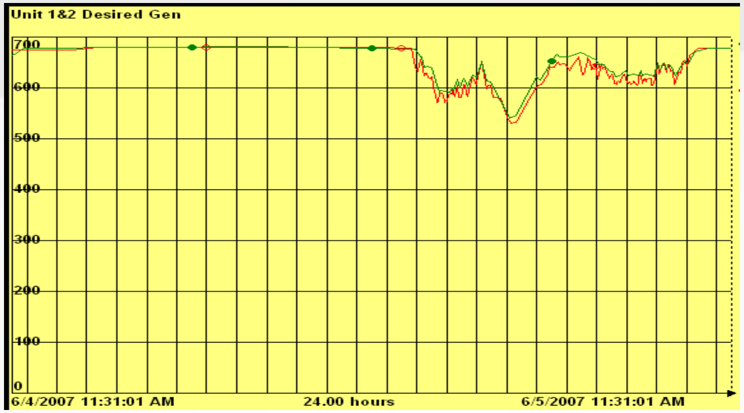
• **Russian**

• **Other Foreign Coals As Requested by**

Operation

• **Day: high load regulation - 680**

• **Night: lower loads – 550 and below**



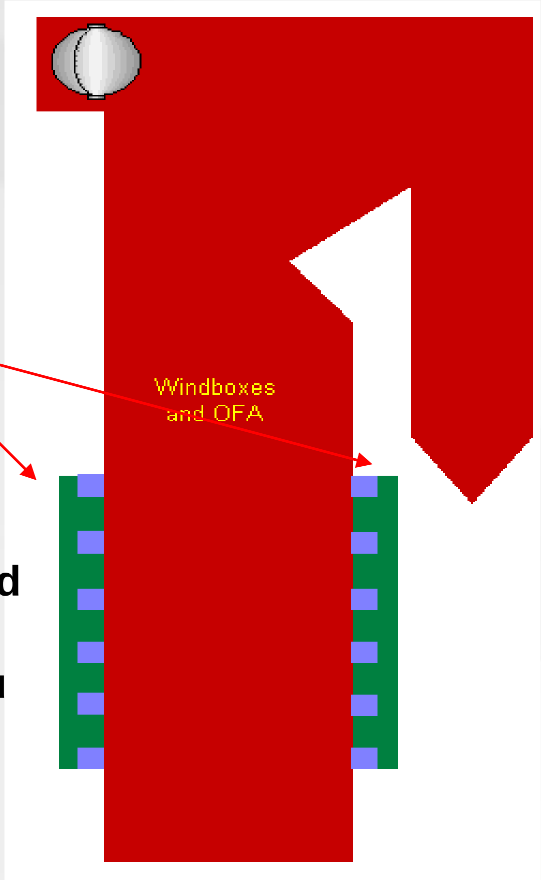
Ozone Season – May to September

Rules:

- **SCR Design is 90% NOx Reduction (Diff. Between SCR Outlet and Inlet NOx)**
- **Minimum Desired SCR Inlet Temp. = 585° F (can achieve 90% NOx reduction at or above this temp.)**
- **Minimum Inlet Temp. = 555° F (if temp. drops below, ammonia flow ceases)**
- **Maximum Economizer Outlet Temp. = 680° F (limitation is ductwork expansion joint material)**
- **Ammonia Slip < 5 ppm (measured at SCR Outlet)**
- **Temperature controlled by combination of economizer bypass dampers and economizer outlet dampers**

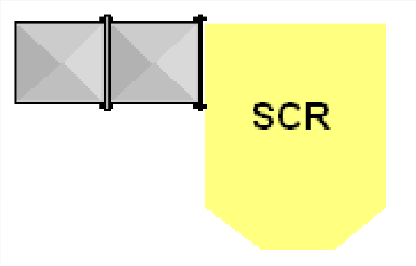
NOx Reduction Capabilities

Overfire Air:



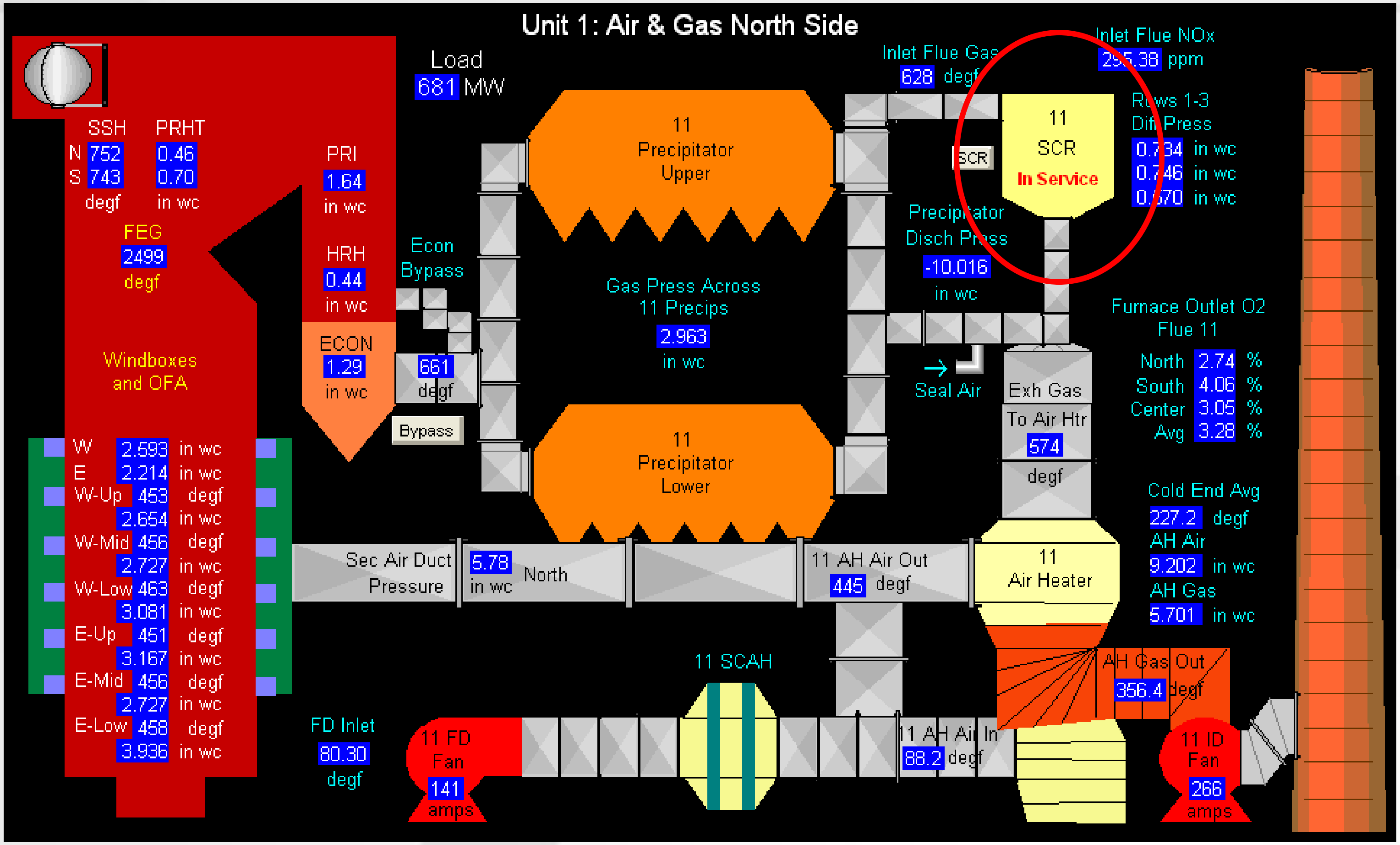
Used to reduced inlet NOx down to 0.4 lb/mmBtu

SCR:



Expected NOx Reduction: 90% (Delta between inlet & outlet NOx)

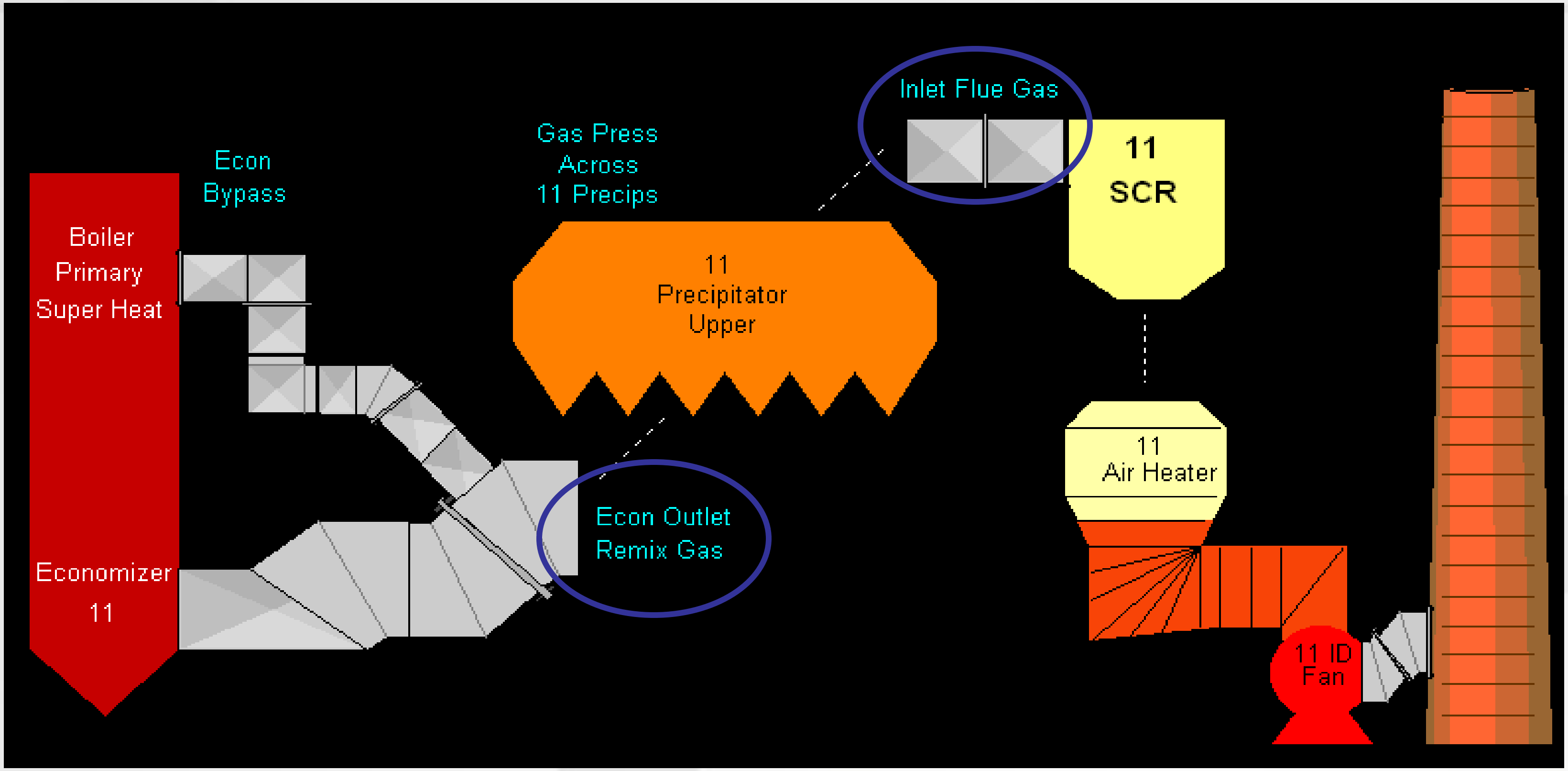
SCR Systems



Located on the hot-side of the boiler after the hot-side precipitators.

