Rapid Low Loss Cryogenic H_2 Refueling

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Project ID # PD074

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Overview

Timeline

- Start date: **October 2009**
- End date: **10/2011***
- Percent complete: **30%**

Budget

- Total project funding
  - DOE: **$1,300k**
- Funding for FY10:
  - **$300k**
- Funding for FY11:
  - **$1,000k**

Barriers

- **J. Refueling site operations**

Targets

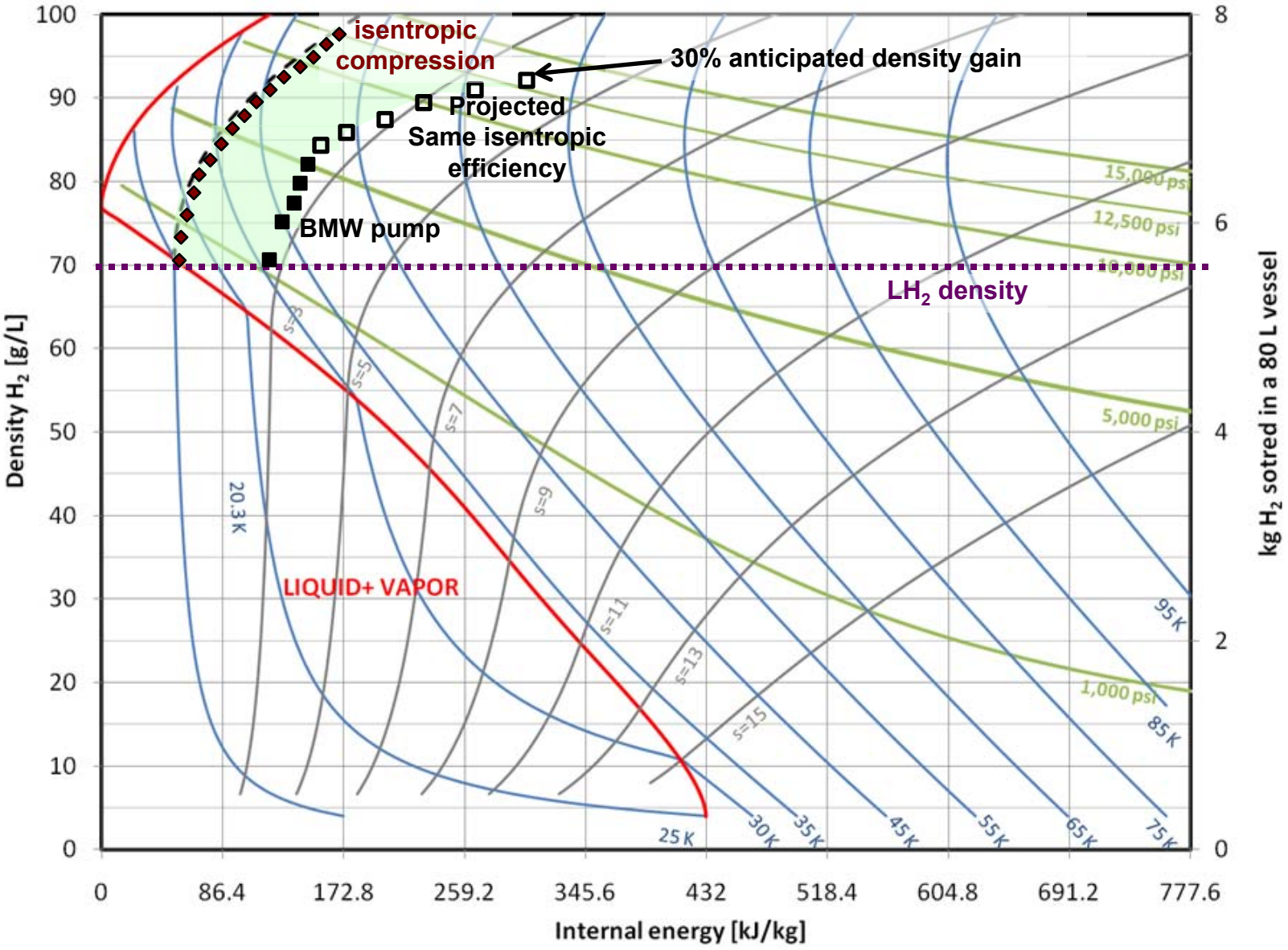
- **2015 refueling efficiency**

Partners

- Collaborating with **Linde** and **BMW** to demonstrate practical refueling of cryogenic pressure vessels

*** Project continuation and direction determined annually by DOE**

Relevance: We believe onboard H_2 densities above 90 g/L are achievable, increasing hydrogen density by 30% over LH_2

