AMMONIA-FREE NOx CONTROL SYSTEM

QUARTERLY TECHNICAL PROGRESS REPORT NO. 41865R7

APRIL 1 THROUGH JUNE 30, 2005

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Disclaimers

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Abstract

Research is being conducted under United States Department of Energy (DOE) Contract DE-FC26-03NT41865 to develop a new technology to achieve very low levels of NOx emissions from pulverized coal fired boiler systems by employing a novel system level integration between the PC combustion process and the catalytic NOx reduction with CO present in the combustion flue gas. The combustor design and operating conditions will be optimized to achieve atypical flue gas conditions. This approach will not only suppress NOx generation during combustion but also further reduce NOx over a downstream catalytic reactor that does not require addition of an external reductant, such as ammonia.

This report describes the work performed during the April 1 to June 30, 2005 time period.

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1.0 EXECUTIVE SUMMARY

1.1 Project Overview

State-of-the-art NOx control technology for pulverized coal (PC) steam plants involves a combination of low NOx combustion and selective catalytic reduction (SCR) technologies. Development of these systems has approached a plateau and further improvements will likely be incremental. To advance NOx control technology to the next level, new concepts must be considered.

The objective of this project is to evaluate the viability of a novel integration between the PC combustion process and flue gas NOx reduction. The concept exploits the relationship between CO and NOx both in the combustion and flue gas NOx destruction processes to achieve very low levels of NOx from the boiler system without adding any external reductant, such as ammonia, typically used for SCR processes.

The project starts with a review and evaluation of commercial and developmental catalysts for NOx reduction and CO oxidation, including those catalysts formulations successfully used in the automotive applications, for their use in PC power plants. This knowledge, combined with prior catalyst research experience for power plant applications allows the project team to identify and test catalyst formulations robust enough for the oxidizing flue gas environment in power plants, and capable of achieving competitive NOx reduction performance and economic targets.

A detailed PC combustion study, applying computational fluid dynamics simulation program to perform boiler and burner design modeling, complements the catalyst development effort by investigating ways to optimize the combustion process for the lowest NOx formation while generating sufficient levels of CO needed by the downstream catalytic NOx reduction process. Furnace configuration, air staging, and burner design are evaluated in this process.

The study will then focus on the comparative evaluation of a conceptual, 400 MWe, coal-fired PC boiler system, utilizing this novel NOx control concept. For this evaluation, the concept plant will be compared to a traditional PC boiler configured with current low NOx combustion technology and an ammonia-based SCR system. The comparison will involve conceptual level design of the furnace and catalyst reduction system (an ammonia-free selective catalytic reactor, or AF-SCR) to obtain equipment pricing, operational costs, performance data as well as qualitative reliability information.

1.2 Progress During the Quarter

The project work during this quarter was primarily on Task 4 – System Conceptual Design. The work of Task 4 provides the basis for Task 5 Comparative Evaluation of performance and costs.

The key to realistic design of a commercial-scale catalytic reactor is reliable scale-up from the small test rig in laboratory. Successful scale-up requires careful characterization and modeling of transport phenomena such as bulk mass transfer; pore diffusion and distribution of active ingredients in the substrate. These topics are the focus of the project work in the January thru March quarter and their outcome forms the basis of the conceptual design. During the current quarter, a 400 MWe size AF-SCR reactor has been designed and its performance has been predicted.

2.0 EXPERIMENTAL

No experimental work was performed during this quarter.

3.0 RESULTS AND DISCUSSIONS

As the previously reported work on Task 3 - Furnace Optimization indicates, adequate CO/NO ratios, as required by the downstream reactor (the AF-SCR), can be obtained by modifying furnace operating conditions, without significant physical changes to the burner and boiler equipment. Therefore, the design and cost impact on the furnace / boiler proper due to the new NOx control system will be minimal, and the system design effort is mainly devoted to the conceptual design of the catalytic reactor.