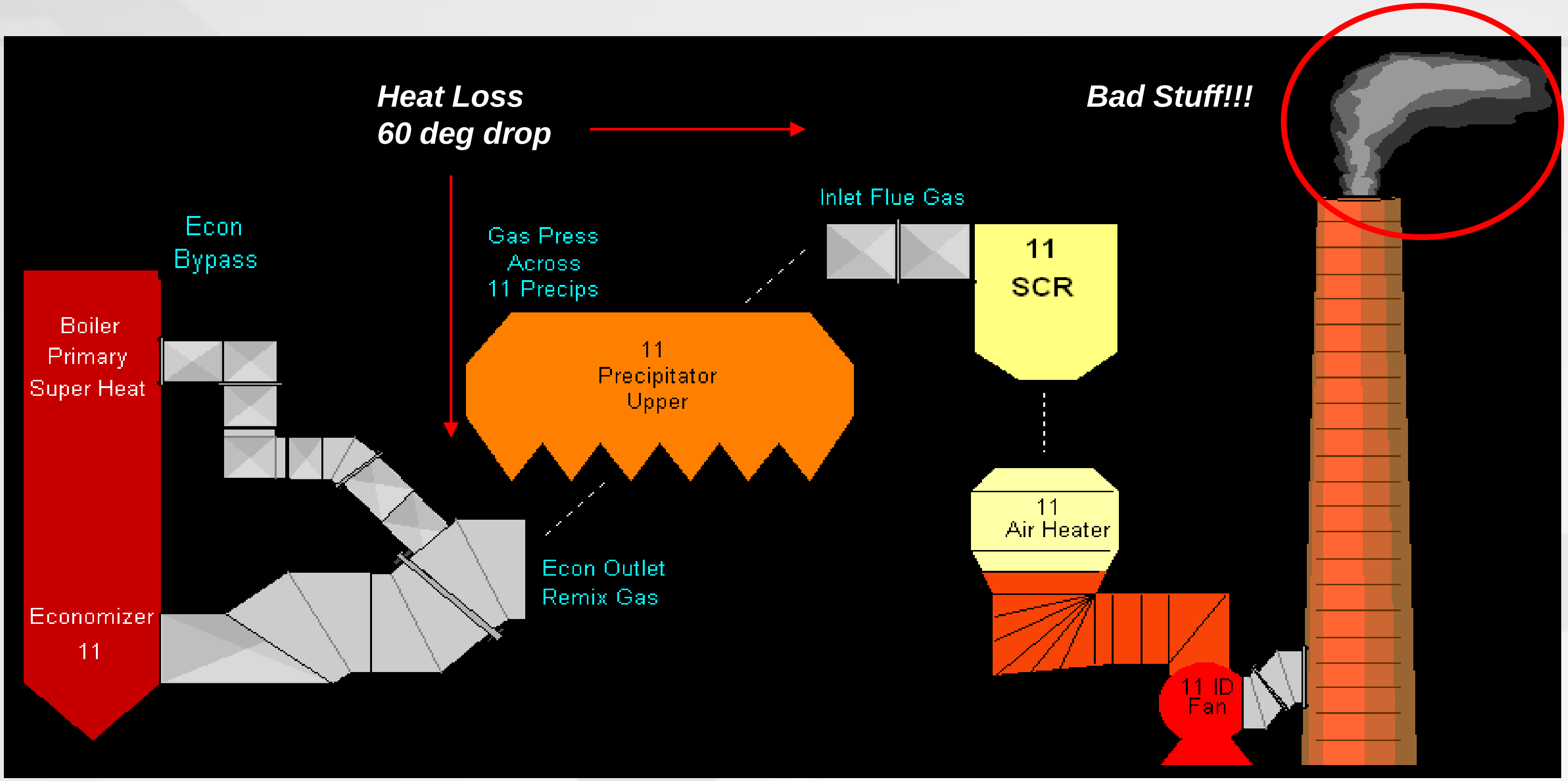
Installed in 2001 to reduce NOx

The SCR Design



The SCR design mandates a minimum inlet flue gas temperature of 555 degf to keep the SCR's in-service. An economizer bypass system, which was part of the initial design, allows flue gas to bypass the economizer section of the boiler and then “re-mix” with the economizer outlet flue gas to increase overall flue gas temperature to the SCR. Some temperature is also lost as the gas passes through the precipitator (see details on next slide).

The Problem



After installation of SCRs and for several years following, Brandon Shores struggled with standard DCS controls to maintain this minimum SCR inlet temperature during ozone season mainly due to the heat loss experienced across the precipitators and limitations of the standard DCS control strategies. When the SCR inlet temperature goes below 555 degf, the SCR ammonia system in the SCR automatically trips off and all NOx emissions are sent directly to stack which results in a high cost to the utility.

Before This Project

Solution:

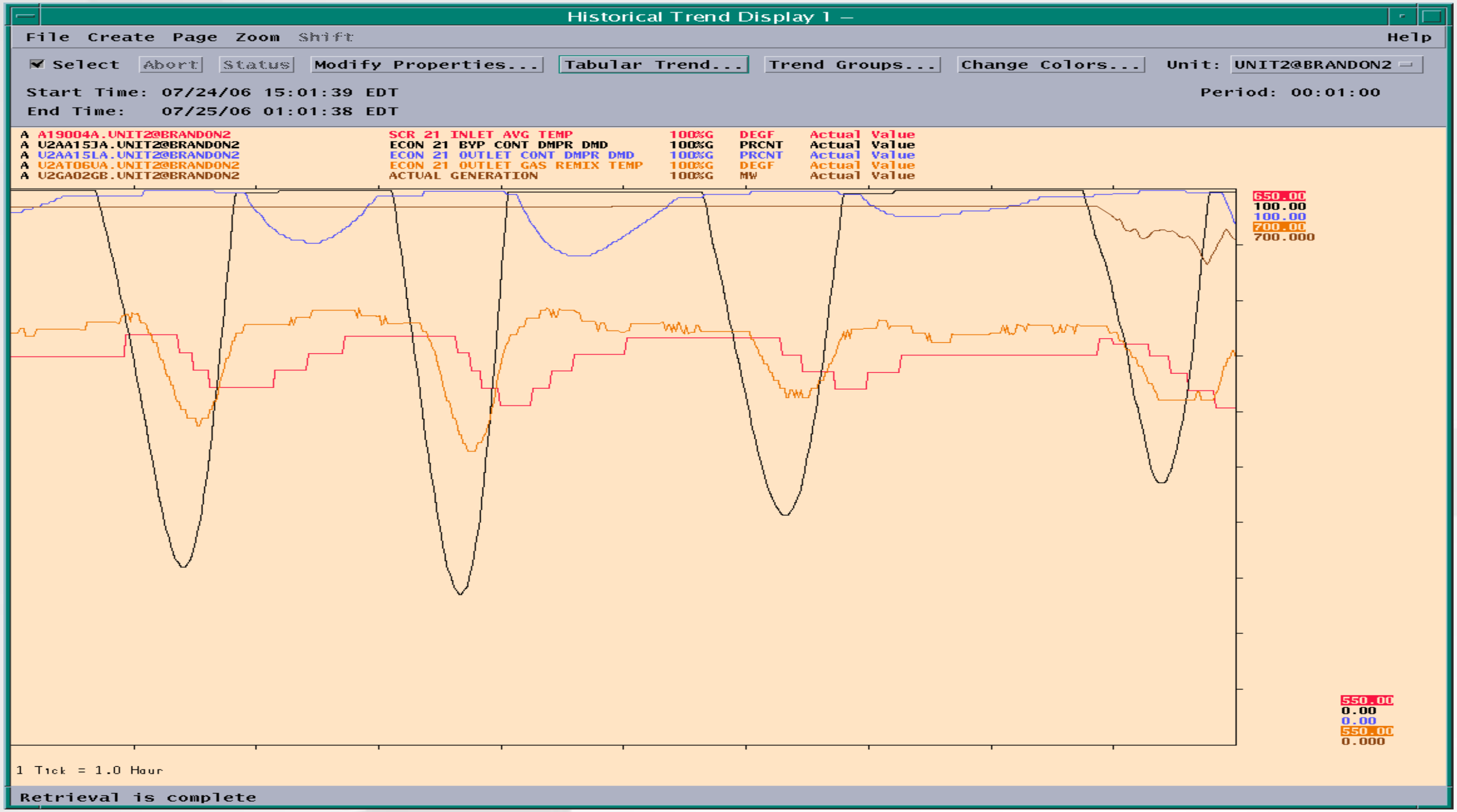
- Control the SCR Inlet Temperature using the Economizer Bypass Damper and Economizer Inlet Damper
- Use Economizer Remix Temperature as Feed-forward

Results:

- The base controls would go into a “Hunting” mode unexpectedly. The bypass damper would continually move from 0-100% (trend on next slide)
- The SCR inlet temperature lagged behind the economizer remix temperature significantly.
  - Controlling the SCR inlet temperature was difficult.
  - A change in the remix temperature could take up to 90 minutes to fully realized in the SCR inlet temperature
  - Low SCR inlet temps (due to low loads) tripped the ammonia system. This resulted in a large cost Impact due to higher NOx.
  - SCR inlet temperature below 585° F results is less than optimum SCR performance (SCR Catalyst is most effective between 585° F & 600° F)

Overall there were design problems with the original base DCS controls

Damper Swings



Where ideas become solutions.

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Combustion Optimization Ruled Out

Why?

