Low NO_X Catalytic Combustion for ATS Gas Turbine Engines

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Abstract

Improvement of lean-premixed combustion performance in ATS engines can be achieved by catalytically reacting a portion of the total fuel. This catalytic pre-reaction improves lean combustion stability, reduces combustion-induced pressure oscillations, and permits simultaneous low NO_X and low CO/UHC emissions, well below the ATS targeted levels of <10 ppm NO_X and <20 ppm CO/UHC.

With DOE (FETC and OIT) support, Precision Combustion, Inc. (New Haven, CT) is developing ATS catalytic combustion technology for natural-gas-fired industrial and utility turbines, in full collaboration with turbine OEMs. Extensive sub-scale reactor development and high-pressure testing has been conducted. For high-firing temperature applications, robust reactor performance has been demonstrated, with controlled catalyst temperatures (below material limits) at high pressure, and without flashback or pre-ignition. Low single-digit NO_X levels have been measured at pressure, with good flame stability.

Initial durability testing has been conducted, with no measurable sign of performance degradation. On this basis, long-term durability studies will be conducted at actual engine pressure levels, which will enable the characterization of the reactor for 8,000 hours of engine operation.

Full-scale atmospheric- and high-pressure rig testing has also been conducted to measure the overall performance from engine startup to base-load operation, under both steady-state and transient conditions. Further full-scale high-pressure testing is planned for early in 2000, with subsequent system integration.

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Precision Combustion Inc.

New Haven, CT

Advanced Turbine Systems

Annual Program Review Meeting

Pittsburgh, PA

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Objectives

Develop enabling catalytic combustion technologies for single digit NO_x emission from gas turbines

- Catalytic Reactor
- Combustion Completion

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Catalytic Reactor

Improved reactor geometry/design

- Wide operating envelope - High firing temperature
- Resistance to flashback/pre-ignition

