

Waterfront Maritime Hydrogen Demonstration Project

Narendra Pal

Hornblower Energy LLC

DOE Project Award # DE-EE0009251

June 6, 2023

Project ID # TA045

DOE Hydrogen Program 2023 Annual Merit Review and Peer Evaluation Meeting

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Project Overview

PI: Narendra Pal, Hornblower

Team Leads:

Lennie Klebanoff, Sandia
Rich Berman, Port of San Francisco
Sean Caughlan, Glosten

Nick Monroe, Hornblower
Daniel Frank, Hornblower
Sarah McDonald, Hornblower

Award #	DE-EE0009251
Start/End Date	10/01/2021–06/30/2025
Project Funding	\$7.994M

Project Vision

To demonstrate bunkering of fuel-cell vessels with green hydrogen produced in a maritime context, establishing the solid technical foundation for maritime H₂ production, compression, storage and over-the-water fueling, thereby catalyzing a “green hydrogen ecosystem” (both marine and landside) in the SF Bay Area, while also paving the way to its large-scale implementation across the United States.

Project Impacts

- ❖ Create the blueprint for designing and building a H₂ production barge.
- ❖ Ease regulatory approval by local authorities and USCG.
- ❖ Create procedures for safe over-the-water transfer of hydrogen to vessels and landside trailers.
- ❖ Promote the development of a hydrogen ecosystem in the greater SF Bay Area and beyond.

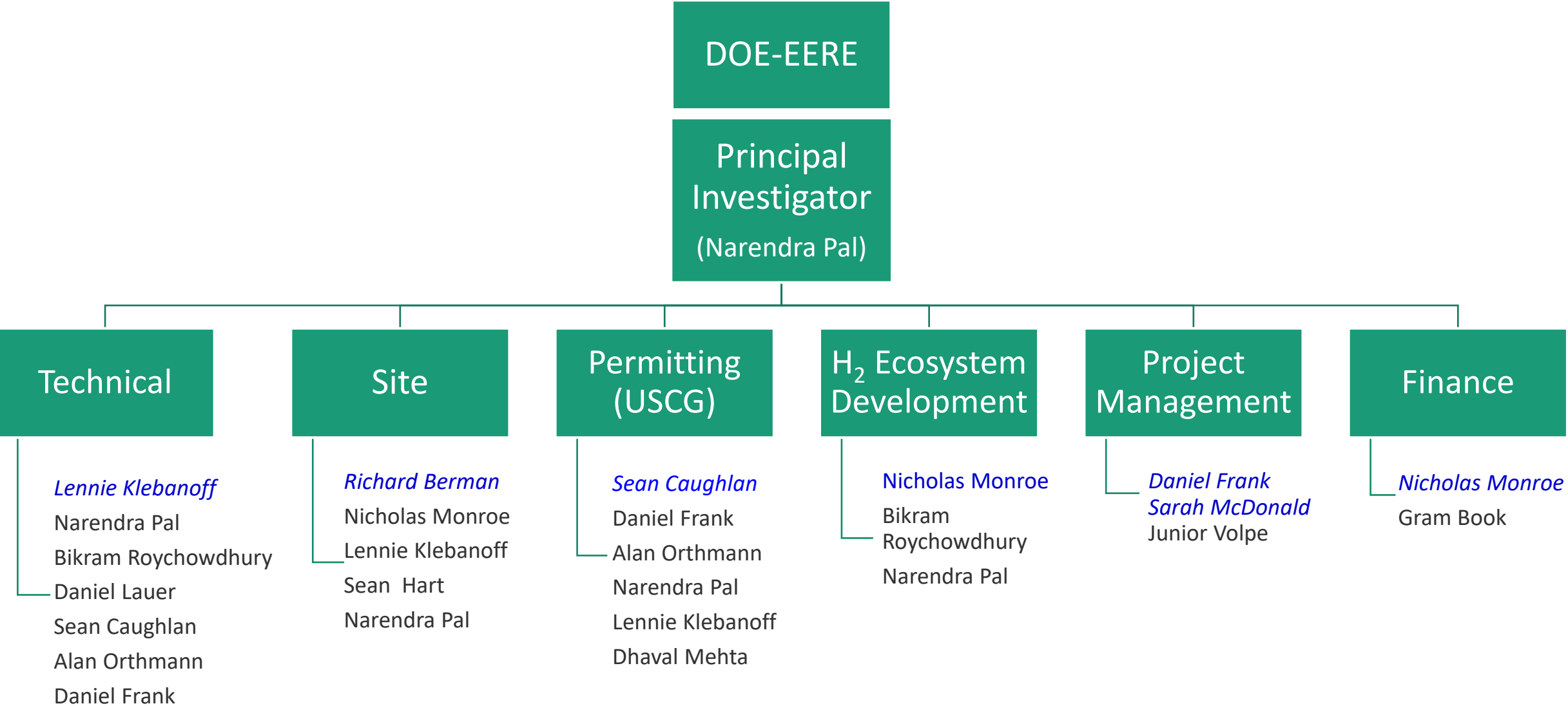
Barriers

- ❖ Renewable hydrogen refueling infrastructure- **Hydro-electricity, PEM Electrolyzer**
- ❖ Safety Codes & Standards – **Utilizing Existing NFPA and USCG codes**
- ❖ Refueling protocol for vessel to vessel, vessel to land and land to vessel – **Utilizing existing knowledge about refueling land-based applications to develop maritime refueling protocol**
- ❖ Techno-economic analysis data – **Extensive data will be collected during demonstration phase of the project**

Project Goal

- ❖ To demonstrate bunkering of fuel-cell vessels with green hydrogen produced in a maritime environment
- ❖ Establishing the solid technical foundation for maritime H₂ production, compression, storage and over-the-water fueling
- ❖ Developing safety codes & standards for deployment of hydrogen bunkering facilities for maritime hydrogen vessels
- ❖ Catalyzing a “green hydrogen ecosystem” (both marine and landside) in the SF Bay Area
- ❖ Paving the way to its large-scale implementation across the United States waters.

Project Organization and Team Structure



The H₂ Barge Project Participants



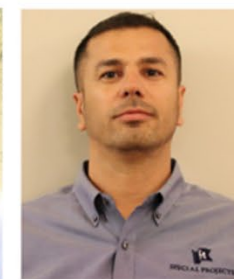
Narendra Pal



Nick Monroe



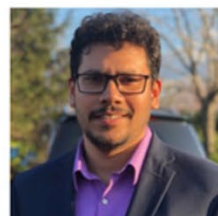
Dan Frank



Junior Volpe



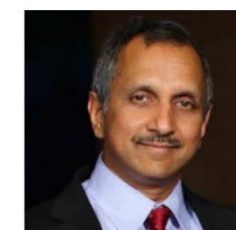
Sarah McDonald



Bikram Roy Chowdhury



Daniel Lauer



Sumanth Addagarla



Sean Caughlan



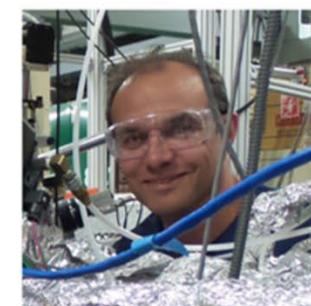
Marcos Da Conceicao



Sean Hart



Rich Berman



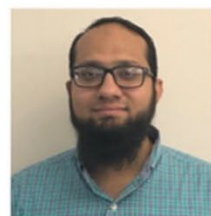
Lennie Klebanoff



Dhaval Mehta



Anthony Borski



Abdul Valiulla



Alan Orthmann



Cody Conard



Zhifeng Zhang

Approach – Summary

Project Motivation

- ❖ To demonstrate the feasibility, viability and methods of hydrogen production, storage, and fueling in a maritime context to fuel the Sea Change and Discover Zero fuel-cell vessels.
- ❖ In doing so, catalyze a “green hydrogen ecosystem,” (both marine and landside) via localized production of renewable hydrogen at the San Francisco Waterfront.
- ❖ Beyond the immediate project, we seek to establish the solid technical foundation required to sustainably and safely replicate the technology in other locales.

Key Impacts

Metric	State of the Art	Expected Advance
H ₂ Bunkering Facility	Immobile and Land-based	On movable barge, and maritime-based
H ₂ Bunkering Protocols	None for marine vessels	Maritime-specific over-the water bunkering protocols
Hydrogen Ecosystem	Limited land-based	Integrated land/sea hydrogen eco-system

Partnerships

Hornblower Energy LLC;	Lead
Sandia National Laboratories;	Design, Demo, Compliance
Port of San Francisco;	Compliance, Demo
Air Liquide;	Refueling Protocol
BayoTech Inc.;	H ₂ Storage, H ₂ Offtake/Supply
Nel Hydrogen US;	PEM Electrolyzer
Glosten;	Platform Design, USCG Liaisoning
Moffatt & Nichol;	Civil & Electrical Engineering

Approach – Innovation

- ✓ Understanding and overcoming Pier-side infrastructure challenges (electricity, water, pier structure) to operating a new and novel hydrogen barge.
- ✓ Project to include comprehensive test of business case for hydrogen vessels and landside uses of renewable hydrogen.
- ✓ Breaking new ground with local (Port of SF (POSF), City of San Francisco) fire marshals to allow safe operation of a hydrogen production and fueling barge.
- ✓ The USCG has determined how it will be reviewing our project and we will be engaging with USCG Sector San Francisco soon.
- ✓ Developing over-the-water fueling procedures for safe transfer of hydrogen to vessels and landside trailers.
- ✓ Through modeling, developing refueling protocols that will allow fueling of Type III and Type IV tanks so as not to exceed thermal limits.
- ✓ First exposure of the public to a maritime-based hydrogen production and fueling facility.



Raman Singh, Port of SF, examines Pier 68 electrical infrastructure.



Narendra Pal introduces Port of SF Fire/Safety and Engineering staff to the Hydrogen Barge.

All Photo Credits: L.E. Klebanoff

Approach – Innovation

- The unique San Francisco Waterfront Maritime Hydrogen Demonstration Project (i.e., H₂ Barge) will prove renewable H₂ production on the water with capabilities to bunker high-pressure H₂ to fuel-cell vessels and land-based hydrogen trailers.
- After successful demonstration, the project could be easily implemented in other parts of the United States to catalyze a national H₂ maritime program.
- Data collected during the demonstration will pave the way for improved versions of the floating H₂ platform, which could be self-propelled and could be readily moved from one port to another to provide emergency support to local communities based on hydrogen technology.

