

2005 DOE Hydrogen Program Review Presentation

COST AND PERFORMANCE ENHANCEMENTS FOR A PEM FUEL CELL TURBOCOMPRESSOR

**MARK K. GEE
HONEYWELL ENGINES, SYSTEMS & SERVICES**

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Project ID # FC27

Honeywell

This presentation does not contain any proprietary or confidential information

Timeline

- Project start date: 12/2002
- Project end date: 09/2006
- Percent complete: 70%

Budget

	Total (\$M)	DOE Share, 75% (\$M)	Honeywell Share, 25% (\$M)
Total Program	\$ 3.053	\$ 2.289	\$ 0.763
FY			
2004	\$ 0.407	\$ 0.305	\$ 0.102
2005	\$ 0.972	\$ 0.729	\$ 0.243

Partners

- Department of Energy, Washington D.C.
 - Valri Lightner and John Garbak
- Argonne National Laboratory
 - Dr. Rajesh Ahluwalia, Dr. Romesh Kumar, Dr. Brian Concannon and Dr. Robert Sutton
- Fuel cell power system/automotive OEM's

Barriers

3.4.4.2. Transportation Systems Barriers

- **E. Compressors/Expanders.** Automotive-type compressors/expanders that minimize parasitic power consumption and meet packaging and cost requirements are not available. To validate functionality in laboratory testing, current systems often use off-the-shelf compressors that are not specifically designed for fuel cell applications resulting in systems that are heavy, costly, and inefficient. Automotive-type compressors/expanders that meet the FreedomCAR and Fuel Cell Partnership technical guidelines need to be engineered and integrated with the fuel cell stack so that the overall system meets packaging, cost, and performance requirements.

Input Power ^a at Full Load, 40°C Ambient Air (with Expander / without Expander)
Overall Motor/Motor Controller Conversion Efficiency, DC Input
Input Power ^b at Full Load, 20°C Ambient Air (with Expander / without Expander)
Compressor/Expander Efficiency at Full Flow (C/E Only) ^c
Compressor/Expander Efficiency at 20-25% of Full Flow (C/E Only) / Compressor at 1.3 PR/Expander at 1.2 PR
System Volume ^e
System Weight ^e
System Cost ^f
Turndown Ratio
Noise at Maximum Flow (excluding air flow noise at air inlet and exhaust)
Transient Time for 10-90% of Maximum Airflow

Objectives

- The objectives of the program during the past year was to complete Technical Objectives 2 and 3 and initiate Technical Objective 4 as described below
- To assist the Department of Energy in the development of a low cost, reliable and high performance air compressor/expander
 - Technical Objective 1: Perform a turbocompressor systems PEM fuel cell trade study to determine the enhanced turbocompressor approach
 - Technical Objective 2: Using the results from technical objective 1, an enhanced turbocompressor will be fabricated. The design may be modified to match the flow requirements of a selected fuel cell system developer.
 - Technical Objective 3: Design a cost and performance enhanced compact motor and motor controller
 - Technical Objective 4: Turbocompressor/motor controller development

