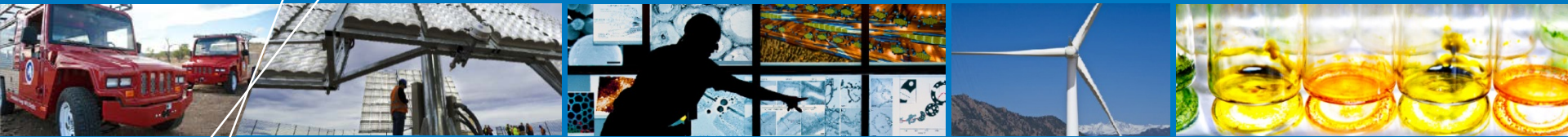


Overview of an Integrated Research Facility for Advancing Hydrogen Infrastructure



**Kevin Harrison (PI), Josh Martin, Mike Peters
(Presenter), Owen Smith, Danny Terlip**

**National Renewable Energy Laboratory
DOE 2016 Annual Merit Review
June 7, 2016**

**Project ID:
TV038**

Overview

Timeline

Project start date: February, 2015

Project end date: TBD

Budget

Total Budget: \$1.1M

Barriers

- *Technology Validation Barriers*
- *D. Lack of Hydrogen Refueling Infrastructure Performance and Availability Data*
- *E. Codes and Standards - Validation projects will be closely coordinated with Safety, Codes and Standards*
- *Safety Codes and Standards Barriers*
- *F. Enabling national and international markets requires consistent RCS*
- *G. Insufficient technical data to revise standards*
- *J. Limited participation of business in the code development process*

Partners

- Air Products and Chemicals, Inc.

Relevance & Project Objective

Design, build, commission, and operate a hydrogen station to understand industry challenges, provide hydrogen to DOE and industry funded research projects, fill hydrogen fuel cell vehicles, and provide a test platform for hydrogen infrastructure components.

