# Hydrogen Dispenser Certification

## Hydrogen Field Standard, Test Program and Results to Date

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Project ID # TV023



California Environmental Protection Agency
AIR RESOURCES BOARD

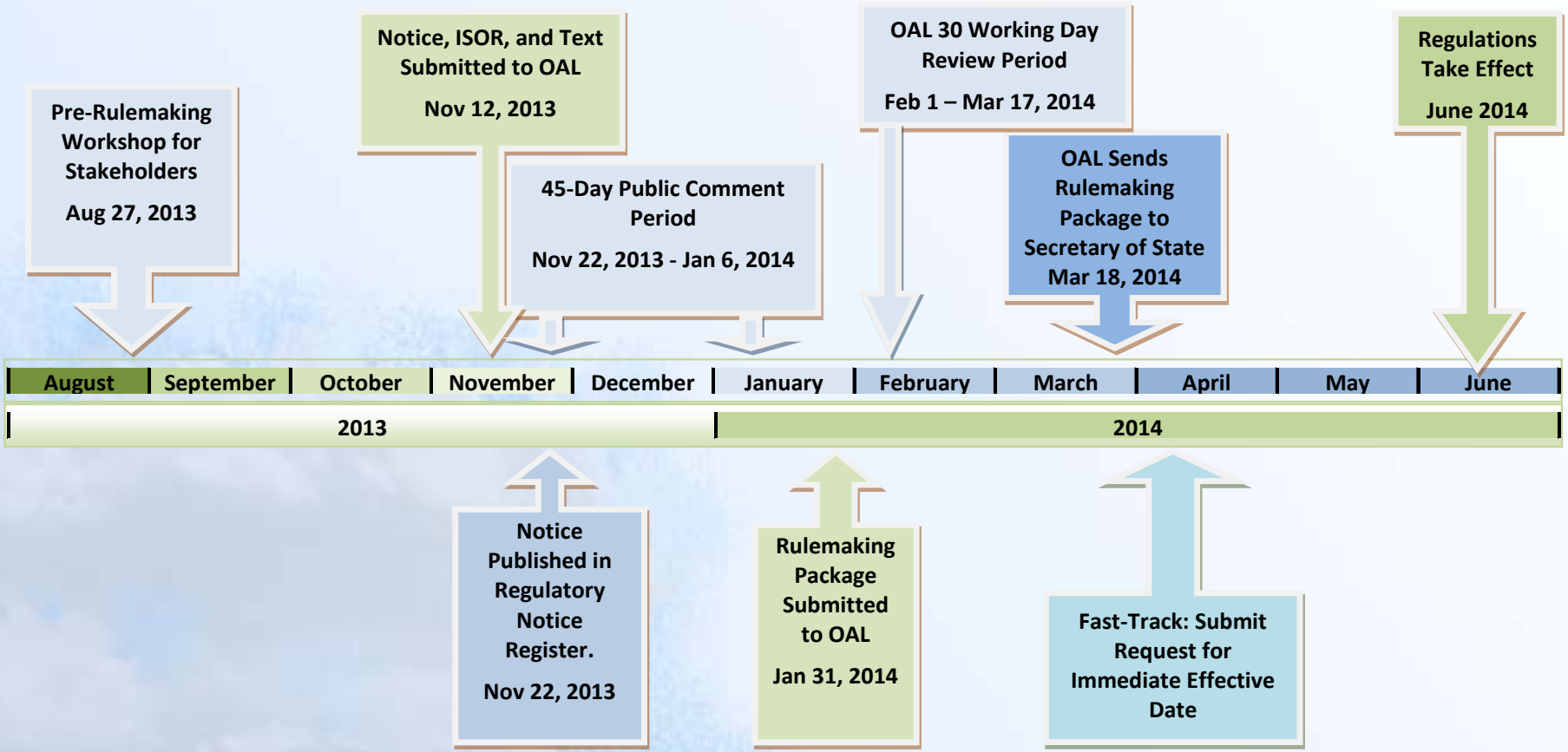
# Purpose

- The California Air Resources Board's (CARB) Zero Emission Vehicle (ZEV) regulation requires that 15.4 % of all vehicles sales be ZEVs – either Fuel Cell Electric (FCEV), Battery Electric (BEV) or plug-in Hybrid Electric (PHEV) by 2025
- The California Department of Food and Agriculture (CDFA), Division of Measurement Standards (DMS) must certify hydrogen dispensers so hydrogen can be legally sold to fuel FCEVs
- To do this, this test program:
  - Developed specifications and tolerances for new regulations to address current dispenser technology accuracy
  - Fabricated and evaluated a reference standard
  - Built a portable hydrogen field standard for field testing
  - Conducted initial metrology testing of seven existing hydrogen stations
- The test program will continue testing newer dispenser designs in late 2014 and follow-up permanence testing of stations into 2015

# Background

- **Regulatory Driver**
  - State Goal - GHG  reductions 80% below 1990 levels by 2050
  - Zero Emission Vehicle Rule and Hydrogen Fuel Cell Vehicles
  - Motor fuel dispensers must receive a Certificate of Approval before they may be used in commerce in California
- **Setting**
  - National Institute of Standards and Technology Handbook 44 language with modifications adopted by CDFA
- **Next Steps:**
  - Fabrication and evaluation of reference standards
  - Statewide testing program
  - Results to date – testing approximately one third complete…

# CDFA-DMS Rulemaking Timeline



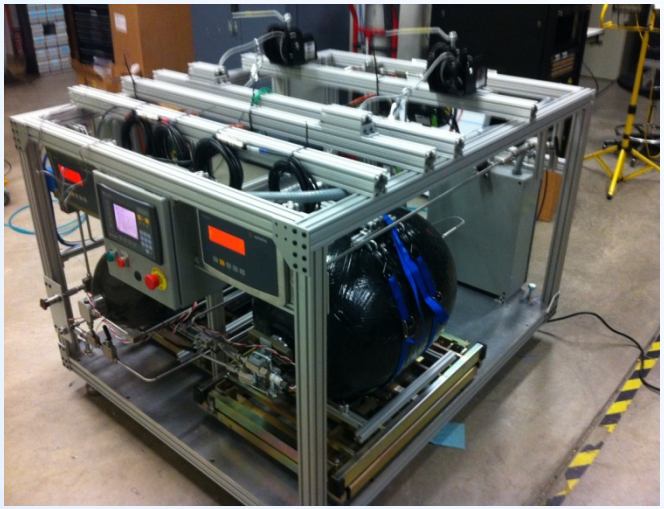
# Fabrication of the Reference Standard

- California funded /subcontracted National Renewable Energy Laboratory (NREL) to build Hydrogen Field Standard (HFS)
  - Included three working standards
    - Gravimetric - Precision scale (150 kg x 0.001 kg)
    - Volumetric – Tanks, tubing, pressure/temperature sensors
    - Master Meter - Mass flow meter
  - Programmable Logic Controller, Data Acquisition & Display Electronics
  - Two hydrogen tanks – Approximately 60 and 70 liters
  - Valves, piping, structural support, and securing mechanism to allow transport for field use

