MAY 14-16, 2013

ROSEMONT, IL

DONALD E. STEPHENS CONVENTION CENTER

ELECTRIC POWER™ CONFERENCE & EXHIBITION

SNCR Technology for Fleetwide Compliance

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Outline

- Review MWGen Requirements
- Technology Options and Evaluations
- SNCR Technology Overview
- Teaming and Project Approach
- Project Scope, Schedule and Equipment
- Project Challenges
- Current Status

MWGen Requirements – State of Illinois

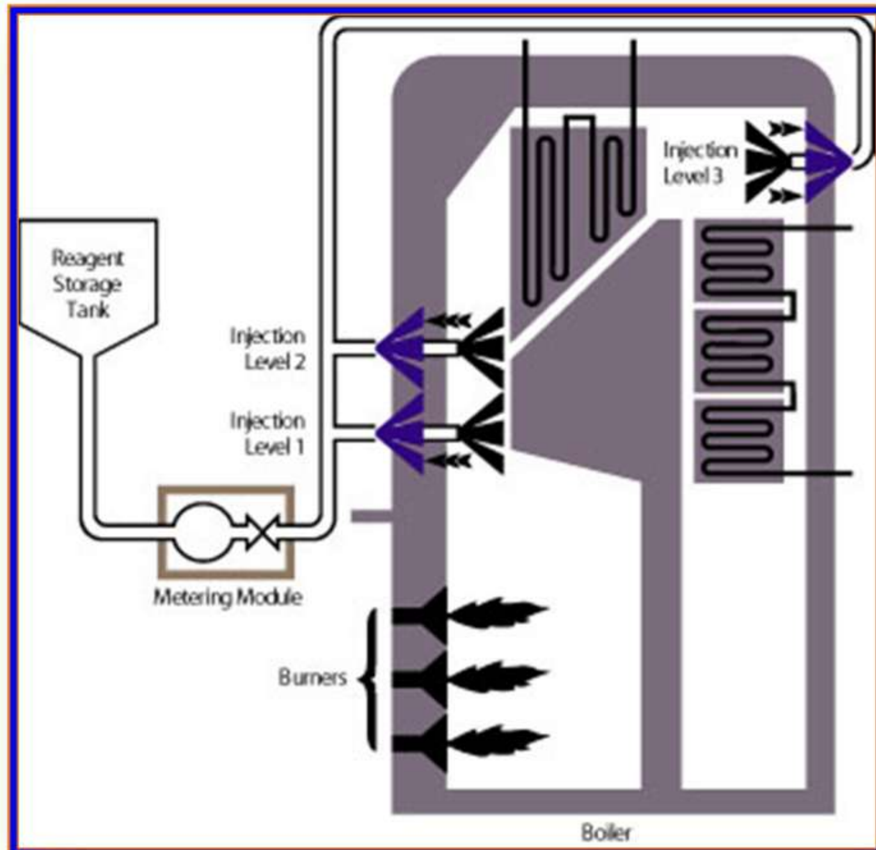
- Combined Pollutant Standard (CPS)
  - 2006 Agreement
  - Mercury Controls – July 2009
  - NOx
    - January 2012 Compliance date
    - Annual Fleet Average - 0.11lb/MMBtu
  - SO2
    - January 2013 Compliance date
    - Fleet average 0.44 lb/MMBtu
    - Fleet Average steps down each year to 0.11lb/MMBtu by 2019

MWGen NOx Assessment

- Fleet operating with Low-NOx burners
- PRB coal operation
- Low fleetwide baseline emissions – 0.20-0.25 lbMbtu
- Options to meet NOx target
  - Install SCR on largest cyclone fired units
  - Install In- Duct SCR on largest units
  - Consider SNCR and RRI as alternative on multiple units
  - Derate units

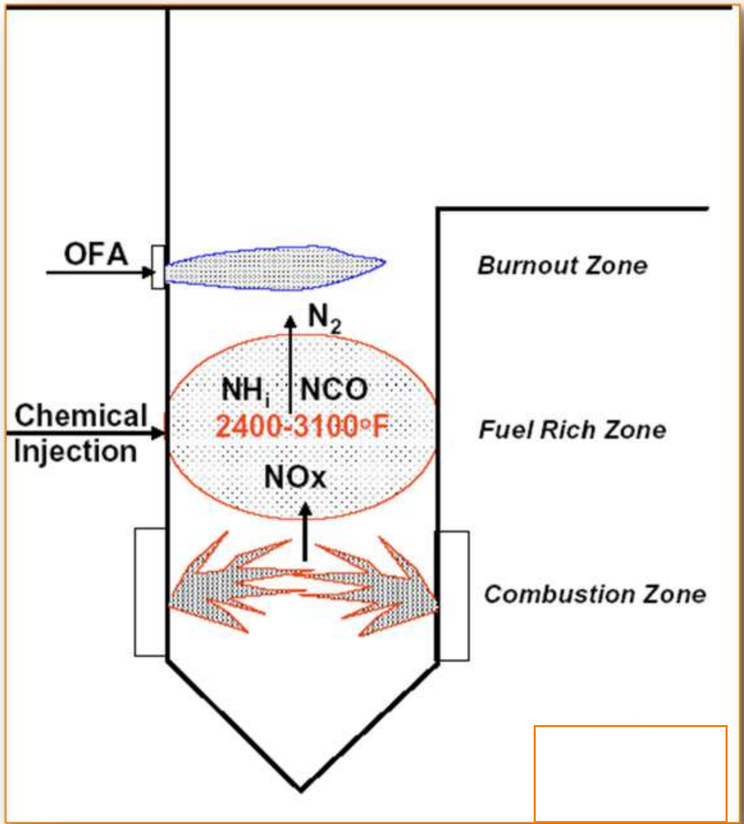
SNCR Technology Overview: NOxOUT® and HERT™ Systems