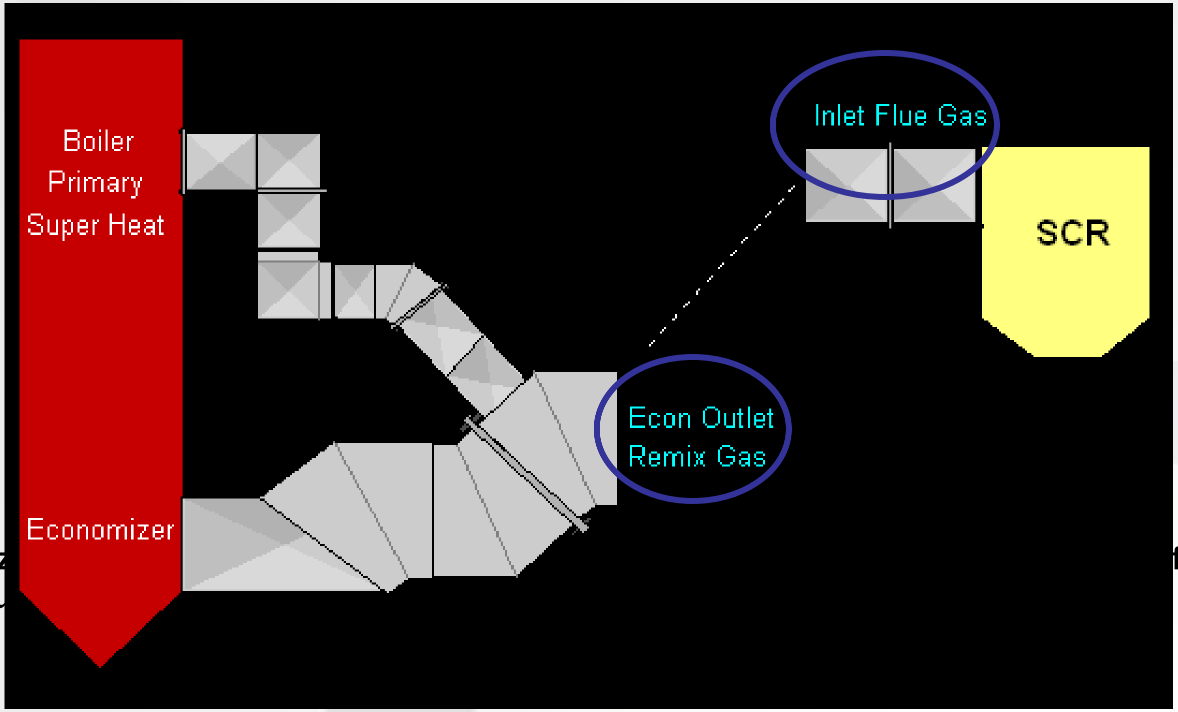
- Burner Register Controls are Manual.
- No DCS feedback regarding burner register positions.
- The flyash quality is constantly monitored by flyash processing facility and must me maintained at all times (process cannot handle large fluctuations in LOI).
- Prior attempt to manipulate combustion via a Neural Network was unsuccessful.

Emerson SmartProcess

In 2006, Constellation contracted Emerson Process Management Power and Water Solutions to provide an optimization system to first study the boiler design and provide an optimization system to optimize the SCR inlet flue gas temperature using a combination of advanced DCS control structures and a fuzzy neural model based optimization system.

Goals of Project

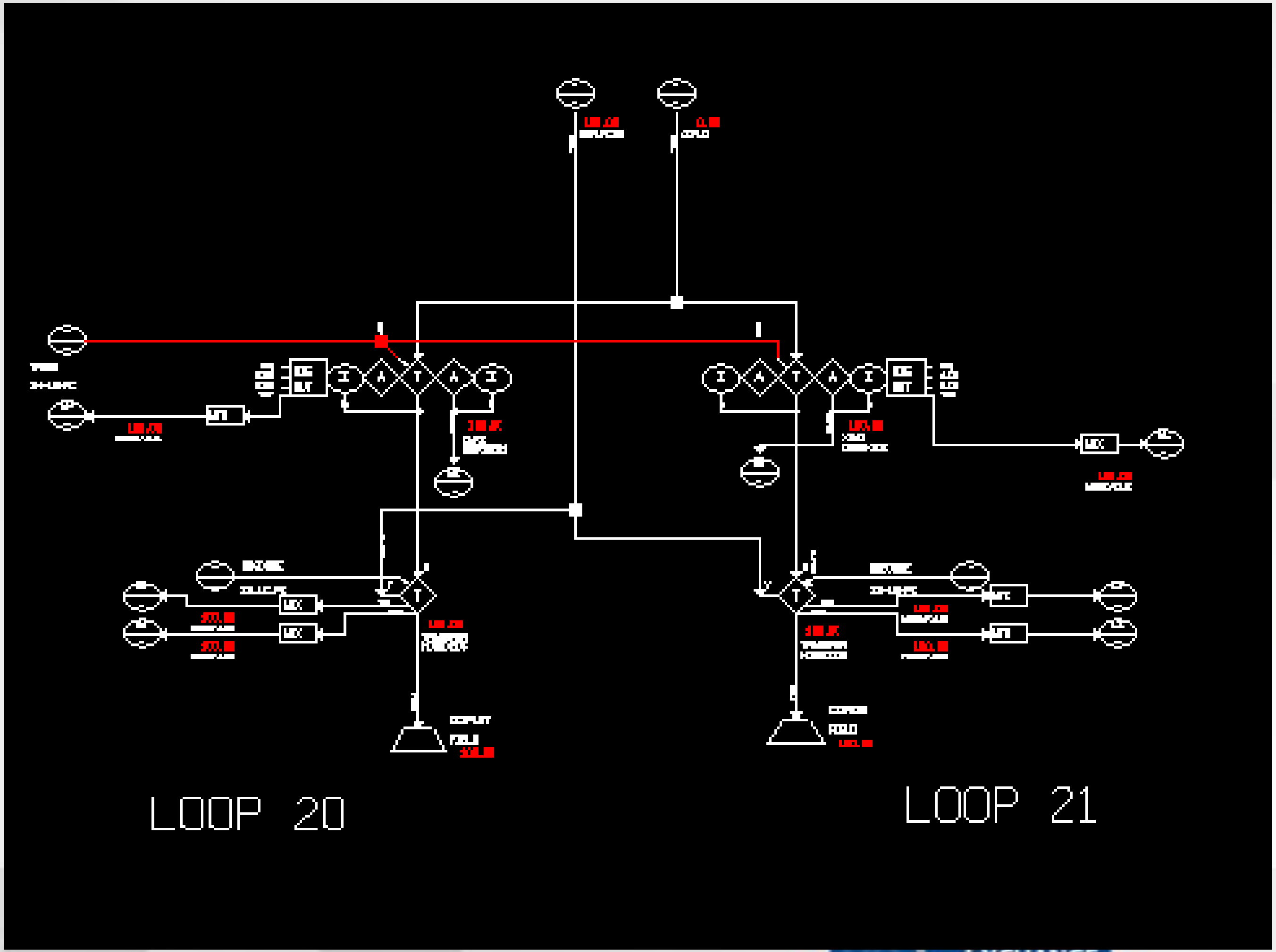
- Improve Base Ovation DCS Controls at Higher Loads for More Consistent Economizer Remix Temperature and SCR Inlet Temperature



- Add Optimiz ff of Ammonia Du

SCR Temperature Optimization

Part #1
New DCS Base Temperature Controls Design

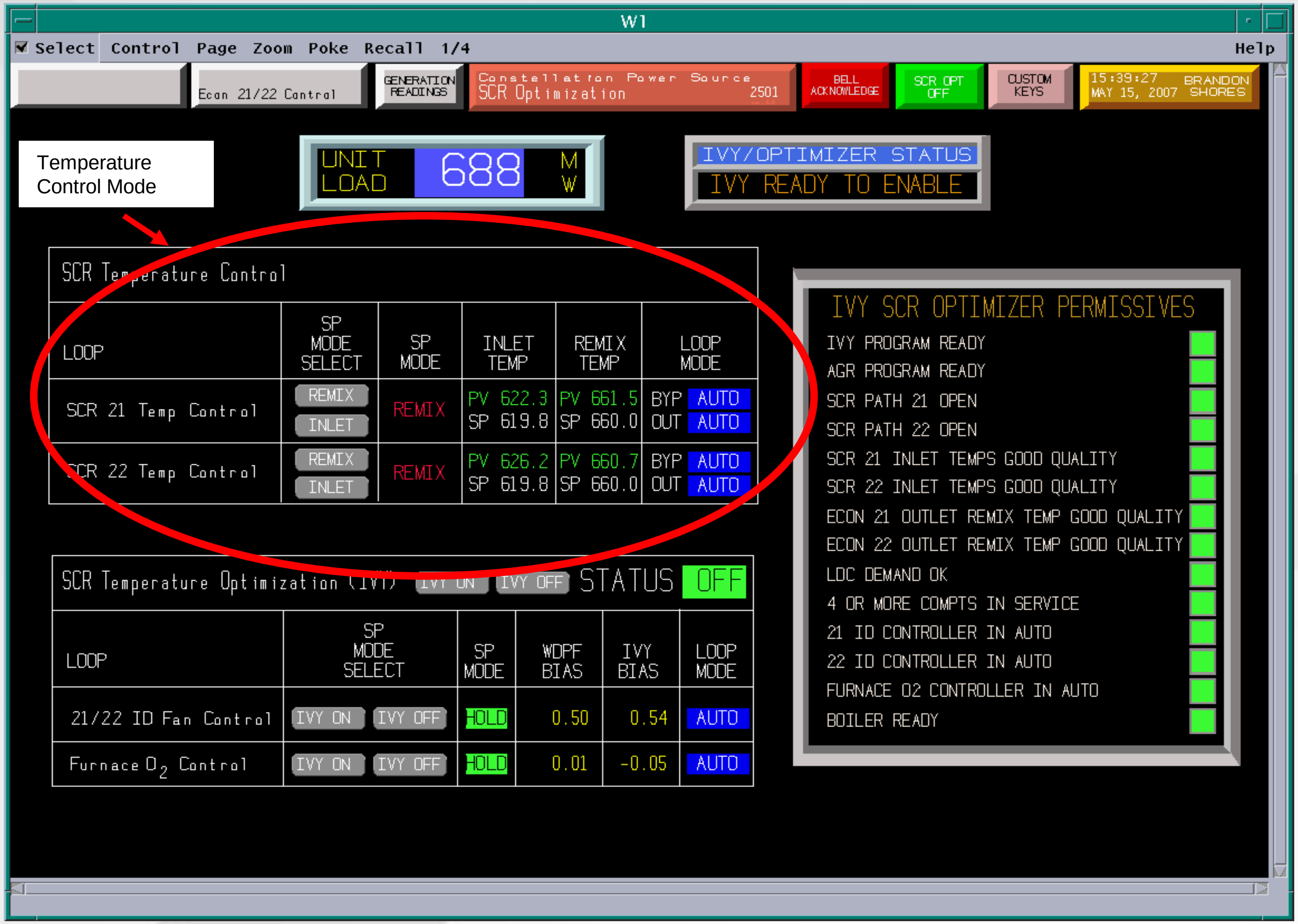


New Ovation DCS Base Remix Temperature Controls Design

- Ovation DCS is Now Controlling Economizer Remix Temperature by Using the Economizer Bypass Damper and Economizer Outlet Damper (rather than attempting to control SCR inlet temp).
- Control Structures Use Bypass Damper First Then Begin to Use the Economizer Outlet Damper When Bypass is Fully Opened and Remix Temperature is Below Setpoint
- SCR Inlet Temperature is More Consistent/Predictable as a Result of the Better-Controlled Remix Temperature
- Base Full Load Remix Temperature Setpoint is ~ 600° F
- Remix Temperature Must Not Exceed 680° F Due To Precipitator Issues
- Remix Temperature Setpoint Slides to ~600° F as Load Decreases
- 600° F is Minimum Setpoint

