



2006 DOE Review Presentation

A Cassette Based System for Hydrogen Storage and Delivery

*Department of Energy
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This presentation does not contain any proprietary or confidential information

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Strategy

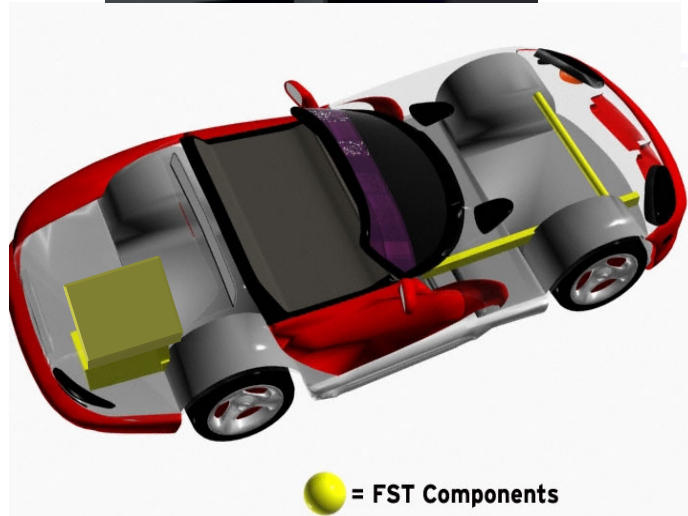
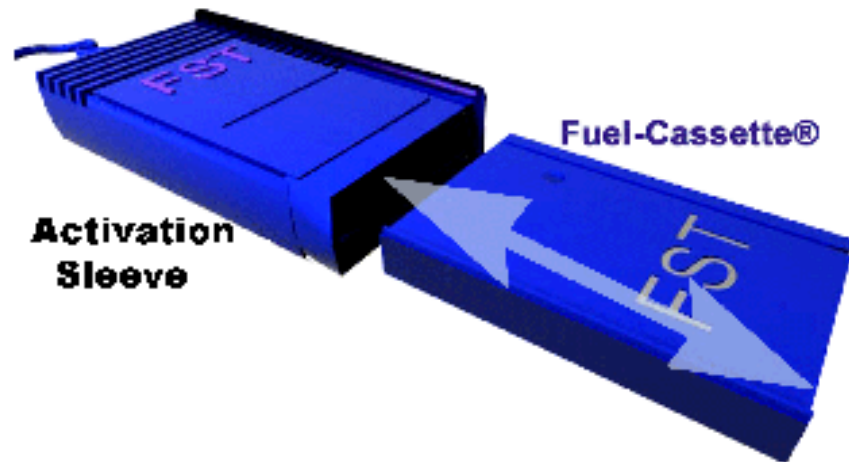
***To Develop a Hydrogen Storage
and Distribution Technology that is:***

**Safer
Modular
Adaptive
Regenerative
Transportable**

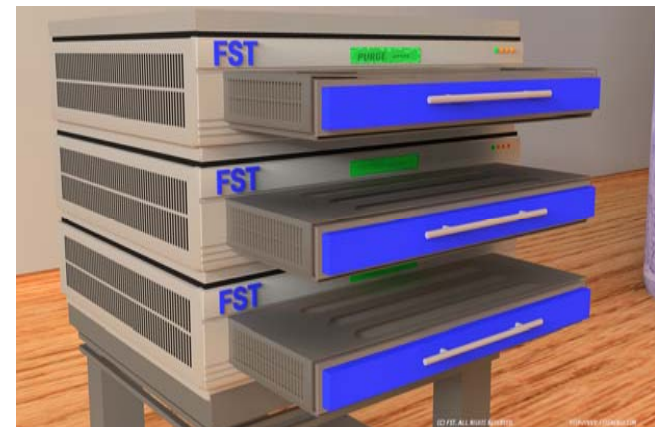
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Fuel Cassette Based System with Multiple Applications



Hydrogen sending machine



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.												

