In Situ Device for Real-Time Catalyst Deactivation Measurements*

R. A. Smith, L. J. Muzio

FERCo, Laguna Hills, CA

K. E. Harrison

Southern Company

DOE Project 42298 – Project Kick-Off Meeting

Morgantown, West Virginia

November 8, 2005

*** Patent Pending**

FERCo
FOSSIL ENERGY RESEARCH CORPORATION

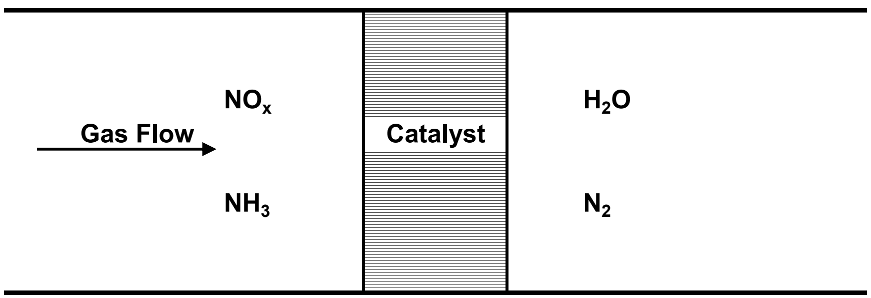
Agenda

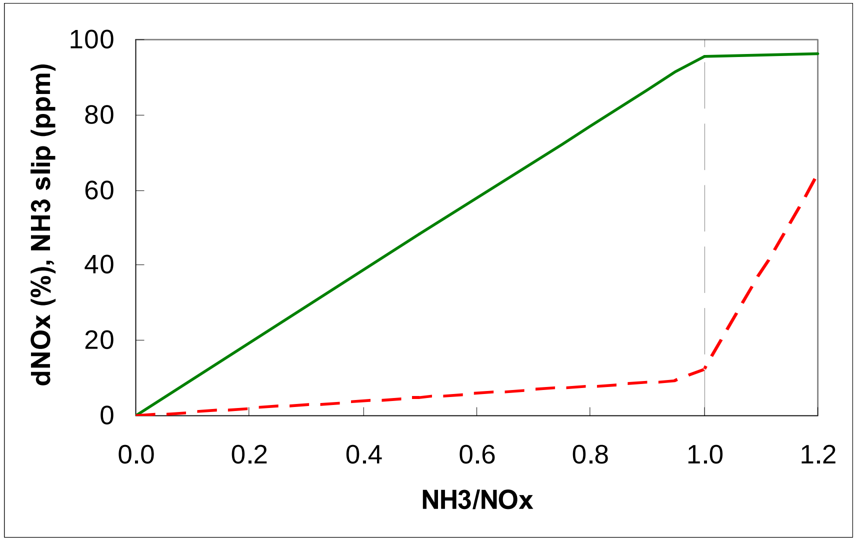
Presentation will cover the following topics:

- **Project Background**
- **Project Overview**
- **Proposed Approach**
- **Host Site Description**
- **Current Project Status**
- **Activity Test Results**
- **Reactor Potential**
- **Activities for 2006**
- **Upgraded System Design**
- **Catalyst Management Software**
- **Project Schedule**
- **Market Assessment**

Project Background

Overview of the SCR Process





$$NO + NH_3 + \frac{1}{4} O_2 \rightarrow N_2 + 1.5H_2O \qquad (1)^*$$

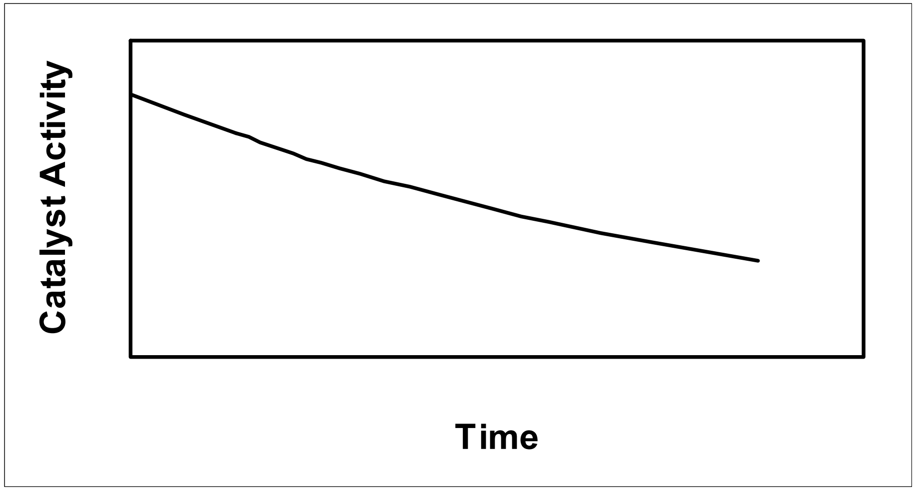
$$6NO_2 + 8NH_3 \rightarrow 7N_2 + 6H_2O \qquad (2)$$

$$2NO_2 + 4NH_3 + O_2 \rightarrow 3N_2 + 6H_2O \qquad (3)$$

* The vast majority of NO$_x$ in coal-fired applications is in the form of NO, so reaction (1) dominates

Project Background

Catalyst Deactivation in Coal-Fired Applications



- **In coal-fired SCR applications, the NO_x reduction potential, or activity, of the catalyst will slowly decrease over time with exposure to flue gas, and each catalyst layer will degrade at a different rate.**
- **As nominally one-third of the catalyst material will need to be replaced every 15,000 to 25,000 hours, utilities need to implement catalyst management plans.**
- **A key issue in implementing a catalyst management plan is how to monitor catalyst activity.**

Project Background

Measuring Catalyst Activity (K)

- Remove catalyst sample from full-scale reactor
- Place sample in a laboratory device where combustion products containing NO_x (actual flue gas or simulated) flow through the sample
- Inject ammonia at $NH_3/NO_x > 1$
- Measure NO_x reduction across the sample
- Calculate K from
  - $K = -A_V \cdot \ln(1- \Delta NO_x)$ (4)
- Where
  - A_V = area velocity at which the test is conducted (m/hr)
  - ΔNO_x = NO_x reduction measured in the laboratory apparatus
  - K = Resulting catalyst activity value (m/hr)

Project Background

SCR Terms and Parameters

Term	Symbol	Relation	Units	Significance
Activity	K	$= -A_V \cdot \ln(1- \Delta NO_x)$ $= 1/(1/h_m+1/K_{chem})$	m/hr	A measure for how active the catalyst is for reducing NO_x
Specific Surface Area	A_{sp}	Honeycomb: $= \frac{4 \cdot (pitch-wall)}{(pitch)^2}$	m^2/m^3	A measure of the catalyst surface area per unit volume of catalyst (sometimes referred to as geometric surface area)
Space Velocity	SV	$= Q/V_{cat}$	1/hr	A measure of flue gas flow per unit volume of catalyst. A smaller SV value means more catalyst per unit of flue gas.
Catalyst Surface Area	A_{cat}	$= A_{sp} \cdot V_{cat}$	m^2	Total catalyst surface area in the reactor
Area Velocity	A_V	$= Q/(A_{sp} \cdot SV)$ $= Q/A_{cat}$	m/hr	A measure of flue gas flow per unit surface area of catalyst. A smaller AV value means more surface area per unit of flue gas.
Reactor Potential	RP	$= (K \cdot A_{cat})/Q$ $= K/A_V$	no units	A measure of the overall potential of the reactor to reduce NO_x

Project Background

Issue

- SCR operation moving from just seasonal to year-round
- Opportunities to physically remove catalyst samples for activity analysis become less frequent
- Even for ozone season operation, access to the SCR reactor may require an outage

Need

- An in situ device capable of measuring catalyst activity across multiple locations and multiple layers in an operating, full-scale SCR reactor

Project Overview

Demonstrate the viability of the in situ approach

- **Install a prototype in situ system at a host utility site**
- **Conduct test program to characterize deactivation rate for individual catalyst layers over two ozone operating seasons**
- **Utilize host unit operator's annual O&M catalyst sampling/analysis activities to validate the in situ deactivation measurements**

