2008 DOE Review

A Cassette Based System for Hydrogen Storage and Delivery

Department of Energy
Golden Field Office
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Limnia, Inc.
601 Van Ness Avenue, Suite E3613
San Francisco, CA 94102
Direct: 1.510.868.2862
Main: 1.800.515.0526, Ext. 104
FAX: 1.510.868.2862
contact@limnia.com http://www.limnia.com

STP 34

This was a FY 2006 project that has been completed. The funding for this project was DOE: $825,000 FST: $206,250 Total: $1,031,250

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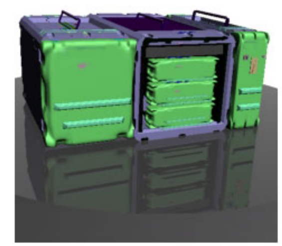
Strategy

To Develop a Hydrogen Storage and Distribution Technology that is:

- **S**afer
- **M**odular
- **A**daptive
- **R**egenerative
- **T**ransportable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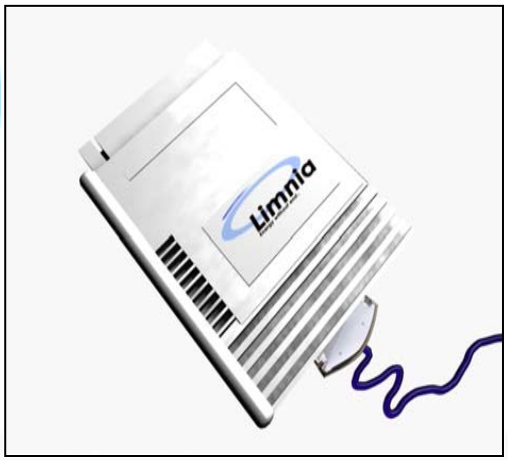
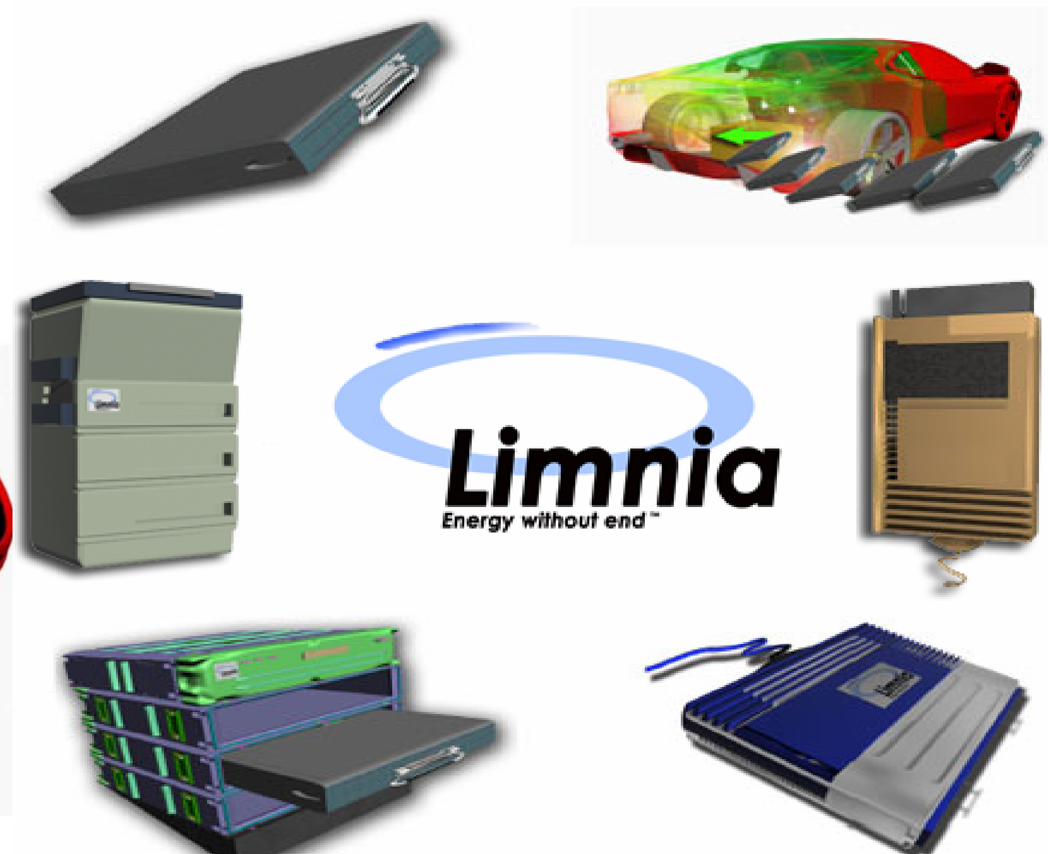
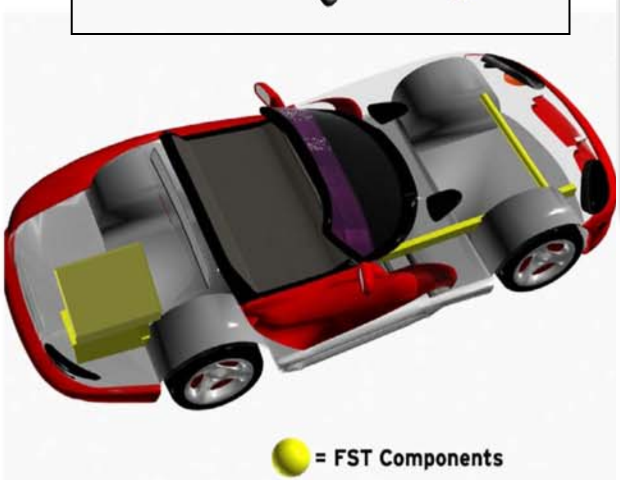
Fuel Cassette Based System with Multiple Applications



