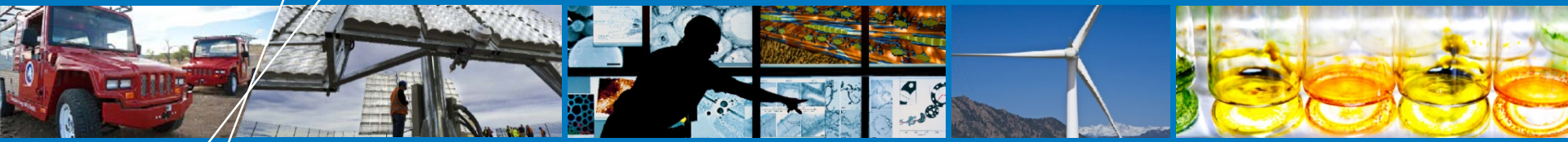
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Overview of an Integrated Research Facility for Advancing Hydrogen Infrastructure



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National Renewable Energy Laboratory

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June 7, 2017

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

Partners

- Proton OnSite
- Giner Inc.
- PDC Machines Inc.
- H2FIRST

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**

Budget

Total Budget: N/A

Project Objective & Relevance

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.

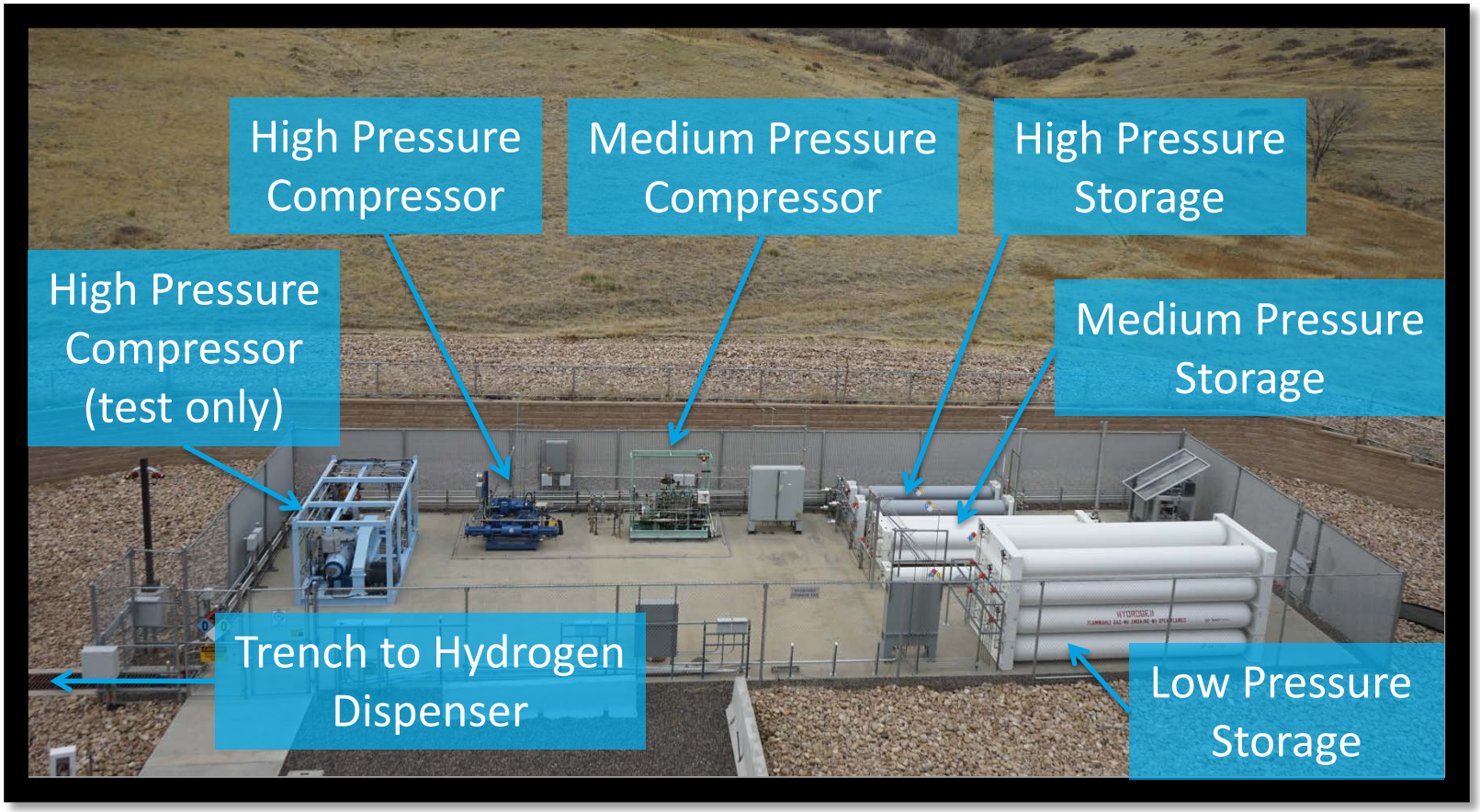
- **The Hydrogen Infrastructure Testing and Research Facility, HITRF, encompasses all elements of a commercial gaseous hydrogen fueling station with on-site forecourt production**
- **The integrated system leverages NREL's research in production, compression, storage, and dispensing into a unified system capable of fueling fuel cell electric vehicles and fuel cell forklifts**
- **Station is utilized to help achieve H2FIRST objective to ensure that the fuel cell electric vehicle customers have a positive fueling experience similar to conventional gasoline/diesel stations.**