Project funding

- **U.S. Department of Energy**
- **EPRI**
- **Southern Company**

Proposed Approach

Measure catalyst activity in situ

- **Testing can be conducted at any time, irrespective of unit outage schedule**

Multiple devices can be placed in the reactor

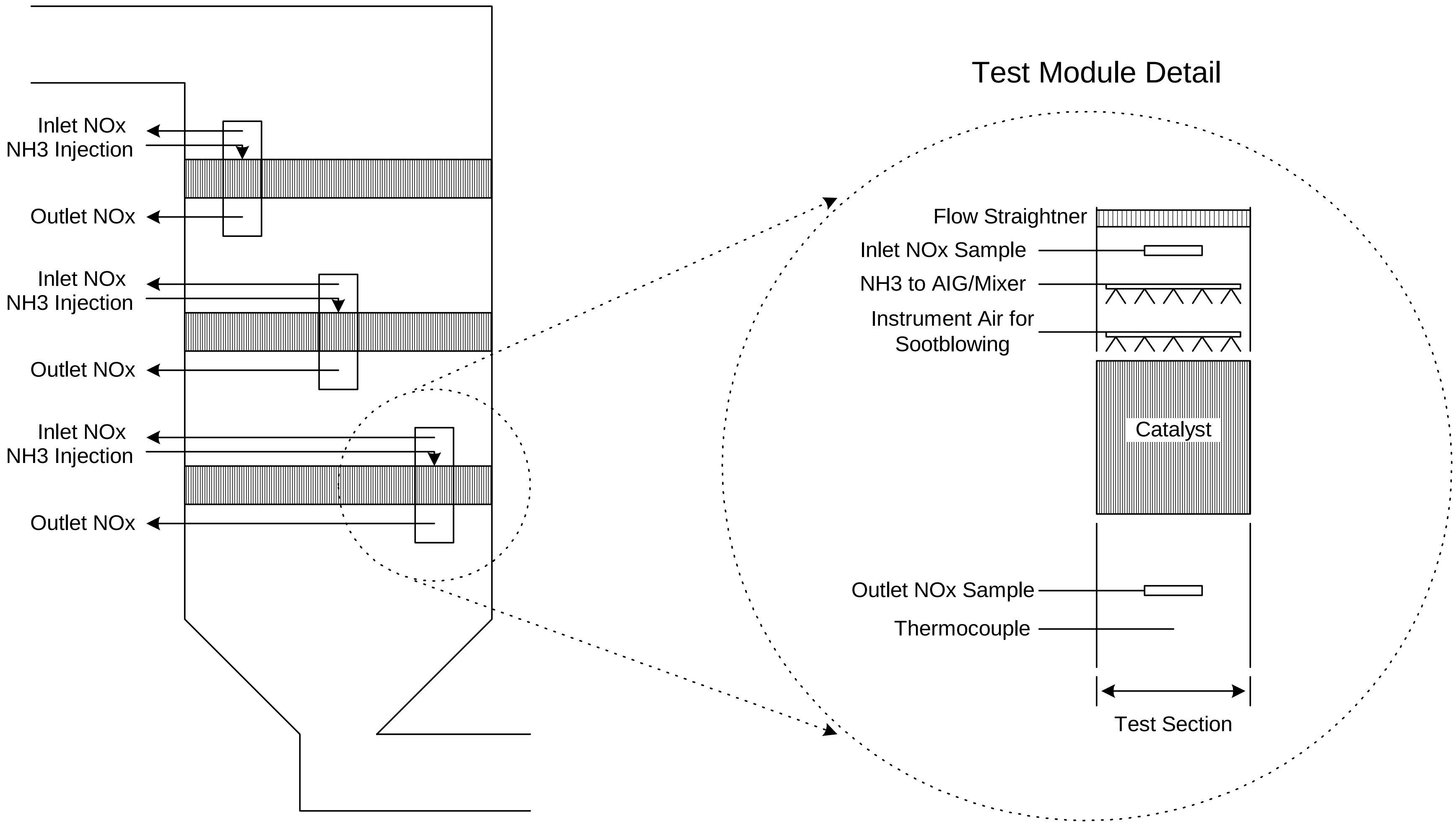
- **Monitor each layer independently**
- **Monitor multiple locations per layer**

Technique

- **Similar to laboratory measurements performed by catalyst vendors and third-party testing organizations**
- **Measures ΔNO_x @ $NH_3/NO_x > 1$**
- **$K = -A_V \cdot \ln(1- \Delta NO_x)$**
- **Provides more data for K/K_0 versus time curve than periodic manual sampling**

Proposed Approach

Multiple In-Situ Test Modules



Host Site Description

Demonstration host site provided by Southern Company

- **Alabama Power Company's Gorgas Unit 10**
  - **700 MW**
  - **Twin-furnace, tangentially-fired**
  - **Started operation 1972**
  - **Alabama bituminous coal**
- **SCR on-line May 2002, ozone season operation**
  - **Two reactors**
  - **3 + 1 configuration**
  - **Anhydrous NH_3**
  - **Extruded honeycomb catalyst**

Current Project Status

Cold-Flow modeling of test module AIG

- Optimize NH_3 distribution ahead of in situ catalyst test location

Prototype system installed in April of 2005

- Three in-situ test modules (one per catalyst layer in a single reactor, Reactor B)
- A manual system for NH_3 injection, and flue gas sampling
- Activity measurements were made manually during monthly site visits by FERCo personnel utilizing a portable gas sampling and analysis system (NO and O_2 only)

2005 ozone season activities

- Six sets of activity data were collected on nominal 4-week intervals from May 1 to September 30, 2005
- Site visit in October 2005 to inspect the testing equipment installed inside the reactor

Activity Test Results

Testing Protocol

- Measure NO removal across test module without injection of additional NH_3
- Add NH_3 via test module AIG until point of maximum NO removal is achieved
- Calculate catalyst activity from the maximum NO removal via

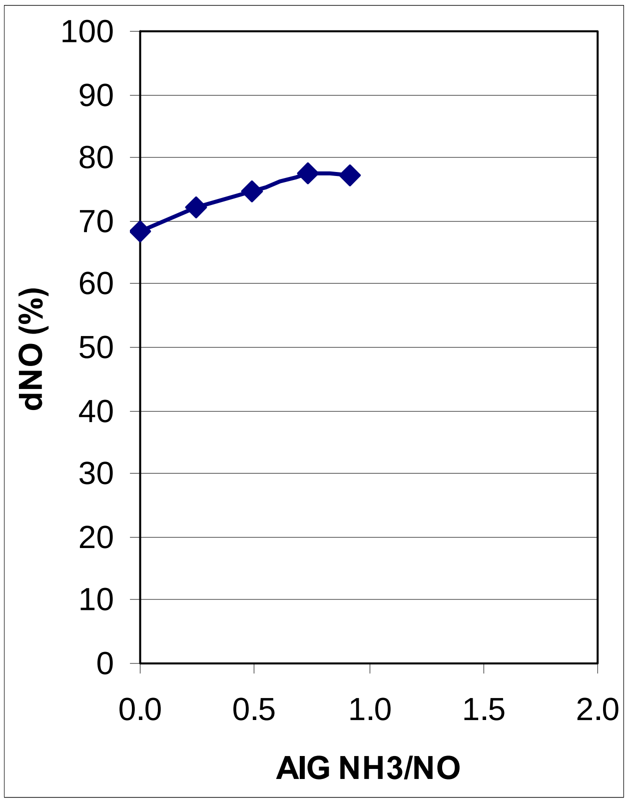
  $K = -A_V \cdot \ln(1- \Delta NO)$,

  where A_V is adjusted for variations in flue gas flow rate

Activity Test Results

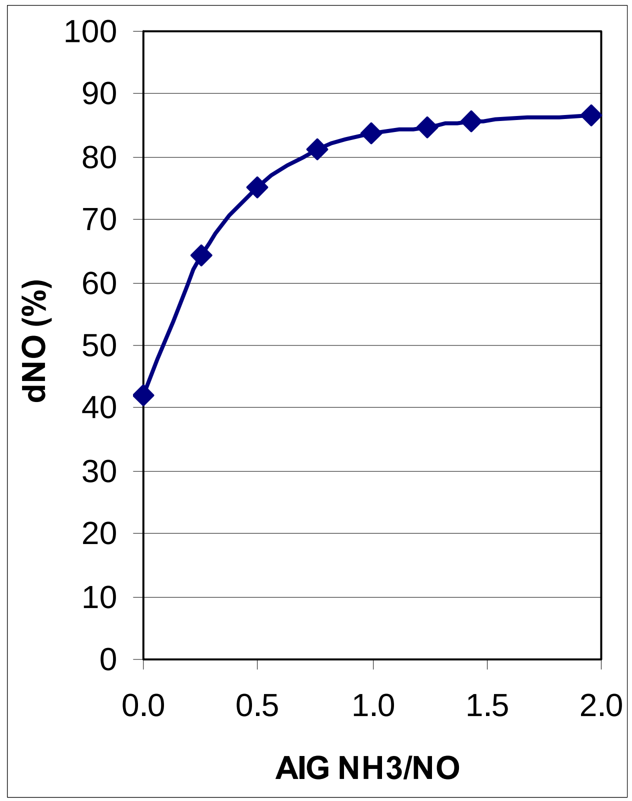
Typical NO Removal Curves (6/9/2005)