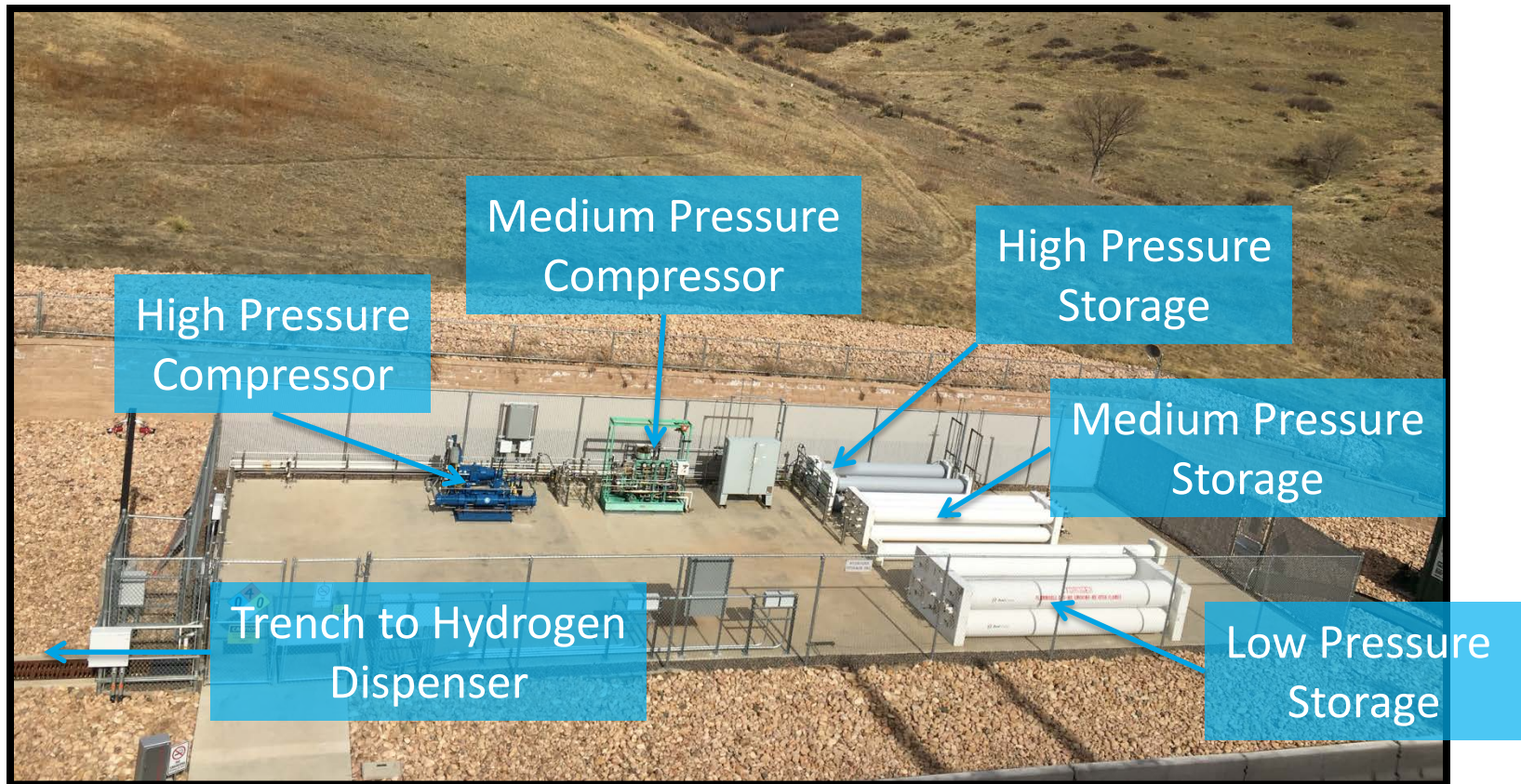
- The Hydrogen Infrastructure Testing and Research Facility, HITRF, encompasses all elements of a commercial gaseous hydrogen fueling station with on-site forecourt production**
- The integrated system leverages NREL's research in production, compression, storage, and dispensing into a unified system capable of fueling fuel cell electric vehicles and fuel cell forklifts**
- By tracking hydrogen infrastructure performance, NREL will inform DOE, federal and state governments, academia, and industry of issues and solutions to commonly observed problems at hydrogen stations.**