- In-furnace, Post-combustion NO_x Control
- Injection of Urea in Upper Furnace
- Process Reaction Temperature Range: 1600°F to 2200°F
- 20-30% typical NOx reduction on utility units
- $5 – 20/kw typical of total installed price



Rich Reagent Injection (RRI) Technology Overview

- 40 to 60% NO_x Reduction Combined with SNCR on Cyclone Boilers
- NO_x Reduction in 30% Range with RRI Only
- Non-catalytic Reduction of NO_x via Urea Injection in sub-stoichiometric Conditions (SR: 0.85 to 0.95)
- No Reagent Slip Due to High Residence Time and Reagent Oxidation in the Burnout Zone
- Process Reaction Temperature Range: 2600°F to 3100°F
- Technology Licensed from REI and EPRI



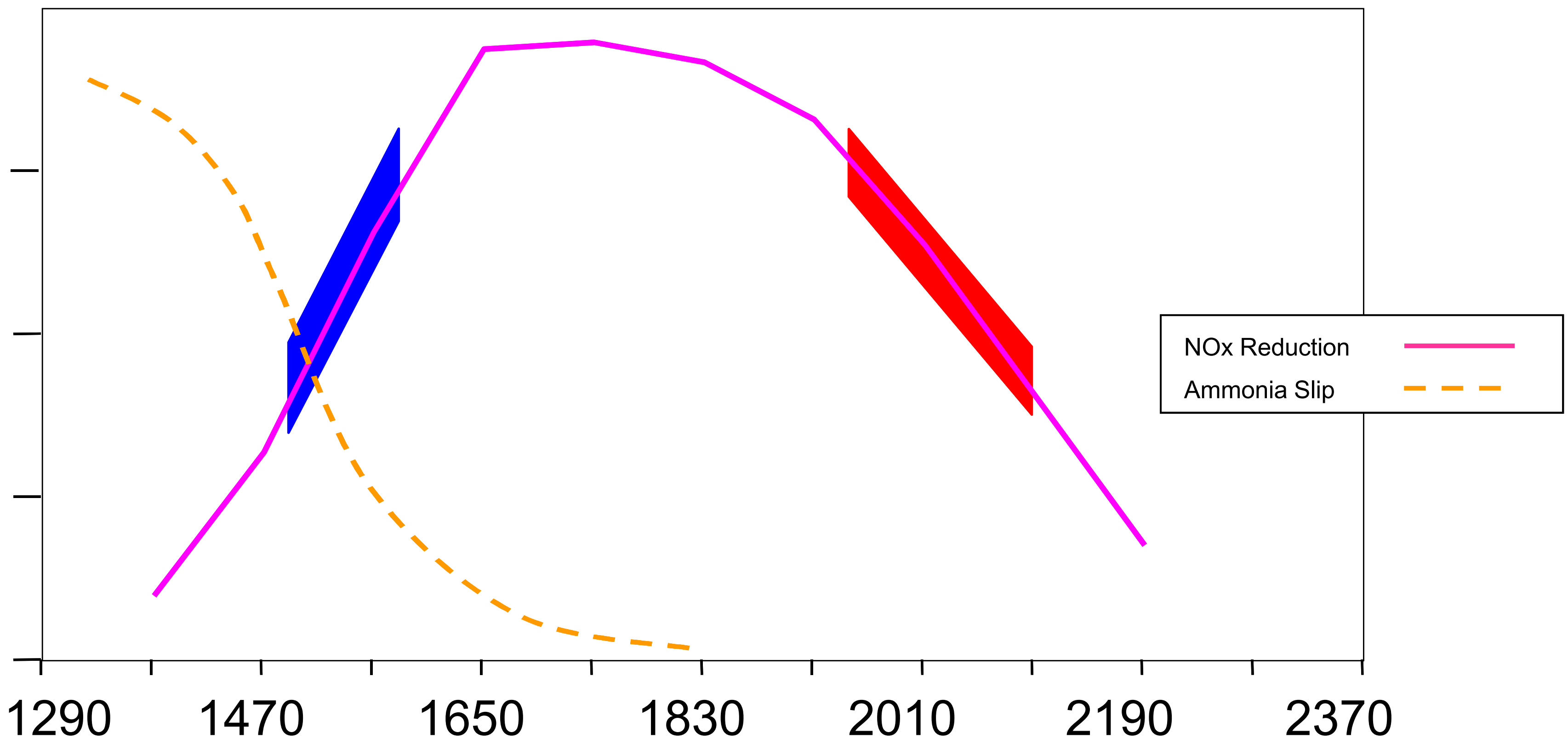
“Right Side of Slope” Injection

Low Temperature Issues

- Slow Droplet Evaporation
- Slow Kinetics
- Low OH Concentration
- Ammonia Slip Increase

