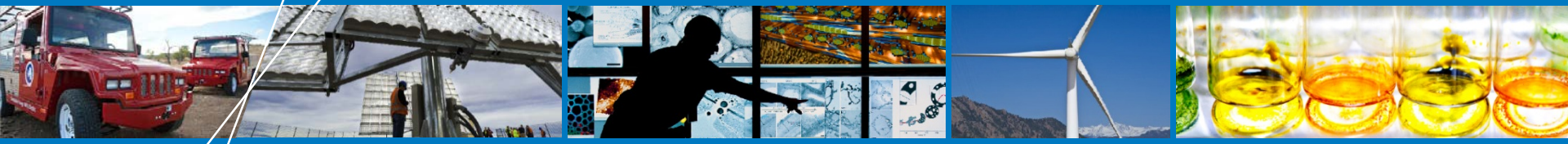
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

# Overview of an Integrated Research Facility for Advancing Hydrogen Infrastructure



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**National Renewable Energy Laboratory**

**DOE 2016 Annual Merit Review**

**June 7, 2016**

**Project ID: TV038**

This presentation does not contain any proprietary, confidential, or otherwise restricted information.

# 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.**

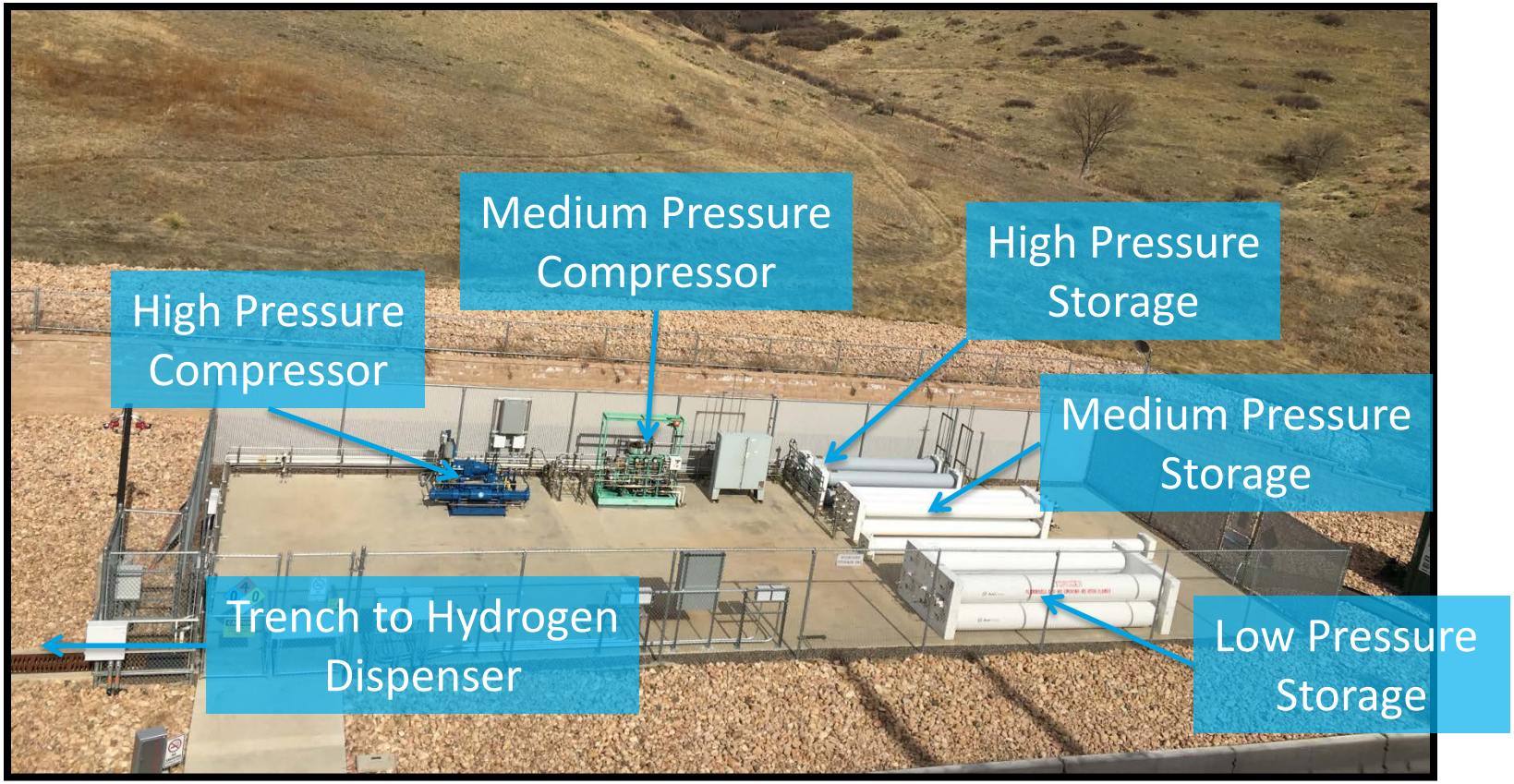
- The Hydrogen Infrastructure Testing and Research Facility, HITRF, encompasses all elements of a commercial gaseous hydrogen fueling station with on-site forecourt production
- The integrated system leverages NREL's research in production, compression, storage, and dispensing into a unified system capable 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

