HNEI NELHA HYDROGEN PRODUCTION & FUELING STATION VISITOR BRIEFING

This is a working document, which will be updated as necessary to adapt to project changes, improved processes, applied technologies, industry best practices, government regulations, and any determination of additional safety risks.

LAST REVISION: 11/26/2018 AM/ME
HYDROGEN STATION RULES

- All visitors are to sign in to the visitor log book
- Eye protection is available on site, and is required during maintenance operations
- Smoking and ignition devices (lighters, matches, etc.) are prohibited
- Phone use is prohibited during fueling operations and in classified areas
- Do not touch anything unless instructed to do so
- If an alarm (horn/strobe) is triggered, evacuate the site using the one of the gates and gather at the Hale Iako building (circled below). The alarm will automatically trigger the ESD circuit
- If an emergency is detected press any of the sites ESD and evacuate the site

EVACUATION ROUTES

If an [unscheduled] alarm has been triggered while within the hydrogen fueling station area evacuate via. the routes shown below. **Note:** motorized gates may not be available for egress if closed.
HNEI-NELHA HYDROGEN STATION OVERVIEW:

The Hawaii Natural Energy Institute Hydrogen Station is located in the Hawaii Ocean Science & Technology (HOST) park at the Natural Energy Laboratories of Hawaii Authority (NELHA), south-west of the Ellison Onizuka Kona International Airport at Keahole Point on the Big Island of Hawaii.

MAJOR STATION COMPONENTS

- Generation and compression container, including the compressor, electrolyzer and control room.
- Three 450 bar tube trailers, each composed of 12 Type 3 DOT composite storage cylinders. Each trailer can hold up to 102 kg of hydrogen compressed to 450 Bar.
- Hydrogen dispenser composed of a 350 bar nozzle assembly, programmable logic controller (PLC), and human-machine interface (HMI) screen.
- Cooling systems, including an electrolyzer chiller, electrolyzer air cooler, and compressor chiller.
- Two connection posts used to connect the generation and compression container to the tube trailers, and connect the tube trailer to the dispensers.
The fueling station provides touch screen user interfaces, manual override capabilities for station maintenance personnel, data logging and an automated email feature for sending reports and fault messages.

Hydrogen is produced on site by a Proton OnSite C30 electrolyzer using Proton Exchange Membrane aka. Polymer Electrolyte Membrane (PEM) electrolysis to convert water in an electrochemical reaction into hydrogen and oxygen using electrical energy from the HELCO grid and filtered county water. The C30 electrolyzer can produce up to 65 kg of gaseous hydrogen per day at 99.999% purity.

The electrolysis of water at the HNEI NELHA hydrogen station uses approximately 65 kWh of electricity per kg of gaseous hydrogen produced, and approximately 2.6 gallons of water per kg of H₂. 1 kg of gaseous hydrogen has approximately the same energy content as 1 gallon of liquid diesel fuel.

Renewable sources of energy at NELHA such as Ocean Thermal Energy Conversion (OTEC) and solar power have the potential to help offset the energy used to produce the hydrogen on site.

After the hydrogen is produced through PEM electrolysis, it is compressed to 450 Bar (atmospheric pressure is 1 Bar at sea level), and is stored in mobile hydrogen transport trailers that can hold 102 kg of hydrogen each. These tube trailers are used as mobile hydrogen storage, and can be hauled to other sites on the island of Hawaii with dispensing capabilities. A hazmat certified hauling company will be responsible for tube trailer delivery between NELHA and off-site fueling operations.

The hydrogen tube trailers interface with the 450 Bar Hydro-Pac compressor and 350 Bar hydrogen dispenser via connection posts. Manual connections and control valves are operated by qualified HNEI personnel. Programmable logic controllers ensure safe automated operations through temperature and pressure sensing as well as gas detection sensors.
Hydrogen that is produced at the HNEI-NELHA hydrogen station will be used by hybrid hydrogen-electric fuel cell vehicles that use 350 Bar hydrogen for electromotive drive. The first vehicle that will be supported by the station is a 29 passenger US-Hybrid ADA compatible Hele-On fuel cell shuttle bus based on a Ford F550 Cabin manufactured by Eldorado National Co. and converted to hydrogen-electric drivetrain by US-Hybrid. The Hele-On shuttle bus will be operated by the County of Hawaii.

