# Fact Sheet:

## "Premixer Design for High Hydrogen Fuels"

## DOE Contract No: DE-FC26-03NT41893

## I Project Description:

### A. Objective:

This study will develop combustion technology that will enable fuel flexible gas turbines that are capable of operating on coal derived synthetic gas to achieve NOx emissions corrected to 15% Oxygen by volume of 2 ppmvd or less at the exit of the gas turbine. Today, the combustion of Integrated Gasification Combined Cycle (IGCC) fuels use diffusion flame combustors with high amount of diluents to abate NOx to 15-25 ppmvd level. This program, which will reduce NOx from combustion of high hydrogen content IGCC fuels, is based on the Dry Low NOx (DLN) lean premixed approach for the combustion of natural gas with DLN. The lean premixed technique will be adapted to the challenging and unique demands of high hydrogen content fuels in an effort to achieve low NOx with elimination/reduction of the diluents that are currently required for NOx abatement of IGCC fuels. This will be accomplished by the design of an IGCC premixed combustor nozzle that is revolutionary in both its ability to accommodate fuels with high hydrogen content and at the same time deliver dramatically reduced emissions with no or minimum diluent injection.

### B. Background/Relevancy

Background:

Emissions regulations for power plants have gradually become more stringent over the past few decades. This has driven interest towards gasification and gas turbines due to the potential for lower emissions and higher efficiency. Coal combustion in gas turbines is achieved by gasifying coal resulting in a mix of hydrogen, CO, nitrogen and other minor constituents. Depending on the gasification process, the relative proportion of hydrogen and CO can vary. Gas turbines utilizing these fuels are referred to as IGCC (Integrated Gasification Combined Cycle) machines.

IGCC fuels are currently burned in diffusion mode in gas turbine combustors. With diffusion combustion and diluent injection, current NOx guarantees for gas turbines utilizing IGCC fuels are still only as low as 25 ppmvd, with a few select offerings at 9 ppmvd. Reducing NOx by an order of magnitude requires a change in combustor design philosophy. In the past, natural gas combustion was first carried out in diffusion mode before premixed combustors were developed. This resulted in NOx guarantees dropping from about 25 ppmvd to 9 ppmvd. A similar evolution is needed for IGCC fuels to reduce NOx from 25 ppmvd towards the challenging DOE Turbine Program goal of 2 ppmvd.

Relevancy:

Achieving the goal of this program will constitute a significant engineering breakthrough and will set the stage for overall process improvements, broader application of gas turbines, and improve the economics of pre-combustion carbon capture concepts. IGCC combustion has been confined to diffusion combustors primarily because of the risks involved in premixing hydrogen. Using only diffusion mode combustion, the only strategy that can be successfully used for NOx control to levels below 25 ppmvd remains diluent injection, which has limits both from a materials and chemical kinetics viewpoint.

Currently, most of the advances that are being made in gas turbine design are focused on premixed combustion. The achievement of a IGCC premixer design for hydrogen based fuels will enable the use of alternative premixed combustion approaches such as Late Lean Injection or Catalytic combustion for IGCC applications. Designing a premixer for IGCC fuels will advance the gas turbine combustion of pure hydrogen in premixed mode, and be a significant first step in overcoming the obstacles of operating with hydrogen as a fuel without compromising on efficiency or capital cost.

The significant benefit to the US public will be the development of environmentally friendly power plants and broader use of our abundant coal resource, both from the point of view of decreased source emissions and, potentially, fuel efficiency. The increased fuel efficiency can be translated to lower $CO_2$ emissions, which is a greenhouse gas. Further, increased availability will translate to lower costs of electricity to the US public.