Graphic Changes for the new Temperature Control Design

Graphic Changes for the new Temperature Control Design



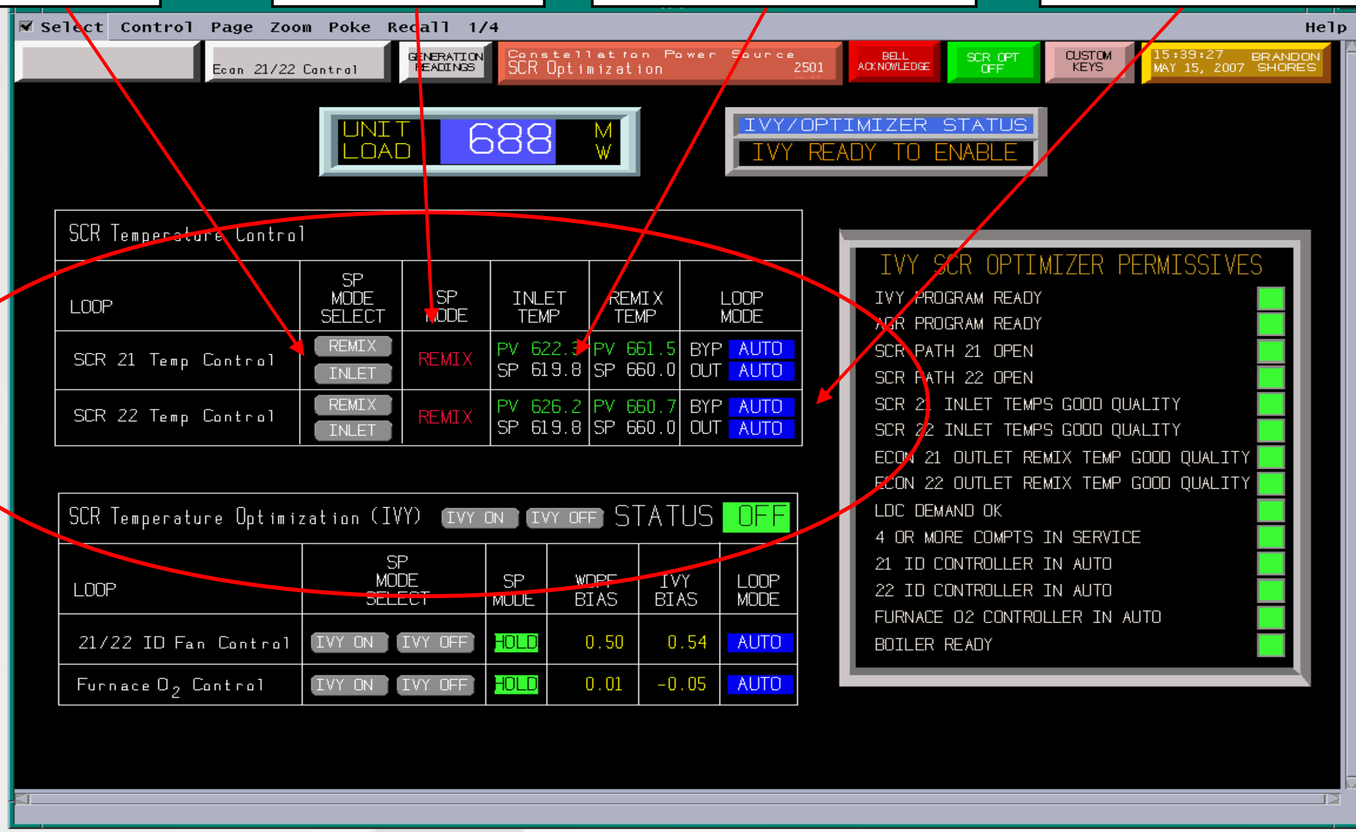
Graphic Changes for the new Temperature Control Design

Select: Remix or SCR Inlet Mode

Current Mode indication

Process & Setpoint Values

Bypass & Outlet Dampers Auto/Manual



Graphic Changes for the new Temperature Control Design

Damper Mode Indications: REMIX = Ctrl Remix Temp; INLET = Ctrl SCR Inlet Temp

Where ideas become solutions.

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Remix Temperature Controls: General Tips

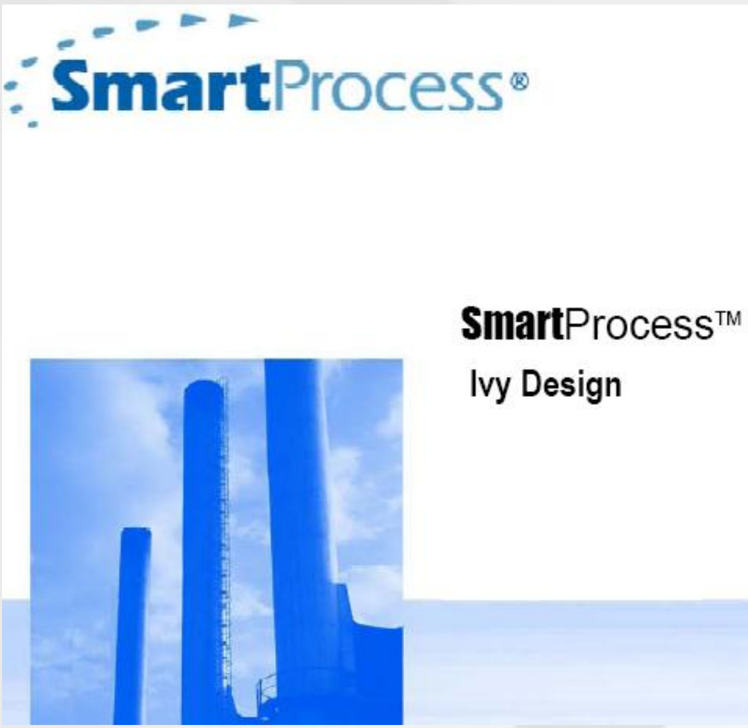
- The new DCS controls for the Econ Remix temperature are designed to be used: through the entire load range, year round, and with the SCR in or out of service
  - If remix temperature thermocouple goes *Bad Quality*, an alarm will appear. The recommendation is for operator to go to **Manual** on both dampers
  - Switching to old mode of controlling the SCR inlet temp is an option, but this mode utilizes remix temperature as *Feed-Forward*
- Switching between the old temperature controls and new temperature controls can be done with the dampers in **Auto.**

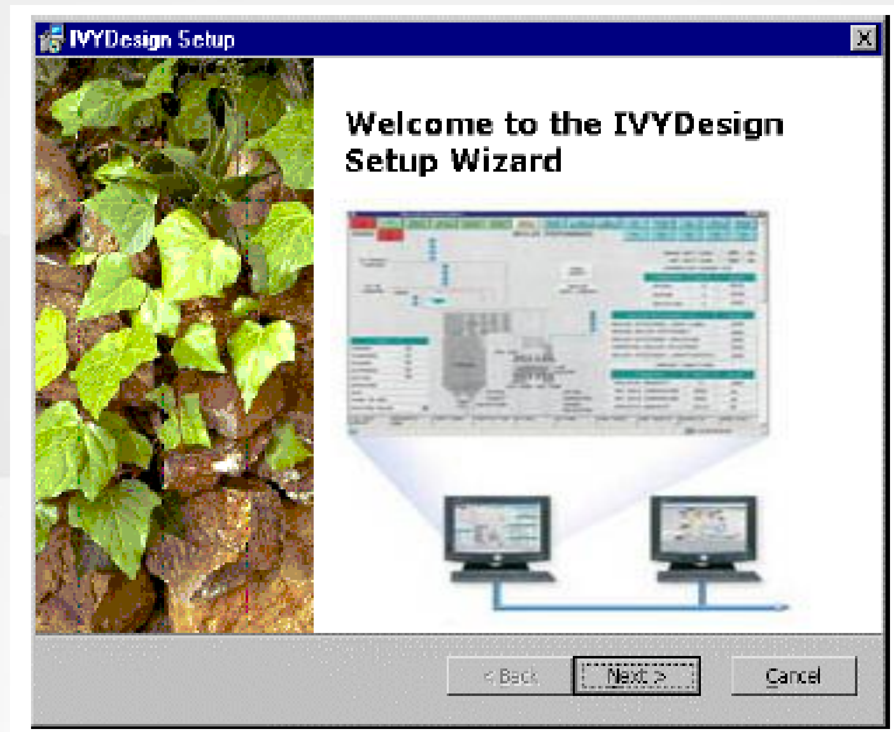
  Note: A small bump may occur since the two modes are controlling slightly different processes.