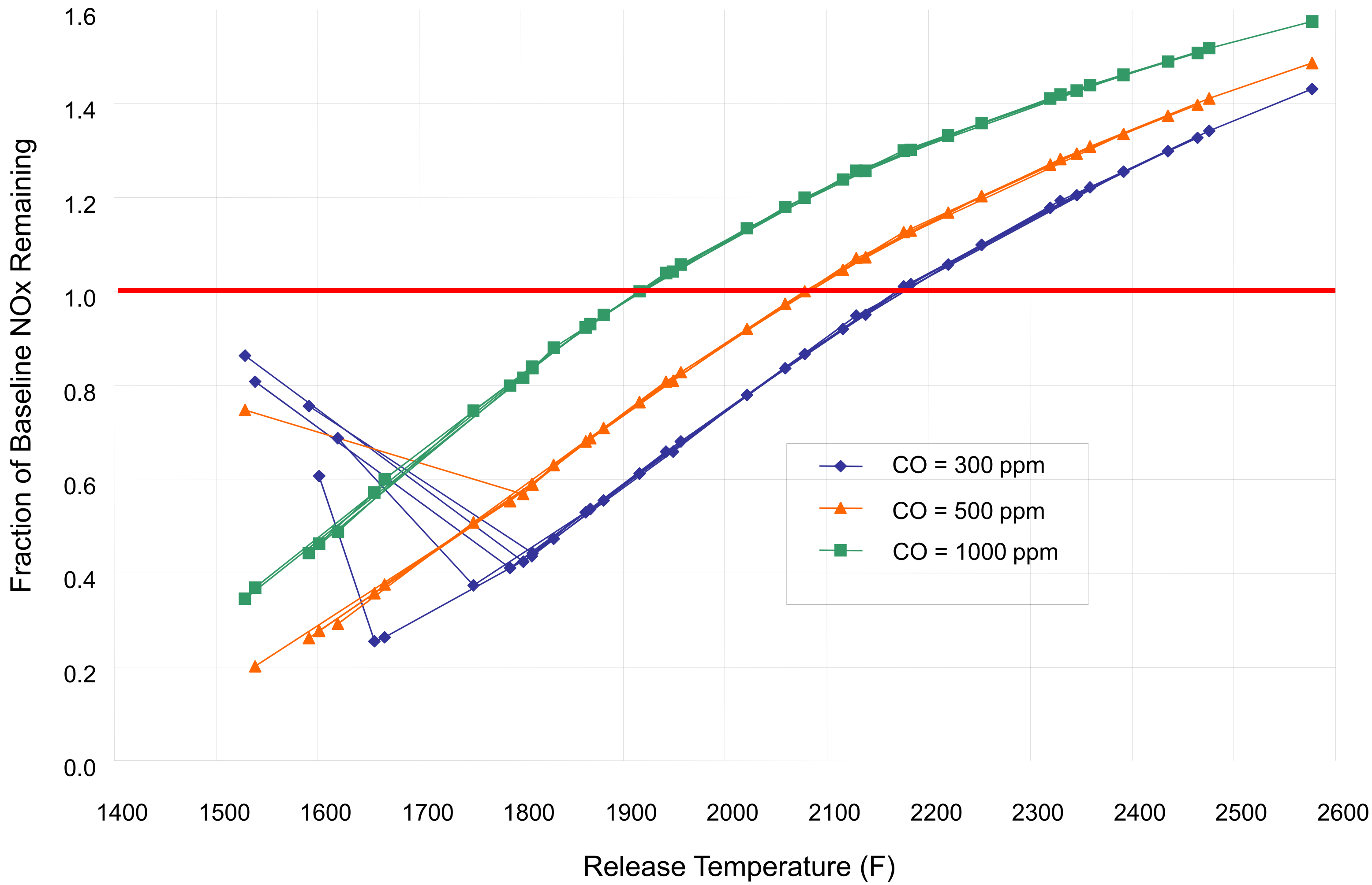
High Temperature Issues

- Rapid Droplet Evaporation
- Fast Kinetics
- Increased OH Concentration
- Urea Oxidation to NOx