Catalyst Layer 1



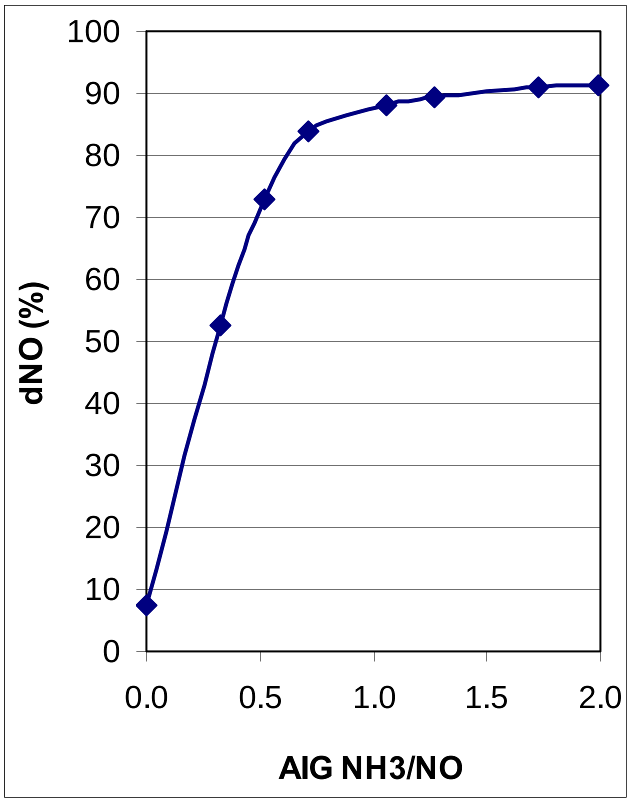
- **ΔNO maximum = 77.3%**

Catalyst Layer 2



- **ΔNO maximum = 86.6%**

Catalyst Layer 3

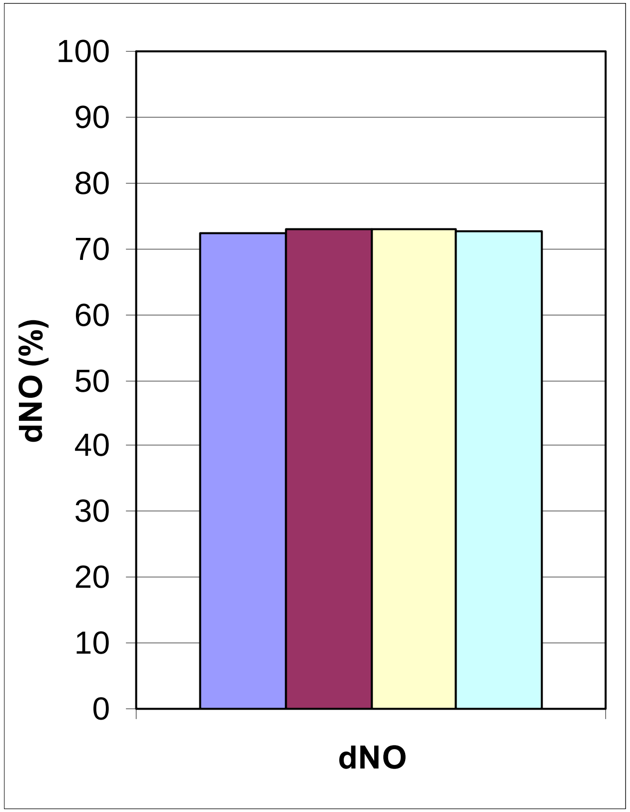


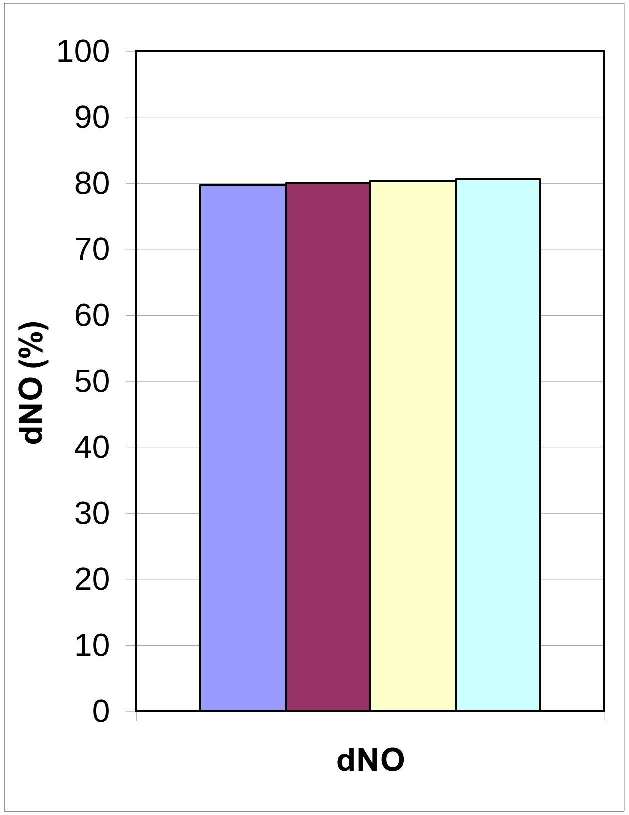
- **ΔNO maximum = 91.3%**

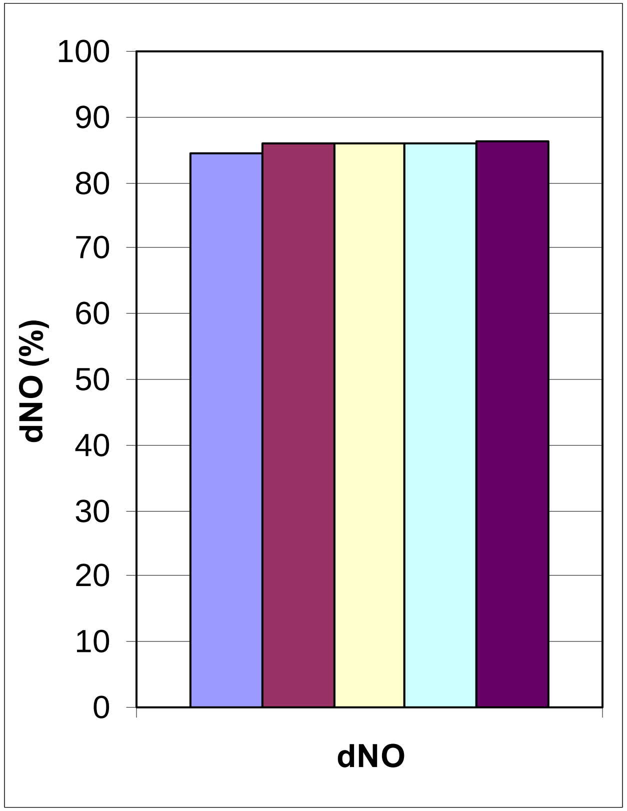
Activity Test Results

Typical Repeatability Test Results (9/28/2005)