Approach: Operation and Data Collection

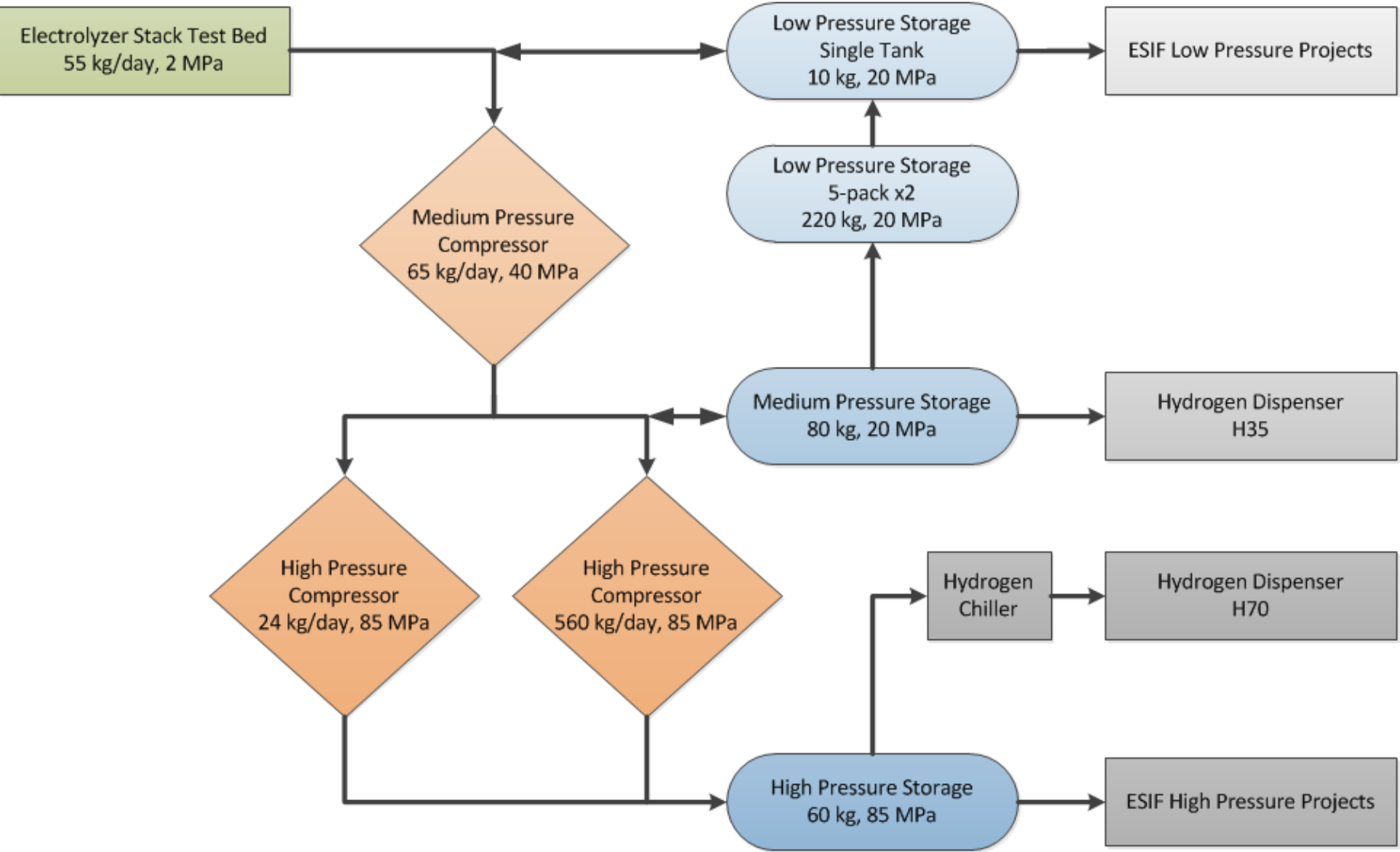
- Mimic current and future hydrogen stations by fueling FCEVs and simulated vehicles to report on hydrogen station performance.
- Collect and report on every facet of a hydrogen station:
 - System efficiency
 - Downtime
 - Maintenance cost/time
 - Capital cost
 - Lead times based on components
 - System integration
 - Safety
 - Controls

Approach: Layout

- Station pad is more spaced out than typical hydrogen stations to allow for infrastructure components, both research and commercial, to be moved in and out easily



