

# 2005 DOE Hydrogen Program Active Magnetic Regenerative Liquefier (AMRL) Development

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This presentation does not contain any proprietary or confidential information

Project ID #  
PDP47

# Overview

## Timeline

- May 2005
- April 2007
- Just beginning (<1 % complete)

## Budget

- Total: \$2.9 MM
  - DOE: \$2.3 MM
  - Team: \$0.6 MM
- FY 04: \$0
- FY 05: ~\$0.5 MM

## Barriers

- Barriers addressed
  - High cost and low energy efficiency of hydrogen liquefaction
  - 30 mtons/day; \$1.80/gge → \$1.50/gge and
  - 25 % → 35 % electrical energy efficiency

## Partners

- NCRC
- Prometheus Energy Company and its subcontractors

# Project Objectives

- DOE Hydrogen Program relevance: To significantly reduce the cost of liquefaction of hydrogen on a distributed-scale.
  - During the coming 12 months we intend to analyze/design a laboratory-scale AMRL prototype for liquefaction of 10-20 kg/day of hydrogen in an external process stream.
  - Our target is to create a complete design simultaneously more efficient and less expensive than comparable liquefier systems.
  - Within the next 12 months we intend to build and test the first stage of the AMRL to verify the design for the other five stages.
  - In the next 12 months we expect to finish fabrication and assembly of the entire liquefier in preparation for tests and demonstration during the second year of this project.

# Approach

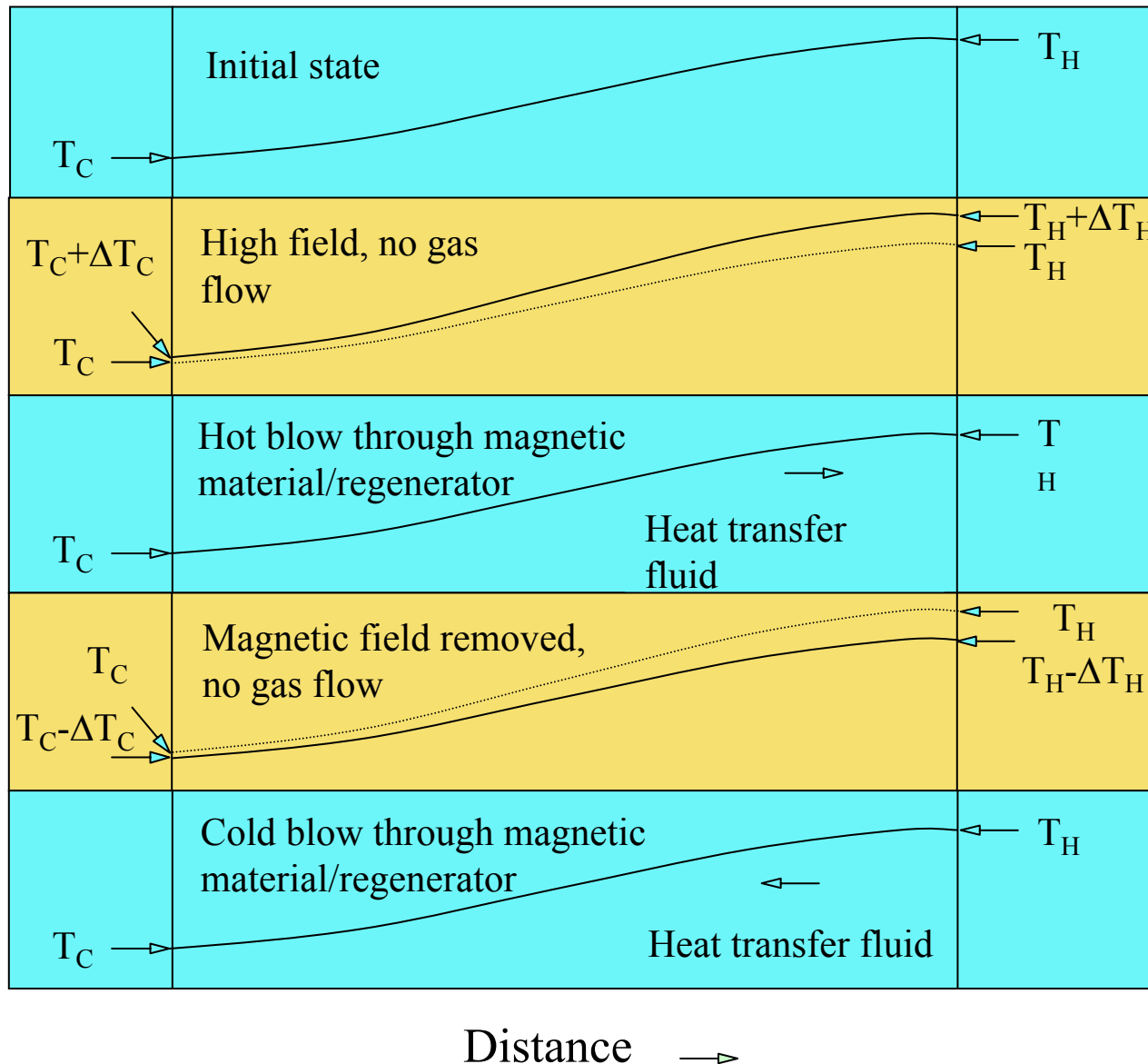
- Perform a detailed engineering design of a lab-scale, six-stage AMRL
  - Numerically model to analyze energy, entropy, & efficiency of complete magnetic refrigerator
  - Cool H<sub>2</sub> gas from RT to LH<sub>2</sub> via system of six AMRRs
    - Process gas source; purification; heat exchangers; o/p catalysts; liquid receiving vessel, cold box, work input, heat rejection.
- Build & test first stage AMRR operating from ~300 K to ~190 K to validate design calculations
  - Magnetic materials and layered magnetic regenerator
  - Conduction-cooled Superconducting magnet subsystem
  - Pressured He heat transfer fluid subsystem coupling
  - Process stream heat exchanger
  - Cold box, supports, drive subsystem;
  - Instrumentation & controls including H<sub>2</sub> gas, B, T, P, mass flow, torque, etc sensors subsystem.

