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

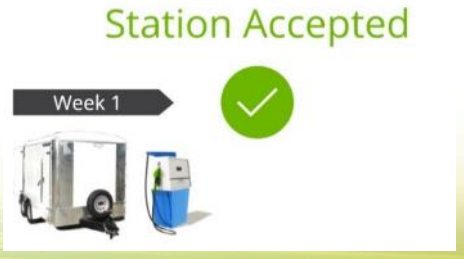
Follow standards:

- 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

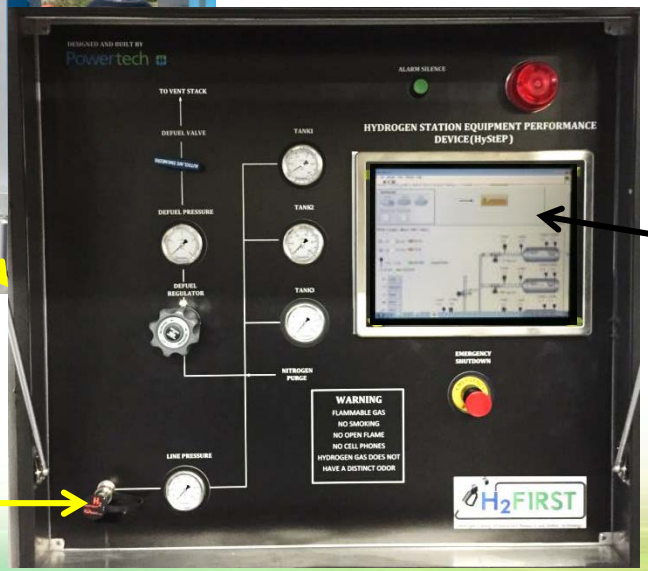
Key Features:

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



Touchscreen User Interface

Operator panel

Receptacle

Approach: Safety and Performance Validation

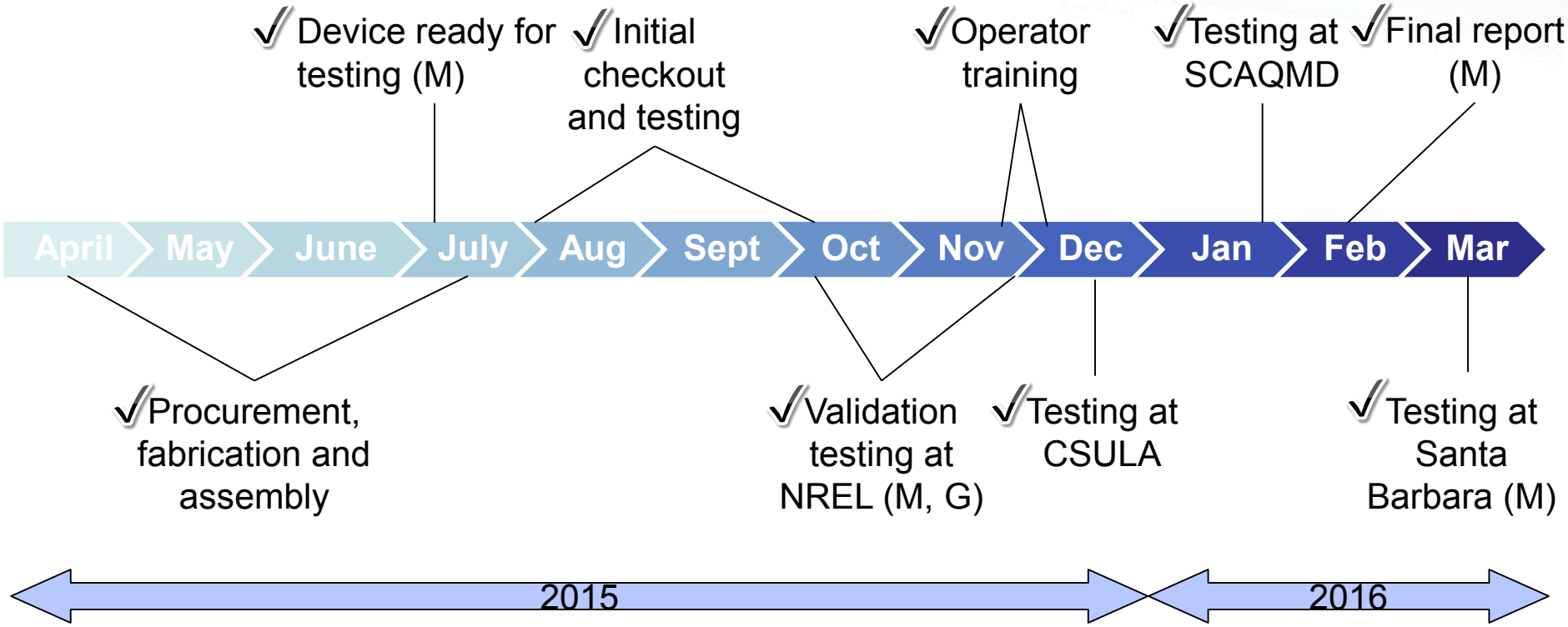
Safety

- 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

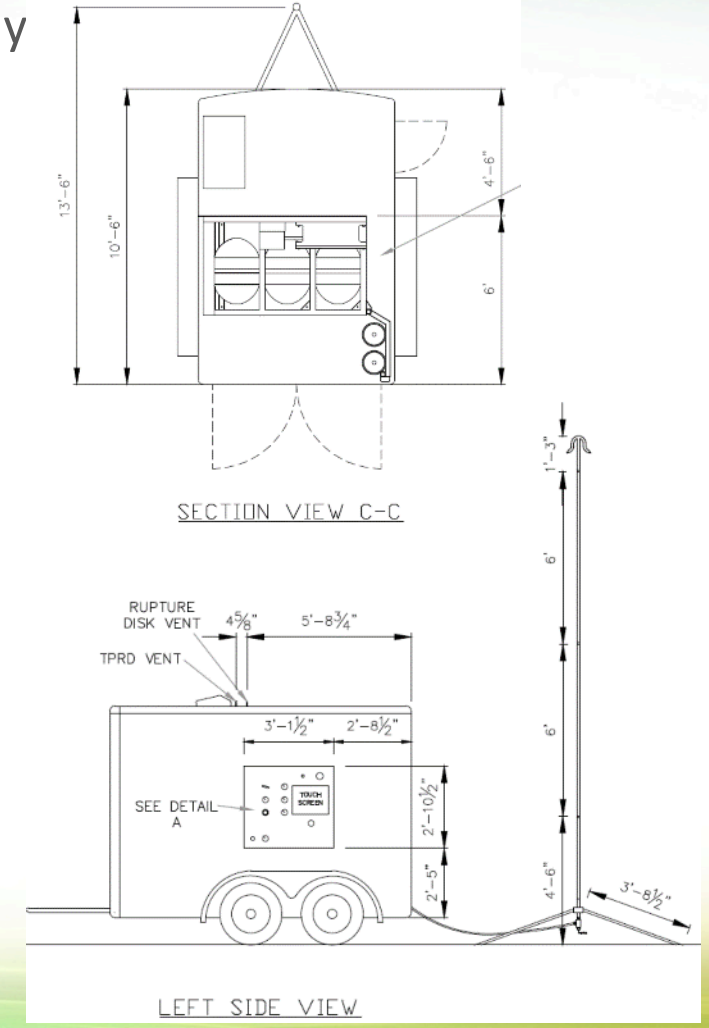
Accomplishments: HySTEP Device fabrication completed