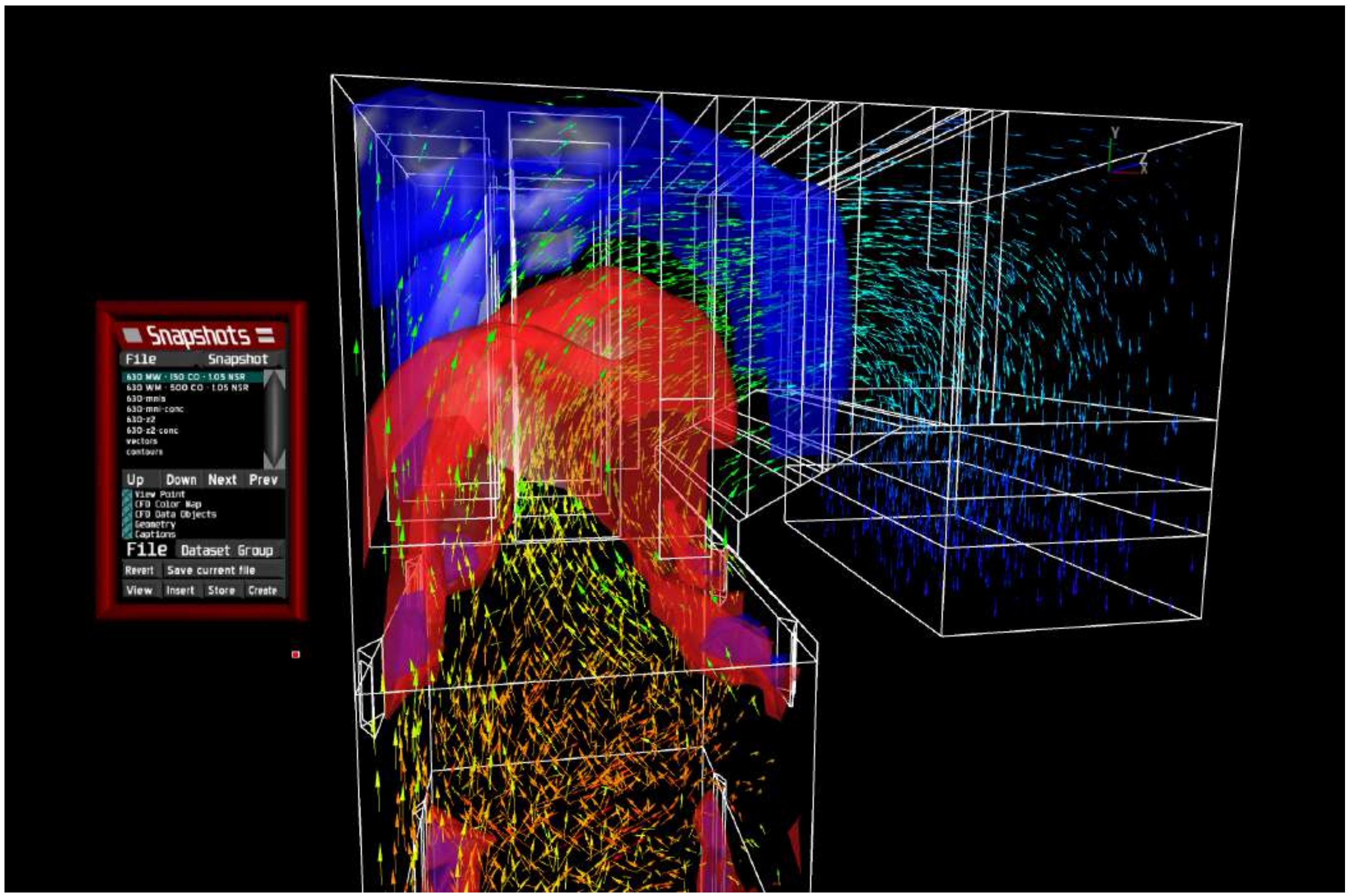


Impact of CO on SNCR Process

Note: Higher CO Levels Increase the Rates of NH2 Formation and NH3 Oxidation to NO; Effective NOx Reduction Window for Process is Shifted to a Lower Temperature.

