PerNOxide NO_x Control Technology

URS and FMC Corporation
McIlvaine Hot Topic
February 23, 2012

Introduction

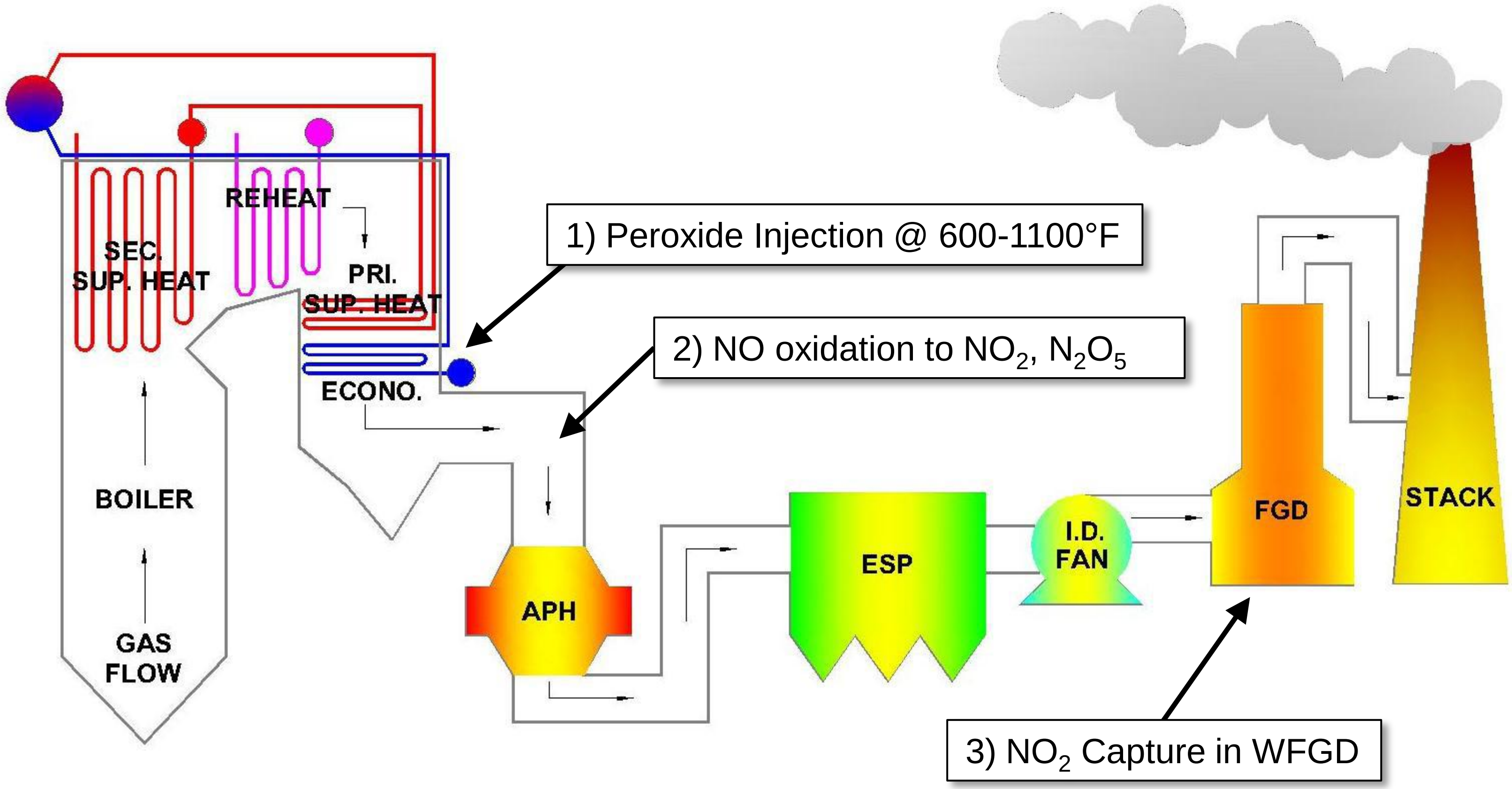
- Current and future regulations will require further NOx reductions from coal fleet
- SCR widely implemented on larger, higher-emitting plants where capital investment justified
- Low Nat Gas prices have reduced dispatch of smaller, higher cost plants
- Technology void exists for plants needing moderate (40-60%) NOx reductions with minimal capital investment
- FMC/URS are developing technology to meet need

