REINHOLD ENVIRONMENTAL Ltd.

2011 NOx-Combustion Round Table & Expo Presentation

February 7-8, 2011, in Birmingham, AL / Hosted by Southern Company

NOx-Combustion Round Table
Birmingham, AL

Regenerative SCR & Multi-Pollutant Catalytic Reduction

February 8, 2011

Presentation by:
John Bowman
Vice President - BPI Green
Babcock Power Environmental Inc.

bpigreen℠

RSCR & MPCR Systems Overview

- Regenerative SCR Business Drivers
- RSCR Systems Description
- RSCR Method of Operation
- MPCR System Description
- Current / Achievable Performance

RSCR Drivers

Initial RSCR Drivers

- Low NO_x emissions
- RPS programs in New England require low NO_X emissions
  - 0.075 lb/MBtu (CT) (52 ppm)
  - 0.065 lb/MBtu (MA, NH) (45 ppm)
- Avoidance of PSD review (< 250 tpy of NO_x)
- Applications elsewhere for NO_X offsets
- BACT

Typical NO_X removal efficiency required ~ 75%

RSCR Drivers

Biomass Options to Achieve Low NO_x / CO

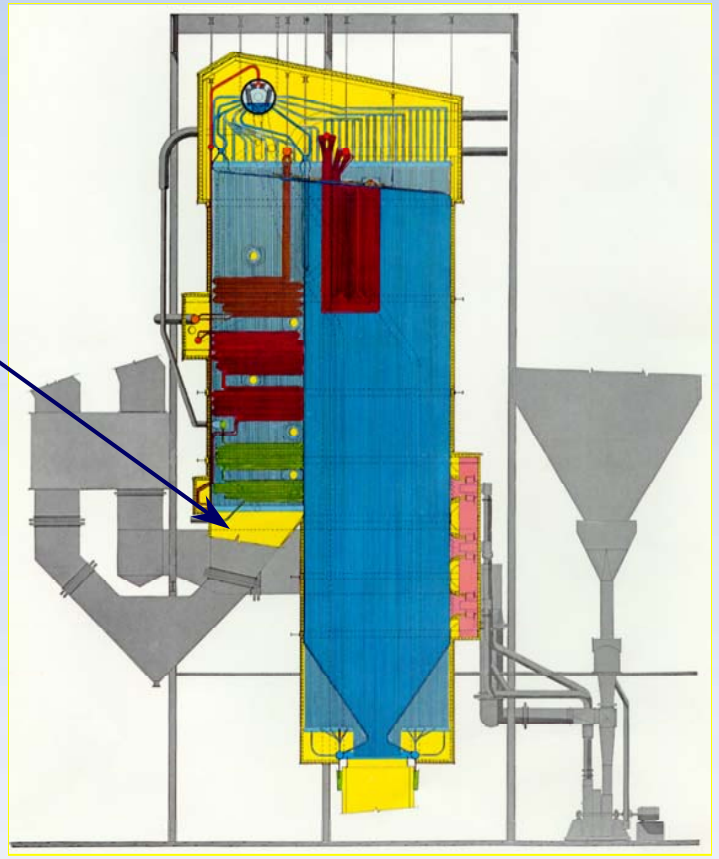
- "Conventional" technologies can't get reduction
  - SNCR
  - Over-Fire Air / Flue Gas Recirculation
- "Advanced" technologies can't get reduction
  - Ceramic injection tubes/NH_3 injection
  - High pressure rotating OFA/NH_3 injection

Conclusion: SCR required to achieve <0.075 lb/MBtu

RSCR Drivers

‘Conventional’ High Dust SCR – typical location

- Economizer outlet
- 600° - 750°F
- Full flyash loading



RSCR Drivers

Initial consideration was for “conventional” SCR

- Poisons affect all SCR catalysts the same
  - Potassium, sodium, arsenic are irreversible
- High K/Na concentrations in wood ash preclude use of conventional SCR
- Heavy metals in WTE flue gas will poison catalyst – conventional SCR not possible