Approach: Operation and Data Collection

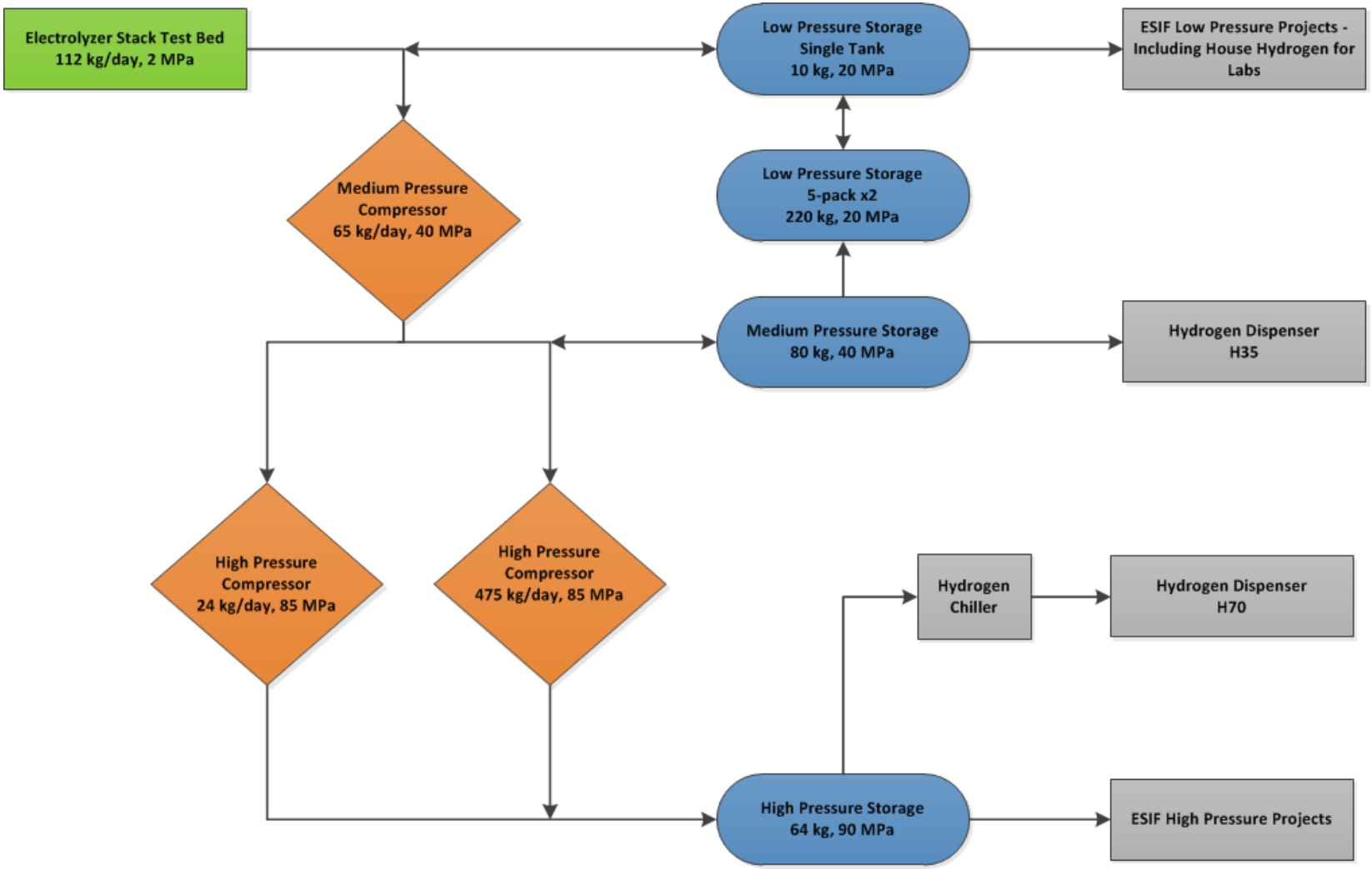
- **Mimic current and future hydrogen stations by fueling FCEVs and simulated vehicles to report on hydrogen station performance.**
- **Collect and report on every facet of a hydrogen station:**
  - System efficiency, downtime, maintenance cost/time, capital cost, lead times based on components, system integration, safety, controls
- **Engage industry on findings and work together on solutions**

