PROTON
THE LEADER IN ON SITE GAS GENERATION.

Deployable Hydrogen Fuel Supply for Clean and Quiet Power

2017 Joint Service Power Expo
Session 3: Fuel Cells
May 2, 2017

Company Overview….for today

- World leader in PEM water electrolysis
- HQ in Wallingford, Connecticut, USA (founded 1996)
- 2,700 Systems delivered in 75 countries for:
  - Industrial applications
  - Laboratory markets
  - Military customers
  - Fueling and energy storage
- ISO 9001:2008 certified
- ~ 100 employees

And an exciting new development for tomorrow…

Contemplated acquisition of Proton OnSite

27 February 2017

"Acquiring the world's largest manufacturer of PEM hydrogen electrolysers"

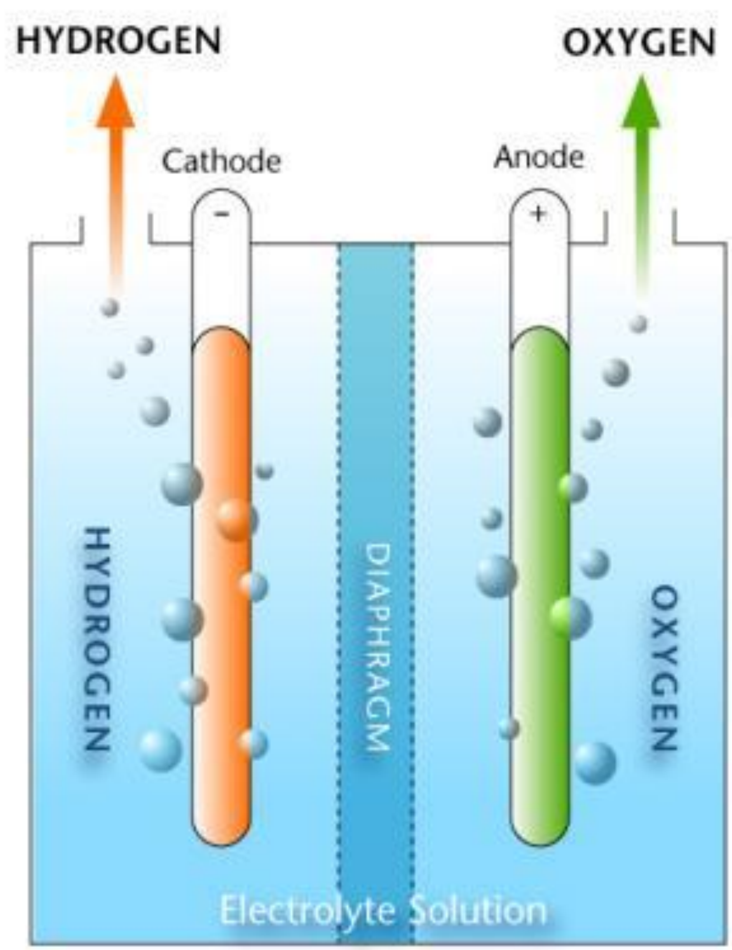