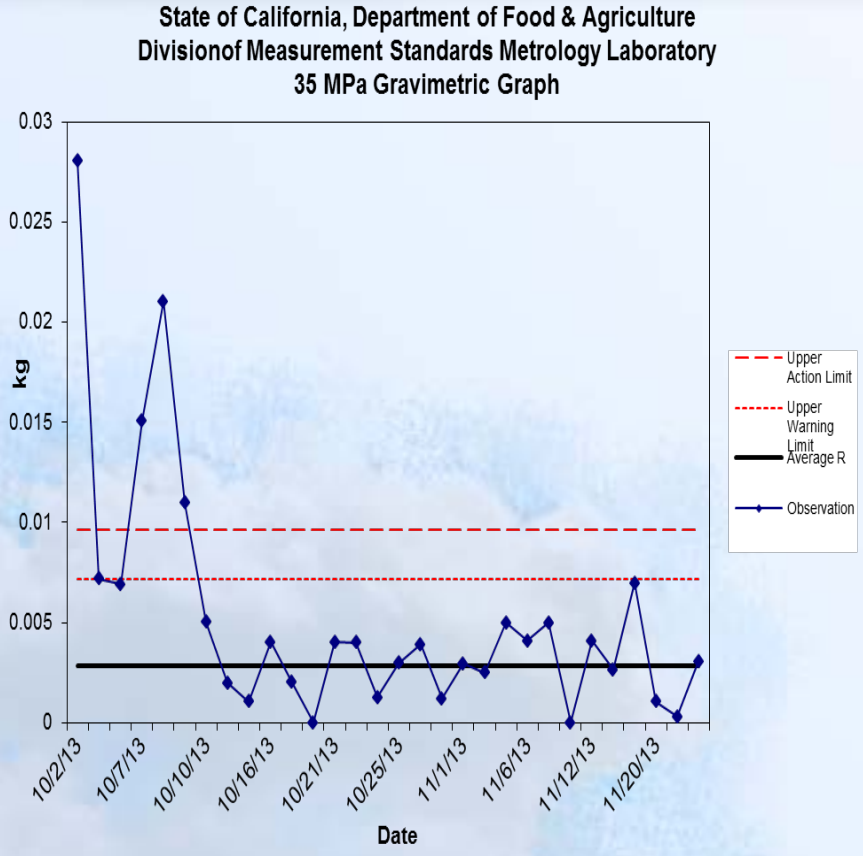
# Hydrogen Field Standard (HFS) Metrology Testing Device

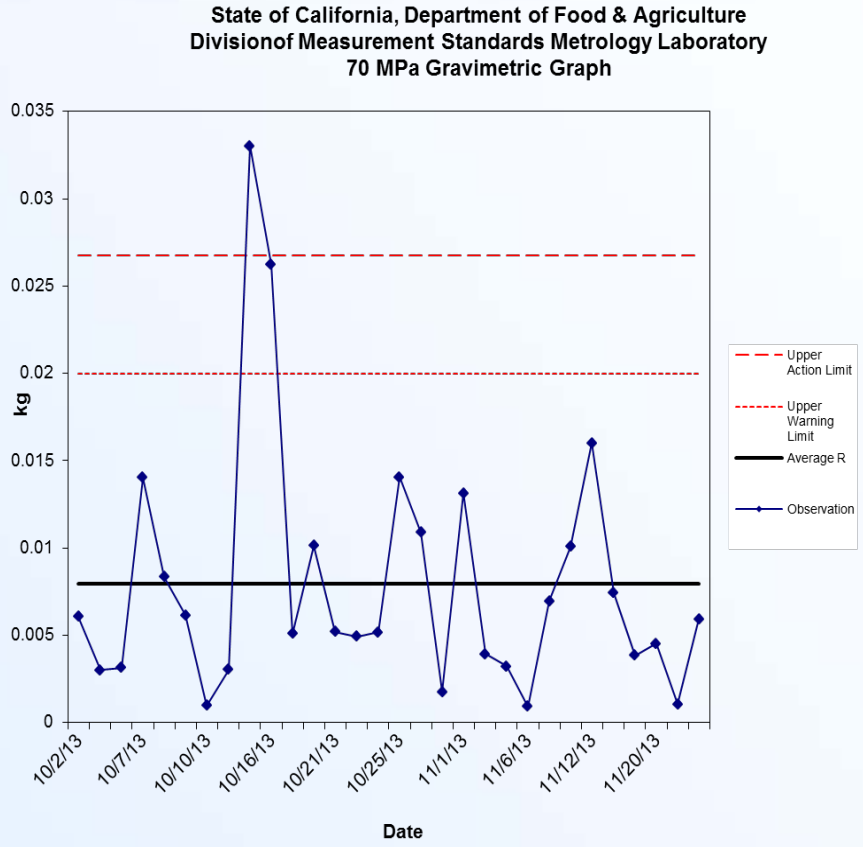
Timeline

- First version (top image) completed summer 2013
- Final field device (lower image) completed November 2013
- Required 30 test fills completed December 2013
- Raw data has been analyzed by DMS
- Preliminary determination that gravimetric method is most reliable, most suitable for verifying accuracy



