High Pressure, High Flow Rate Dispenser and Nozzle Assembly For Heavy Duty Vehicles

Project
ID# TA049

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Electricore, Inc.
DOE Agreement #DE-EE0008817
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Project Goals

- Develop a dispenser and nozzle assembly (nozzle, receptacle, hose, and breakaway) capable of fueling heavy-duty (HD) vehicles
- Test and demonstrate the system at the National Renewable Energy Laboratory (NREL) and under real-world conditions
- Based upon industry feedback, the team will target 100 kg fueling in 10 minutes at a nominal pressure of 70 MPa and will meet key industry standards
- The heavy-duty dispenser and nozzle assembly (HDND) will accelerate the development and adoption of sustainable transportation technologies.

Overview

Timeline

- Project Start Date: 10/01/2019
- Project End Date: 10/31/2022
  - Phase 1 – Specification and Design (Complete)
  - Phase 2 - Manufacturing, Testing and Demonstration (Ongoing)

Budget

- Total Project Budget: $3,329,225
  - Total Recipient Share: $750,188
  - Total Federal Share: $2,579,037
  - Total DOE Funds Spent*: $1,296,205
  - Total Recipient Share Spent*: $417,954

* As of 03/31/2022

Barriers and Targets

- **Barriers**
  - A robust, domestic manufacturing and component supplier base for hydrogen and fuel cell technologies needs to be developed
  - Lack of Hydrogen Refueling Infrastructure Performance and Availability Data to revise standards
- **Targets**
  - Support efforts to reduce the cost of manufacturing components and systems to produce and deliver hydrogen at <$4/gge (2007 dollars)

Partners

- Electricore Inc. – Federal Project Manager / PI
- WEH Technologies Inc. – Nozzle Technology Provider
- Bennett Pump Company – Dispenser Technology Provider
- Quong & Associates Inc. – Technical Lead
- NREL – Testing Facility

Relevance to DOE Goals

DOE Goals

- Lower greenhouse gas emissions
- Create good-paying jobs in the U.S.
- Build clean energy infrastructure
- Support environmental justice

Project Goals

- Acceleration of the development of H70 high flow components will reduce roadblocks for the entry of HD hydrogen vehicles
- The project will increase domestic jobs at the project partners (Bennett, WEH) and expand the entire industry
- Expansion of hydrogen trucks will reduce emissions in communities unfairly impacted by pollution

Barriers and Impacts

The HDND project address the need for and enables wide-scale hydrogen production, delivery, storage, and use across HD vehicle sector.

Barriers

- No commercial-ready HD H70 dispensers or nozzle assemblies are limiting expansion of HD H2 vehicles
- No clear specifications for diverse market with varying vehicle and station size and capabilities
- No data or real-world experience with new market and components

Project Goals

- Develop commercial ready HD dispenser (one) and three nozzle assemblies to lower fueling costs
- Survey HD vehicle, station, user, and supplier industry to develop specifications for the HD market
- Test HDND at NREL's Hydrogen Infrastructure Testing and Research Facility and then demonstrated under real-world conditions

It will incorporate a new high flow rate nozzle with a specialized dispenser for a complete, integrated, high throughput fueling solution.

Approach

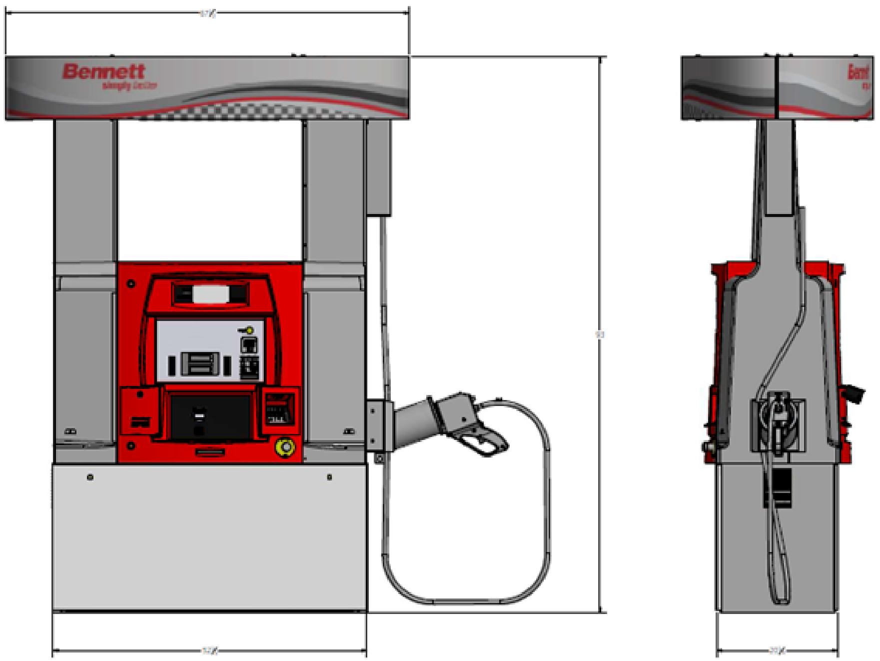
- Industry stakeholder survey and Specifications (Complete)
- Develop specification and design of heavy-duty dispenser and nozzle assembly (Complete)
- Go/No-Go Decision: Design Review (Complete)
- Manufacture and testing of components (Ongoing)
- Real-word HD station demonstration (Target July-Aug 2022)
- Publish results of the testing and demonstration