Overview

Timeline

- Start Oct. 2005
- Finish Sept. 2006
- 67% Complete

Budget

- Total Project Funding
 - \$825k DOE
 - \$206k FST

Barriers

- Hydride Percentage
- Hydride Density
- Hydride Thermal Properties

Consulting Partners

- Sandia
- SigNaChem
- Nick Tran (NRL)
- Vitalij Pecharsky (Ames)



Statement of Objectives

- Develop hardware/software system that stores and releases H₂ 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

Approach

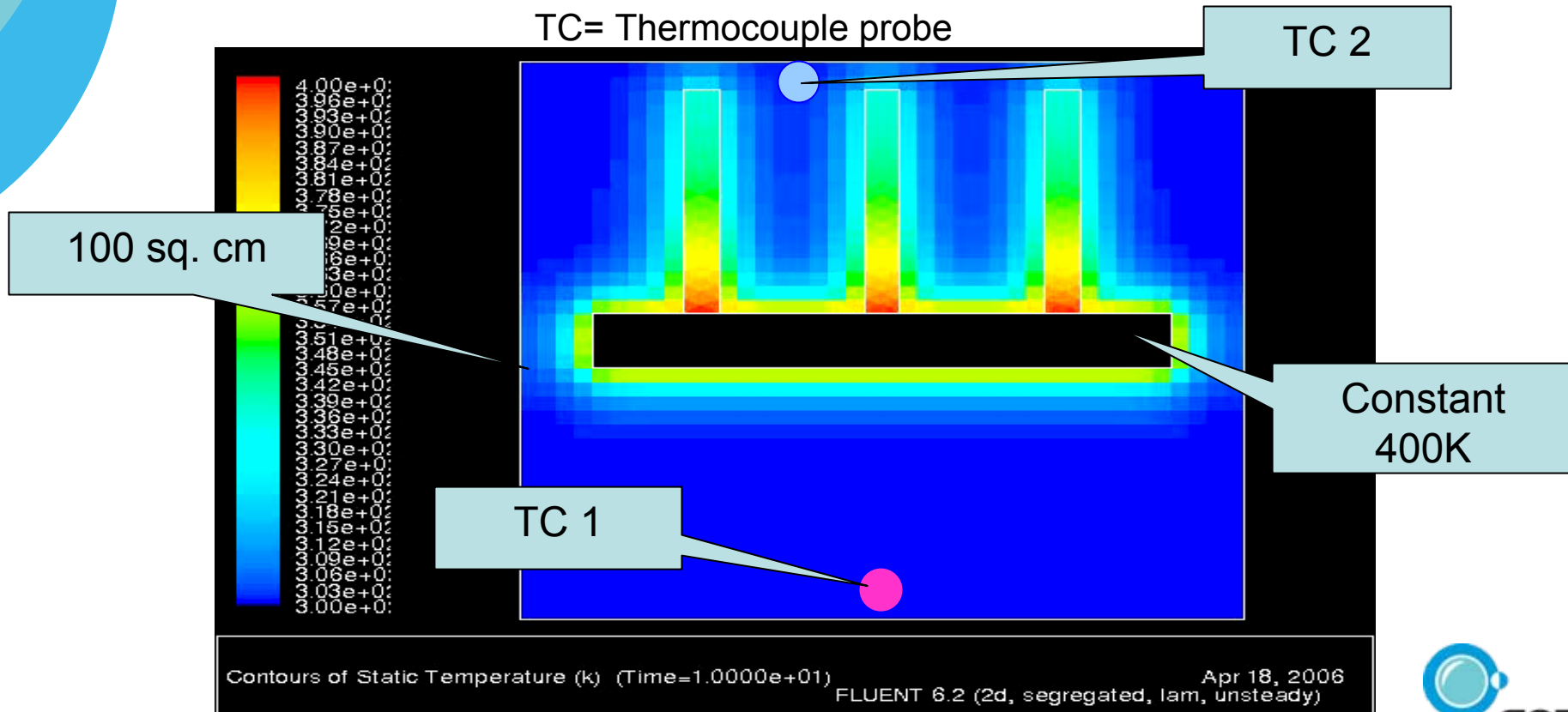
-
- MODELING: of heat transfer systems for H₂ release from test materials for specific cassette configurations
 - EVALUATE: modification of H₂ storage materials to facilitate manipulation of storage capacity, thermodynamics and kinetics
 - DESIGN: a simple experimental cassette system to demonstrate cassette concept, feasibility and performance
 - TEST: heat transfer concepts, materials manipulation, balance of plant requirements with cassette model