  Ops should monitor dampers while making the switch
- The goal is to remove the old temperature controls at the end of the year

SCR Temperature Optimization

Part #2
Optimization of SCR Inlet Temperatures at Lower Loads (SCR OPT)





SCR Inlet Temperature Optimization at Lower MW Loads

- The Specific Low Loads: ~350 MW to ~450 MW
- The Goal: Raise SCR Inlet Temperatures at Lower MW Loads to Keep Ammonia System in Service and Raise % Removal of NOx
- The Method: Calculate and inject optimal bias settings for 2 Ovation DCS control parameters

1. Bias O2 Setpoint

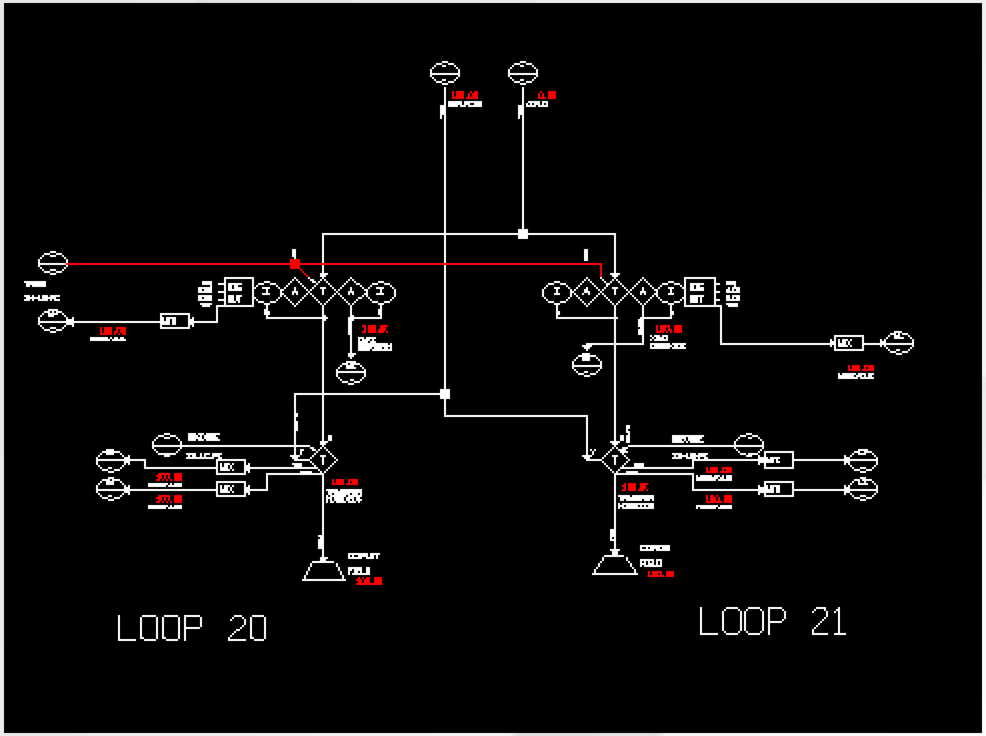
   Purpose: More Air in Boiler Gives Higher Temperatures. The current range of bias is a 0 – 1.9% increase in O2

2. Biases ID Fans

   Purpose: Bring two SCR inlet temperatures closer together to raise minimum temperature. The current range is 5% of total bias (One Fan +2.5% and the Other Fan -2.5%)

SCR Inlet Temperature Optimization at Lower MW Loads

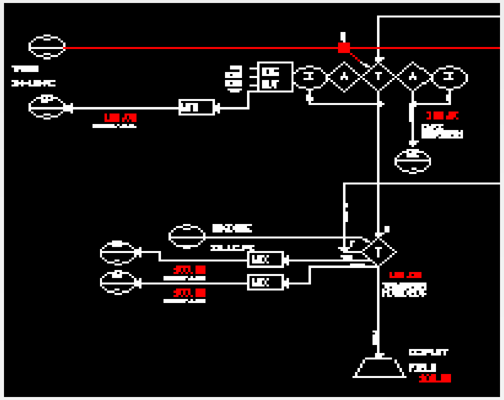
Ovation DCS Control Modifications



SCR Inlet Temperature Optimization at Lower MW Loads

Ovation DCS Control Modifications

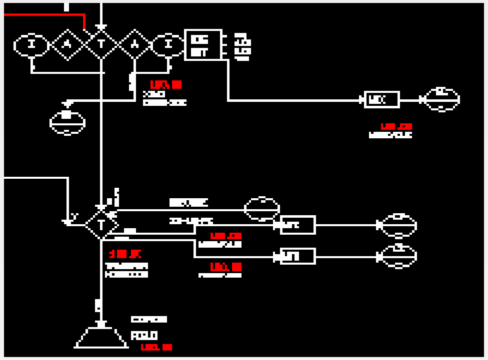
Furnace O2 Control Loop



- **New Optimization Bias Added to O2 Loop**
  - **When SCR OPT Optimization System is On and SCR OPT O2 Bias is selected, SCR OPT O2 Bias will be used instead of operator bias**
  - **Range of Bias is 0-1.9%: Additional air will result in higher SCR inlet temps at lower loads**
  - **SCR OPT O2 Bias will be removed once load > 450 MM**
  - **If the operator needs to bias O2 at loads > 450, then the O2 Bias should be removed from the SCR OPT control and the bias should be done as before.**
  - **When MW load is decreasing at night, the operator should put SCR OPT in control of the O2 bias**

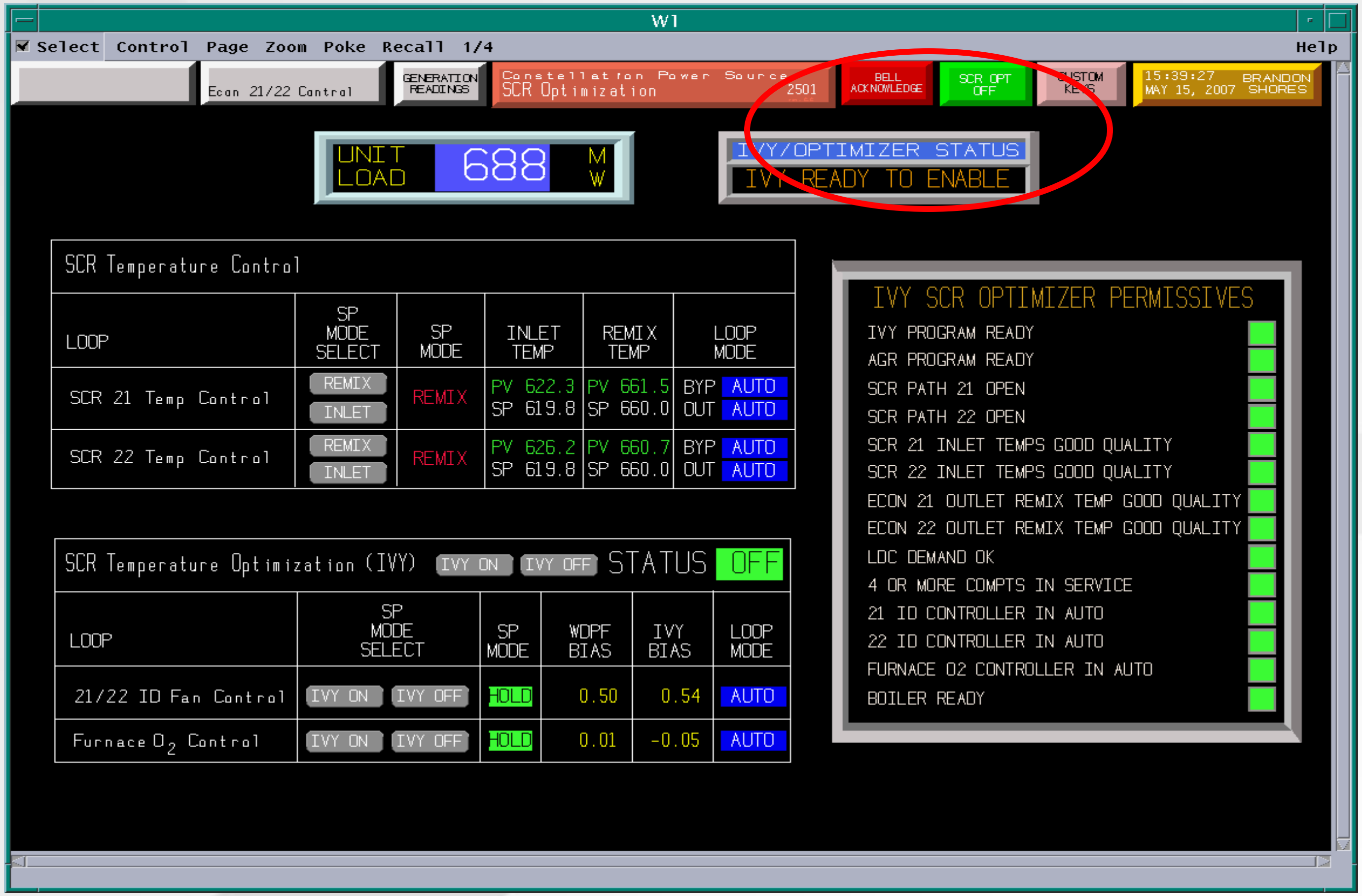
SCR Inlet Temperature Optimization at Lower MW Loads
Ovation DCS Control Modifications

21/22 ID FAN Control Loop



- **New Optimization Bias Added to ID Fan Loop**
  - **When the SCR OPT Optimization System is On and the SCR OPT ID Fan Bias is selected, the SCR OPT ID Fan Bias will be used instead of any operator bias**
  - **The current range of bias is a total of 5% (one ID Fan can be +2.5% and the other can be -2.5%). This bias will allow the SCR inlet temps to be controlled closer together.**
  - **The SCR OPT ID Fan Bias will be removed once load > 450 MM**
  - **If the operator needs to bias the ID Fans at loads > 450, then the ID Fan Bias should be removed from SCR OPT control and the bias should be done as before**
  - **When load decreases at night, SCR OPT should be put in control of ID Fan Bias.**