Catalyst Layer 1	Catalyst Layer 2	Catalyst Layer 3





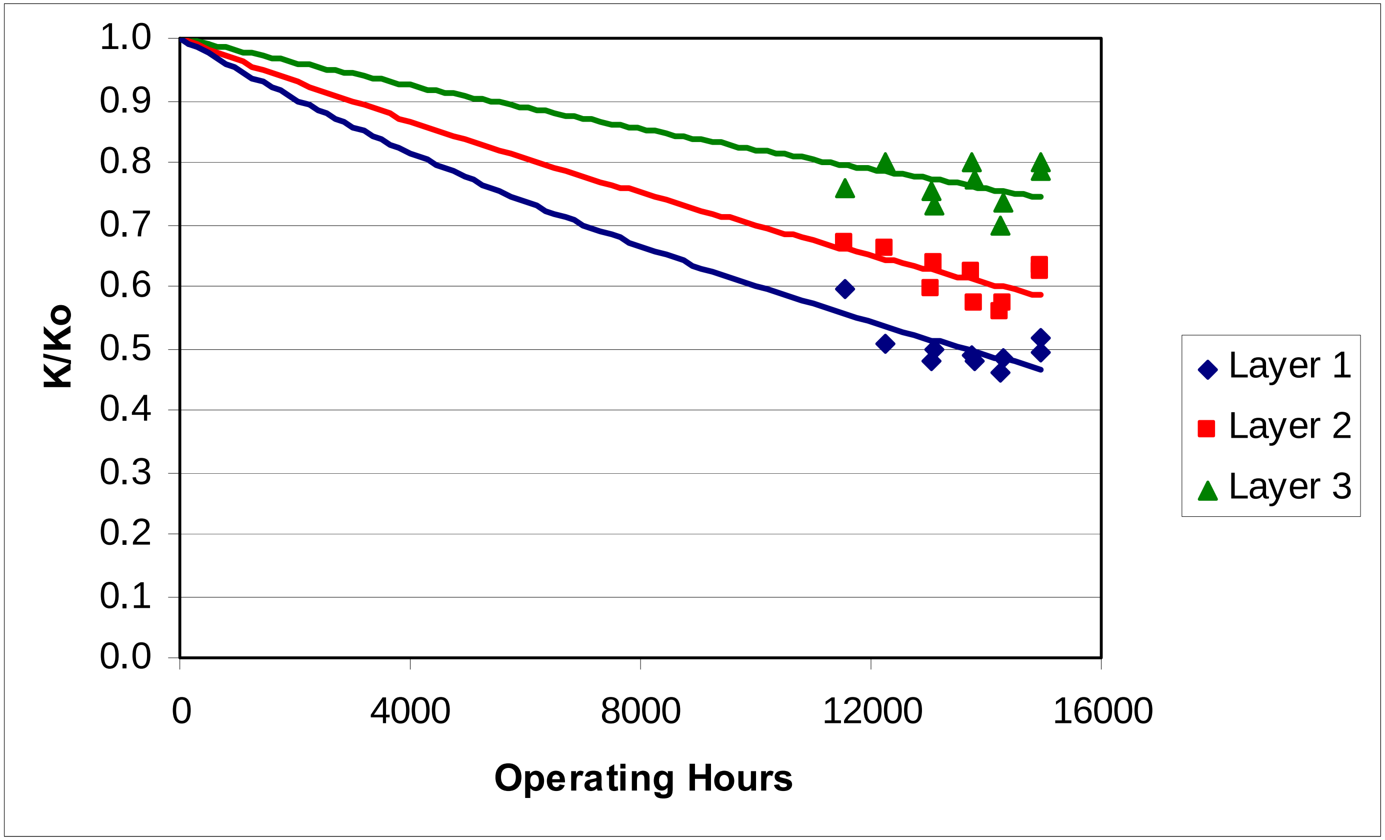


- **ΔNO average = 72.7%**
- **ΔNO average = 80.2%**
- **ΔNO average = 85.7%**

Activity Test Results

Relative Activity (K/K_0)

- **Utilize K_0 value determined by Southern Company's third-party testing organization to normalize the monthly K measurements**



FERCo
FOSSIL ENERGY RESEARCH CORPORATION

Reactor Potential

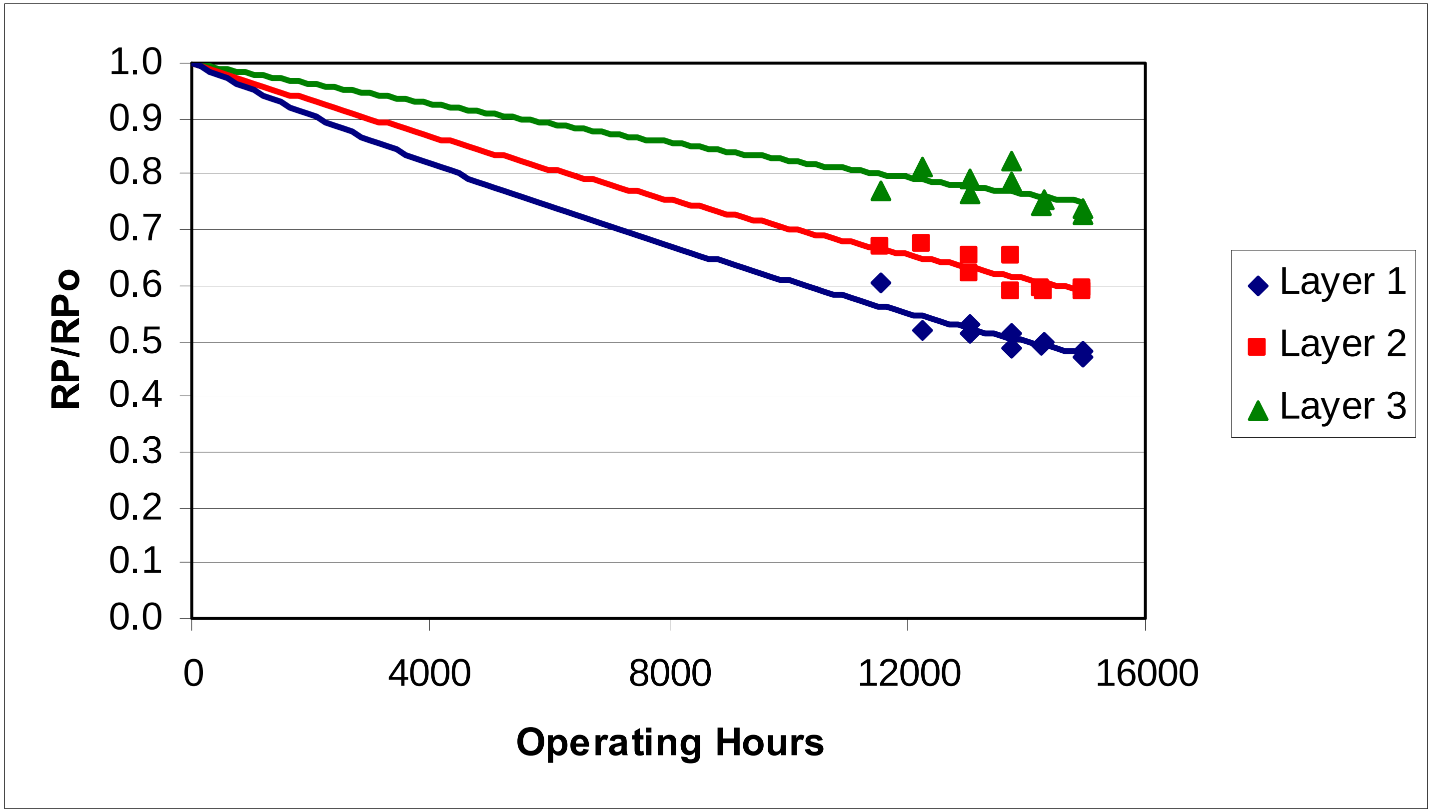
RP – Another View of Activity

- Reactor Potential is a measure of the overall potential of the catalyst layer to reduce NO_x
- $RP = K/A_V = -\ln(1- \Delta NO_x)$
- RP can be calculated directly from the in situ ΔNO_x measurement without needing to calculate and/or estimate A_V
- Inherently accounts for both K/K_0 and blockage, thereby providing a true assessment of the condition of the SCR reactor

Reactor Potential

Relative Reactor Potential (RP/RP$_0$)