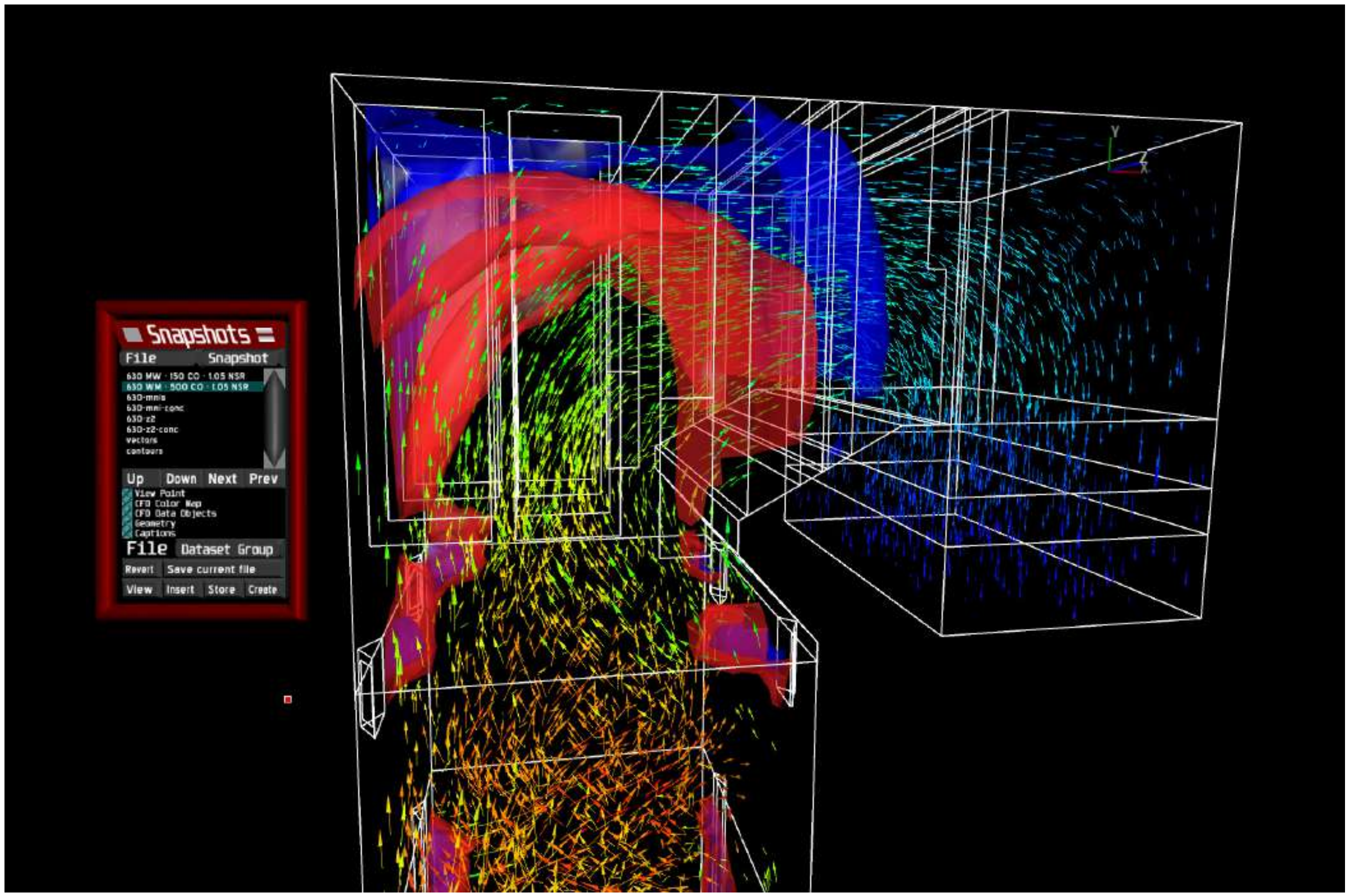


Temperature Window
150 ppm CO



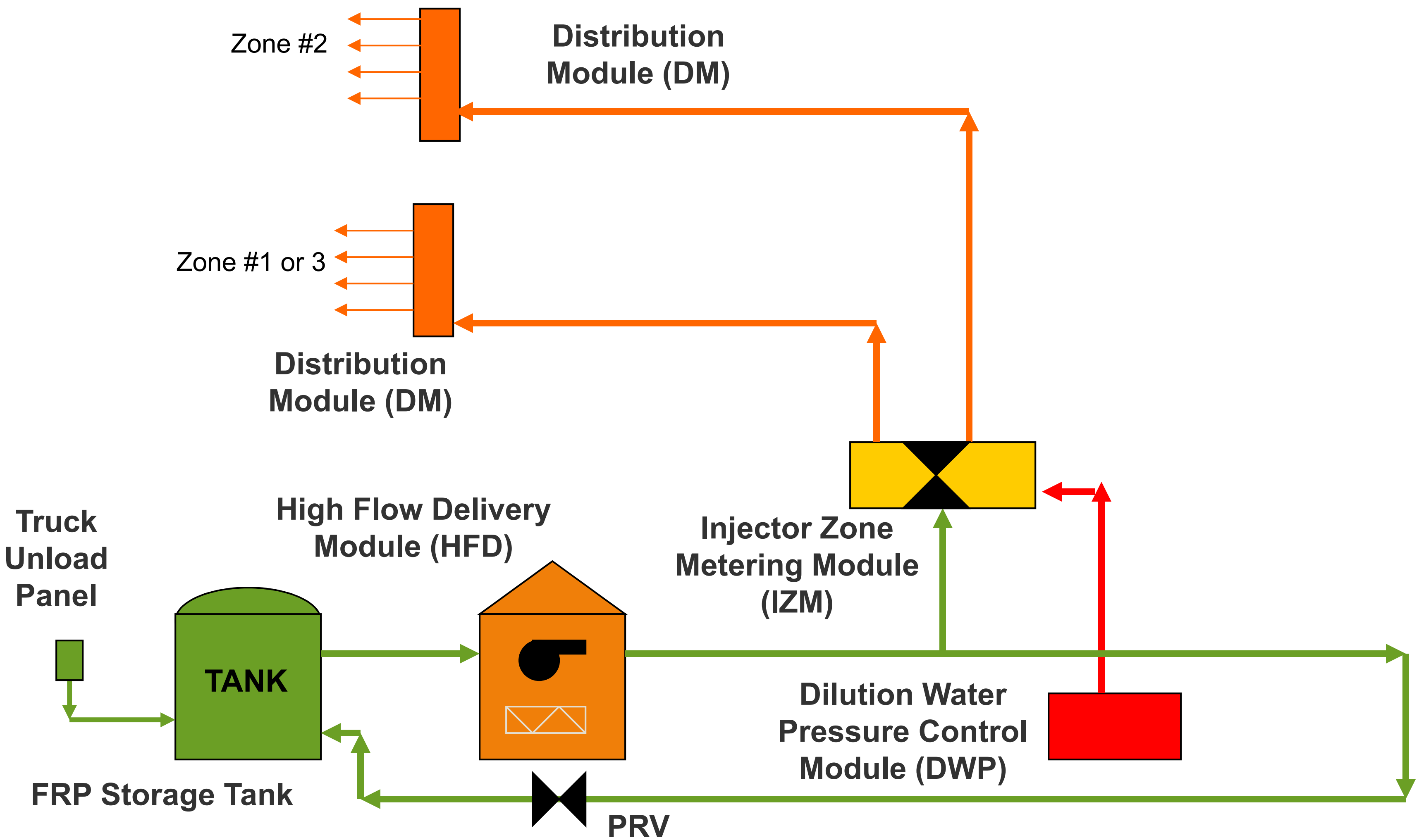
1950°F 1750°F

Temperature Window
500 ppm CO



1750°F 1450°F

SNCR Simple Schematic



Urea Solution and Water Requirements

- 50% urea solution for storage
- Dilution water used to maximize chemical coverage and minimize urea usage
- Site by site dilution water
- NOxOUT urea solution needed when lower quality dilution water is used
- Scaling and system pluggage can result
- Fuel Tech does not supply urea reagent
- MWGen utilized high quality dilution water and installed systems to meet requirements
  - Reverse osmosis or softeners