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

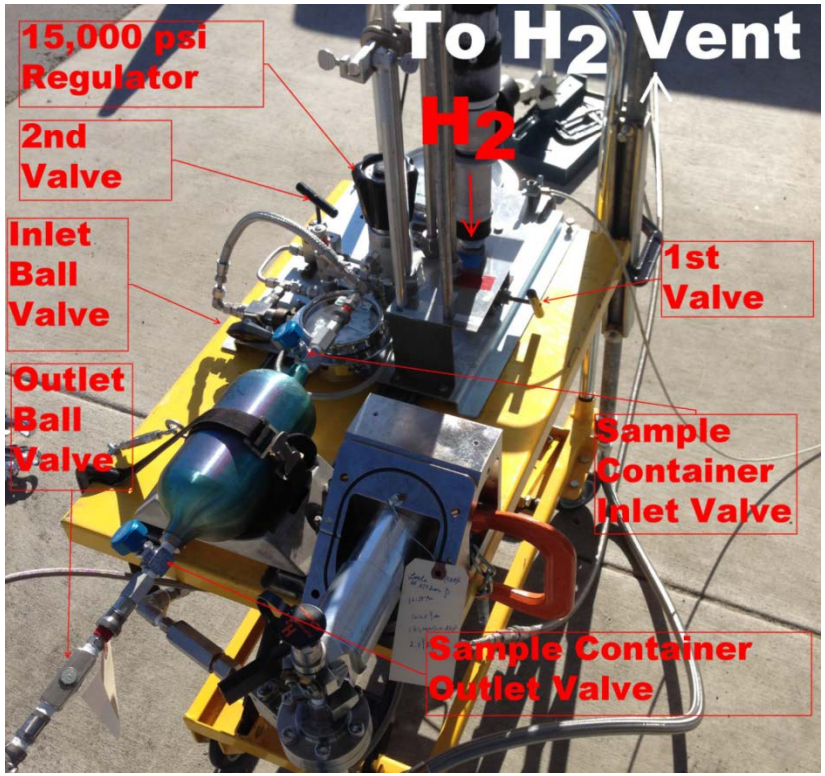


Approach: Station Flow Diagram



Accomplishment: Hydrogen Quality

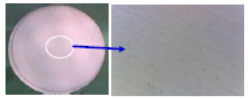
Station passed SAE J2719: Hydrogen Fuel Quality for Fuel Cell Vehicles



