# Maritime Fuel Cell Generator Project

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Subcontractor:
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Project End Date: Project continuation and direction determined annually by DOE

## Overall Objectives

- Lower the technology risk of future port fuel cell deployments by providing performance data of hydrogen proton exchange membrane (PEM) fuel cell technology in this environment.
- Lower the investment risk by providing a validated economic assessment for this and future potential projects.
- Enable easier permitting and acceptance of hydrogen fuel cell technology in maritime applications by assisting the U.S. Coast Guard and the American Bureau of Shipping develop hydrogen fuel cell codes and standards.
- Engage potential adopters/end users of hydrogen fuel cells to enable more widespread acceptance of the technology.

## Fiscal Year (FY) 2018 Objectives

- Repair and upgrade the 100-kW maritime fuel cell (MarFC) unit based on prior deployment experience in Hawaii.
- Locate another deployment partner that can advantageously use the MarFC unit while satisfying hydrogen safety requirements. Deploy the unit if all requirements are met.

## Technical Barriers

This project addresses the following technical barriers from the Market Transformation section of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan[1]:

(A) Inadequate standards and complex and expensive permitting procedures

(E) A lack of flexible, simple, and proven financing mechanisms

(F) Inadequate user experience for many hydrogen and fuel cell applications.

## Technical Targets

No specific technical targets have been set.

## FY 2018 Accomplishments

- Repaired and upgraded the MarFC unit based on prior deployment in Hawaii.
- Completed unit testing both indoors and in cold weather, proving the MarFC works reliably.
- Engaged with the Port of Massachusetts, Curtin Maritime, and the Scripps Institution of Oceanography (SIO) for deployment of the unit, and down-selected SIO for the next deployment site.
- Successfully negotiated with the legal department of SIO to gain full approval for the MarFC deployment.
- Hydrogenics and Sandia visited and successfully reviewed the SIO Nimitz Marine Facility site for compatibility with unit operation and refueling. The MarFC unit will be used to provide shore power for the Robert Gordon Sproul research vessel in FY 2019.

[1] https://www.energy.gov/eere/fuelcells/downloads/fuel-cell-technologies-office-multi-year-research-development-and-22

## INTRODUCTION

Fuel costs and emissions in maritime ports are an opportunity for transportation energy efficiency improvement and emissions reduction efforts. Ocean-going vessels, harbor craft, and cargo handling equipment are still major contributors to air pollution in and around ports. Diesel engine costs continually increase as tighter criteria pollutant regulations come into effect and will continue to do so with expected introduction of carbon emission regulations. Diesel fuel costs will also continue to rise as requirements for cleaner fuels are imposed. Both aspects will increase the cost of diesel-based power generation on the vessel and on shore.

Although fuel cells have been used in many successful applications, they have not been technically or commercially validated in the port environment. One opportunity to do so was identified in Honolulu Harbor at the Young Brothers Ltd. wharf. At this facility, barges sail regularly to and from neighboring islands and containerized diesel generators provide power for the reefers while on the dock and on the barge during transport, nearly always at part load. Due to inherent efficiency characteristics of fuel cells and diesel generators, switching to a hydrogen fuel cell power generator was found to have potential emissions and cost savings.

Deployment in Hawaii showed the unit needed greater reliability in the start-up sequence, as well as an improved interface to the end user, thereby presenting opportunities for repairing/upgrading the unit for deployment in another locale. In FY 2018, the unit was repaired and upgraded based on the Hawaii experience, and another deployment site was identified for another 6-month deployment of the 100-kW MarFC.

## APPROACH

This project developed and demonstrated a nominally 100 kW, integrated fuel cell prototype for marine applications (Figure 1).


**Figure 1. The 100-kW maritime fuel cell generator (MarFC), with integrated hydrogen storage, PEM fuel cell power generation, and power conditioning equipment**

This project brought together industry partners in this prototype development as a first step toward eventual commercialization of the technology. To be successful, the project incorporated interested industry and regulatory stakeholders: an end user, technology supplier and product integrator, and land- and maritime-based safety and code authorities. Project costs were shared by the primary stakeholders in the form of funds, in-kind contribution, and material/equipment either loaned or donated to the project. Co-funding was provided by the U.S. Department of Transportation, Maritime Administration's Maritime Environmental and Technical Assistance program.

The project had five phases:

1. Establishment and specification (September 2013–December 2013)
2. Detailed design and engineering (January 2014–March 2015)
3. Prototype fabrication/site construction (October 2014–June 2015)
4. Demonstration at Young Brothers and analysis (August 2015–June 2016)
5. Deployment of a repaired/upgraded MarFC unit at a site to be determined.

## RESULTS

Early in the project year, Hydrogenics completed its upgrade and repair of the MarFC unit, as well as testing of the unit in cold weather. The improvements included the following:

1. Reliability problems with the MarFC conditioning electronics upon start-up were resolved by providing a converter solution that is robust with no start-up concerns. Working with ABB's maritime group based in Finland, Hydrogenics modified the MarFC to include a proven ruggedized HESS-880 converter solution. The complete solution includes other electronic components including a 440 VAC to 230 VAC step-down transformer and filtering of the AC output.
2. A ruggedized system display was installed, making it easy for the operator to ascertain the state of the MarFC, especially during start-up (Figure 2).
3. System heaters and controls were added to allow the MarFC to operate in weather down to -25°C (Figure 3) in anticipation of a future deployment in cold weather.