Potential Impact

- ✓ Will substantially reduce the cost of delivered renewable hydrogen in the SF Bay Area by producing it locally, reducing delivery costs.
- ✓ First exposure of the USCG* to a hydrogen fueling barge. The USCG has determined how it will be reviewing our project and we will be engaging with USCG Sector San Francisco soon.
- ✓ Affordable and available renewable hydrogen should stimulate the SF Bay hydrogen ecosystem, not only for vessels, but for land-based uses (e.g., forklifts, Port fleets, mobile lights, backup power).
- ✓ Educating local and national stakeholders (fire & safety and engineering staff) to the safety-related physical and combustion properties of hydrogen.

*USCG = United States Coast Guard



Hydrogen Fuel Cell Mobile Light at the San Francisco International Airport (DOE Project)



Technical Lead Lennie Klebanoff gives seminar to USCG HQ about the safety-related properties of hydrogen, 9/26/2022.

Potential Impacts

- ✓ This project will create a blueprint for optimally designed hydrogen bunkering infrastructure on the water, stimulating the demand for hydrogen, advance the deployment of maritime hydrogen technologies and promote the development of a hydrogen ecosystem in the greater SF Bay Area.
- ✓ This project will catalyze the adoption of maritime hydrogen applications to decarbonize the marine sector which aims to reduce 50% GHG by 2050.
- ✓ This project will also demonstrate how to integrate hydrogen production and refueling infrastructure, not only to support maritime hydrogen applications but also to cater to the hydrogen needs of land-based applications such as fuel-cell cars, fuel-cell fork-lifts and emergency appliances.
- ✓ This project, by catalyzing hydrogen applications in and around ports, will ultimately improve the ambient air quality of local communities which otherwise are disadvantaged due to their poor air quality for which port emissions are in part responsible.

Accomplishments and Progress: Milestone Summary Table: Period -1

Task #	Task or Subtask	Milestone Number*	Milestone Description	Anticipated Date	Current Status	Relative Problems	Possible Solutions
	Subtask (if applicable) Title	(Go/No-Go Decision Point Number)	(Go/No-Go Decision Criteria)	(Months from Start of the Project)			
1	Evaluate equipment to assess need for marinization	M 1.0	Summary Document on Equipment Modification Needs	2	consolidated report prepared and submitted to DOE		
2	Design Study for Optimized Barge-mounted H ₂ Technology	M 2.1	Report on Design Study and H ₂ Technology Technical Specifications	2	consolidated report prepared and submitted to DOE		
2	Design Study for Optimized Barge-mounted H ₂ Technology	M 2.2	HB Integration Plan and Report	3	consolidated report prepared and submitted to DOE		
2	Design Study for Optimized Barge-mounted H ₂ Technology	M 2.3	Complete the development of thermodynamic models	12	65% Complete. Initial model developed for boundary conditions. Real time refueling test set up approved by local AHJ for testing. Testing planned in May 2023. Outcome of test results will guide us on pre-cooling requirements to achieve 45 min bunkering time.		
3	Finalize Equipment Specifications	M 3.1	Electrolyzer Specifications Summary Report	12	80% Complete		
3	Finalize Equipment Specifications	M 3.2	Specifications Summary Report of compressor, storage and BOP items	12	90% Complete. Compressor and storage system are specified but we continue to work on BOP items.		
3	Finalize Equipment Specifications	M 3.3	H ₂ Barge Availability Estimate	12	50% Complete. We have availability numbers but need to verify and finalize.		
3	Finalize Equipment Specifications	M 3.4	Conduct Safety Review and Finalize Safety Plan	12	Not yet started		
4	Design Basis Letter from USCG	M 4.0	DBL from USCG Marine Safety Center	10	10% complete. Revised Design basis application submitted to USCG on June 27, 2022. Application in process at different departments within USCG.	The USCG has determined how it will be reviewing our project and we will be engaging with USCG Sector San Francisco soon.	Weekly review with USCG to expedite the process.

- Overall, the design is progressing well and on time.
- The USCG has determined how it will be reviewing our project and we will be engaging with USCG Sector San Francisco soon.

Accomplishments and Progress: Milestone Summary Table: Period -1 (Cont'd)

Task #	Task or Subtask	Milestone Number*	Milestone Description	Anticipated Date	Current Status	Relative Problems	Possible Solutions
	Subtask (if applicable) Title	(Go/No-Go Decision Point Number)	(Go/No-Go Decision Criteria)	(Months from Start of the Project)			
5	Engage Local Reg. Bodies for Site and Op. Approval	M 5.1	Secure CEQA and BCDC Approvals	8	Quarterly meeting set up with Port Authorities		
5	Engage Local Reg. Bodies for Site and Op. Approval	M 5.2	Public feedback Report to DOE	8	Not yet started		
5	Engage Local Reg. Bodies for Site and Op. Approval	M 5.3	SFFD Approval via project presentation and review	8	Quarterly meeting set up with Port Authorities		
5	Engage Local Reg. Bodies for Site and Op. Approval	M 5.4	Port Commission & Sr Mgmt. Approval	8	Quarterly meeting set up with Port Authorities		
5	Engage Regulatory Bodies for Site and Op. Approval	M 5.5	Receive Building and Encroachment permits	10	Quarterly meeting set up with Port Authorities		
6	Develop fueling contracts	M 6.0	Receive contract commitments for no less than Budget Period 2 fiscal needs.	10	Working to confirm availability of maritime customers (Sea Change & Discover Zero) in market		
		Decision Point #1	Status of permitting by regulatory bodies	10			
		Decision Point #2	Status of system design (technical)	12			
		Decision Point #3	Project funding commitments for Budget Period 2	12			
7	Purchase Order (PO) for Equipment Procurement	M 7.0	Equipment PO Released	12			

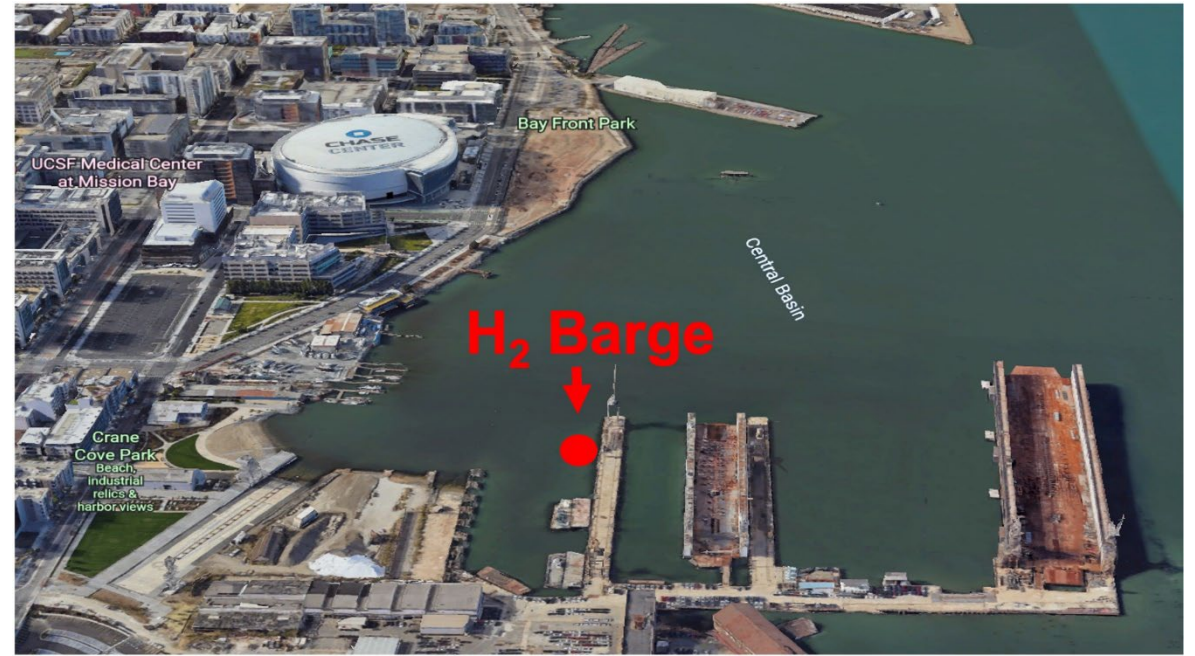
Most Important Technical Accomplishments to Date:

- * Completed initial hydrogen barge design compliant with NFPA 2. Selected all major component suppliers.
- * Completed initial Piping and Instrumentation Diagram (P&ID) for H₂ Barge.
- * Completed thermal modeling of hydrogen vessel tank filling.
- * Designed and constructed approved H₂ Tank Test Stand at Air Liquide.

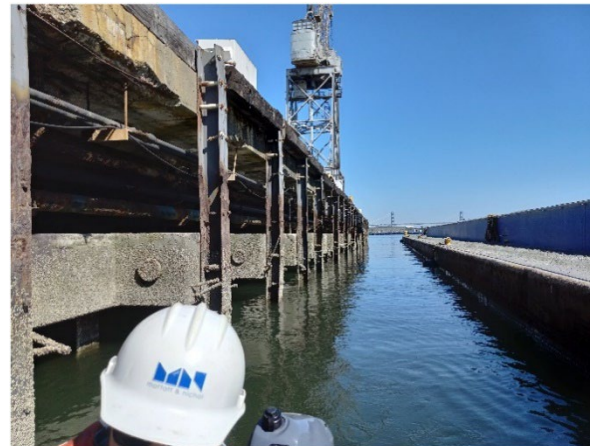
Outlook and Projected Outcomes:

- * The technical Go/No-go milestones concerning barge design and equipment selection will be met.
- * The USCG has determined how it will be reviewing our project and we will be engaging with USCG Sector San Francisco soon.
- * Inflation (30% in some items) is making obsolete our original budget request. Supply chain issues will cause schedule slip.

Accomplishment: Evaluated and selected barge site, Pier 68 at Port of SF



- ✓ Pier 68/Wharf 3 chosen in collaboration with Port of SF engineering staff.
- ✓ Located at old BAE Shipyard.
- ✓ Clean hydroelectric power from Hetch Hetchy Reservoir.
- ✓ Easy access from SF freeways.
- ✓ Pier is structurally sound, compatible with H₂ trailers.
- ✓ Site water compatible with electrolyzer.



(L) Inspecting wharf structural integrity; (R) testing Pier 68 water.

All Photo Credits: L.E. Klebanoff

Accomplishment: Evaluated/Certified Wharf 3/Pier 68 Electrical Utilities

Electrical Infrastructure inspected on 12/23/22 by M&N, Sandia, Hornblower and POSF



Kamran Kermani (L, M&N) and Raman Singh (R, POSF) examine electrical infrastructure drawings for Pier 68.