Improved catalyst formulations

- Methane reactivity
- Reactor durability

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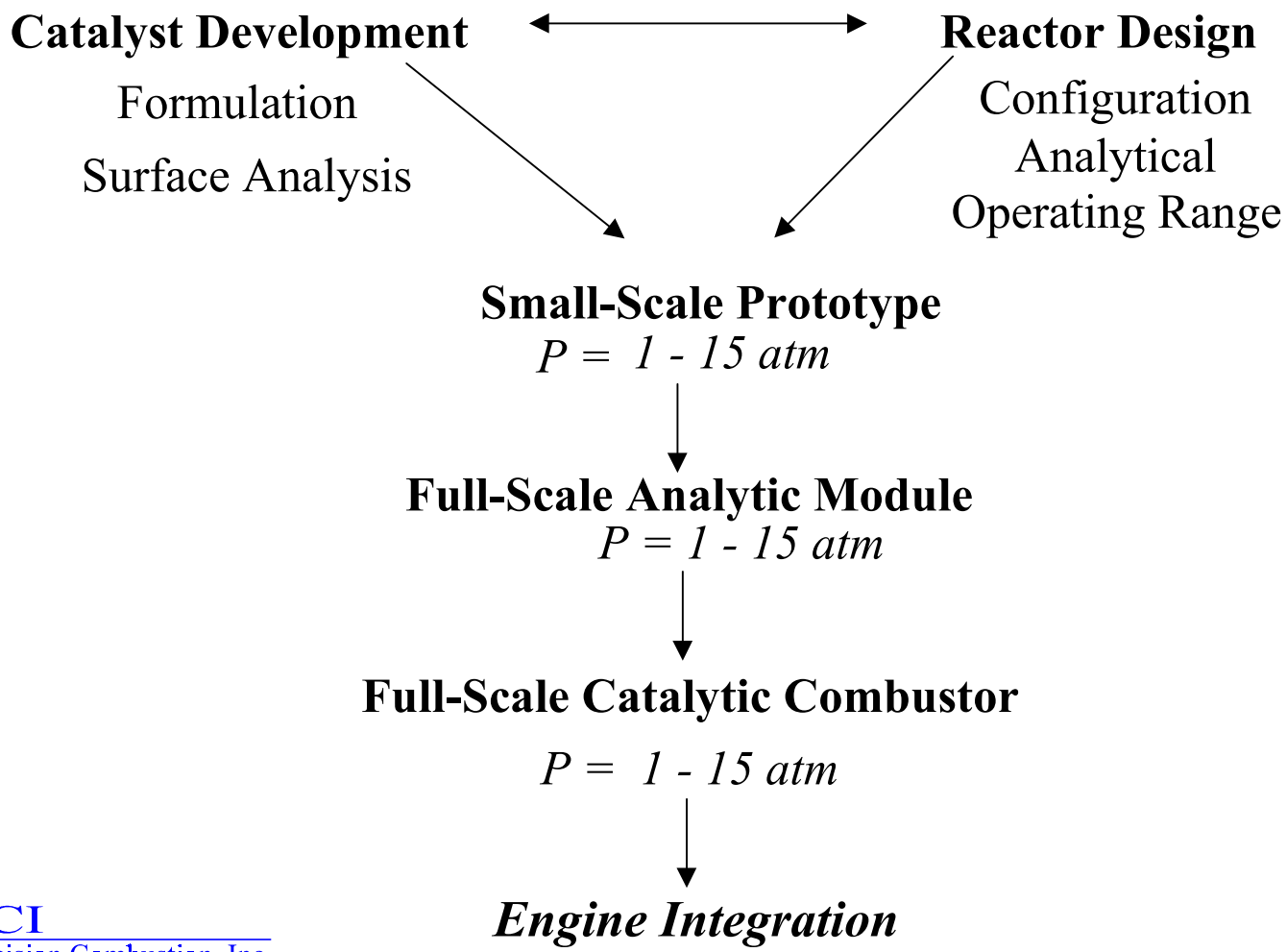
Catalytic Reactor Development Approach



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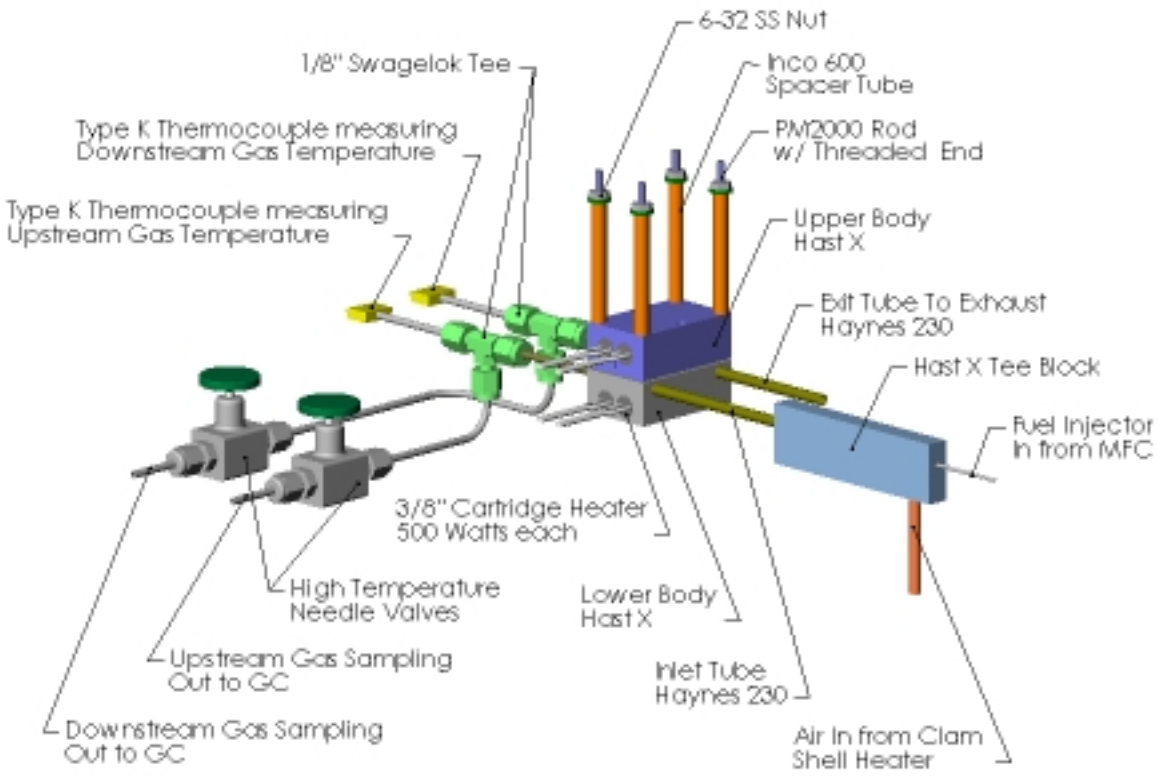
Catalyst Development Coupon Rig