SAE J2719	SAE J2719 Limits (µmol/mol)	Smart Chemistry Detection Limits (µmol/mol)	H70 H2 @Nozzle sampled on 06/30/2016 Concentration (µmol/mol)	Analytical Method
Water	5	1	< 1	
Total Hydrocarbons (C_1 Basis)	2		**0.043**	ASTM D7892
Methane			0.013	
Acetone			0.024	
Isopropyl Alcohol			0.0063	
Oxygen	5	1	< 1	ASTM D7649
Helium	300	10	< 10	ASTM D1946
Nitrogen, Argon	100			
Nitrogen		5	**5.1**	ASTM D7649
Argon		0.4	< 0.4	ASTM D7649
Carbon Dioxide	2	0.1	< 0.1	ASTM D7649
Carbon Monoxide	0.2	0.0005	**0.0015**	ASTM D5466
Total Sulfur	0.004	0.000001	**0.000074**	ASTM D7652
Hydrogen Sulfide		0.000001	0.000023	ASTM D7652
Carbonyl Sulfide		0.000001	0.000047	ASTM D7652
Methyl Mercaptan (MTM)		0.00001	< 0.00001	ASTM D7652
Ethyl Mercaptan (ETM)		0.00001	< 0.00001	ASTM D7652
Dimethyl Sulfide (DMS)		0.00001	< 0.00001	ASTM D7652
Carbon Disulfide		0.000002	0.0000037	ASTM D7652
Isopropyl Mercaptan (IPM)		0.00001	< 0.00001	ASTM D7652
Tert-Butyl Mercaptan (TBM)		0.00001	< 0.00001	ASTM D7652
n-Propyl Mercaptan		0.00001	< 0.00001	ASTM D7652
n-Butyl Mercaptan		0.00001	< 0.00001	ASTM D7652
Tetrahydrothiophene (THT)		0.00001	< 0.00001	ASTM D7652
Formaldehyde	0.01	0.001	< 0.001	ASTM D7892
Formic Acid	0.2	0.001	< 0.001	ASTM D5466
Ammonia	0.1	0.01	< 0.01	ASTM D5466
Total halogenates	0.05			
Chlorine		0.001	< 0.001	ASTM D5466
Hydrogen Chloride		0.003	< 0.003	ASTM D5466
Hydrogen Bromide		0.001	< 0.001	ASTM D5466
Organic Halides (32 compounds in red and bold listed in "Other Hydrocarbons"). Both Smart Chemistry and method limits is for each individual organic halide.		0.001	< 0.001	ASTM D7892

Particulate Concentration - ASTM D7651

Particulates Found & Size - ASTM D7634



0.51 mg/kg

There are total 39 particulates found with the sizes in micrometer: 106, 97, 93, 84, 78, 70, 70, 70, 67, 66, 64, 63, 62, 59, 57, 55, 55, 53, 51, 51, 49, 49, 49, 49, 47, 46, 46, 45, 43, 43, 39, 39, 33, 29, 29, 28, 25, 20, 16.

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

99.99949%

Accomplishment: Fuel Cell Vehicles

- NREL has 2 Fuel Cell Electric Vehicles onsite
  - Toyota Mirai
  - Hyundai Tucson
- NREL uses the vehicles for education, outreach, and VIP tours