Approach: Station Flow Diagram



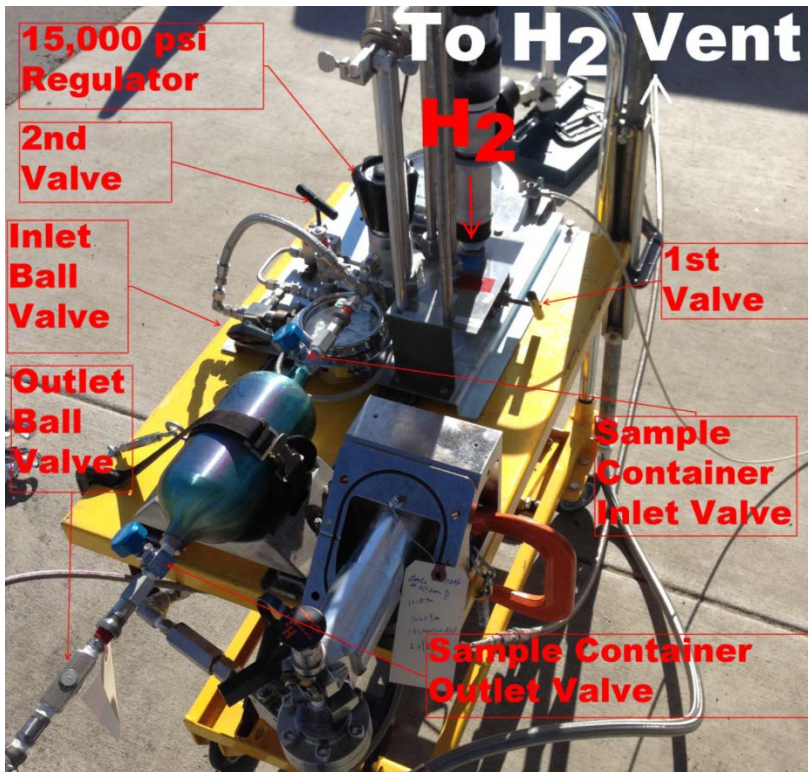
Accomplishment: Commissioned Station

- Air Products and NREL commissioned the station in February, 2015
- Full auto OEM station acceptance did not happen until October, 2015
 - Added a high pressure hydrogen vessel after APCI commissioning
 - NREL did not have a test skid available to perform shakedown fills with the station



Accomplishment: Hydrogen Quality

Station passed SAE J2719:
Hydrogen Fuel Quality for Fuel
Cell Vehicles



SAE J2719		SAE J2719 Limits (µmol/mol)	Smart Chemistry Detection Limits (µmol/mol)	H70	Concentration (µmol/mol)
Water		5	1		< 1
Total Hydrocarbons (C ₁ Basis)		2	1		0.13
	Methane		0.001		0.021
	Acetone				0.0081
	Ethene				0.012
	Ethanol				0.011
	Isopropyl Alcohol				0.024
	Propane				0.018
	2-Methyl 2-Propanol				0.04
Oxygen		5	2		< 2
Helium		300	10		< 10
Nitrogen, Argon		100			
	Nitrogen		2		62
	Argon		0.5		< 0.5
Carbon Dioxide		2	0.1		< 0.1
Carbon Monoxide		0.2	0.0005		0.0013
Total Sulfur		0.004	0.000001		0.0000070
	Hydrogen Sulfide		0.000002		0.0000035
	Carbonyl Sulfide		0.000001		0.0000017
	Methyl Mercaptan (MTM)		0.00002		< 0.00002
	Ethyl Mercaptan (ETM)		0.00002		< 0.00002
	Dimethyl Sulfide (DMS)		0.00002		< 0.00002
	Carbon Disulfide		0.000001		0.0000017
	Isopropyl Mercaptan (IPM)		0.00002		< 0.00002
	Tert-Butyl Mercaptan (TBM)		0.00002		< 0.00002
	n-Propyl Mercaptan		0.00002		< 0.00002
	n-Butyl Mercaptan		0.00002		< 0.00002
	Tetrahydrothiophene (THT)		0.00002		< 0.00002
Formaldehyde		0.01	0.001		< 0.001
Formic Acid		0.2	0.005		< 0.005
Ammonia		0.1	0.001		< 0.001
Total halogenates		0.05			0.010
	Chlorine		0.001		< 0.001
	Hydrogen Chloride		0.007		< 0.007
	Hydrogen Bromide		0.003		< 0.003
Organic Halides (32 compounds in red and bold listed in "Other Hydrocarbons")			0.001		0.010
Tetrachloro-hexafluorobutane					0.010
Particulate Concentration		1mg/kg			0.069 mg/kg
Particulates Found & Size (ASTM D7634-10) - Images of particulates found is in Table 1					
	Size	# Found	Size	# Found	
	0.03µm	1	0.09µm	1	
	0.1 µm	1	0.16µm	1	
All particulates are found in the center of the filter.					
Hydrogen Fuel Index					99.99381%
<small>The Hydrogen Fuel Index is the value obtained when the amount of aggregate impurities, as expressed as percent (mole/moles), is subtracted from 100%. (Section 3.5 of SAE J2719)</small>					