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

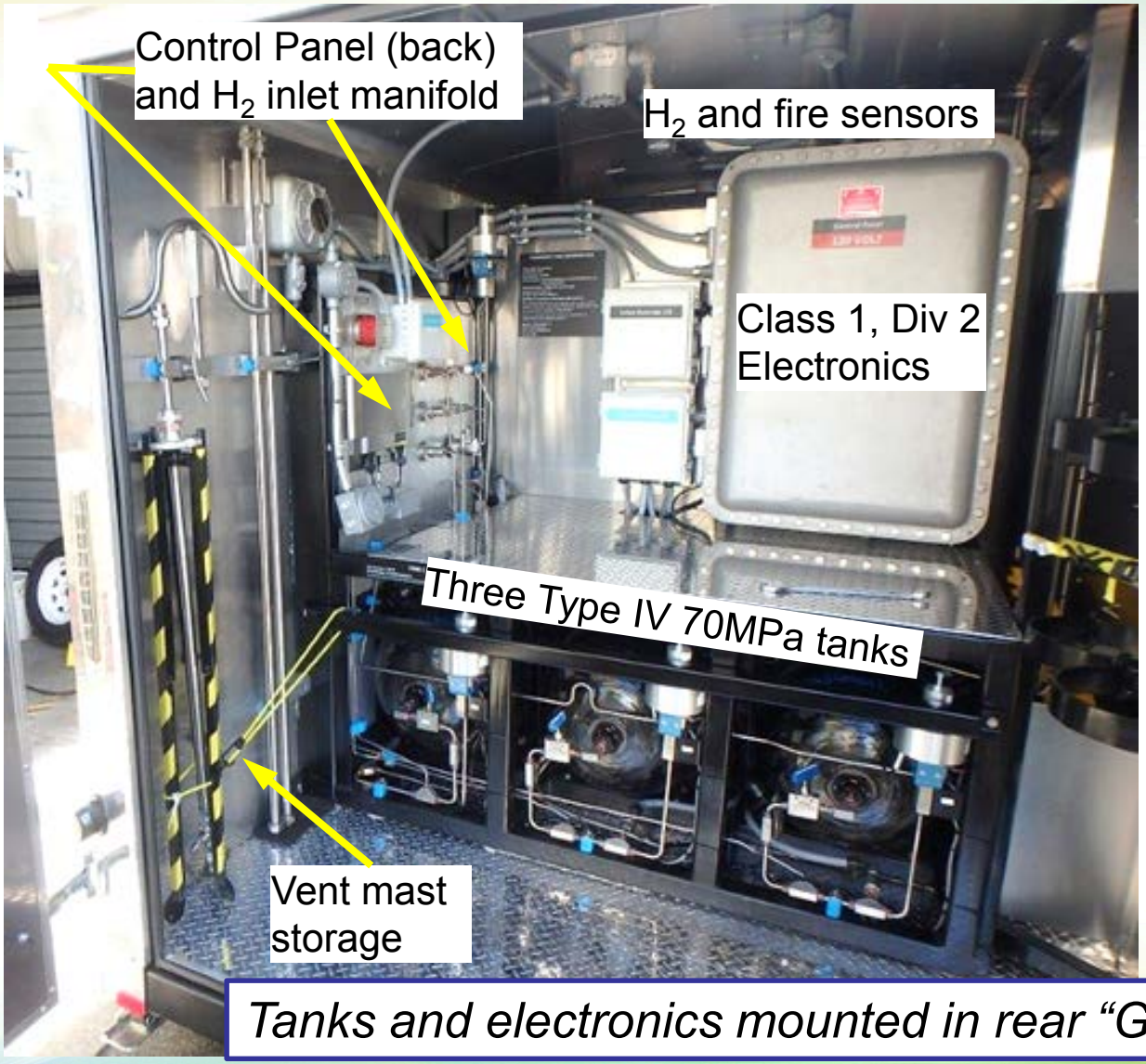
Trailer pros:

- 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



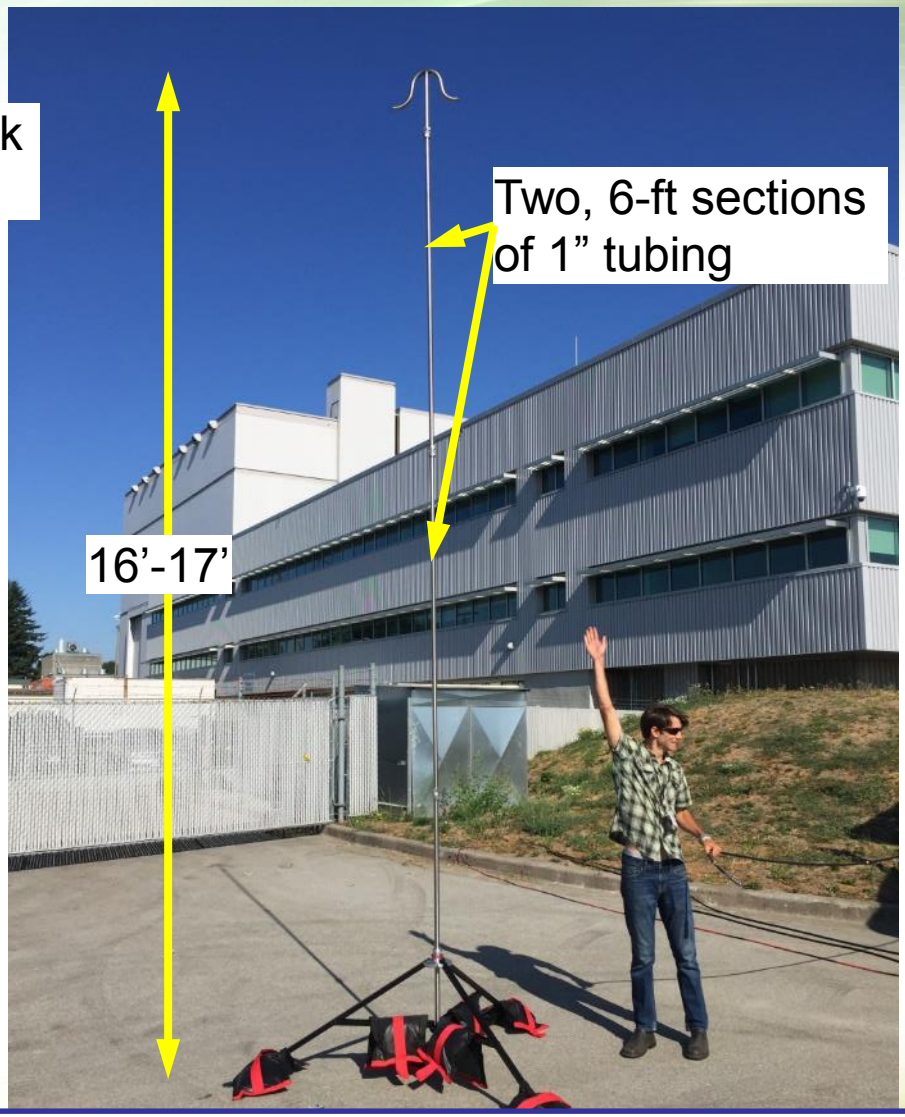
Accomplishments: HySTEP Device fabrication completed



Tanks and electronics mounted in rear "Gas Room"

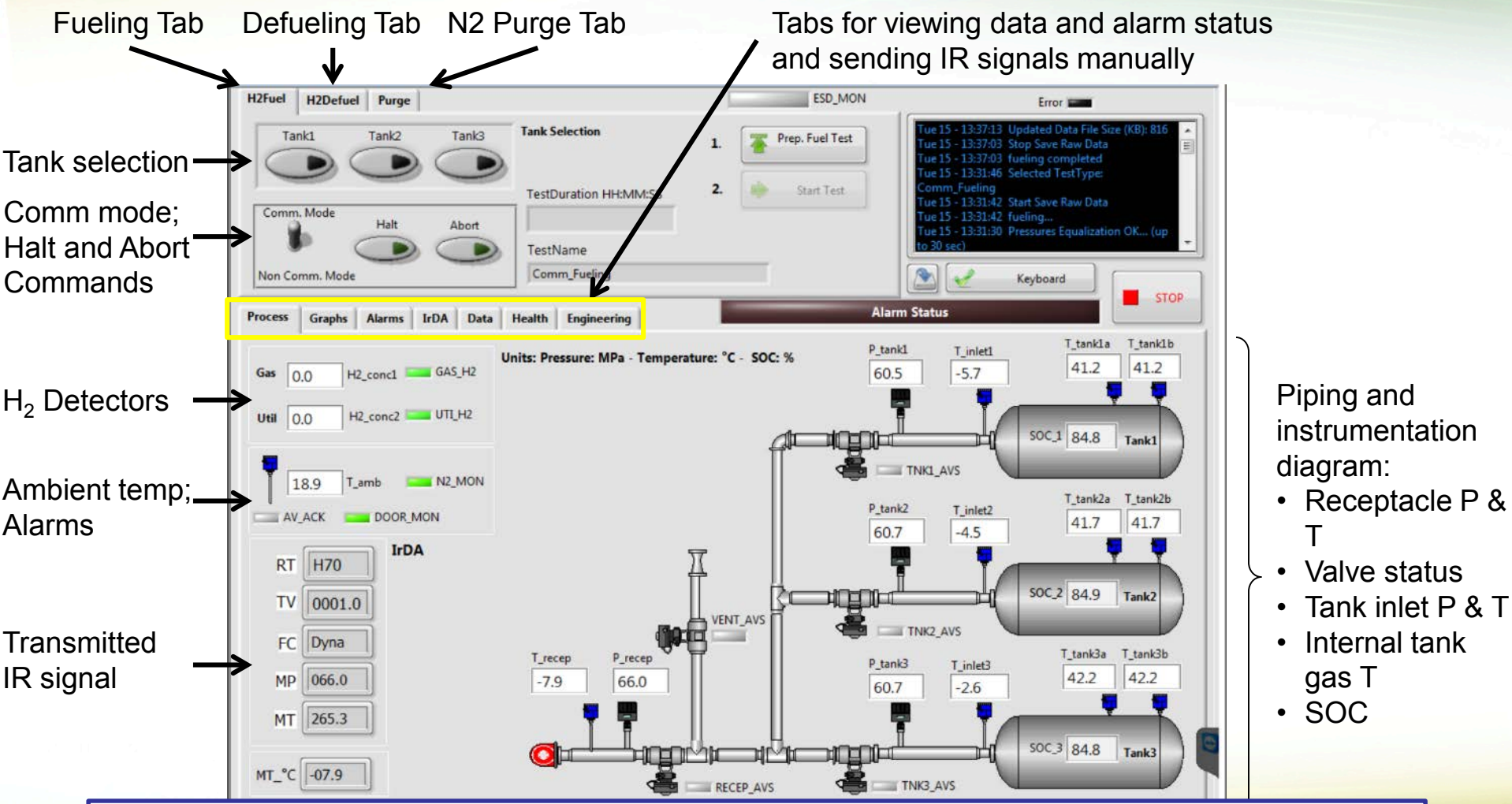
Accomplishments: HyStEP Device fabrication completed