Accomplishment: Supporting Research

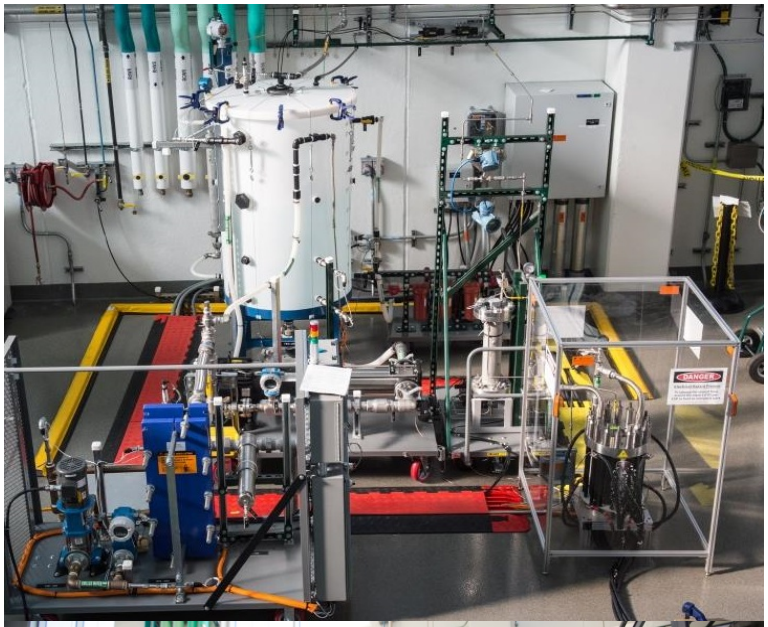
HITRF supports numerous high pressure research projects

- H2FIRST
  - Consolidation (**FY16 AMR PD133)**
  - HySTEP
  - Meter Benchmarking **(FY16 AMR TV037)**
  - Hose Reliability **(FY16 AMR PD100)**
- Component Validation **(FY16 AMR TV019)**
- Renewable Electrolysis **(FY16 AMR PD031)**
- INTEGRATE – Electrolyzers for use in grid applications (**FY16 AMR TV031)**
- Hydrogen Contaminant Detection (HCD)

Top: Vehicle Simulator (5 vehicles) Bottom: H2FIRST Testing

Accomplishment: Electrolysis Production

- Onsite H_2 production – 112 kg/day
- Flexible platform for large active area stack balance-of-plant testing
- AC-DC power supplies capable of 4,000 A DC, 250 V DC
- Real time monitoring of stack and cell efficiency through stack and individual cell voltage measurements
- Electrolyzer and power supply hardware-in-the-loop testing capabilities with millisecond time step and remote grid simulation



Accomplishment: Compression

Hydro Pac – Upgraded high pressure compression capabilities to 18 kg/hr

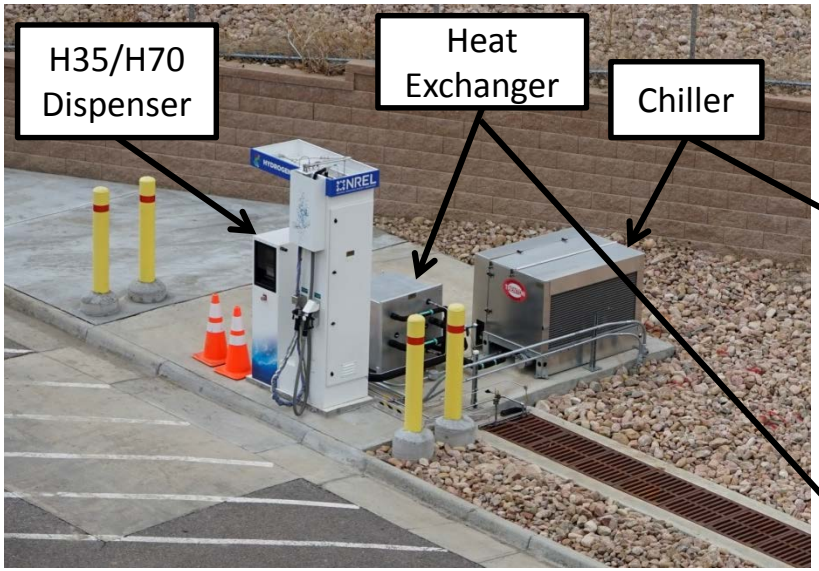
*PDC – New compression capabilities to support Consolidation **PD133***

Parameter	HYDRO PAC	PDC
Max Discharge Pressure (MPa)	96.5	90
Flow Rate (kg/hr)	18	45.4
Start of Operation	Sept 2016	April 2017