- Rapid screening of catalyst formulation

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Small Scale Reactor

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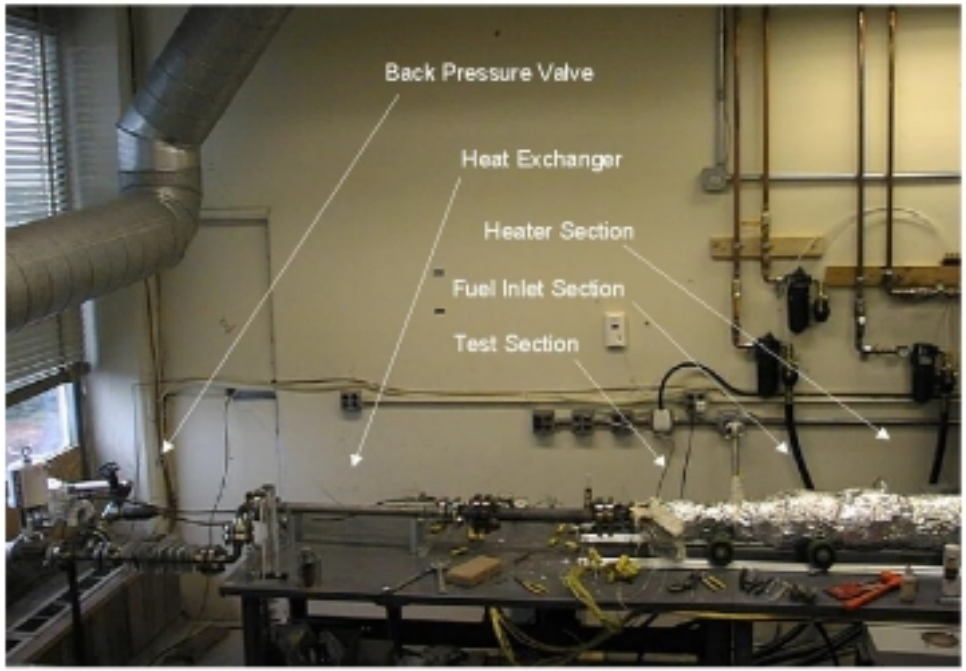
High Pressure Small Scale Test Rig