Requires the use of a “low dust” SCR system

RSCR Drivers

Difficult NO_x Control Applications

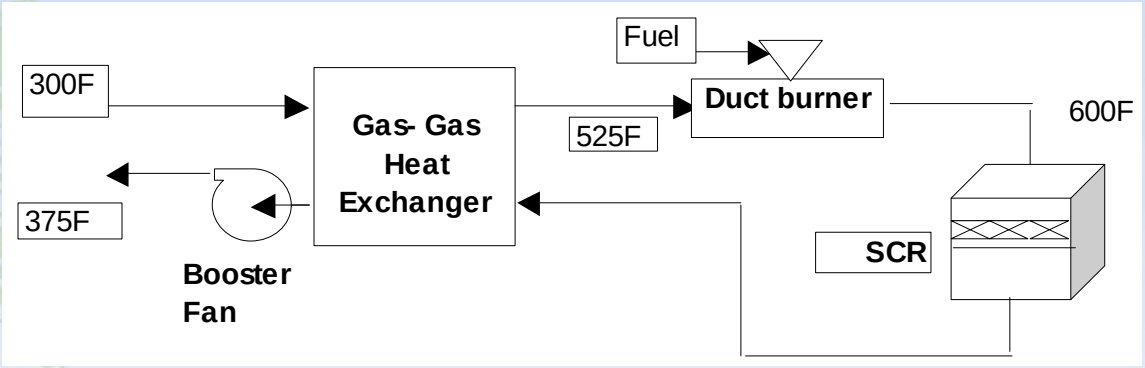
- Biomass boilers
- WTE furnaces
- Downstream of a scrubber
- Boilers with physical constraints (coal,oil)
- Process applications

Require the use of a "tail-end" SCR system

RSCR Drivers

Typical ‘tail-end’ SCR systems

- Installed downstream of particulate removal, upstream of stack
  - Clean, low temperature gas (~ 300°F)
- Large physical size, high initial, erection, and operating costs
- Consists of:
  - Gas/Gas HX
  - Duct burners
  - SCR
  - Booster Fan



