Hydrogen Fueling Infrastructure Research and Station Technology

Development of the Hydrogen Station Equipment Performance (HyStEP) Device

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Project ID # TV026

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Overview

Timeline

- Task Start Date: 08/22/2014
- Task End Date: 03/31/2016
- Percent Complete: 100%

Budget

- Total Task Budget: $1.145M
  - DOE Share: $1.093M
  - Cost Share: $ 52K
    - Air Liquide ($11.3K)
    - Toyota ($11.3K)
    - CARB ($21.5K)
    - Boyd Hydrogen ($7.5K)
- DOE Funds Received To-date: $1.093M

Barriers – Technology Validation

D. Lack of Hydrogen Refueling Infrastructure Performance and Availability Data

E. Codes and Standards

Partners

- Lead: Sandia National Laboratories
- National Renewable Energy Laboratory
- Air Liquide
- Boyd Hydrogen
- CA Air Resources Board
- Toyota

Relevance: HyStEP Device will shorten lengthy station acceptance process

Main Objective – *Accelerate commercial hydrogen station acceptance by developing and validating a prototype device to measure hydrogen dispenser performance.*

Fill safely: Common goal of vehicle manufacturers, consumers, station operators, and state stakeholders

Follow standards:

- SAE J2601-2014 (fueling protocol), specifies how to fill hydrogen vehicles safely.
- CSA HGV 4.3 (test method), defines how to test dispensers for compliance with SAE J2601.

Test stations: HyStEP Device will be capable of testing to the CSA HGV 4.3 test methods.

Today's Problem: Each OEM performs vehicle test fills to validate station

Tomorrow's Solution: HyStEP acts as FCEV surrogate; operated by testing agency

Approach: HyStEP, the Hydrogen Station Equipment Performance Device

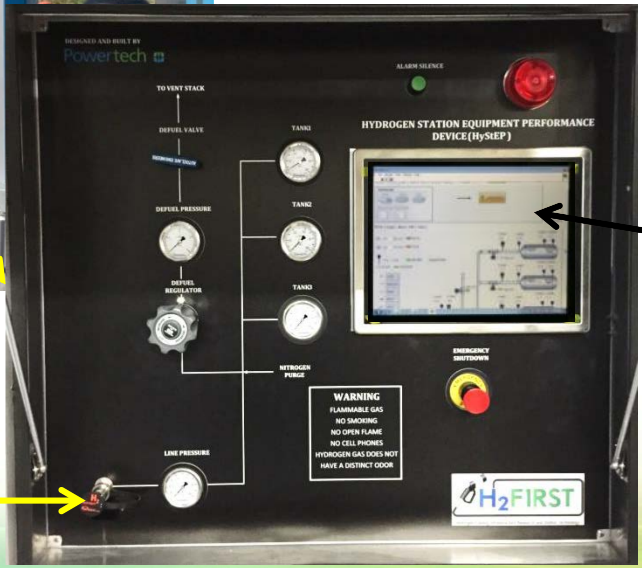
Key Features:

Three 76L Type IV tanks (3.1 kg H2 capacity each)

IrDA communications

70 MPa receptacle

Tanks and receptacle instrumented with P and T sensors



Approach: Safety and Performance Validation

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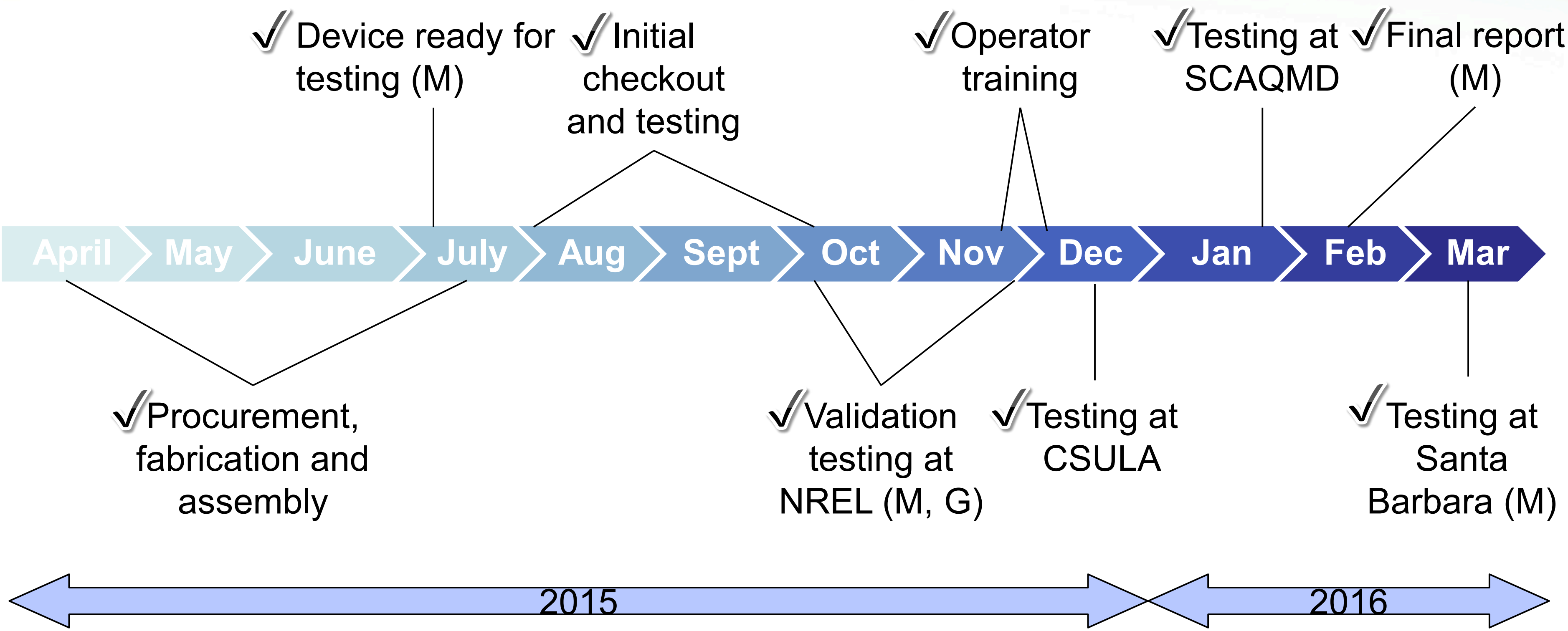
Safety

- Safety features by design:
  - Emergency Shutdown System activated by hardware, software or the operator
  - Pressure relief valves and devices
  - H_2 detection
  - Class 1 Zone 2 electrical
  - Grounding connection
- Facilitated HA/FMEA will be carried out by Powertech and Project Team
- Final design review by Project Team
- H2 Safety Panel review
- Onsite visit to Powertech for initial acceptance testing
- Testing at NREL's ESIF facility
  - Training and technical support from Powertech

Performance

- At Powertech:
  - Control and DAQ communications
  - IrDA operation
  - Leak checks and proof test of the pressure components
  - Automated procedures
- NREL-ESIF: Device validation testing
  - H70-T40 research dispenser
  - All required tests will be carried out and verified per CSA HGV 4.3.
  - Measured and calculated parameters checked for completeness and accuracy.
- Pre-deployment station testing in CA
  - Hydrogen Research/Fueling Facility at California State University Los Angeles
  - Diamond Bar station at SCAQMD headquarters