Deliverables

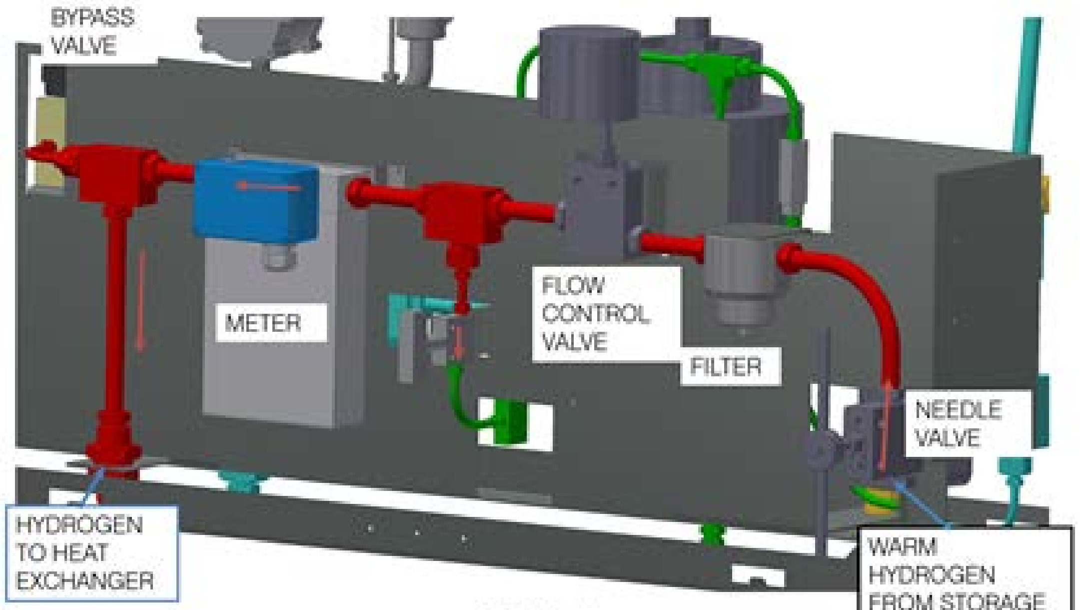
- Specifications report
- Design report
- 3 HD nozzle assemblies
- 1 HD dispenser
- Component and system testing
- Real-world demonstration
- Final report