Urea and Dilution Water Quality

QUALITY SPECIFICATIONS – UREA				
	NOxOUT® A	NOxOUT® HP	UNSTABILIZED UREA	NOxOUT® LT
Description	Modified 50% Aqueous Solution of Urea	Modified 50% Aqueous Solution of Urea	50% Aqueous Solution of Urea	Modified 32.5% Aqueous Solution of Urea
Density (g/ml @ 25° C)	1.13 - 1.15	1.13 - 1.15	1.13 - 1.15	1.085 - 1.105
pH	7.0 - 10.8	7.0 - 10.8	7.0 - 10.8	5.0 - 10.8
Appearance	Light Yellow, Clear to Slightly Hazy	Light Yellow, Clear to Slightly Hazy	Light Yellow, Clear to Slightly Hazy	Light Yellow, Clear to Slightly Hazy
Salt Out Freeze Point	64°F (18°C)	64°F (18°C)	64°F (18°C)	40°F (4°C)
Foam (after bottle is shaken)	Foam Lasts > 15 seconds	Foam Lasts > 15 seconds	Not Applicable	Foam Lasts > 15 seconds
Free NH_3	< 5000 ppm	< 5000 ppm	< 5000 ppm	< 3000 ppm
Biuret Content	< 5000 ppm	< 5000 ppm	< 5000 ppm	< 3000 ppm
Organic Phosphate	55 - 85 ppm as PO_4	22 - 40 ppm as PO_4	Not Applicable	55 - 85 ppm as PO_4
Orthophosphate	< 6 ppm as PO_4	< 6 ppm as PO_4	< 2 ppm as PO_4	< 6 ppm as PO_4
Suspended Solids	< 10 ppm	< 10 ppm	< 10 ppm	< 10 ppm
Urea Makeup Water	Total Hardness as $CaCO_3$ ≤ 300 ppm	Total Hardness as $CaCO_3$ ≤ 150 ppm	Total Hardness as $CaCO_3$ ≤ 20 ppm	Total Hardness as $CaCO_3$ ≤ 300 ppm

QUALITY SPECIFICATIONS – DILUTION WATER				
	NOxOUT® A	NOxOUT® HP	UNSTABILIZED UREA	NOxOUT® LT
	Dilution Water Analysis	Dilution Water Analysis	Dilution Water Analysis	Dilution Water Analysis
Total Hardness as $CaCO_3$ (ppm)	<450	<150	<20	<450
"M" Alkalinity as $CaCO_3$ (ppm)	<300	<100	<100	<300
Conductivity (μmho)	<2500	<1000	<1000	<2500
Silica as SiO_2 (ppm)	<60	<60	<60	<60
Iron as Fe (ppm)	<1.0	<1.0	<1.0	<1.0
Manganese as Mn (ppm)	<0.3	<0.3	<0.3	<0.3
Phosphate as P (ppm)	<1.0	<1.0	<1.0	<1.0
Sulfate as SO_4 (ppm)	<200	<200	<200	<200
Turbidity (NTU)	< 10	< 10	< 10	< 10
pH	<8.3	<8.3	<8.3	<8.3

SNCR Injection Options

- HERT
  - Lower ammonia slip
  - Higher allowable injection rates
  - Higher NOx reduction performance and higher chemical usage
  - NOx reduction occurs close to injection point
  - Mechanical atomization with blower carrier air
- NOxOUT
  - More flexibility to control reaction zone and adjust droplet size for downstream reaction
  - Lower chemical usage
  - Air atomized injector to control droplet size

SNCR and RRI Evaluation

- Demonstrations conducted in March/April 2009 to determine achievable performance
  - Tangentially Fired Boilers
    - Will County 3
    - Crawford 8
    - SNCR performance showed significant NOx reduction
  - Cyclone Fired Boilers
    - Joliet 6
    - Powerton 51
    - SNCR/RRI performance showed significant reduction

SNCR System Wide Evaluation

- Fuel Tech completes initial SNCR evaluations
  - Fleetwide proposal
  - July 2009 design study with budget prices and performance evaluations
- Develop commercial guarantees
  - Boiler temperature and species mapping
  - Site data collection to confirm design basis
  - Establish equipment and injector designs
  - Define utility requirements and guarantees: urea, dilution water, power, instrument air
  - Firm guarantees established December 2009

SNCR – Alliance Agreement

- Fuel Tech selected as Alliance Agreement SNCR provider in May 2010
- System wide pricing agreement
- Opportunity for savings across multiple units
- Sharing of cost savings
- MWGen existing arrangement with GSL
- GSL is a joint venture between Sargent and Lundy and Graycor Construction
- Fuel Tech to be a part of the overall team

Teaming Arrangement

MWGen Scope of Work

- Secure IEPA Construction Permits
- Procure & install port tubes in all boilers
- Manage commissioning and acceptance testing
- Manage work scopes, schedules, and cash flow
- Provide oversight to contracts, interface between construction partners and plant personnel

GSL Scope of Work

- Installation Engineering for SNCR Equipment
- Balance of Plant Engineering
- Installation Materials
- Installation Labor
- Master Schedule

Team Approach and Communications

- Joint Design Review Meetings
  - Face to face meetings to meet accelerated schedules
- Use of GSL Master Schedule
- Weekly team meetings
- Site meetings at each plant
  - Kick off scope and equipment locations
  - Port tube location interferences
- Monthly project meetings
  - During execution at each plant
- Quarterly Executive Steering Meetings
- Team priorities were safety, quality, and communication