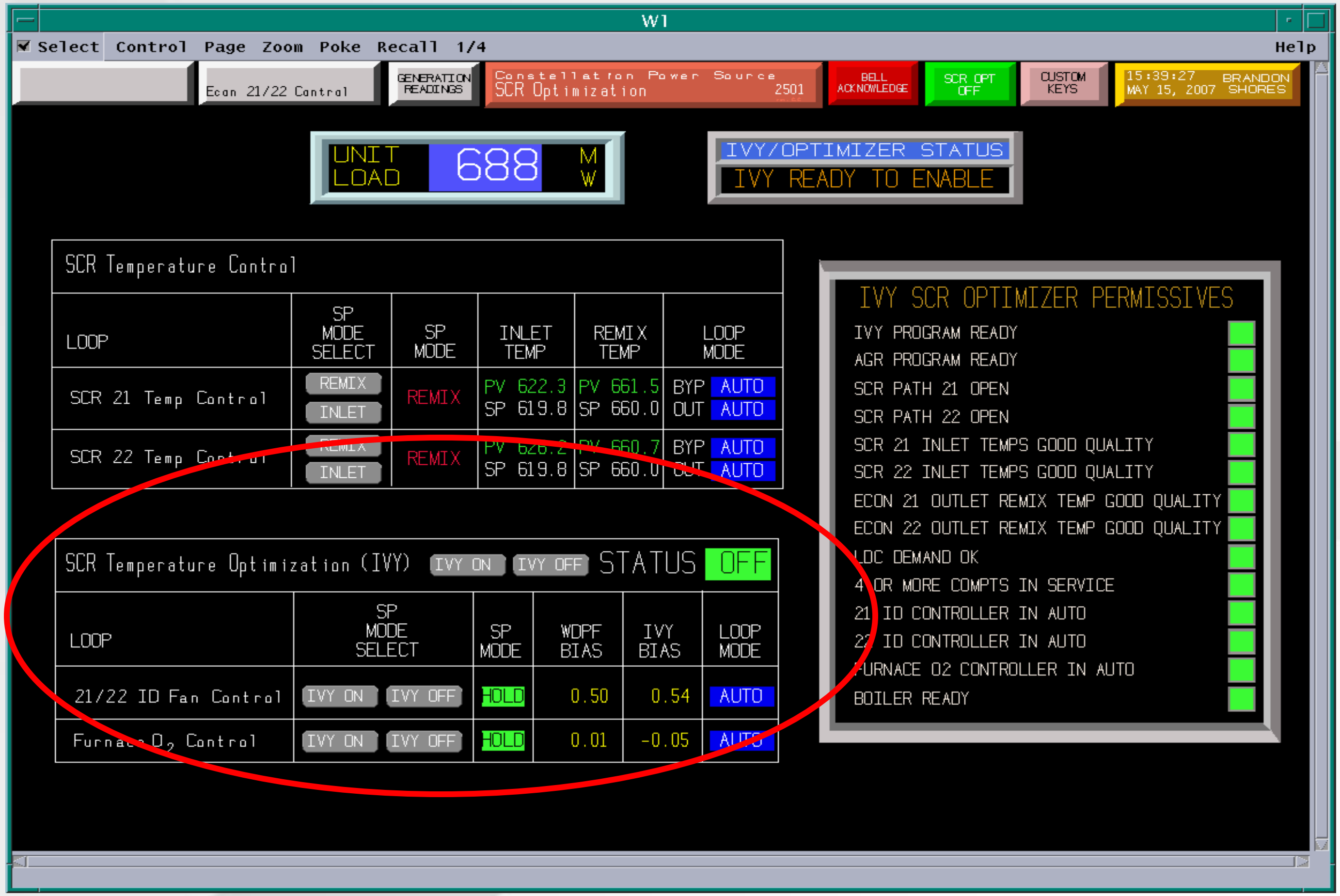
Graphic Changes for the new SCR Inlet Temperature Optimization
Optimizer Status



Graphic Changes for the new SCR Inlet Temperature Optimization *Optimizer Status*

- **SCR OPT PROGRAM TROUBLE**
  - SCR OPT Program is Not Running or Aggregates Program is Not Running
    - ACTION: Call Emerson
- **BOILER NOT READY**
  - Boiler Permissives Have Not Been Met for Boiler Optimization
    - ACTION: Check Permissive Window on This Graphic to See Which Permissive is Not Met
- **SCR OPT READY TO ENABLE**
  - All Boiler Permissives Made
  - SCR OPT Programs Are Running
  - SCR OPT Optimization is OFF
- **OPTIMZER READY**
  - All Boiler Permissives Made
  - SCR OPT Programs Are Running
  - SCR OPT Optimization is ON
  - O2 and ID Fans Are Not in SCR OPT Control
- **OPTIMIZER ON O2 ONLY**
  - All Boiler Permissives Made
  - SCR OPT Programs Are Running
  - SCR OPT Optimization is ON
  - O2 Bias in SCR OPT Control, ID Fan Bias Not in SCR OPT Control
- **OPTIMIZER ON IDS ONLY**
  - All Boiler Permissives Made
  - SCR OPT Programs Are Running
  - SCR OPT Optimization is ON
  - O2 Bias Not In SCR OPT Control, ID Fan Bias In SCR OPT Control
- **OPTIMIZER RUNNING**
  - All Boiler Permissives Made
  - SCR OPT Programs Are Running
  - SCR OPT Optimization is ON
  - O2 Bias In SCR OPT Control, ID Fan Bias In SCR OPT Control

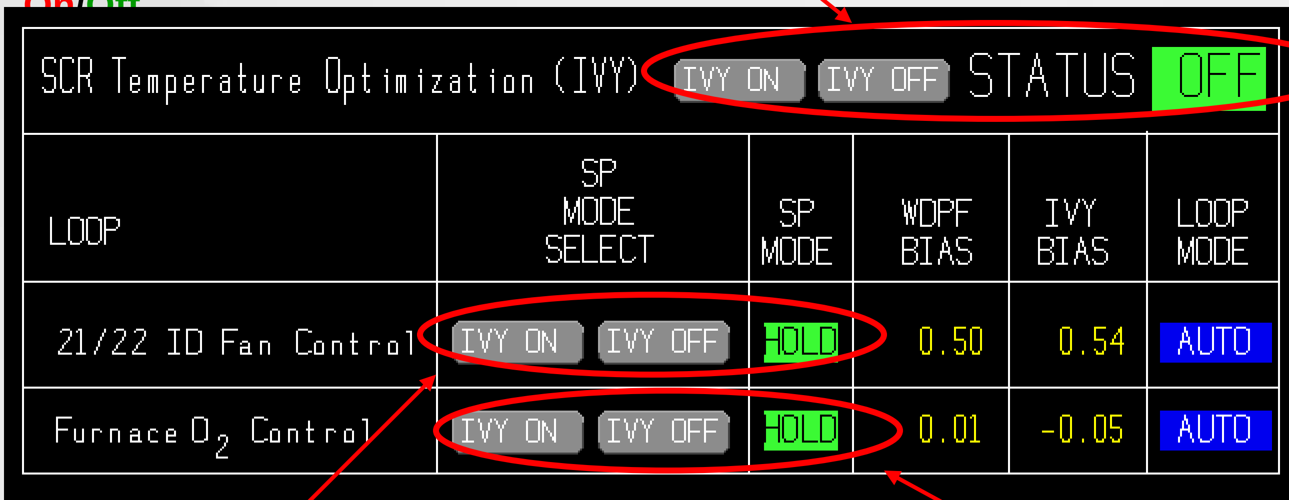
Graphic Changes for the new
SCR Inlet Temperature Optimization
Optimizer System Buttons



Graphic Changes for the new SCR Inlet Temperature Optimization

Optimizer System Buttons

Overall SCR OPT Optimization System: On/Off



SCR OPT Optimizer - Bias ID Fans Status

- **On** – Optimize On & controlling ID bias
- **Off** – Optimizer Off & not controlling ID bias
- **Hold** – SCR OPT Optimizer Off, but does have control of ID Bias (if SCR OPT optimizer is turned on, it will have control of ID Bias)

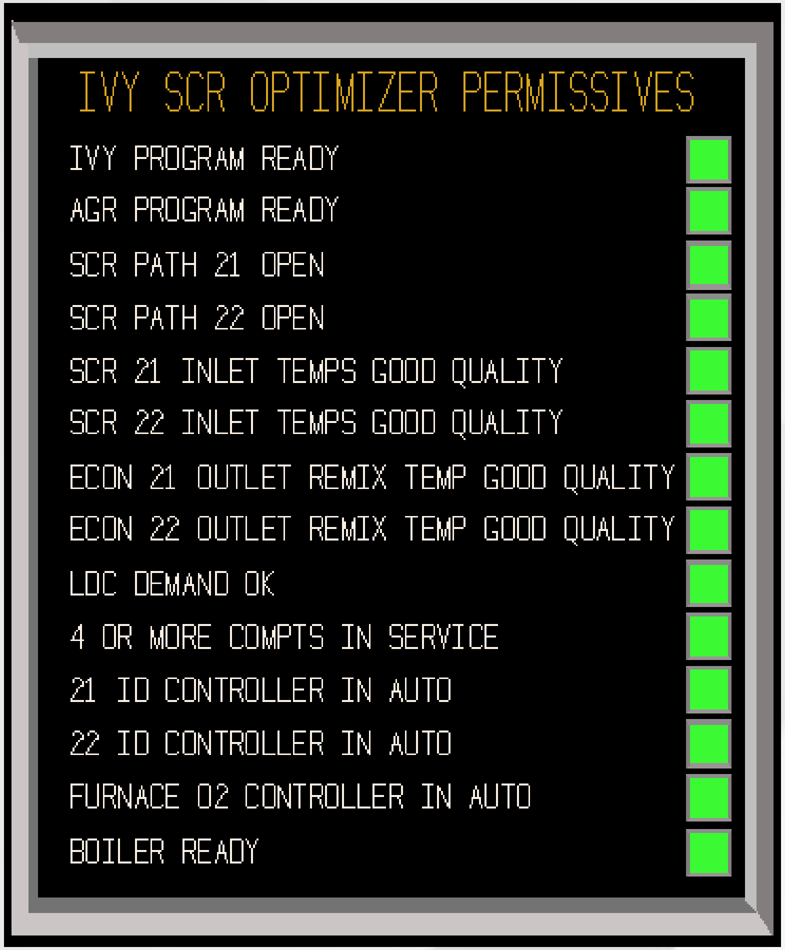
SCR OPT Optimizer - Bias O2 Status

- **On** – Optimize On & controlling O2 bias
- **Off** – Optimizer Off & not controlling O2 bias
- **Hold** – SCR OPT Optimizer Off, but does have control of O2 Bias (if SCR OPT optimizer is turned on, it will have control of O2 Bias)