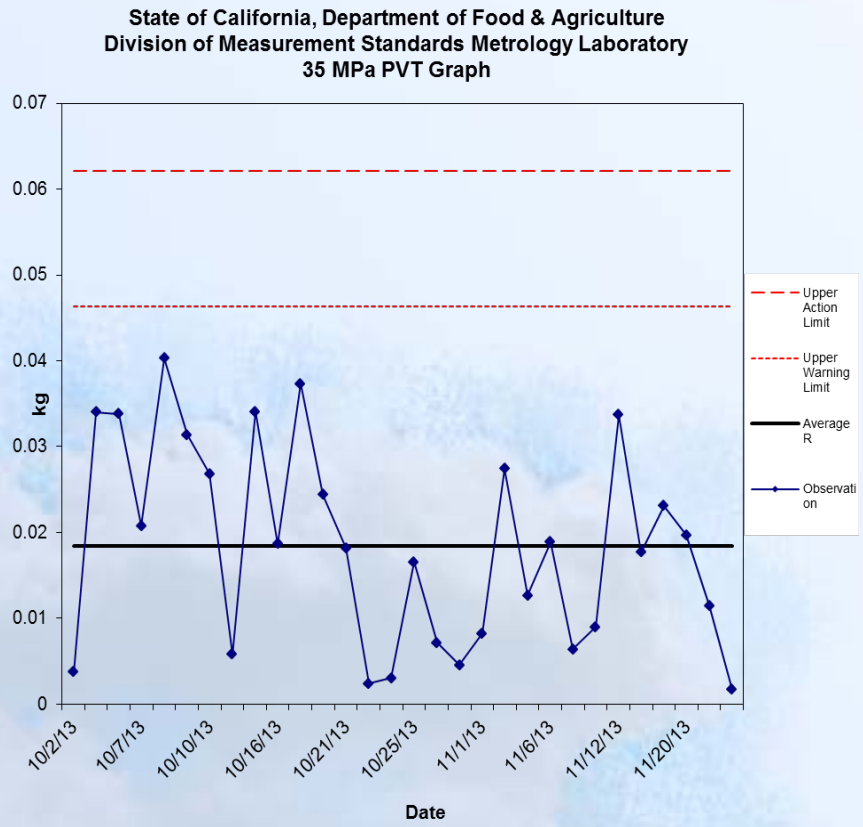
# Validation of the Reference Standard Gravimetric Control Charts