GSL Engineers & Constructors

GSL

AQEC Construction & Engineering Schedule_Executive Level Summary

MIDWEST GENERATION

Activity ID	Activity Name	Original Duration	Start	Finish
Powerton		338d	05-Jan-10 A	16-Aug-11
SNPW0C.186	GSL Engineering	225d	05-Jan-10 A	28-Apr-11
SNPW0C.191	FT PO# 2 Release- Unit 5 & 6	0d		10-May-10 A
SNPW0C.189	FT Engineering	78d	17-May-10 A	18-Mar-11
SNPW0C.185	GSL Construction- Unit 5 & 6	212d	17-May-10 A	28-Jun-11
SNPW0C.190	GSL PO# 2 Release- Unit 5 & 6	0d		04-Jun-10 A
SNPW0C.188	FT Fabrication and Delivery	110d	12-Jul-10 A	03-Feb-11
SNPW0C.187	Commissioning	34d	29-Jun-11	16-Aug-11
Joliet		439d	05-Jan-10 A	23-Sep-11
SNJL0C.186	GSL Engineering	227d	05-Jan-10 A	03-Feb-11
SNJL7C.191	FT PO # 2 Release- Unit 7 & 8	0d		10-May-10 A
SNJL0C.189	FT Engineering	131d	06-Jul-10 A	04-Mar-11
SNJL6C.191	FT PO # 2 Release- Unit 6	0d		06-Jul-10 A
SNJL6C.190	GSL PO# 2 Release	0d		02-Aug-10 A
SNJL0C.188	FT Fabrication and Delivery- Unit 6	0d	02-Aug-10 A	15-Feb-11
SNJL0C.185	GSL Construction- Unit 6,7,8	169d	08-Sep-10 A	30-Jun-11
SNJL7C.188	FT Fabrication and Delivery- Unit 7 & 8	31d	07-Mar-11	18-Apr-11
SNJL0C.187	Commissioning / Start-up Optimization	60d	30-Jun-11	23-Sep-11
Crawford		229d	29-Apr-10 A	29-Sep-11
SNCR0C.186	GSL Engineering	225 d	29-Apr-10 A	01-Jun-11
SNCR0C.190	GSL PO# 2 Release- Unit 7 & 8	0d		28-Sep-10 A
SNCR7C.191	FT PO# 2 Release- Unit 7	0d		03-Nov-10 A
SNCR8C.191	FT PO# 2 Release- Unit 8	0d		03-Nov-10 A
SNCR0C.189	FT Engineering	155d	04-Nov-10 A	23-Jun-11
SNCR0C.185	GSL Construction- Unit 7 & 8	180d	06-Dec-10	18-Aug-11
SNCR0C.188	FT Fabrication and Delivery	47d	04-Apr-11	09-Jun-11
SNCR0C.187	Commissioning	29d	19-Aug-11	29-Sep-11
Will County		366d	17-May-10 A	21-Nov-11
SNWC0C.186	GSL Engineering	280d	17-May-10 A	01-Aug-11
SNWC0C.190	GSL PO# 2 Release- Unit 3 & 4	0d		13-Oct-10 A
SNWC3C.191	FT PO# 2 Release- Unit 3	0d		15-Dec-10
SNWC4C.191	FT PO# 2 Release- Unit 4	0d		15-Dec-10
SNWC0C.189	FT Engineering	133d	15-Dec-10	23-Jun-11
SNWC0C.185	GSL Construction- Unit 3 & 4	154d	01-Mar-11	05-Oct-11
SNWC0C.188	FT Fabrication and Delivery	41d	06-May-11	05-Jul-11
SNWC0C.187	Commissioning	33d	06-Oct-11	21-Nov-11

Planned LOE — Actual Work — Remaining Work — Critical Remaining Work — ◆ Milestone — Summary

Date	Revision	Checked	Approved
06-Aug-10	Issued for planning - DATA DATE March 1, 2010	JAP	KWG
13-Apr-10	Issued for planning - DATA DATE July 7, 2010	JAP	ABM
06-Nov-10	Issued for planning - DATA DATE October 18, 2010	JAP	ABM
06-Dec-10	Issued for planning - DATA DATE November 30, 2...	JAP	ABM

Powerton 5&6

Field Erected UREA Storage Tanks

Independent Zone Metering Module

- Use: Separates and dilutes urea solution into zones
- Size: 4' x 8' x 6'H and up
- Weight: 2,500lbs and up
- Construction: Stainless steel
- 4 injector zones shown here with flanged outlets
- Control valves, transmitters, and motor op valves all wired to control panel
- Flow through circulation loop piping
- Stainless steel piping and sump base with forklift holes and removable lifting lugs
- Automatic water flush on normal shutdown (no flush on System Stop)

Dilution Water Pressure Control Module

- **Use: Supplies dilution water to MM**
- **Size: 4’ x 8’ x 6’H**
- **Weight: 1,500lbs**
- **Construction: Stainless or carbon steel**
- **100% automatically redundant VFD pumps**
- **Maintains constant dilution water pressure**
- **Stainless steel piping and base**
- **Module base with corner drains**
- **Can be welded or bolted to deck or structural steel**
- **Controls, transmitters, gauges, valves, and electrical equipment are included**

