

# High-Speed Oil-Free Centrifugal Compressor for Hydrogen Delivery

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# Overview

## Timeline

- June 9, 2008
- June 8, 2011
- 0 Percent Complete

## Budget\*

- Total proposed project funding
  - \$2,992,416 DOE
  - \$1,149,253 MiTi<sup>®</sup>/MHI
- \$0 FY07 Funding
- \$TBD FY08 Funding

## Barriers

- Hydrogen Delivery Compressor
  - Reliability
  - System Cost
  - Efficiency of H2 Gas Compression

## Partners

- Lead: Mohawk Innovative Technology, Inc. (MiTi<sup>®</sup>)
- Mitsubishi Heavy Industries

\*Project not yet started contract negotiations in progress

# Objectives

- **Demonstrate key technologies needed to develop reliable and cost effective centrifugal compressors for hydrogen delivery**
  - Flow to 1,000,000 kg/day
  - Pressure rise to 300-500 psig
  - Contaminant-Free/Oil-Free

Category	2005 Status	Project Target	
		FY2012	FY2017
Reliability	Low	Improved	High
Energy Efficiency	98%	98%	>98%
Capital Investment (\$M) (based on 200,000 kg of H <sub>2</sub> /day)	\$15	\$12	\$9
Maintenance (% of Total Capital Investment)	10%	7%	3%
Contamination	Varies by Design		None

# Project Milestones

Month/Year	Milestone or Go/No-Go Decision
Oct-08	<b>Project Milestone:</b> Complete preliminary modular centrifugal compressor frame design to achieve pressure and flow. Select stage for detailed design, fabrication and test.
July-09	<b>Project Milestone:</b> Complete single stage compressor design including inlet, impeller, diffuser, return channel. Complete oil-free bearing and seal mechanical component system designs

Oct-09	<b>DOE Milestone:</b> Down select novel compression technology for hydrogen delivery.
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# Project Plan