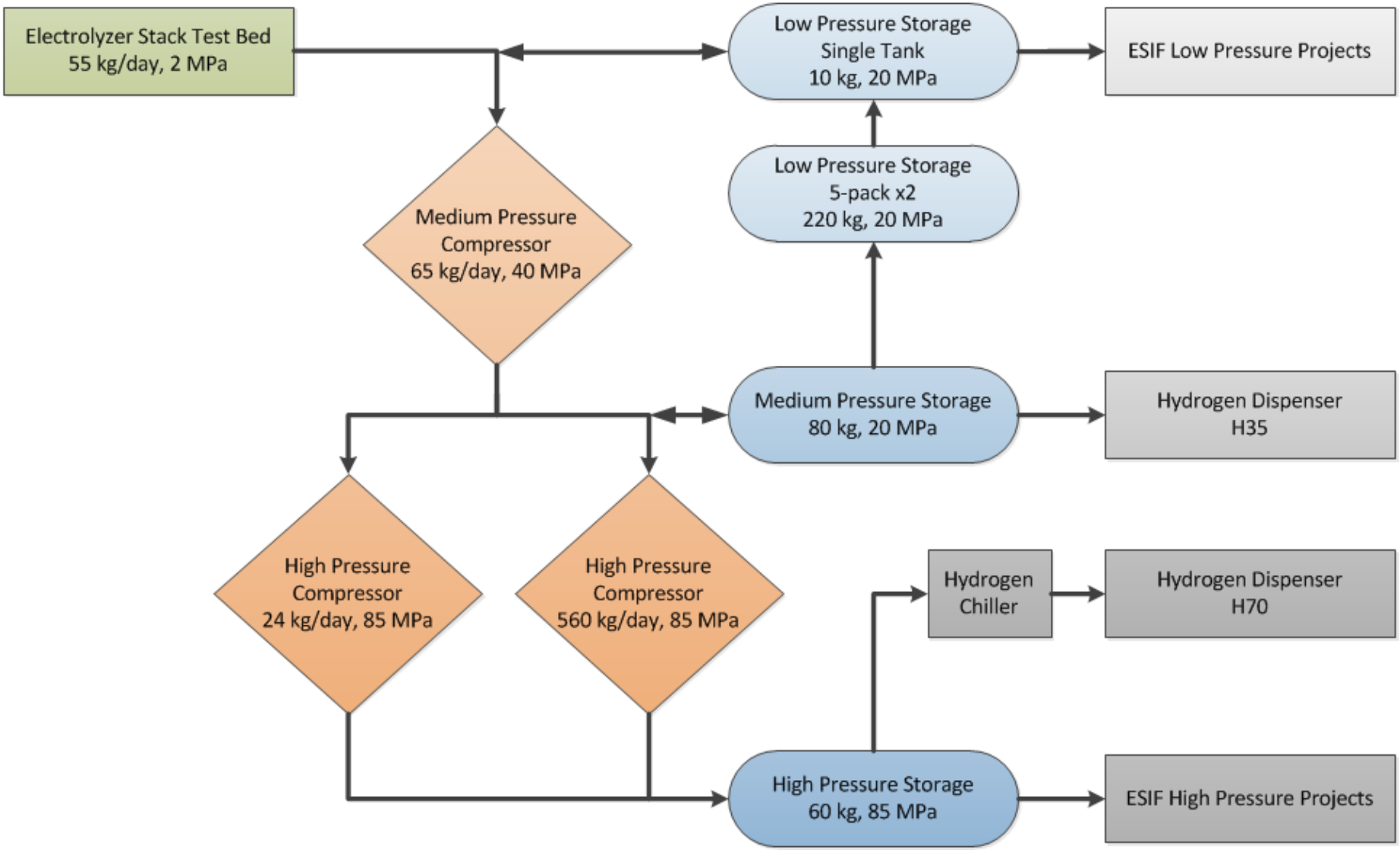
- **Mimic current and future hydrogen stations by fueling FCEVs and simulated vehicles to report on hydrogen station performance.**
- **Collect and report on every facet of a hydrogen station:**
  - System efficiency
  - Downtime
  - Maintenance cost/time
  - Capital cost
  - Lead times based on components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