3.1 Selection of Reactor Type

The basic configuration of the catalytic reactor will be an activated alumina (AA) based, honeycomb type fixed bed reactor. This configuration is selected because of its good structural strength and thermal stability. In addition, it can utilize most of the manufacturing and construction methods currently employed for conventional SCR applications, and will likely be readily accepted by the utility industry. Other configurations, such as entrained flow (injection – capture), granular fixed bed, fluidized bed or moving bed reactors, may be developed to deliver adequate performance and cost-effectiveness, particularly when utilizing the low cost, activated carbon based catalysts. However, these alternative configurations represent a large departure from the current SCR process and therefore may have additional hurdles to gain commercial acceptance.

The selected honeycomb configuration is one that is typical for conventional SCR catalysts, with 7.1 mm pitch, 0.7 mm wall thickness, and 1 m monolith length. The honeycomb will be prepared by mixing powders of substrate material, active species and binder material into a homogeneous paste and extruding the paste into monolith form.

3.2 Reactor Conceptual Design and Performance

The basis for the commercial-scale design of the ammonia-free selective catalytic reactor (AF-SCR) is an existing, typical 400 MWe bituminous coal-fired power plant. The plant is assumed to have existing low NOx burners and to add the AF-SCR system to further reduces NOx. The assumed site conditions are an elevation of 425 feet above sea level; a design ambient temperature of 60ºF; and a relative humidity of 60%. The reactor is designed to produce an 80% NOx reduction (outlet NOx = 0.08 lb/MMBtu).

Similar to the conventional SCR catalyst, the AF-SCR reactor will be located in the boiler heat recovery area, between the economizer and the air preheater. The flue gas temperature at the inlet to the AF-SCR is 600 ºF. Table 1 presents the performance and geometry of the catalyst. The detailed catalyst test data analyses and modeling reported last quarter revealed that the AA catalysts had very high catalyst effectiveness and catalyst activity can be increased by increasing the amount of active components in the catalyst. Based on this, active components loadings higher than those used in the laboratory testing have been selected for the honeycomb catalysts to reduce the volume of catalyst. Since the active metals were distributed in only a thin layer of the experimentally tested substrate granules (as described in the previous quarterly report), increasing the metal loadings should be feasible. The catalyst inlet molar CO/NO ratio is 2.0. The CO is reduced by 85% by the catalyst producing an outlet CO concentration of 86 ppmv.