Progress/Accomplishments

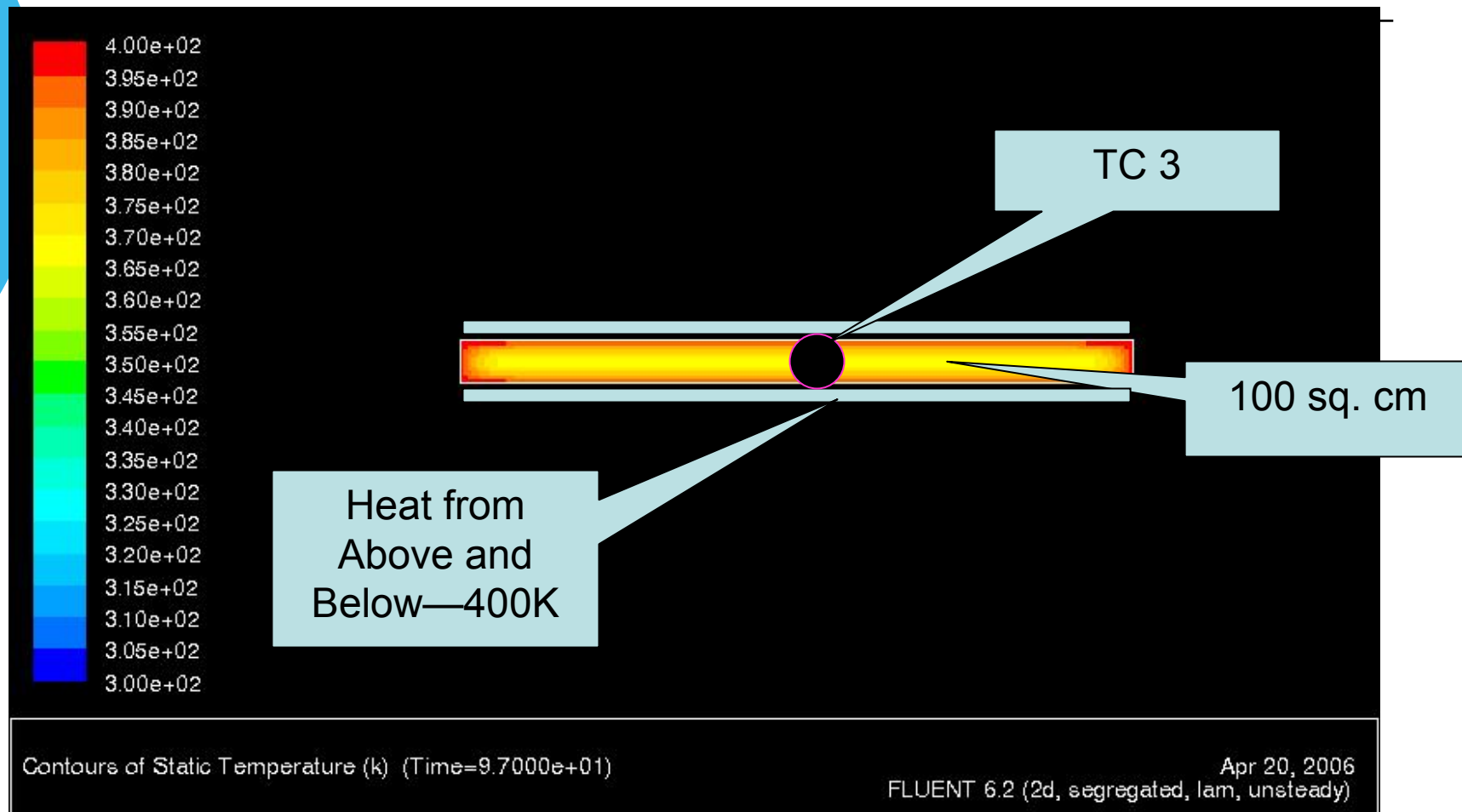
- Selected parameters for a hypothetical metal hydride—used sodium alanate as a model. Applied this to several cassette system designs to meet end-user requirements
- Modeled heat transfer concepts for cassette model and compared results for selected approaches
- Compared virtual cassette with other 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 H₂ storage systems in cassette test system
- Constructed dual Sievert's test system