PRESS RELEASE / OSE FILING

27 February 2017 – Oslo, Norway

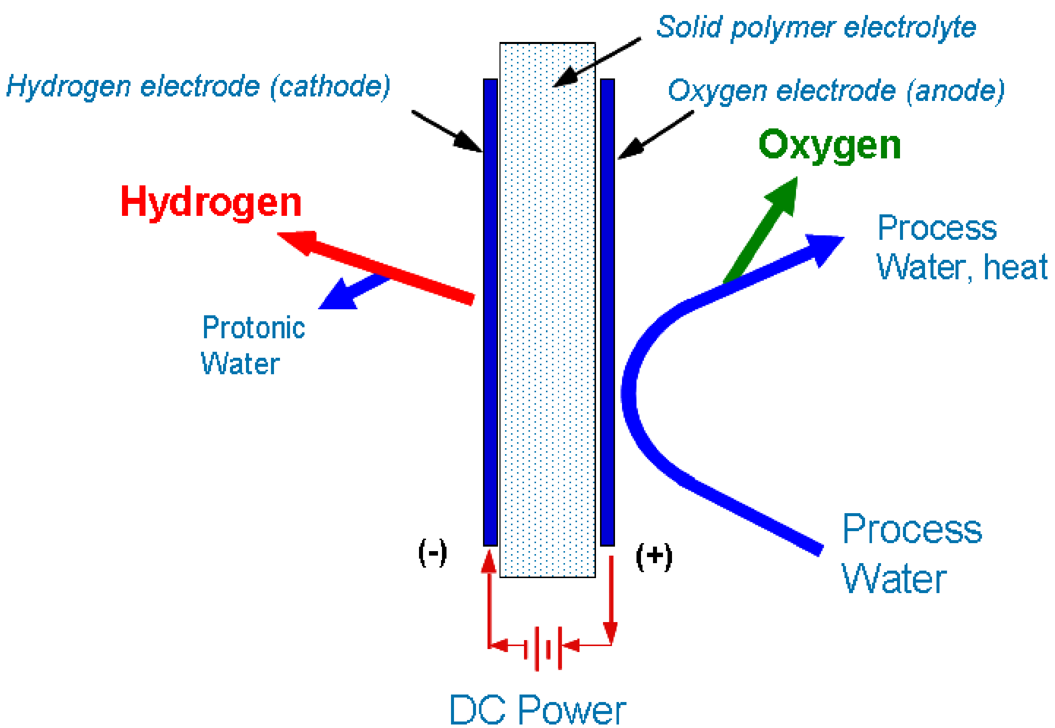
Nel ASA: Acquires Proton OnSite to create the world's largest electrolyser company and launches private placement

Commercial Electrolysis Technologies

- Liquid KOH
  - Corrosive electrolyte
  - Complicated BOP and controls
- PEM = solid electrolyte
  - Simple BOP, safer system



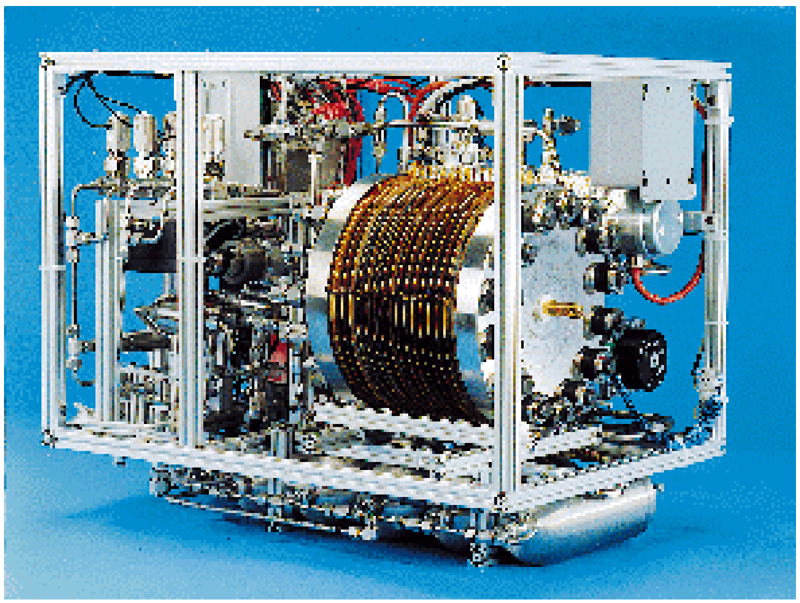
Liquid KOH



Proton Exchange Membrane (PEM)

PEM Electrolysis Legacy

- Originally designed for military and space applications
  - Providing O2 for critical life support function
- Reliability and safety essential
- Highly overdesigned and costly



