Design, construction, and commissioning of a deployable liquid hydrogen production and fueling system for unmanned aerial systems

Cryogenic Engineering Conference
July 22, 2021

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IEEE CSC & ESAS SUPERCONDUCTIVITY NEWS FORUM (global edition), No. 50, October 2021.
U.S. Army grant supports development of hydrogen-powered Unmanned Aerial Vehicle

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Jacob Leachman, associate professor in Washington State University’s School of Mechanical and Materials Engineering, has received a $1.8 million grant from the U.S. Army to demonstrate a liquid hydrogen-powered UAV and refueling system.

The $7.2 million total grant includes researchers from Mississippi State University, Insitu Inc., and Navmar Applied Sciences Corporation. Insitu, a subsidiary of Boeing, will provide their ScanEagle® UAV, equipped with a fuel cell-powered electric engine. MSU will measure performance characteristics of the drone.
Liquid Hydrogen Fueling Infrastructure

- Lack of small-scale LH2 infrastructure
  - Smallest industrial gas liquefiers are 1 tonne/day, doesn’t include H2 generation or storage.

- Small LH2 vehicles need a fueling solution
  - LH2 deliveries geographically limited and typically require orders of 1 tonne.

- WSU developed a containerized fueling station that generates, liquefies, and stores LH2
MHGU Specifications

• Refuel a small LH2 fuel tank in the field
• Liquefy 1-2 liter of hydrogen per hour
• Store approximately 50L of LH2
• Power requirements:
  • 208 V or less
  • 200 A or less
  • Single or three phase power
• Consumables:
  • Tap water
  • Gaseous helium
• Refill LH2 fuel tank in 20 minutes or less
• Standard military C130 container – minimal footprint
• Operate with minimal human interaction
• Comply with NFPA codes and industry best practices for hydrogen
Mobile Hydrogen Generation Unit 2 (MHGU 2)

**Equipment Room**
- **H2 Supply**
  - 2500psi, 99.999% H2, 5x K-sized cylinders
- **Cryocooler Compressor**
  - 208V, 3-phase, 42A
  - Op Temp: 41 F – 95 F
- **Water Purifier**
  - 7.5-30 psig inlet, 20l/h, Potable H2O
  - Temp: 34 F – 95 F
  - 24 VDC

**Hydrogen Room**
- **H2 Storage**
  - 200psi, 10 gallon
- **Electrolyzer**
  - 0-200psig outlet, 18.8SLPM, 99.9995% H2
  - Temp: 41 F – 140 F
  - 208V, 41A, 1φ
- **LH2 Dewar and Cold Head**
  - 60L, 20K, 85psi MAWP
- **LH2 Transfer Line**
  - 100 psi MAWP

**Helium Supply**
- UHP Helium
  - 2200psig

**Water Supply**
- Potable water main

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**LH2 Fuel Tank**
- 2.5L, 20K, 30psi MAWP

**H2 Vent Stack**
- 220psi PRV

**H2 Vent Stack**
- 85psi PRV

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**MHGU 2 Boundary**
- 2-hour Fire Wall

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MHGU 2 Safety Features

Unclassified - Equipment Room

- Inlet Fan 1440 CFM
- Water Purifier
- Cryocooler Compressor
- H2 Detector HY-ALERTA 1600
- Flame Detector Honeywell FSL100 UV/IR

Sealed, 2-hour Fire Wall

Class I Division II Group B - Hydrogen Room

- H2 Vent Stack 10ft off room
- LH2 Dewar and Cold Head
- Exhaust Fan ISFX160 Hazardous Fan ~260 CFM
- H2 Detector HY-ALERTA 2620
- Flame Detector Honeywell FSL100 UV/IR

Safety Features
- Positive Pressure
- Sealed 2hr. Fire Wall
- Negative Pressure
- Ducted Electrolyzer Inlet/Outlet
- C1D2 Equipment and Wiring
## Shutdown Table and Controls

<table>
<thead>
<tr>
<th>Type of Consequence</th>
<th>Trigger</th>
<th>Outcome</th>
<th>Control System</th>
<th>Cleared By</th>
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</thead>
<tbody>
<tr>
<td>Process Stop 1</td>
<td>-H2 above 1%</td>
<td>-Electrolyzer OFF</td>
<td>PLC</td>
<td>Process Stop Reset Button</td>
</tr>
<tr>
<td></td>
<td>-Loss of ventilation</td>
<td>-Isolate H2</td>
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<td></td>
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<tr>
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<td></td>
<td>-Alarm strobe ON</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Process Stop 2</td>
<td>-H2 above 2%</td>
<td>-Electrolyzer OFF</td>
<td>PLC</td>
<td>Process Stop Reset Button</td>
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<tr>
<td></td>
<td></td>
<td>-Cryocooler OFF</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Vent H2 out stack</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Alarm horn and strobe ON</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E-Stop</td>
<td>-Fire</td>
<td>-Electrolyzer OFF</td>
<td>Safety</td>
<td>E-Stop Reset Button</td>
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<tr>
<td></td>
<td>-Dewar pressure &lt; 3psig</td>
<td>-Cryocooler OFF</td>
<td>Controller</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-E-stop button</td>
<td>-Vent H2 out stack</td>
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<td>-Alarm horn and strobe ON</td>
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</tbody>
</table>
MHGU2 Overview
Hydrogen Room
Liquefier

• Major Components
  • 60 L Dewar
  • Cryocooler Coldhead
  • Thermocouple Rake
  • AlSi_{10}Mg Additively Manufactured Heat Exchanger
  • Heater Block
  • Superconducting Liquid Level Gauges with Heaters
Liquefier

- Safety Features
  - Dual PSV – 80 psig & 105 psig
  - Active temperature controls
Liquid Hydrogen Transfers

- Vacuum-jacketed transfer line
- Quick connect coupler
- Helium shroud
- 50+ LH2 transfers conducted
User Interface

- Touch screen display
  - Monitoring and control
- Push button operation
- Remote access
External Interfaces

- Vent Stack
- Electrolyzer Ducts
- Helium Ports
- Water
- Drain
- Power
Outdoor Liquid Hydrogen Test Facility

Hydrogen Storage Requirements
- LH2: up to 150 L
- gH2: up to 68 std. m^3
  (2400 std. ft^3)

Power Requirements
- 200 A, 208V, 3-Phase

Site Requirements
- Water
- Lighting
- Video Monitoring
- Fire/EMS access
- Near Fire Hydrant
Liquid Hydrogen Test Facility
Summary

- Developed a transportable LH2 fueling station
- Developed an outdoor LH2 test facility
- Field testing later this summer
Thank you!

http://www.hydrogen.wsu.edu