Technical Accomplishments

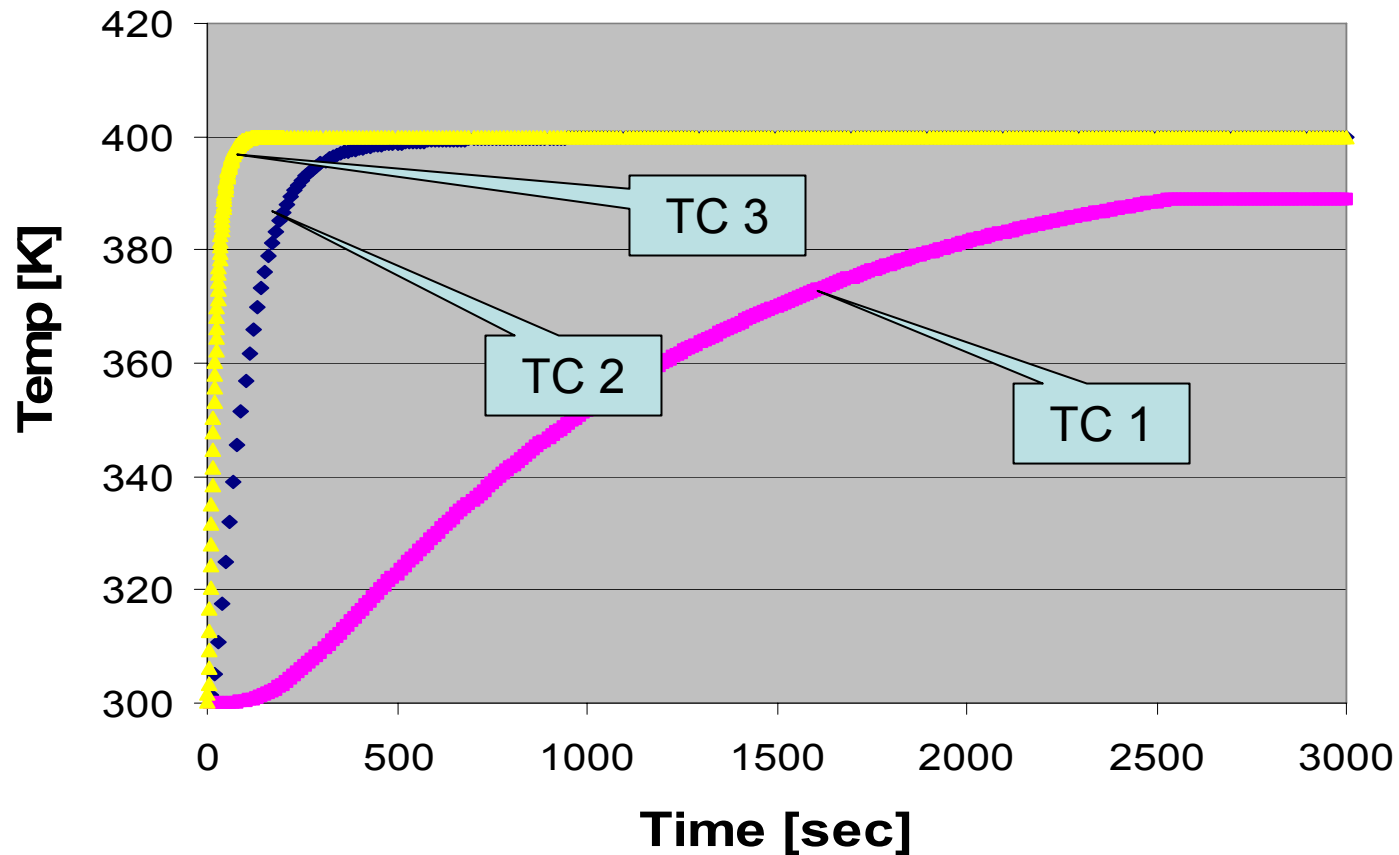
Heat transfer Fluent Model Illustrating Efficacy of Heat Transfer Fins (top): No Fins (bottom)



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

<i>Cassette</i>	<i>4% H₂</i>	<i>6% H₂</i>	<i>Units</i>
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
H ₂ Wt	0.12	0.18	Kg
Cylinder Eq.	0.16	0.24	Cylinders
Gasoline Eq.	0.47	0.71	Liters

Comparison of Cassette with Metal Hydrides with High Pressure Cylinders

Parameter	Metal hydride 1		Metal Hydride 2		Metal Hydride 3		5000	10000	LH2
	H2 %	density	H2 %	density	H2 %	density	psi	psi	
	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