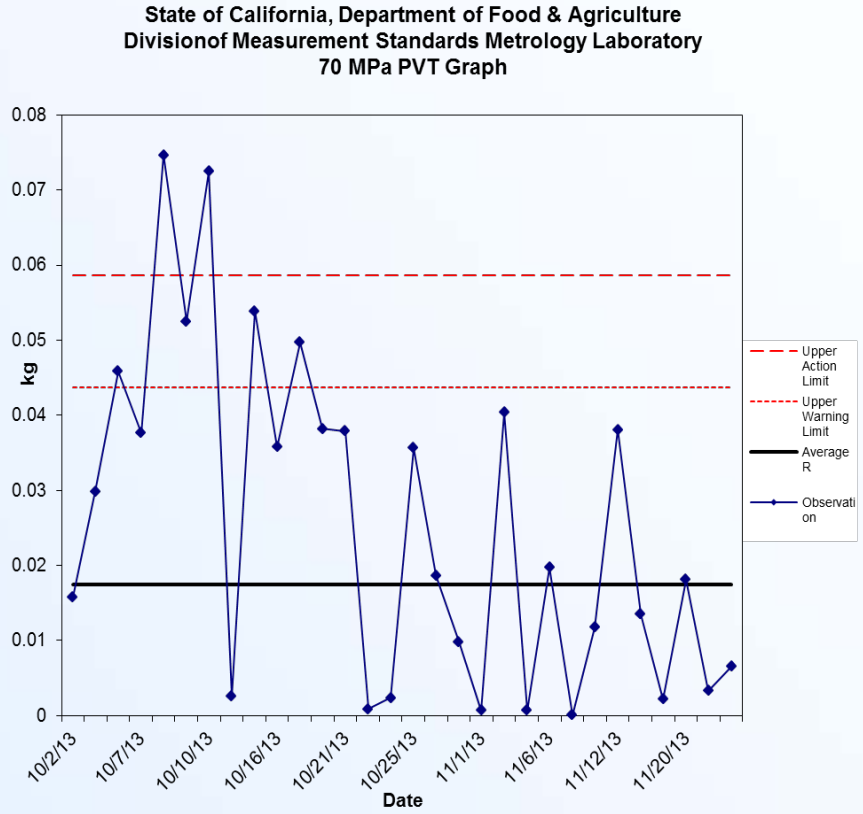


# Validation of the Reference Standard

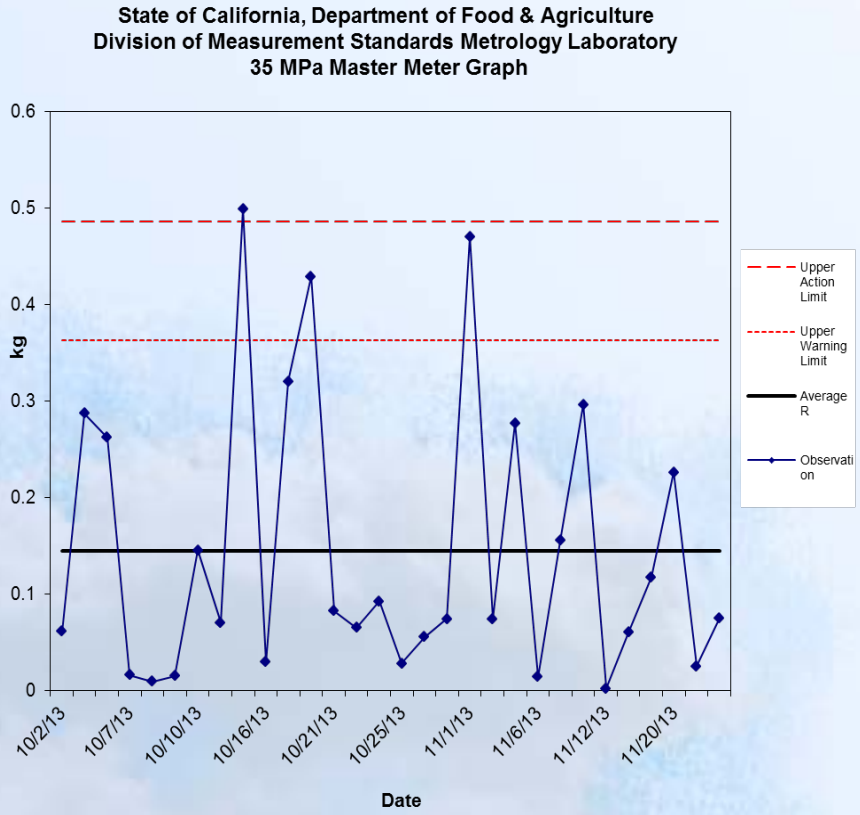
## PVT Control Charts

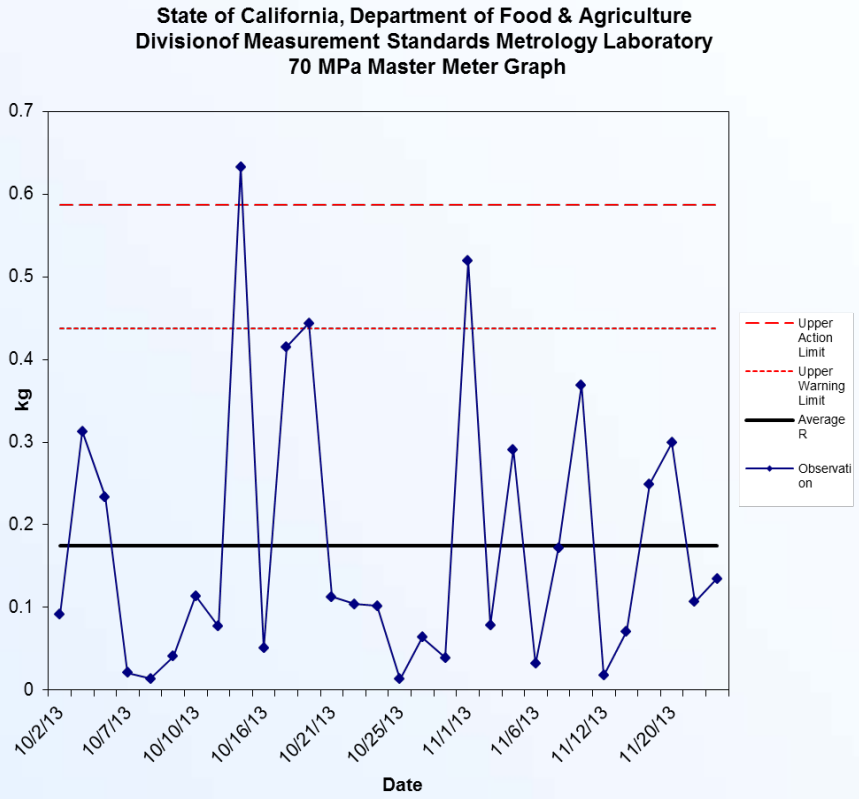


# Validation of the Reference Standard

## Master Meter Control Charts



# Assessing Control Chart Data

To calculate the expanded uncertainty, the measurement uncertainty was multiplied by a coverage factor, k, based on the degrees of freedom (number of data points, n – 1) to provide a level of confidence of approximately 95%

| 2kg 35 MPa | | | | |
|---|---|---|---|---|
| **Procedure** | **Degrees of Freedom (n-1)** | **Measurement Uncertainty** | **Coverage Factor k** | **Expanded Uncertainty** |
| Gravimetric | 19 | 2.4 g | 2 | 4.8 g |
| Volume | 29 | 15.5 g | 2 | 31 g |
| Master Meter | 29 | 144.4 g | 2 | 288.8 g |

| 4kg 70 MPa | | | | |
|---|---|---|---|---|
| **Procedure** | **Degrees of Freedom (n-1)** | **Measurement Uncertainty** | **Coverage Factor k** | **Expanded Uncertainty** |
| Gravimetric | 29 | 7.6 g | 2 | 15.2 g |
| Volume | 19 | 16.8 g | 2 | 33.6 g |
| Master Meter | 29 | 170.0 g | 2 | 340 g |

# California's Proposed Accuracy Classes* and Tolerances for Hydrogen Fuel

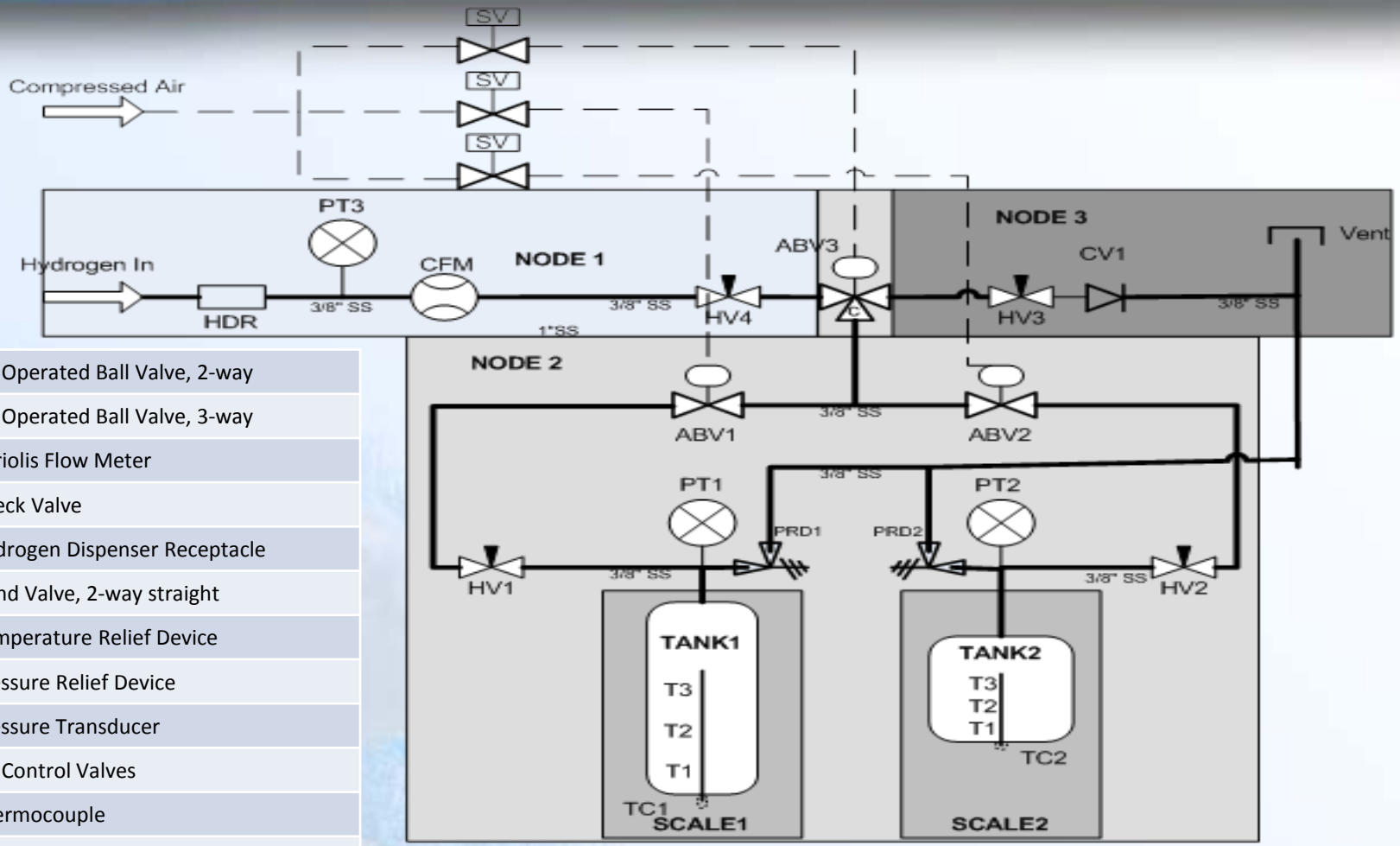
| Accuracy Class | Acceptance Tolerance | Maintenance Tolerance |
|---|---|---|
| 2.0 | 1.5% | 2.0% |
| 3.0 installed before 2020* | 2.0% | 3.0% |
| 5.0 installed before 2020* | 4.0% | 5.0% |
| 10.0 installed before 2018* | 5.0% | 10.0% |