Approach

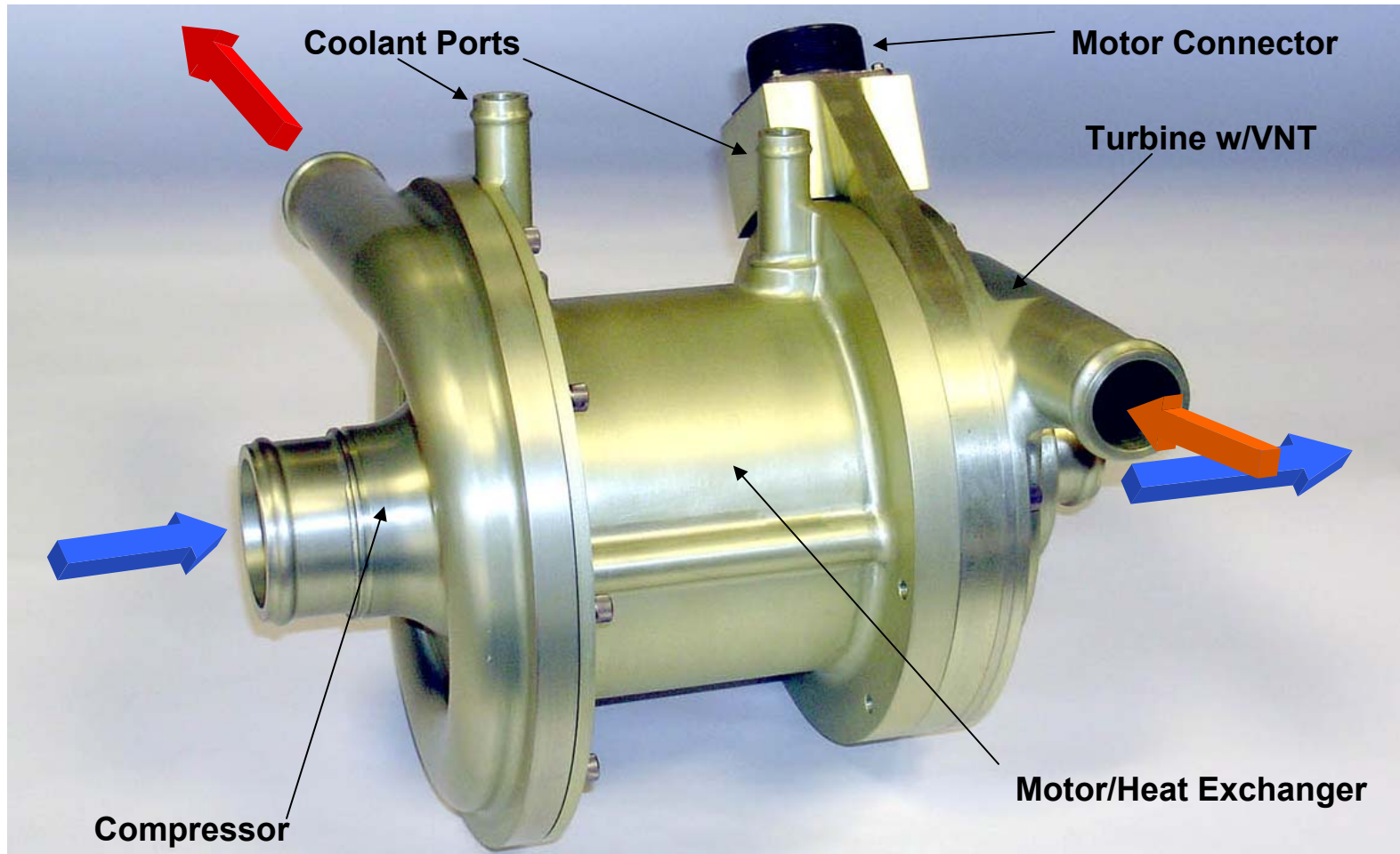
- Use automotive and aerospace turbomachinery technologies for low cost and low weight/volume design
- Build upon previous turbocompressor experience using VNT™ variable nozzle turbine inlet geometry for improved turbine performance and turndown ratio across the operating flow range
- Use a mixed flow type compressor for improved low flow performance
- Use contamination/oil free; zero maintenance compliant foil air bearings
- Use a modular approach to improve design flexibility
- Use a high efficiency, low cost two pole motor
- Use a low cost, no sensor required variable speed motor-controller topology design

Technical Accomplishments/Progress/Results



- Technical Objective 2
 - Detailed design
 - Majority of detailed drawings completed
 - Completion of drawings underway
 - Fabrication and assembly
 - Majority of parts ordered and fabricated with assembly initiated
 - To order and fabricate remainder of parts