- NO_X reductions 60 - 90%; energy efficiency **~ 60 to 75%**

RSCR Drivers

Regenerative SCR (RSCR)

- Targeted at tail-end applications
  - Gas relatively free of particulates, poisons (As, Pb, K/Na)
  - Low SO_3 content
  - Low temperature flue gas (approx 200° to 350°F)
- Achieves high heat recovery to minimize energy costs
- Modular, standard design to minimize installation cost
- Uses proven, guaranteed catalyst
- Proven high NO_X (and CO) reductions
- Thermal efficiency ~95% (1/10 the fuel of typical tail-end unit)

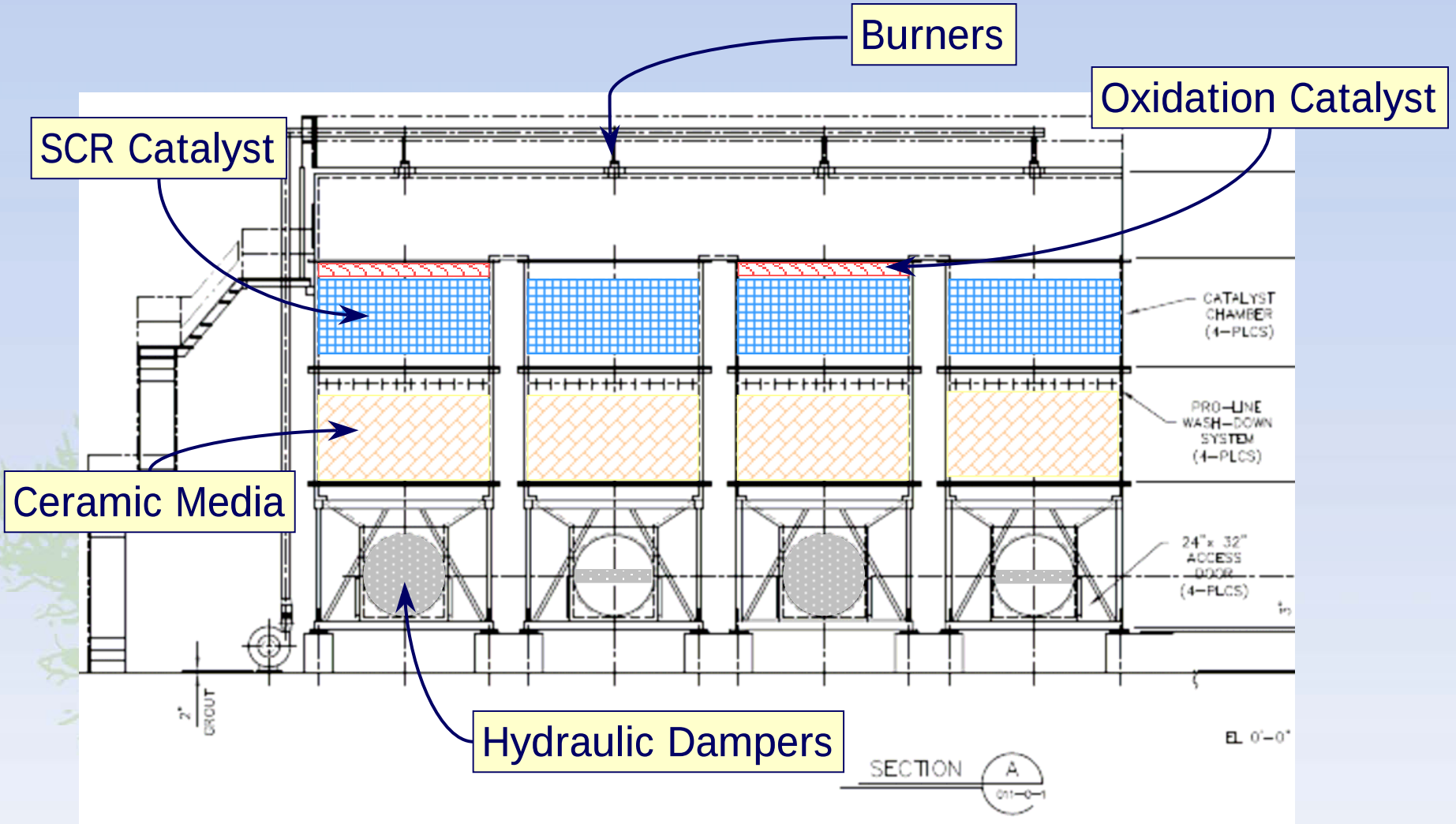
Regenerative Selective Catalytic Reduction