- Evaluation of pressure effect on reactor performance

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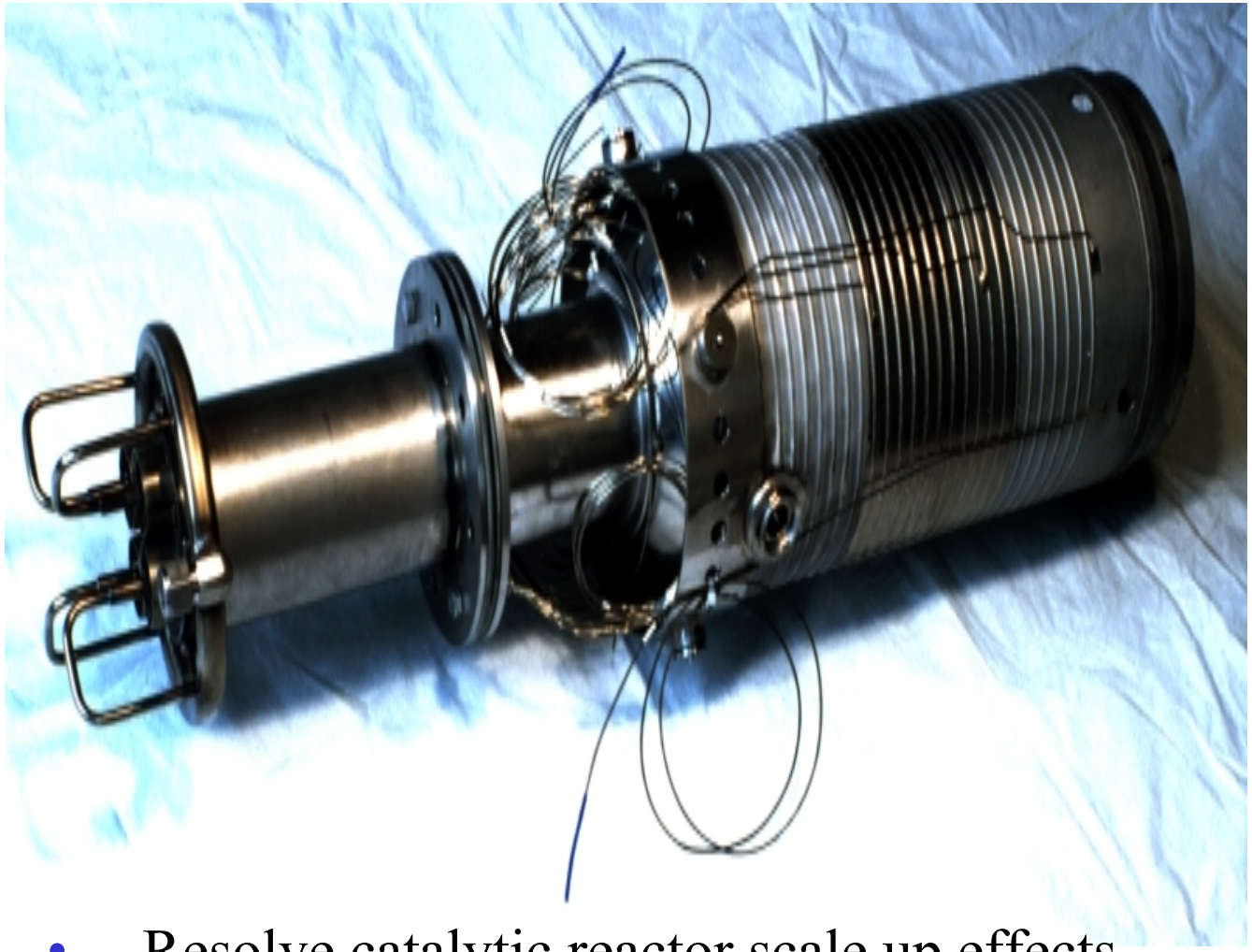
Full Scale Catalytic Module