Advanced Solid State Technologies for the Generation, Storage, and Delivery of Clean, Renewable Energy





Project Objectives
3 Phase Timeline

Key Tasks	Mo.1	Mo. 2	Mo.3	Mo.4	Mo.5	Mo.6	Mo.7	Mo.8	Mo.9	Mo.10	Mo.11	Mo.12
1.0 **Program Management**												
(Est. October 2005-September 2006)												
1.1 Project Management												
1.2 Lab Preparation and Equipment												
1.3 Research Documentation/Control												
1.4 Project Cost Control												
2.0 **FST H-Matrix Compounds Research and Development**												
Phase 1 (Est. November 2005-January 2006) *Test reliability of alanate compound within Fuel Cassette housing/ Optimization*												
2.2.1 Lifetime cycle testing w/ variant catalysts												
2.2.2 Material and Apparatus Analysis												
2.2.3 Final Results												
2.2.4 Milestone/Decision point:						1/15/06						
2.2.5 Documentation												
Phase 2 (Est. February 2006-May 2006) *Demonstrate DOE %/wt/pr/temp goals within proposed system.*												
2.4.1 Refinement of materials and system to optimize BoP												
2.4.2 Material Analysis pertaining to apparatus with the goal of weigh reduction and TD stability/reliability.												
2.4.3 Final Results												
2.4.4 Milestone/Decision point:												
2.4.5 Documentation												
Final Report and Presentations												
4.1.2 Computer model validation - chemical scale, kinetic,												
4.1.3 Material and apparatus Analysis												
4.1.4 Final Results												9/30/06
4.2 Completion of Final Report and presentations, quality assurance oversight review and next steps high-level draft proposal.												