Sean Hart (M&N) and Raman Singh remove a manhole cover at the foot of Wharf 3.



Raman Singh inspects electrical wiring at the foot of Wharf 3.



Raman Singh inspects a 480VAC shore power box on Wharf 3.

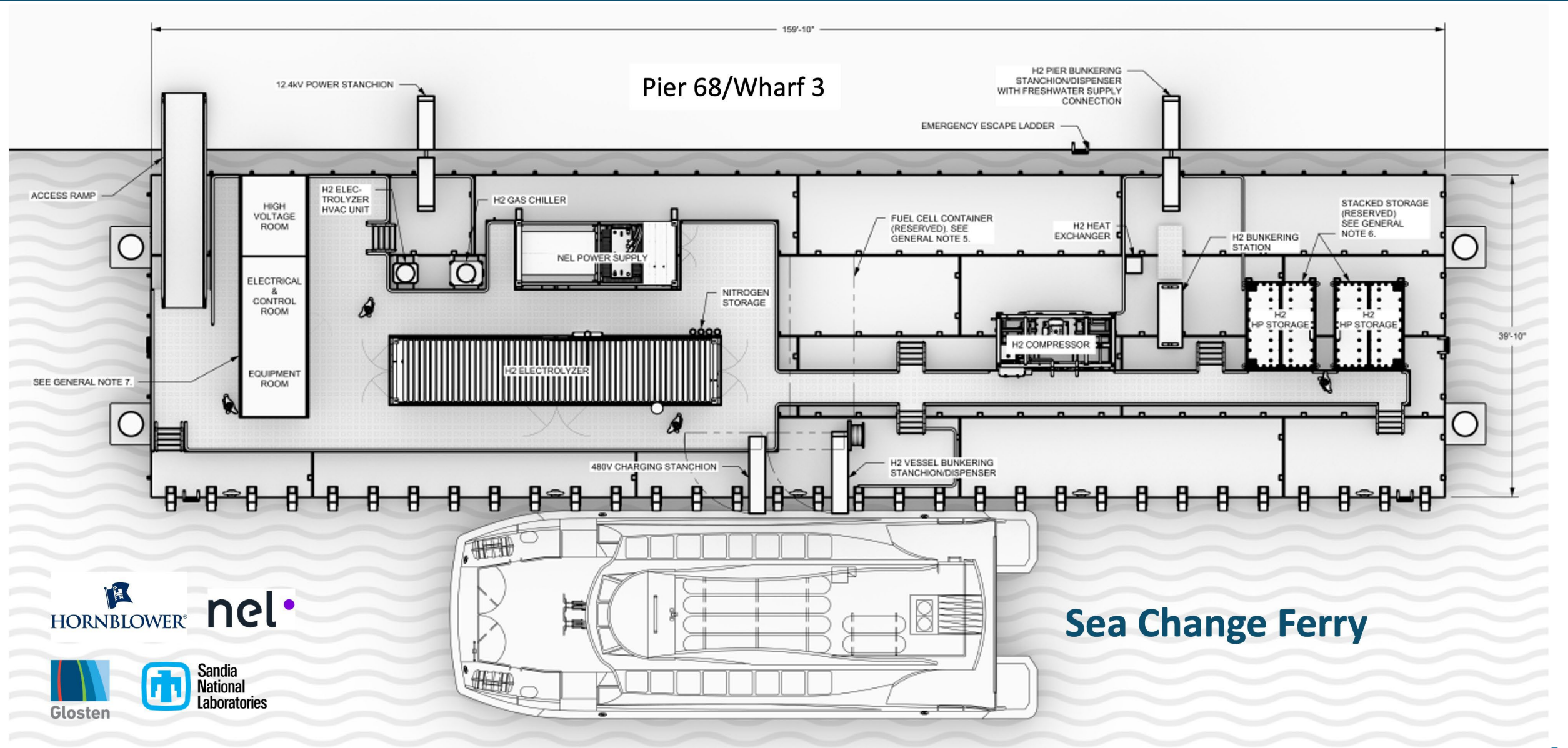
Key Results:

- ✓ Pier 68 power derives from a PG&E substation only a few blocks away, ensuring good “source” electrical power (both 12 kV and 480 VAC) to the H₂ Barge.
- ✓ The overall electrical power supply to Pier 68 is more than enough for the H₂ Barge.
- ✓ At Wharf 3, we will need to perform some re-wiring of 12 kV power up to the barge site near the end of the Wharf. We are still sorting through these options.



(L)-(R): Nick Monroe (Hornblower), Sean Hart (M&N), Patrick Forrester (POSF), Kamran Kermani (M&N), Raman Singh (POSF). All Photo Credits: L.E. Klebanoff

Accomplishment: Generated NFPA 2 Compliant Initial General Arrangement



 **HORNBLOWER** 

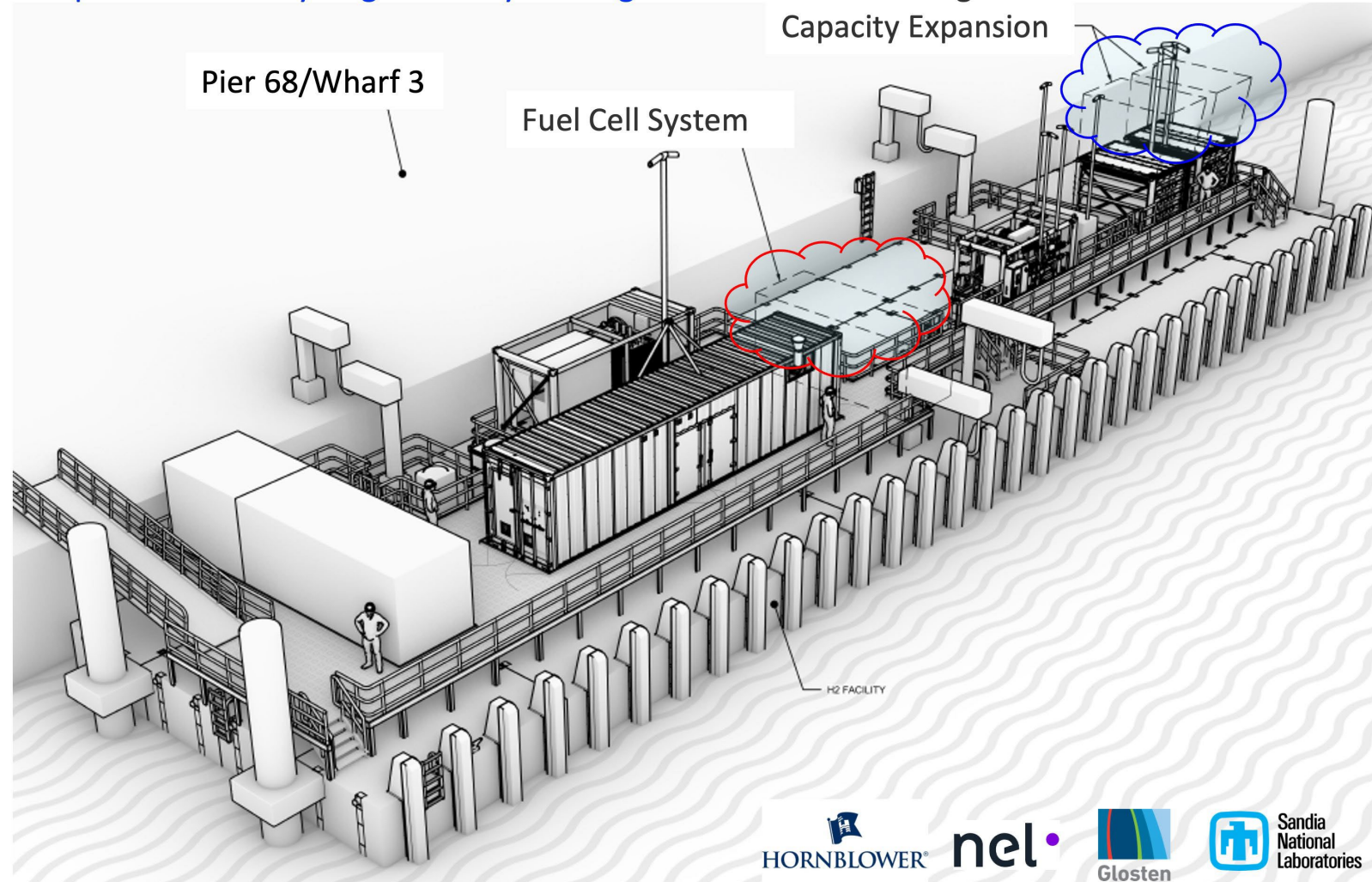
 **Glosten**  **Sandia National Laboratories**

Sea Change Ferry

Accomplishment: Generated NFPA 2 Compliant Initial General Arrangement

- 160' x 40' x 7' overall dimensions
- General Arrangements (GA) are advancing with more detail.
- All major equipment suppliers chosen.
- H₂ system design transitioning from Process Flow Diagram to full Piping & Instrument Diagram (P&ID).
- Evaluating flexifloat vs. single-unit barge options.
- Over-water interface and electrical feed design is advancing.
- Contracting with Moffatt & Nichol (M&N) for pile design and water analysis.
- Designing Barge to be compliant with the Hydrogen Safety Code NFPA 2.