NOx Technology Comparison

	SNCR	PerNOxide	SCR
Reagent	Urea	Peroxide	Ammonia
Nox Removal	15-40%	30-70%	75-90%
Capital Cost	Low	Low	High
Operating Cost	Low	Mid-High	Mid

PerNOxide offers moderate NOx reductions with low upfront capital investment

PerNOxide Injection Process



Note: Other possible capture options include SDA, CDS, CFB

PerNOxide Process Overview

- Two-Step Process
  - NO oxidation using hydrogen peroxide
  - Capture of the oxidized nitrogen species
- NO Oxidation
  - Hydrogen peroxide injected via dual-fluid nozzles
  - Injection between economizer & air preheater
  - Products include NO_2 & higher-order oxides
- Capture via Wet or Dry Scrubbing
  - NO_2 removal is critical for good performance

NO_x Capture Options

- NO_x Capture Enhancement
  - Wet lime / limestone / sodium scrubbers
  - Spray Dryer Absorbers (SDA) - lime
  - Circulated Dry Scrubbers(CDS) – lime
- NO_x Removal in Wet Scrubbers
  - Higher-order nitrogen oxides are very soluble with removal efficiencies > 95%
  - NO_2 is less soluble, but removal is enhanced by dissolved sulfite
  - Reaction products include nitrate, S-N species, and nitrogen gas

Technology Development

- Early Development (1996-2003)
  - Univ. Central Florida, EPA, NASA KSC, others
  - Treatment of NO_x from KSC boilers
  - Patent #6,676,912 – NASA
- Later Development (2006-2010)
  - FMC Corporation – exclusive licensee of IP
  - Pilot Low-Temp Testing (SDA)
  - Full-scale High-Temp Trials (proof of concept)
- Current Development (2011-2012)
  - URS/FMC – Joint Commercialization Agreement
  - Laboratory R&D programs to optimize process
    - WFGD NOx Capture (URS)
    - NO Oxidation and Dry NOx Capture (EERC)
  - FMC – additional patents pending – peroxide activation