Approach: Dispenser

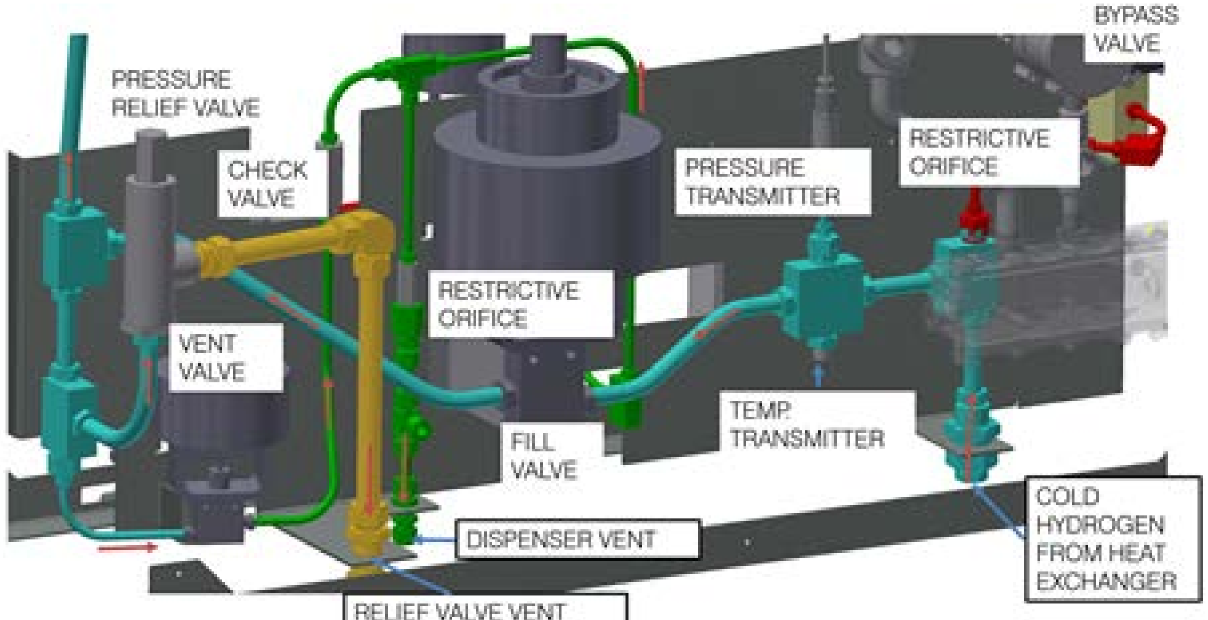
- Dispenser design and software complete
  - Will initially use SAE J2601 CHSS D protocol
  - Considering other HD protocols, including EU PRHYDE
- Build started April 2022
- Following HGV 4.1 for most factory tests including but not limiting to:
  - Pneumatic Strength / Leak check
  - Dielectric Voltage
  - Calibration
  - Functional tests
  - PLC I/O Tests
  - IDRI Extended OD (optional data field)
- Nozzle boot mounted on the side of the dispenser to prevent interference with vehicles.
- Support both Type B and Type C nozzles
- Test breakaway, hose and nozzle interface to dispenser



Dispenser Design



Front Angle

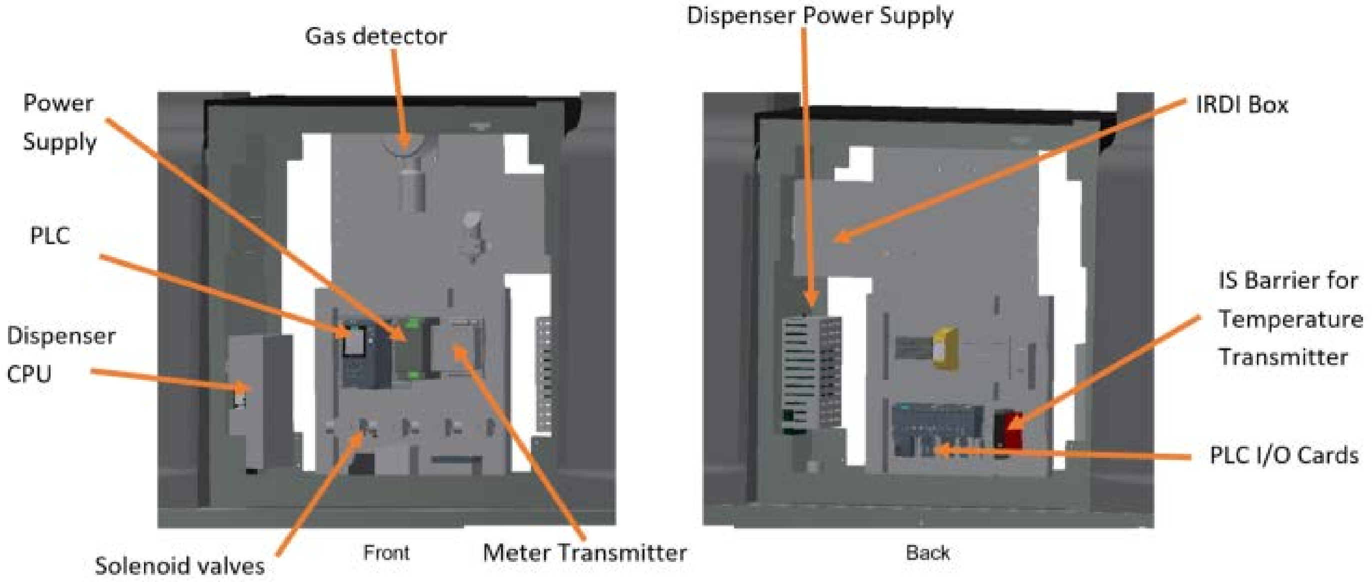


Back Angle

Dispenser Design

Bennett Dispenser Controls:

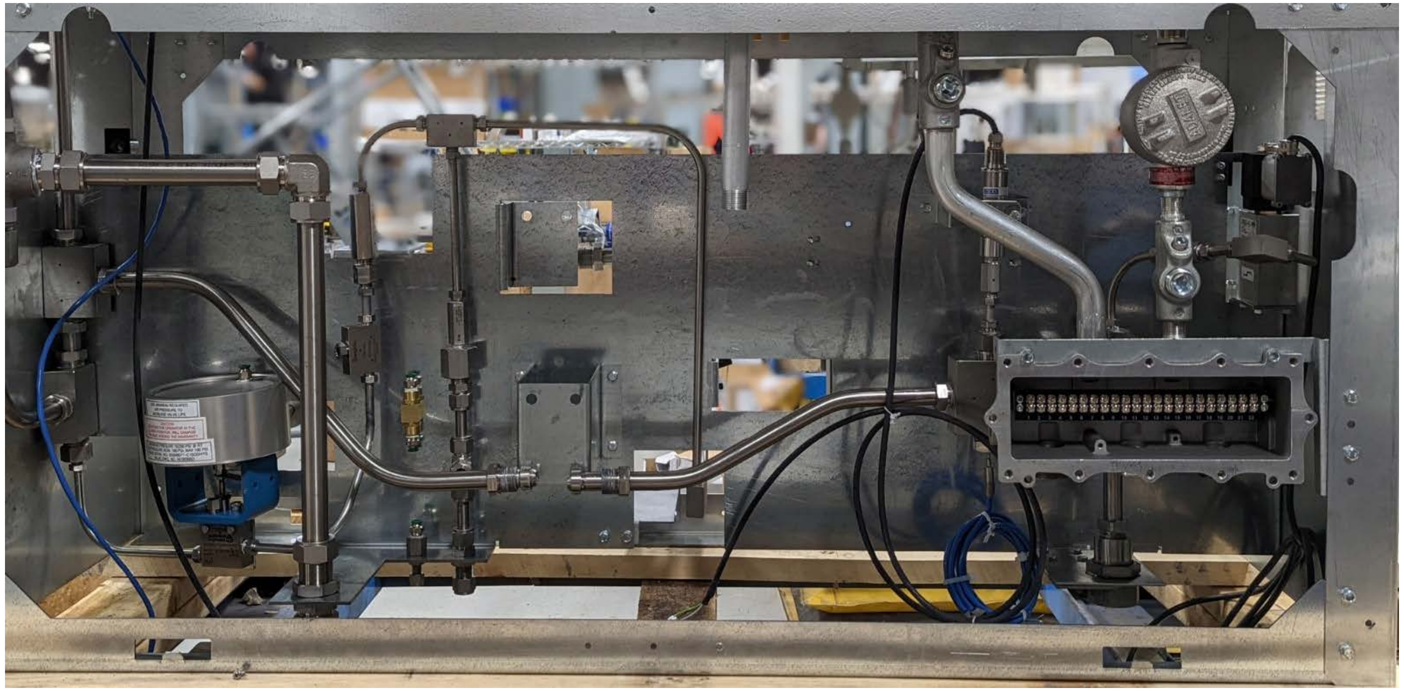
- Filling algorithm protocol
- IRDI interface to vehicle
- Valve control interface
- Meter pulse input
- Modbus communication to dispenser, meter and external PLC (station)
- Modbus communication to the nozzle
- ESTOP interface
- Ambient temperature
- Thermocouples
- Pressure Sensors
- Gas Detectors
- Payment CPU Interface



Dispenser Design

Standards dispenser is being designed to:

- CSA HGV 4.1*, 4.3*, 4.9*
- SAE J2601*+, 2799
- NFPA 2
- ASME B31.2
- ISA 12.13.03
- CSA C22.1



Dispenser build at Bennett

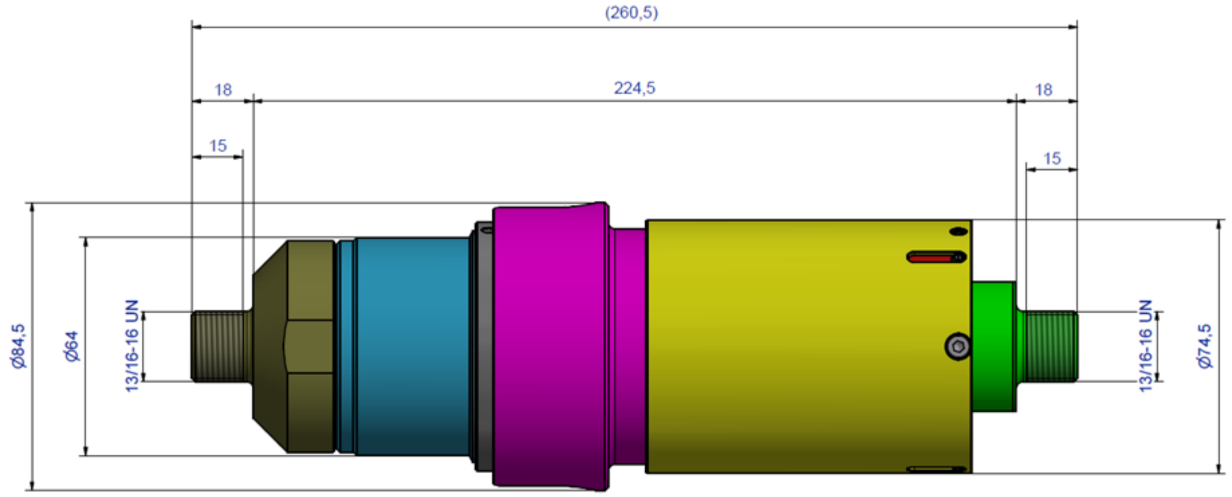
* Modified for heavy duty
+ Team engaging with standards group

Approach: Nozzle Assembly

- Type C nozzle with purging line
  - Bore ID = 10 mm
- Prototype built and undergoing initial functionality testing
- Will include electrically activated interlock and display
- Final component testing based upon ISO 17268 with limited durability cycling

Nozzle Assembly

- Single hose, single breakaway design
- Prototype breakaway built and undergoing initial functionality testing
- Hose supplier selected and initial testing underway
- Final testing based on ISO 19880-3, 19880-5, and CSA standards with limited durability testing



HD breakaway (left) compared to LD breakaway (right)

Nozzle Design

Nozzle assembly is principally being designed to fulfill some of them following standards if applicable

- CSA HGV 4.2*. 4.4*
- SAE 2799
- ISO 19880-3*, -5*, 17268*+
- PED

LD nozzle/receptacle (top)
compared to
HD nozzle/receptacle (bottom)

* Modified for heavy duty
\+ Team engaging with standards group

Approach: NREL Testing & Demonstration

- NREL team preparing for installation and testing of HDDN system into NREL HD research station.
  - P&ID, installed interconnects, drafted test plans, process hazard analysis, risk assessments, and design reviews
  - Provided NREL baseline requirements for evaluating hardware at the laboratory (pressure, temperature, electrical, certification, etc.)
  - Discussing hardware implementation plans with SMEs and AHJs specifically regarding hydrogen setback distances for NFPA 2 compliance.
- Commissioning NREL HD Station (under IHS project) through May 2022
  - Relaying observed performance, data, and concerns to project team(s) for dispenser design considerations.
- Supporting other collaborations (e.g., EU PRHYDE) for HD fueling protocol development at NREL HD station.

NREL's HD Hydrogen Infrastructure Testing and Research Facility

Accomplishments

- The design phase is complete (Budget Period 1), and build has started (Budget Period 2)
- Bennett Pump dispenser team engaging EU PRHYDE program and others to install additional fueling protocols
- Initial testing on nozzle assembly prototypes positive and initial testing should be complete by end of May 2022
- Installation scheduled to begin July-August 2022 at NREL HD research station
- HDND team engaging EU PRHYDE program and others to install additional fueling protocols