ISS OGA system: NASA

UTAS ILPE system: Navy

Scalable Technology:
From Single to Multi-Stack Systems

HOGEN® GC

HOGEN® S Series

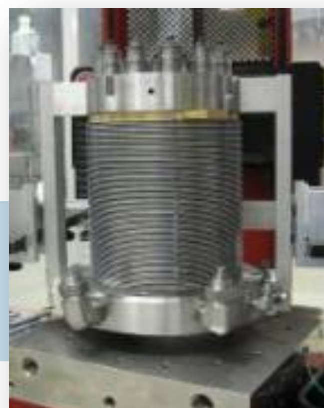
HOGEN® H Series

HOGEN® C Series

HOGEN® M Series

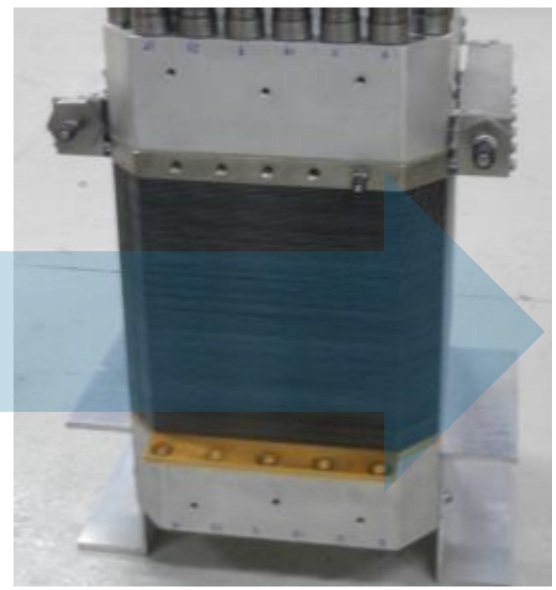
28 cm^2
0.05 Nm^3/hr
0.01 kg/day

86 cm^2
2 Nm^3/hr
4.3 kg/day



210 cm^2
10 Nm^3/hr
21.6 kg/day

680 cm^2
50 Nm^3/hr
100 kg/day



How much H_2 can we make?

7 kW

1 day:
2.3 kg

40 kW

1 day:
12.9 kg

175 kW

1 week:
455 kg

1,000 kW

1 day:
451 kg

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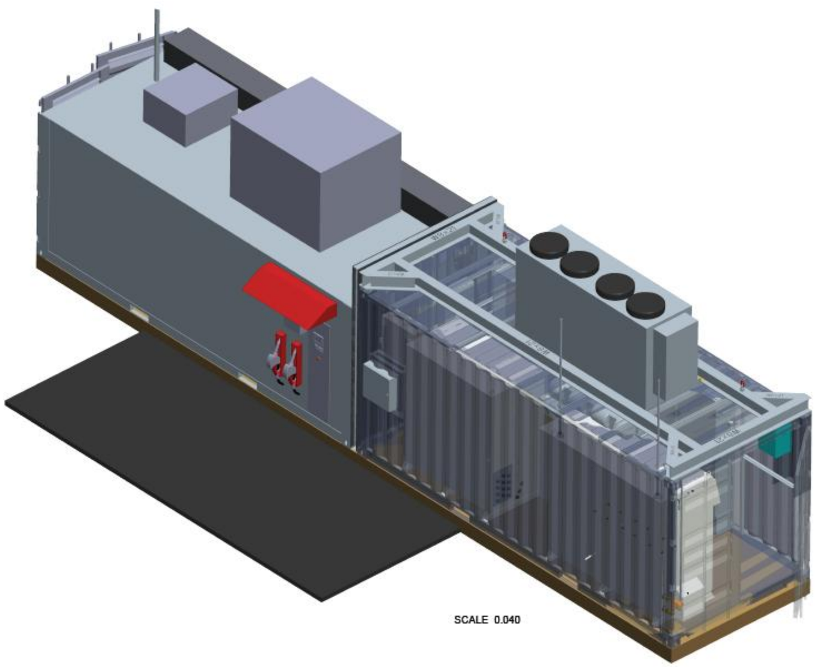
Commercial Fueling Status: TRL9