Approach: Project milestones completed



M = Milestone; G = Go/No-Go Decision

Accomplishments: HySTEP Device fabrication completed

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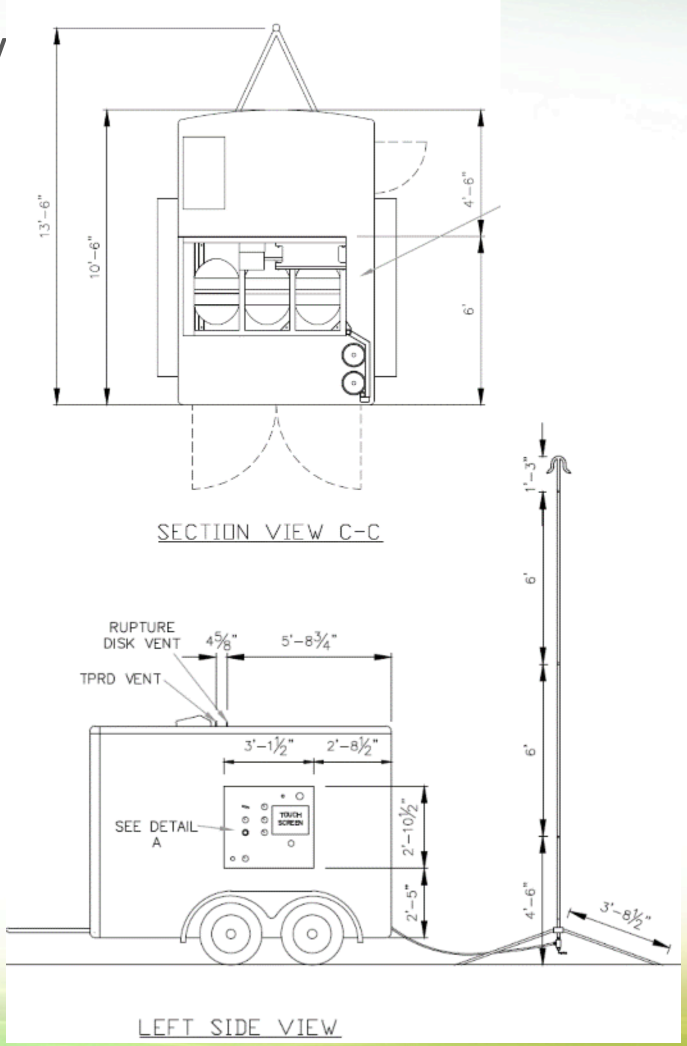
A trailer-based system was chosen based on Powertech's experience

Trailer pros:

- Protection from the environment/weather
- Easy to hand off to various end-users
- Allows for isolation of hazardous location
- Easy access to controls/user interface
- Doesn't require a dedicated vehicle
- Better access to system for maintenance

Trailer lay



Accomplishments: HyStEP Device fabrication completed

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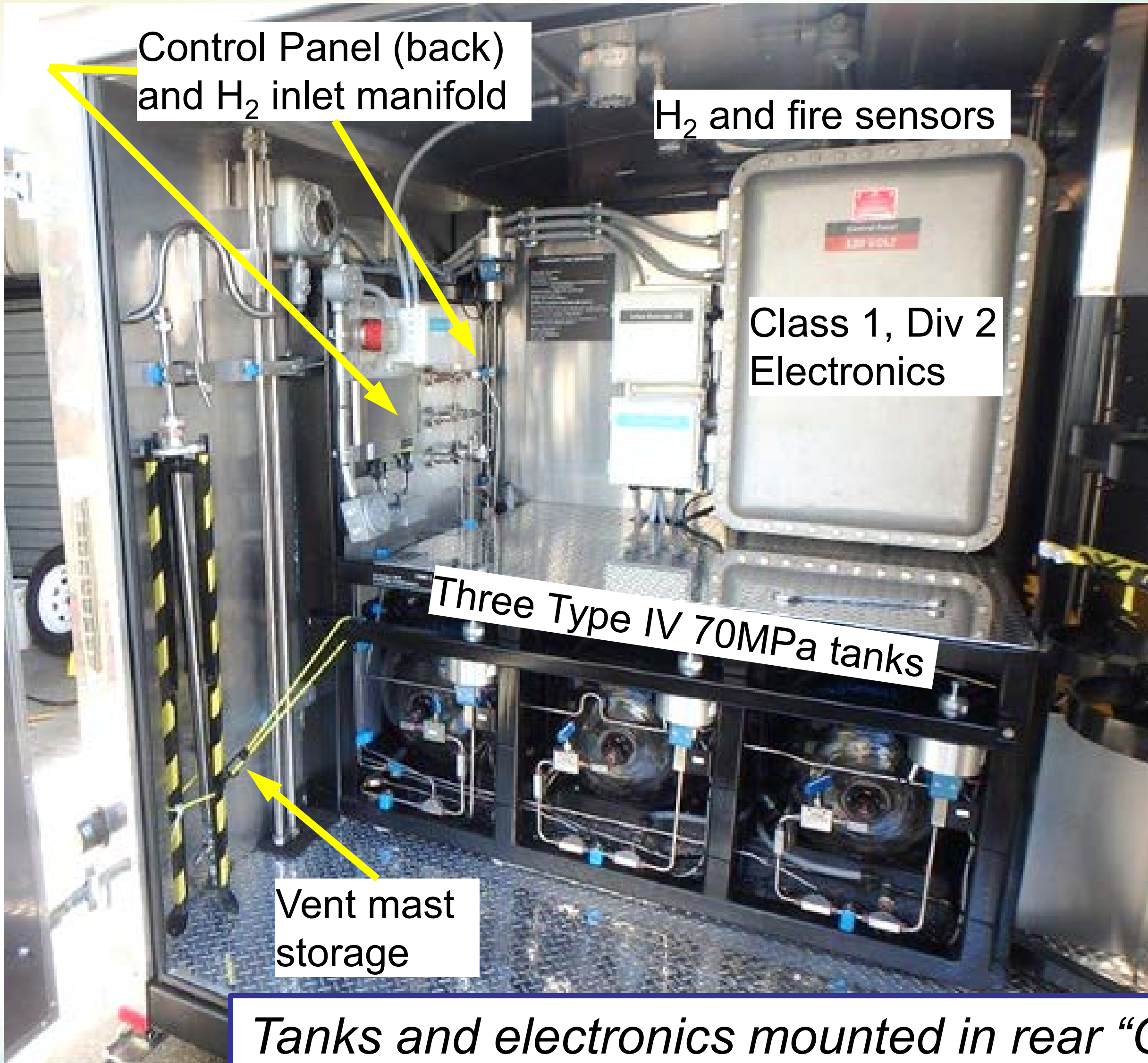
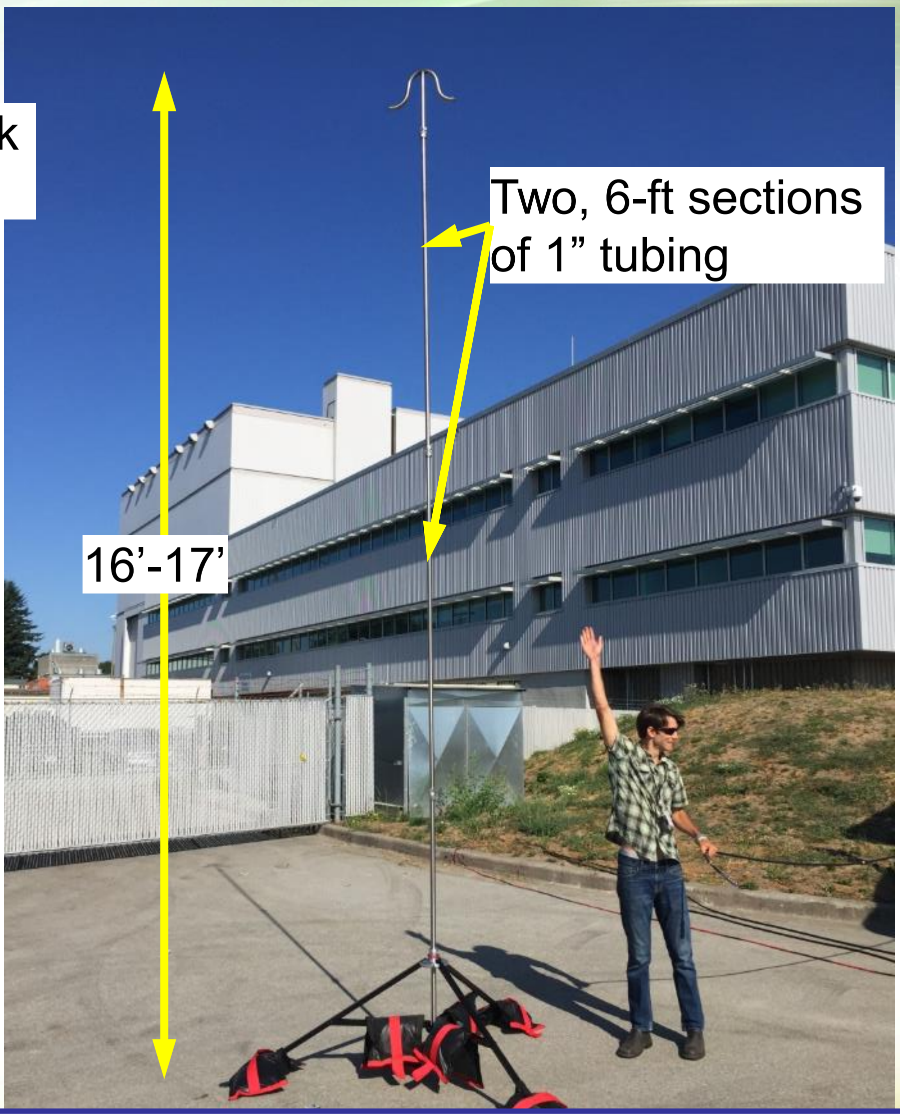