McNeil Station 54 MW Burlington, VT

RSCR System Description

- High efficiency tail-end SCR—$\eta_{thermal}$ < 95%
- Shop-built reactor / heat exchange chambers
- Hydraulically-operated dampers rapidly switch direction of flow through chambers
- Typically an even number of chambers—half are in-flow (up thru a chamber), half are out-flow (down thru chamber)
- Heat is stored in (down flow) or released from (up flow) ceramic honeycomb blocks
- BPE proprietary and patented technology

RSCR System Description



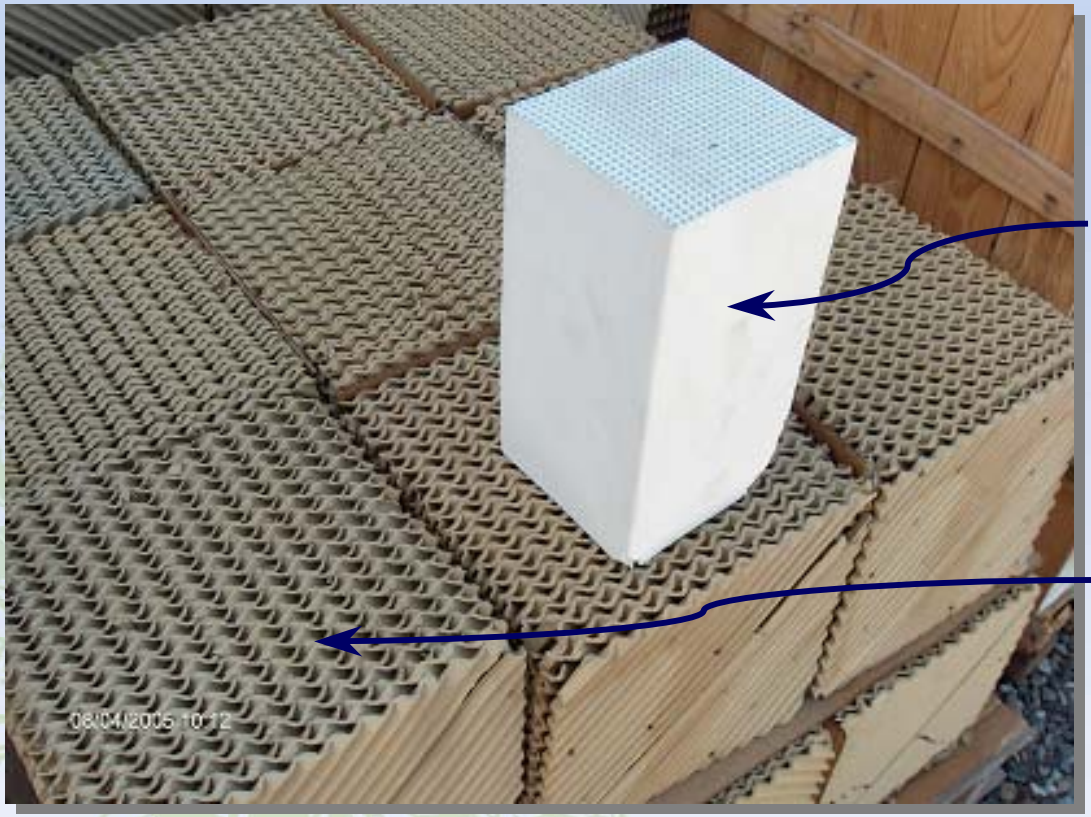
RSCR System Description

Hydraulic Dampers – 2 per Chamber

Hydraulic Dampers / Actuators
- Fast acting
- Soft closing

RSCR System Description

Ceramic Media – 2 Types



Honeycomb
- 6” x 6” blocks
- Several layers
- Heat storage

Flexeramic
- 2 layers of 1 ft^3 blocks
- Flow mixing / distribution

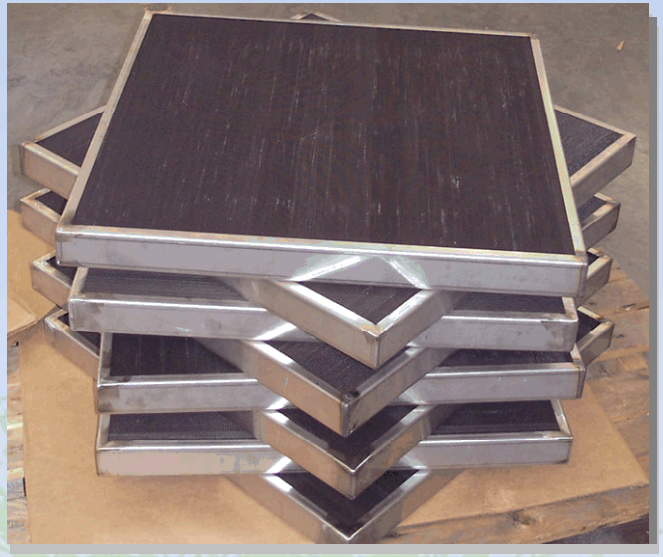
RSCR System Description

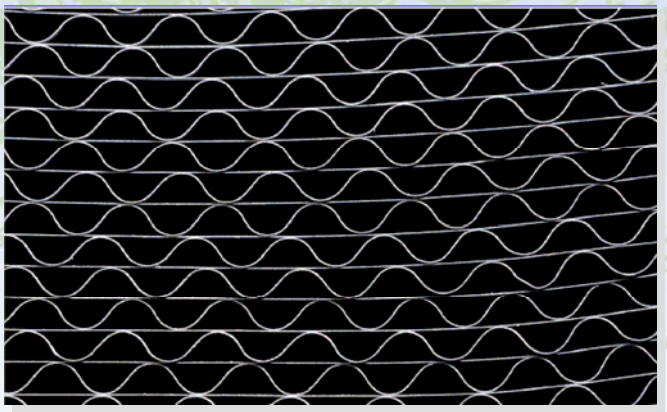
SCR Catalyst

SCR Catalyst Modules
- -Honeycomb
- -Top-loaded
- -Bottom sealed
- -Variable module height

RSCR System Description

Oxidation Catalyst





Oxidation Catalyst Elements
- -Precious metal formulations
- -Nominally 18” x 24”