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Statement of Objectives

- Develop hardware/software system that stores and releases H_2 at optimum efficiency
- Flexibility that facilitates use of the best available metal hydrides
- System Characteristics:
  - Built from readily available materials
  - Scalable for multiple applications
  - Market adoptable via simple adjustments to existing infrastructure

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Approach

- MODELING: of heat transfer systems for H_2 release from test materials for specific cassette configurations
- EVALUATE: modification of H_2 storage materials to facilitate manipulation of storage capacity, thermodynamics and kinetics
- DESIGN: a simple experimental cassette system to demonstrate cassette concept, feasibility and performance
- TEST: heat transfer concepts, materials manipulation, balance of plant requirements with cassette model

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Progress/Accomplishments

- Selected parameters for a hypothetical metal hydride—used sodium alanate as a model. Applied this to several cassette system designs to meet end-user requirements
- Modeled heat transfer concepts for cassette model and compared results for selected approaches
- Compared virtual cassette with other hydrogen storage methods
- Evaluated heat transfer in selected systems
- Designed and constructed demonstration cassette system hardware and software to illustrate features of a multiplexed cassette system
- Modified materials and evaluated properties
- Compared different H_2 storage systems in cassette test system
- Constructed dual Sievert's test system

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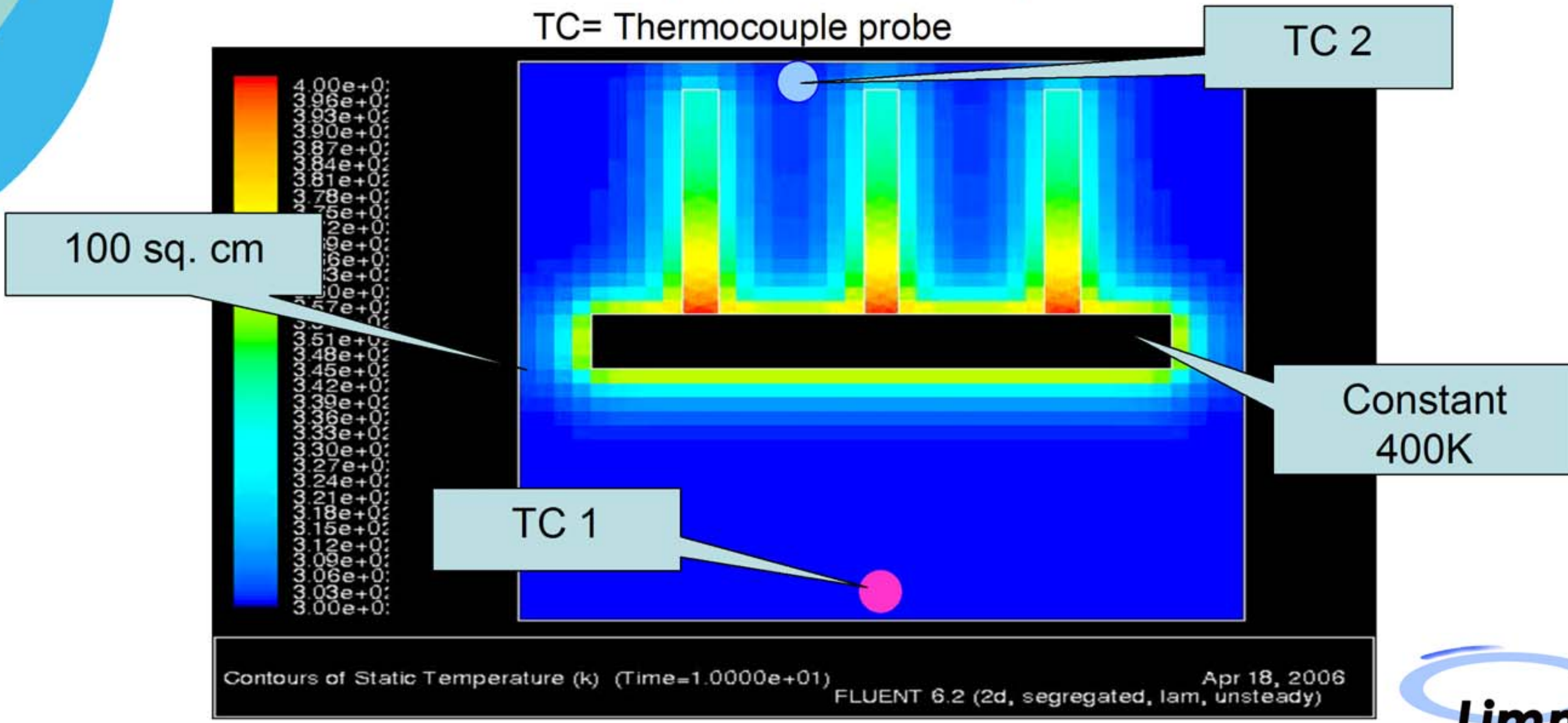
Technical Accomplishments