The fuel cell shuttle bus incorporates an electric drive system with plug-in battery charging customized to the vehicle configuration of the Ford F550-Eldorado Bus.

Two (2) 14 kW-hr Lithium-ion (Li-ion) battery packs provide power to a 200 kW electric drive system during acceleration and cruise with the electric motor generating power back into the battery during deceleration and braking (regenerative braking).

A Fuel cell system composed of a US-Hybrid 40kW PEM hydrogen fuel cell and type III composite hydrogen tanks holding up to 20kg of gaseous hydrogen compressed to 350 Bar acts as a range extender, keeping the battery charged when the bus is in use. The bus has a range of approximately 200 miles (25 miles on the battery alone).

In addition, a power export system has been added to the bus to enable the bus to provide 110/220VAC electric power for various uses such as support for civil defense operations during environmental disaster events. The power export system is capable of producing 10kW of continuous power for up to 30 hours with 20kg of hydrogen stored.
SAFETY SYSTEMS OVERVIEW

GAS DETECTION
The hydrogen gas detection system is comprised of gas detection probes connected to a monitoring panel. The monitoring panel reads hydrogen measurements from each probe and triggers an alarm if a threshold is crossed. The alarm outputs are connected in series with the ESD (emergency stop device aka. emergency shut down) circuitry.

FIRE DETECTION
The fire detection system is comprised of thermal probes and a hydrogen flame detection sensor. All thermal probes are connected in series with the ESD circuitry.

The hydrogen flame detectors are focused on the hydrogen dispenser and tube trailer connection posts. If a flame detector or any thermal probe is triggered, the station’s control air is shut down, causing all air-actuated valves to revert to a fail-safe state and become inoperable. The control system deactivates all station functions, including dispensing and compression, and prevents the flow of hydrogen from the storage vessels. This will also occur if any of the station’s polyurethane control air lines are damaged.

HIGH PRESSURE SAFETY
The hydrogen storage systems contain high-pressure hydrogen gas stored at a service pressure of 6,350 psig (438 bar) for the 350 bar system. In the event of a high pressure incident, each storage system is equipped with a pressure relief valve set at 6,960 psig (480 bar). The hydrogen compressor is equipped with pressure relief valves to protect the compressor from an over-pressure event at the suction inlet and discharge outlet. These pressure relief valves have a pressure switch in the relief vent stack which alerts the PLC if there is an over pressure event. All vent stacks direct vented gas upward and away from any personnel.

VENTILATION
The hydrogen compressor room includes ventilation fans, to mitigate any hydrogen leaks. The ventilation fans run continuously at a nominal speed to allow for a minimum of 1 cfm per square foot of floor area. If the control system detects a hydrogen leak in the vicinity, the appropriate fan is run at a higher speed to help disperse the leak.

EMERGENCY SHUT DOWN (ESD)
When any ESD button is pressed, the station’s control air is shut down, causing all air-actuated valves to revert to a fail-safe state and become inoperable. The control system receives an “ESD fault” signal, and responds by deactivating all station functions, including dispensing and compression.

DISPENSER PURGE
The dispenser is able to use non-rated electrical equipment in an area classified as hazardous, by housing this equipment in a partially sealed cabinet and using a purge fan to continuously purge and
pressurize the cabinet – as long as the purge is maintained, the electrical cabinet interior is considered an unclassified area

If the purge air is lost (e.g. due to the cabinet being opened), a pressure switch is triggered, which sends an alarm signal to the control system. If the control system detects a loss of purge, the dispenser power supply is interrupted immediately, and the control system deactivates all station functions.

When the cabinet is re-pressurized, there is a 10-minute delay before the dispenser power is re-enabled, to allow time for at least four complete purges of the electrical cabinet (as per NFPA 496).

