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Hydrogen Component Validation

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Project ID #TV019

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

Overview

Timeline and Budget

- Project start date: Oct 2012
- Project end date: TBD
- DOE funding
  - FY16 $47k (carryover)
  - FY17 $0k
- Total DOE funds received to date: $758k

Barriers

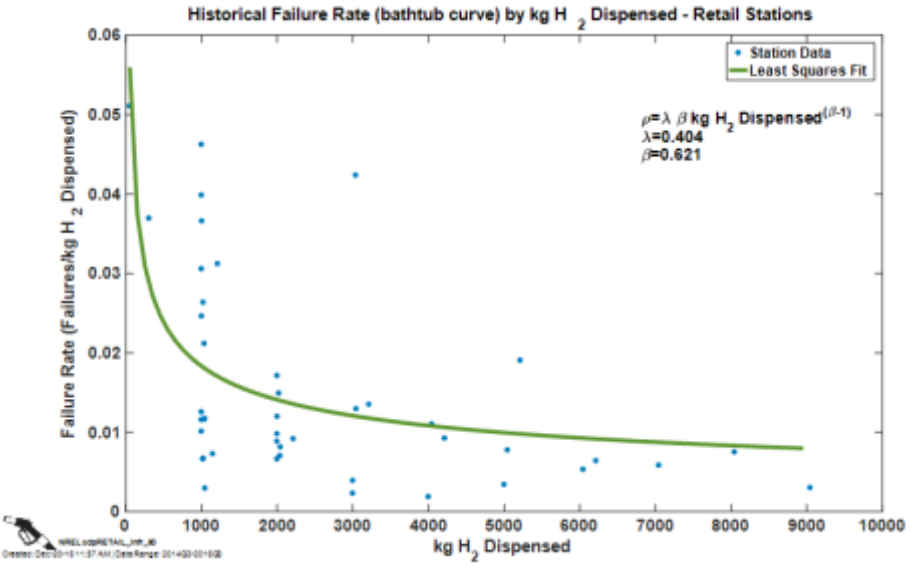
- D. Lack of Hydrogen Refueling Infrastructure Performance and Availability Data

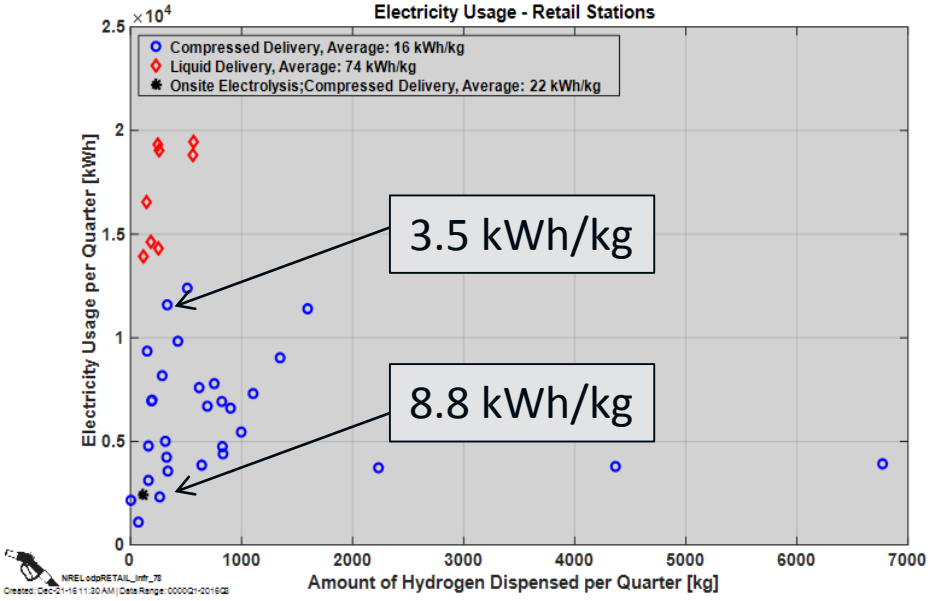
Partners

- PDC
- PPI/Sundyne
- Shell Hydrogen
- CSULA
- SCAQMD
- Sunline
- H2Frontiers
- ANL
- Proton OnSite
- First Element