* No new installations after the end of the designated calendar year unless regulations are further amended. Existing installations allowed to operate until decommissioned.

# Preparing the HFS for Transport

- Installed into Ford F250 pickup truck
  - 2,200lb cargo weight rating
- Custom fiberglass protective shell
  - Protection from elements
  - Security against theft and vandalism
  - Features a capped, passive vent at the high point of the roof to prevent accumulation of hydrogen
- HFS is mounted into the bed similar to the way a fifth wheel trailer is mounted

# HFS P & ID




| | |
|---|---|
| ABV 1-2 | Air Operated Ball Valve, 2-way |
| ABV 3 | Air Operated Ball Valve, 3-way |
| CFM | Coriolis Flow Meter |
| CV1 | Check Valve |
| HDR | Hydrogen Dispenser Receptacle |
| HV 1-4 | Hand Valve, 2-way straight |
| PRD 1 | Temperature Relief Device |
| PRD 2 | Pressure Relief Device |
| PT 1-3 | Pressure Transducer |
| SV | Air Control Valves |
| TC 1--3 | Thermocouple |
| UFM | Ultrasonic Flow Meter |

# HAZOPs Conducted

- Identify hazards and develop appropriate operational procedures to mitigate risks associated with those hazards
- The process used is based on NREL's experience with conducting HAZOP studies and DOE's recommendations outlined in "DOE Handbook – Chemical Process Hazard Analysis" Document # DOE-HDBK-1100-2004
- **Results of the hazard analysis show risk levels ranked in the low and routine categories.**
- These risk levels are determined to be acceptable by NREL and DOE process safety guidelines
- Process safeguards such as hydrogen detection, trained operators and overpressure protection will ensure that an acceptable level of safety is achieved when operating the metering apparatus at dispensing stations

# H2 Station Testing Plan

- Surveyed station operators last summer
  - Station capacity, dispenser features, type of meter present, timing,  etc.
- Created a list of ten stations to test with “high value” and one station for “shakedown” testing
- Presented/discussed in a November California Fuel Cell Partnership Working Group call:
  - List of stations and a weekly from monthly testing schedule
  - A proposed geographic sequence of testing
  - Adjustments made for DMS workload (2 weeks on 1 week off)
  - Sequence adjustments made for ensuring device and procedures thoroughly tested before testing at high value customer stations
- **Important:** ensuring effective communication procedures to inform customers when/how long station will be out of service

# 2014/15 California Test Schedule

## (Subject to Change)

| Testing Order | Station | Expected Evaluation Outcome | Initial Test Date | Permanence Test Date |
|---|---|---|---|---|
| 1 | Berkeley | Accuracy Assessment / shakedown | February 10-14, 2014 | Unlikely |
| 2 | Emeryville | Temporary Use Permit | March 3 – 7, 2014 | June 9 - 13, 2014 |
| 3 | Thousand Palms | Accuracy Assessment / Temporary Use Permit | March 24 - 28, 2014 | May 26 - 30, 2014 |
| 4 | Torrance | Accuracy Assessment | April 1 – 4 , 2014 | Unlikely |
| 5 | Burbank | Accuracy Assessment | April 14 - 18, 2014 | Unlikely |
| 6 | CSULA | Temporary Use Permit | April 21 – 25, 2014 | June 23 - 27, 2014 |
| 7 | Newport Beach | Temporary Use Permit | May 5 - 9, 2014 | June 30 – July 3, 2014 |
| 8 | West Los Angeles | Temporary Use Permit | May 12 - 16, 2014 | July 21-25, 2014 |
| 9 | Diamond Bar | Full Type Evaluation | July 14 - 18, 2014 | October 13-17, 2014 |
| 10 | Anaheim | Full Type Evaluation | October 6 - 10, 2014 | January 5 - 9, 2015 |
| 11 | West Sacramento | Full Type Evaluation | October 27 – 31, 2014 | January 12- 16, 2015 |

# Typical Testing Regimes

**Day 1**

- Travel to site
  - Driving to So Cal sites will take an entire day
  - *If flying - may proceed with next steps of testing regime*
- Set up, site/dispenser inspections, applications
  - Approximately 120+ min
- Pressure /safety test, run first draft
  - Approximately 120+ min for dispensing & venting 4 kg
- Breakdown
  - Approximately 60 min