Foldable base with quick disconnect and drain



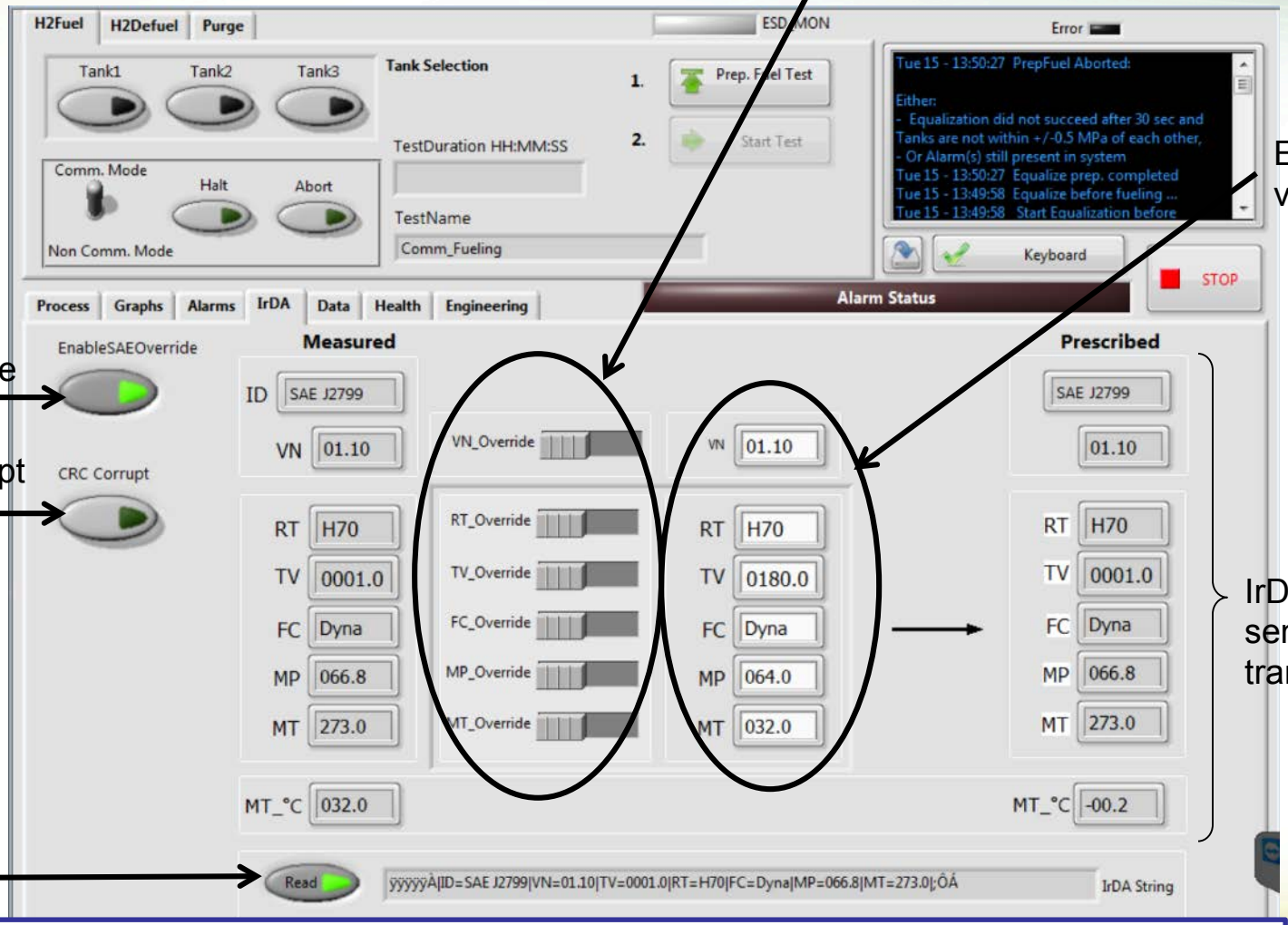
Remote vent stack is easy to set up and very stable; stores in Gas Room

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



HyStEP operator uses the touchscreen control panel to carry out tests

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



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

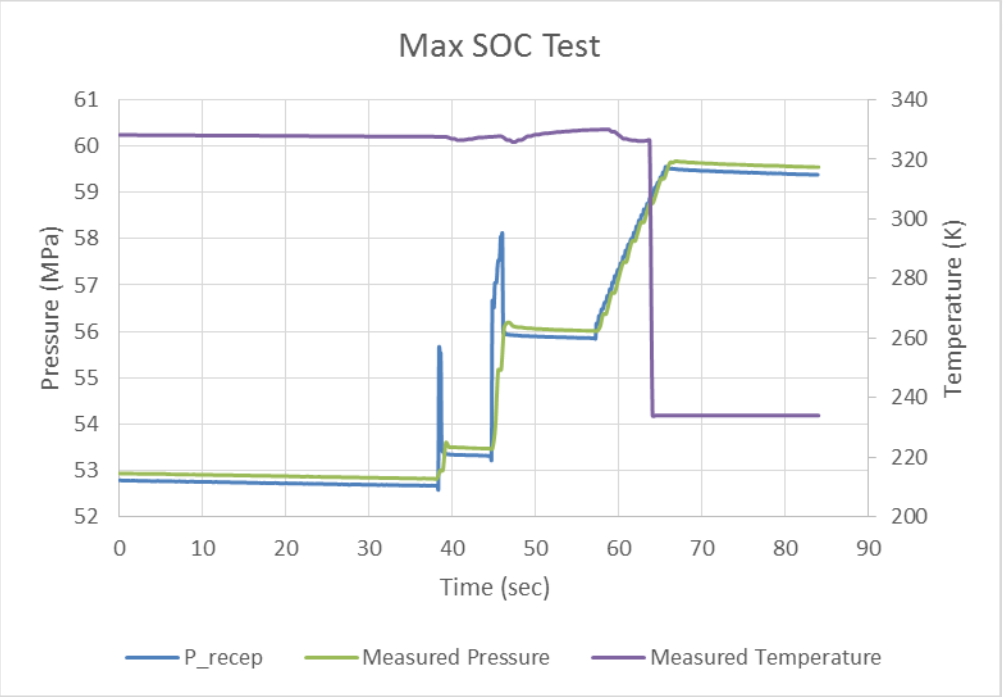
- 6 Fault Detection tests
- 9 Communications tests
- 6 non-comm fills
  - 3 H35-T20 (2 and 3 tanks)
  - 3 H70-T40 (1, 2, and 3 tanks)
- 11 H70-T40 comm fills (1, 2, and 3 tanks)
  - 4 fill tests were side-by-side comparisons to FCEVs
- 3 No Fueling tests

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)