Relevance

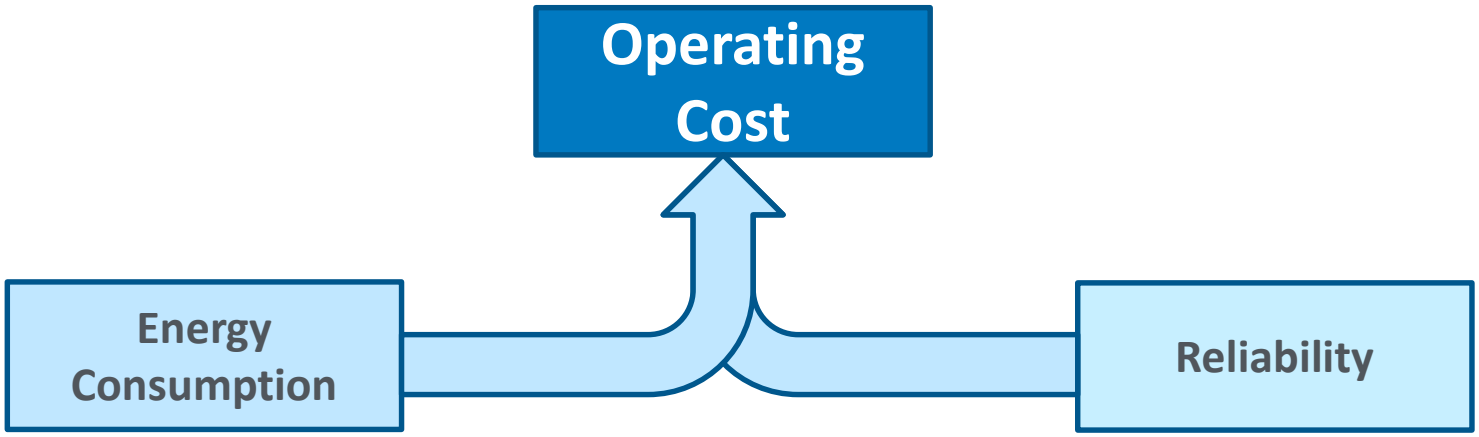
- **Issues**
  - Energy cost contribution to station is not well understood
  - Station reliability is very poor at the beginning of operation
  - Training a growing workforce





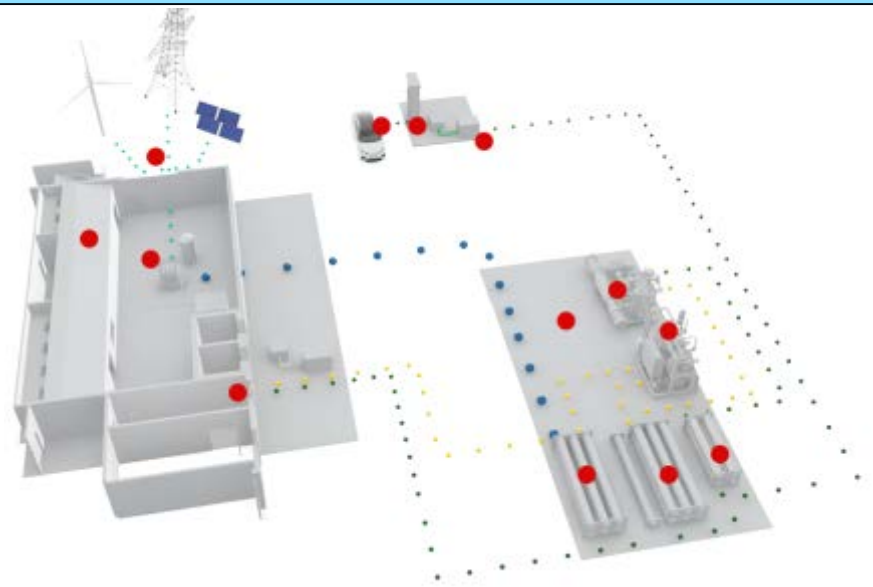
Relevance

- **Objectives**
  - Understand common failures at hydrogen stations
  - Understand the source of particulate contamination in hydrogen stations
  - Quantify the costs incurred when operating a hydrogen station

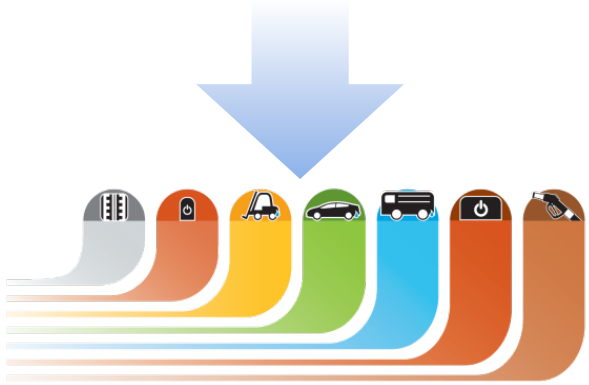


Approach – Energy Consumption Data Collection

Compare AC and DC power and energy meters at HITRF with aggregate power and energy data from retail stations