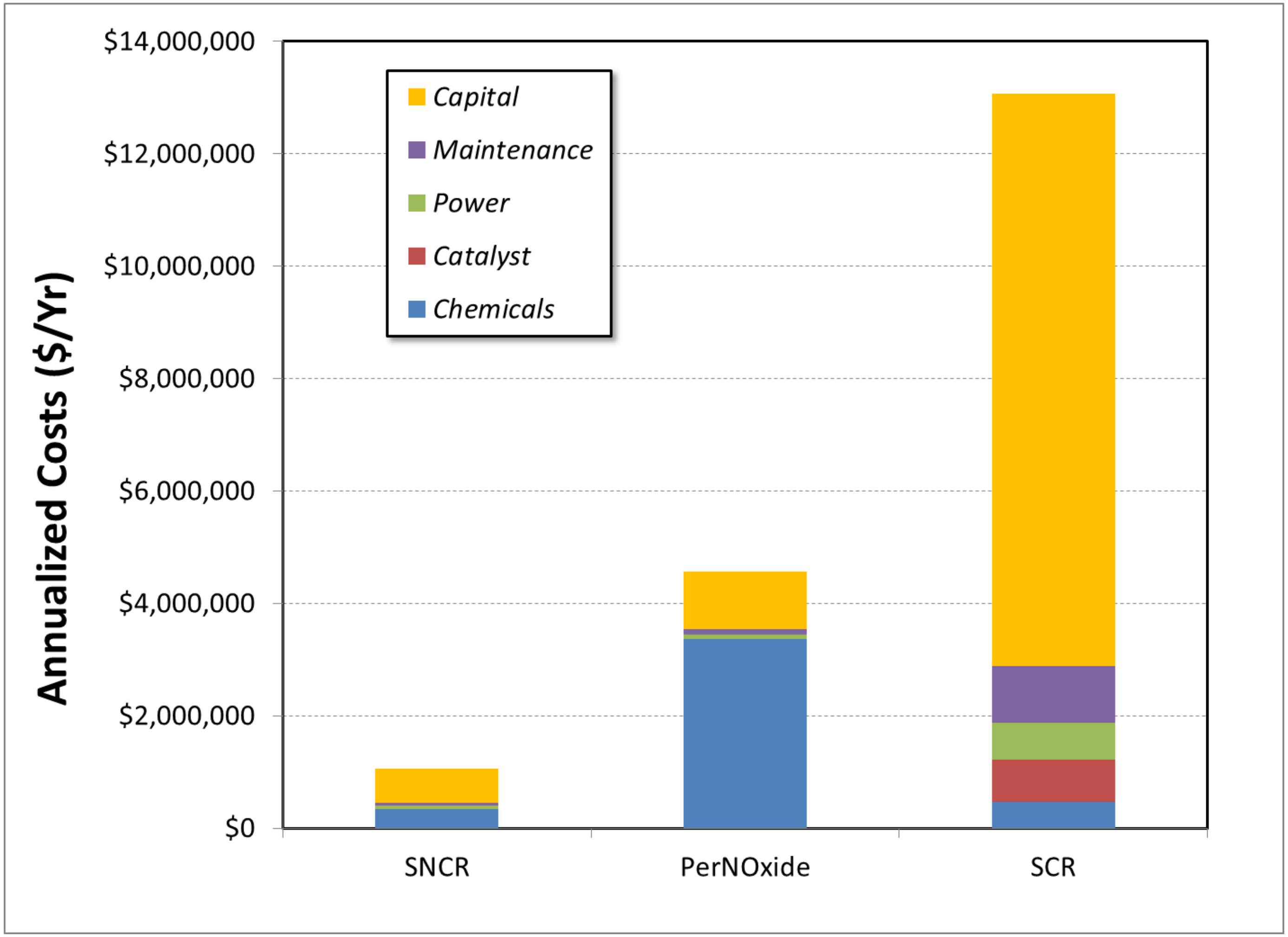
Technology Demonstration

- Full-Scale Demonstrations (FMC-2010)
    - 120 MW, E. Bit, No FGD
    - 440 MW, H-S Lignite, Limestone Inhibited-Ox FGD
    - 800 MW, PRB, Limestone Gypsum FGD
  - High NO oxidation achieved (50-80%)
  - Relatively poor NOx capture in WFGD
- Wet FGD Chemistry Lab Study (URS-2011)
  - NO_2 capture of >70% achieved
  - Key chemistry variables liq-sulfite, pH, buffer
- Dry FGD Pilot Study (EERC-2011)
  - Tested various fuels (NG, PRB, E. Bit, Lignite)
  - Up to 50% NOx capture achieved in SDA
- Pilot WFGD and Full-Scale Demo (URS/FMC-2012)