Accomplishment: Fuel Cell Vehicles

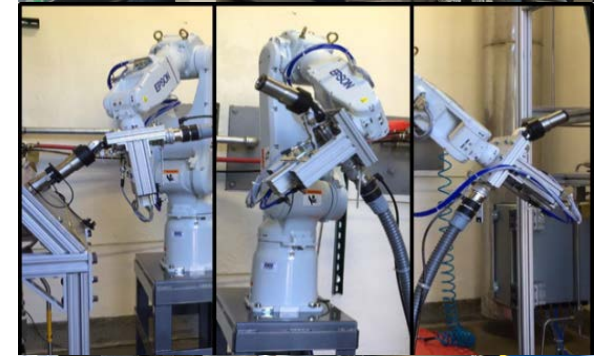
- NREL has 5 Fuel Cell Electric Vehicles onsite
 - Toyota Mirai
 - Hyundai Tucson
 - Mercedes Benz F-Cell
 - Toyota Highlander (2)
- NREL uses the vehicles for education, outreach, and VIP tours



Accomplishment: Supporting Research

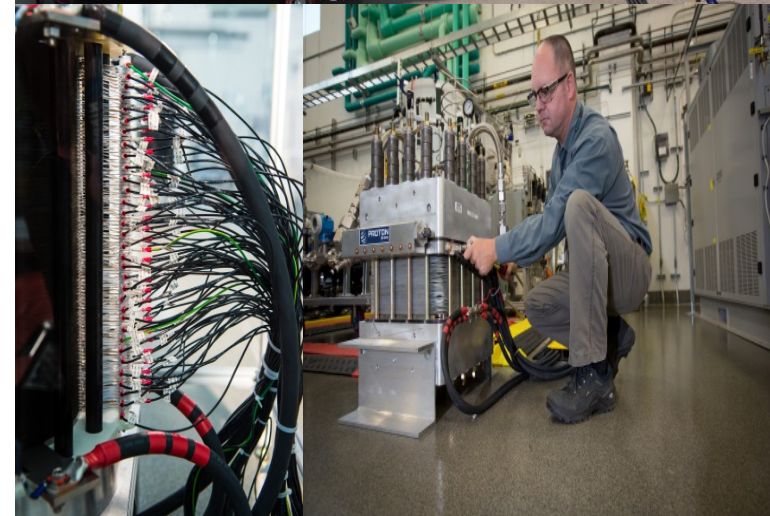
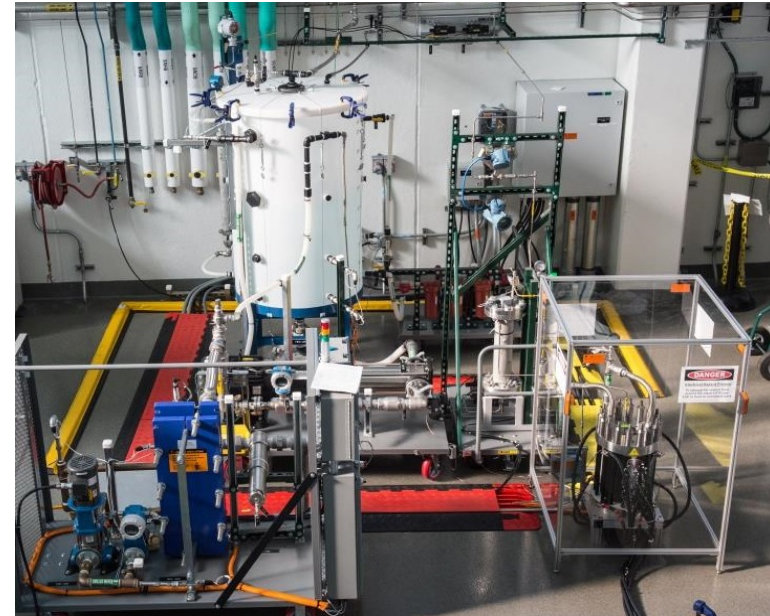
The hydrogen station supports numerous high pressure research projects