Perspective of the Hydrogen Facility Looking East



HORNBLOWER

nel

Glosten

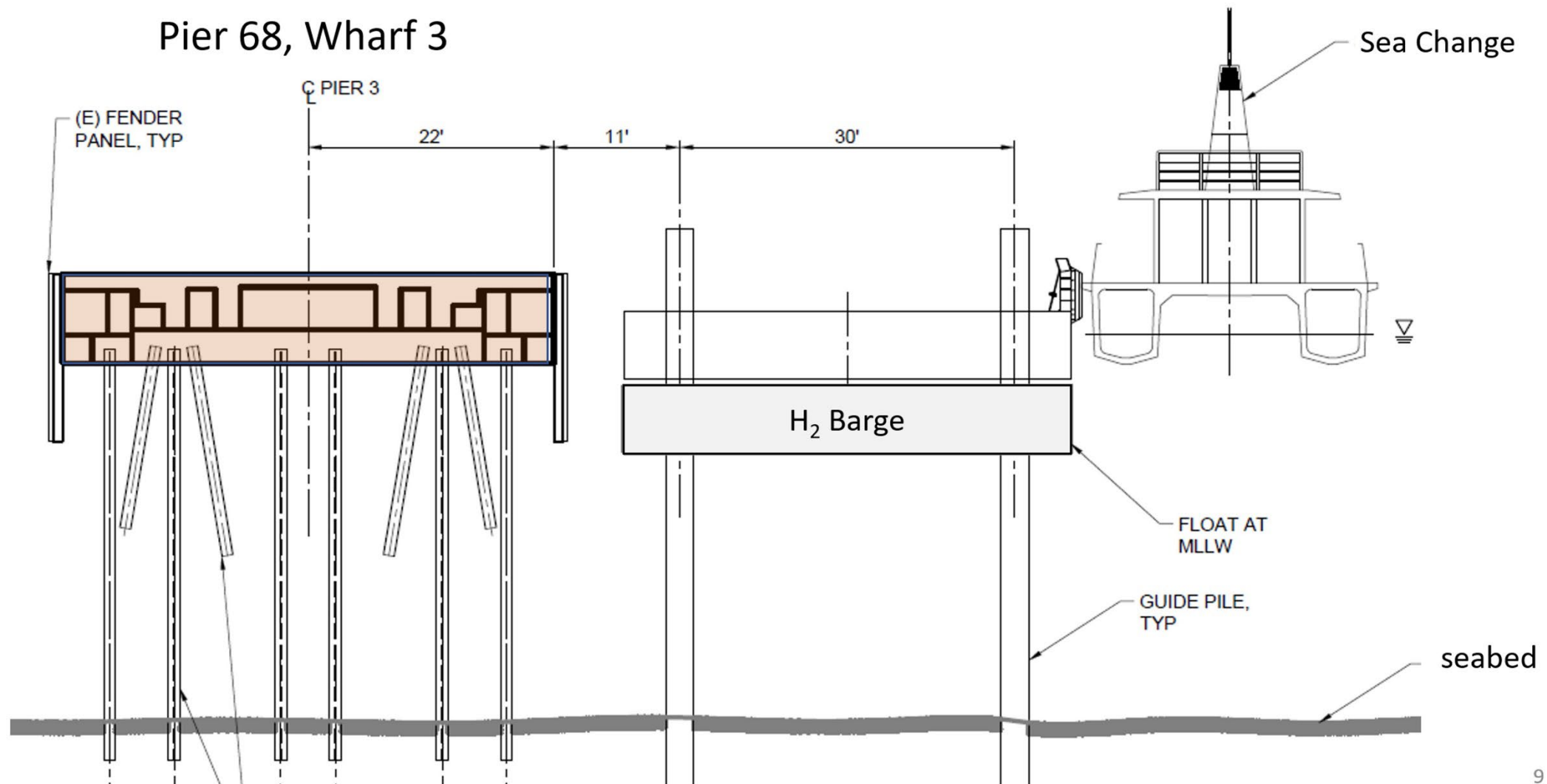
Sandia
National
Laboratories

Accomplishment: Developed Initial Design for Guide Pile Mooring Concept, vetting with Port of San Francisco Engg. Deptt.



moffatt & nichol

Pier 68, Wharf 3



Accomplishments: Barge Design to Fuel H₂ Vessels and Tube Trailers

Potential Customers

- *Sea Change* (SWITCH) – 100% hydrogen, CARB Funded.
- *Discover Zero* (Hornblower) – Hybrid diesel-battery-H₂
- Land-based H₂ Gas Tube Trailers (GTS, Air Liquide, Air Products, Linde)
- San Francisco Airport (SFO)
- Others

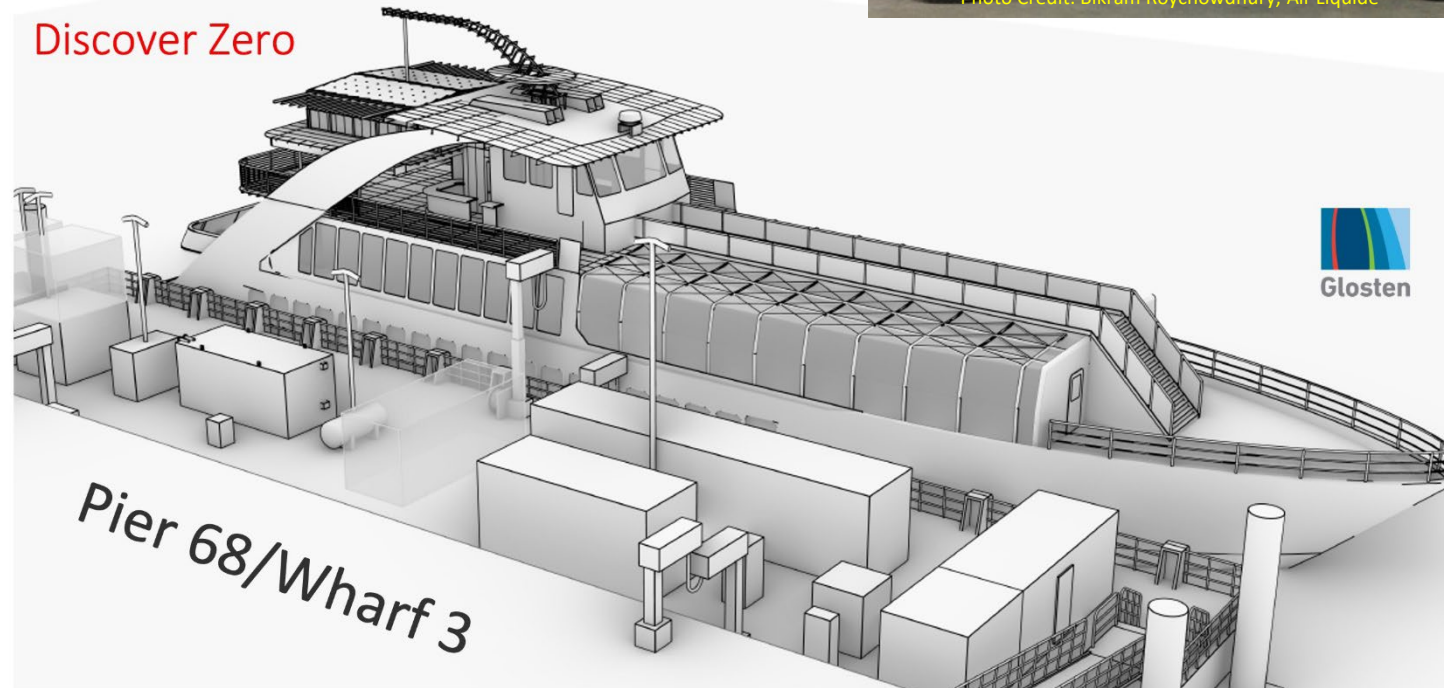


Note: The H₂ Barge should be available in 2025. No commitments for H₂ offtake have been established from vessel owners or gas companies.