Tanks and electronics mounted in rear "Gas Room"

Accomplishments: HyStEP Device fabrication completed



Remote vent stack is easy to set up and very stable; stores in Gas Room

Accomplishments: HyStEP Device safety, control and data acquisition system completed

Fueling Tab

Defueling Tab

N2 Purge Tab

Tabs for viewing data and alarm status and sending IR signals manually

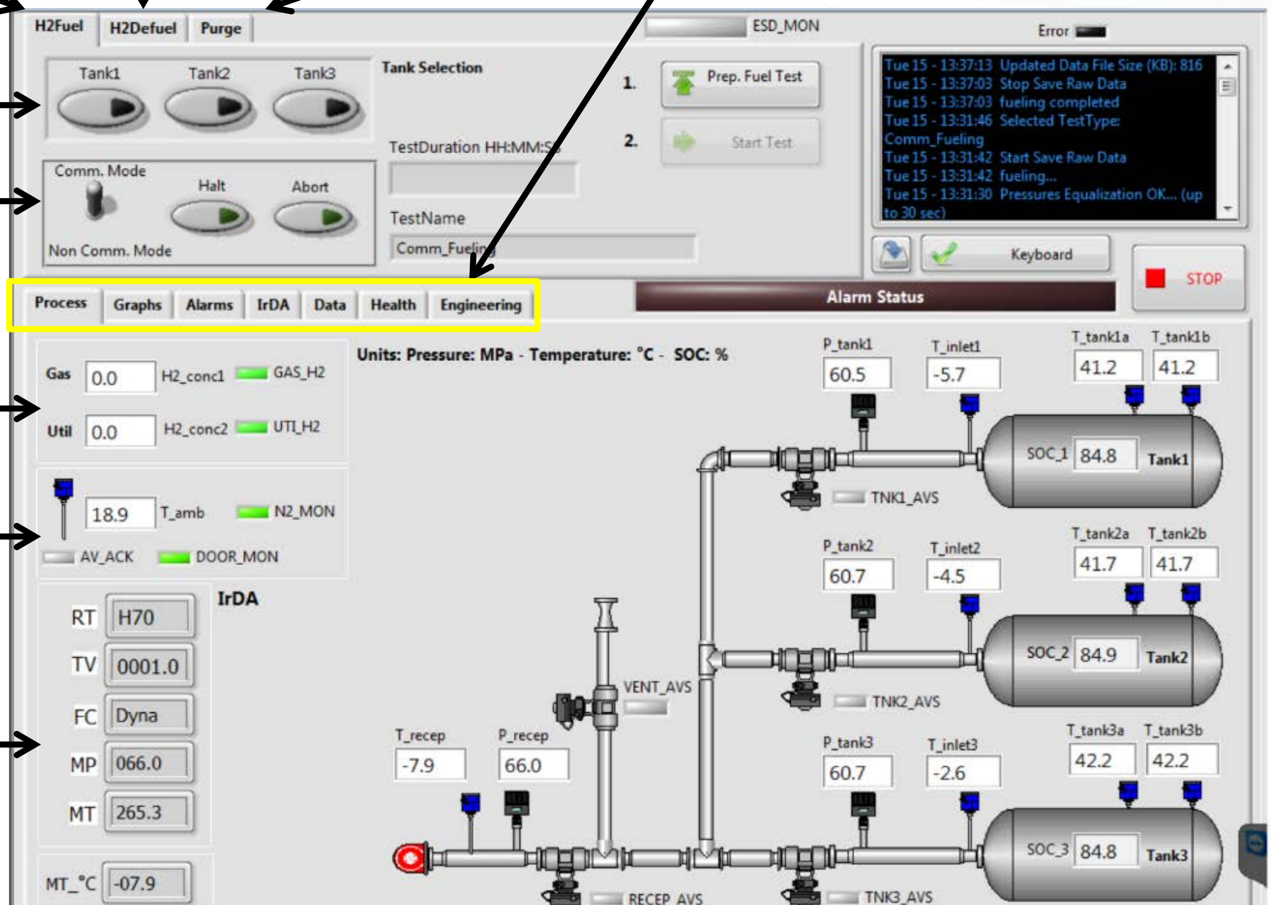
Tank selection

Comm mode; Halt and Abort Commands

H_2 Detectors

Ambient temp; Alarms

Transmitted IR signal



Piping and instrumentation diagram:

- Receptacle P & T
- Valve status
- Tank inlet P & T
- Internal tank gas T
- SOC

HyStEP operator uses the touchscreen control panel to carry out tests

Accomplishments: HyStEP Device safety, control and data acquisition system completed