Accomplishment: Storage

- Low Pressure Storage
  - 200 kilograms total at 20 MPa
    - 100 kilograms added in 2017
  - Provides house hydrogen to fuel cell lab experiments
  - Feeds medium pressure compressor
  - Supports consolidation testing
- Medium Pressure Storage
  - 80 kilograms at 40 MPa
  - Used for 35 MPa forklift fills and 70 MPa vehicle cascade fills
  - Feeds high pressure compressors
- High Pressure Storage
  - 64 kilograms at 90 MPa
  - Used for 70 MPa vehicle fills, hose validation, dispenser component testing, and high pressure test bay experiments

Accomplishment: Chilling and Dispensing



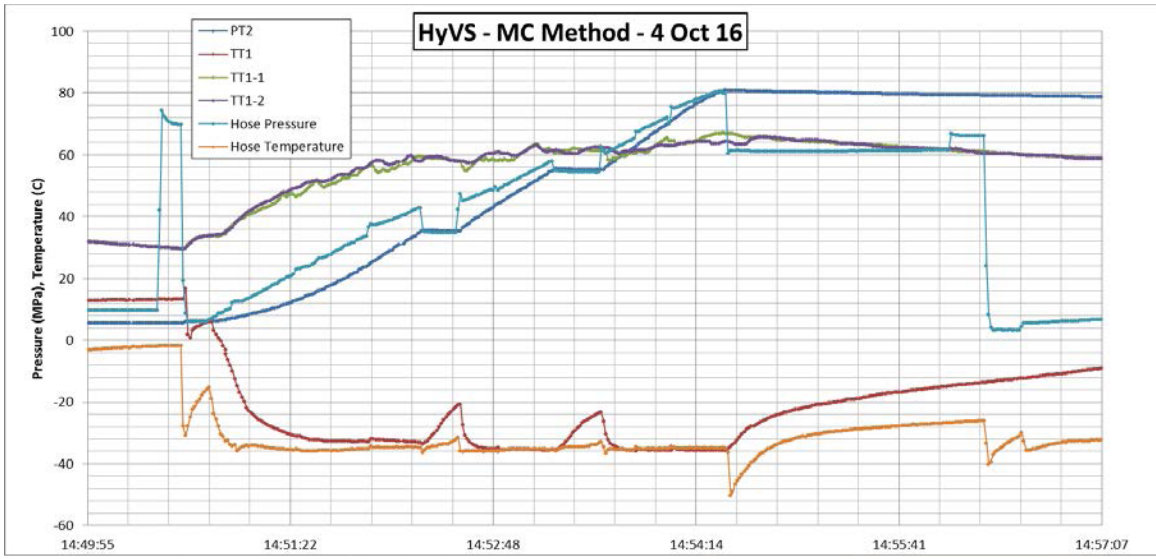
2016 - Dispenser, chiller, and heat exchanger

Upgraded to 12 kW chiller and triple block heat exchanger provided by Air Products

2017 - Dispenser with new chiller and triple block heat exchanger

Accomplishment: Chilling and Dispensing

- Dispenser is programmed to SAE J2601-2014 table based fueling protocol
- MC Formula capable
- Completed Metering Testing
- Initiated particulate contamination study
- Vehicle Simulator (HyVS) completed
- Key parameters tracked
  - H70 Hose Pressure
  - H70 Hose Temperature
  - Cooling Block Temperature
  - Vehicle Tank Pressure
  - Vehicle Tank Temperature
  - Vehicle Tank Volume



Responses to Reviewer Comments

This project was not reviewed last year.

Collaborations:

- Proton OnSite
- Giner Inc.
- PDC Machines Inc.
- H2FIRST

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 the NREL hydrogen fueling 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 – Vortex Tube
- MC Formula Testing
- Tube trailer consolidation model verification

Plans for future projects

- Test new hydrogen chiller technologies

Any proposed future work is subject to change based on funding levels.