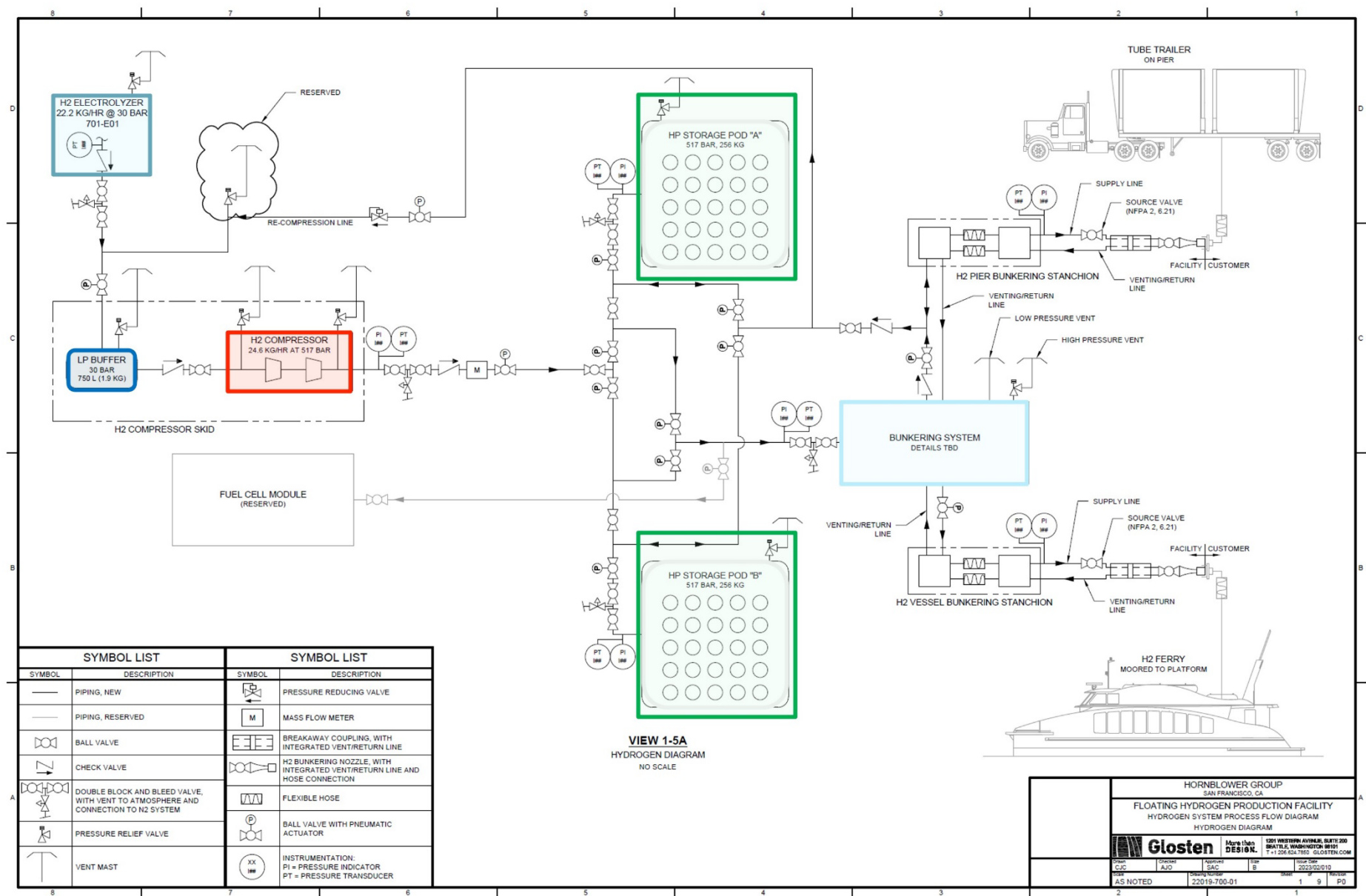
Sea Change



Discover Zero

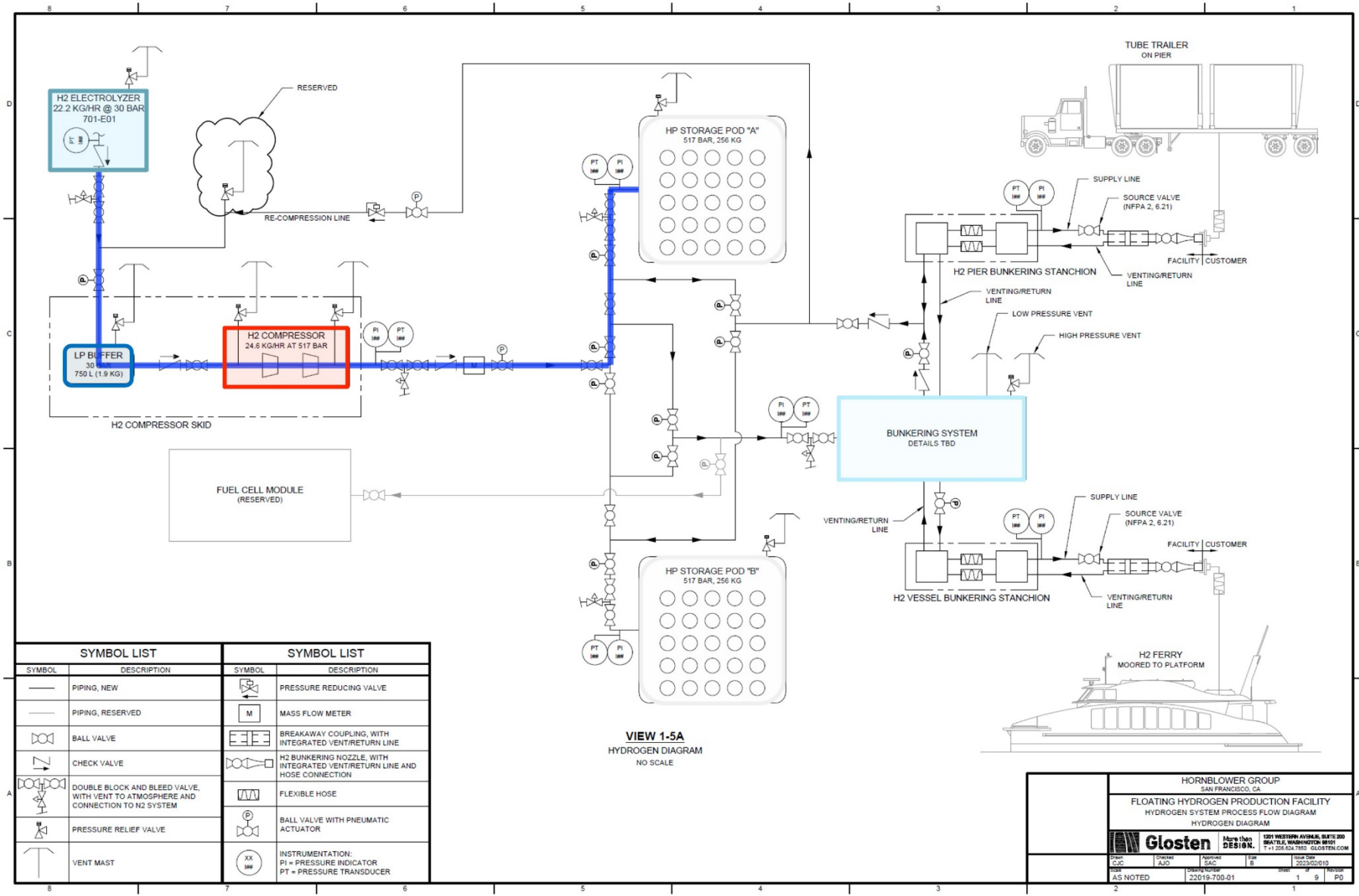


Accomplishments: Completed Initial P&ID for Hydrogen Barge



Accomplishments: Defined the H₂ Flow Diagrams for All Barge Activities.

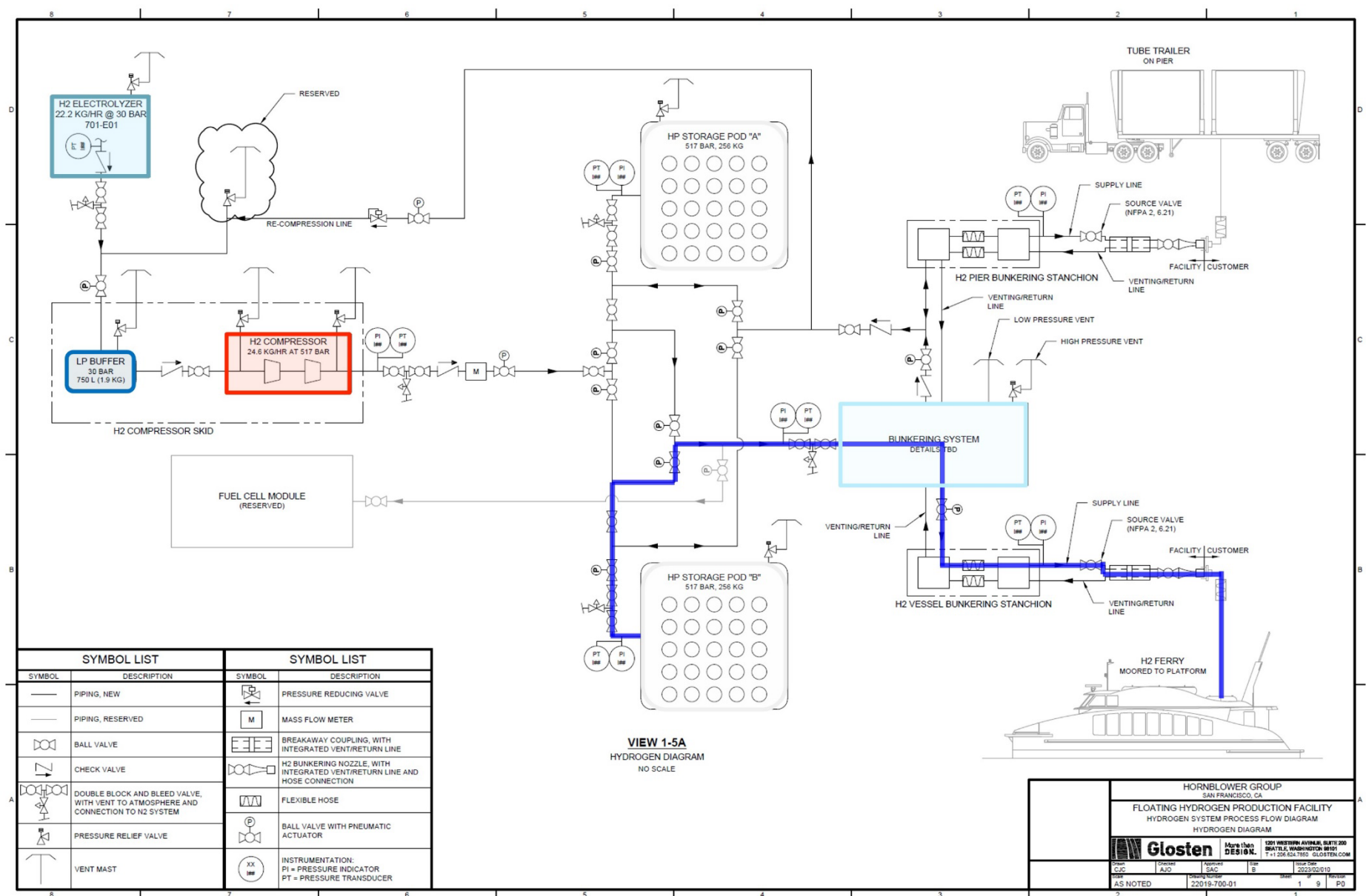
Example: Generating H₂ and Filling High-pressure Storage Pods



HORNBLLOWER GROUP SAN FRANCISCO, CA			
FLOATING HYDROGEN PRODUCTION FACILITY HYDROGEN SYSTEM PROCESS FLOW DIAGRAM HYDROGEN DIAGRAM			
Glostent		More than DESIGN. 1201 WESTERN AVENUE, SUITE 200 SEATTLE, WASHINGTON 98101 T 206.463.7100 F 206.463.7101 WWW.GLOSTENT.COM	
Drawn C.D.	Checked A.D.	Approved S.A.C.	Issued B
AS NOTED	220119-700-01	1	9

Accomplishments: Defined the H₂ Flow Diagrams for all Barge Activities.

Example: Fueling the Sea Change



SYMBOL LIST		SYMBOL LIST	
SYMBOL	DESCRIPTION	SYMBOL	DESCRIPTION
	PIPING, NEW		PRESSURE REDUCING VALVE
	PIPING, RESERVED		MASS FLOW METER
	BALL VALVE		BREAKAWAY COUPLING, WITH INTEGRATED VENT/RETURN LINE
	CHECK VALVE		H2 BUNKERING NOZZLE, WITH INTEGRATED VENT/RETURN LINE AND HOSE CONNECTION
	DOUBLE BLOCK AND BLEED VALVE, WITH VENT TO ATMOSPHERE AND CONNECTION TO N2 SYSTEM		FLEXIBLE HOSE
	PRESSURE RELIEF VALVE		BALL VALVE WITH PNEUMATIC ACTUATOR
	VENT MAST		INSTRUMENTATION: PI = PRESSURE INDICATOR PT = PRESSURE TRANSDUCER