Enable override of individual signals

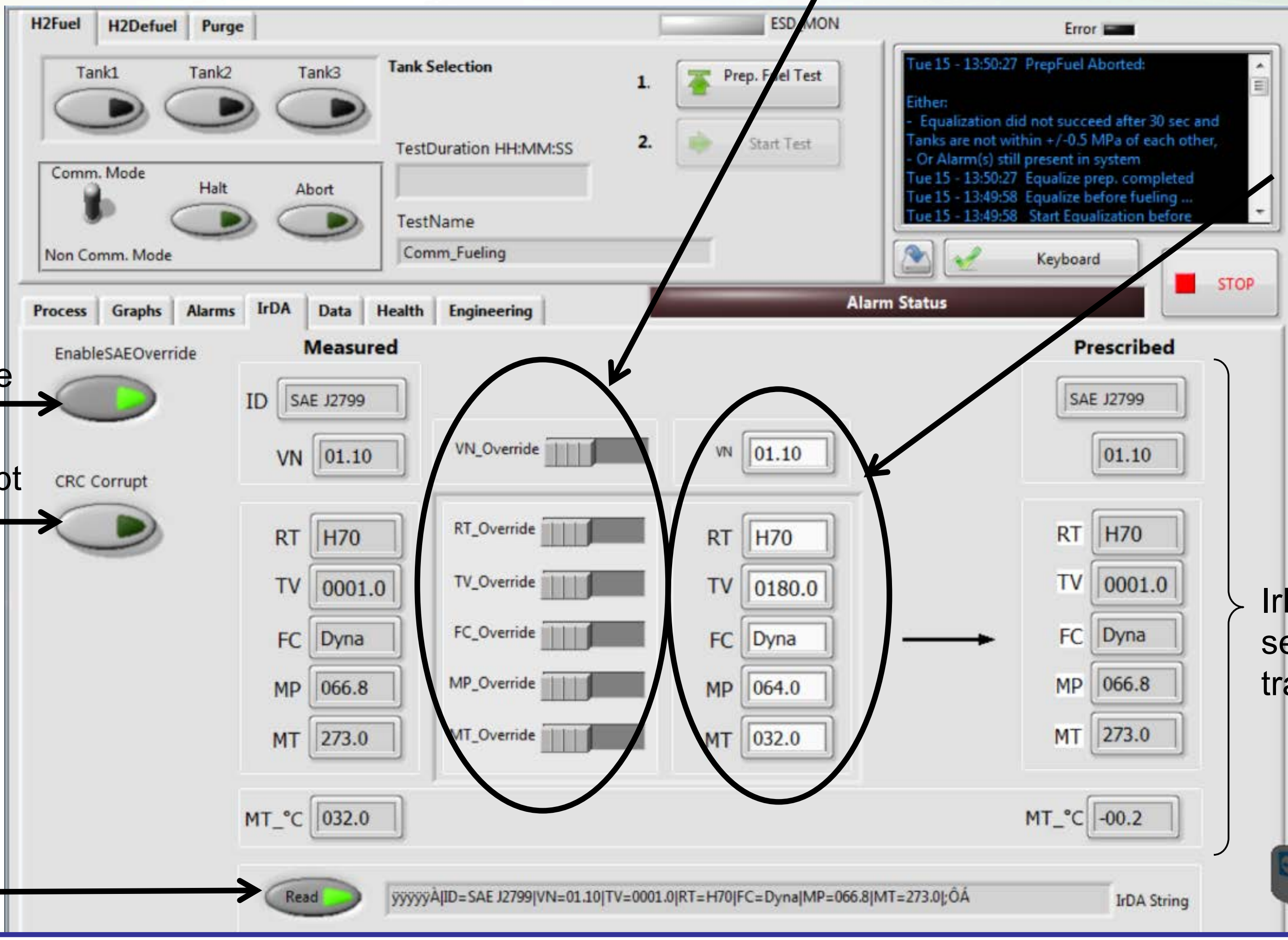
Enter override values

Enable override of IrDA signal

Simulate corrupt CRC string

IrDA parameters sent by the transmitter

Display the IrDA string



IrDA tab is used for fault detection and communication tests

Accomplishments: HyStEP Device performance validated at three hydrogen stations

Diamond Bar station at SCAQMD headquarters

NREL's Hydrogen Infrastructure Testing and Research Facility

Hydrogen Research/Fueling Facility at California State University Los Angeles

Accomplishments: HyStEP Device performance validated at three hydrogen stations

NREL HITRF

- Instrument/sensor accuracy
- 5 Fault Detection tests
- 20 Communication tests (repeats)
- 3 H70-T40 non-comm fills (1, 2, and 3 tanks)
- 6 H70-T40 comm fills (1, 2, and 3 tanks)

CSULA

- 6 Fault Detection tests
- 9 Communication tests
- 2 B-70 non-comm fills (1 tank)
- 3 B-70 comm fills (1, 2, and 3 tanks)
- 3 No Fueling tests

SCAQMD

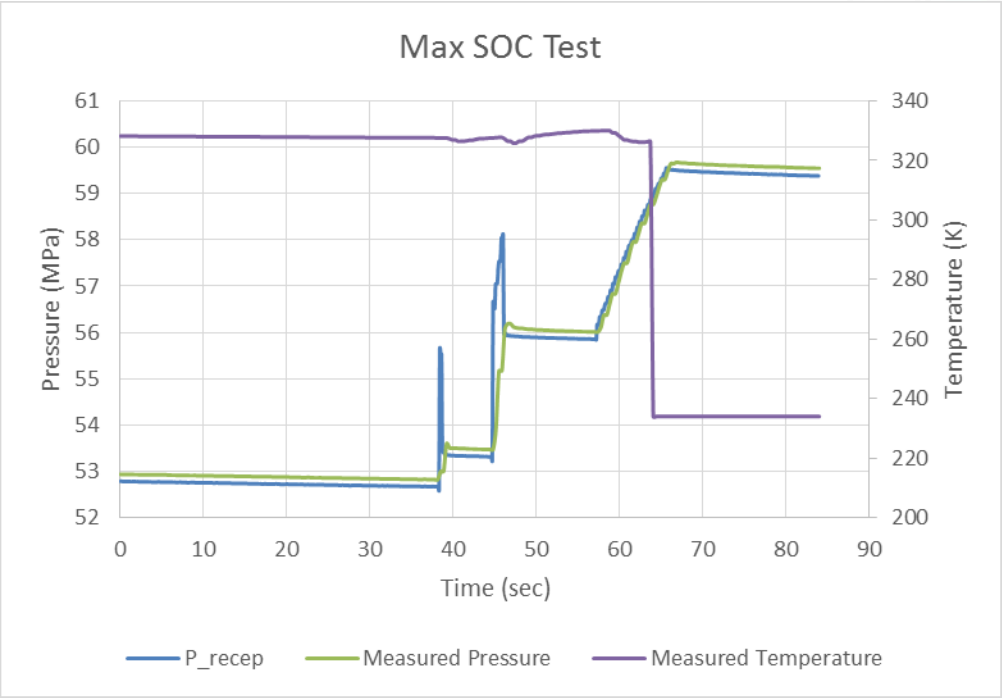
- 6 Fault Detection tests
- 9 Communications tests
- 6 non-comm fills
  - 3 H35-T20 (2 and 3 tanks)
  - 3 H70-T40 (1, 2, and 3 tanks)
- 11 H70-T40 comm fills (1, 2, and 3 tanks)
  - 4 fill tests were side-by-side comparisons to FCEVs
- 3 No Fueling tests

Validation tests included more than 30 fills

Accomplishments: HyStEP Device performance validated at three hydrogen stations

Example Fault Detection Test: Maximum State of Charge (SOC)