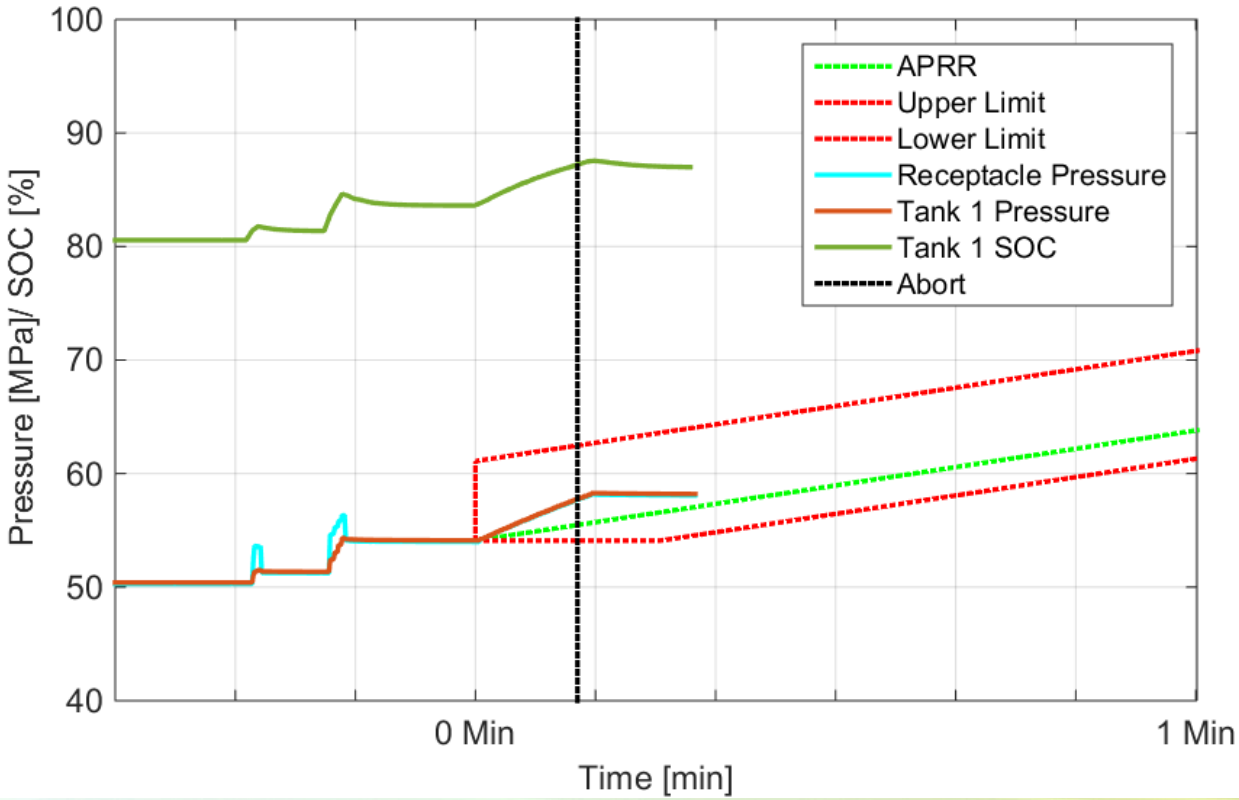
- H70 Comm fill
- IrDA temperature signal modified so that SOC > 100%
  - Set MT = 234 K when MP was 58 MPa
  - Resulting SOC = 102%
- Dispenser terminated fueling within a few seconds



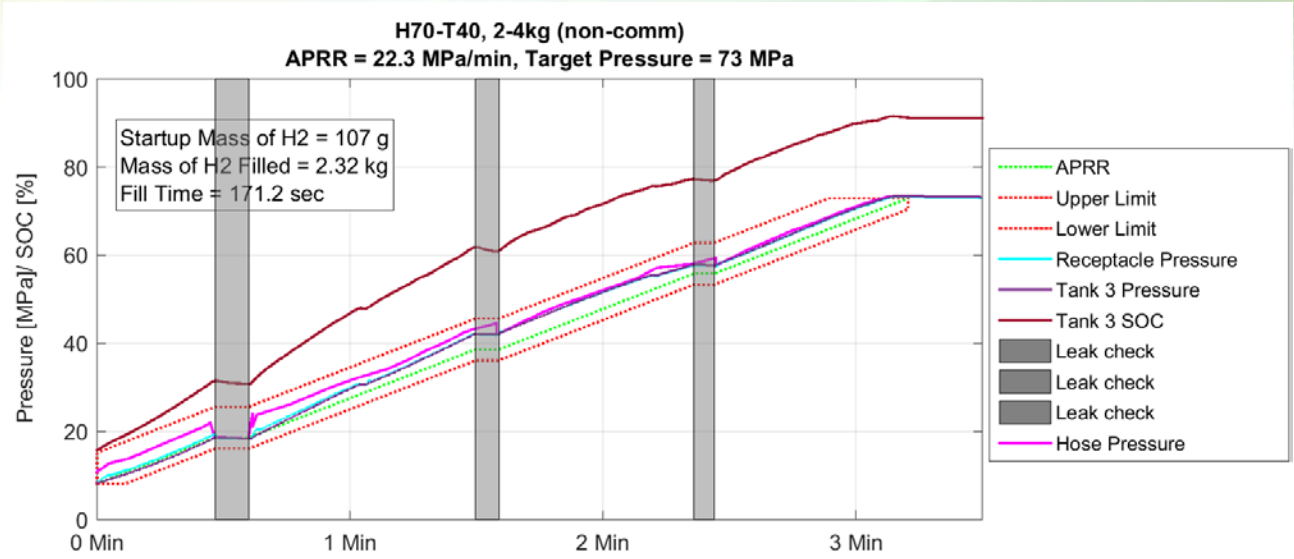
Accomplishments: HyStEP Device performance validated at three hydrogen stations

Example Communication Test: ABORT

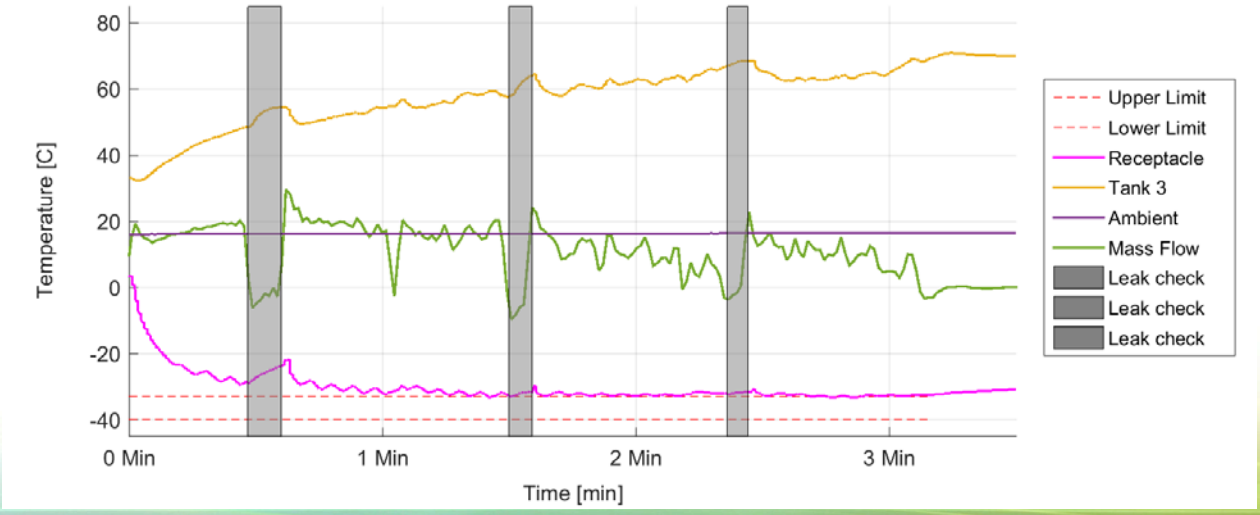
- H70 Comm fill
- IrDA Abort signal transmitted by HyStEP operator
- Dispenser terminated fueling within a few seconds