Electrical Resistance of Modified Sodium Alanate

<i>Carbon 1</i>	<i>Carbon 2</i>	<i>Al/Ni powder</i>	<i>Resistance</i>	<i>Thickness</i>
<i>(%)</i>	<i>(%)</i>	<i>(%)</i>	<i>(ohms)</i>	<i>(cm)</i>
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

Patents

IP and Patents

- 2 issued patents, 4 due for release
 - Hydrogen Storage, Distribution, and Recovery System
 - Cassette System Claims
 - Hydride Interrogation Methods claims
 - Improved Methods for Hydrogen Storage Using Doped Alanate compositions

Multi-Channel Prototype

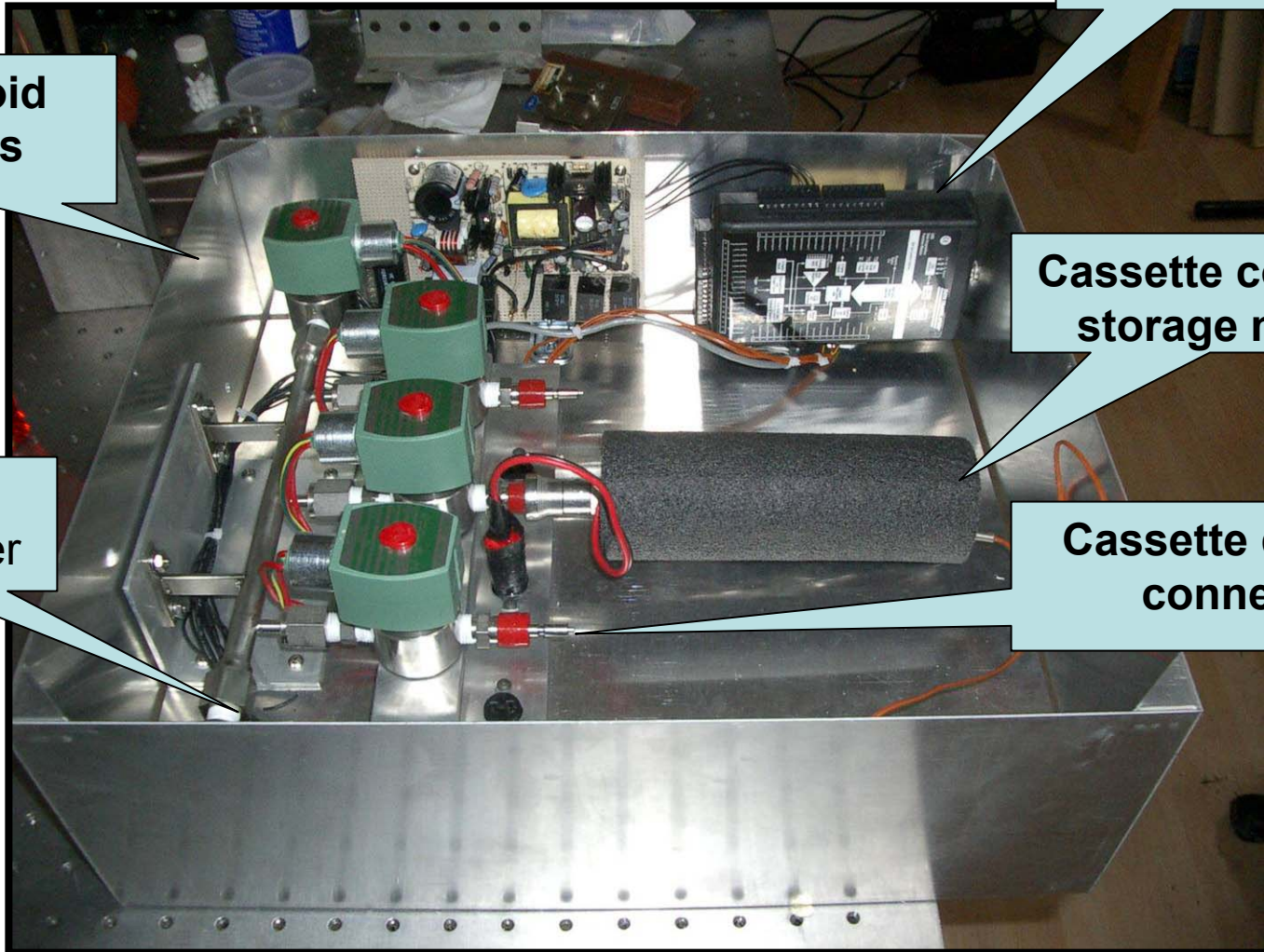
**Solenoid
Valves**

**Computer
Interface**

**Cassette containing
storage material**

**Pressure
Transducer**

**Cassette quick-
connect**



Picture of Dual Automated Sievert's

(Front cover removed for viewing)