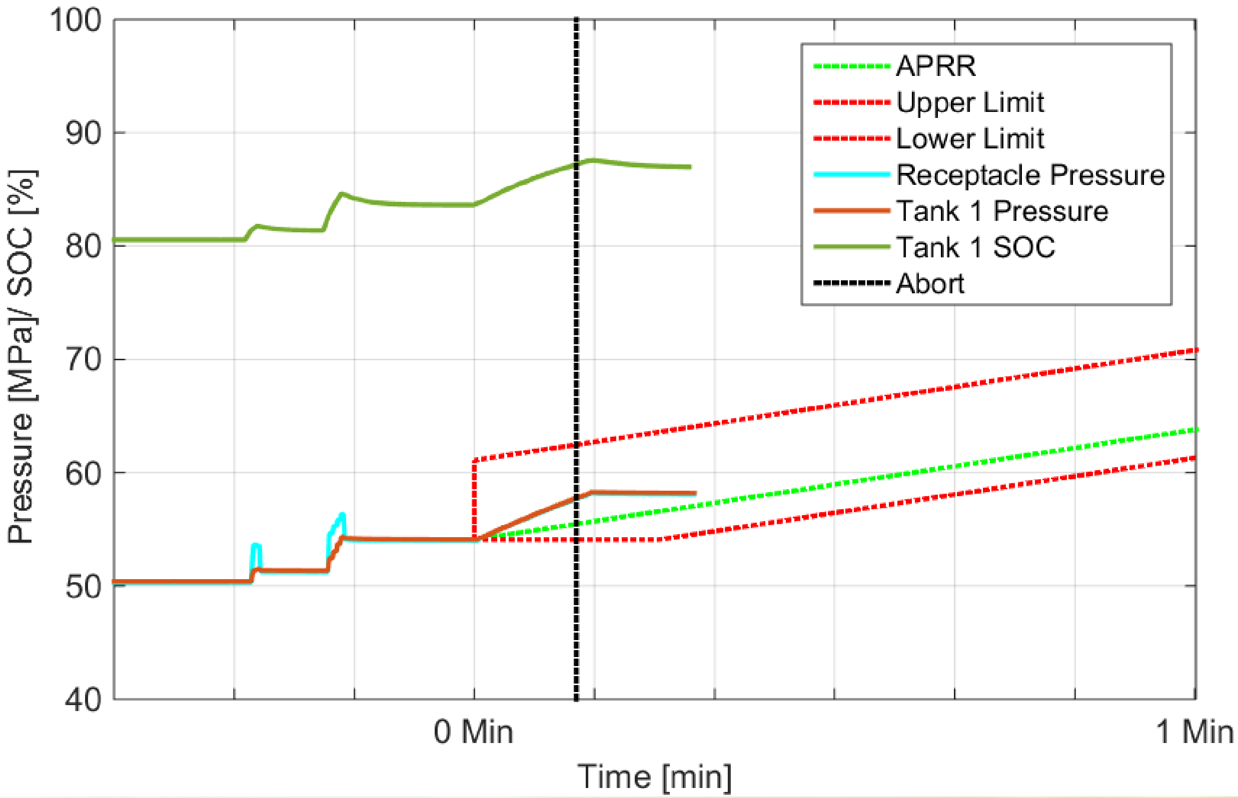
- H70 Comm fill
- IrDA temperature signal modified so that SOC > 100%
  - Set MT = 234 K when MP was 58 MPa
  - Resulting SOC = 102%
- Dispenser terminated fueling within a few seconds



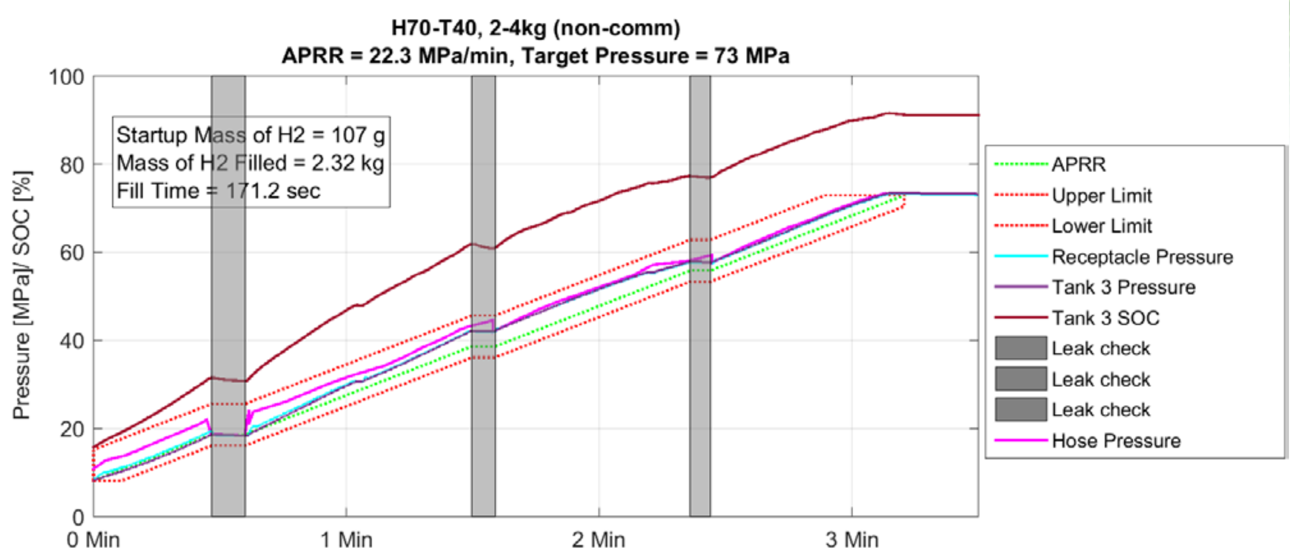
Accomplishments: HyStEP Device performance validated at three hydrogen stations

Example Communication Test: ABORT

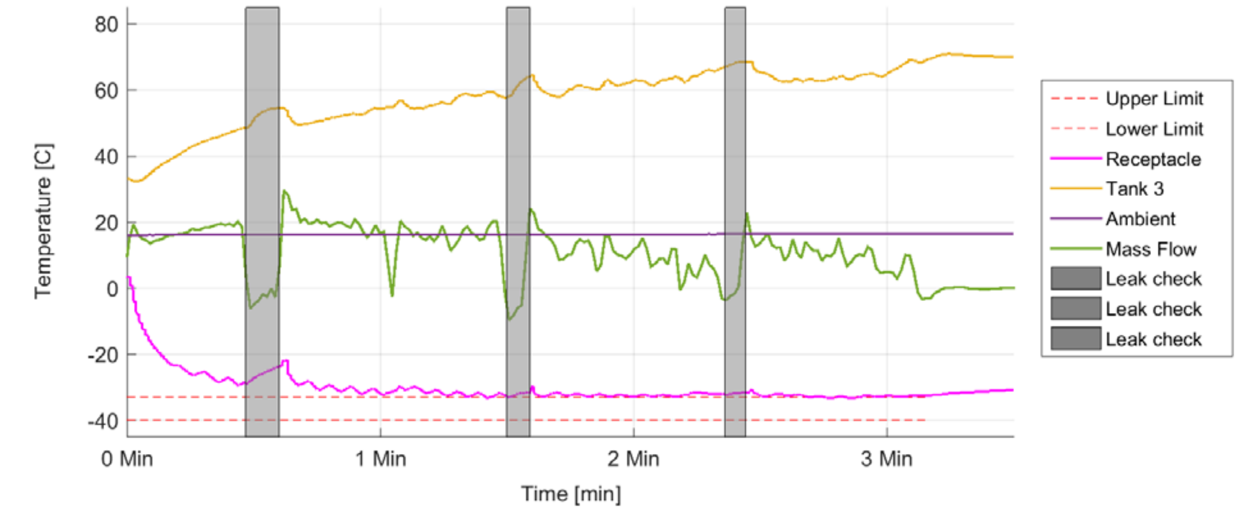
- H70 Comm fill
- IrDA Abort signal transmitted by HyStEP operator
- Dispenser terminated fueling within a few seconds