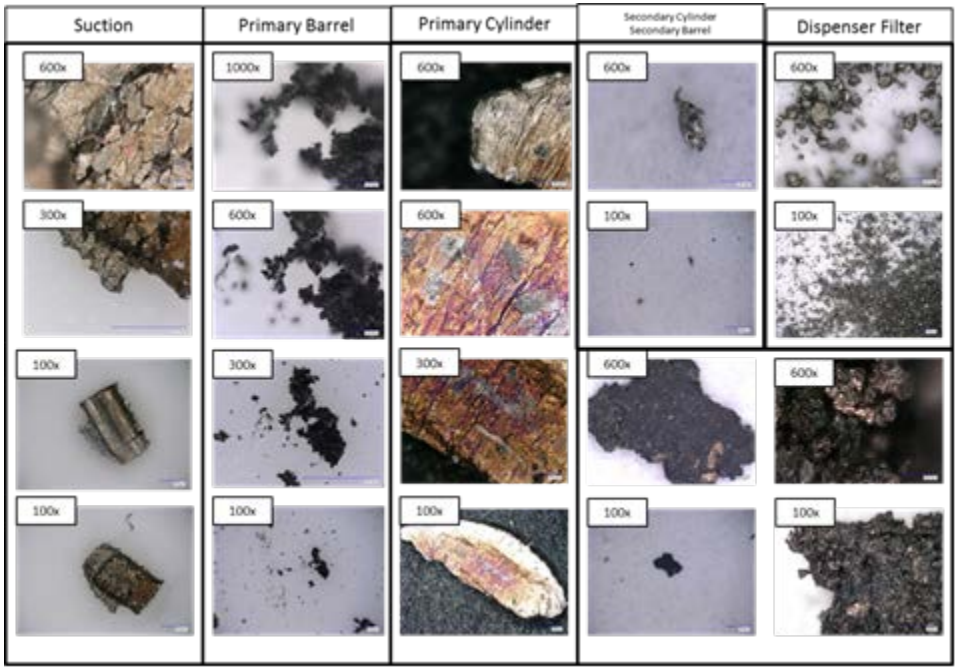
Component	Maximum Hydrogen Flow Rate	Major Electrical Rating	Balance of Plant Electrical Usage
Hydrogen Pre-Cooling Compressor	N/A	6.7 kW	N/A
40 MPa Compressor	2.3 kg/hr	15 kW	2.5 kW
90 MPa Compressor	18 kg/hr	30 kW	3.9 kW
PEM Electrolyzer	4.5 kg/hr	250 kW	7.6 kW



NREL's National Fuel Cell Technology Evaluation Center

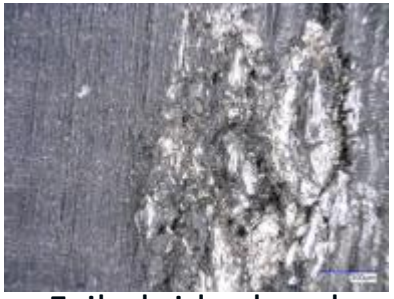
Approach – Failed Part Collection and Analysis

Understand common failures on a detailed level that lead to downtime



Material from throughout a failed compressor

Failed valve seal



Failed rider band

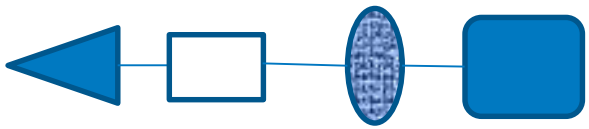
Failed check valve

- 11 retail stations participating – filters, compressor parts, particulate
- 1 non-retail station – check valves, valve seats, filters, tubing
- High prevalence of metal particulate in the failed parts
- Optical and SEM analysis performed – metals found are 316 SS