Technical Accomplishments/Progress/Results Honeywell



6.5 Liters; 11 kg

Technical Accomplishments/Progress/Results



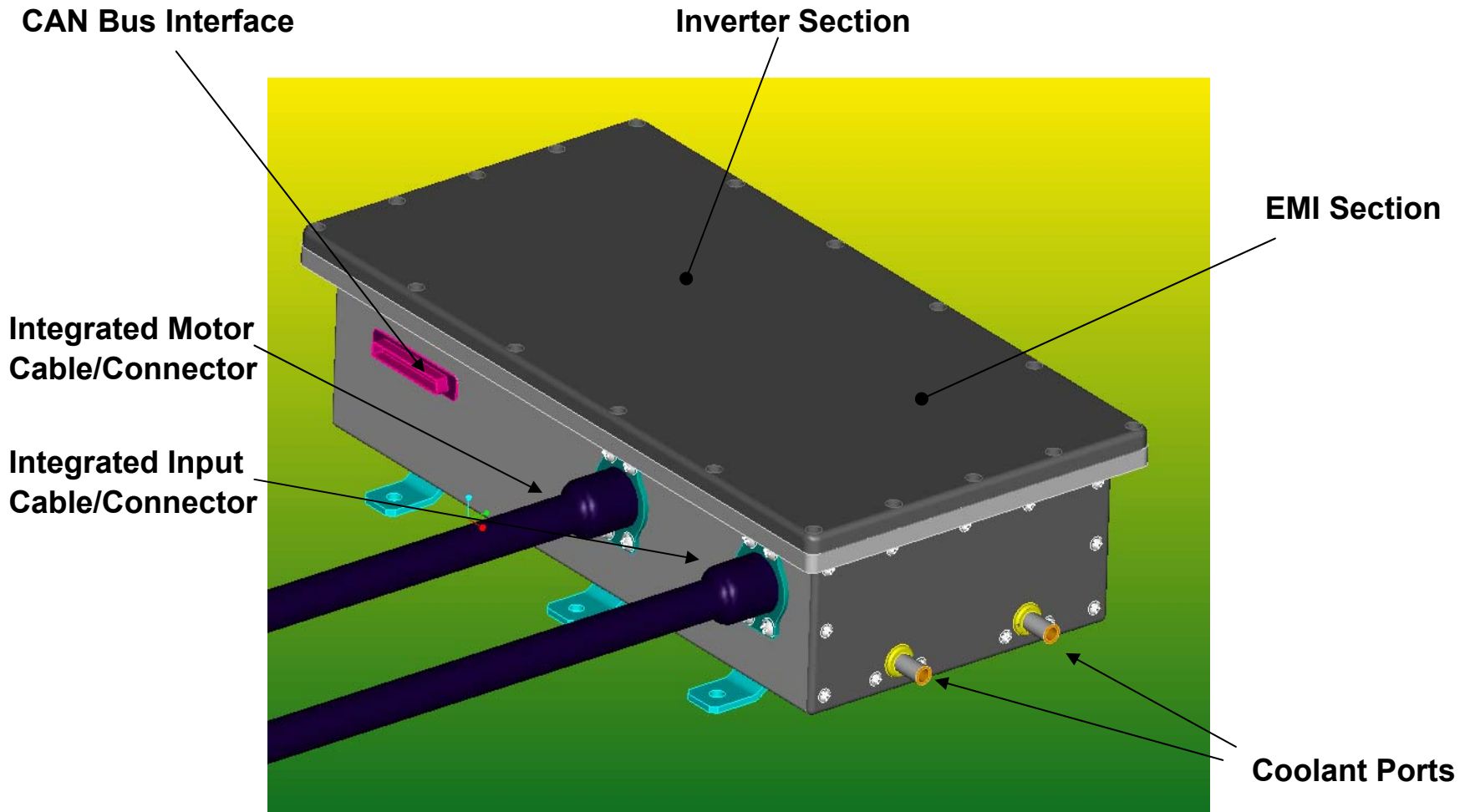
- Technical Objective 3
- Motor
 - Detailed design drawings completed
 - Parts ordered and fabricated
 - Motor testing initiated

Technical Accomplishments/Progress/Results



- Technical Objective 3
- Motor controller
 - Analysis underway
 - Detailed design drawings underway
 - Parts ordering and fabrication initiated with some parts received

Technical Accomplishments/Progress/Results **Honeywell**



8.5 Liters; 6.5 kg

Technical Accomplishments/Progress/Results



- Technical Objective 4
- Turbocompressor/motor controller development testing
 - To be initiated in FY2005

Technical Accomplishments/Progress/Results Honeywell

Table 3.4.11. Technical Targets: Compressor/Expanders (C/E) for Transportation Fuel Cell Systems						
Characteristic	Units	2004 Status	2005	2010	2015	2005 Honeywell Estimates
Input Power ^a at Full Load, 40°C Ambient Air (with Expander / without Expander)	kW _e	6.3/13.7 ^b	6.3/13.7	5.4/12.8	5.4/12.8	9.4/15.7 ^g
Overall Motor/Motor Controller Conversion Efficiency, DC Input	%	85	85	85	85	87
Input Power ^b at Full Load, 20°C Ambient Air (with Expander / without Expander)	kW _e	5.2/12.4 ^b	5.2/12.4	4.4/11.6	4.4/11.6	8.0/14.3 ^g
Compressor/Expander Efficiency at Full Flow (C/E Only) ^c	%	75/80 ^d	75/80	80/80	80/80	77/82
Compressor/Expander Efficiency at 20-25% of Full Flow (C/E Only) /Compressor at 1.3 PR/Expander at 1.2 PR	%	45/30 ^d	55/45	60/50	60/50	50/45
System Volume ^e	Liters	22 ^b	15	15	15	15
System Weight ^e	Kg	22 ^b	15	15	15	17.5
System Cost ^f	\$	700	600	400	200	700 ^h
Turndown Ratio		10:1	10:1	10:1	10:1	10:1
Noise at Maximum Flow (excluding air flow noise at air inlet and exhaust)	dB(A) at 1 meter	65	65	65	65	TBD
Transient Time for 10-90% of Maximum Airflow	Sec	1	1	1	1	2-3