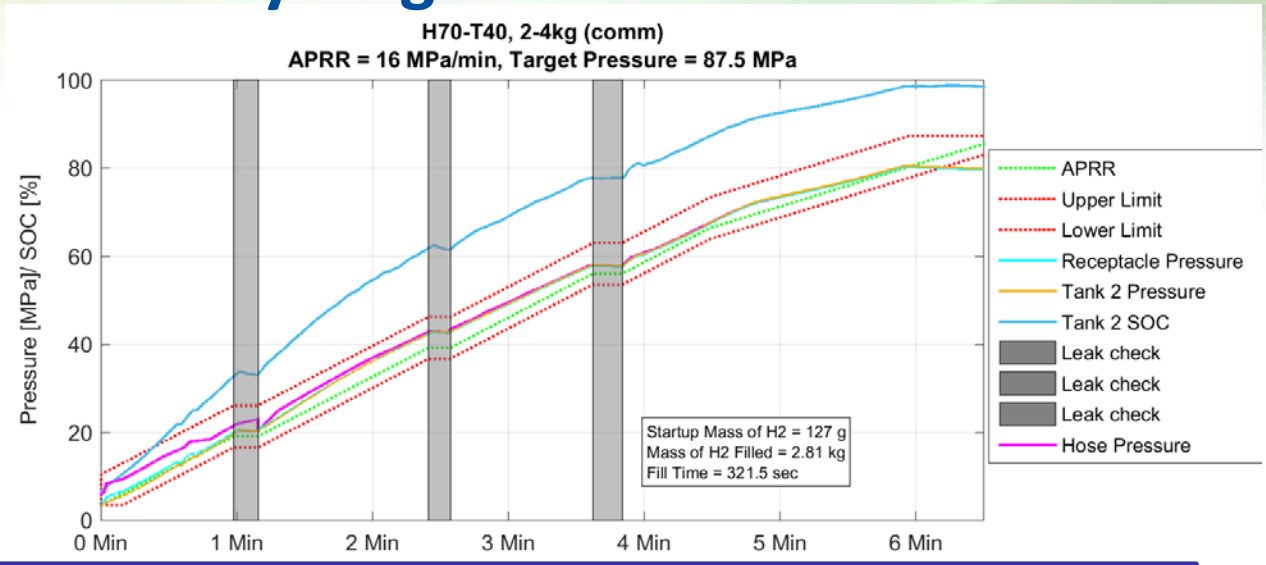
Accomplishments: HySTEP Device performance validated at three hydrogen stations



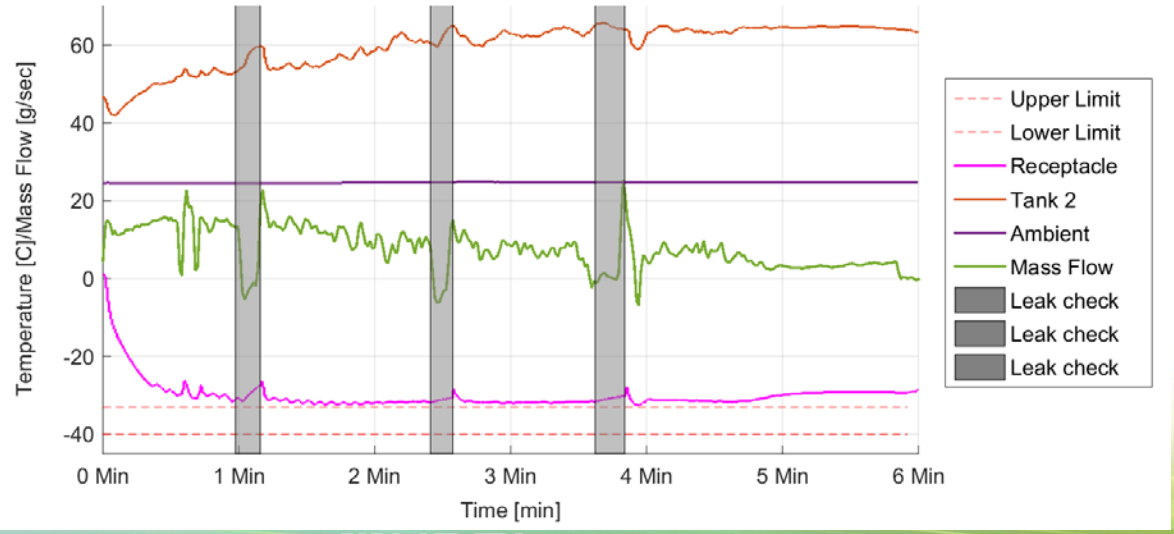
Example Fueling Test: H70-T40 non-comm, 3kg



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

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

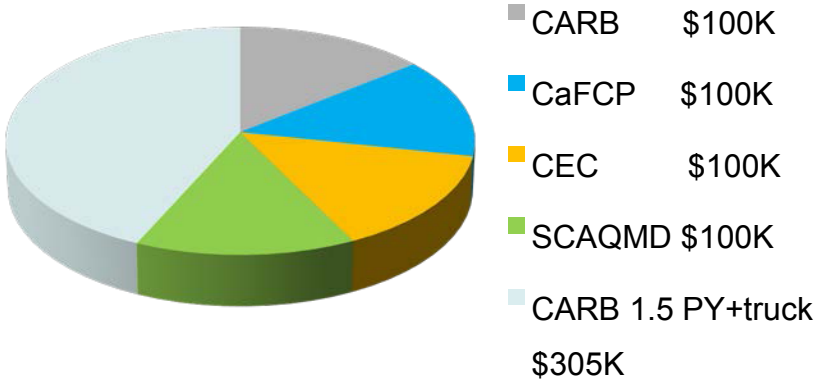
Deployment of HyStEP in CA to help commission new stations