- H2FIRST
 - Consolidation
 - HySTEP
 - Meter Benchmarking
 - Hose Reliability
- Component Validation
- Renewable Electrolysis
- INTEGRATE

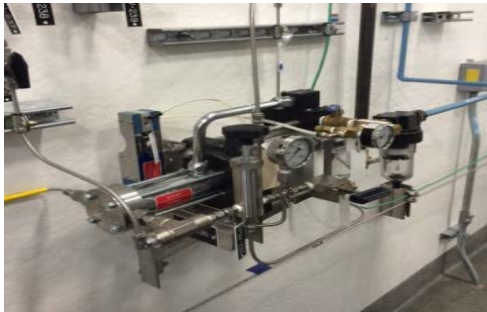


Accomplishment: Production

- **Onsite H₂ production – 50 kg/day**
 - Upgrade planned 2016
 - Double production capacity
 - Adding (2) 1000A power supplies
- Flexible platform for large active area stack testing
- **AC-DC power supplies capable of 4,000 Amp DC, 250 V DC**
- Stack and individual cell voltage measurements are taken to provide real time monitoring of stack and cell efficiency



Accomplishment: Compression



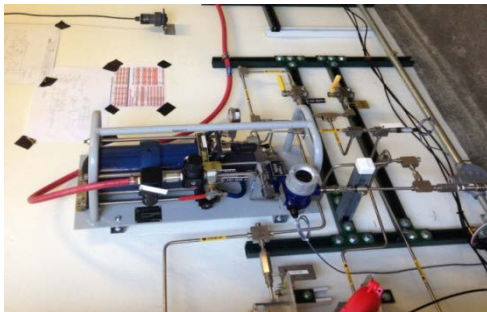
MaxPro – Low Pressure



PPI – Medium Pressure



Hydropac – High Pressure