RSCR System Description

Burners – in the plenum above catalyst

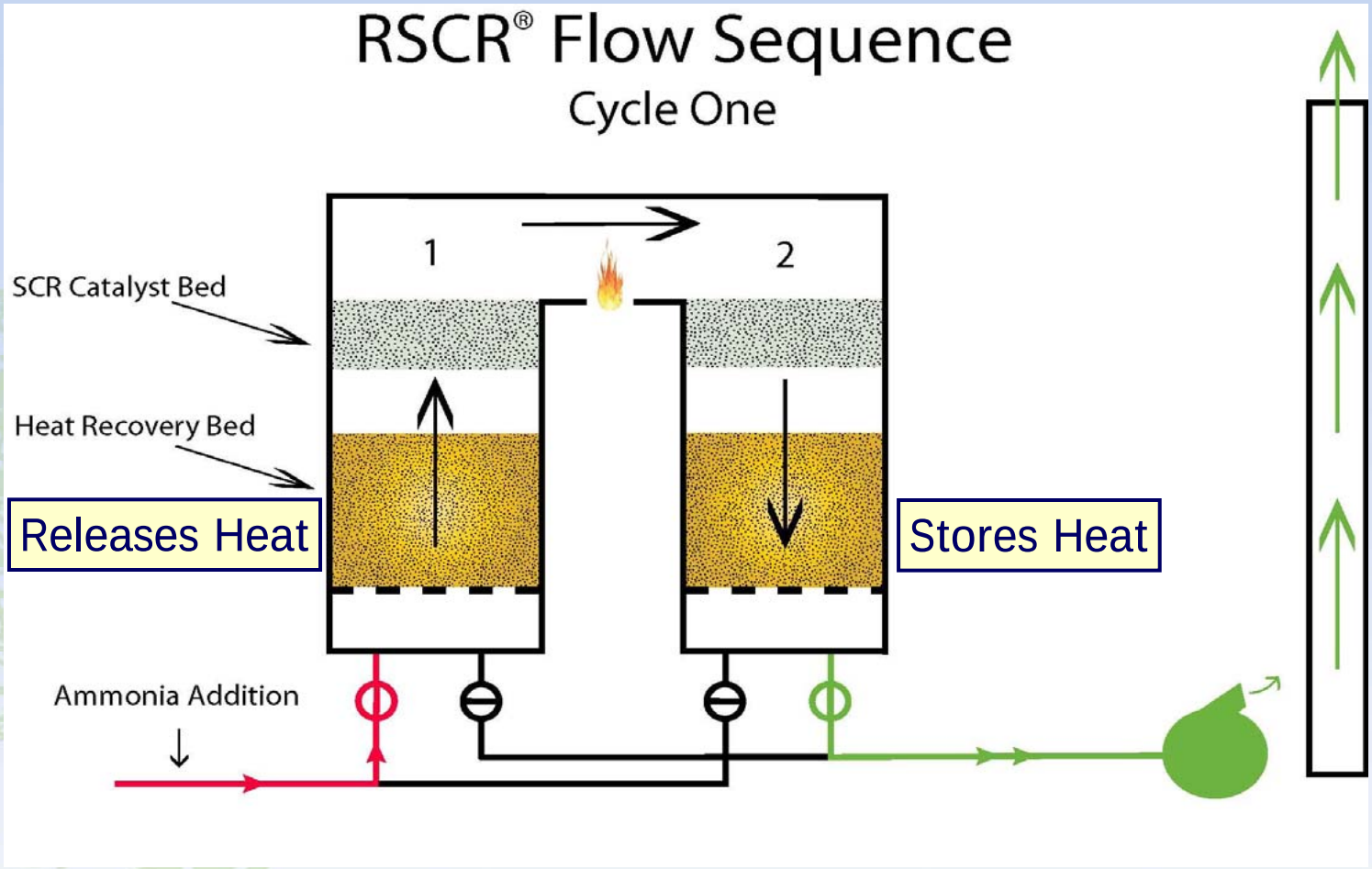

RSCR at Boralex

Burners

- Natural gas typically, oil and dual-fueled available
- Variable firing rate
- ~3 MMBtu/h average firing for 50 MW, 350 F to 580 F