**C. Period of Performance:** January 01, 2004 to June 30, 2005

**D. Project Summary:**

This 18-month project will translate DLN technology to the unique properties of high hydrogen content IGCC fuels, and yield an design in preparation for future testing and validation phase. Fundamental flame characterization, mixing, and flame property measurement experiments will be conducted to tailor computational design tools and criteria to create a framework for predicting nozzle operability (e.g., flame stabilization, emissions, resistance to flashback/auto-ignition). This framework will be used to establish, rank, and evaluate potential solutions to the operability challenges of IGCC combustion. The leading contenders will be studied and developed with the most promising concepts evaluated via computational fluid dynamics (CFD) modeling and using the design rules generated by the fundamental experiments as well as using GE's combustion design tools and practices. Finally, this project will scope the necessary steps required to carry the design through mechanical and durability review, testing, and validation, towards full demonstration of this revolutionary technology.

This project will be carried out in three linked tasks.

1. Develop conceptual designs of premixer and down-select the promising options.
2. Carry out CFD on chosen options (1 or 2) to evaluate operability risks.
3. Optimize design and reevaluate operability risks.

A series of fundamental experiments has been planned and will be executed as part of realigned CA41448 "RAM" program Task 3 Combustion program to this High Hydrogen premixer program. These experiments will support Task 2 and 3 and will provide fundamental knowledge of premixed Hydrogen flame, resulting in better understanding of specific fundamental combustion phenomena deemed crucial to the development of robust premixers for IGCC applications.

## II Project Participants:

**A. Prime Participant:**
General Electric Company

**B Sub-Award Participants**:
None

## III Project Costs

**A. DOE Costs:** $310,618 (60%)

**B. Prime Contractor Cost Sharing:** $207,079 (40%)

## IV Major Accomplishments Since Beginning of the Project:

| Dates: | Accomplishment: |
|---|---|
| • February 27th | The Task 1 Conceptual Design Review (CDR) of potential high Hydrogen pre-mixer designs was completed. Two designs were down-selected: (a) swirl based pre-mixer and (b) direct multi-point injection based pre-mixer. This also completes the 2Q04 DOE Headquarters Quarterly Milestone to conduct a CDR. |
| • May 13th | An Assumptions Review was held with the Chief engineer's office to establish the CFD analysis methodology. |
| • May 28th | A "red flag" technical review was held with the Chief Engineer's office to establish the test procedure, test plan, and test sections for the high hydrogen fuel flame characterization experiments being conducted at the GE Global Research Center as a result of the newly re-allocated tasks from CA-41448. |
| • May28th | Development of the swirl-based premixer CFD models completed. The swirl-based premixer was the first of the two down-selected concepts and is based on axial air swirlers with fuel injection from swirler vanes itself. |

- July 23rd — Development of the multiple point lean direct injection based premixer CFD model completed. This concept was the second of the two down-selected concept and is based on direct injection of counter-swirling air and fuel-jets inside the premixer to achieve fuel-air premxing.

## V Major Activities Planned During Next 6 Months:

**Planned Activity:**

- Complete CFD analysis and evaluation of 2 designs to meet 4Q04 DOE Headquarters milestone.
- Monthly Highlight Status Reports (Monthly)
- Quarterly Milestone Status Report (Quarterly)
- Technical Progress Report (Semi-annual)
- Program Fact Sheet (Semi-annual)
- Financial Status Report (Quarterly)
- Federal Cash Transaction Report (Quarterly)

