# FACT SHEET

## I. PROJECT PARTICIPANTS

*Parker Hannifin Corporation* (Lead)
Gas Turbine Fuel Systems Division,
9200 Tyler Blvd., Mentor OH 44060
PI: Dr. Adel Mansour (e-mail: amansour@parker.com, Ph.: 440-954-8171)

*University of California at Irvine*
UCI Combustion Laboratory, Irvine, CA 92617

*Solar Turbines Incorporated*
2200 Pacific Highway, San Diego CA 92101

## II. PROJECT DESCRIPTION

### A. Objective(s)

The overall objective of this DOE-Supported research and development program is to develop and test a *next-generation, practical and scalable, high-performing, multi-point injector module for hydrogen and syngas fuels*. The injector will use Parker Hannifin's demonstrated *Macrolamination* technology, incorporating a large number of small mixing cups for air and fuel, similar to what has been successfully demonstrated to yield ultra-low emissions for liquid-fuel. The specific objectives are to design and test multi-cup hydrogen/syngas injectors that achieve NOx emissions of 3 ppm or less, to establish methods to extend the LBO margin and flash-back resistance of the injectors through aerodynamic design, and to perform bench-scale and full scale tests of the injectors. The ultimate goal is to demonstrate in a high-pressure rig a low-emission and stable operation of a 1 MW multi-cup hydrogen/syngas injector module.

### B. Relevancy

The program supports the Department of Energy Office of Fossil Energy Advanced Turbine Program, the focus of which is to develop key technologies that enable advanced power generation gas turbine engines that operate on coal-derived syngas and hydrogen fuels. This particular project supports DOE program goals for minimizing pollutant emissions from mega-Watt-scale turbines (1-100 MW turbines), one of which is to develop hydrogen-fueled and syngas-fueled combustion systems. The program also supports goals for IGCC-based FutureGen applications through the development of a scalable, multipoint injector technology.

### C. Project Summary

In Phase I of the project, conceptual injector designs will be established based on assessment of operating conditions, fuel compositions and operability requirements. The designs will be screened and optimized using numerical simulations (CFD) and possibly some simple experiments. A test plan will be established that identifies the potential diagnostics to be used and the range of tests to be conducted in Phases II and III. This will lead to a formal *R&D Implementation Plan* to be carried out in Phases II and III.

The Phase II effort will start with experimental studies using single mixing cup designs arrived at in Phase I. The objective of the studies will be to assess the potential of the

multipoint injection / multi-flame zone approach to meet the emissions goals. The experiments will be conducted using testing facilities at UC Irvine. Based on the single mixing-cup results, designs for multiple point injection concepts will be developed and two will be selected for further detailed experimental evaluation at UC Irvine. Numerical simulations will continue to be used in Phase II to provide added insight into the performance of the various concepts. Based on the results from the tests and simulations, a configuration will be designed for testing in Phase III.

The Phase III effort will start with the detailed design and fabrication of the full-scale injectors selected for further development and testing at the end of Phase II. This will be followed by atmospheric testing at UC Irvine, and high-pressure tests at Solar Turbines.

**D. Period of Performance**

| Phase | Description | Start Date | End Date |
|---|---|---|---|
| I | Conceptual Design and R&D Implementation Plan: Concept to Commercial Deployment | 8/01/06 | 1/31/07 * |
| II | Detailed Design and Validation Test Program | 2/01/07 * | 10/30/08 |
| III | System Fabrication and Testing | 11/01/08 | 7/31/09 |

* Parker will be submitting, under separate cover, a request to extend Phase I through 4/30/07. If such extension is granted, this will not affect the overall program schedule of Phase II and Phase II.

## III. PROJECT COSTS

$1,533,000 (Phase I, II, III)

**A. DOE Costs** $1,040,820 (DOE Share of Total Approved Budget for Phase I)

**B. Prime Cost Sharing** $492,180 (Recipient share of Total Approved Budget for Phase I)

## IV. MAJOR ACCOMPLISHMENTS SINCE THE BEGINNING OF THE PROJECT

In the initial stages of the program, the effort focused on the preparatory work required for systematic evaluation of mixing-cup concepts and designs via a Design of Experiments (DoE) approach.

- October and November, 2006: A classification of mixing-cup concepts according to geometry and means for introducing fuel was developed. Based on the classification, parametric CAD models were created that allow rapid generation of new designs. Design tools have been prepared that can be used to drive the CAD models. Preliminary CFD work has been done, both to establish a CFD methodology and to evaluate preliminary mixing-cup designs.
- November, 2006: A design configuration has been identified which, according to CFD predictions, will give unmixedness values of 0.05 near the mixing-cup exit (here, unmixedness is computed as mass-averaged rms-value of the deviation of local equivalence ratio from the mean equivalence ratio). With optimization, the unmixedness value can be reduced even further.

## V. MAJOR ACTIVITIES PLANNED DURING THE NEXT 18 MONTHS

The next 18 months will see a completion of planned Phase I activities and a substantial portion of planned Phase II activities. At the end of Phase I, several promising mixing-cup concepts will have been identified and evaluated using CFD. In Phase II, detailed design and analyses of these injectors will be carried out. The single-cup injectors will be fabricated and tested, and the best performing concepts will be carried forward in multi-cup configurations.

*Phase I Activities:*

- Completion of Test and Diagnostic plan for Phases II and III (04/07)
- Completion of CFD analyses for multiple mixing-cup configuration, followed by selection of six injector concepts for testing in Phase II that hold promise for meeting the project goals of low emissions, scalability, LBO margin and flash-back resistance (04/07).
- Completion of a detailed R&D Implementation plan for Phases II and III (04/07)

*Phase II Activities:*

- Complete detailed design and fabrication of six single-cup injectors for combustion testing at UCI (07/07).
- Complete testing and detailed analysis of the six single-cup prototype injectors (02/08)
- Complete detailed design and fabrication of multi-cup injectors (04/08)
- Complete testing and analysis of multi-cup injectors (09/08)
- Down-select a concept for a full-scale 1-MW multi-point injector for high-pressure testing (10/08)

## VI. ISSUES

- Due to the length of time that was required to resolve various "cooperative agreement" issues and in receiving the final award, some time was lost at Parker at the onset of the budget period as we worked to redirect some of Parker personnel from other projects to spend time on this project. Also, an unforeseen delay in arriving at a mutually-acceptable IP agreement with project partner, University of California at Irvine, has delayed the full start of the project by four months. For this reason, the project partners will soon be applying for a three-months no-cost extension to the first phase of the program, while compressing Phase II from 21 months to 18 months so as not to delay the overall schedule of the project. This Request for Extension is being submitted to DOE under separate cover. The University of California plays an important role in the project, providing support in establishing likely fuel compositions and operating conditions of engines of interest, doing substantial fraction of the planned CFD analyses, and in future testing.