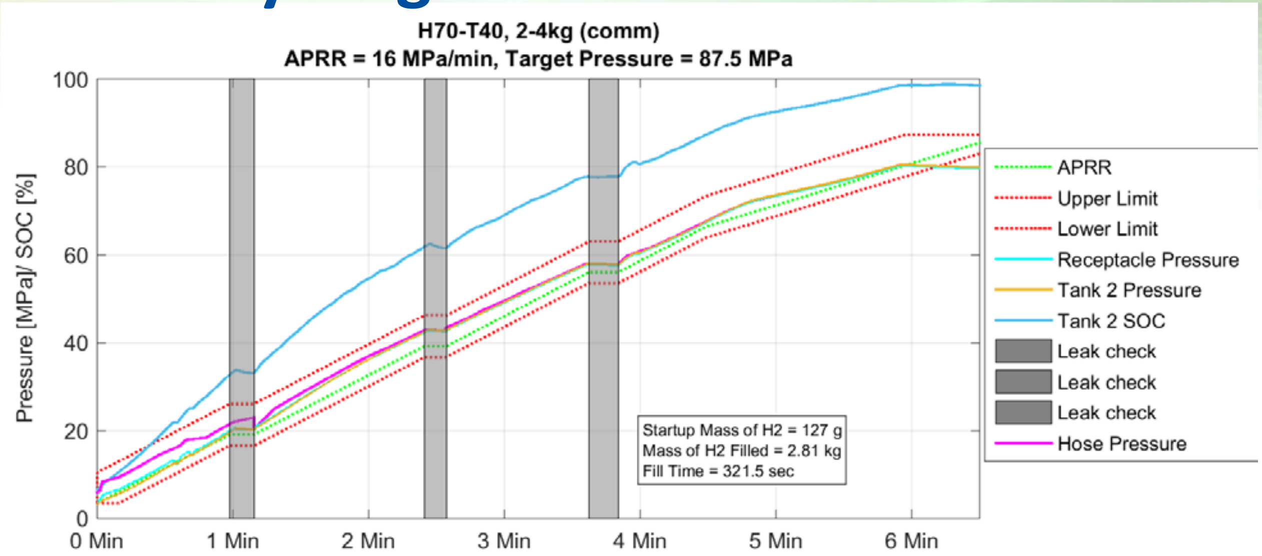
Accomplishments: HyStEP Device performance validated at three hydrogen stations



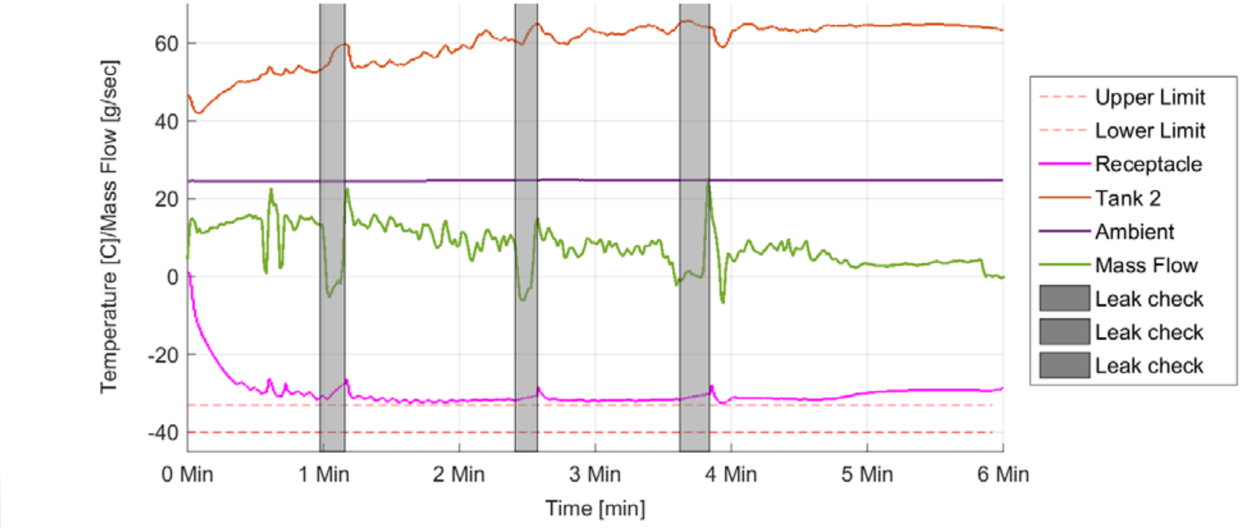
Example Fueling Test: H70-T40 non-comm, 3kg



Accomplishments: HyStEP Device performance validated at three hydrogen stations



Example Fueling Test: H70-T40 comm, 3kg, top off



Accomplishments: Responses to Previous Year Reviewer's Comments

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Comment #1: While the project is quite limited in scope, it is addressing a key piece of the puzzle for the FCEV market.

Response #1: The limited scope, focusing only on fueling protocol, was purposefully chosen so that the device could be completed quickly.

Comment #2: The one-year schedule for completion of project work, from equipment design through validation testing at the National Renewable Energy Laboratory and field testing in California, seems demanding (which is positive). However, a case could be made to hold off validation testing of the device until revision of the CSA HGV 4.3 test method is completed later in 2015.

Response #2: With the delayed timing of the device, the validation testing proceeded in parallel with the completion of HGV 4.3.

Comment #3: Significant progress has been made, especially on the design and safety evaluation of the device. It is not clear how much progress the team has made on acceptance criteria.

Response #3: Acceptance criteria were based on the ability of the device to carry out the test methods defined in CSA HGV 4.3.

Collaborations: HyStEP Project Team consisted of key stakeholders

Partner	Project Roles
Sandia National Laboratories	Project lead, management and coordination; device design; safety analysis
National Renewable Energy Laboratory	Device design; safety analysis; device validation testing
Air Liquide	Device design; safety analysis; facilitate pre-deployment testing
Boyd Hydrogen	Device design and safety analysis
CA Air Resources Board	Device design; safety analysis; facilitate pre-deployment testing
Toyota	Device design; safety analysis; vehicle participation/comparison for pre-deployment testing
PNNL H_2 Safety Panel	HyStEP design and safety review by HSP

Remaining Challenges and Barriers for Deployment

- Coordinating/scheduling station tests with vehicle OEMs
- Complete reliance by OEMs on HyStEP data
- Station readiness
  - Pre-tests complete?
  - Weights and measures completed?
  - Hydrogen quality assessed (SAE J2719)?
  - Point of Sale operational?
- Transition/timeline to third party validation testing (NRTL)
- Factory acceptance tests vs. field tests
- Compliance and enforcement
- Testing budget – who pays/how much?

Proposed Future Work

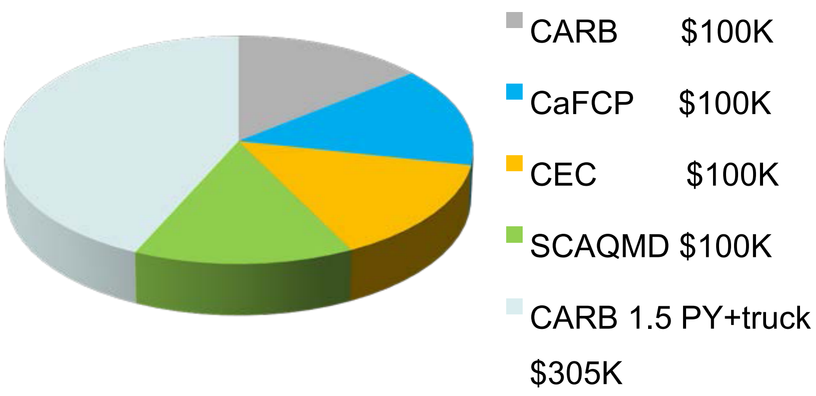
Deployment of HyStEP in CA to help commission new stations

Who?

- HyStEP project manager – Michael Kashuba (CARB)
- HyStEP Operators – Raed Mahdi (CARB), Norman Ingram and Andrei Brezoica (CDFA/DMS)
- Station Confirmation Group
  - Jackie Birdsall/Spencer Quong, Toyota
  - Tim McGuire/Matthew Forrest, Mercedes Benz
  - Kevin Lee, Hyundai
  - Steve Mathison, Honda
  - Lance Atkins, Nissan
- Key CA fuel cell program staff
  - Tyson Eckerle, GoBIZ
  - Michael Kashuba, CARB
  - Phil Casel, CEC
  - Bill Elrick/Jennifer Hamilton, CaFCP
  - Station developer/technology provider

How?