Heat transfer Fluent Model Illustrating Efficacy of Heat Transfer Fins (top): No Fins (bottom)

TC= Thermocouple probe



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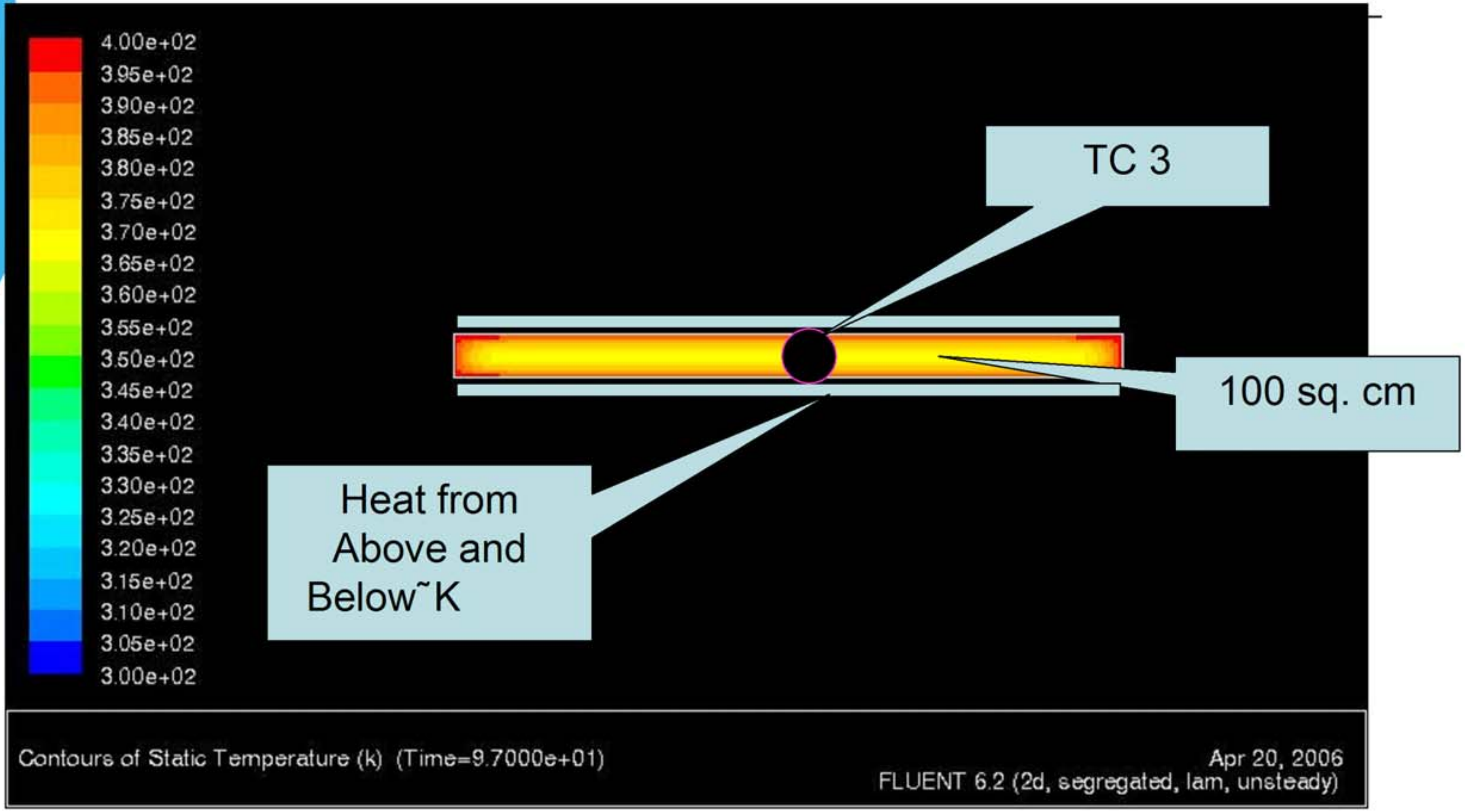
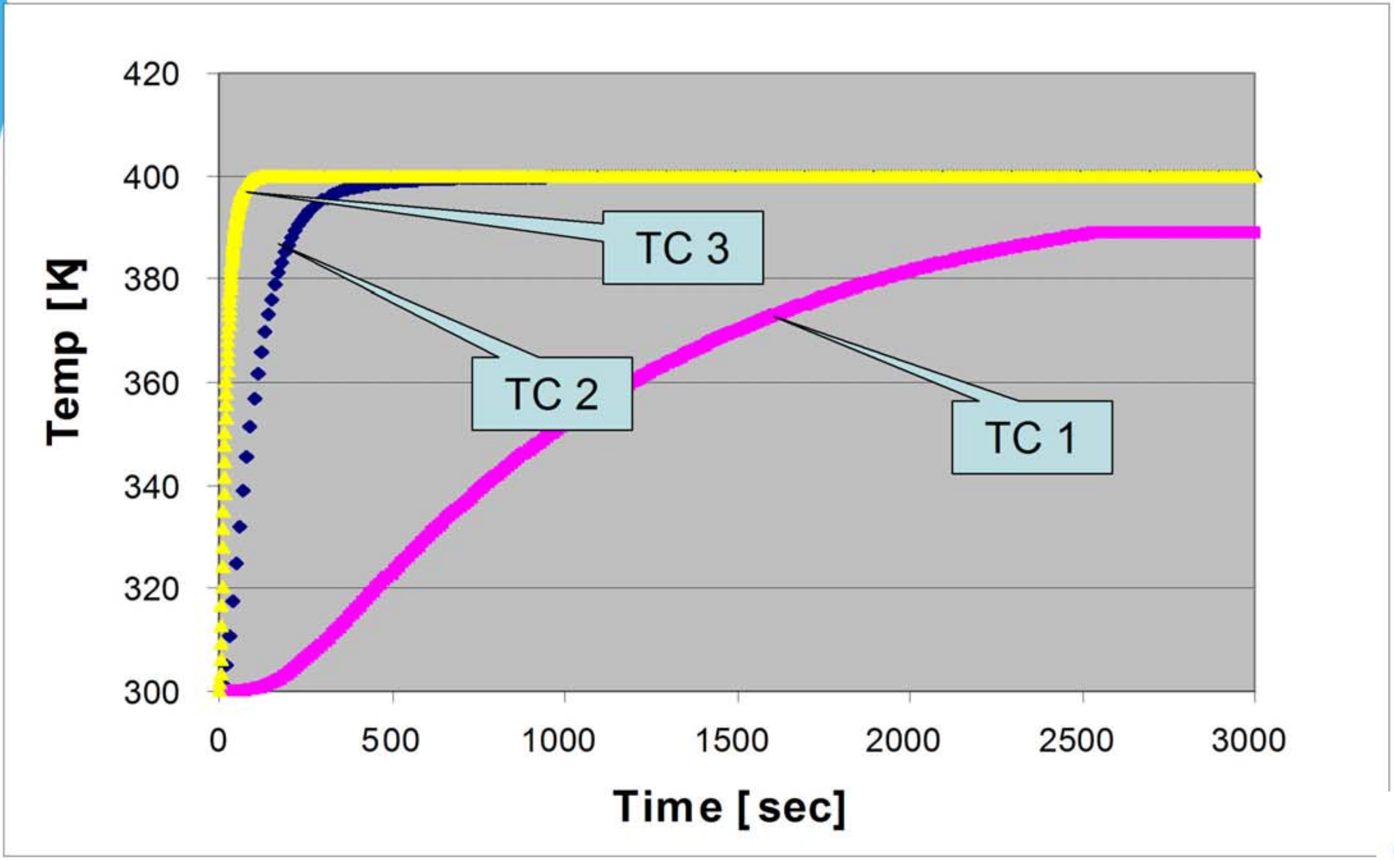
Heating Alanate plus Hydrogen (Fluent Model)