timeline

**Preliminary System Design**

**Refine System Configuration**

Multi-Stage Sizing

Compressor Stage Flow & Pressure

Shaft Speed

Bearing & Seal Requirements

**Detailed Design & Fabrication**

**Single Stage Compressor**

Single-Stage Compressor, Inlet, Diffuser & Return Channel

Shaft, Seals & Bearings for High-Speed Operation

**Test, Evaluate & Refine Design**

**Single Stage Compressor**

Verify High-Speed Dynamics

Measure Compressor Performance

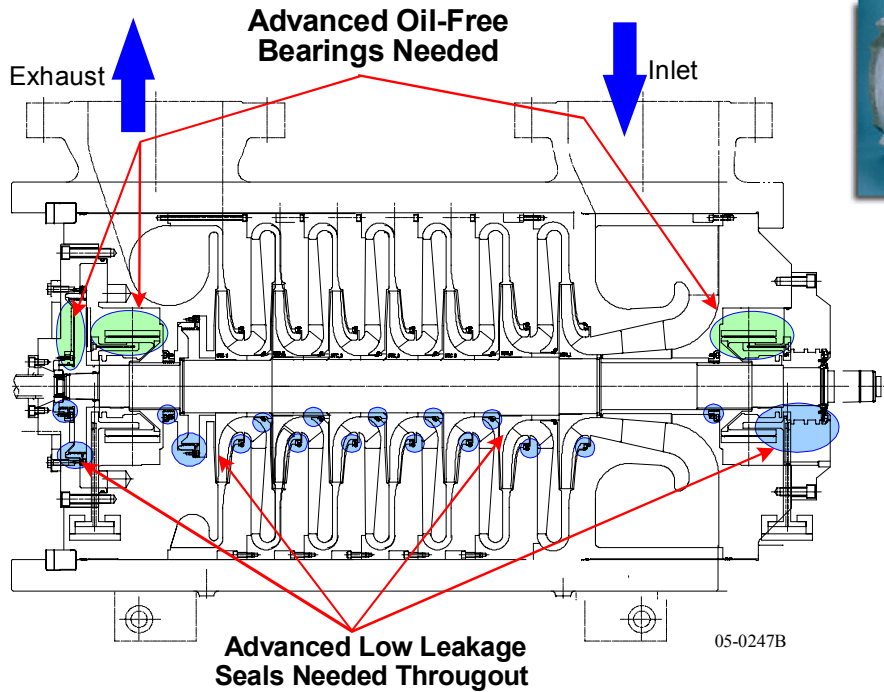
Refine and Scale Design

**Demonstrate feasibility of very high speed hydrogen centrifugal compressor through component test**

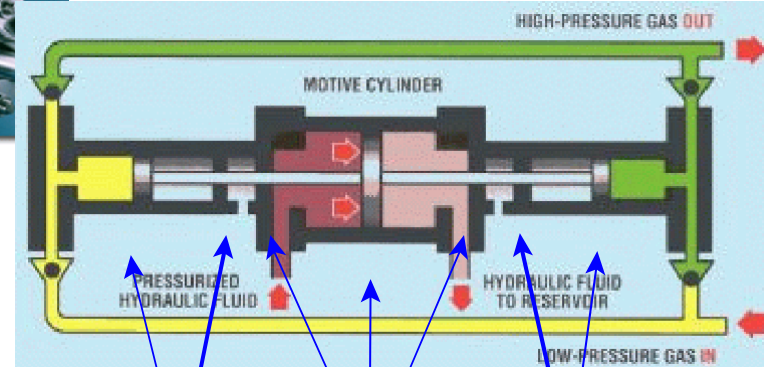
# Progress

- **Contract Negotiations In Progress**
- **Previous Efforts Identified Centrifugal Compressor Configuration Feasibility and Technology Needs**
  - Internal MiTi & MHI Company Funding
  - DOE SBIR

# Candidate Compressors



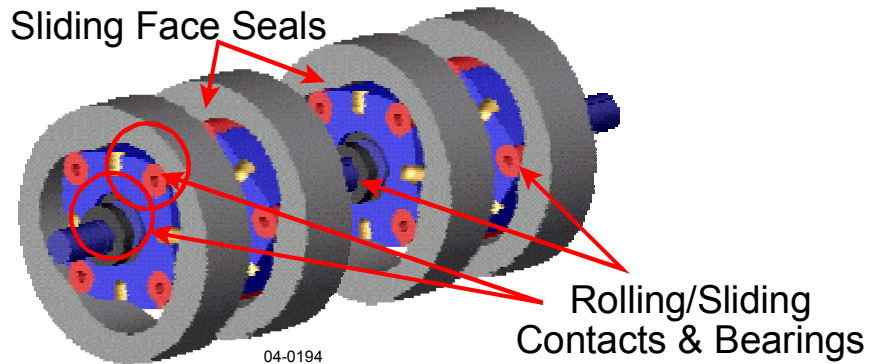
## Piston Compressor



## Sliding Contacts

## Guided Rotor Compressor

Sliding Face Seals



## Centrifugal Compressor

- One Moving Part
- High Reliability
- Minimal Contact/Sliding Parts
- High Efficiency and High Flow