HI – High Pressure

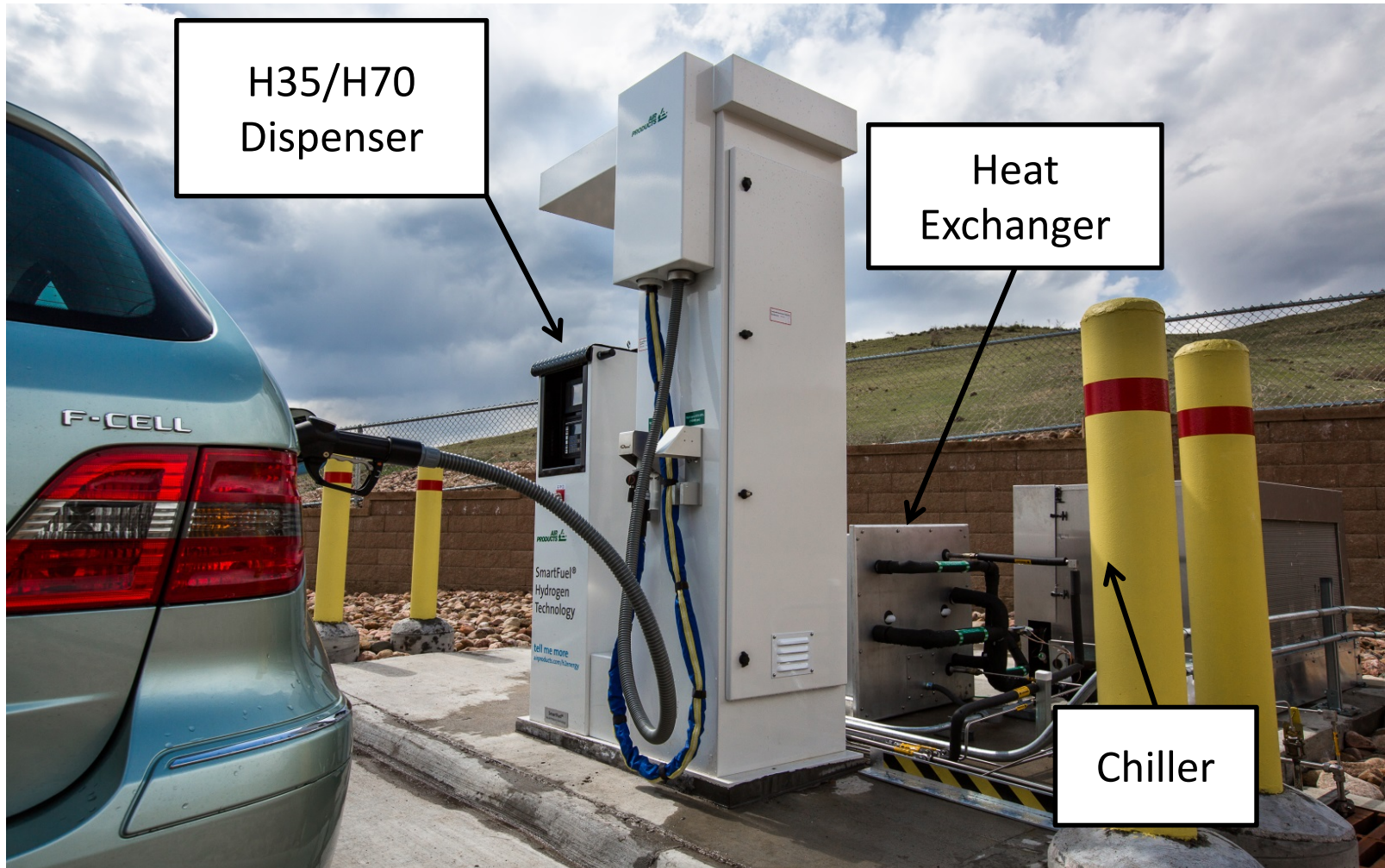
Parameter	MaxPro	PPI	HI	HYDRO PAC
Duty Cycle	As Needed	As Needed	As Needed	As Needed
Max Discharge Pressure (MPa)	20	40	138	96.5
Flow Rate (SCFM ¹)	3	18.8	5	140
Start of Operation	October 2014	December 2014	January 2015	Sept 2015

Accomplishment: Storage

- Low Pressure Storage
 - 330 kilograms at 20 MPa
 - Provides house hydrogen to fuel cell labs
 - Feeds medium pressure compressor
- Medium Pressure Storage
 - 110 kilograms at 40 MPa
 - Used for 35 MPa forklift fills and 70 MPa vehicle cascade fills
 - Feeds high pressure compressors
- High Pressure Storage
 - 60 kilograms at 85 MPa
 - Provides hydrogen to high pressure projects
 - Used for 70 MPa vehicle fills