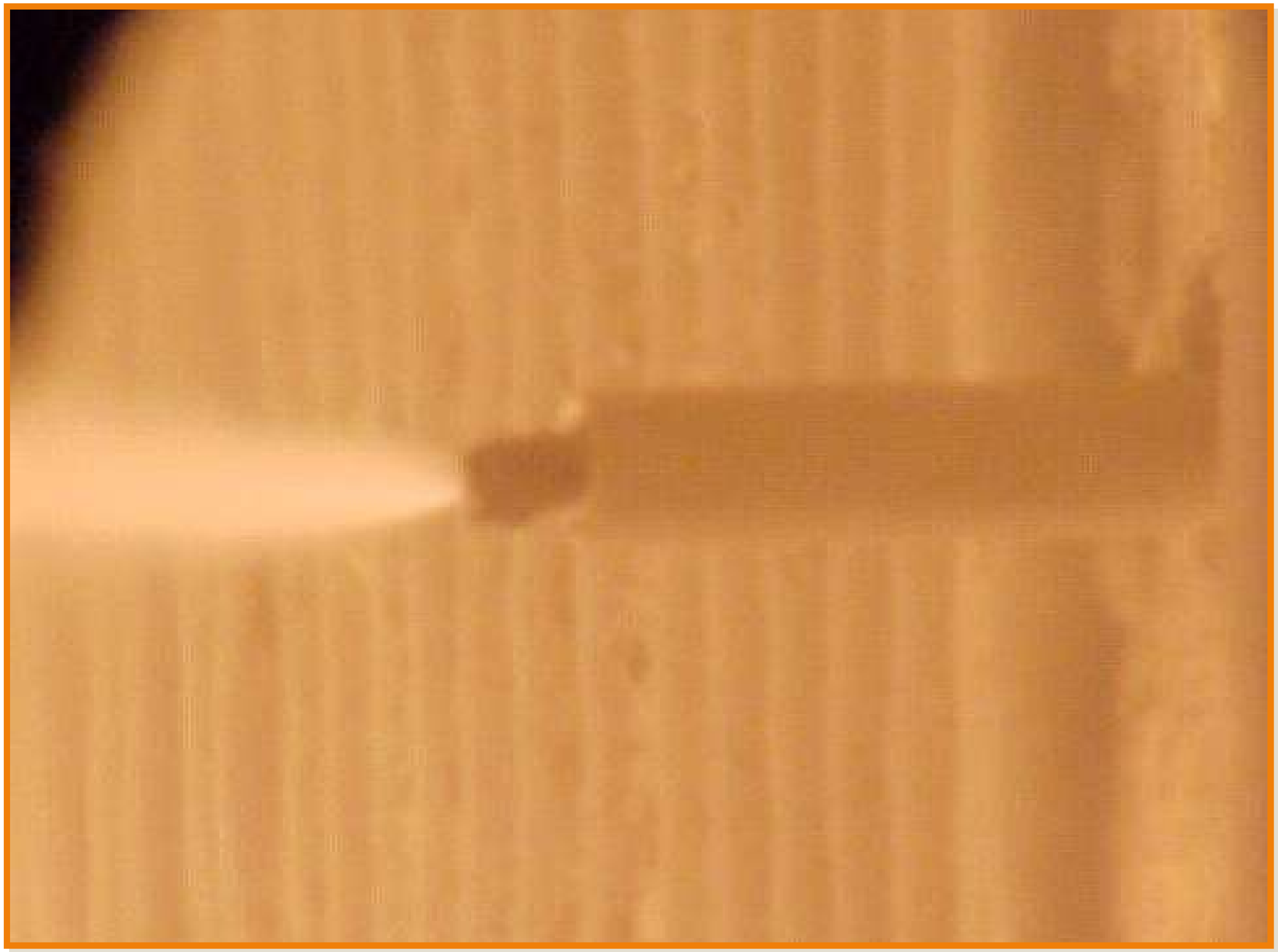
Wall Injector Distribution Module

- **Use: Controls delivery of diluted urea and atomizing air to each injector**
- **Size: 3' x 3.5' x 6'H (varies)**
- **Weight: 300lbs and up**
- **Construction: Stainless steel**
- **Flanged inlet connections**
- **Ball valves on all lines**
- **Needle valve on mixed chemical; regulator on compressed air**
- **Rotometers on mixed chemical tubing**
- **Pressure gauges on all outlets**
- **Tube compression fittings outlets**
- **Stainless steel piping, tubing, and base steel (base can be deleted for compact installation)**
- **Solenoid valve for continuous cooling air to injectors**

Standard SNCR Wall Injector

- Use: Injection of diluted urea into boiler
- Size: 36" but can change depending on boiler wall construction
- Weight: 10lbs and up
- Construction: Stainless steel
- Approximately ¾" diameter
- Requires minimum 1" boiler port
- Atomizing/cooling air and mixed chemical connections on body
- Camlock connection for chemical and air automatically shut off when disconnected
- Camlock connection to adjust insertion depth
- Port should be provided with aspirating air on positive pressure boiler

SNCR Wall Injector in Operation



Project Challenges and Solutions

- Resource constraints for multiple projects
- CO levels on several units
  - Combustion tuning for CO improvements or reductions
  - Changes in injector configuration to accommodate
- Outage schedules and resource requirements
- New configurations for injection
  - Flexible hose RRI injector
  - Retractable long HERT injector
- Port installation priorities different than equipment installation
- Documentation control – multiple units at multiple stations with overlapping schedules

SNCR Overview by Site

SITE	TANKS	INJECTION LEVELS PER UNIT	INJECTOR TYPE	TOTAL QUANTITY
POWERTON 5&6 820 MW each	2 x 350,000 gal – field erected	3 1	HERT RRI	92 32
JOLIET 6 325 MW	3 x 55,000 gal	3 1	HERT RRI	46 16
JOLIET 7&8 540 MW each	2 x 47,000 gal	3	HERT	56
WILL COUNTY 3&4 275/535 MW	2 x 26,000 gal	3	NOxOUT HERT	20 8
CRAWFORD 7&8 230/350MW	2 x 15,000 gal	3	NOxOUT HERT	20 26

Current Status and Next Steps

- MWGen fleet met the goal and remains below the 0.11 NOx requirement
- Significant savings generated using Alliance Agreement sourcing were shared between Fuel Tech and MWGen
- Total Capital Cost less than 30% of SCR Option
- SNCR and RRI system optimization to minimize operating costs including urea consumption
- Crawford and Fisk units no longer in operation
- Optimize system and operation to reduce urea consumption

Questions?