**Day 2 through Day 5**

- Setup and pressure test (if necessary)
  - Approximately 90-120 min dispensing & venting 4 kg
- Run drafts
  - 5 drafts expected
  - Dispense approximately 20 kg
  - Approximately 90+ min each for venting
- Make dispenser adjustments, if appropriate
  - Continue or restart drafts/testing
- Breakdown
  - Approximately 60 min
- *Day 5 only:* return travel

**Initial Setup**

- Position HFS
- Set up cones/safety zone
- Stabilize test vehicle
- Install vent stack
- Unstrap tanks/scales
- Level HFS skid
- Warm up scales
- Calibrate scales

# Expected Outcomes

- **Issuance of a Temporary Use Permit or Certificate of Approval would allow the legal commercial sale of hydrogen on a per kilogram basis**

| Type of Testing | Description |
|---|---|
| 1. Certificate of Approval | In addition to the initial assessment, subsequent permanence testing is required. DMS Certificate of Approval issued are applicable to other stations using the same type of dispenser. Handbook 44 metered dispensers new APCI, Linde, Air Liquide dispensers. |
| 2. Temporary Use Permit | Following successful initial assessment, a limited-time, temporary use permit is issued only for the station tested. Successful permanence testing is required for a DMS Certificate of Approval. Stations with older metering technology may be one-of-a-kind or limited-use dispensers. |
| 3. Accuracy assessment | Data collected at the station to only determine the accuracy of dispenser. No follow-up permanence testing is required. No use permit is issued – reverse PVT stations. |

# Estimated Testing Costs

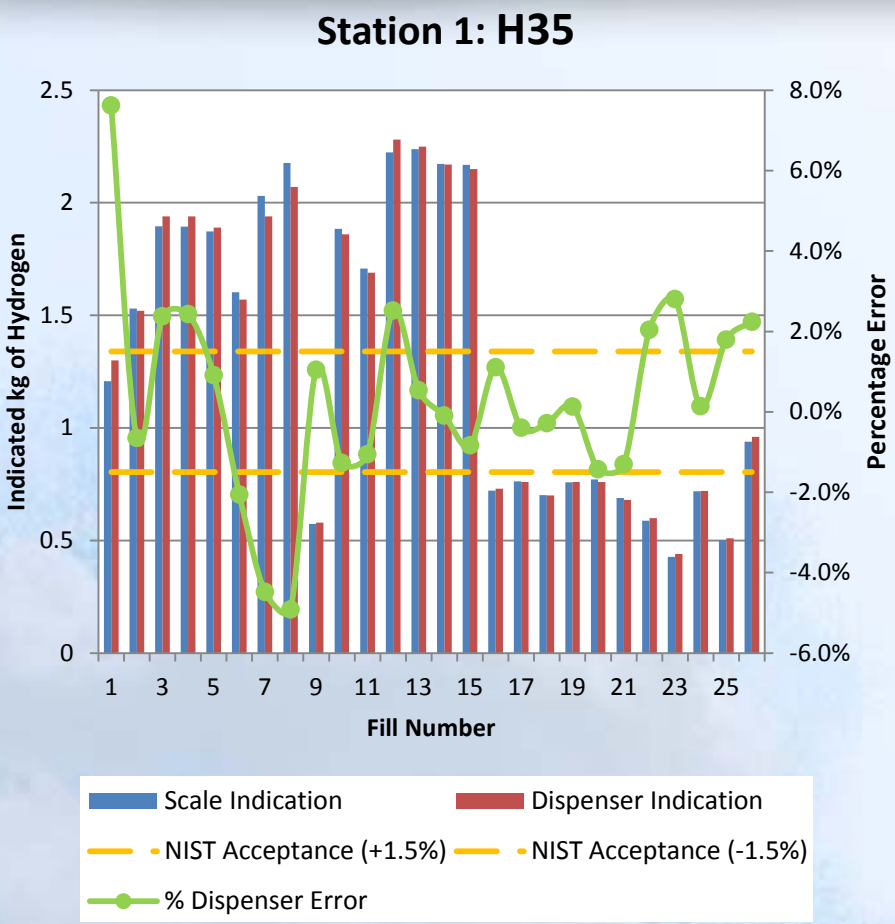
| Item | Cost Per Station | Total Approximate Cost |
|---|---|---|
| 1. DMS cost recovery | $14,000 - $26,000 | $200,000 |
| 2. Vented hydrogen | $2,100 - $4,200 | $29,400 - $33,600 |
| 3. Support from station technician(s) | $5,000 - $11,000 | $24,000 - $75,000 |
| 4. Contingency | - | $38,000 - $46,000 |
| Total Estimated Cost/budget | | $291,000 - $355,000 |

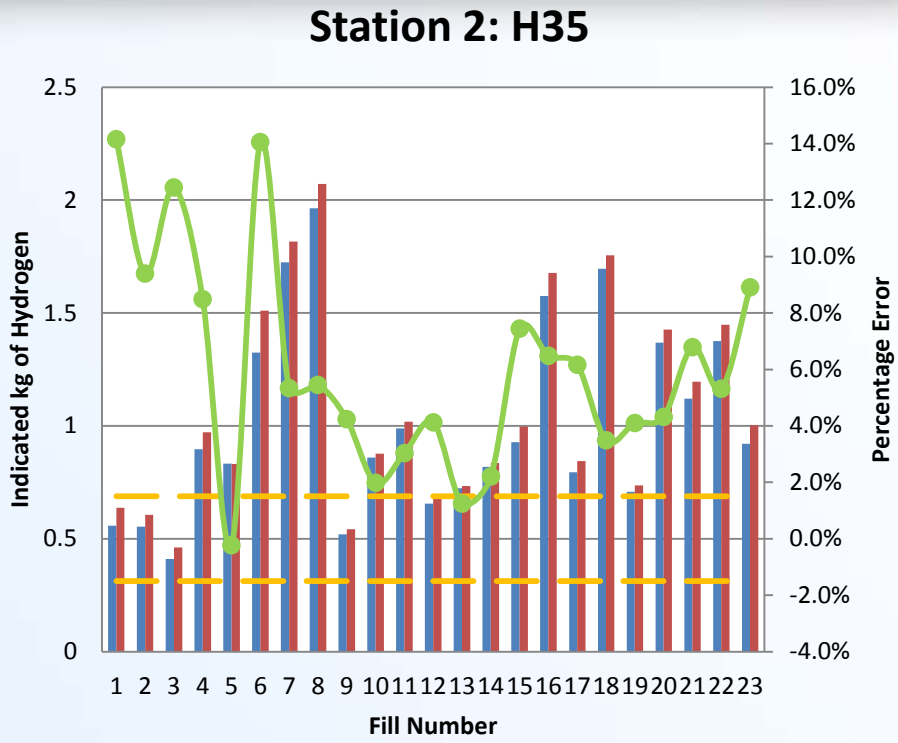
- DMS mandated to recover all costs including, tests, travel, data analysis, etc
- 150-300kg of H2 will be vented - $14/kg
- 27-60 hours of technician support labor - $175/hr
- Costs may be less depending on cost share and other potential efficiencies
- Contingency cost is 15% of the total of item 1,2,3 for unforeseen expenses
- Testing program funded collectively by CARB, California Energy Commission, South Coast Air Quality Management District, and the California Fuel Cell Partnership