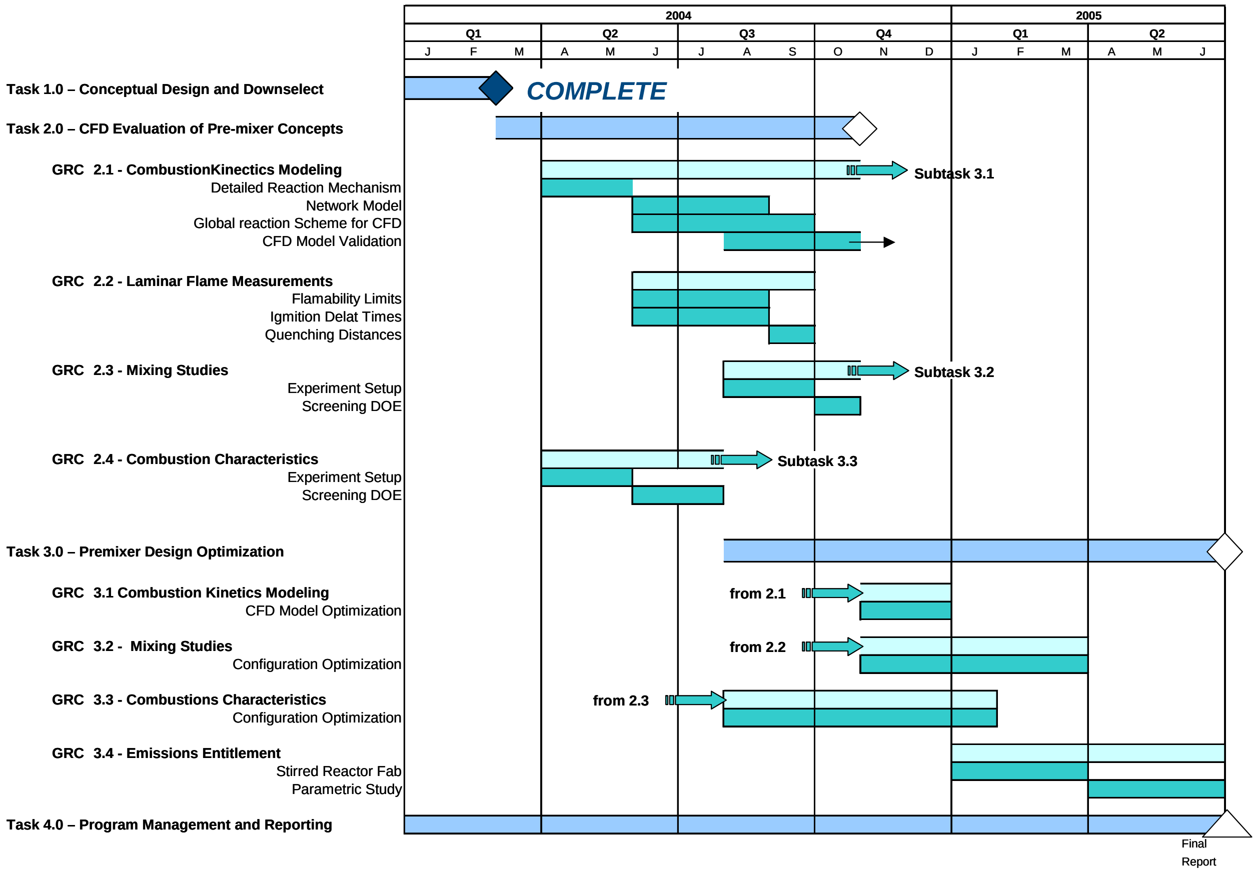
## VI Issues:

No issues have been identified.

## VII Attachments:

**A. Schematic**: None warranted

**B. Project Schedule - with Re-Allocated CA41448 Task 3 Additions:**


2004
2005
Q1
Q2
Q3
Q4
Q1
Q2
J F M A M J J A S O N D J F M A M J
Task 1.0 – Conceptual Design and Downselect
COMPLETE
Task 2.0 – CFD Evaluation of Pre-mixer Concepts
GRC 2.1 - CombustionKinectics Modeling
Detailed Reaction Mechanism
Network Model
Global reaction Scheme for CFD
CFD Model Validation
Subtask 3.1
GRC 2.2 - Laminar Flame Measurements
Flamability Limits
Igmition Delat Times
Quenching Distances
GRC 2.3 - Mixing Studies
Experiment Setup
Screening DOE
Subtask 3.2
GRC 2.4 - Combustion Characteristics
Experiment Setup
Screening DOE
Subtask 3.3
Task 3.0 – Premixer Design Optimization
GRC 3.1 Combustion Kinetics Modeling
CFD Model Optimization
from 2.1
GRC 3.2 - Mixing Studies
Configuration Optimization
from 2.2
GRC 3.3 - Combustions Characteristics
Configuration Optimization
from 2.3
GRC 3.4 - Emissions Entitlement
Stirred Reactor Fab
Parametric Study
Task 4.0 – Program Management and Reporting
Final Report