Approach – Tube Cleaning Practices – Metal Particulate

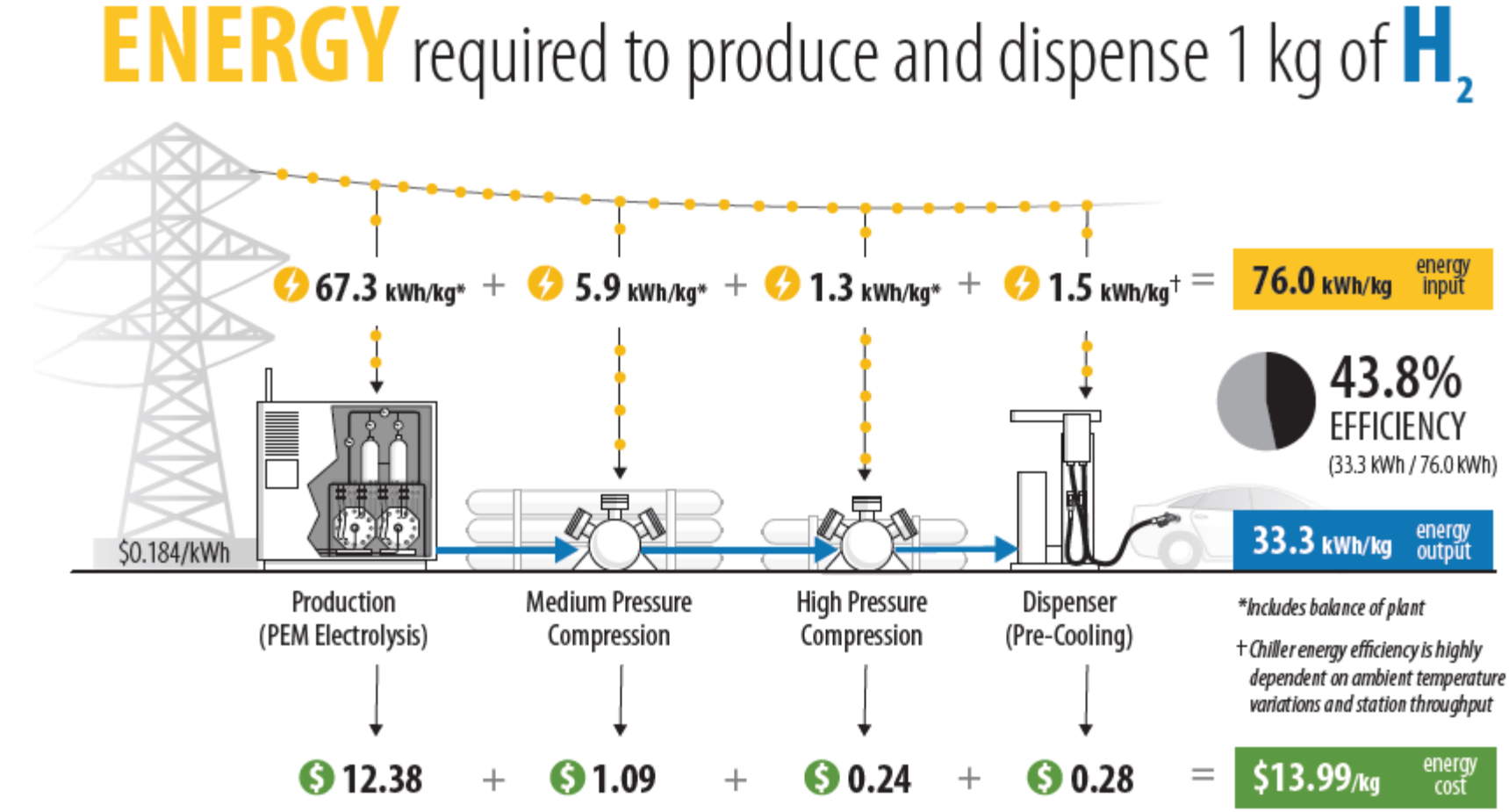
Determine the impact of tube cleaning techniques on particulate contamination

Tubing cut, beveled and threaded	Tubing cleaned using three common techniques	Hydrogen passed through tube with filter collection