SunHydro 2 Project: Showcasing a new fast install station design

- Proton OnSite has developed a new compact “site ready” station design, “SunHydro 2”.
- In collaboration with DOE and NPS, this equipment design is being demonstrated at the NPS site on Brentwood Ave.
- The station will provide an important fueling capability for FCV’s that will be used for outreach and market development efforts.



Ribbon cutting at NPS facility:
July 11, 2016

DOD investment in H2/electrolysis infrastructure

Schofield Barracks (TARDEC)

DDJC (DLA)

JBPHH (AFRL)

MCBH (ONR)

What about “deployable” H2?

“Silent Camp” (CERL)

Remote balloon filler (NOAA)

“PEPSAE” (AFRL)

“HyHauler” (TARDEC)

Remote aerostat filler (Army REF)

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Electrolyzers offer a safe and deployable replacement for helium lifting gas for aerostats

Proton electrolyzer producing hydrogen from solar power

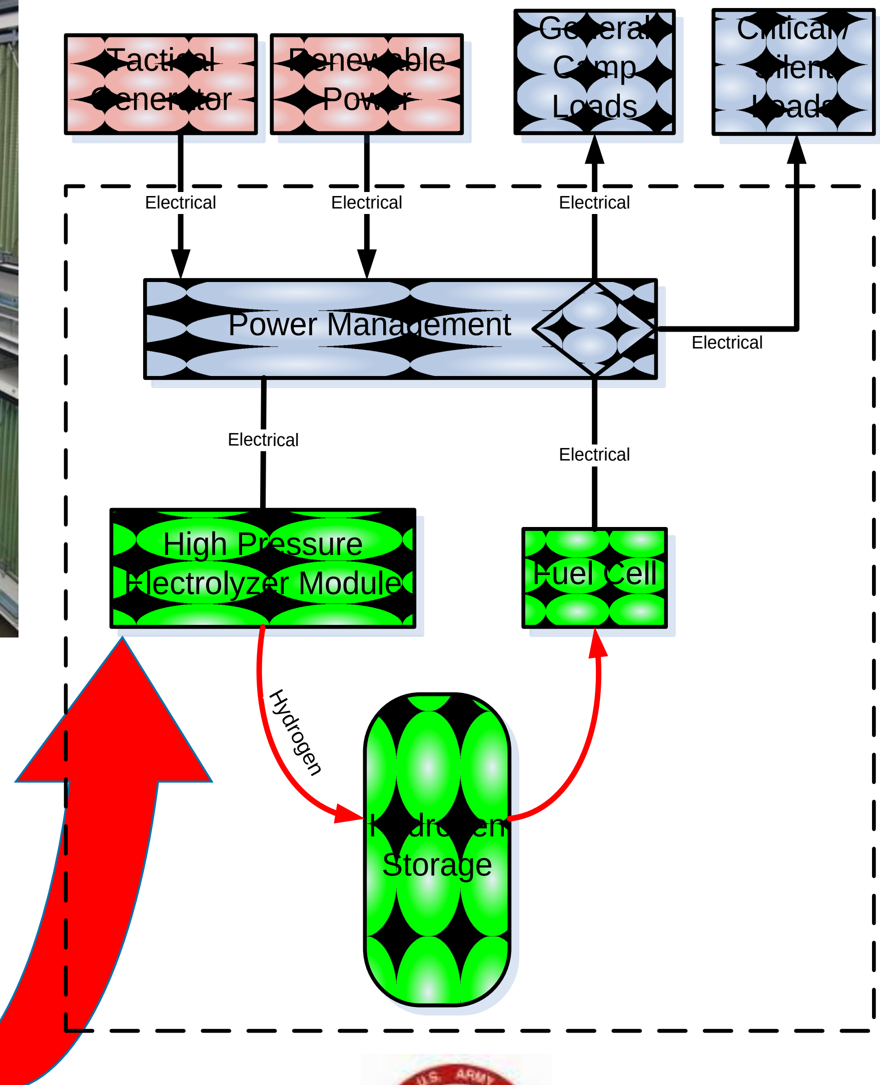
DoD aerostats in remote areas need a sustainable source of lifting gas