Graphic Changes for the new SCR Inlet Temperature Optimization

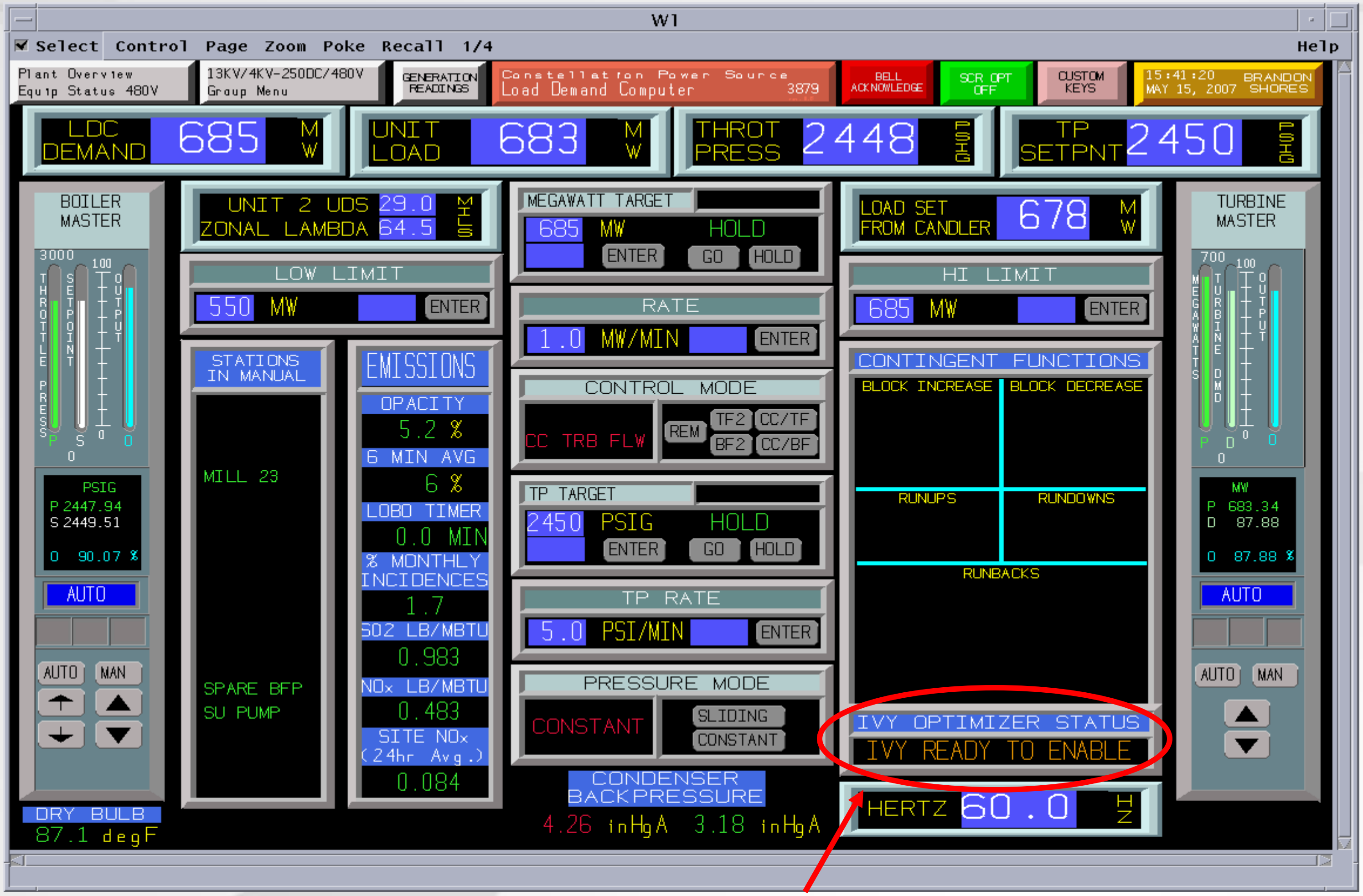
Optimizer System Permissives

Graphic Changes for the new SCR Inlet Temperature Optimization
Optimizer System Permissives



- SCR OPT PROGRAM READY
  - SCR OPT program is operational
- AGR PROGRAM READY
  - AGR program is operational
- SCR PATH 21 AND 22 OPEN
  - Both flow paths must be open to turn scr optimization system on
- SCR 21/22 INLET TEMPS AND 21/22 REMIX TEMPS GOOD QUALITY
  - Must have good quality on all 4 temperatures for optimization to be on
  - Bad quality on any of the 4 will automatically turn SCR OPT scr optimization off and optimization biases will go to ~0
- LDC DEMAND OK
  - LDC demand must be >310 mw to turn optimization system off
  - If demand goes below 310 mw, optimization system will automatically turn off and any optiimization biases will go to ~0
- 4 OR MORE COMPS IN SERVICE
  - SCR OPT SCR optimization system can only be turned on if 4 or more compartments are in service
- 21/22 ID CONTROLLER IN AUTO
  - 21/22 ID fan controllers must be in AUTO for CRO to enable the ID fan bias for SCR OPT
- FURNACE O2 CONTROLLER IN AUTO
  - Furnace O2 controller must be in AUTO for CRO to enable the o2 bias for SCR OPT
- BOILER READY
  - Logical AND of permissives 3-8 above. Indicates the boiler is ready for optimization

Graphic Changes for the new SCR Inlet Temperature Optimization *LDC*



Messages are the same as in slide 28

Where ideas become solutions.

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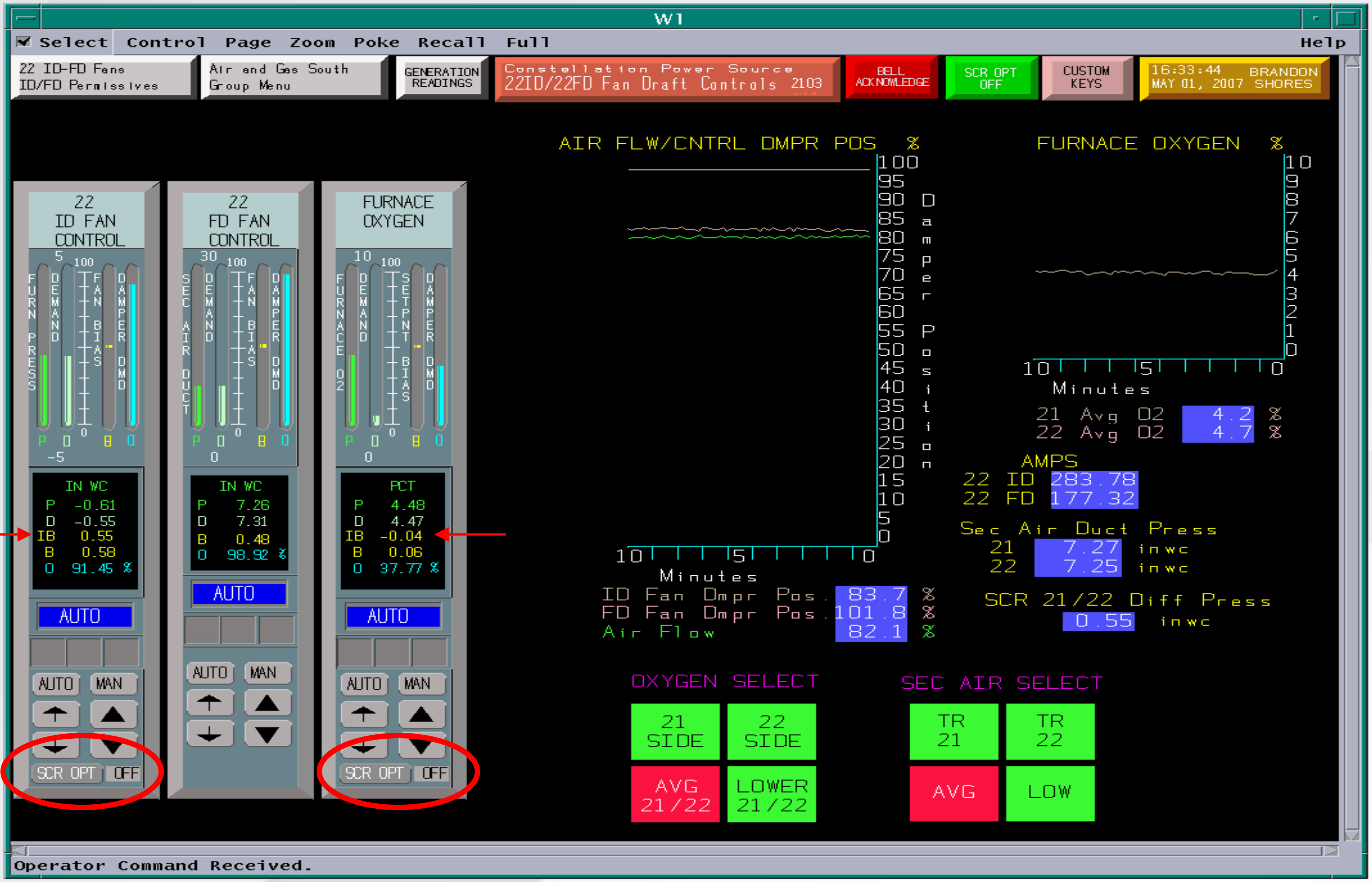
Graphic Changes for the new
SCR Inlet Temperature Optimization
Fan Controls