Reviewer Comments

Reviewer Comment	Response
The extent to which new standards and/or standards revisions will be necessary to drive compatibility and interoperability is unclear. Changes in driving standards do not appear to be part of the scope of this project, but an understanding is needed of whether the solution is completely bound by existing standards and what needs to change, and this should be appropriately identified. The widespread adoption of technological developments will be dependent on interoperability. Also, there was no mention of communication specifications.	All of the components will be designed and tested to existing SAE, CSA, and ISO component standards modified for heavy duty, including SAE J2799 standard (with limited durability testing). The team is working directly with standard groups to inform them of any changes needed.
Address supply chain robustness and manufacturing challenges for mass commercialization, considering technology compatibility with other hydrogen pressures or cryogenic hydrogen, addressing cost impacts of technology, and challenges with different station integration approaches.	After survey of the industry, the team decided to focus on 70 MPa gaseous hydrogen components, especially since 35 MPa high flow components are already in the market. Cryogenic hydrogen was outside the original DOE FOA and project scope.
Building a mechanical design for the dispenser is likely not the highest-risk or most challenging portion of a commercially viable dispenser. External interface standardization and the integration of components into a single package to support quality, testing, manufacturing, and constructability will be commercial roadblocks that need attention as well.	The team is working with CSR groups, industry consortiums, and other projects to ensure that the system will overcome some of the future roadblocks. For example, Bennett Pumps has become a member of the EU PRHYDE team and may integrate some of the new HD protocols being developed.
Not having an explicit station customer who will pilot the first hardware and not having a clear high-flow 700 bar tank integrator ready to use the nozzle.	The team decided to integrate the HDDN at NREL because it will be the first heavy duty station in the US that will be able to deliver the high flow rates that the system is designed to. NREL also has a heavy-duty vehicle simulator with several different tank designs that will be fueled.

Reviewer Comments

Reviewer Comment	Response
This is new territory. H70 may not be the ultimate/optimal solution for HD hydrogen fast fueling.	The original DOE FOA focused on 35 and 70 MPa. The HDDN team decided to propose H70 because H35 high flow components are already in the market.
The project might consider exploring whether there is any need for inclusion of HD nozzle design characteristics that allow for receptacle design that facilitates cryo-compressed hydrogen fueling or other forms of hydrogen (i.e., not only 700 bar gaseous hydrogen).	Cryogenic hydrogen was outside the original DOE FOA and project scope.
Additional time could be devoted to nozzle design and scenario planning if the first choice fails at validation. The four options look radically different, and simulation may not capture the optimum nozzle to-hose configuration options.	The team is focusing on a Type C nozzle with a single hose/single breakaway approach.
The project should identify necessary standards modifications and communicate those changes with standards committees.	The team is working directly with standard groups to inform them of any changes needed.

Collaboration and Coordination

Team Members		Role
	WEH Technologies, Inc.	Design and Fabrication of Nozzle Assembly
	Bennett Pump Company	Design and Fabrication of Dispenser
	Quong & Associates, Inc.	Technical Lead
	National Renewable Energy Laboratory	Field Testing and Analysis

Collaboration	Role
Multiple station manufacturers and OEMs	Advisor on component specifications
US Department of Energy - Hydrogen and Safety Panel	Safety Analysis
Industry stakeholders (27)	Provided feedback to develop specifications
Hydrogen Safety Panel	Safety plan review

Remaining Challenges & Barriers

Challenge/Barrier	Solution
HDND cannot handle high flow rates	• Initial flow modeling and testing provided guidance on design and ID. NREL will conduct high flow rate testing which will help identify other issues and confirm modeling results.
Nozzle assembly has design flaw (icing, usability, etc)	• Initial pressure, flow and functionality testing is assisting team in determining any design modifications necessary to improve the design.
HDND cannot integrate into NREL HD station properly	• HDND and NREL teams are planning several design, safety, and installation review meetings to reduce risk.
Supply chain issues delay project	• Team has identified components at risk and determined potential backup solutions.

Proposed Future Work

Fiscal Year	Activity
FY 2022	• Manufacturing of 1 dispenser and 3 nozzle assemblies • Component level testing • Integration into NREL HD research station • System validation testing • Demonstration and truck fueling
FY 2023	• Final Reporting • Project Closeout

Summary

- The team is currently in the build phase, and plans to install the HDND system in July 2022
- Bennett Pump, WEH and the team have learned considerably from the start of building and initial component testing which will reduce the risk during full system testing.
- The HDND team is working with other organizations and consortiums to integrate their heavy-duty fueling protocols and components.
- Work with NREL has increased to ensure that the installation is safe an minimizes risk.