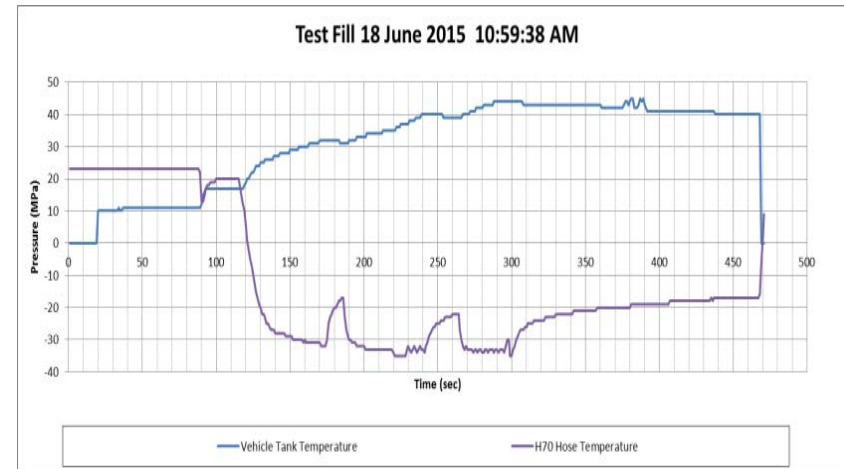
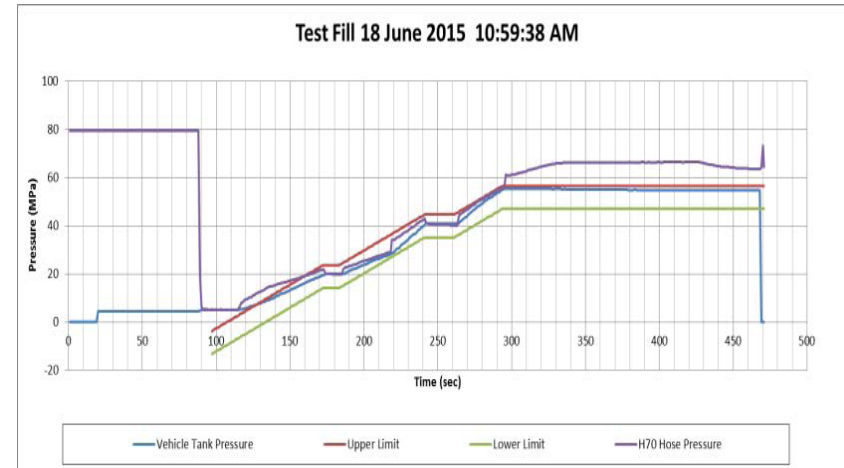


Accomplishment: Chilling and Dispensing



Accomplishment: Chilling and Dispensing

- Hydrogen dispenser, chiller, and heat exchanger provided by Air Products
- Dispenser is programmed to SAE J2601 2014 fueling protocol
- Currently working on MC Method upgrade
- Key parameters tracked
 - H70 Hose Pressure
 - H70 Hose Temperature
 - Cooling block temperature
 - Vehicle Pressure
 - Vehicle Temperature
 - Vehicle Volume



Responses to Reviewer Comments

This project was not reviewed last year.

Collaborations:

- Air Products
- Multiple other stakeholders have helped with the station commissioning and operation but some wish to remain anonymous, we have emails out to the stakeholders asking for permission to use their name in our poster

Challenges and Barriers

- Station downtime is an issue with hydrogen stations and NREL has seen these issues firsthand at their station
- NREL is actively working on how to engage research and industry more with their station.
- Findings from NREL's station need to be public knowledge and reported in places where people can easily find them
 - NREL is working with H2Tools to begin reporting station findings and issues that arise

Proposed Future Work

New projects already scheduled for the station

- Power to Gas (Collaboration with Southern California Gas)
- H₂ Liquefaction
- MC Method Testing

Plans for future projects

- Test new hydrogen fueling protocols
- Test new hydrogen chiller technologies

Summary

Relevance:

- Tracking hydrogen infrastructure performance NREL will inform DOE, federal and state governments, academia, and industry of issues and solutions to commonly observed problems at hydrogen stations.

Approach:

- Mimic current and future hydrogen stations by fueling FCEVs and simulated vehicles to report on hydrogen station performance
- Collect and report on every facet of a hydrogen station

Technical Accomplishments:

- Station Commissioning
- Passed Hydrogen Quality
- Fueling Hydrogen Fuel Cell Vehicles

Collaborations:

- Air Products

Proposed Future Research:

- Power to Gas (Collaboration with Southern California Gas)
- H₂ Liquefaction
- MC Method Testing

Technical Back-Up Slides

HITRF Layout