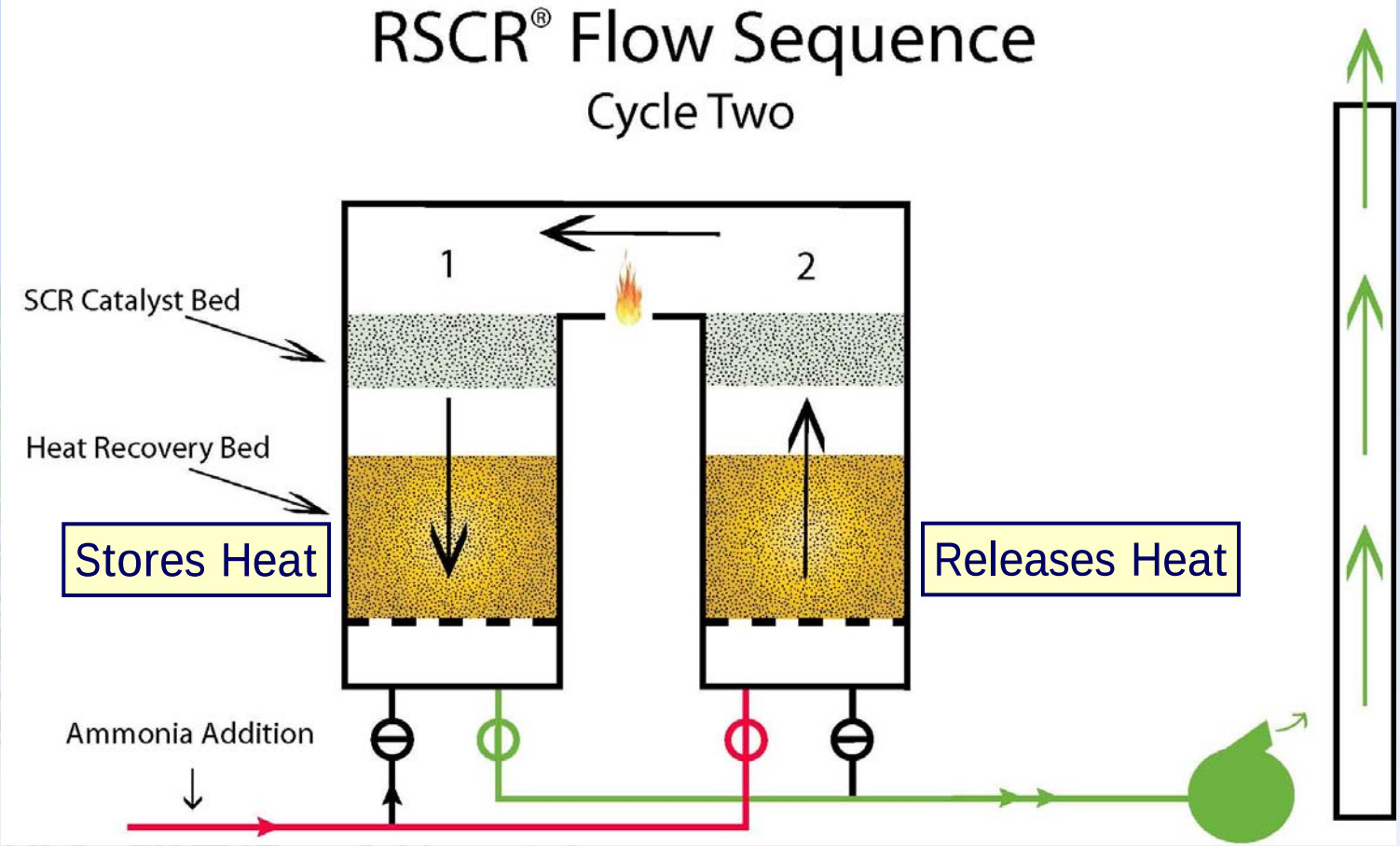
RSCR Method of Operation

Flue gas flows in this direction



RSCR Method of Operation

Dampers switch and flows is in the other direction



RSCR Performance

- Successfully operating for >6 years
- Original catalyst still operating (>50,000 hrs.)
- Extrapolated life is 80,000+hrs.
- Oxidation catalyst operating for 2 years with minimal loss of activity or pressure drop change
- NO_x reduction is typically from 0.25 lb/MMBtu to REC required <0.075 lb/MMBtu (70%)
- Systems are run at <0.05 lb/MMBtu (80%)
- Systems have proven to be highly reliable – never missed qualifying for RECS