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: HyStEP 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

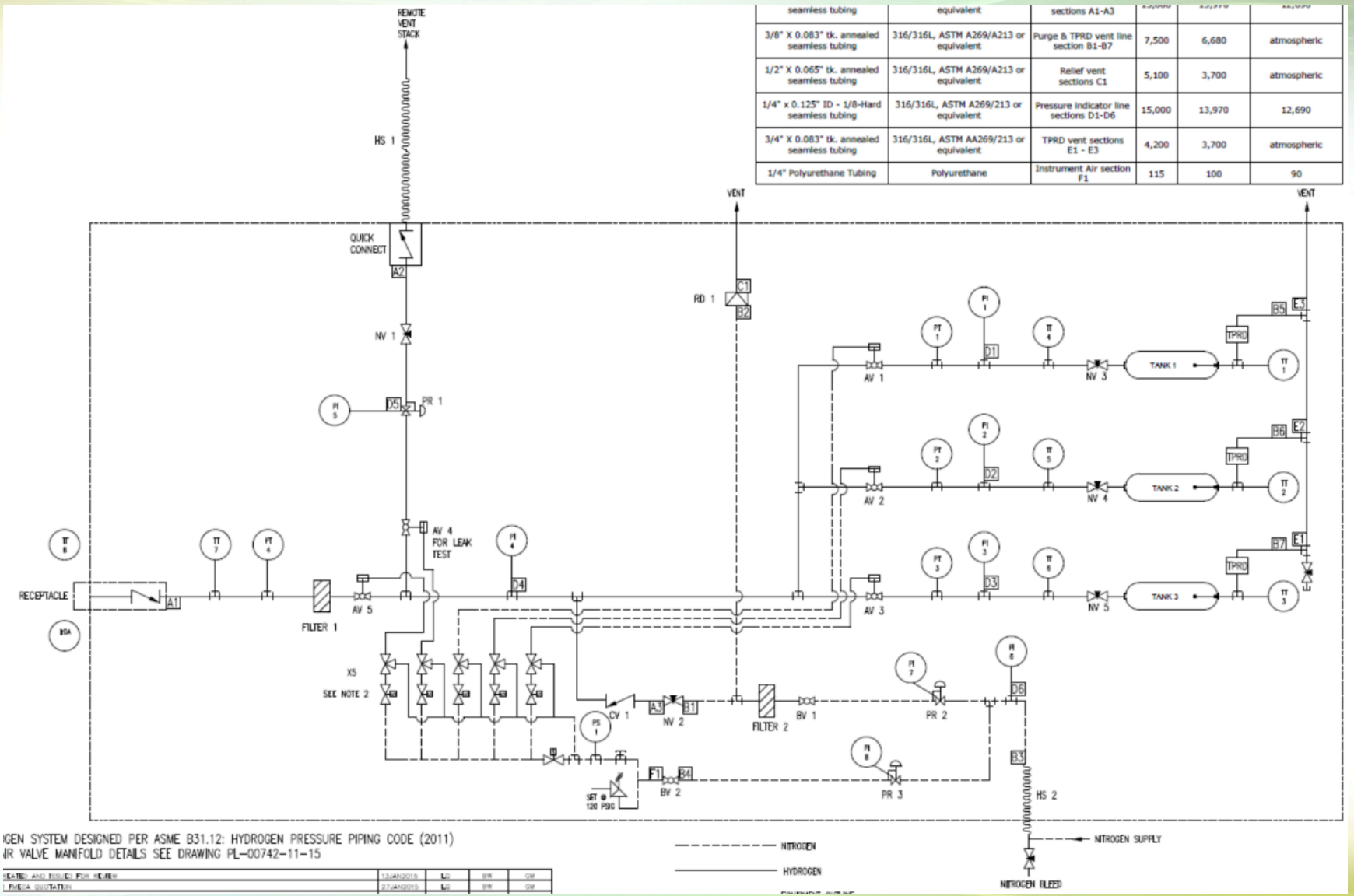
https://h2tools.org/h2first/HyStEP

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

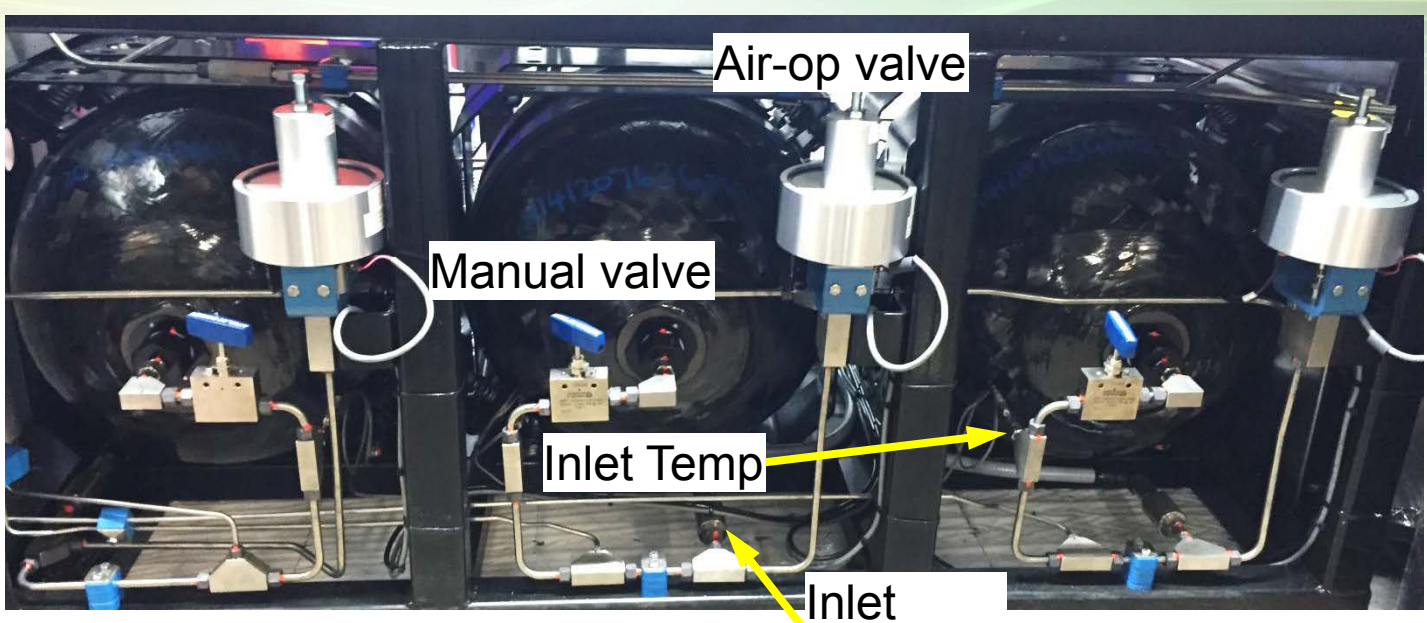
Technical Back-Up Slides

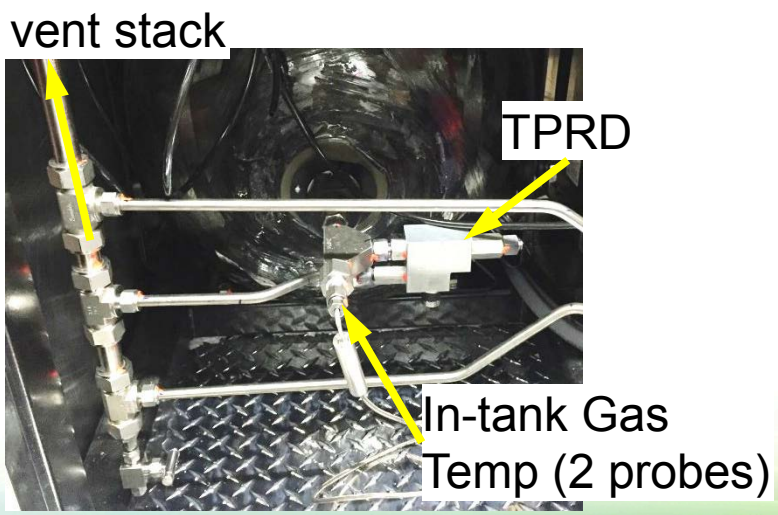
Piping and Instrumentation Diagram (P&ID)

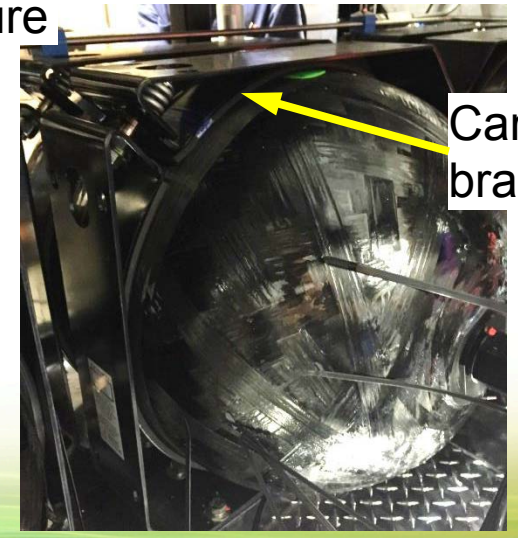


seamless tubing	equivalent	sections A1-A3			
3/8" X 0.083" tk. annealed seamless tubing	316/316L, ASTM A269/A213 or equivalent	Purge & TPRD vent line section B1-B7	7,500	6,680	atmospheric