**Figure 2. Installation of a ruggedized system display, making it easy for the operator to ascertain the state of the MarFC, especially during start-up**


Figure 3. System heaters and controls that were installed to allow the MarFC to operate in weather down to -25°C in anticipation of a future deployment in cold weather

After completion of the repairs/upgrades, the unit was tested both indoors as well as outdoors in cold weather at the Hydrogenics site in Mississauga, Ontario, Canada (Figure 4).


Figure 4. (L) Indoor testing of the MarFC unit at Hydrogenics after system repair and upgrade; (R) outdoor testing of the MarFC unit in cold weather at the Hydrogenics site in Mississauga, Ontario, Canada, December 2017

Different test data were logged during the outside test, including output power and temperatures of the fuel cell and inverter coolants and container interior (Figure 5). An upgrade/testing report was written by Hydrogenics and delivered to Sandia. Pending identification of a suitable deployment site, Hydrogenics moved the unit to a temperature-controlled storage facility nearby the Hydrogenics site.

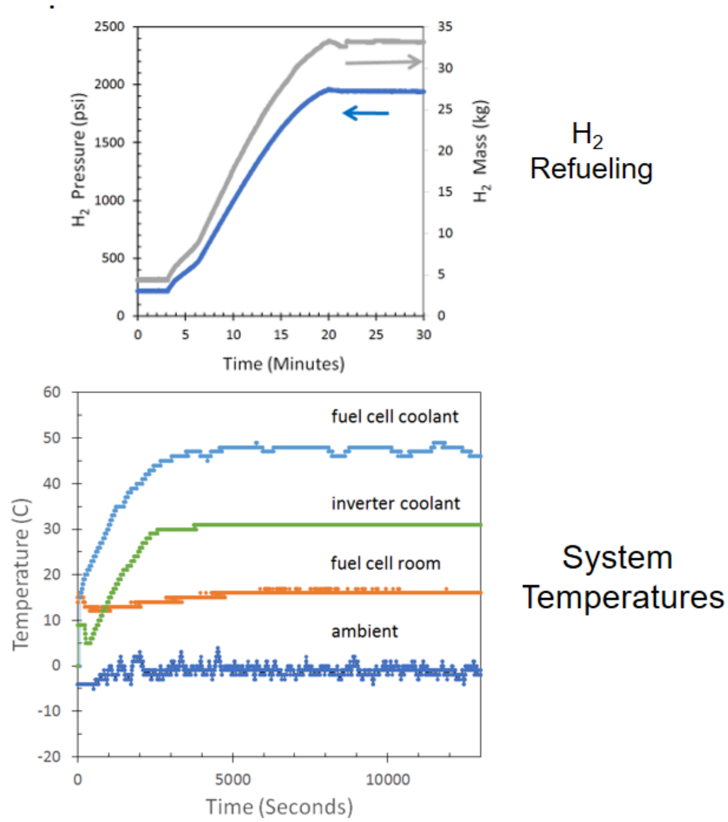


**Figure 5. Test data logged during the outside MarFC test. (Top) Hydrogen refueling rate data; (Bottom) MarFC system temperatures during operation.**

Initially, the Port of Massachusetts (Massport) was identified as a possible deployment location for the powering of refrigerated units, so called "reefers." Unfortunately, Massport and Sandia could not come to agreement on the legal and insurance terms and conditions. At the recommendation of the Port of Long Beach, Curtin Maritime (a tenant at the Port of Long Beach) was contacted. Unfortunately, due to the narrow geometry of the Curtin lot, as well as various "no-go" regions of the lot which could not be used for the unit, there was no location on the site that could satisfy the required offsets for storing hydrogen.

The Scripps Institution of Oceanography (SIO) expressed interest in using the unit to cold-iron the research vessel Robert Gordon Sproul when in port. This vessel requires ~50 kW of shore power during the day, with a reduced ~14 kW of shore power at night. Legal terms and conditions were discussed and approved, and the Nimitz Marine Facility at SIO satisfied the site locations for the storage and delivery of hydrogen. However, the Scripps vessel requires 480 VAC power, whereas the MarFC unit is wired for 208 VAC power. In FY 2019, the unit will be upgraded to provide 480 VAC power and deployed at SIO for use with the Robert Gordon Sproul. Figure 6 shows the research vessel Robert Gordon Sproul in port at the Nimitz Marine Facility of SIO, as well as the MarFC unit indicated notionally.

Figure 6. The SIO research vessel Robert Gordon Sproul, in port at the Nimitz Marine Facility of the SIO, San Diego, California. The blue box notionally indicates the future deployment and location of the MarFC.

## CONCLUSIONS AND FUTURE DIRECTIONS

Last year's deployment in Hawaii pointed to several ways the unit could be improved and items needing repair. These upgrades and repairs were implemented and tested, with the result being a unit that is much more reliable and easier for the operators to use. Several deployment sites were identified for the next use of the MarFC unit, with SIO satisfying the legal and regulatory requirements, as well as providing a strong test of the unit. In FY 2019, the unit will be upgraded to provide the 480 VAC power required by the research vessel Robert Gordon Sproul, and the unit will be deployed for 6 months at SIO.

## FY 2018 PUBLICATIONS/PRESENTATIONS

1. L.E. Klebanoff, "$H_2$ Maritime Webinar," U.S. Department of Transportation/MARAD, U.S. Department of Energy Fuel Cell Technologies Office, California Air Resources Board, California Energy Commission, and Bay Area Air Quality Management District Joint Webinar (August 23, 2018).
2. L.E. Klebanoff, "Maritime Fuel Cell Generator Project," DOE Hydrogen and Fuel Cells Program Annual Merit Review, Washington DC (June 14, 2018).