California Partners to Date Funding Contribution = $705K



Proposed Future Work

- Sandia support of CA deployment team
  - Contract with CARB for Sandia support in progress
- Feedback to Codes and Standards groups
  - CSA HGV 4.3
  - SAE J2601
  - ISO TC 197 WG 24
- Gather station data and publish CDP
  - Non-attributable data will feed into NREL Composite Data Products developed at the National Fuel Cell Technology Evaluation Center (NFCTEC) at NREL.
- Investigate potential Gen 2 design?
  - Back-to-back fill capability
  - Medium and heavy duty capability

Technology Transfer Activities: HySEP Device design package published

1. Device specification
2. User manual including operating instructions and a troubleshooting guide
3. Maintenance schedule and instructions
4. A final piping and instrumentation diagram (P&ID)
5. Dimensioned drawings of the overall system
6. Electrical wiring diagram
7. Control software code, description, and instructions for modification
8. Report summarizing the HA/FMEA
9. List of components (Bill of Materials) and the manufacturer's documentation (if applicable)
10. Component certifications
11. Documented leak and pressure tests
12. Device Validation Test Report

https://h2tools.org/h2first/HyStEP

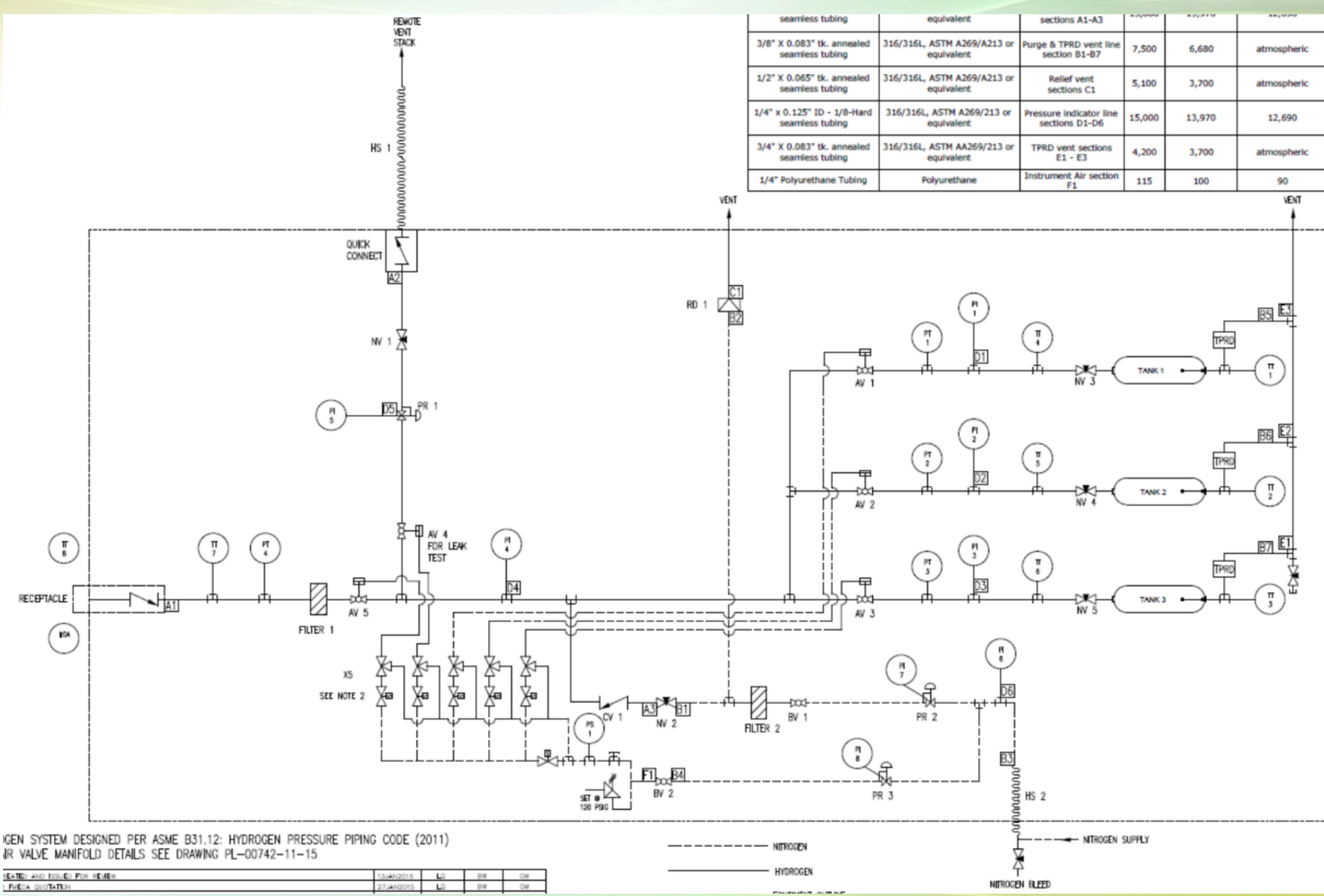
Summary – Progress and Accomplishments

- HyStEP Device fully validated to carry out all CSA HGV 4.3 tests
- Tested the first CA H_2 station in December, 2015
- All project milestones completed by March, 2016
- HyStEP Device enabling more rapid hydrogen station commissioning

Technical Back-Up Slides

Piping and Instrumentation Diagram (P&ID)

[illegible] seamless tubing	equivalent	sections A1-A3	[illegible]	[illegible]	[illegible]
3/8" X 0.083" tk. annealed seamless tubing	316/316L, ASTM A269/A213 or equivalent	Purge & TPRD vent line section B1-B7	7,500	6,680	atmospheric
1/2" X 0.065" tk. annealed seamless tubing	316/316L, ASTM A269/A213 or equivalent	Relief vent sections C1	5,100	3,700	atmospheric
1/4" x 0.125" ID - 1/8-Hard seamless tubing	316/316L, ASTM A269/213 or equivalent	Pressure indicator line sections D1-D6	15,000	13,970	12,690
3/4" X 0.083" tk. annealed seamless tubing	316/316L, ASTM AA269/213 or equivalent	TPRD vent sections E1 - E3	4,200	3,700	atmospheric
1/4" Polyurethane Tubing	Polyurethane	Instrument Air section F1	115	100	90



GEN SYSTEM DESIGNED PER ASME B31.12: HYDROGEN PRESSURE PIPING CODE (2011)
IR VALVE MANIFOLD DETAILS SEE DRAWING PL–00742–11–15