- Resolve catalytic reactor scale up effects

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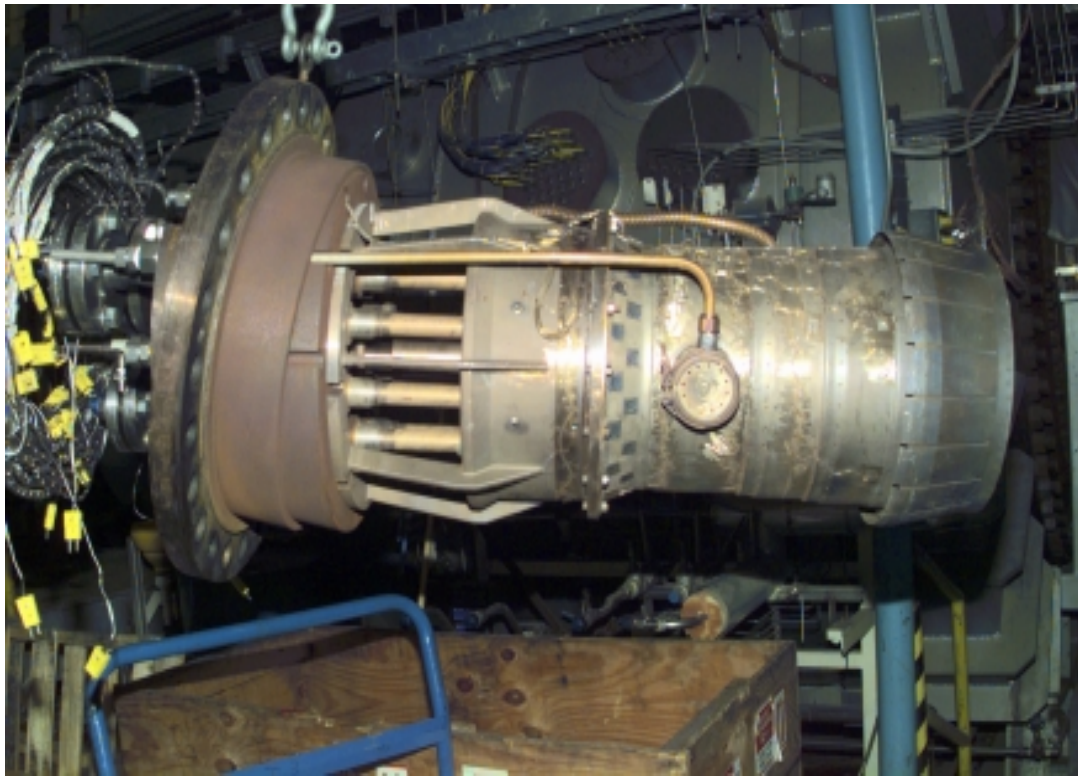
Full Scale Rig



- Reactor integration into full combustor

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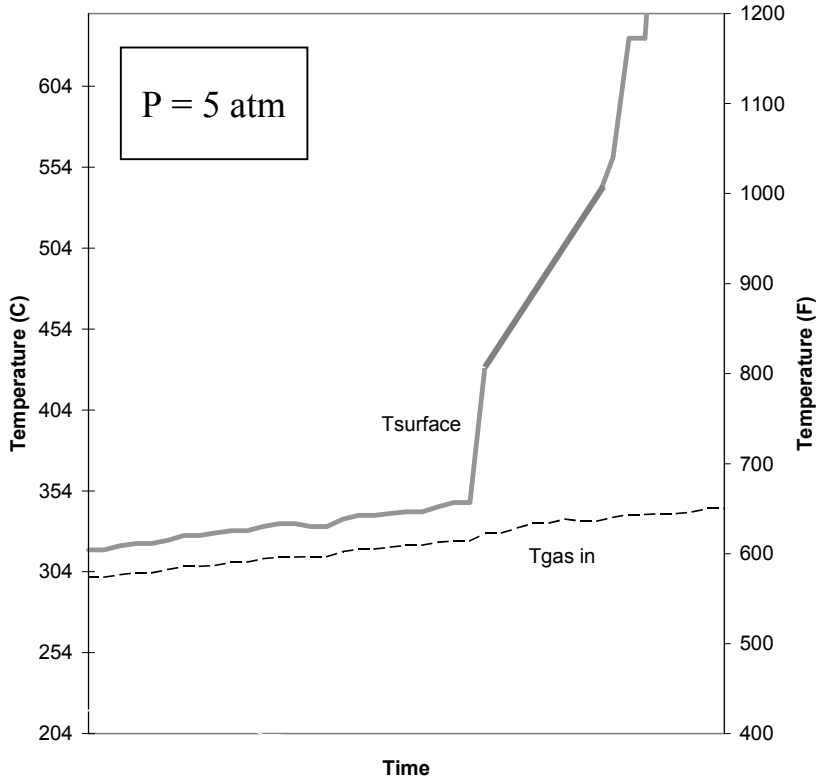
Light-off of the catalytic reactor