Compare Temperatures in Previous Two Models



Comparison of a Cassette System with Standard Steel Cylinders

Two Prototypical Metal Hydrides

Cassette	***4% H2***	***6% H2***	***Units***
Size	28X36X5	28X36X5	cm
Media Wt	2.99	2.99	Kg
Thermal Mgt	0.50	0.50	Kg
Housing Wt.	1.49	1.49	Kg
Plumbing Wt	0.25	0.25	Kg
H2 Wt	0.12	0.18	Kg
Cylinder Eq.	0.16	0.24	Cylinders
Gasoline Eq.	0.47	0.71	Liters

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Comparison of Cassette with Metal Hydrides with High Pressure Cylinders

Parameter	Metal hydride 1		Metal Hydride 2		Metal Hydride 3		5000 psi	10000 psi	LH2
	H2 %	density	H2 %	density	H2 %	density			
	4	0.65	6	0.8	9	0.9			
Material Weight, Kg	25		16.7		11.1		1	1	1
Material Volume, l	38.5		20.8		12.3		35.3	17.65	14.3
Packaged Wt, Kg*	58.8		39.3		26.1		14.7	15.9	
Packaged Vol, l*	51.7		28.0		16.6		55.3	37.6	
Cassette Vol, l	42.0		24.0		13.6		55.3	37.6	
Cassette Wt., Kg	X		X		21.3		14.7	15.9	
System Grav. density	X		X		0.047		0.068	0.063	

*Data from TIAX 2005 DoE Report

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Electrical Resistance of Modified Sodium Alanate

Carbon 1 (%)	Carbon 2 (%)	Al/Ni powder (%)	Resistance (ohms)	Thickness (cm)
10			7800	1
20			350	1
30			130	1
	10		>100K	1
	20		5500	1
	30		200	1
		10	>100K	1
		20	>100K	1
		30	>100K	1

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Patents

IP and Patents

Multiple issued patents on use of solid state energy storage.

- Hydrogen Storage, Distribution, and Recovery System
  - Cassette System Claims
  - Hydride Interrogation Methods claims
- Improved Methods for Hydrogen Storage Using Doped Alanate compositions