- **Utilize K_0 and A_V from Southern Company's third-party testing organization to calculate RP_0, and then normalize the RP values from the monthly in situ measurements**



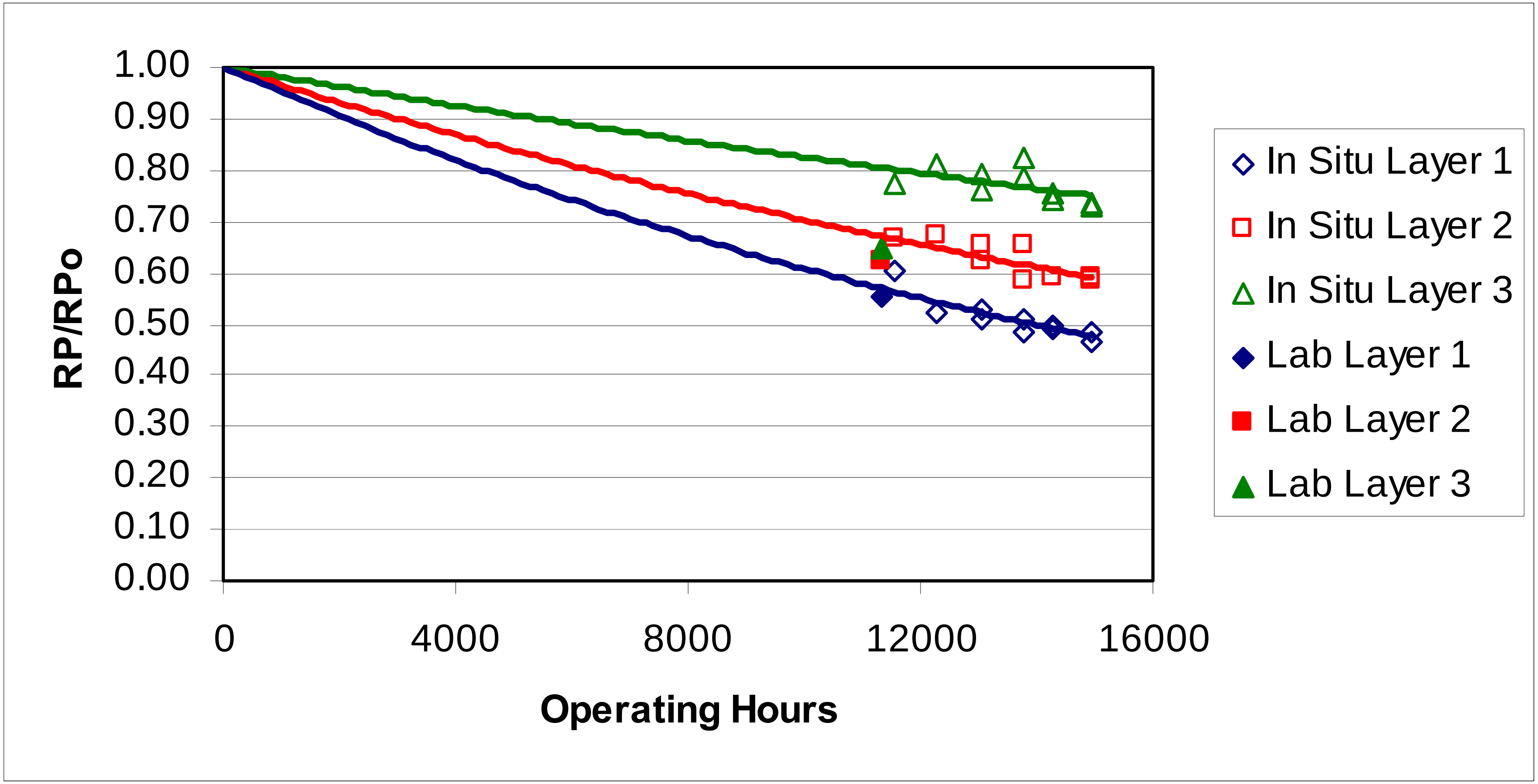
Reactor Potential

Laboratory Assessment of K vs. RP

- **Remove catalyst sample from each layer of the full-scale reactor**
- **Measure $K = -A_V \cdot \ln(1-\Delta NO_x)$ in a test apparatus at NH_3/NO_x of 1.0 or 1.2 depending on apparatus (VGB Guideline)**
- **Blockage of each catalyst sample is assessed and total gas flow through reactor is adjusted to maintain full-scale conditions**
- **Calculate K for each sample and report activity relative to that for fresh catalyst sample as K/K_0**
- **This only assesses the change in catalyst activity with time (K/K_0), not the change in overall reactor potential, RP/RP_0**
- **RP/RP_0 requires K/K_0 as well as knowledge of how the average overall blockage of each catalyst layer changes with time**
- **Utilize a visual assessment of the blockage to calculate an adjusted A_V for each layer, and then calculate RP via $RP = K/A_V$**

Reactor Potential

Comparison of In Situ and Laboratory RP/RP$_0$



Reactor Potential

Discussion of RP/RP_0 Results

- **By design, the in situ method measures the true Reactor Potential at any point in time**
  - **Based only on ΔNO_x measurement**
  - **Actual operating conditions of SCR system (i.e. at the real A_V conditions accounting for catalyst blockage)**
- **Laboratory analysis of K combined with an A_V adjustment to account for the blockage effects in the full-scale reactor, should result in a similar RP value**
- **Differences may be due to variations in K across the catalyst layer or variations in cell pluggage across the layer**

Activities for 2006

- Compare the in situ RP values at the conclusion of the 2005 ozone season to those calculated from physical catalyst samples removed and analyzed during the current outage
- Add a second test module to each catalyst layer
- Upgrade the prototype system
  - Automated control systems for NH_3 injection and flue gas sampling
  - Remote access and control capabilities
- Utilize the in situ activity data as an input into EPRI's CatReact^{TM} program to demonstrate the value of real-time activity measurements with respect to the optimization of a catalyst replacement strategy

Upgraded System Design

Stand-Alone System

- All control functionality, gas switching valves, and gas analysis instrumentation housed in an enclosure adjacent to the reactor
- PLC control of gas sampling and NH_3 injection functionality provides for "one button" activity testing
- Remote access and control capabilities

Cart-Based System

- Flue gas and NH_3 switching valves housed in an enclosure adjacent to the reactor
- Gas analysis instrumentation and NH_3 mass flow control housed on a portable cart
- Semi-automated activity testing via laptop computer interface to cart

Upgraded System Design

Benefits Comparison

Stand-Alone	Cart-Based
Pro • Fully-automated • Remote access • Integration with plant DAS	**Pro** • More cost-effective solution for plants with multiple SCRs
Con • Expensive per-unit cost	**Con** • Semi-automated testing • Personnel required for operation

While a preliminary assessment of SCR owner/operators has indicated interest in both system designs, the vast majority of interest has been in the cart-based system.

Catalyst Management Software

Overview

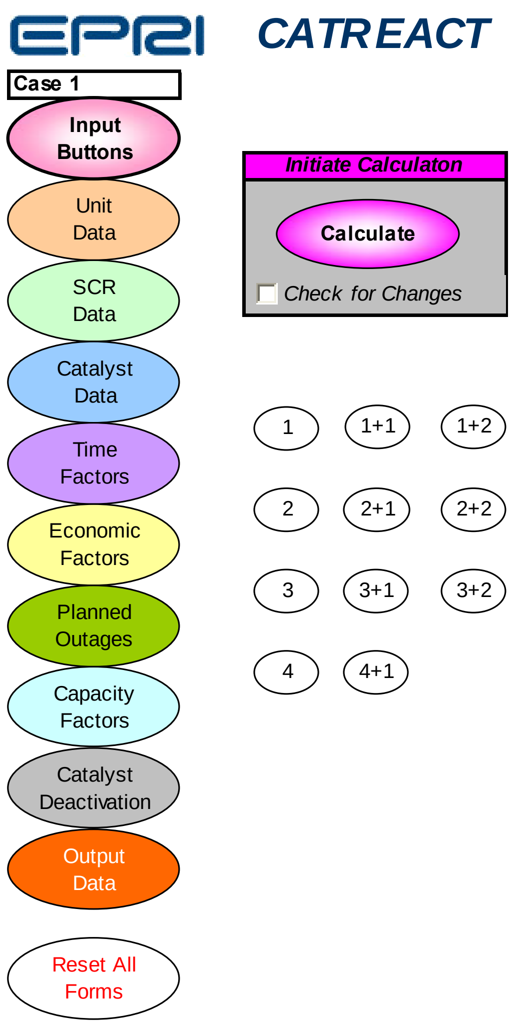
- **Software tool that helps operators of SCR systems in coal-fired power plants make catalyst management decisions throughout the lifetime of the plant**
- **The program determines when future catalyst additions and/or replacements will be necessary and calculates SCR operating and maintenance (O&M) costs**