- Low light-off eliminates need for preheater

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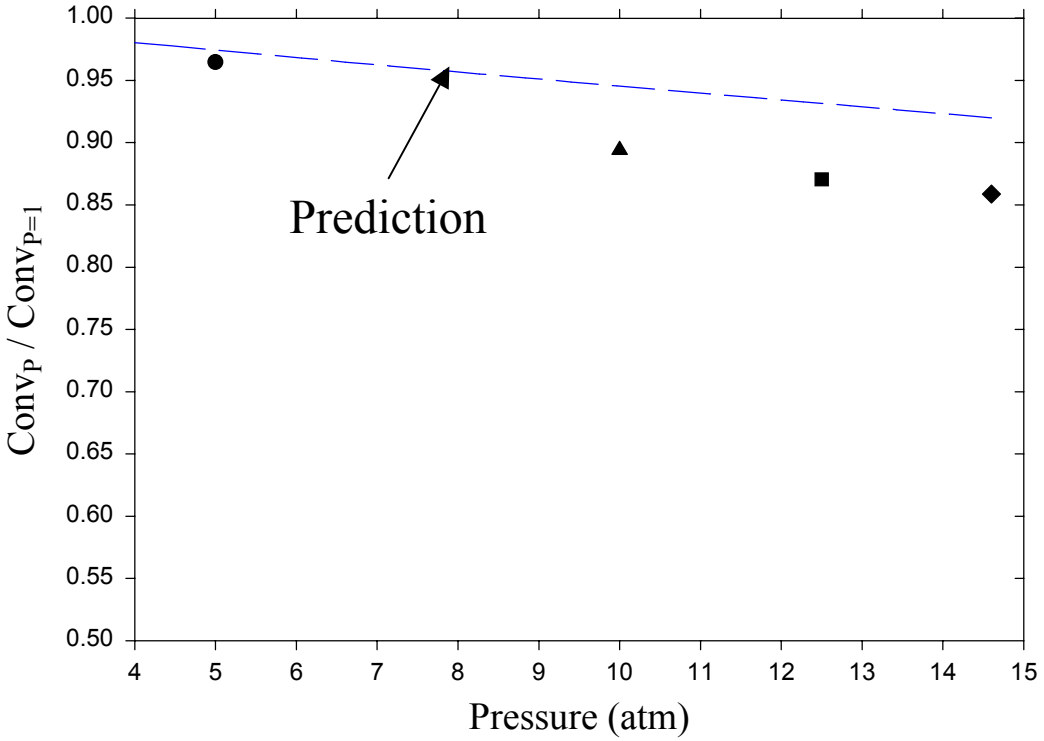
Relative Conversion as Function of Pressure