Technical Backup Slides

Overall Specifications

Overall	Units	Min	Max	Requirement
Maximum H2 dispensed	kg		100	
Target fueling time for max H2 dispensed	min		10	
Time between fuelings	min		3	
Maximum operating pressure	MPa		87.5	
Average flow rate	g/s		180	
Peak flow rate	g/s		300	
Ambient temperature	C	-40	65	
Relative humidity	%	0	100	
Outdoor operations				Operates under rain, snow, wind, sun
Materials compatibility				All materials exposed to hydrogen shall be compatible and not introduce impurities at the designed pressures and temperatures

Dispenser Specifications

Dispenser	Units	Min	Max	Requirement
Gas operating temperature	C	-40	65	
Dimensions				Designed to fit on typical truck fueling island
Fueling protocol				Based upon industry standard or SAE J2601 2020 CHSS D
Retail system				EMV point of sale system
Display				Point of sale; Optional - information material
Vehicle communications				IRdA Communication fueling designed to SAE J2799 with backup non-communication fill
Station & POS communications				Bennett Open Protocol - Modbus
Design standards				NFPA2 and ANSI/CSA HGV 4.1^{+}, DMS, NFPA 496, CTEP, MET Labs Certification for purged and non-purged.
Products/Hoses				Up to 2 per side
Test requirements				ISO 19880-1 Section 12.5 Fueling safety and performance functional testing. CSA HGV 4.3 2021 for protocol

*To be determined as part of the project. $^{+}$Modified for heavy duty

Nozzle Specifications

Nozzle Assembly	Units	Min	Max	Requirement
Kv*			15	SAE J2601 2020 Section 7.2

Nozzle	Units	Min	Max	Requirement
Weight	kg		4.5	
Gas operating temperature	C	-40	85	
Communications				Field replaceable IRdA system designed to SAE J2799 which is electrically classified
Disconnection time	s		30	Designed to prevent freeze lock that prevents disconnection within 30 seconds
User protection				Designed to dissipate static electricity and protect user from frostbite
Receptacle inter-compatibility				Designed to prevent connection to nozzles designed for other vehicles or other higher-pressure heavy-duty nozzles
Nozzle inter-compatibility				Designed to prevent connection to receptacles designed for other vehicles or other lower pressure heavy duty receptacles
Hose protection				Designed with strain relief and twisting protection for the hose
Hose connection*				13/16"-16 UNF medium pressure female for 9/16" hose
Design standard				ISO 17268 2020+
Testing standard				ISO 17268 2020+ except durability
*To be determined as part of the project. +Modified for heavy duty				

Breakaway Specifications

Breakaway	Units	Min	Max	Requirement
Weight	kg		5	
Separation force	N	222	1000	
Gas operating temperature	C	-40	65	
Connection*				9/16" - 16 UNF medium pressure female
Design standard				ISO 19880-3 2020+, CSA HGV 4.4 2013+
Testing standard				ISO 19880-3 2020+, CSA HGV 4.4 2013+

*To be determined as part of the project. +Modified for heavy duty

Hose Specifications

Hose	Units	Min	Max	Requirement
Length	m	0.5	4	
Bending radius	mm	250		
Cycle life	years		2	Assuming 100 cycles per day
Design				Will consider approach to reduce hose whip
Gas operating temperature	C	-40	85	
Connection*				9/16" - 16 UNF medium pressure male
Hose protection				Include hose cover
User protection				Designed to dissipate static electricity and protect user from frostbite
Design standard				ISO 19880-5 2019^{+}
Testing standard				ISO 19880-5 2019^{+}
*To be determined as part of the project. +Modified for heavy duty				

Technology Transfer Activities

No technology transfer activities are planned at this time

Contribution to Achievement of DOE Targets or Milestones

- Because there are very few HDDN systems, there are no specific cost predictions for HDDN

- Once the dispenser is finalized, the team plans to compare their results to LDV dispenser cost estimates in the FCTO MYRDD

	FY 2015 Status	FY 2020 Target	Ultimate Target
Light duty vehicle Uninstalled cost/dispenser (1 hose per dispenser) (USD 2007)	$65000	$60000	$40000
% Reduction from 2015		%8	%38
HDND cost		TBD	TBD
FCTO MYRDD Plan Section 3.2 Hydrogen Delivery Table 3.2.4			

Special Recognition or Awards

There are no awards to report.

Publication and Presentations

There are no publications or presentations to report.

Reviewer Only Slides