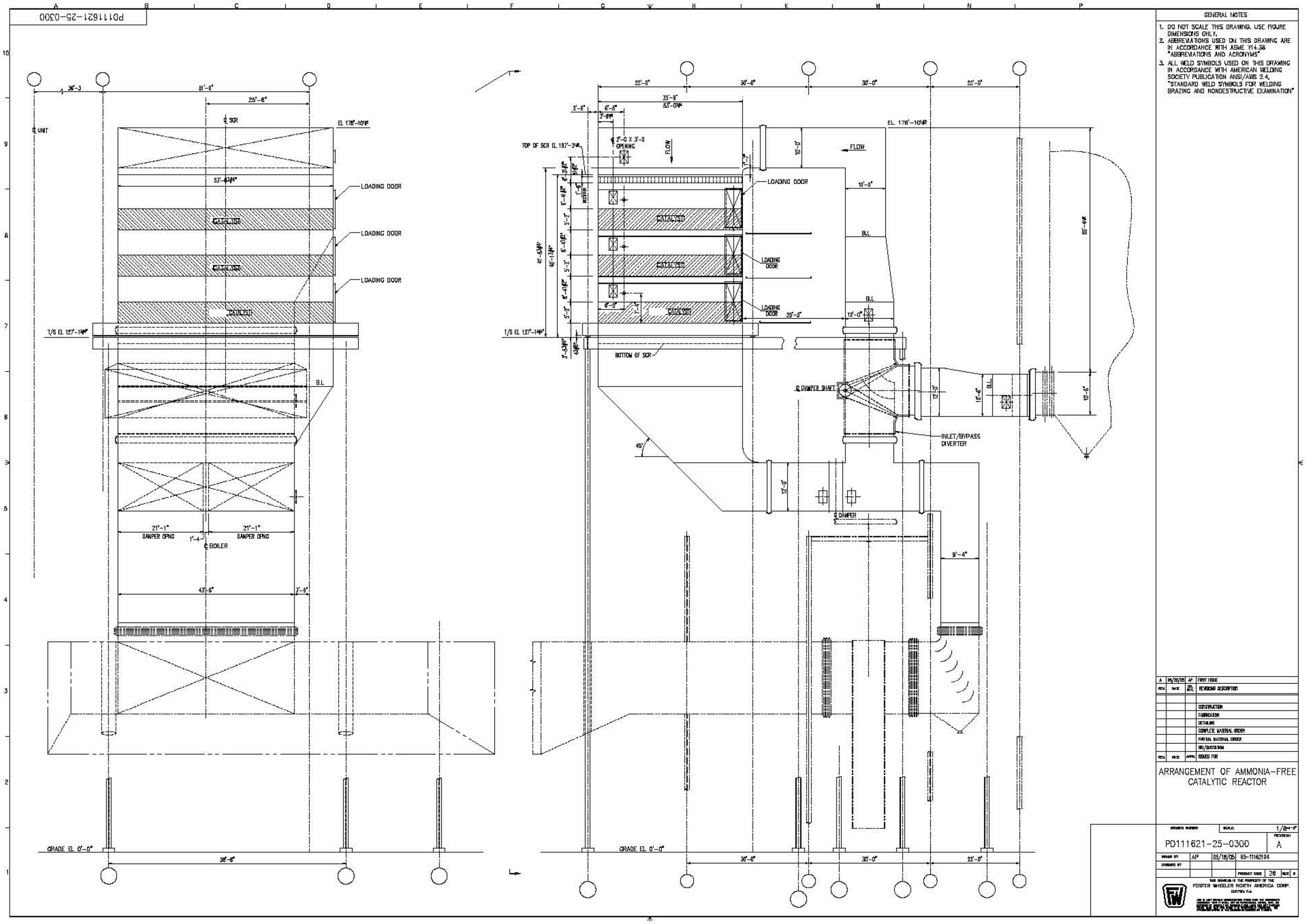
The catalyst volume and monolith geometry detailed in Table 1 is similar to current ammonia-based SCR catalysts. Catalyst opening size and gas velocity are selected to maximize catalyst life in a high dust coal-fired power plant. Pressure loss through the reactor is limited to 2.0 in H_2O.

Figure 1 presents the arrangement of the AF-SCR, which is very similar to the ammonia-based SCR system, but without the ammonia storage, handling and injection system. The dimensions of the reactor are 35’-9” X 53’ X 41’-9” (height). Turning vanes (not shown) are provided in the reactor entrance hood to create even downward flow distribution to the catalyst. Upstream of the catalyst is a rectifier, which straightens the flow to reduce catalyst erosion. The reactor contains three layers with acoustic horns or soot blowers upstream of each layer for ash removal.

Table 1 – 400 MWe AF-SCR Performance and Catalyst Geometry

Gas Flow Rate	lb/hr	3,500,000
Gas Temperature	F	600
Inlet NOx	ppmv	285
	lb/MM Btu	0.40
Outlet NOx	ppmv	57
	lb/MM Btu	0.08
NOx Removal Efficiency	%	80%
Inlet CO	ppmv	570
Outlet CO	ppmv	86
CO Removal Efficiency	%	85%
Pressure Drop	in H2O	1.9
Catalyst		
Flow Area	ft2	1247
Open Area	%	81.3%
Opening	mm	6.4
Length	m	2.60
Layers		3
Pitch	mm	7.1
Wall Thickness	mm	0.7
Surface Area	ft2	2,026,982
Volume	ft3	13,095
Space Velocity	1/hr	3582
Internal Linear Velocity	ft/sec	21.3
Approach Linear Velocity	ft/sec	17.3

Figure 1 – 400 MWe AF-SCR System General Arrangement



4.0 CONCLUSION

Based on data obtained from bench scale catalyst testing and reaction modeling, conceptual design of a 400 MWe size ammonia-free selective catalytic reactor (AF-SCR) has been developed. The AF-SCR uses honeycomb monolith elements with similar geometry to those used in the conventional ammonia-based SCR, but it uses the activated alumina as substrate and base metal active components developed in this work. The conceptual design provides a basis for cost evaluation of the new NOx control process.