Army REF sponsored a proof of concept demo

Proton electrolyzer at remote launch site, Fort Benning, GA, December 2012

Energy storage for FOB's: Silent Camp

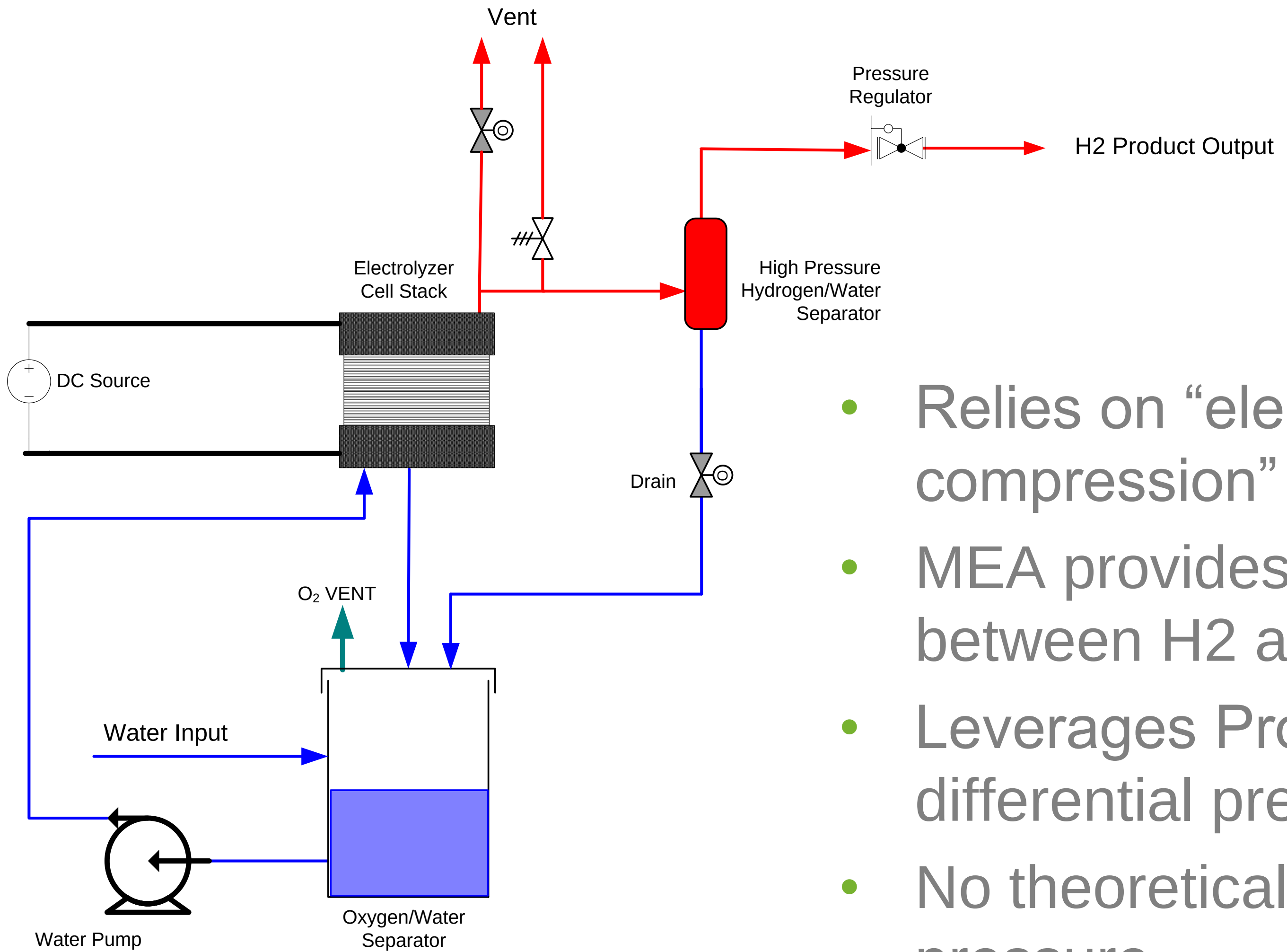
Silent Camp system concept optimizes the operation of tactical gensets by loading them to a more efficient operating point and providing quiet backup power.