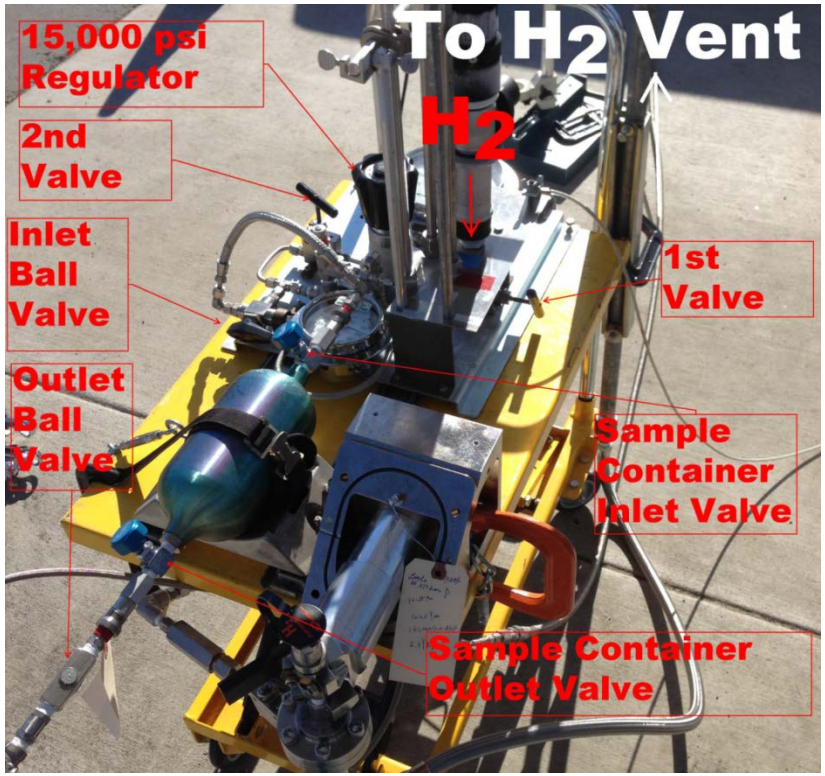


# Accomplishment: Commissioned Station

- 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** — **H70**

© Headquarter sampled on 2/5/2015

| | SAE J2719 Limits (µmol/mol) | Smart Chemistry Detection Limits (µmol/mol) | 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") Smart Chemistry limit is for each individual organic halide | | 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 |
|---|---|---|---|
| 0.03mm | 1 | 0.09mm | 1 |
| 0.1 mm | 1 | 0.16mm | 1 |

All particulates are found in the center of the filter.

**Hydrogen Fuel Index**

The hydrogen fuel index is the value obtained when the amount of aggregate impurities, as, expressed as percent (v/v/v/v/v), is subtracted from 100%. (Section 3.5 of SAE J2719)