Commercially-Available Packages

- **CATLife (TackTicks LLC)**
- **CAT MANAGER™ (Andover Technology Partners)**
- **CatReact™ (EPRI)**
- **NOxVision (KEMA)**

Catalyst Management Software

CatReact™ Input Buttons Worksheet



Calculation Scenario					
	Layer 1	*Layer 2*	*Layer 3*	*Layer 4*	*Layer 5*
Startup	1	1	1		
Event 1				1	
Event 2	1				
Event 3		1			
Event 4			1		
Event 5				1	
Event 6	1				
Event 7		1			
Event 8			1		
Event 9				1	
Event 10	1				
Event 11		1			
Event 12			1		
Event 13				1	
Event 14	1				
Event 15		1			
Event 16			1		
Event 17				1	
Event 18	1				
Event 19		1			
Event 20			1		

Note: Numbers signify Catalyst Type

Catalyst Management Software

CatReact™ Output Data Worksheet (sample data)

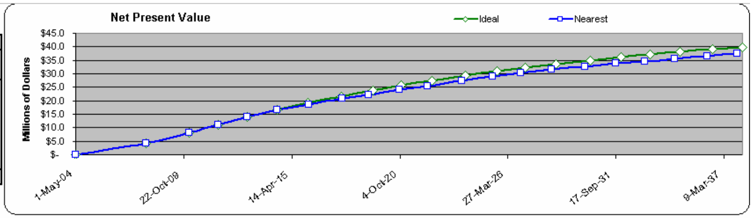
EPRI

CATREACT

Case 1

Input Buttons | Unit Data | SCR Data | Catalyst Data | Time Factors | Economic Factors | Planned Outages | Capacity Factors | Catalyst Deactivation | **Output Data** | Print All | Copy Output to Blank Sheet | Clear All on Blank Sheet

Summary Report	Ideal	Nearest
As of Date	12/31/16	12/31/16
Total Cost NPV	**$ 19,792,545**	**$ 19,044,575**
Catalyst NPV	$ 4,603,245	$ 4,600,896
Reagent NPV	$ 8,950,479	$ 8,961,310
Labor NPV	$ 82,495	$ 82,453
Electricity NPV	$ 5,556,585	$ 4,799,441
NOx Credit NPV	$ -	$ -
dP NPV	$ 599,741	$ 600,474
Catalyst Layers Installed	6	6



Ideal Change Analysis

Layer 1	Layer 2	Layer 3	Layer 4	Layer 5		Date	Operating Hours (hrs)	Total Cost ($ 10^6)	dNOx (%)	NH3slip (ppm)	Cost Components: Catalyst ($ 10^6)	Reagent ($ 10^6)	Labor ($ 10^6)	Electricity ($ 10^6)	NOx Credits ($ 10^6)	dP ($ 10^6)	SO2 Conv (%)	dP (in H2O)	RP/RPo used	RP/RPo new
1	1	1			Start	5/1/2004	0	$ -	85	0.1	$ -	$ -	$ -	$ -	$ -	$ -	0.5%	1.6		1.00
			1		Event 1	11/24/2007	16000	$ 4.09	85	1.8	$ 0.94	$ 1.90	$ 0.02	$ 1.11	$ -	$ 0.13	0.7%	2.2	0.65	0.98
1					Event 2	1/24/2010	34051	$ 8.14	85	1.8	$ 1.78	$ 3.91	$ 0.03	$ 2.16	$ -	$ 0.26	0.7%	2.2	0.65	0.89
	1				Event 3	7/23/2011	46153	$ 11.18	85	1.8	$ 2.57	$ 5.13	$ 0.05	$ 3.10	$ -	$ 0.34	0.7%	2.2	0.65	0.89
		1			Event 4	1/2/2013	58270	$ 14.02	85	1.8	$ 3.30	$ 6.26	$ 0.06	$ 3.98	$ -	$ 0.42	0.7%	2.2	0.65	0.87
			1		Event 5	7/13/2014	70678	$ 16.68	85	1.8	$ 3.97	$ 7.34	$ 0.07	$ 4.80	$ -	$ 0.49	0.7%	2.2	0.65	0.86
1					Event 6	2/1/2016	83692	$ 19.20	85	1.8	$ 4.60	$ 8.39	$ 0.08	$ 5.56	$ -	$ 0.56	0.7%	2.2	0.65	0.93
	1				Event 7	10/22/2017	97824	$ 21.60	85	1.8	$ 5.18	$ 9.44	$ 0.09	$ 6.25	$ -	$ 0.63	0.7%	2.2	0.65	0.90
		1			Event 8	5/24/2019	110772	$ 23.74	85	1.8	$ 5.72	$ 10.33	$ 0.10	$ 6.90	$ -	$ 0.69	0.7%	2.2	0.65	0.85
			1		Event 9	10/26/2020	122672	$ 25.66	85	1.8	$ 6.22	$ 11.09	$ 0.11	$ 7.50	$ -	$ 0.74	0.7%	2.2	0.65	0.85
1					Event 10	5/20/2022	135431	$ 27.50	85	1.8	$ 6.68	$ 11.85	$ 0.12	$ 8.05	$ -	$ 0.80	0.7%	2.2	0.65	0.94
	1				Event 11	2/1/2024	149751	$ 29.28	85	1.8	$ 7.10	$ 12.63	$ 0.13	$ 8.57	$ -	$ 0.85	0.7%	2.2	0.65	0.90
		1			Event 12	9/4/2025	162743	$ 30.85	85	1.8	$ 7.50	$ 13.29	$ 0.13	$ 9.04	$ -	$ 0.89	0.7%	2.2	0.65	0.85
			1		Event 13	2/5/2027	174588	$ 32.27	85	1.8	$ 7.86	$ 13.85	$ 0.14	$ 9.48	$ -	$ 0.93	0.7%	2.2	0.65	0.85
1					Event 14	8/29/2028	187342	$ 33.62	85	1.8	$ 8.20	$ 14.40	$ 0.15	$ 9.89	$ -	$ 0.97	0.7%	2.2	0.65	0.94
	1				Event 15	5/29/2030	201675	$ 34.93	85	1.8	$ 8.52	$ 14.98	$ 0.15	$ 10.27	$ -	$ 1.01	0.7%	2.2	0.65	0.90
		1			Event 16	12/16/2031	214668	$ 36.08	85	1.8	$ 8.81	$ 15.46	$ 0.16	$ 10.62	$ -	$ 1.04	0.7%	2.2	0.65	0.85
			1		Event 17	6/1/2033	226508	$ 37.12	85	1.8	$ 9.08	$ 15.87	$ 0.16	$ 10.94	$ -	$ 1.07	0.7%	2.2	0.65	0.85
1					Event 18	12/10/2034	239264	$ 38.12	85	1.8	$ 9.33	$ 16.28	$ 0.17	$ 11.24	$ -	$ 1.10	0.7%	2.2	0.65	0.94
	1				Event 19	8/8/2036	253598	$ 39.08	85	1.8	$ 9.56	$ 16.71	$ 0.17	$ 11.52	$ -	$ 1.12	0.7%	2.2	0.65	0.90
		1			Event 20	2/10/2038	266591	$ 39.94	85	1.8	$ 9.77	$ 17.06	$ 0.18	$ 11.78	$ -	$ 1.15	0.7%	2.2	0.65	0.85