Summary

Relevance:

- Experiencing 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 Upgrades
- Fueling Hydrogen Fuel Cell Vehicles

Collaborations:

- Proton OnSite, Giner Inc., PDC Machines Inc., H2FIRST

Proposed Future Research:

- Power to Gas (Collaboration with Southern California Gas)
- H_2 Liquefaction – Vortex tube
- MC Formula Testing

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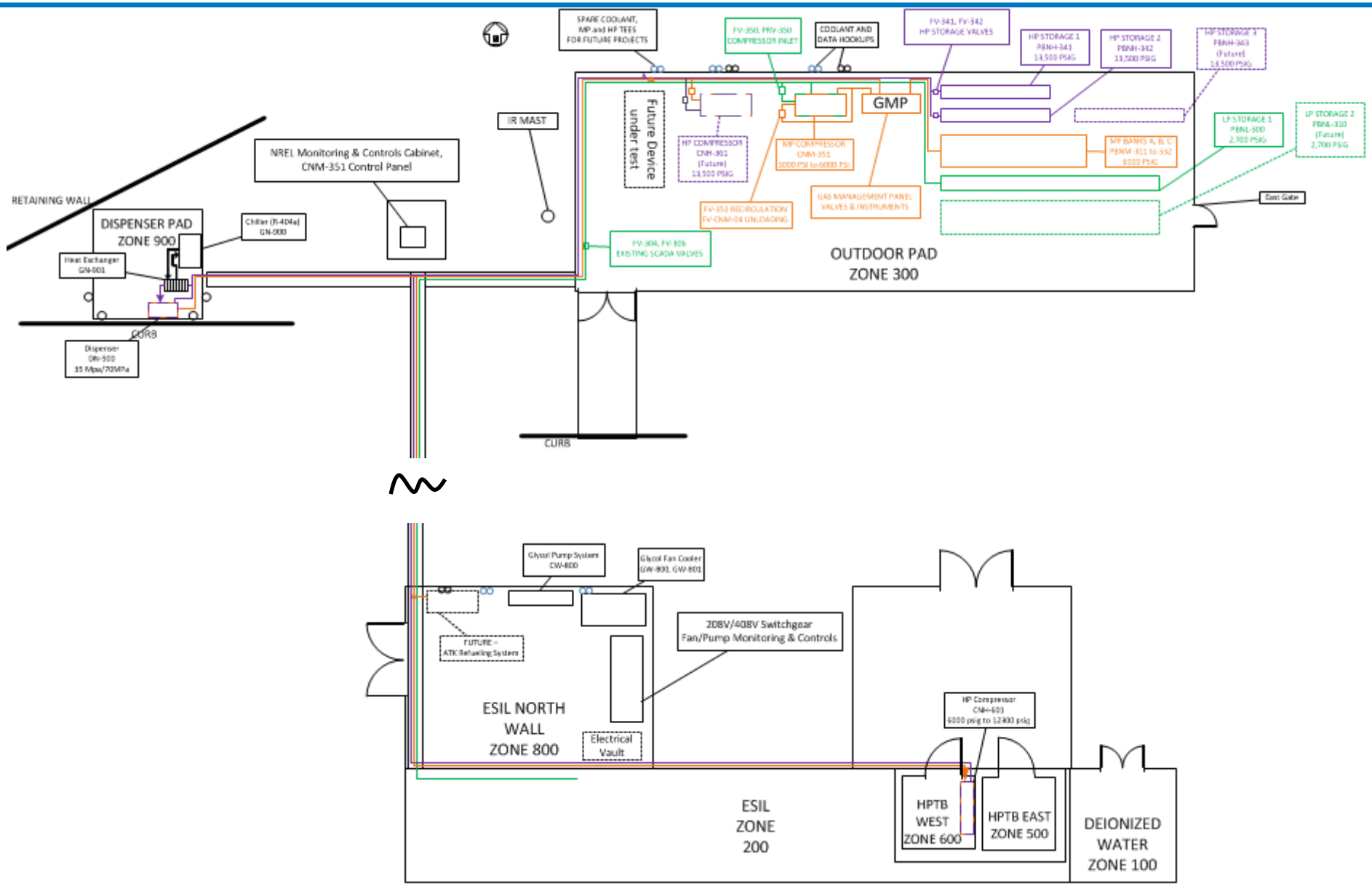
Technical Back-Up Slides

HITRF Layout