99.99381%

# 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



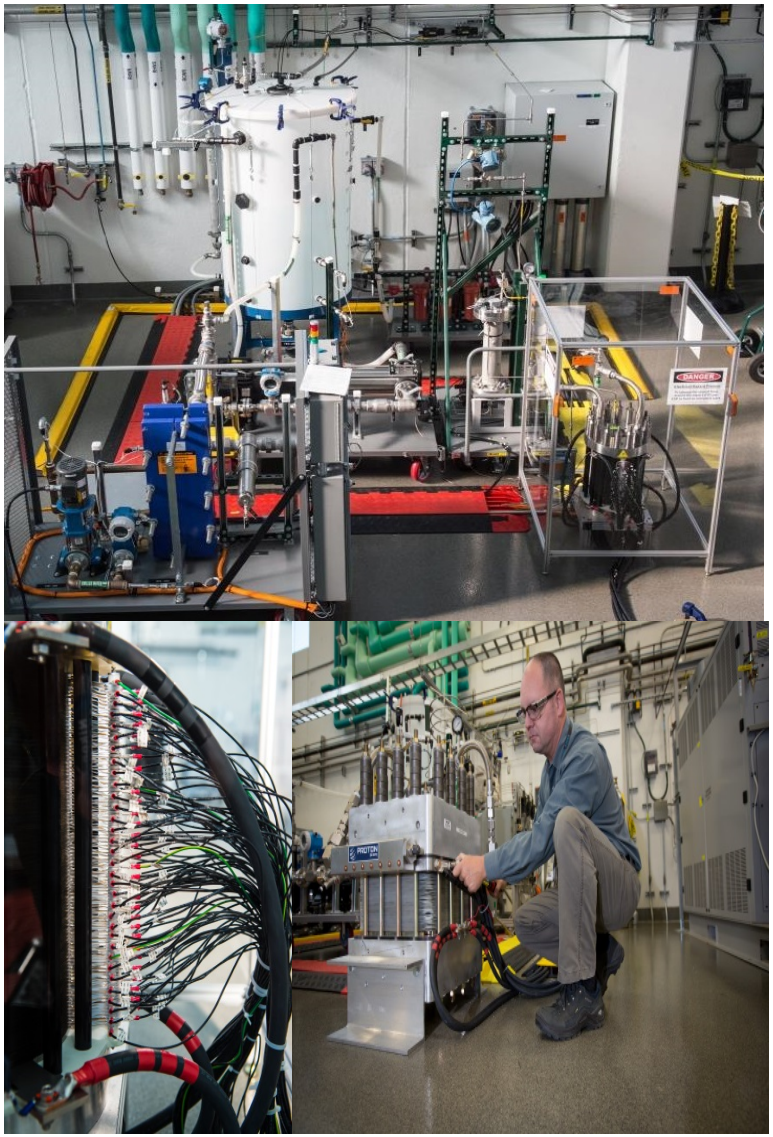
# Accomplishment: Supporting Research

***The hydrogen station supports numerous high pressure research projects***

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

# Accomplishment: Production

- **Onsite $H_2$ 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*

*HI – High Pressure*

*PPI – Medium Pressure*

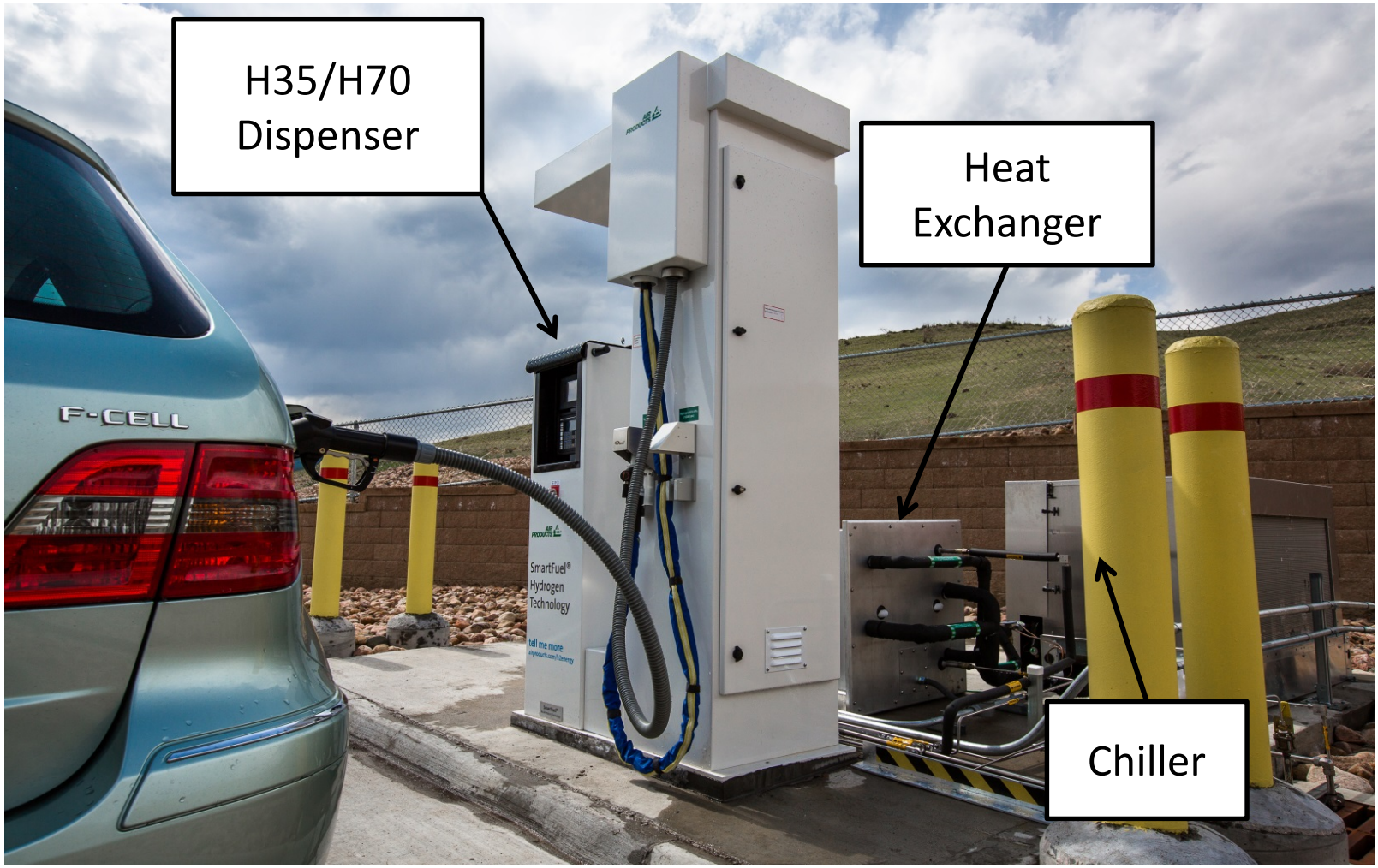
*Hydropac – High Pressure*

| 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

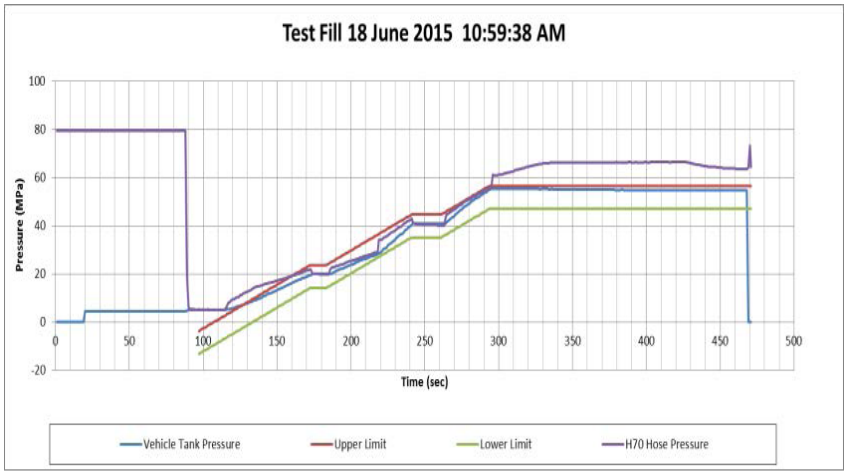
- Low Pressure Storage
  - 330 kilograms at 20 MPa