- 15 fold increase in pressure has small effect on reactor performance

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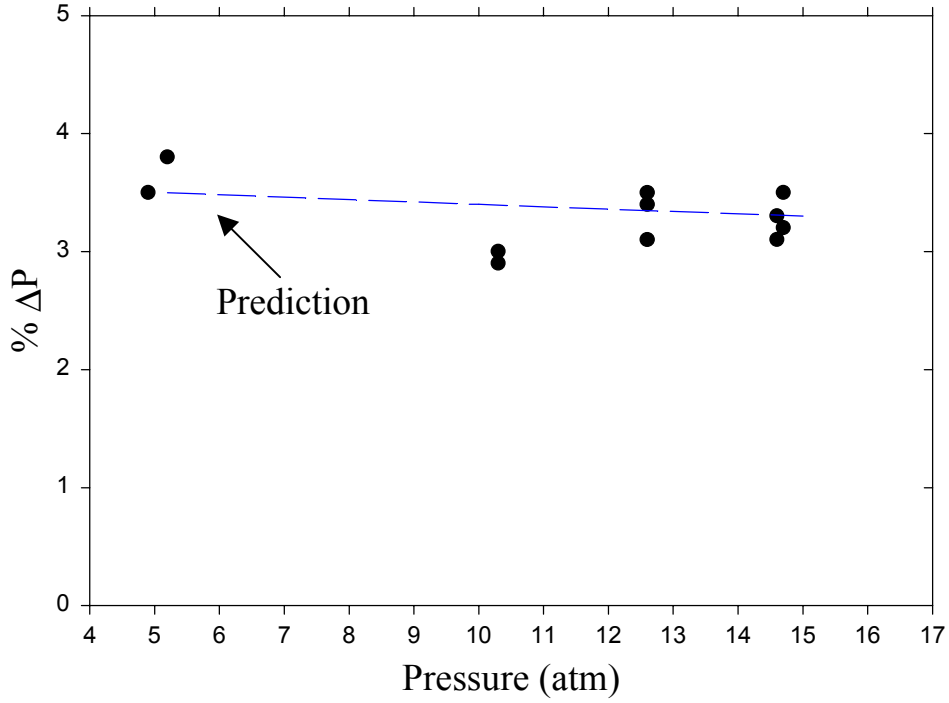
Pressure Drop as a Function of Pressure



- 3.5% pressure drop at design conditions while fitting into existing envelope

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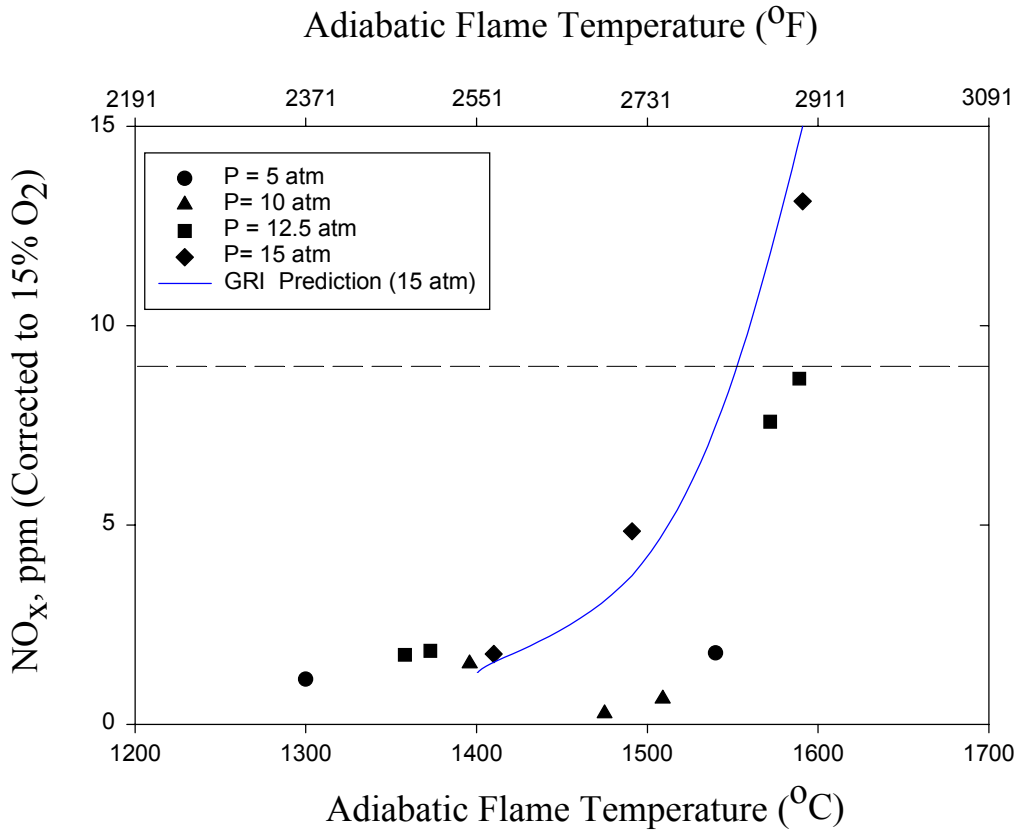