Nearest Outage Analysis

Layer 1	Layer 2	Layer 3	Layer 4	Layer 5		Date	Operating Hours (hrs)	Total Cost ($ 10^6)	dNOx (%)	NH3slip (ppm)	Cost Components: Catalyst ($ 10^6)	Reagent ($ 10^6)	Labor ($ 10^6)	Electricity ($ 10^6)	NOx Credits ($ 10^6)	dP ($ 10^6)	SO2 Conv (%)	dP (in H2O)	RP/RPo used	RP/RPo new
1	1	1			Start	**5/1/2004**	0	$ -	85	0.1	$ -	$ -	$ -	$ -	$ -	$ -	0.5%	1.6		1.00
			1		Event 1	11/24/2007	16000	$ 4.09	85	1.8	$ 0.94	$ 1.90	$ 0.02	$ 1.11	$ -	$ 0.13	0.7%	2.2	0.65	0.98
1					Event 2	1/24/2010	34051	$ 8.14	85	1.8	$ 1.78	$ 3.91	$ 0.03	$ 2.16	$ -	$ 0.26	0.7%	2.2	0.65	0.89
	1				Event 3	7/23/2011	46153	$ 11.18	85	1.8	$ 2.57	$ 5.13	$ 0.05	$ 3.10	$ -	$ 0.34	0.7%	2.2	0.65	0.89
		1			Event 4	1/2/2013	58270	$ 14.02	85	1.8	$ 3.30	$ 6.26	$ 0.06	$ 3.98	$ -	$ 0.42	0.7%	2.2	0.65	0.87
			1		Event 5	7/13/2014	70678	$ 16.68	85	1.8	$ 3.97	$ 7.34	$ 0.07	$ 4.80	$ -	$ 0.49	0.7%	2.2	0.65	0.86
1					Event 6	**2/29/2016**	84360	$ 18.49	85	2.0	$ 4.60	$ 8.44	$ 0.08	$ 4.80	$ -	$ 0.57	0.7%	2.2	0.64	0.93
	1				Event 7	10/24/2017	98131	$ 20.87	85	1.8	$ 5.18	$ 9.47	$ 0.09	$ 5.50	$ -	$ 0.63	0.7%	2.2	0.65	0.90
		1			Event 8	**2/28/2019**	108960	$ 22.22	85	1.4	$ 5.72	$ 10.22	$ 0.10	$ 5.50	$ -	$ 0.69	0.7%	2.2	0.69	0.88
			1		Event 9	9/21/2020	122318	$ 24.25	85	1.8	$ 6.22	$ 11.08	$ 0.11	$ 6.10	$ -	$ 0.74	0.7%	2.2	0.65	0.85
1					Event 10	**2/27/2022**	133920	$ 25.47	85	1.7	$ 6.69	$ 11.77	$ 0.12	$ 6.10	$ -	$ 0.79	0.7%	2.2	0.66	0.95
	1				Event 11	11/19/2023	148703	$ 27.30	85	1.8	$ 7.12	$ 12.59	$ 0.13	$ 6.62	$ -	$ 0.85	0.7%	2.2	0.65	0.90
		1			Event 12	6/18/2025	161581	$ 28.88	85	1.8	$ 7.52	$ 13.25	$ 0.13	$ 7.10	$ -	$ 0.89	0.7%	2.2	0.65	0.85
			1		Event 13	11/23/2026	173525	$ 30.31	85	1.8	$ 7.89	$ 13.81	$ 0.14	$ 7.54	$ -	$ 0.93	0.7%	2.2	0.65	0.85
1					Event 14	6/13/2028	186197	$ 31.67	85	1.8	$ 8.23	$ 14.37	$ 0.15	$ 7.96	$ -	$ 0.97	0.7%	2.2	0.65	0.94
	1				Event 15	**2/25/2030**	200160	$ 32.60	85	1.8	$ 8.55	$ 14.94	$ 0.15	$ 7.96	$ -	$ 1.01	0.7%	2.2	0.66	0.91
		1			Event 16	9/14/2031	213391	$ 33.79	85	1.8	$ 8.84	$ 15.44	$ 0.16	$ 8.31	$ -	$ 1.04	0.7%	2.2	0.65	0.85
			1		Event 17	**2/24/2033**	225480	$ 34.52	85	1.9	$ 9.11	$ 15.86	$ 0.16	$ 8.31	$ -	$ 1.07	0.7%	2.2	0.65	0.85
1					Event 18	8/31/2034	238034	$ 35.52	85	1.8	$ 9.37	$ 16.27	$ 0.17	$ 8.62	$ -	$ 1.10	0.7%	2.2	0.65	0.94
	1				Event 19	4/29/2036	252366	$ 36.50	85	1.8	$ 9.60	$ 16.70	$ 0.17	$ 8.90	$ -	$ 1.12	0.7%	2.2	0.65	0.90
		1			Event 20	11/2/2037	265390	$ 37.37	85	1.8	$ 9.82	$ 17.07	$ 0.18	$ 9.16	$ -	$ 1.15	0.7%	2.2	0.65	0.85

Note: In the above output tables "**black**" entry dates correspond to planned outages
"red" entry dates correspond to special outages just to add or replace catalyst

FERCo
FOSSIL ENERGY RESEARCH CORPORATION

Project Schedule

Calendar Year 2005

Month Task/Activity	Feb 1	Mar 2	Apr 3	May 4	Jun 5	Jul 6	Aug 7	Sept 8	Oct 9	Nov 10	Dec 11
	2005										
1 Design/Build Manual Sampling/Control Systems											
1.1 Locate Host Site/Procure Host Site Agreement					Complete						
1.2 Cold-Flow Modeling for AIG/Mixer											
1.3 Design/Build Manual Sampling/Control Systems											
2 Design, Build & Install Site-Specific Equipment					Complete						
2.1 Design/Build/Test 3 Test Modules											
2.2 Install at Host Site											
3 Testing Ozone Season #1					Complete						
3.1 On-Site Activity Tests											
4 Outage #1 Activities					Complete						
4.1 Outage Inspection											
5 Design, Build & Install Automatic System											
5.1 Design/Build Automatic System											
5.2 Install at Host Site											
6 Testing Ozone Season #2											
6.1 On-Site Activity Tests											
6.2 Weekly Remote Monitoring											
7 Outage #2 Activities											
7.1 Outage Inspection & Decomission System											
8 Catalyst Management Program Integration											
8.1 Integrate CatReact Software											
8.2 Update Software with Activity Data											
9 Data Analysis & Reporting											
9.1 Data Analysis											
9.2 DOE/NETL Briefings (kickoff + final)											
9.3 Interim Report (outage #1)											
9.4 Final Report											
9.5 Contractor Review Mtgs/Presentations											