  - Provides house hydrogen to fuel cell labs
  - Feeds medium pressure compressor
- Medium Pressure Storage
  - 110 kilograms at 40 MPa
  - Used for 35 MPa forklift fills and 70 MPa vehicle cascade fills
  - Feeds high pressure compressors
- High Pressure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

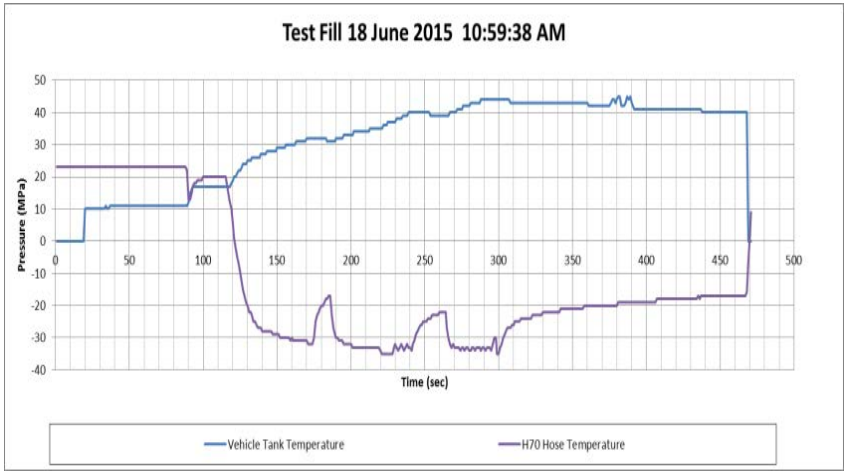
# Accomplishment: Chilling and Dispensing



# 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)
- $H_2$ 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)
- $H_2$ Liquefaction
- MC Method Testing

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# Technical Back-Up Slides

# HITRF Layout