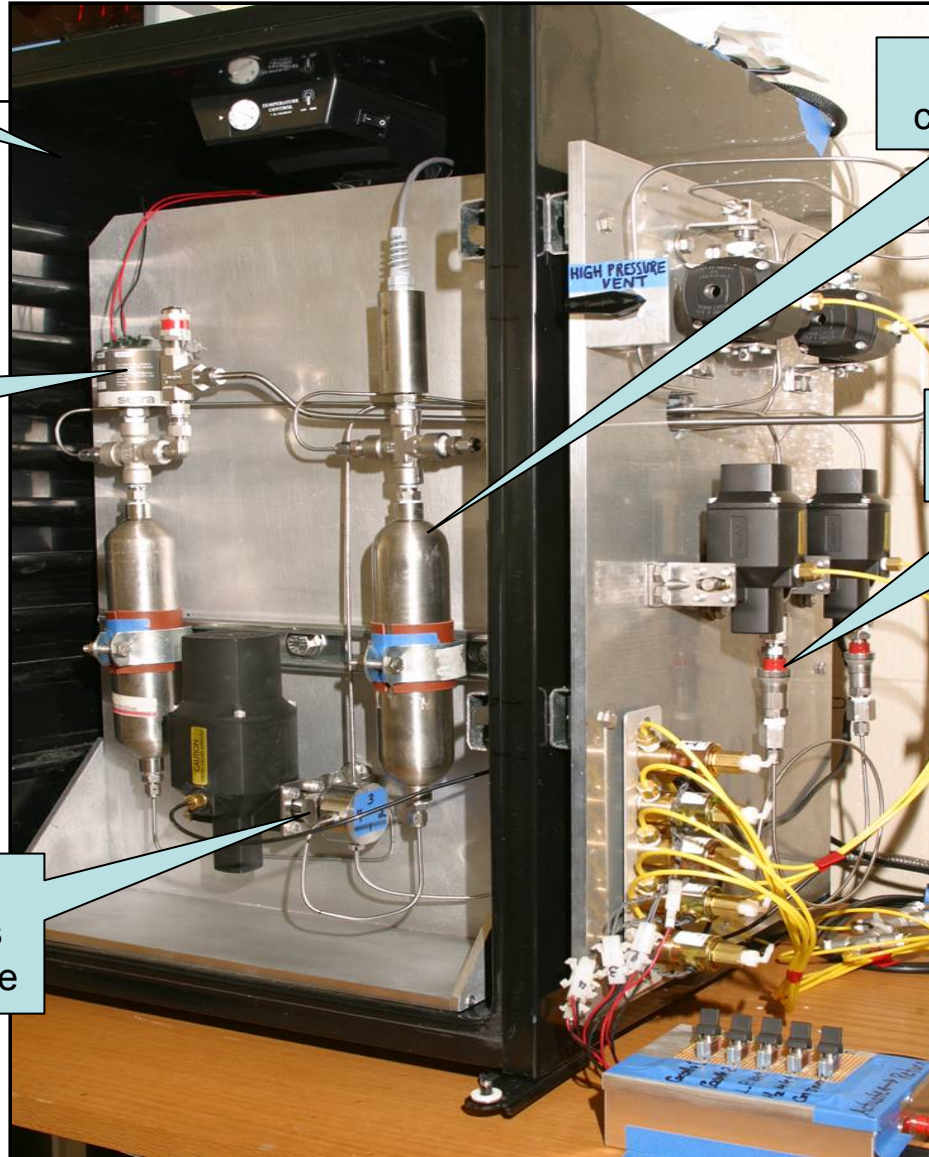
Temp.
Controlled
Vented Cabinet

One of two
pressure
transducers

Crossover valve
interchanges cassettes
from charge to discharge

One of three
calibrated volumes

One of two quick
connects for cassettes



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

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.

Acknowledgment

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