Low NOx Emissions in a Fuel Flexible Gas Turbine
FACT SHEET

I. PROJECT DESCRIPTION

A. Objective:
The objective of this project is to design a gas turbine combustor system for new and existing turbines with a combination of air flow management control and fuel composition control to achieve 2 ppm NOx emissions. Since most Integrated Gasification Combined-Cycle (IGCC) systems consider the use of natural gas as an alternative fuel and there is a large infrastructure of existing natural gas based turbines, it is imperative that the combustor design be amenable to operating on both coal derived fuel gas and natural gas. The specific objectives of each phase of this program are:

Phase I: Develop conceptual design of turbine combustor with air flow control and fuel composition control, and assess economic viability versus Selective Catalytic Reduction (SCR).

Phase II: Develop detailed designs, and build and test the prototype combustor with simulated fuel. Design and build fuel processor that will produce the optimized fuel. Integrate and test both systems.

Phase III: Full-scale field demonstration of integrated fuel generator-combustor with a turbine.

B. Background/Relevancy:
Emissions regulations for NOx from stationary combustion sources – such as gas turbines – continue to be reduced by both federal and state agencies. As compliance levels continue to drop, the number of technologies capable of meeting such levels decreases as well. Currently, the only technology that has been proven at a commercial scale to be capable of meeting 2 ppm NOx emissions is the selective catalytic reduction (SCR) process. While capable of meeting the NOx compliance levels, this process has several inherent limitations. These include the requirement of transporting, transferring and storing ammonia (NH_3), a material that is on the EPA's list of Extremely Hazardous Substances under Title III, Section 302 of the Superfund Amendments and Reauthorization Act of 1986 (SARA). Additionally, due to imperfections in mixing within the process, excess ammonia is required resulting in ammonia emissions from the treatment system. Finally, catalyst beds placed within the heat recovery steam generator (HRSG) result in an additional pressure drop thereby lowering the efficiency of the system. Lower efficiencies result in higher heat rates and consequently higher emissions of CO_2. Clearly, an alternative solution that provides NOx reductions without (i) the simultaneous production of other potentially harmful emissions and (ii) minimal heat rate penalty is desired.

In addition to developing NOx reduction solutions, technologies with fuel flexibility are of increasing importance. As energy demands and natural gas prices continue to grow in the United States, opportunities for the use of coal will grow as well. Estimates suggest that 31 gigawatts of new coal-based power generation will be installed over the next 17 years. Integrated gasification combined-cycle technology (IGCC) utilizing advanced combustion systems have the potential to supply much of this added capacity. Clean, efficient and cost effective coal based power systems depend on the development of advanced power turbine technology to achieve higher levels of efficiency while simultaneously achieving lower criteria and unregulated pollutant emissions. The development of gas turbine combustor technology that is capable of operating on natural gas as well as coal derived synthesis gas represents a major step toward diversifying the energy platform of the United States. Furthermore, the development of gas turbine combustors capable of operating on coal derived synthesis gas is a step towards the goal of ultimately converting energy production to a hydrogen based economy.

In accordance with the above needs, the Turbine Program of the Strategic Center for Natural Gas has identified the development of improved combustion turbine performance with coal derived synthesis gas and the development of NOx emissions reduction technology for fuel flexible turbines as key areas of focus in support of the Vision 21 (V21) goals for gas turbines. The technology to be developed under this program will result in a fuel flexible combustor design, applicable to both new and existing turbines, operating on coal or natural gas, capable of achieving near zero (2 ppm) NOx emissions with reliability and availability standards established for pre-1999 gas turbines. These specific goals will support the V21 goal of 2 ppm NOx emissions at the turbine exhaust at a cost significantly less than conventional backend technologies such as SCR.

C. Period of Performance:
The scheduled project period is 10/1/03 through 9/30/06.
Phase I (Budget Period 1) of the project commenced on 10/1/03 and is expected to be completed 3/30/04.
Phase II (Budget Period 2) to be determined. Proposed 12 month duration.
Phase III (Budget Period 3) to be determined. Proposed 18 month duration.

D. Project Summary:
The proposed program shall develop a robust, fuel flexible, NOx control technology based on a combination of combustor modification and a fuel modification to achieve 2 ppm NOx with a variety of fuels. The envisioned system shall be a hybrid diffusion/lean premixed combustor. This system shall have fuel flexibility similar to diffusion combustors and NOx performance beyond that achievable with Dry Low NOx (DLN) combustors. Adding small amounts of H_2 to natural gas increases the flame speed, decreases the lower flammability limit of the fuel, and permits stable combustion at lower flame temperatures. This stability enhancement coupled with active air flow control to the primary combustion zone provides the basis for designing a robust combustor that minimizes flame temperature and produces low NO_x emissions. Unlike previous gas turbine combustor designs, this program shall focus on a combustor that takes advantage of the unique characteristics of coal derived fuel gas and modify the composition of natural gas to optimize performance when fired on the more conventional fuel. For natural gas, a fuel processor shall be developed to provide a fuel with an appropriate H_2 content.