# Ownership and Sharing of Testing Data/Results

- Test data (e.g., checklist, data calculations for individual draft fills, etc.) are considered working notes
- Working notes are considered “exempt” from public disclosure
- DMS will sanitize results (Pass/Fail, % Accuracy) and release information after multiple stations have been tested so data cannot be traced to a particular station
- Final results will be very public – No sticker (Fail), Temporary Use Permit sticker (Pass initial tests), Approval Seal and Accuracy Class sticker with +/- 2%, 3%, 5% or 10% accuracy (Pass all tests and Certificate issued)

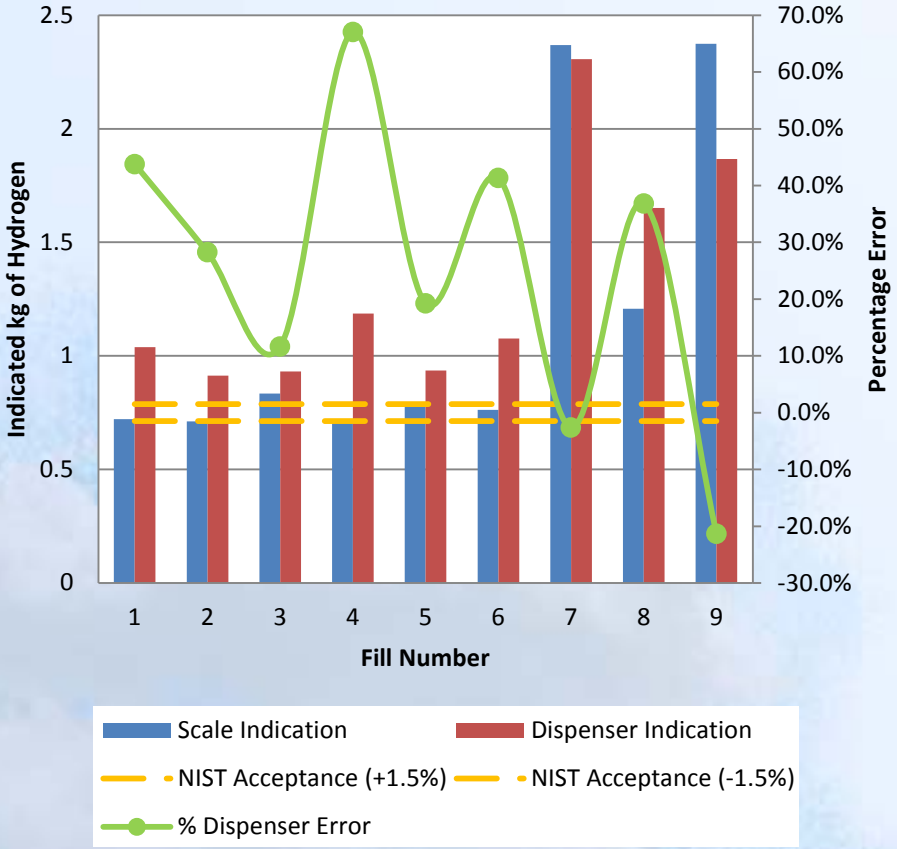
# H35 Dispenser Delivery and Associated Errors