# Technical Accomplishments/ Progress/Results

- We have updated our library of literature on magnetic refrigeration and liquefaction.
  - Magnetic materials; advanced regenerators
  - Superconducting magnets; cryocoolers
- We have reviewed our system analyses for efficient liquefaction of hydrogen.
  - Establish technology targets for design team
- We have created a detailed project plan using MS Project for management of the multiple tasks.
- We have added several additional staff to our Advanced Development Department
- We have begun modifications to our natural gas test facilities to enable us to test the prototype with hydrogen
- We have completed subcontracts to test the layered magnetic regenerator and the design of the conduction-cooled magnets

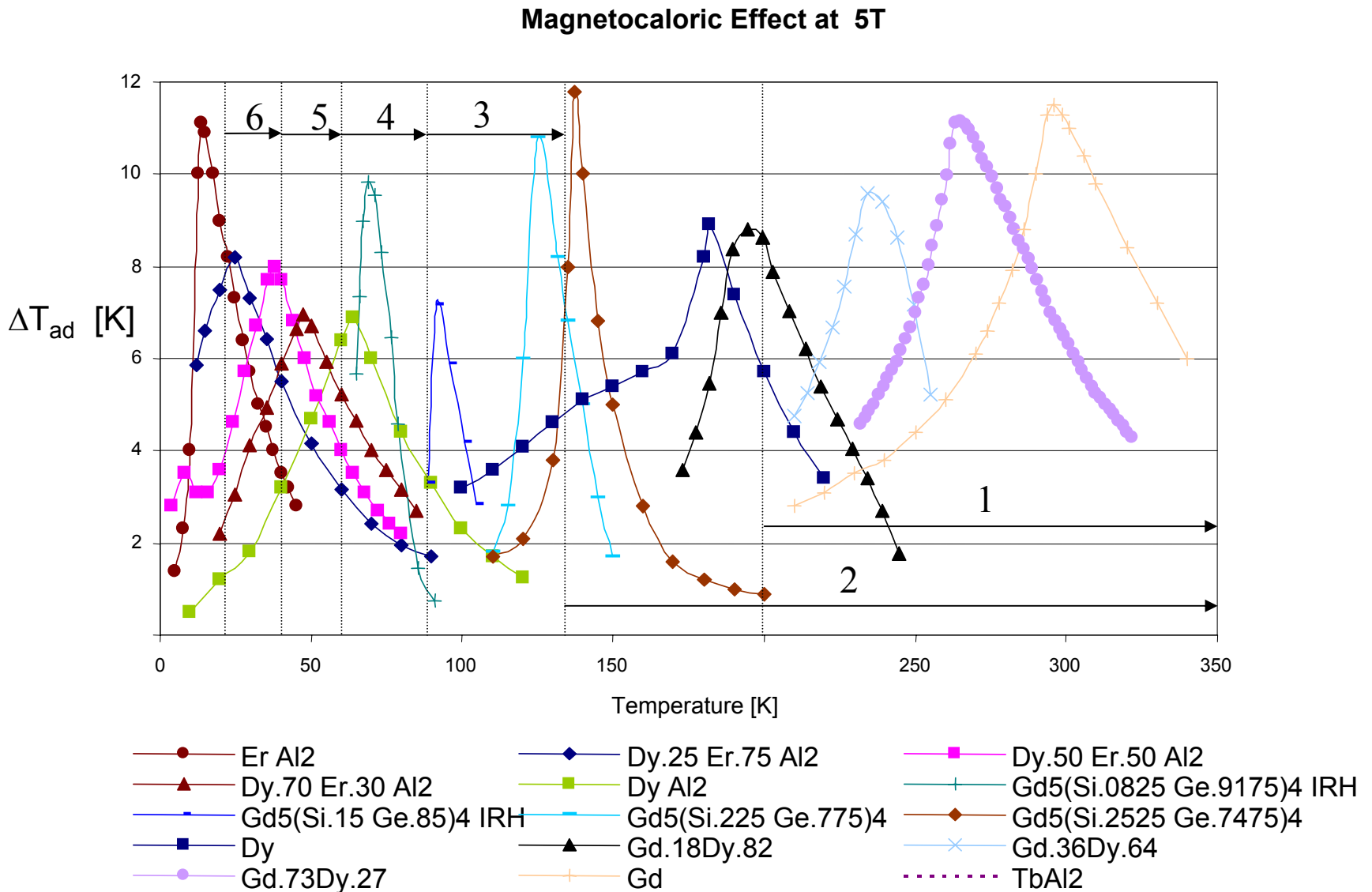
# Technical Accomplishments

The operational cycle of an AMRR requires periodic reversal of a heat transfer fluid