Phase I shall consist of concept development. During this phase, alternative system designs involving reactor designs, means for active air control, and fuel gas processing alternatives shall be identified. The alternatives shall be compared against cost and performance of gas turbines with SCR's and the best candidates shall be selected for testing. Phase II shall be devoted to laboratory testing and integration of the combustor and fuel processor concepts. Phase III shall involve field demonstration of the solution developed in Phases I and II.

II. PROJECT PARTICIPANTS

Prime Participant:	Praxair, Inc.
Sub-award Participant:	Power Systems Manufacturing, LLC

III. PROJECT COSTS

		Phase I	Total Project
A.	DOE share	$225,579	$3.80 million
B.	Praxair share	$112,301	$2.63 million
C.	PSM share	$23,046	$0.33 million
D.	Total:	$360,926	$6.76 million

IV. MAJOR ACCOMPLISHMENTS SINCE BEGINNING OF THE PROJECT

Since the beginning of the program the following accomplishments have been made:

- The base cases for both an IGCC system and a NGCC system have been developed. Both systems are based on a GE 7241FA gas turbine. In the case of the IGCC system, a Destec gasifier has been assumed. NETL report PED-IGCC-98-003 offered significant guidance in the definition of the base case for the IGCC plant.
- Significant data on the cost structure of SCR systems has been gathered to facilitate cost estimations comparing the conceptual technologies developed herein with traditional SCR aftertreatment systems.
- A Chemkin model for a lean premixed combustor has been developed to allow estimation of fuel gas composition to allow target emissions to be met. This model is currently being validated with experimental data from a high pressure test rig that was gathered outside the scope of the DOE program. A Chemkin model is also being developed for an alternative modified diffusion combustor. The Chemkin models will serve as a basis to compare the dynamic range of both technologies with regard to emissions performance over a range of operating conditions.
- Representatives from Praxair, Inc. and Power Systems Manufacturing, LLC met with representatives from the DOE's National Energy Technology Laboratory for a kickoff meeting on December 1, 2003.

V. MAJOR ACTIVITIES PLANNED DURING THE NEXT SIX MONTHS

- *Identification of fuel gas composition and airflow requirements*
  One of the major objectives of this program is to identify a combination of air flow requirements and fuel gas composition to allow operation at lower adiabatic flame temperatures to facilitate lower NOx emissions. Chemkin models that are under development will be used to identify both the air flow requirements, the required hydrogen content of the fuel gas as well as the influence of any diluents on emissions performance. This data will then be used to evaluate the viability of designs targeted at providing the necessary requirements.

- *Identification of fuel gas processor(s)*
  Based on the requirements identified from the Chemkin models, a fuel gas processor or multiple processors will be identified that are capable of providing a fuel gas with the appropriate composition from either a coal gasifier or a natural gas feedstock.

- *Development of cost and performance profiles*
  Preliminary equipment design and capital cost estimates for designs selected for the combustor and fuel processor will be developed. Process models will be utilized to develop to predict gas turbine performance characteristics for the selected alternatives over a variety of operating conditions. The model predictions shall be used to develop overall cost profile for selected alternatives. The cost and performance of the selected designs will be compared with similar analyses for a conventional system outfitted with an SCR.

- *Recommendations for future work*
  Based on the techno-economic analysis performed during Phase I, a recommendation of either a go or no-go decision will be offered as to the need for future work. If the recommendation is to proceed, a plan outlining the development path to arrive at detailed designs for both the combustor and fuel processor as well as plans to test each concept will be developed. This work is to be done under Phase II of the award.

- *Development of combustor design and fabrication of prototype for testing*
  Assuming the recommendation from Phase I is to continue the development of the concepts identified, early work in Phase II will focus on the detailed design of the conceptual combustor identified in Phase I. The design will allow operation on both coal derived fuel gas derived fuels as well as fuels containing natural gas and hydrogen. The new combustor design will be completed and fabrication will commence. The objective for this work will to begin rig testing of a full head end version of the combustor near the end of the six month period.

- *Development of fuel gas processor and fabrication of pilot plant*
  Based on the concepts developed during Phase I, a pilot plant scale fuel processor will be designed and fabricated to test the suitability and scaleability of the concepts developed during Phase I. The pilot plant will be operated at conditions typical of those that would be experienced in the field in order that its dynamic performance can be evaluated.

VI. ISSUES

None

VII. ATTACHMENTS

None