RSCR Commercial Units

MPCR System Description

MPCR

Multi Pollutant Catalytic Reduction

MPCR System Description

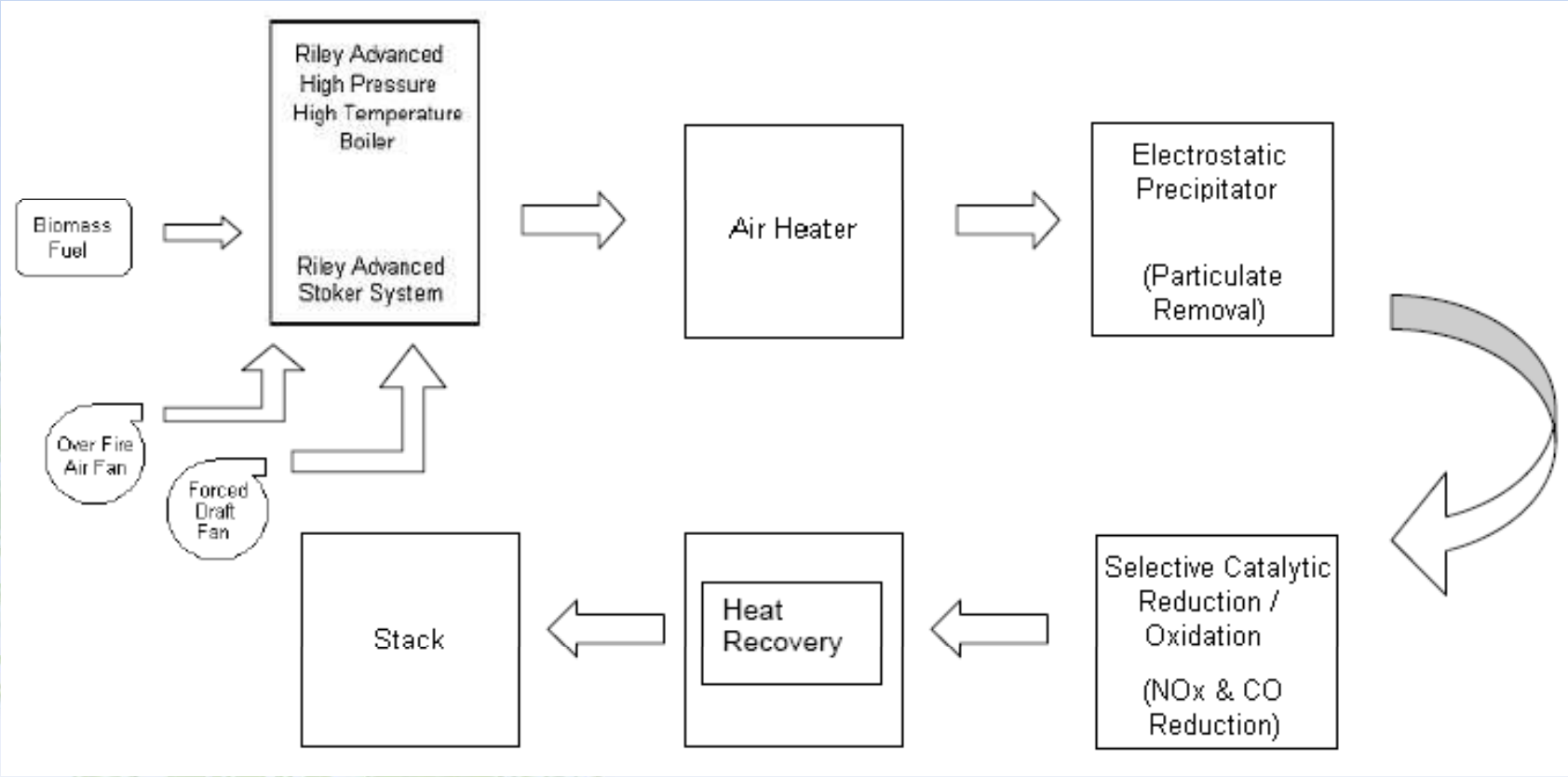
MPCR System Evolved from the RSCR

- Have operated successfully for 6 years
- BPI worked with owners to optimize
- Some RSCR units had elevated A/H flue gas temperature
- Converted them to “cold” operation – *no reheat*
- Operating in this mode 1 to 3 years
- Provided unparalleled SCR catalyst experience
- CO catalyst installed in all converted units
- Original catalyst is in all units thru Oct. 2010

MPCR System Description

MPCR in the Optimized Integrated Biomass System

Patent Pending



MPCR System Description

MPCR in the Optimized Integrated Biomass System

- Utilizes years of catalyst experience *on biomass*
- Single reactor contains catalyst beds
  - NO_x SCR
  - Oxidation for CO/VOC (“HAPs”)
- ESP or baghouse upstream of MPCR
- Flue gas temperature sufficient to “light off”; no reheat required
- Heat recovery downstream of MPCR
- Low overall pressure drop
- Can achieve very low NOx/CO/VOC emissions

MPCR System Description

Advantages - MPCR & Optimized Integrated Biomass System

- While a conventional stoker/ESP/RSCR has a lower heat rate than BFB; this technology offers a *better* heat rate
- Very low emissions
- No auxiliary fuel required
- Low parasitic power
- Low system cost
- Reliable, proven, fuel flexible
- “Standard” design reduces cost
- Single point “chute-to-stack” guarantee