Accomplishments and Progress – HITRF Station Energy

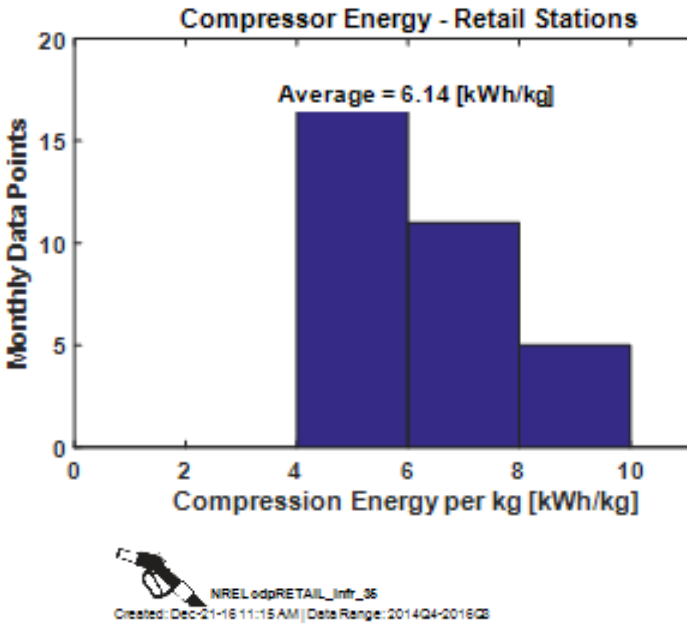
Energy Consumption of Major HITRF Station Components Quantified

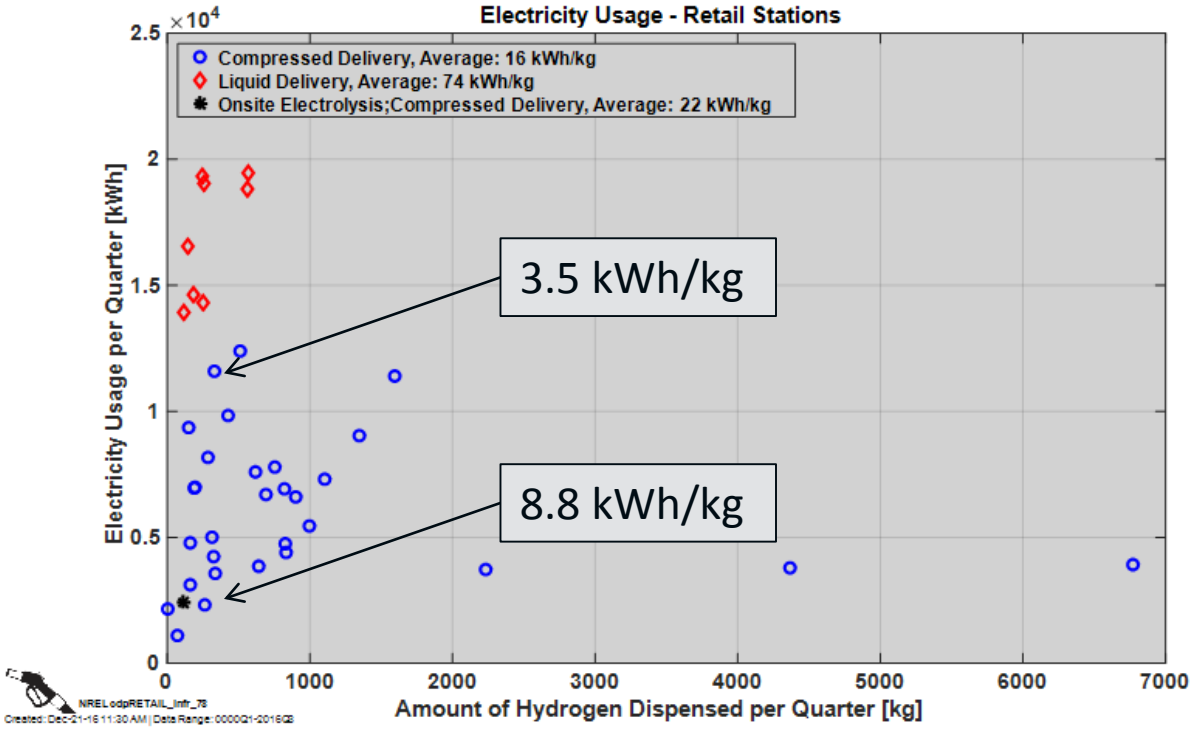


"By 2020, reduce the cost of hydrogen compression, storage, and dispensing at on-site production stations to **< $2.15/gge** to meet the production and delivery cost target of <$4/gge by 2020 (2007 dollars) (untaxed, delivered, dispensed). " – *FCTO MYRDD Hydrogen Delivery 2015*