HORNBLOWER GROUP
SAN FRANCISCO, CA

FLOATING HYDROGEN PRODUCTION FACILITY
HYDROGEN SYSTEM PROCESS FLOW DIAGRAM
HYDROGEN DIAGRAM

Glosthen

More than
DESIGN

1500 WESTERN AVENUE, SUITE 200
SANTA CLARA, CALIFORNIA 95050
T +1 206 624 7193 GLOSTHEN.COM

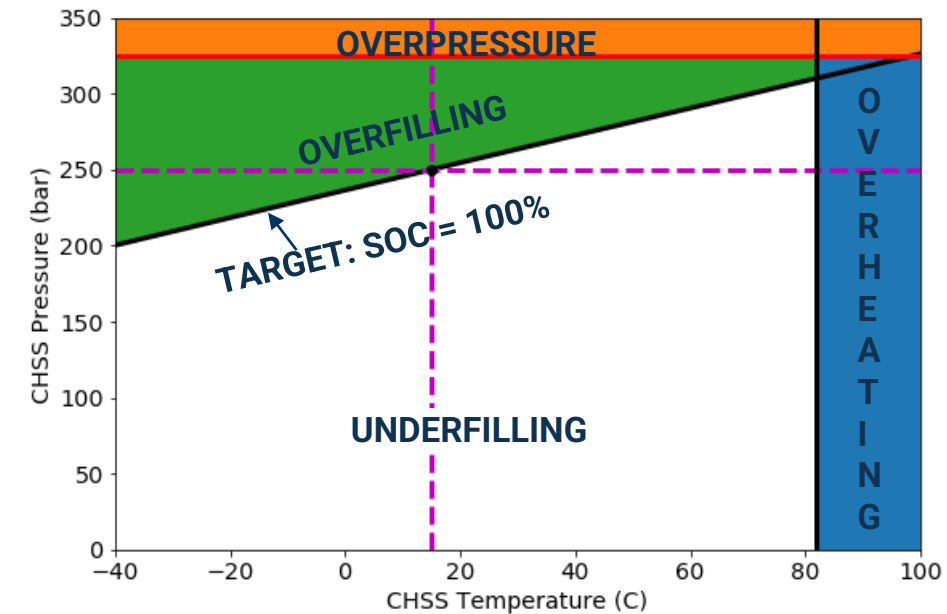
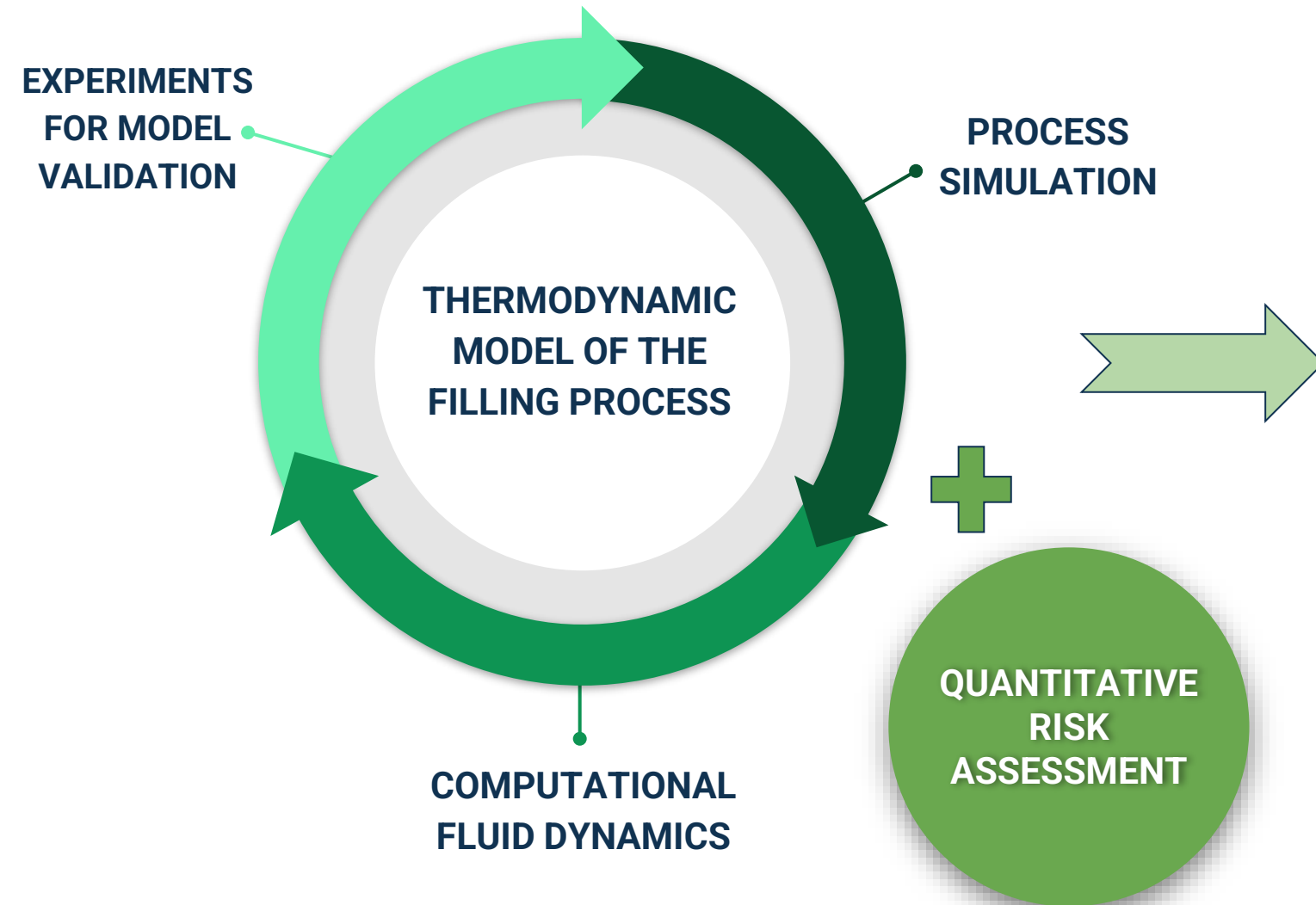
Project: CJC
Client: AS NOTED

Design: AJO
Drawn: SAC
Checked: B

Project No: 22019-700-01
Revision: 1
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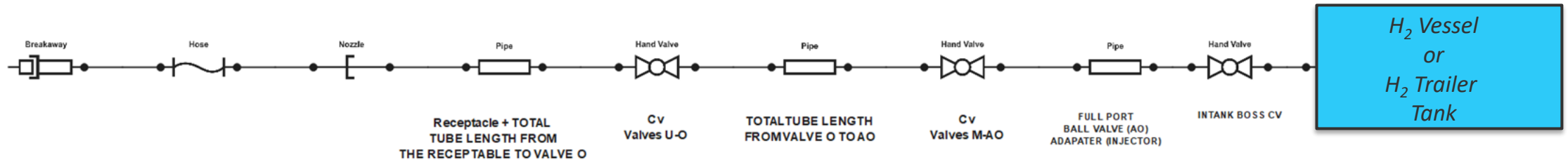
Accomplishments: Development of an Integrated Modeling-Experiment Approach to Science-based Hydrogen Refueling Protocols

Development of Refueling Protocol

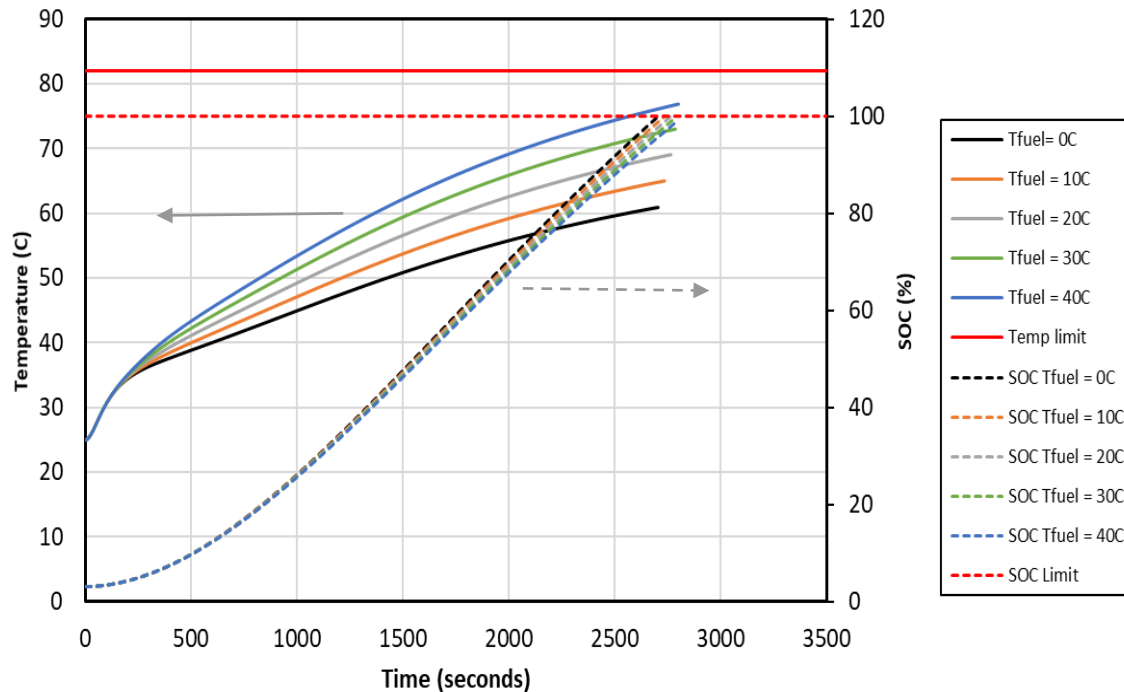


Accomplishments: Preliminary thermodynamic modelling results for Filling 250-bar Tanks on H₂ Ferries

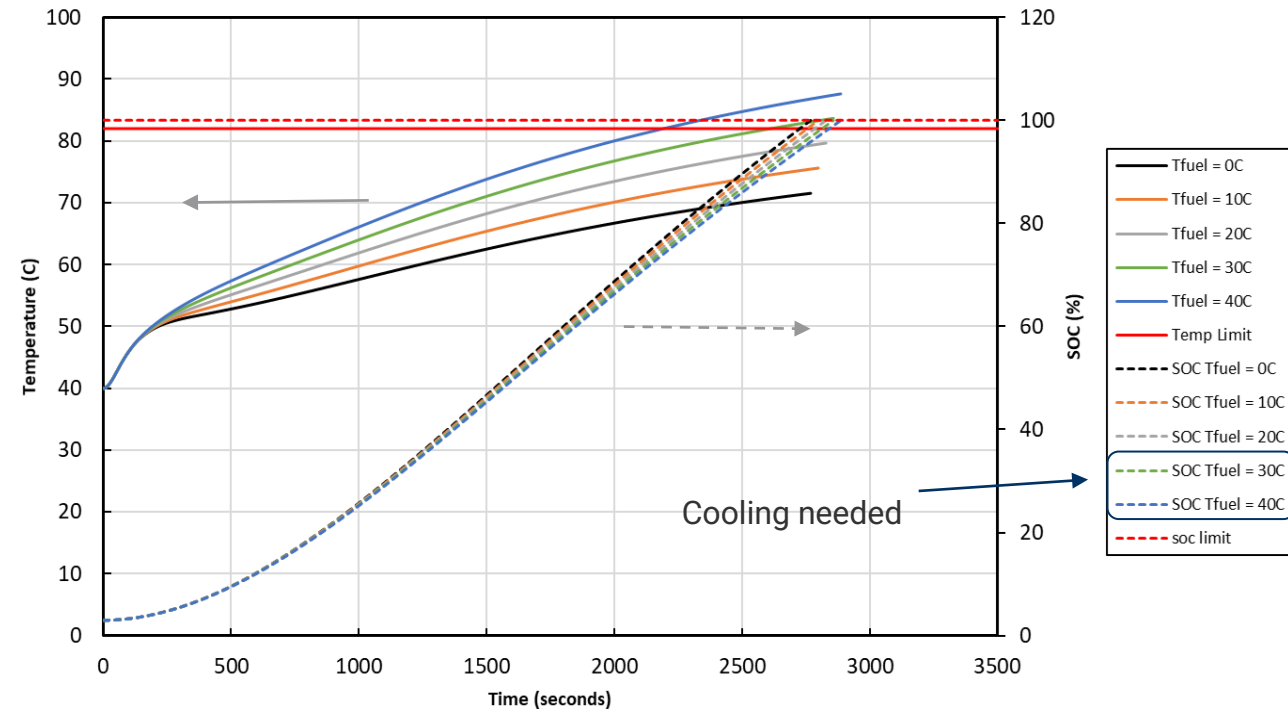
Development of Refueling Protocol: Process Simulation