^a Input power to the shaft to power a compressor/expander, or compressor only system, including motor/motor controller with an overall efficiency of 85%. 80kW_e compressor/expander unit for hydrogen/air flow – 90 g/sec (dry maximum flow for compressor, compressor outlet pressure is specified to be 2.5 atm. Expander (if used) inlet flow conditions are assume to be 93 g/sec (at full flow), 80°C and 2.2 atm.

^b Projected

^c The pressure ratio is allowed to float as a function of load. Inlet temperature and pressure used for efficiency calculations are 20-40°C and 2.5 atm.

^d Measure blade efficiency.

^e Weight and volume include the motor and motor controller.

^f Cost targets based on a manufacturing volume of 100,000 units per year, includes cost of motor and motor controller.

^g Input power includes leakages, bearing losses, cooling flows, and motor and motor controller losses. Testing will have to be completed to verify a Honeywell method to lower the input power at the 40°C and 20°C ambient air conditions to 8.6/15.7kW_e and 7.3/14.3 kW_e or lower respectively and to determine if surge is a significant issue at low flows. The input power at part load is within specification.

^h The estimate is in 2005 dollars. The estimate is for hardware only and does not include labor, testing, nonrecurring engineering or capital equipment costs.

Responses to Previous Year Reviewers Comments **Honeywell**

- Project started in 1996 still in redesign/build/demonstrate mode. Need to rethink deliverables of this project. Specific hardware or design tool to rapidly tailor compressor/expander for each developer
 - Latest design is modular to enable more rapid change of aerodynamic components to better meet specific developers needs
- Need to team with other experts who could provide unique insight to design and power aspects
 - A trade study was performed in Technical Objective 1 that addressed the unique design and power aspects of a fuel cell turbocompressor, Honeywell continues to be in contact with fuel cell developers to update specifications as necessary

Responses to Previous Year Reviewers Comments

- Will the cost reductions be adequate for fuel cell developers to use this machine?
 - Cost is a concern, and the Team is continuing to work with the Honeywell Transportation Systems group that produces automotive turbochargers to work on lowering the cost of the machine
- Can air bearings achieve automotive stop/start/drive cycle durability requirements?
 - Over 200,000 start/stop cycles have been demonstrated on foil air bearing turbomachinery and has been determined to be adequate for an automotive drive cycle in the Technical Object 1 trade study

Future Work

- Remainder of FY 2005:
 - Complete detailed design
 - Complete fabrication and assembly
 - Complete motor testing
 - Complete preliminary motor controller testing
 - Initiate turbocompressor and motor controller integration testing
- FY 2006:
 - Complete turbocompressor and motor controller integration testing
 - Delivery of turbocompressor and motor controller
 - Final documentation

QUESTIONS/COMMENTS?

MARK K. GEE

PROGRAM MANAGER - FUEL CELL TURBOCOMPRESSORS

Engines, Systems & Services - Torrance, CA

Phone: 310-512-3606

E-mail: mark.gee@honeywell.com

Publications and Presentations

Honeywell

- “Air, Water and Thermal Management for PEM Fuel Cell Systems”, 2004 Fuel Cell Seminar, November 2004. San Antonio, TX

Hydrogen Safety

- The most significant hydrogen hazard associated with this project is:
 - The compromise of various components containing/transporting hydrogen (e.g. hydrogen tanks and associated lines) leading to hydrogen leakage and possible ignition due to lack of containment of the rotating components in case of failure or burst.

Hydrogen Safety

- Our approach to deal with this hazard is:
 - Containment analyses were completed with positive using empirical models based on numerous Honeywell aerospace high speed turbomachines were used in the design of the turbocompressor to ensure tri-hub burst containment of the rotating components. When funding is available, actual testing is also possible to verify the specific analyses above.