EXPLOSION-PROOF CABINETS
All electrical circuitry that cannot be designed as intrinsically safe, and must be located in an area classified as hazardous, is housed in explosion-proof cabinets, to avoid all potential for contact between the electrical circuitry and any flammable gases.

INTRINSIC SAFETY
All electrical circuitry in areas classified as hazardous (e.g. the compressor rooms) is designed to be intrinsically safe, through the use of intrinsically-safe barriers where possible. If not possible, other protection methods are used.

CHEMICALS
Safety data sheets (SDSs) and a detailed chemical inventory are available on site.

HYDROGEN FACTS & SAFETY CONSIDERATIONS

• Hydrogen gas (H2) is a colorless, odorless and tasteless gas. It is non-toxic but can displace oxygen, acting as an asphyxiant if confined.
• Hydrogen gas is 14 times lighter than air and rises twice as fast as helium and 6 times faster than natural gas at a speed of almost 45 mph (65.6 ft./s). Therefore, unless it is contained, the laws of physics prevent hydrogen from lingering near a leak (or near people using hydrogen-fueled equipment).
• Hydrogen leaks present a risk of fire when mixed with air. However, the small molecule size results in very high buoyancy and diffusivity, so leaked hydrogen rises and dilutes quickly in open air.
• Hydrogen flames burn at a high temperature, but have a low radiant heat. Hydrogen flames are nearly invisible in daylight, but can be indirectly visible by way of emanating “heat ripples”.
• The only product of hydrogen combustion is water so there is no smoke or soot.
• Hydrogen has a wide range of flammability concentrations between 4% and 74%. It ignites more easily than any other common gas and a high-pressure leak can even ignite spontaneously. The best way to extinguish a hydrogen fire is by stopping the flow of gas.
• Hydrogen has the highest combustion energy per unit weight of any combustible fuel.
• Hydrogen can be combusted or used in a fuel cell to produce energy, but fuel cells are more efficient.
• 1 kg of Hydrogen has the energy content of approximately 39 kWh of electricity
• 1 bar = 1 atmosphere (atm) = 101.3 kPa = 14.7 psi
• 1 kWh ≈ 3.6 MJ
• For more information on hydrogen as an energy source: https://www.hydrogen.energy.gov/

COMMON USES OF HYDROGEN:

• Oil refinement - for removal of sulfur and nitrogen
• Industrial cooling – Highest heat conductivity of any element
• Electronics & metal production and fabrication – protective atmosphere, also for plasma welding
• Fertilizer – hydrogen is a key ingredient in ammonia production [NH3]
• Food production - Hydrogenated oils i.e. trans-fats have longer shelf lives and seem less greasy, but are also very hard for your body to digest. Common foods include: Doughnuts, cookies, popcorn, frozen pizza, coffee creamers...
• Pharmaceuticals – used in production of sorbitol, vitamins A and C
• Fuel cells and rocket fuel
## PROTON C30 ELECTROLYZER

| Net Production Rate: | 30 Nm³/hr  
|                      | 1141 SCF/hr  
| SCF/HR @ 70° F, 1 Atm | 535 SLPM  
| SLPM @ 70° F, 1 Atm | 65 kg/24hr  
| Kg Per 24 Hours |  
| Delivery Pressure - Nominal | 30 barg (435 PSIG)  
| Power Consumed Per Volume Of Mass H2 Gas Produced** | 5.8 kWh/Nm³  
|                      | 15.3 kWh/100 ft³  
|                      | 64.8 kWh/kg  
| Purity (Concentration of Impurities)** | 99.9998%  
|                      | Water Vapor < 2 PPM, -72°C (-98°F)  
|                      | Dewpoint, N₂ < 2 ppm O₂ < 1 PPM, All others undetectable  
| Max Rate of Water Consumption | 26.9 L/hr (7.1 gal/hr)  
| Operating Temperature | +5°C to 40°C (41°F to 104°F)  
| Input Water Quality | ASTM Type II Deionized Water required, < 1 micro Siemen/cm (>1 M-Ohm-cm) ASTM Type I Deionized Water recommended, <0.1 micro Siemen/cm (> 10 M-Ohm-cm)  
| Cabinet Ventilation With Environment | Vent fan draws fresh air up to 7.1 m³/min (250 ft³/min)  
| Electrical Specification | 432 to 528 VAC, 3 phase, 60 Hz  
| Noise Db(A) at 1 Meter | < 75  