Accomplishments and Progress - Energy Comparison

HITRF Energy Measurements Agree with Retail Station Data, somewhat…





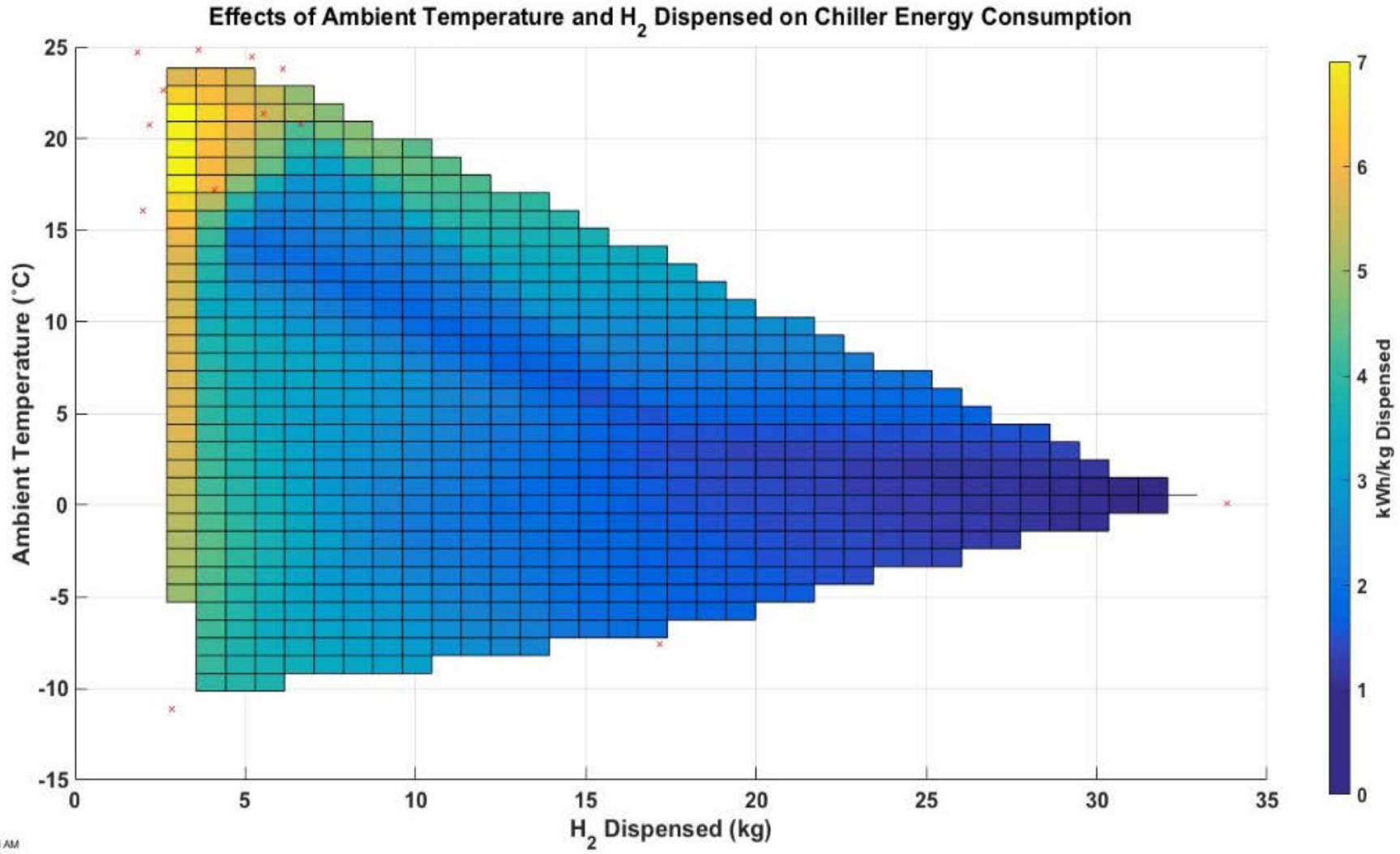
HITRF: 6.5 kWh/kg
Retail: 6.14 kWh/kg

HITRF: ~ 6 kWh/kg*
Retail: 3-9 kWh/kg

*90MPa compression and chilling only

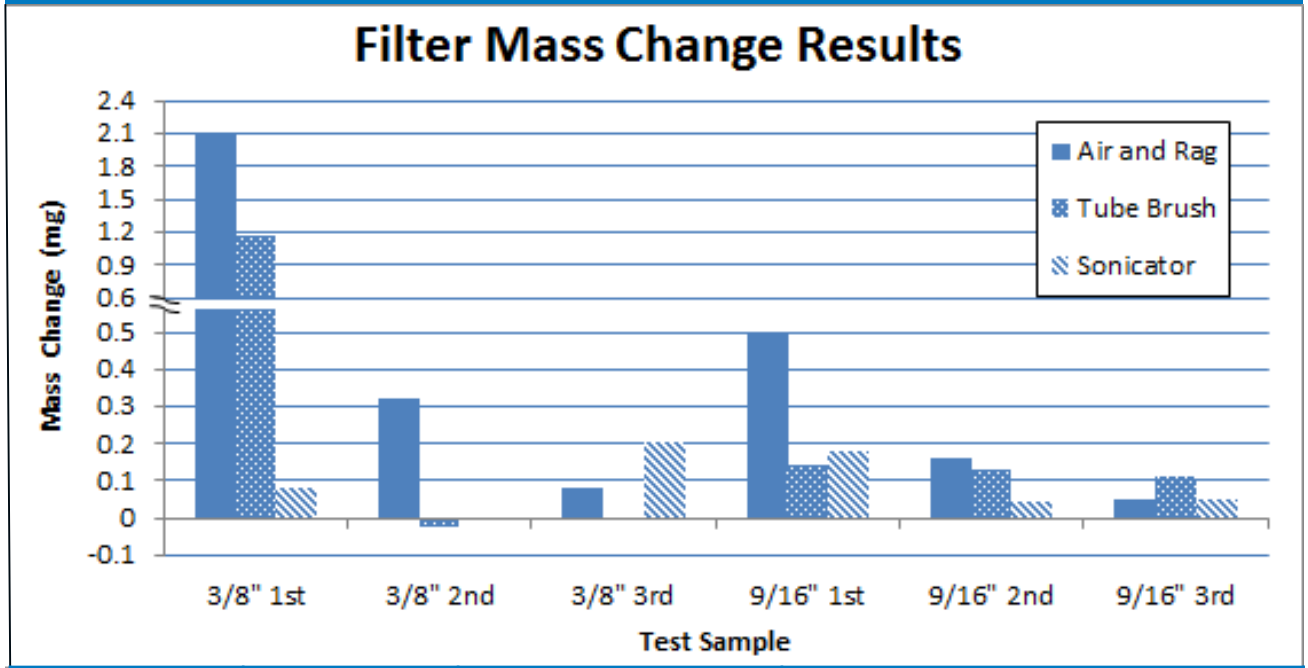
Accomplishments and Progress – Chiller Energy Map