◈ Go/No Go decision point based on DOE acceptance of Host Site Agreement

Current Date

FERCo
FOSSIL ENERGY RESEARCH CORPORATION

MP223b

Project Schedule

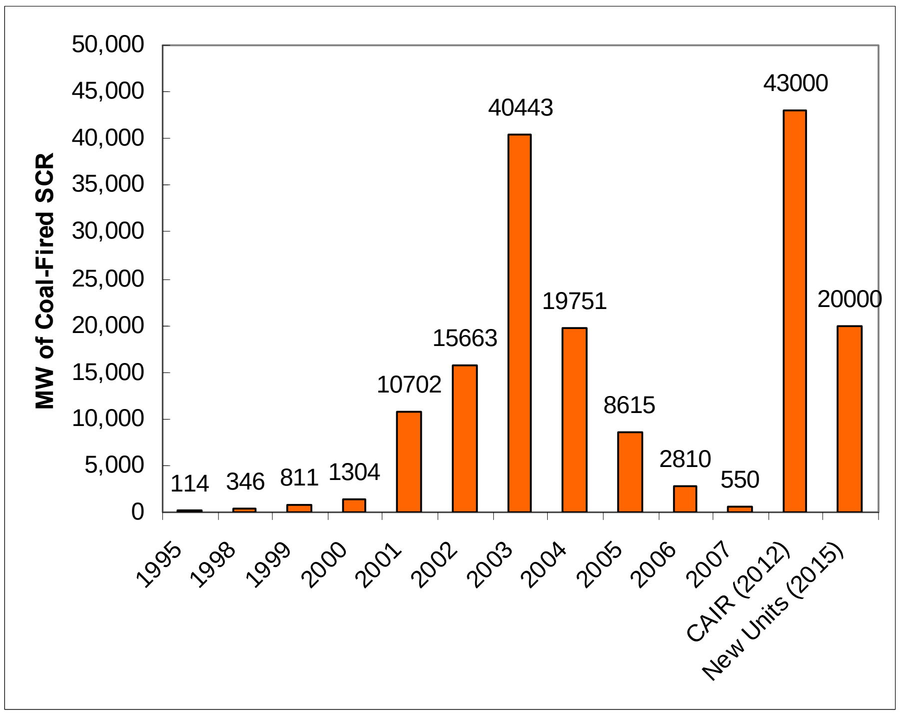
Calendar Years 2006 & 2007

	2006												2007				
Month Task/Activity	**Jan 12**	**Feb 13**	**Mar 14**	**Apr 15**	**May 16**	**Jun 17**	**Jul 18**	**Aug 19**	**Sept 20**	**Oct 21**	**Nov 22**	**Dec 23**	**Jan 24**	**Feb 25**	**Mar 26**	**Apr 27**	**May 28**
1 Design/Build Manual Sampling/Control Systems																	
1.1 Locate Host Site/Procure Host Site Agreement																	
1.2 Cold-Flow Modeling for AIG/Mixer																	
1.3 Design/Build Manual Sampling/Control Systems																	
2 Design, Build & Install Site-Specific Equipment																	
2.1 Design/Build/Test 3 Test Modules																	
2.2 Install at Host Site																	
3 Testing Ozone Season #1																	
3.1 On-Site Activity Tests																	
4 Outage #1 Activities																	
4.1 Outage Inspection																	
5 Design, Build & Install Automatic System																	
5.1 Design/Build Automatic System																	
5.2 Install at Host Site																	
6 Testing Ozone Season #2																	
6.1 On-Site Activity Tests																	
6.2 Weekly Remote Monitoring																	
7 Outage #2 Activities																	
7.1 Outage Inspection & Decomission System																	
8 Catalyst Management Program Integration																	
8.1 Integrate CatReact Software																	
8.2 Update Software with Activity Data																	
9 Data Analysis & Reporting																	
9.1 Data Analysis																	
9.2 DOE/NETL Briefings (kickoff + final)																	
9.3 Interim Report (outage #1)																	
9.4 Final Report																	
9.5 Contractor Review Mtgs/Presentations																	

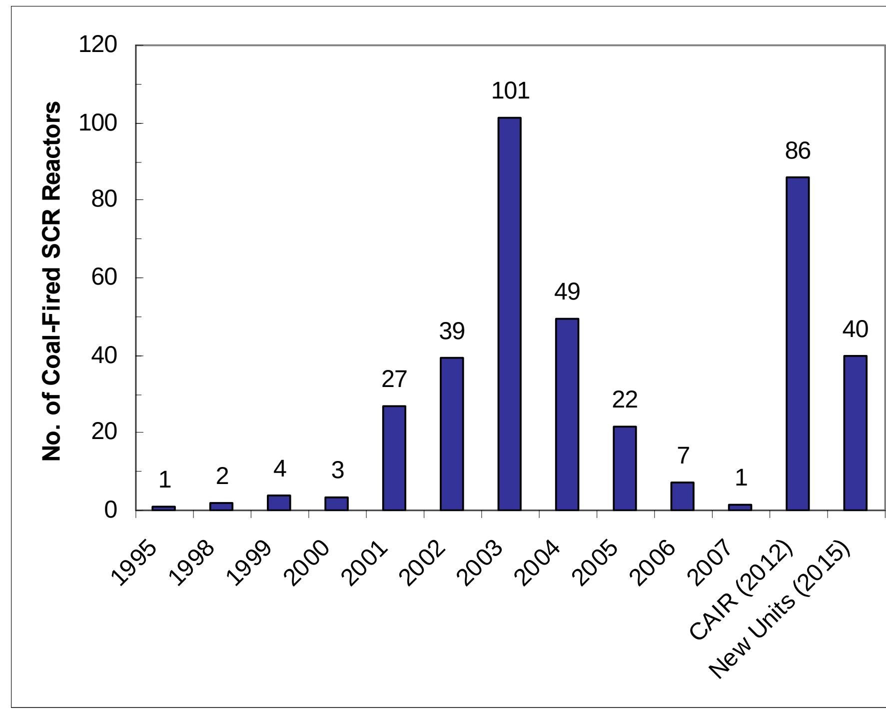
Market Assessment

Existing and Planned SCR Installations

Megawatts Capacity

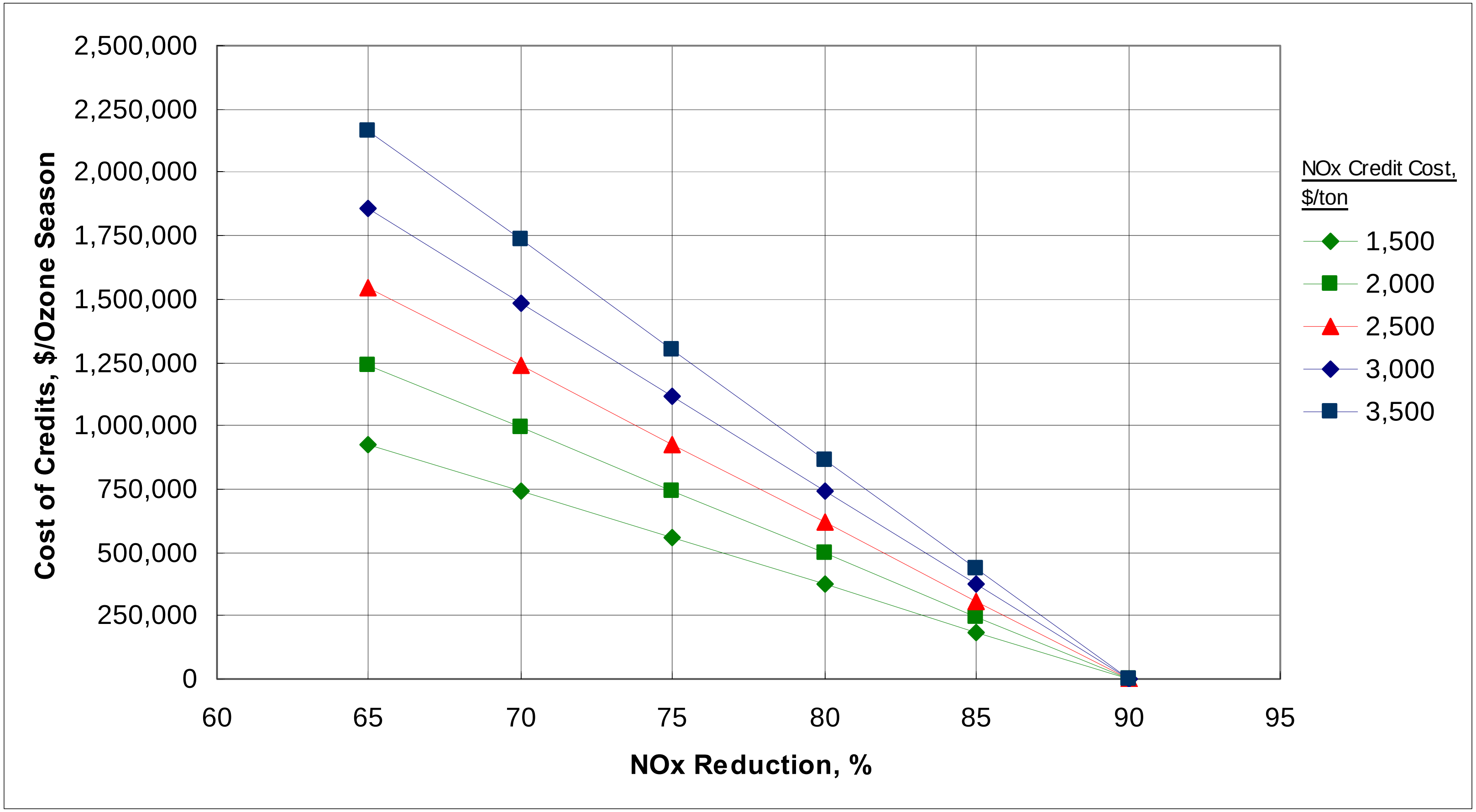


Number of SCR Reactors



Market Assessment

Cost-Benefit Analysis



FERCo
FOSSIL ENERGY RESEARCH CORPORATION