# Modular Compressor Concept

**Frame**

**A**

>50,000 rpm

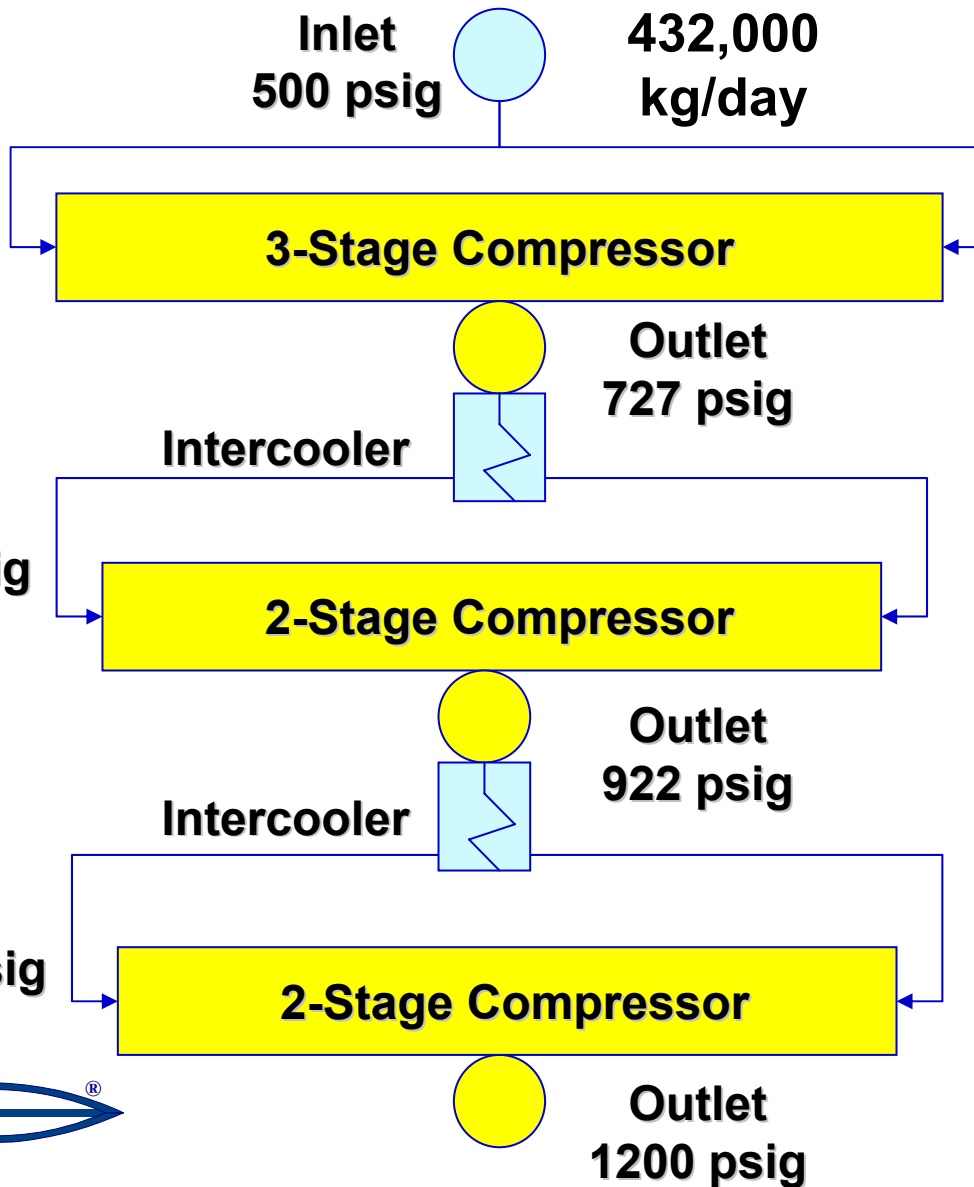
**B**

>50,000 rpm

**C**

>60,000 rpm

Mohawk Innovative Technology, Inc. 



**Power**

5158 HP

3946 HP

4662 HP



# Identified Technology Needs

- **Required High Speeds Dictate**
  - **Advanced Centrifugal Compressor Aerodynamic and Structural Design**
    - High Stresses
    - Efficient and Effective Flow Path
  - **High-Speed, Oil-Free Foil Bearings**
- **Hydrogen Requires**
  - **Novel Low Loss Seals**
  - **Low Friction and Long Wear Life Foil Bearing and Foil Seal Hydrogen Compatible Coatings**
  - **Hydrogen Compatible Materials**

# Future Work for FY08-FY09

- **Refine Multi-Stage/Multi-Frame Compressor Concept**
  - Establish Stage Pressure Ratios and Flows
  - Define and Select Optimum Operating Speeds
  - Select One Stage for Detailed Design and Test
- **Preliminary Design Review with DOE**
- **Conduct Detailed Design**
  - Establish Flow Path Including Inlet, Impeller, Diffuser and Return Channel Designs Using Established Design Analysis and Computational Fluid Dynamics
  - Design Foil Bearings and Seals Using Coupled Elasto-Hydrodynamic Analysis
  - Design Test Shafting Using Finite Element Rotor-Bearing System Analysis

# Project Summary

- This project proposes to demonstrate that advanced and very high-speed, oil-free centrifugal compressors can meet hydrogen delivery needs
- MiTi<sup>®</sup> and MHI have shown analytically that multiple multi-stage very high speed centrifugal compressors operating in series are necessary and feasible.
- A key compressor stage will be designed, fabricated and tested to validate the concept and demonstrate overall system feasibility based upon advanced 3-D aerodynamic designs combined with oil-free compliant foil bearings and close clearance compliant foil seals
- Under this effort, compressor blade tip speeds, and bearing and seal surface velocities exceeding state-of-art will be designed, built and evaluated