Compressor efficiency is constant, yet chiller efficiency variable



Accomplishments and Progress – Metal Particulate Results

Tube Cleaning Results Show Impact of Cleaning Methods on *Mass* of Particulate Collected



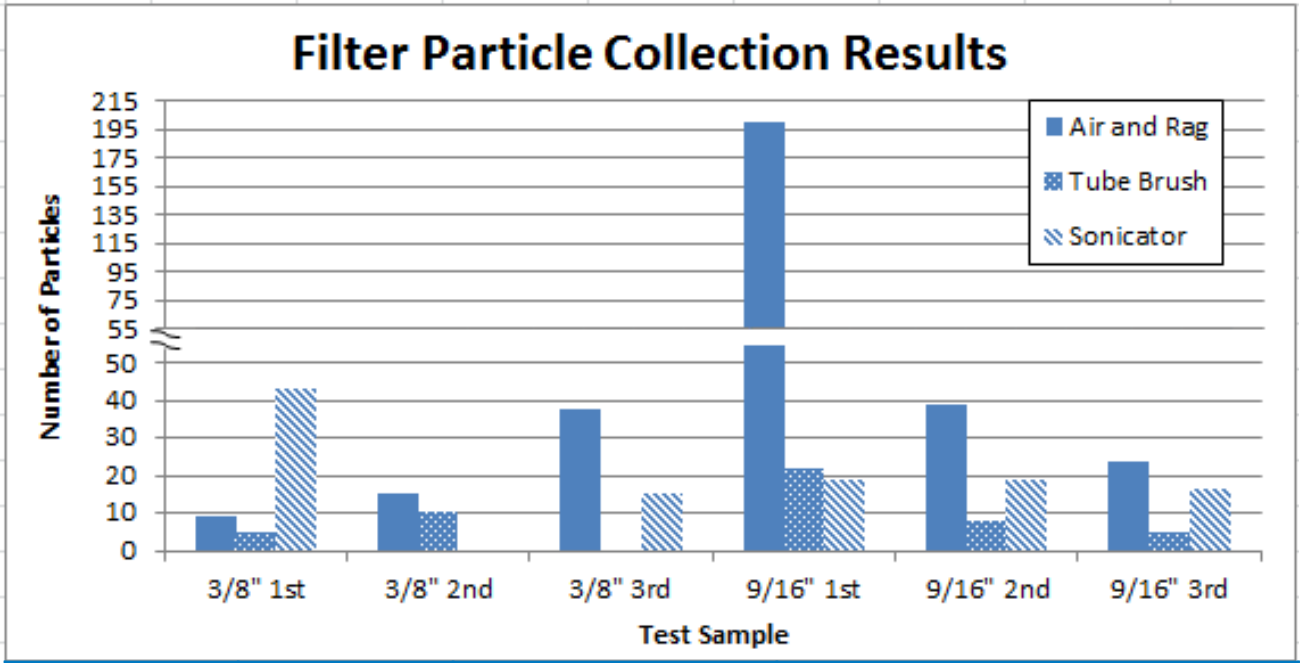
Category	Mean (mg)	Median (mg)	Standard Error (mg)
3/8” OD	0.56	0.2	0.13
9/16” OD	0.15	0.13	
Air and Rag	0.53	0.24	
Tube Brush	0.30	0.13	
Sonicator	0.11	0.08	