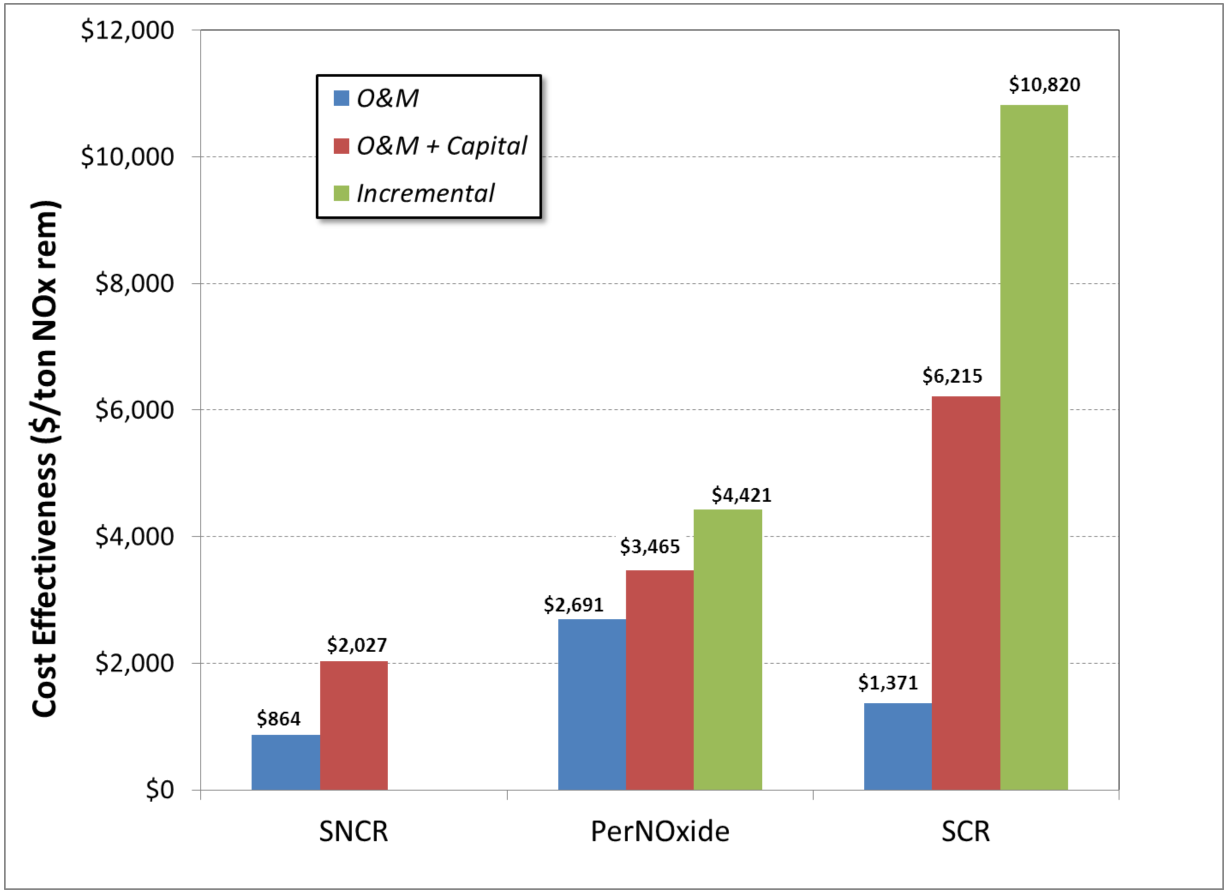
Technology Cost Comparison

Basis	Units	SNCR	PerNOxide	SCR
Capacity Treated	MW	400	400	400
Inlet NOx	lb/MMBtu	0.20	0.20	0.20
NOx Removal	%	20	50	80
NOx Emissions	lb/MMBtu	0.16	0.10	0.04
NOx Removed	TPY	526	1,316	2,102
Capacity Factor	%	75	75	75
Reagent		Urea	Peroxide	Ammonia
Reagent Molar Ratio	mol:mol NOx	0.20	1.50	0.80
Reagent Cost	$/ton	$500	$1,000	$600
Soda Ash Cost	$/ton	$0	$300	
Catalyst Cost	$/c.f.			$150
SCR Catalyst Life	Yrs			3
Power Cost	$/MW-hr	$30	$30	$30
Annual Maint. Cost	% of Capital	1.0	1.0	1.0
Capital Cost	$/kW	$15	$25	$250
Capital Recovery Period	Yrs	20	20	20
Capital Discount Rate	%	8	8	8
Capital Recovery Factor	%	10	10	10

Annualized Costs



Cost Effectiveness Analysis



SNCR + PerNOxide offers 60-70% removal at <$3000/ton NOx

Summary

- PerNOxide Technology is a 2-Step Process
  - Oxidation of NO – Capture in Wet/Dry FGD
- Capture of NO_2 is Critical
  - WFGD: mass-transfer, sulfite, pH - important
  - Scrubber chemistry modification may be required
- PerNOxide is Low-Cost Alternative to SCR
  - Capital costs 1/10th that of SCR
  - Annualized costs 1/3rd that of SCR
  - Cost effectiveness ($/ton) 1/2 that of SCR
  - Incremental SCR costs > $10,000/ton NOx
  - Economics improved when combined with SNCR

Questions?

For more information, contact:

Sterling Gray – URS
sterling.gray @ urs.com
512-633-4975

Bob Crynack – FMC
robert.crynack @ fmc.com
412-551-0925