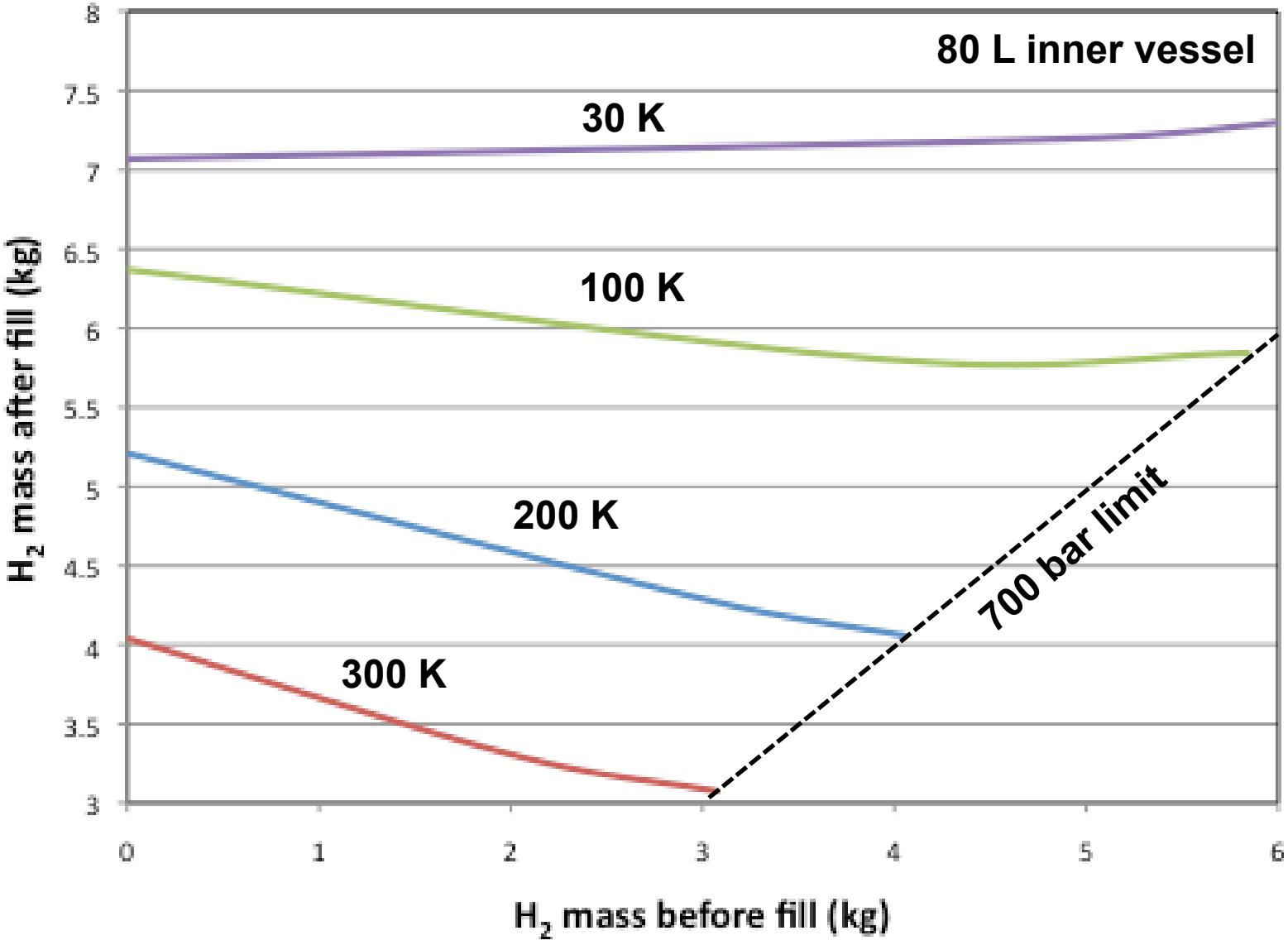


Approach: pressurize LH_2 for rapid refueling of cryogenic vessels with low evaporative losses and pumping power