Silent Camp energy storage system installed at ERDC/CERL test site

High Pressure Electrolysis

Simple Approach to Eliminate Mechanical Compression up to 350 bar:



- Relies on “electrochemical compression”
- MEA provides pressure barrier between H2 and O2 side of cell
- Leverages Proton’s expertise in differential pressure electrolysis
- No theoretical limit to output pressure

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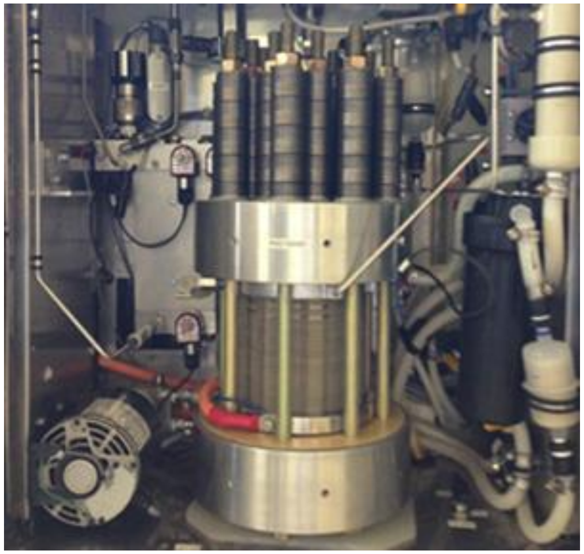
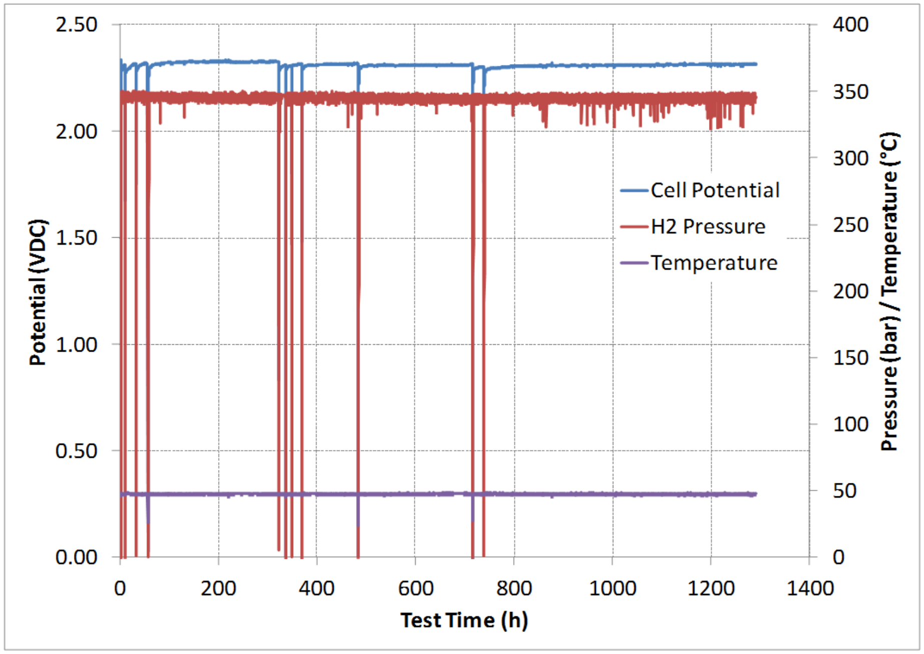
High Pressure Electrolysis for Simplified Fueling