Tamb = 25C = T_{init_tank_temp}; 7 bar; 7 bar/min ramp rate



Tambient = 40C = T_{init_tank}; Init Press = 7bar; 7bar/min ramp rate



Accomplishments: Completed 3-d CFD Simulations of Tank Fueling to Manage Compression Heating of 250 bar Tanks on H₂ Vessels

Development of Refueling Protocol: Process Simulation (Contd...)

- ❑ Preliminary Process Simulation shows that fuel delivery temperature of less than 20 °C can enable fast-fill on hot-days -> Possibility of using ocean water for pre-cooling
- ❑ Next Step: Assessment of the hypothesis embedded in the process simulation models -
 - ❑ Average temperature v/s Spatial Distribution
 - ❑ Homogeneous v/s Heterogeneous Flow Pattern inside the tank
 - ❑ Optimization of injector diameter
 - ❑ Experimental results to be used for model validation



Refueling time: < 45 mins

Desirable thermal distribution 

× **Undesirable** thermal distribution

- No injector (initial design basis)
- Strong Thermal Stratification
- Max. gas temp. > 92°C



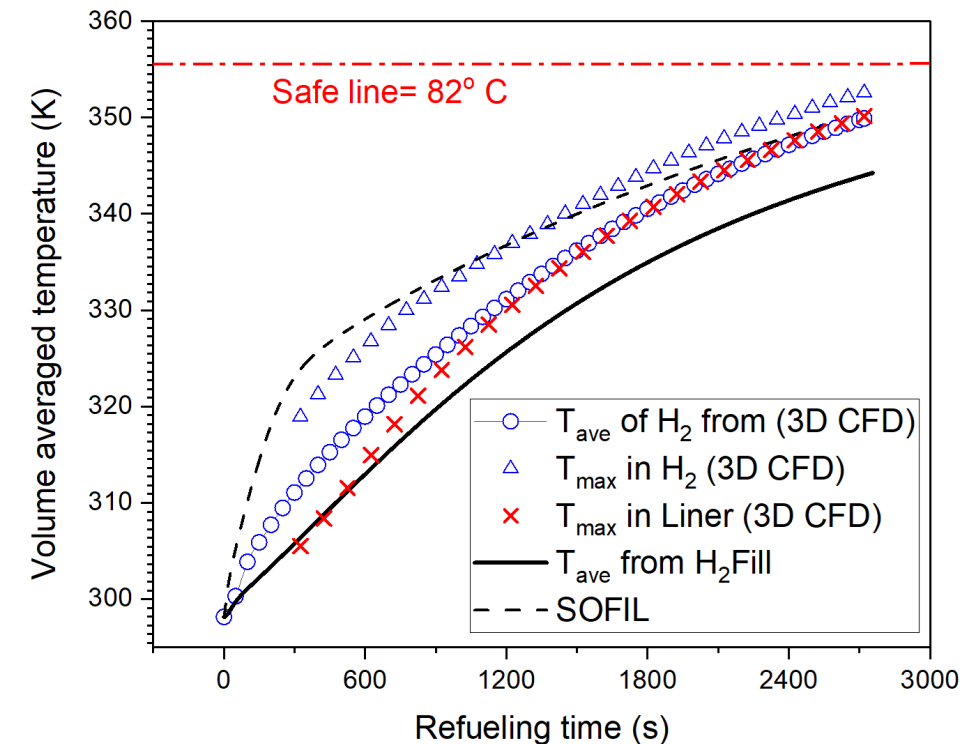
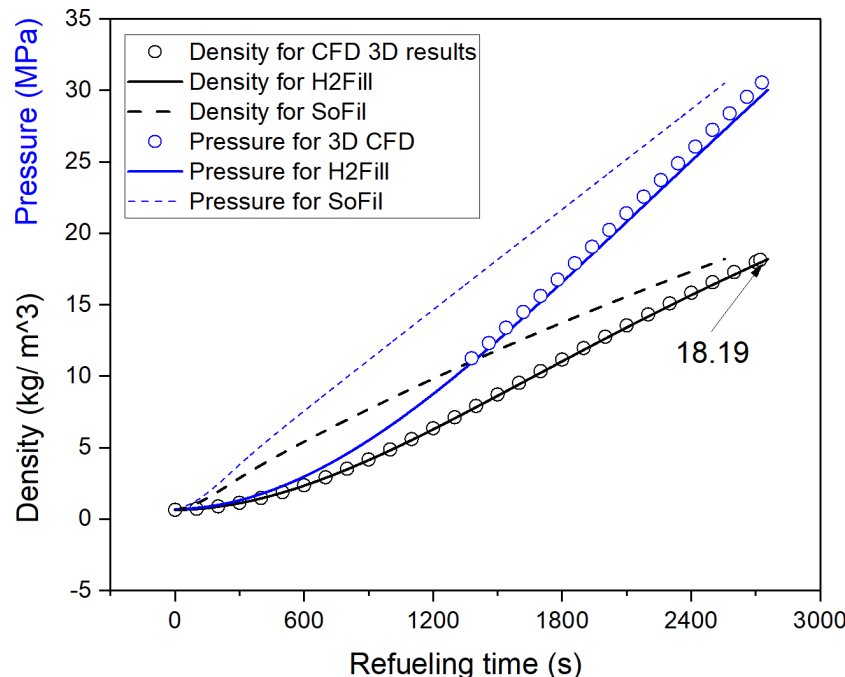
- Injector : 5 mm (ID)
- Uniform Temp. Distribution
- Max. gas temp. < 80°C

Accomplishments: Completed Initial Evaluation of Different H₂ Fill Models, Await Experimental Validation

Development of Refueling Protocol: Process Simulation (contd)



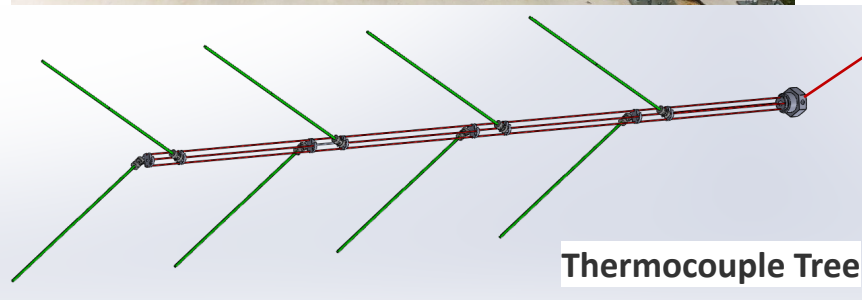
- ❑ Comparison with two process models:
 - ❑ NREL's H2FiLLS
 - ❑ AL's SOFIL
- ❑ Experimental results will be helpful to develop further confidence in the model's accuracy -> This will feed the refueling protocol.



Accomplishments: Experiments

Hydrogen Refueling Test Platform

- Installation of the test platform has been completed
- Successful engagement with the local Fire Marshal : Permit Received
- Commissioning of the facility for high-flow refueling test : Ongoing



Accomplishments: Formulated Experimental Plan for Evaluating Different Tank Injector Designs, to be Evaluated and Validated Experimentally

Development of Refueling Protocol (Next Steps)

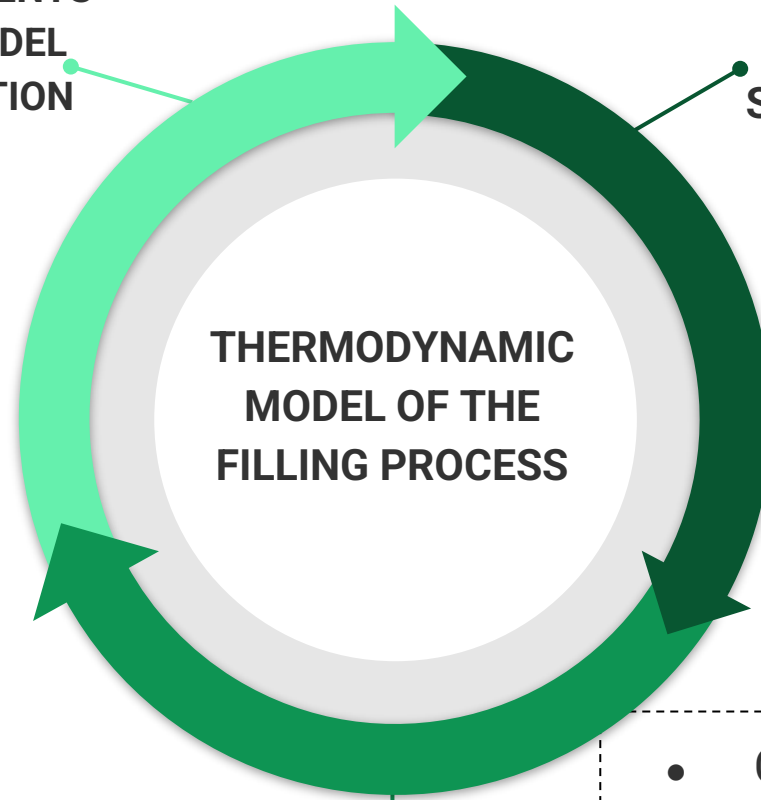


- Test different injector designs:
 - Discover Zero
 - Sea Change
 - Long velocity based design