Tanks mounted securely and instrumented

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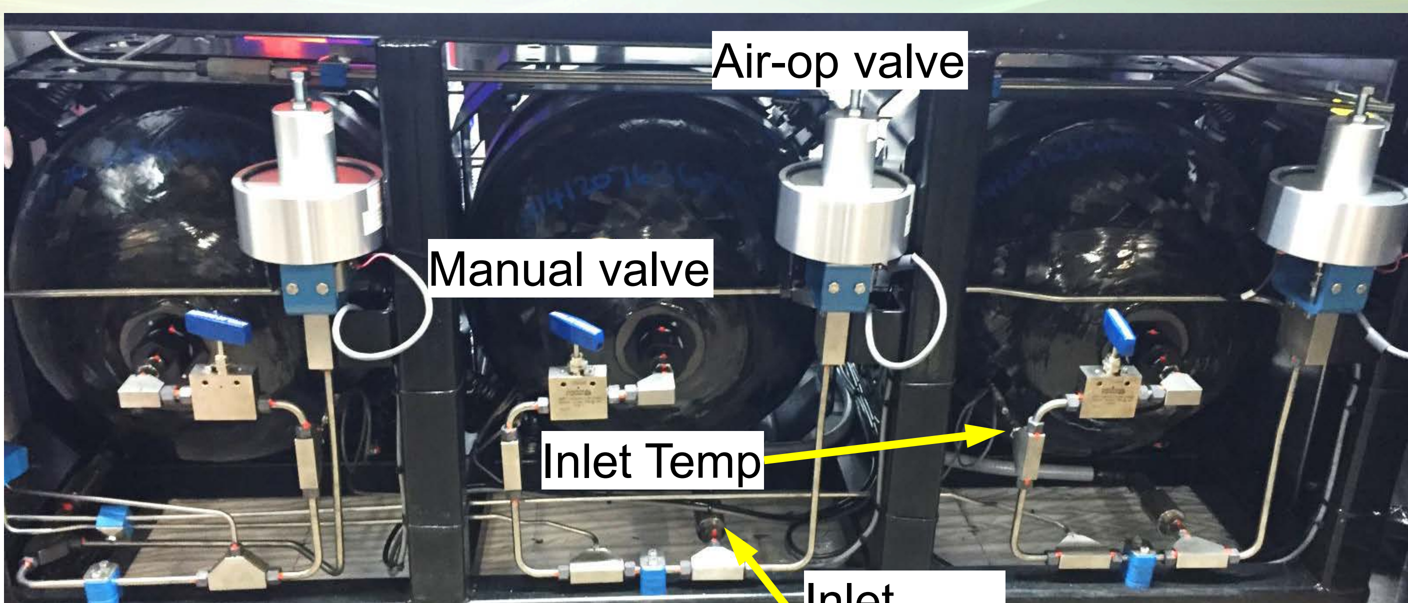
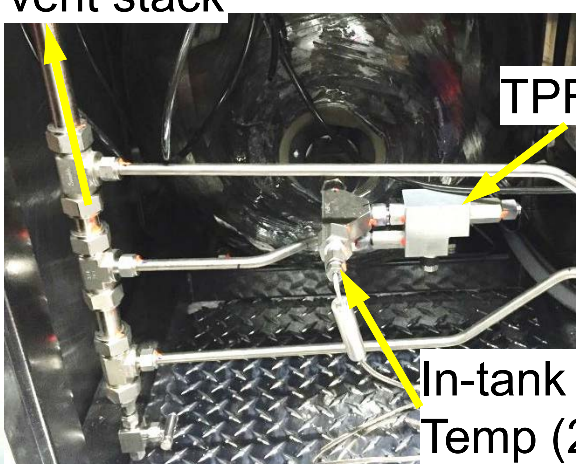
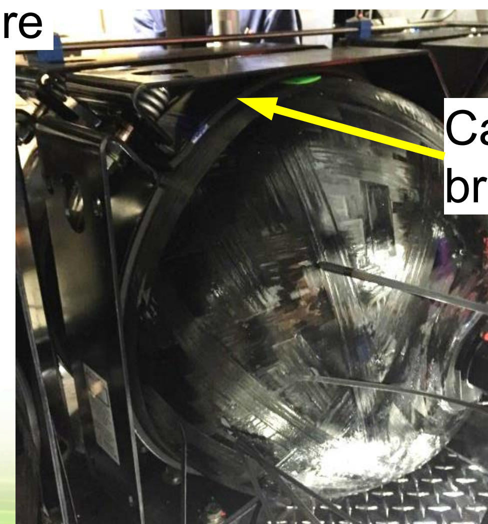
FRONT⟶



BACK⟶





HySTEP designed to test dispenser compliance with SAE J2601-2014 per CSA HGV 4.3

CSA HGV 4.3 defines three sets of tests to verify compliance with SAE J2601

Fault Detection

- CHSS capacity range test
- Ambient temperature test
- Minimum fuel delivery temperature test
- Maximum CHSS gas temperature test
- Minimum CHSS initial pressure test
- Maximum CHSS pressure test
- Maximum state of charge test

Communications

- Abort signal test
- Halt signal test
- Data loss test and then resumed fueling test
- Invalid CRC communication test
- Invalid defined data value test
  - Protocol Identifier (ID)
  - Software Version Number (VN)
  - Tank Volume (TV)
  - Receptacle Type (RT)
  - Fueling Command (FC)
  - Measured Pressure (MP)
  - Measured Temperature (MT)

Fueling Protocol

- Non-comm Fueling tests
- Comm fueling tests
- Repeated table test
- No fueling test
- High pressure capacity test
- Pre-cooling capacity test
- Fallback test
- Top–off fueling test
- Cold dispenser test

Typical test matrix can be carried out in three days

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Day One

- Arrive on site and setup
- Safety inspection
- Instrument and sensor check
- Enter station info and review test matrix with operator
- Fault Detection tests

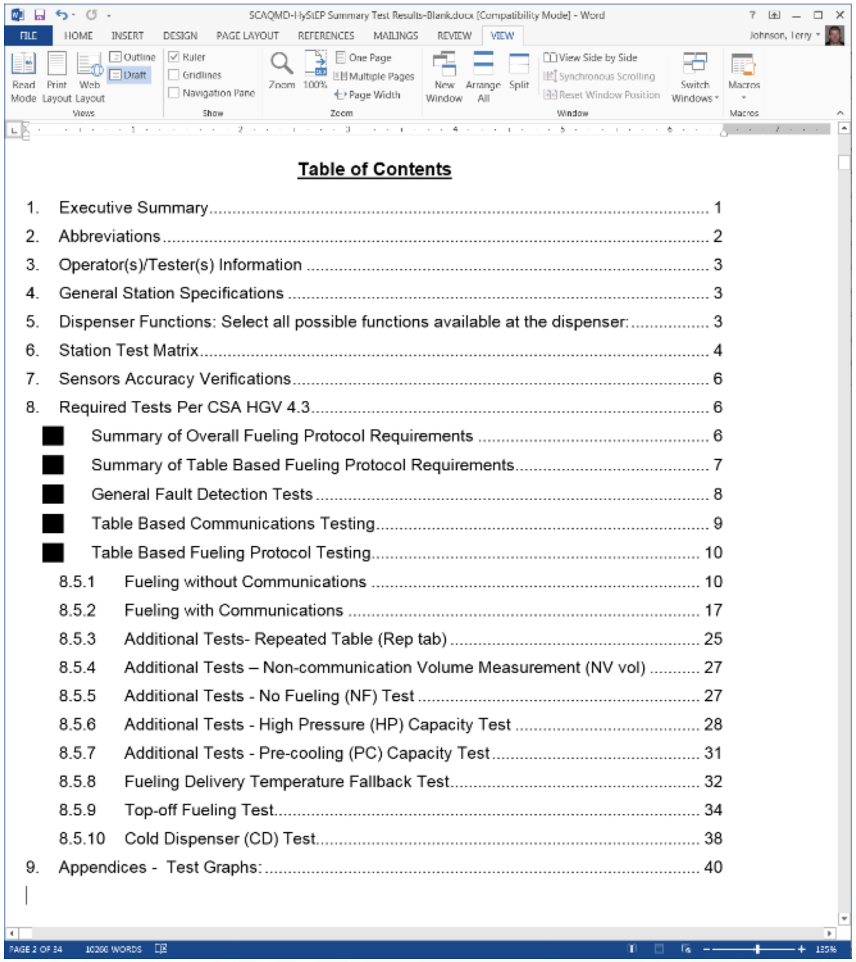
Day Two

- Communication tests
- Begin Fueling Protocol tests
  - 5-7 fills
  - 2-3 vent cycles

Day Three

- Review results from Day Two
- Complete Fueling Protocol tests
  - 5-7 fills
  - 2-3 vent cycles
- Prepare HyStEP for transport
  - Vent and purge

A station performance report will be used to record HyStEP test results



SCAQMD-HyStEP Summary Test Results-Blank.docx [Compatibility Mode] - Word

Table of Contents

Based primarily on CSA HGV 4.3

Includes the following:

- Summary Report Card
- Station description
- Test Matrix
- Requirements
- Test Pass/Fail Checklists
  - General Fault Detection
  - Communication
  - Fueling Protocol