- Proton has unique capability in high differential pressure electrolysis
- 350 bar stack design originally funded by DOE has now been scaled up to a 4.3 kg/day scale
- Eliminates the need for mechanical compression, which is often the weak link in the system solution





350 bar stack on test, and testing data showing stable operation.

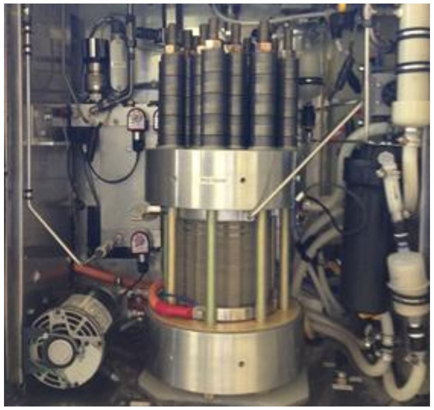
Stack design enhancements: 165 bar to 350 bar

165 bar (CERL funding)

- Plastic frames for sealing and pressure containment
  - Loss of strength with temperature
- Backup ring to control radial deflection
- Advanced custom tie rods and nuts

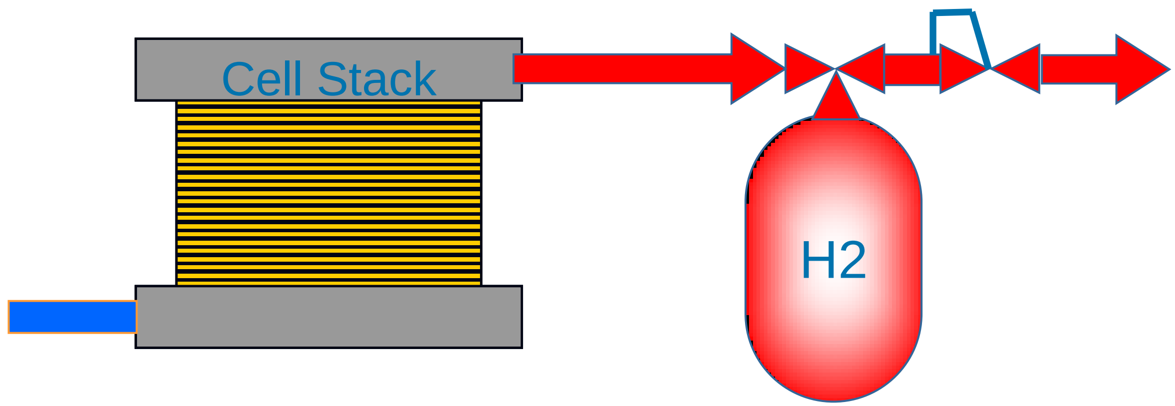
350 bar (DOE + commercial)

- Metal frames for sealing and pressure containment
  - No significant loss in strength with temperature
- No backup ring required
- Commercial-off-the-shelf tie rods and nuts