MPCR / RSCR System Projects

RSCR / MPCR Project List						a/o December 2010	
Site	Boiler Size MW_e	Fuel	NO_x In lb/MMBtu	RSCR Layout	Guaranteed NO_x Out * lb/MMBtu	Renewable Energy Certificates	Start Date
New Hampshire	15	Whole Tree Chips (WTC)	0.25	3 canisters	0.075	CT Earned RECs every quarter	Oct. 2004
Boralex Stratton	50	WTC Waste wood C&D	0.25	2 trains of 5 canisters	0.075	CT Earned RECs every quarter	Dec. 2004
Bridgewater Power	16	Whole Tree Chips (WTC)	0.28	2 canisters	0.075	CT Earned RECs every quarter	Oct. 2007
Burlington Electric	54	Whole Tree Chips Urban wood	0.26	6 canisters	0.065	CT/MA Earned RECs every quarter	Oct. 2008
Meadvilles Renewables	2 x 50	Tire Derived Fuel	0.25	2 trains of 6 canisters	0.075	N/A	2013
Jefferson Renewable	60	RDF C&D	0.33	2 trains of 4 canisters	0.075	N/A	2012
Fairfield Renewable	4 x ~30	Processed Refuse Fuel	0.33	4 trains of 4 canisters	0.077	N/A	2013
University Wisconsin	35	WTC, Pellets, Ag Fuels	0.33	MPCR	0.060 NOx 0.075 CO	N/A	2013

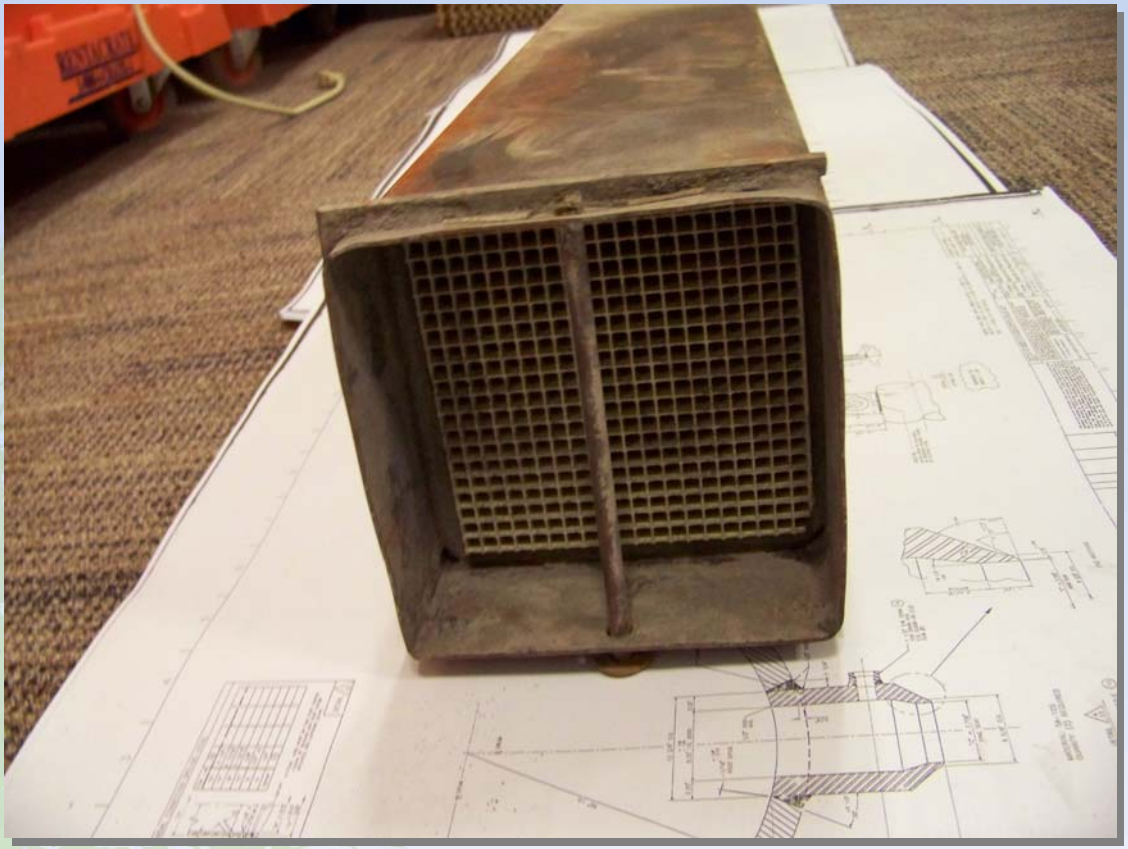
*** RSCRs have demonstrated continuous NOx reduction significantly below the guaranteed levels.**

RSCR Construction / Misc. Photos

RSCR at Boralex

RSCR Construction / Misc. Photos

RSCR Construction / Misc. Photos



Thank You

Questions?

John Bowman
508-854-3689
jbowman@babcockpower.com