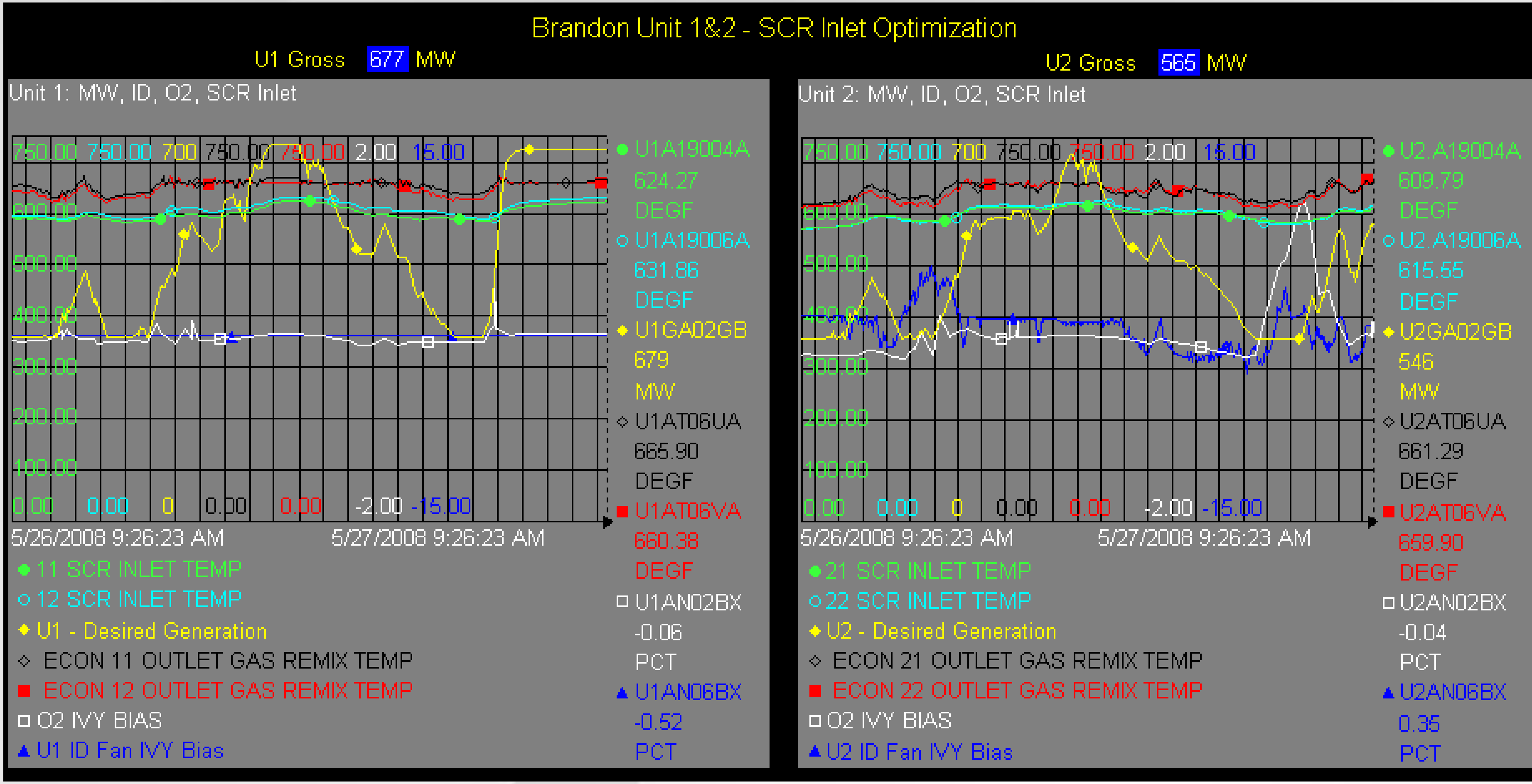


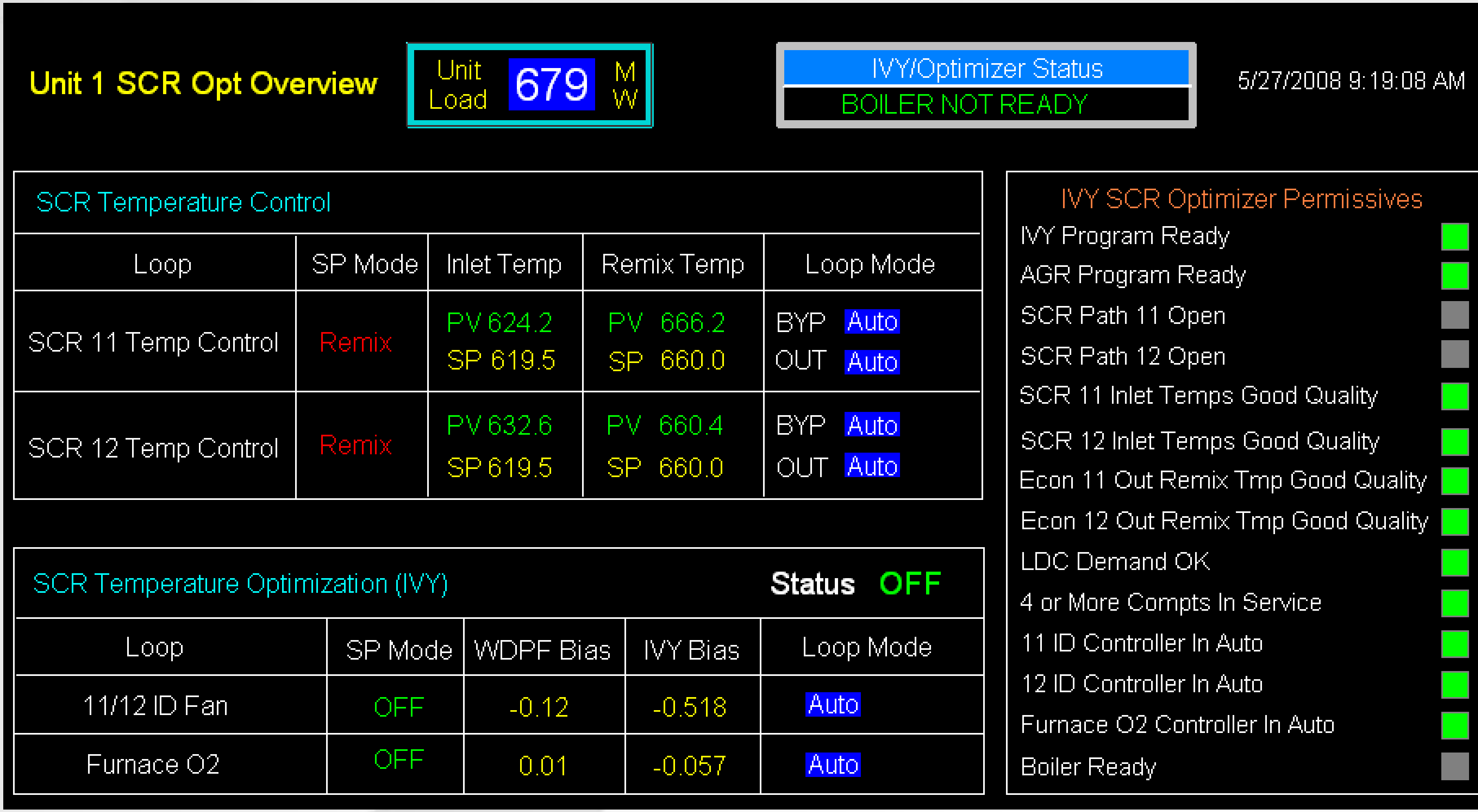
Where ideas become solutions.

EMERSON GLOBAL USERS EXCHANGE

SCR Optimization
General Tips

- IVY Should Be On and In Control of Biases of ID Fans and O2
  - High Loads: SCR OPT should not move ID Fans or O2, Optimization Biases should be 0
  - If operator needs control of either at high loads, SCR OPT should be Off for that parameter. Bias the normal way.
  - Once excursion ends, control of that parameter should be returned to SCR OPT (optimization).
- Ramping Unit Down
  - As unit ramps Down, SCR OPT (optimization) will try to control SCR inlet temp to ~580 – 585° F (alarm occurs at 560° F, ammonia trips at 555 ° F)
  - SCR OPT (optimization) will also try to bring SCR 21 inlet temp and SCR 22 inlet temp closer together
  - Biases will be applied to O2 and ID Fans from SCR OPT (optimization)
  - Make sure SCR OPT is On and Controlling ID Fan Bias and O2 Bias prior to ramp down for maximum effect
- Ramping Unit Up
  - As unit ramps up, SCR OPT (optimization) Biases to O2 and ID Fans should slowly bleed out to a value near 0 as load increases.
  - Unless operator removes optimization control of these Biases, SCR OPT (Optimization) will still have control of Biases


Brandon Unit 1&2 - SCR Inlet Optimization
U1 Gross 677 MW
U2 Gross 565 MW
Unit 1: MW, ID, O2, SCR Inlet
Unit 2: MW, ID, O2, SCR Inlet
750.00 750.00 700 750.00 750.00 2.00 15.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00 0.00 0 0.00 0.00 -2.00 -15.00
5/26/2008 9:26:23 AM
5/27/2008 9:26:23 AM
U1A19004A 624.27 DEGF
U1A19006A 631.86 DEGF
U1GA02GB 679 MW
U1AT06UA 665.90 DEGF
U1AT06VA 660.38 DEGF
U1AN02BX -0.06 PCT
U1AN06BX -0.52 PCT
11 SCR INLET TEMP
12 SCR INLET TEMP
U1 - Desired Generation
ECON 11 OUTLET GAS REMIX TEMP
ECON 12 OUTLET GAS REMIX TEMP
O2 IVY BIAS
U1 ID Fan IVY Bias
U2.A19004A 609.79 DEGF
U2.A19006A 615.55 DEGF
U2GA02GB 546 MW
U2AT06UA 661.29 DEGF
U2AT06VA 659.90 DEGF
U2AN02BX -0.04 PCT
U2AN06BX 0.35 PCT
21 SCR INLET TEMP
22 SCR INLET TEMP
U2 - Desired Generation
ECON 21 OUTLET GAS REMIX TEMP
ECON 22 OUTLET GAS REMIX TEMP
O2 IVY BIAS
U2 ID Fan IVY Bias


Unit 1 SCR Opt Overview
Unit Load 679 MW
IVY/Optimizer Status
BOILER NOT READY
5/27/2008 9:19:08 AM
SCR Temperature Control
Loop | SP Mode | Inlet Temp | Remix Temp | Loop Mode
SCR 11 Temp Control | Remix | PV 624.2 SP 619.5 | PV 666.2 SP 660.0 | BYP Auto OUT Auto
SCR 12 Temp Control | Remix | PV 632.6 SP 619.5 | PV 660.4 SP 660.0 | BYP Auto OUT Auto
SCR Temperature Optimization (IVY)
Status OFF
Loop | SP Mode | WDPF Bias | IVY Bias | Loop Mode
11/12 ID Fan | OFF | -0.12 | -0.518 | Auto
Furnace O2 | OFF | 0.01 | -0.057 | Auto
IVY SCR Optimizer Permissives
IVY Program Ready
AGR Program Ready
SCR Path 11 Open
SCR Path 12 Open
SCR 11 Inlet Temps Good Quality
SCR 12 Inlet Temps Good Quality
Econ 11 Out Remix Tmp Good Quality
Econ 12 Out Remix Tmp Good Quality
LDC Demand OK
4 or More Compts In Service
11 ID Controller In Auto
12 ID Controller In Auto
Furnace O2 Controller In Auto
Boiler Ready

Unit 2 SCR Optimization

Unit Load **575** MW

IVY/Optimizer Status
IVY READY TO ENABLE

5/27/2008 9:29:08 AM

SCR Temperature Control

Loop	SP Mode	Inlet Temp	Remix Temp	Loop Mode
SCR 21 Temp Control	Remix	PV 610.2 SP 614.5	PV 660.2 SP 660.0	BYP Auto OUT Auto
SCR 22 Temp Control	Remix	PV 615.9 SP 614.5	PV 659.7 SP 660.0	BYP Auto OUT Auto

SCR Temperature Optimization (IVY)

Status OFF

Loop	SP Mode	WDPF Bias	IVY Bias	Loop Mode
21/22 ID Fan	OFF	-0.09	0.638	Auto
Furnace O2	OFF	-0.63	-0.047	Auto

IVY SCR Optimizer Permissives

- IVY Program Ready
- AGR Program Ready
- SCR Path 21 Open
- SCR Path 22 Open
- SCR 21 Inlet Temps Good Quality
- SCR 22 Inlet Temps Good Quality
- Econ 21 Out Remix Tmp Good Quality
- Econ 22 Out Remix Tmp Good Quality
- LDC Demand OK
- 4 or More Compts In Service
- 21 ID Controller In Auto
- 22 ID Controller In Auto
- Furnace O2 Controller In Auto
- Boiler Ready

Years of experience in process control design, implementation, and field installation

AES Alliant Energy Ameren Energy Generating American Electric Power Constellation Power Source Generation Dairyland Po... ...rgy Power Generati... ...Edison Mission ... ...im. T. Kosciusz... ...ntergy Louisian... ...thority Keyspan... ...ration (KEPCO... ...evada Power ... ...Public Service of New Hampshire Saudi Electric Company Seminole Electric Cooperative Sempra Energy Resources Southern California Edison University of Michigan We Energies Xcel Energy Zespol Elektrownia Ostroleka, S.A.

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Where ideas become solutions