Bunkering System Design : Ongoing

EXPERIMENTS
FOR MODEL
VALIDATION



PROCESS
SIMULATION

- Needs homogeneous flow pattern
- Review empirical correlations for $L/D > 2.8$ (8.7)
- Analyze the effect of different injection velocity

Target :
Injector design for homogeneous flow

COMPUTATIONAL
FLUID DYNAMICS

- Complete the ongoing 3-D simulation
- Analyze the heat transfer mechanism
- Test the effect of injection velocity and injector design

Accomplishment: Formulated the Regulatory Path, Completed 1st Public Engagement

Approval Steps

Overall Project

- US Coast Guard Design Basis
- Port Commission
- Community Advisory Committee
- BCDC
- CEQA
- Port of San Francisco – Property Agreement

In-Water Work

- Army Corps of Engineers
- Regional Water Quality Control Board
- National Marine Fisheries

Vessel Fueling and Operation

- United States Coast Guard
- San Francisco Fire Department
- Port of San Francisco – Permits

Sooner



Later



Meeting Notice and Agenda
of the
Port's Southern Advisory Committee (SAC)

DATE: Wednesday, March 29, 2023
TIME: 6:00 – 8:00 pm
LOCATION: Hybrid **In Person** and Virtual Public Meeting via Zoom

In Person – Southeast Community Center – 1550 Evans Ave at Third St (Use of Public Transit Encouraged - Parking Access off 3rd St North of Building) Refreshments Provided

Zoom Link: <https://us06web.zoom.us/j/85345172972>
Dial In: +16699006833, 85345172972#
Meeting ID: 853 4517 2972

**** Click on highlighted items below to access background documents ****

AGENDA

1. **Introductions and Announcements** (6:00 - 6:10)
 - Sale of Pier 68 Floating Drydocks
 - Department of the Environment RFP
 - MOU with HSH for Wind-Down of SWL 344 Trailer Site
2. **Acceptance of [Draft 2/22/23 Meeting Notes](#)** (6:10 - 6:15)
3. **Sail GP Base Camp at Pier 80** – Kyle Meyers, Silverback (6:15 – 6:45)
4. **Sea Change Ferry and Hydrogen Fueling at the Former Shipyard** – Rich Berman, Manager of Port Environmental - (6:45 – 7:15)
5. **Mission Bay Parks Transfer to Port and RPD** – David Beaupre, Director of Port Planning and Environment (7:15 – 7:30)

Next SAC Meeting:
4/26/23

The first public briefing of the H₂ Barge project to the Port's Southern Advisory Committee was given by Rich Berman (POSF) on March 29, 2023. The H₂ Barge was well-received.

Accomplishments: Completed Initial Foray into Hydrogen Ecosystem Development

Ecosystem Development:



- ✓ SF Chamber of Commerce invitation for the team to join briefings for local and international trade delegation (exact date TBD)
- ✓ The Project Team briefed the California Air Resources Board (CARB) and the Bay Area Air Quality Management Districts (BAAQMD) on March 16, 2023, regarding the H₂ Barge Project.
- ✓ Developed Slide Deck to allow Michael Kashuba (GO-BIZ) to brief more staff in the CA Governor's Office.
- ✓ Working with sister company Alcatraz Cruises, LLC on Discover Zero improvements (electric or electric plus fuel cell) and monitoring status of Sea Change with Switch Maritime.
- ✓ PI, Narendra Pal participated as Panelist in Panel Discussions on “Shoreside Charging and Fueling” during Port of the Future Conference in Houston, April 4-6, 2023.
- ✓ Team members attended the H₂ View Summit in San Francisco (July 14-15).
- ✓ Hornblower/Team participation in Chevron's Road to Zero event (August 25th) in Richmond, CA.

Collaboration Effectiveness

The H₂ Barge Project is highly collaborative both amongst project partners and with outside stakeholders and subject matter experts.



Klebanoff (SNL) with USCG for H₂ Properties Briefing, in collaboration with Joe Pratt, Zero Emission Industries, 9/26/22



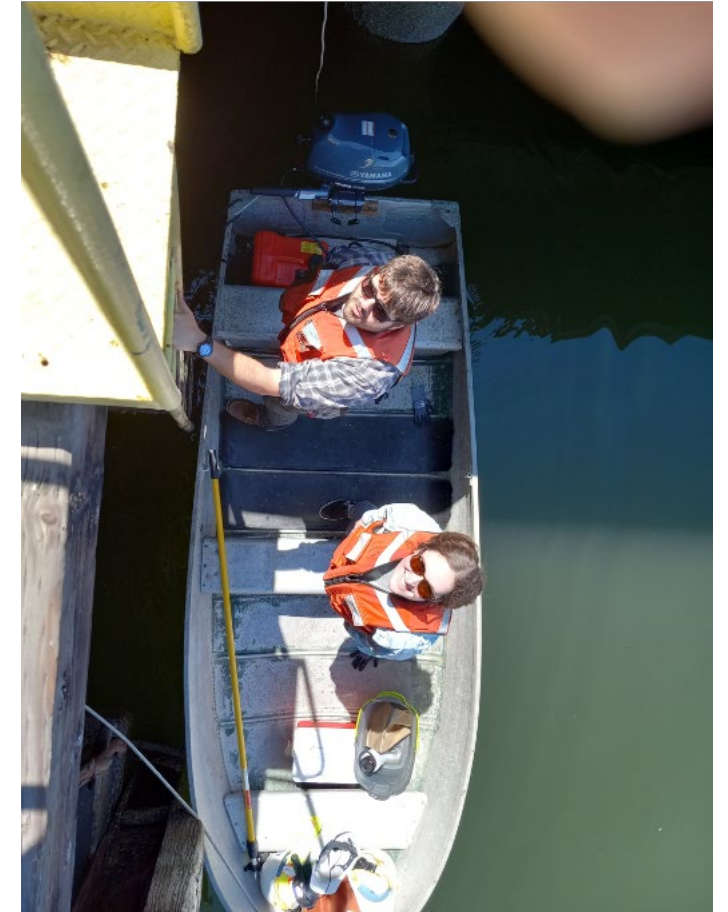
Sandia, Bayotech, Hornblower and Port of SF Fire/Safety and Engineering staff examine a IGX H₂ Refueling Trailer, 5/20/2022



Hornblower, Moffat & Nichol, Port of SF, and Sandia Staff examining electrical infrastructure at Pier 68, 12/23/2022.



Hornblower, Moffat & Nichol, Glosten and Sandia Staff consult with Dave Mik (L) of Power Engineering and Construction Co. about Flexifloat Barges, 3/10/2023



Sean Hart (Moffat & Nichol) and Emma Willey, Summer intern from Cal Poly, examine the Wharf 3 structural integrity, 9/1/2022.

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Collaboration Effectiveness (Cont'd)

- Project collaborators:

Collaborator	Identity	Relationship	Role
Hornblower Energy, LLC	Industry	Prime	Lead, Compliance, Budget, Design & Demonstration
Sandia National Laboratories	National Lab	Sub	Compliance, Design, Demo
Port of San Francisco	Port	Sub	Compliance, Demo
Air Liquide	Industry	Sub	Refueling Protocol
Bayotech, Inc	Industry	Sub	Hydrogen Storage and Hydrogen Off-take / Supply
NEL Hydrogen US	Industry	Sub	Electrolyzer
Glosten	Industry	Sub	Barge Design, Compliance and Liaisoning with USCG
Moffatt Nichol	Industry	Sub	Civil Engineering, Site Preparation

Remaining Project Challenges and Barriers

Phase-I:	❖ Permitting from Local Agencies ❖ Design Approval from US Coast Guard
Phase-II:	❖ Timely Equipment Procurement Due to Supply Chain Issues ❖ Confirming availability of maritime customers and commercial arrangements ❖ Mitigating inflation-driven budget impacts to ensure project's economic viability ❖ Protocol development ❖ Meeting Pile Driving Annual Window (June to November)
Phase-III:	❖ Demonstration of technology ❖ Data Collection and analysis
Barriers:	❖ Permitting & Code Compliance ❖ Design Approval from USCG ❖ Final Inspection by USCG

Proposed Future Work

FY 2023:

- Finalize Design & Development
- Permitting from Authorities Having Jurisdiction
- USCG Approval of Design Basis Letter
- Pass Go/No-Go milestone.
- Equipment procurement

FY 2024 (Assuming Go):

- H₂ refueling and battery-electric recharging protocol development
- USCG Approval of compliance.
- Assemble Barge

Note: Inflation has increased almost all project costs ~ 30% beyond what was budgeted. Furthermore, lead times on even simple items (e.g., tubing) is much longer than usual. These are both putting our future technical progress and schedule at risk.

Project Summary

- Selected Pier 68/Wharf 3 for deployment site.
- Certified Pier 68 electrical and water utilities as sufficient for deployment.
- Completed initial hydrogen barge design compliant with NFPA 2.
- Selected all major component suppliers.
- Completed initial Piping and Instrumentation Diagram (P&ID) for H₂ Barge.
- Completed conceptual flow diagrams for different operational scenarios.
- Completed thermal modeling of hydrogen vessel tank filling.
- Designed and constructed approved H₂ Tank Test Stand at Air Liquide.
- Formulated Regulatory Path, engaged the public for the first time.
- Been working with the United States Coast Guard to establish regulatory basis.
- Engaging with the nascent H₂ ecosystem in the SF Bay Area, with goal to grow it.

Questions?

Thank You!



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Technical Backup Slides

None this time.

Technology Transfer Activities

No Technical Transfer Activities have been conducted thus far.

Publications and Presentations

PI, Narendra Pal, Panelist in Panel Discussions on “Shoreside Charging and Fueling”, University of Houston’s Port of the Future Conference, Houston, TX, April 4-6, 2023.

L.E. Klebanoff and Project Team, “Review of DOE H₂ Barge Project with CARB and BAAQMD Staff,” Zoom presentation to staff of the California Air Resources Board and the Bay Area Air Quality Management District staff, Zoom meeting, March 16, 2023.

L.E. Klebanoff, “On the Safety-related Physical and Combustion Properties of Hydrogen Compared to Natural Gas,” Presentation to the Headquarters of the United States Coast Guard, Washington DC, September 26, 2022.

L.E. Klebanoff, Narendra Pal, “On the Safety-related Physical and Combustion Properties of Hydrogen Compared to Natural Gas,” Presentation to the Port of San Francisco, San Francisco, CA, May 20, 2022.