- Single Digit NO_x
- Safe Operation at high firing temperature

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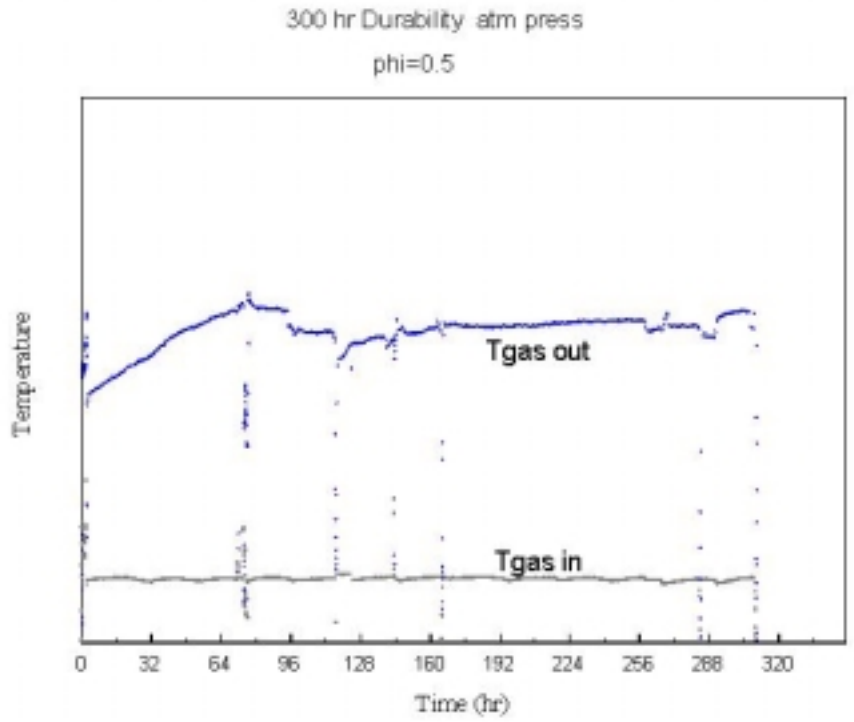
Durability data of catalytic reactor



- Limited atmospheric aging with no measurable degradation
- Pressure aging in progress

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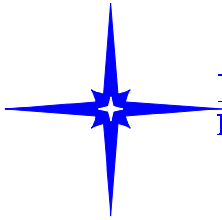
Results for the catalytic reactor and catalyst development

- Low NO_x performance demonstrated at pressures up to 15 atm in a small scale reactor.
- Aged catalytic reactor lightoff @ 350^{o}C on natural gas.
- Completion of a 300 hour atmospheric durability test with no degradation in performance. Pressure aging in progress.
- Modification of a high pressure facility at PCI to accommodate testing of small scale catalytic reactor



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Results for the catalytic reactor and catalyst development *(cont'd.)*

- Design and fabrication of a new sub-scale catalyst screening rig to test catalyst formulations on coupons.
- Ongoing development and testing of several new supports (washcoat) for the precious metal catalysts
- Full-scale testing and engine integration in progress

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