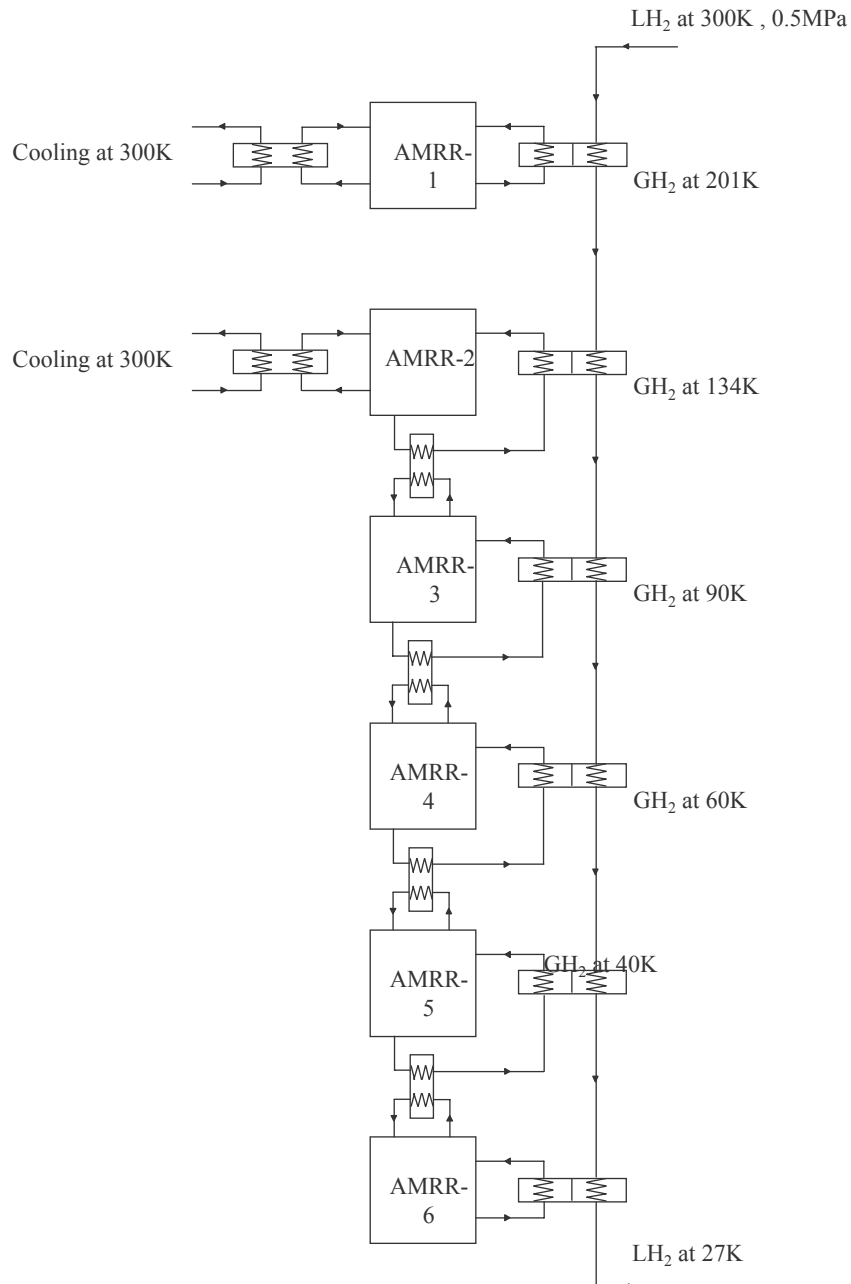


# Technical Accomplishments

Excellent Magnetic Refrigerants are available for design selection over 20 K to 300 K



# Technical Accomplishments



## Magnetic Parallel/Serial Combination

Stage	Temperature range [K]	Load [W]
1	200.8-300	161.2
2	134.4-300	1214.6
3	90.2-134.4	651.8
4	60.3-90.2	340.7
5	40.3-60.3	166.8
6	27.0-40.3	71.5



# Responses to Previous Year Reviewers' Comments

- N/A because project is just beginning.

# Future Work

- FY 05 and FY 06 tasks:
  - During the next 12 months we expect to develop a fully material and temperature dependent numerical code to predict AMRL performance.
  - We expect to modify our test facilities for the AMRR experiments with hydrogen.
  - Within 12 months we expect to complete fabrication and testing of a single stage AMRR from 300 K to ~190 K to validate AMRL performance model predictions and multiple design choices.
  - Complete the design and assembly of a six-stage AMRL in preparation for hydrogen liquefier tests.

# Publications and Presentations

No new technical publications or technical presentations have been made related to this project since the kick-off meeting in late April 2005.

# Hydrogen Safety

The most significant hydrogen hazard associated with this project will be during the testing of the magnetic liquefier system. This involves the setting up a process stream of  $\sim 0.15$  g/s of hydrogen gas at pressures from 0.1 MPa to 0.5 MPa, purifying this stream, before sending the process stream into the cryogenic heat exchangers in the evacuated cold box. The amount of  $\text{LH}_2$  collected in the cold box will be  $\sim 10\text{-}20$  kg/day.

# Hydrogen Safety

Our approach to deal with this hazard is to use properly designed test facilities that are safe for these small quantities of hydrogen. The laboratory space permits are reviewed by flammable gas experts before approval. The liquefier system is designed to be hermetic. The design undergoes a HAZOP analysis prior to approval for fabrication. Hydrogen gas detectors and properly vented and isolated lab space will be used. Inert purge gases and approved SOPs with trained test engineers will be used to insure safe operation of the AMRL.