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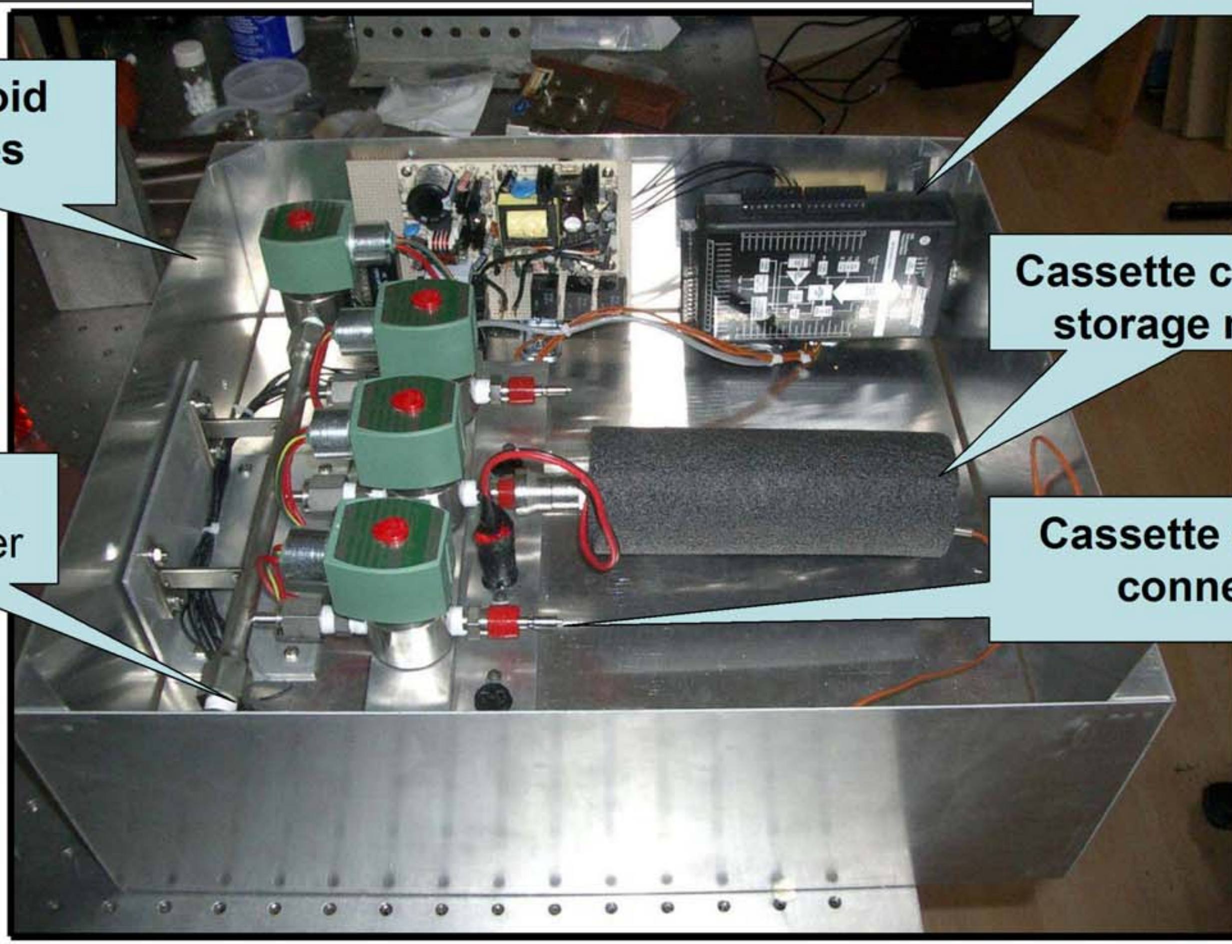
Multi-Channel Prototype



Picture of Dual Automated Sievert's

(Front cover removed for viewing)

Temp. Controlled Vented Cabinet

One of three calibrated volumes

One of two pressure transducers

One of two quick connects for cassettes

Crossover valve interchanges cassettes from charge to discharge

Work in Progress

- Evaluation of new materials within cassette
  - Lithium amide
  - SigNa Chem (NaSi)
- Complete study of carbon doped materials
- Continue study of material densification
- Refine balance of plant calculations
- Adapt cassette model to a slurry system
- Improve automation of experiments and systems

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Summary

A cassette model system for management of hydrogen storage materials has been constructed and model studies of heat transfer have been conducted. Materials have been modified to improve density and afford electrical conductivity for resistive heating. Calculations for hydrogen capacity have been carried out for different cassette models and compared with alternative hydrogen storage methods. Some conclusions and observations are:

A cassette is a replacement fuel tank and charged at a central location. This solves heat transfer problems and refill times. Cassettes have a rectangular form factor and therefore conform readily to systems where space is a premium. A cassette is relatively thin in one dimension and therefore heat transfer can be applied from outside the vessel from a separate independent component keeping the cassette structure simple, transportable, lightweight, and relatively inexpensive.

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Acknowledgment

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