1/2" X 0.065" tk. annealed seamless tubing	316/316L, ASTM A269/A213 or equivalent	Relief vent sections C1	5,100	3,700	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

Tanks mounted securely and instrumented







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

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

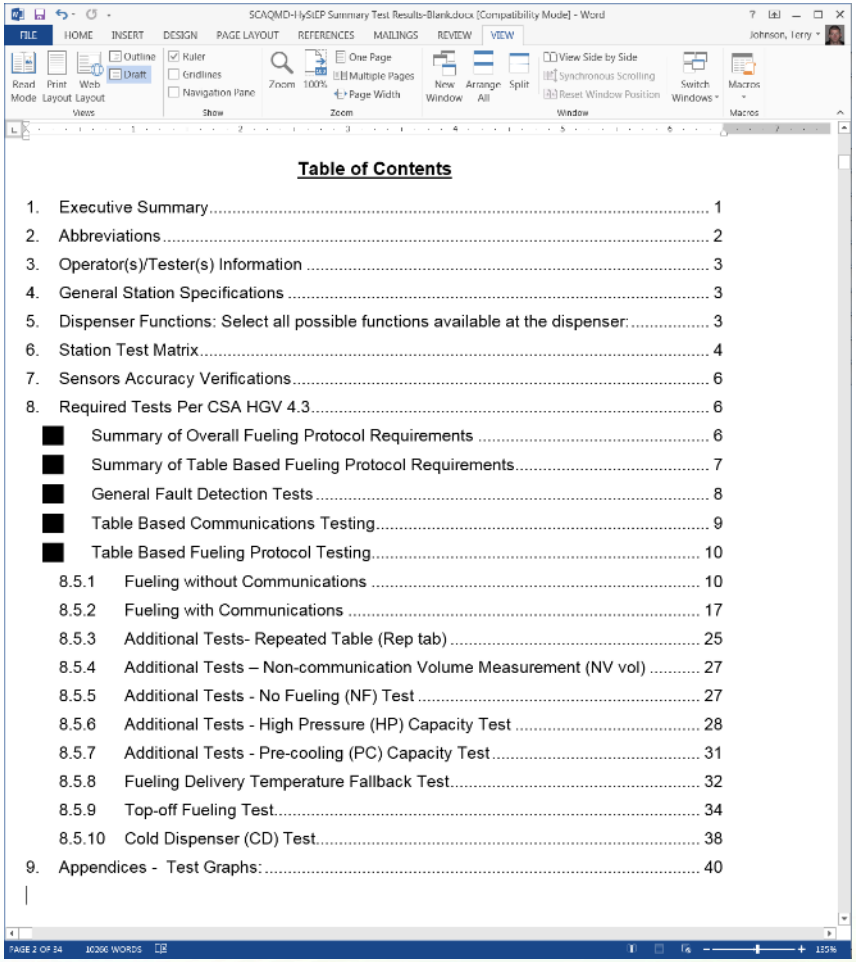
- Communication tests
- Begin Fueling Protocol tests
  - 5-7 fills
  - 2-3 vent cycles

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

California Environmental Protection Agency
Air Resources Board

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



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9. Appendices - Test Graphs: 40

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