Take Aways

- Air and Rag method worse than Sonicator
- Outliers (1st samples) due to cutting oil
- 3/8” OD tubing filters had more mass change than 9/16” OD tubing filters (gas travels at higher velocity through smaller tubing)

Accomplishments and Progress – Metal Particulate Results

Tube Cleaning Results Show Impact of Cleaning Methods on *Number* of Particulate Collected



Category	Mean	Median	Standard Error
3/8” OD	19	15	11
9/16” OD	39	19	
Air and Rag	54	31	
Tube Brush	10	8	
Sonicator	22	19	

Take Aways

- Air and Rag method worse than Tube Brush and Sonicator
- The number of particles collected on filters for the 3/8” OD and the 9/16” OD show more particles on the 9/16” tubing, but means and medians were not outside of the standard error

Responses to Previous Year Reviewers' Comments

- "**Increased collaboration** with stakeholders **through the H2Tools** platform was recommended for the components project"
  - A section has been added to the H2Tools site for contaminant collection
  - With the recently obtained results on hydrogen station energy consumption, NREL will work with H2Tools administrators to add more information
- "Based on the presentation, the objectives and the areas of focus are consistent with H2USA priorities. However, **it is not clear how the objectives** and areas of focus **address barriers identified by the U.S. Department of Energy (DOE).** The presentation should show the barriers being addressed"
  - US DOE barrier addressed is "D. Lack of Hydrogen Refueling Infrastructure Performance and Availability Data"
- "The **project should focus on compressor operation and reliability**, as this component has had the highest downtime and maintenance"
  - Many of the failed parts collected came from compressors. While it is difficult to definitively say that metal particulates are the cause of the failure, they certainly are present where they are not intended to be

Collaborations

Compressor performance and reliability

- PDC
- PPI/Sundyne

Providing expert advice on compressor failures and station fabrication techniques

Contaminant Collection

- Shell Hydrogen
- CSULA
- SCAQMD
- Sunline
- H2Frontiers
- Proton OnSite
- First Element

Provide samples to NREL and descriptions of equipment failures

Remaining Challenges and Barriers

- Representing high throughput stations (HITRF upgrades)
  - Spring 2017: Larger chiller and heat exchanger
  - Fall 2016: More 90 MPa and 20 MPa storage
- More failed parts needed – new outreach efforts will be made
- Impress importance of tube cleaning on hydrogen community – potential paper presentation at International Conference on Hydrogen Safety 2017

Proposed Future Work

- Update chiller performance map with data from upgraded pre-cooling system
- Outreach program for station fabricators on tube cleaning techniques
- Quantify the impacts of variable suction pressure on compressor efficiency
- Continue to collect failed parts and perform analysis

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

Technology Transfer Activities

- none

Summary

- **Energy consumption for major station components quantified**
  - Chiller performance shown to be highly dependent on ambient temperature and station throughput, ranging from <1 kWh/kg to 7 kWh/kg
  - Compressor performance found to be constant around 4-6 kWh/kg
- **Metal particulates found to be common in failed parts collected from stations**
- **Effect of tube cleaning techniques on reducing metal particulates quantified** – plugging with a tube brush does not require significant additional effort, yet it can reduce metal particulates generated during tube cutting, beveling and threading

Technical Back-Up Slides

Technical Back Up – Electrolyzer System Efficiency

The INTEGRATE project TV031 is looking into ways to improve PEM electrolysis system efficiency when operating in a variable power supply environment, which may generate additional revenue streams. The efficiency used in Slide 8 were taken from the following data.