### Hydrogen Compressor:

| Manufacturer | Hydro-Pac  
| Type | Two Stage Hydraulically Driven  
| Allowable Inlet Pressure Range | 200-450 psi  
| Discharge Pressure: | 6,500 psi max  

### Tube Trailer Hydrogen Storage:

| Hydrogen Storage System | 12 Dynetek type 3 tanks  
| Service Pressure | 6,527 psig (450 bar)  
| Maximum Fill Pressure | 8,158 psig (563 bar)  
| Volume | 303 L water volume  
| Capacity | 102 kg of hydrogen at 450 bar per trailer  
| Energy Content at Capacity | ~3500kWh per trailer  

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**Note:** All measurements are approximate and subject to change without notice.
### NELHA Fuel Cell Plug-In Shuttle Bus

#### Overall Vehicle Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>GVWR</td>
<td>19,500-23,500lbs</td>
</tr>
<tr>
<td>Interior and Seating</td>
<td>29 Passengers and ADA Compatible</td>
</tr>
<tr>
<td>OEM Manufacturer and Model</td>
<td>Eldorado Aero Elite 32 Model</td>
</tr>
<tr>
<td>Chassis</td>
<td>Ford F550</td>
</tr>
</tbody>
</table>

#### Vehicle Performance Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range H2 and Battery</td>
<td>200 miles</td>
</tr>
<tr>
<td>Range Battery Electric</td>
<td>15 miles</td>
</tr>
<tr>
<td>Top Speed</td>
<td>60 MPH</td>
</tr>
<tr>
<td>Acceleration 0-40 MPH</td>
<td>8 seconds</td>
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#### Fuel Cell System Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Cell Supplier</td>
<td>US Hybrid</td>
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<tr>
<td>Fuel Cell Power</td>
<td>40kW</td>
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#### Hydrogen Energy Storage System Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage Capacity</td>
<td>19.28kg of H2 (~643kWh of electrical energy)</td>
</tr>
<tr>
<td>Max Pressure- Min Pressure</td>
<td>350 BAR/5076 PSI - 13.8 BAR/200 PSI</td>
</tr>
<tr>
<td>Fueling Time</td>
<td>&lt; 9 minutes, Communication Port (90% capacity)</td>
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</tbody>
</table>

#### Battery Energy Storage Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery Cells Type</td>
<td>Li-Ion</td>
</tr>
<tr>
<td>Battery Voltage</td>
<td>360V Nominal</td>
</tr>
<tr>
<td>Battery Energy</td>
<td>28kWh</td>
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</table>

#### Direct Electric Traction Drive System Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor Type</td>
<td>AC Induction with Integrated Gear Reduction</td>
</tr>
<tr>
<td>Traction Drive Power</td>
<td>200kW</td>
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</table>

#### Power Export Unit Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
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</thead>
<tbody>
<tr>
<td>Export Power Voltage</td>
<td>110/220 VAC</td>
</tr>
<tr>
<td>Export Power Capacity</td>
<td>10 kW continuous for 30 hours</td>
</tr>
</tbody>
</table>

### KEY SITE CONTACTS:

<table>
<thead>
<tr>
<th>Organization/Location</th>
<th>Phone Number</th>
<th>Alternate Number</th>
<th>Address/email</th>
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</thead>
<tbody>
<tr>
<td>NELHA</td>
<td>808-327-9585</td>
<td></td>
<td>73-987 Makako Bay Drive</td>
</tr>
<tr>
<td>Alex Leonard (Project Manager)</td>
<td>808-292-5157</td>
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</tr>
<tr>
<td>HNEI Personnel</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Aaron McCall (O&amp;M)</td>
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<td><a href="mailto:apmccall@hawaii.edu">apmccall@hawaii.edu</a></td>
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<tr>
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<td>808-956-2337</td>
<td><a href="mailto:ewan@hawaii.edu">ewan@hawaii.edu</a></td>
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