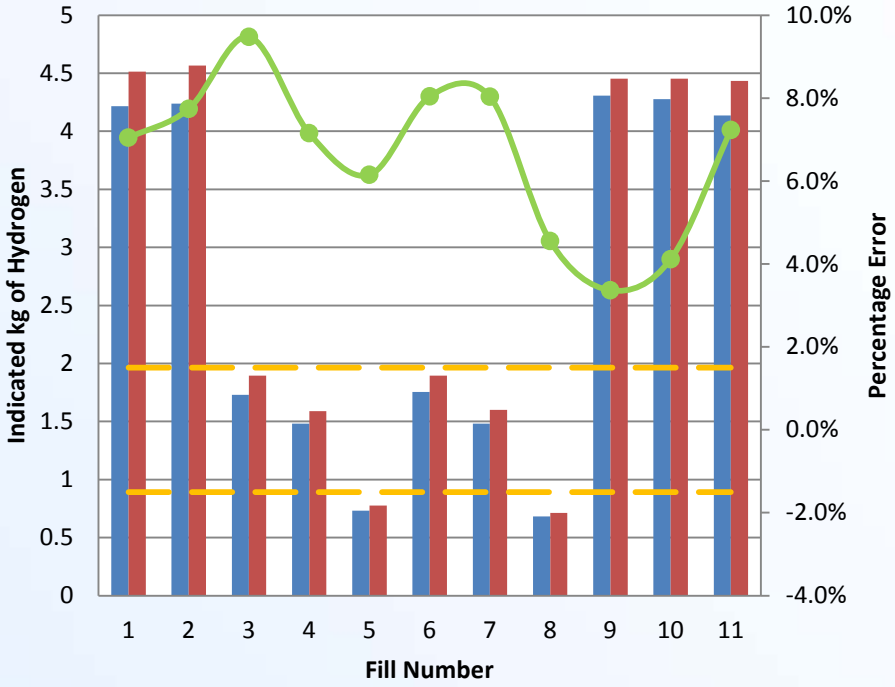



# H70 Dispenser Delivery and Associated Errors

## Station 3: H70

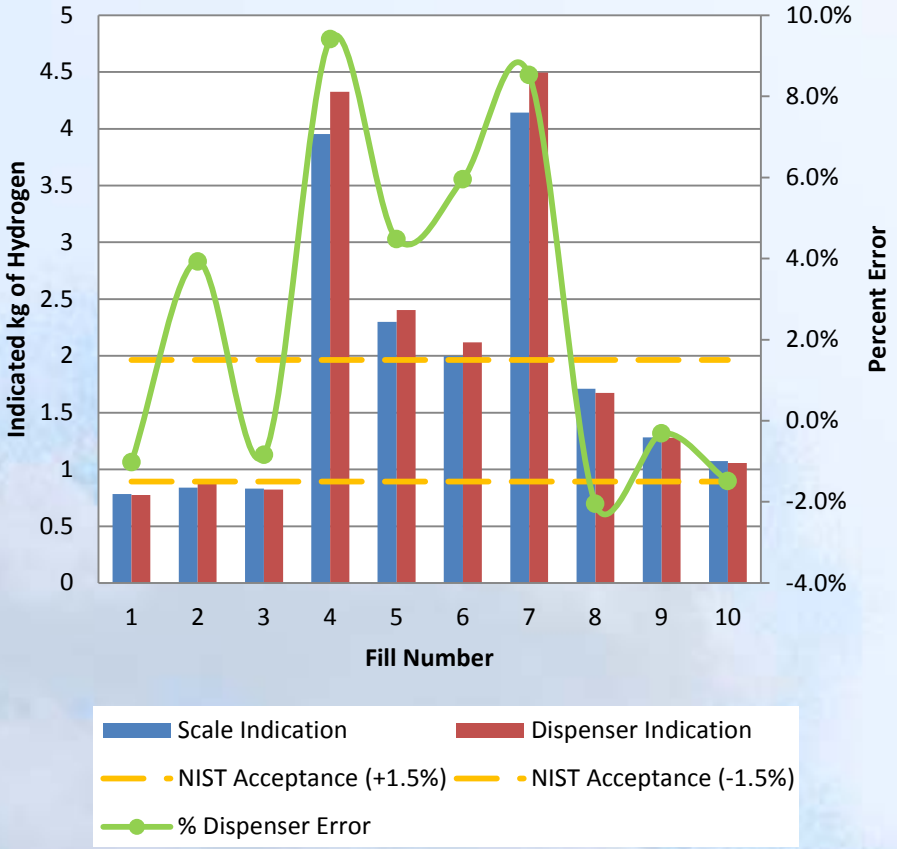



## Station 4: H70

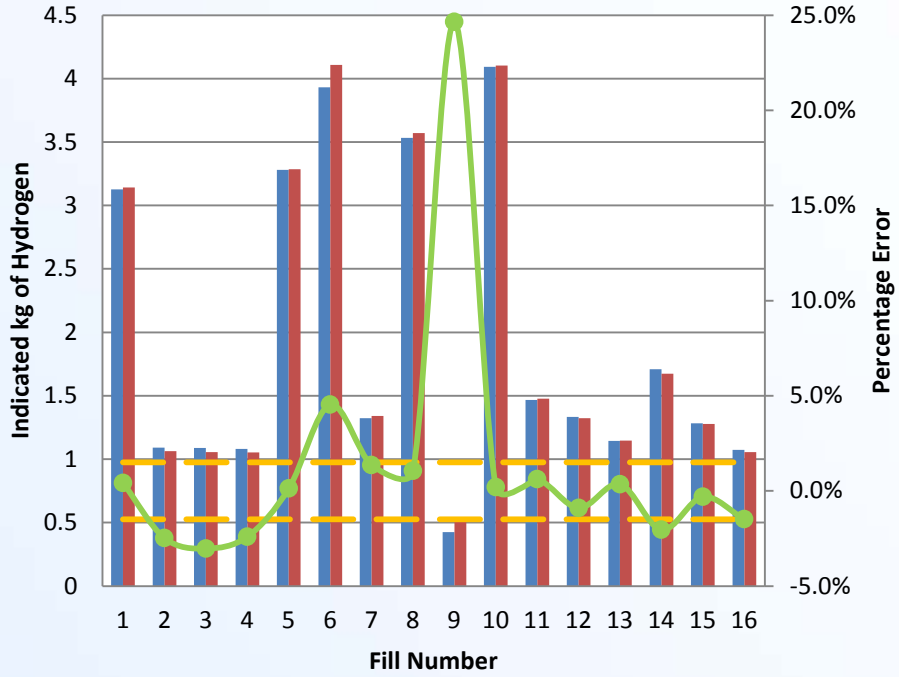


# H70 Dispenser Delivery and Associated Errors

## Station 5: H70




## Station 6: H70



# Expected/Observed Demonstration Dispenser Deficiencies

California Code of Regulations, Title 4, Division 9.

- **Provision for Power Loss** - Need to maintain transaction information on display during a power loss.
- **Display of Quantity and Total Price** - Transaction information needs to be displayed for 5 minutes after the completion of delivery.
- **Provision for Sealing** - The measuring device electronics is exposed allowing access to adjustment parameters.
- **Pressurizing the Discharge Hose –** The discharge hose is not pressurized until after the start of a delivery preventing the customer from receiving metered dispensed product due to venting of the discharges hose at the end of a delivery.
- **Identification Plate –** The identification plate does not have the designated markings for the model number, accuracy class listing, maximum/minimum flow rate in kilograms per unit time, maximum working pressure, minimum measured quantity, and the product for which the dispenser will dispense.
- **Display Resolution –** Resolution should be 1 gram.
- **No Receipt Available –** Recorded representations are not available to customer.

# Challenges, Lessons Learned, Recommendations – To Be Continued

- Coriolis meter in master meter standard exhibited a limited capability to measure gas flows accurately at high pressures and low densities.
- Original plan had a validation process that required 35 and 70 MPa data collection daily for 30 consecutive days at a stations in California. This would interrupt normal station operations. Instead, validation was conducted at NREL's facility.
- Procurement of 70 MPa high volume stationary storage tank created a significant delay. The first tank ordered failed to meet specifications.
- A larger truck bed and enclosure to house the HFS would be preferable. Limited space makes setup, adjustments, and repairs difficult.
- Measurement compensation/corrections may need to be me made for ambient conditions such as wind, relative humidity, and temperature.
- Device design requires careful attention be paid to hydrogen dispenser flow rates.
- Dispenser accuracy at minimum measured quantity remains challenging for today's dispensers.