BMW high pressure cryogenic pump

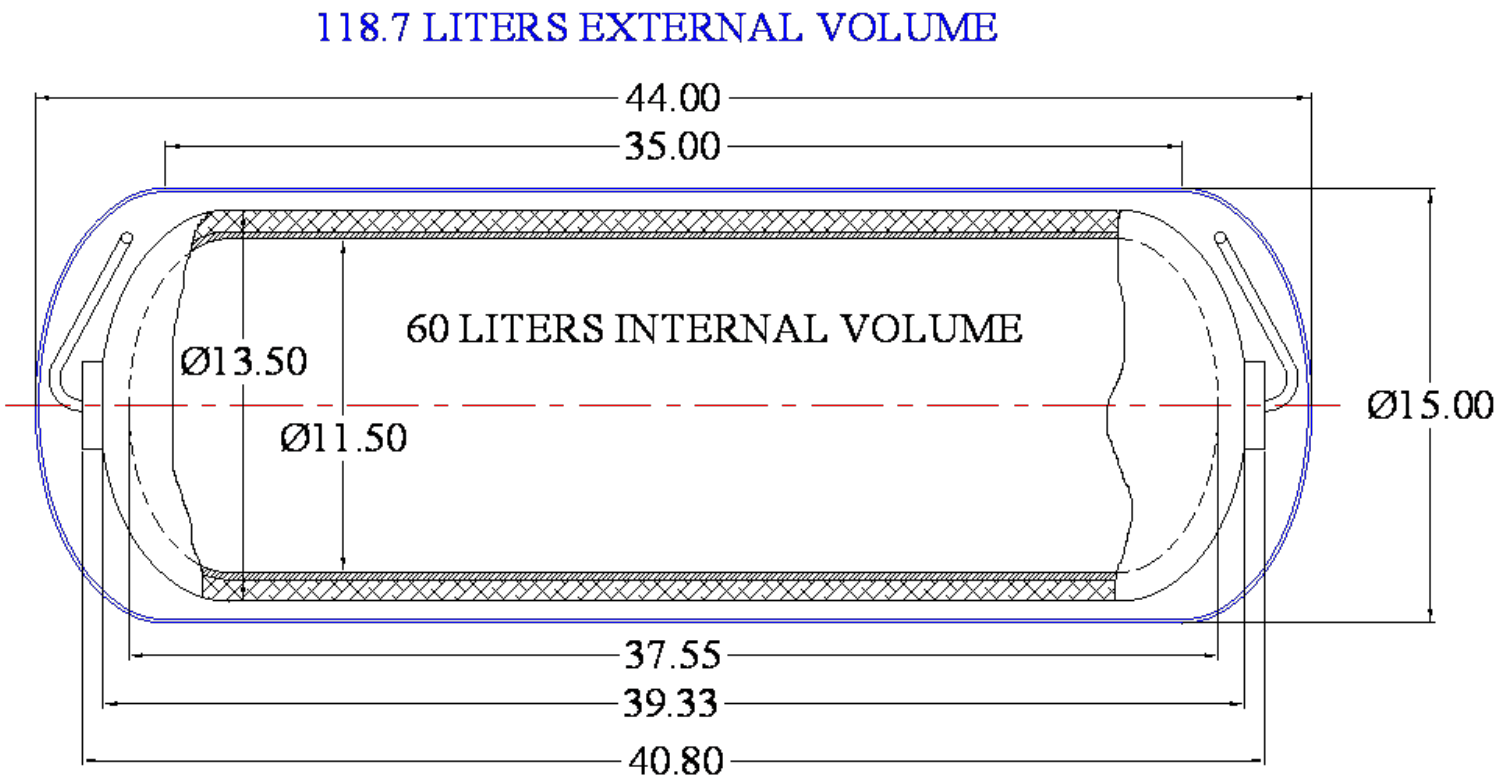
- High LH_2 density minimizes pump power & compression heating
- Pumping power = $\int \frac{dP}{\rho}$
- Compression heating = $\frac{P}{\rho}$
- Pressurized LH_2 pump quickly fills even warm and/or pressurized vessels
- Recycled H_2 vapor from pump maintains stationary vessel pressure

Test matrix: evaluate refuel vessel capacity as a function of initial conditions (ρ, T of vessel in vehicle pulling into station)



A 60 L 700 bar cryogenic vessel will be located forward of existing 151 L 350 bar vessel. Fueling both explores scale and transient vs. steady state refueling differences

We project 51% volumetric efficiency for 60 L & 700 bar cryogenic vessel design with aspect ratio ~3



- ***Simpler high pressure operation*** **with *single* inlet/outlet line**
- ***Measure H_2 temperature in addition to vessel, piping and jacket temperatures*** **by inserting silicon diodes in vessel**
- ***Second independent capacity measurement*** **by weighing vessel ideally *during* refueling**
- ***Aluminum jacket material*** **to improve weight, capacity measurement, and thermal uniformity**

Collaborations: We are working with two major companies in the field of cryogenic hydrogen storage and dispensing

- ***Linde:*** **Extensive expertise on cryogenics and liquid hydrogen automotive systems. Supplier of high pressure cryogenic pump. Delivered first ever system to BMW last year. Planning a custom design for the experimental needs of LLNL.**
- ***BMW:*** **Long standing collaboration with LLNL through cryogenic pressure vessel technology CRADA. Demonstrating first prototype cryogenic pump technology. Contributing technical information and expertise.**

Future work: we will combine a high pressure LH_2 pump & lighter, smaller vessel with a comprehensive experimental strategy

- ***Rapid low loss refueling at higher density*** **up to 880 bar, 90 gH_2/L**
- ***Simpler high pressure operation*** **with *single* inlet/outlet line**
- ***Realistic (warm) refueling conditions:*** **partially full, <99% para H_2**
- ***Measure H_2 temperature in addition to vessel, piping and jacket temperatures*** **by inserting silicon diodes in vessel**
- ***Second independent capacity measurement*** **by weighing vessel ideally *during* refueling**
- ***Aluminum jacket material*** **to improve weight, capacity measurement, and thermal uniformity**

Summary: LLNL will measure real-time cryogenic refueling parameters (P,T) for actual scale (60 L) vessels under full range of drive-up conditions (20-300 K, 0-100% full)

700 bar cryogenic H_2 vessel

- **75 kg system (Al vacuum jacket)**
- **5+ kg usable H_2 capacity**

880 bar LH_2 pump

- **Rapid single phase refueling**
- **Target fuel density 90+ gH_2/L**