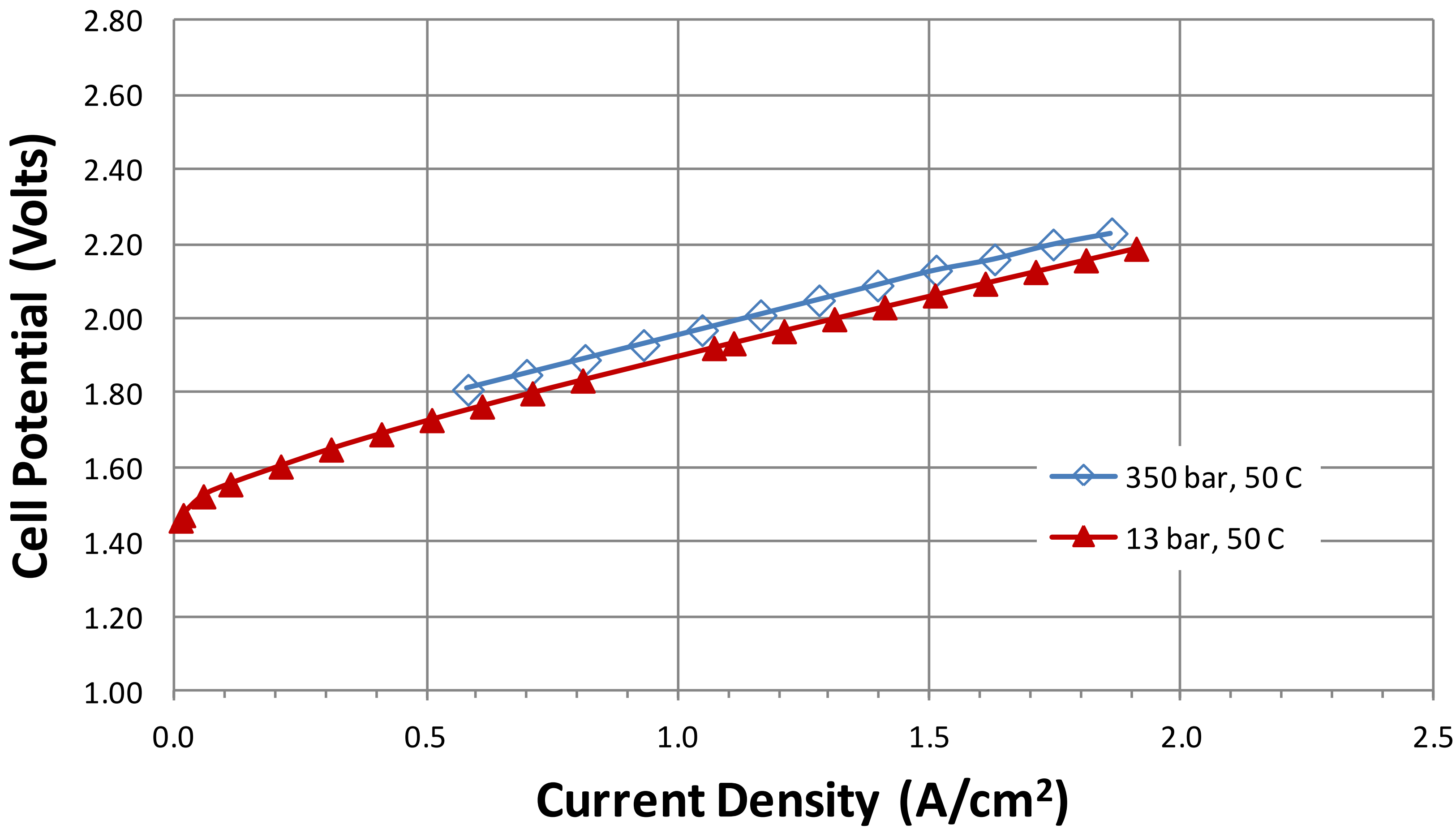
What is electrochemical compression?

- Make the cell structurally sound for the target pressure and typically proof to 1.5X MAWP
- Back pressure the gaseous output of the cell
  - Higher cell potential (Nernst offset)
  - Higher H2 back diffusion across MEA (I_{loss})
- P=IV, requires more power



What is the efficiency loss?

- Voltage performance: 13 bar versus 350 bar
  - Small voltage penalty predicted by the Nernst Equation



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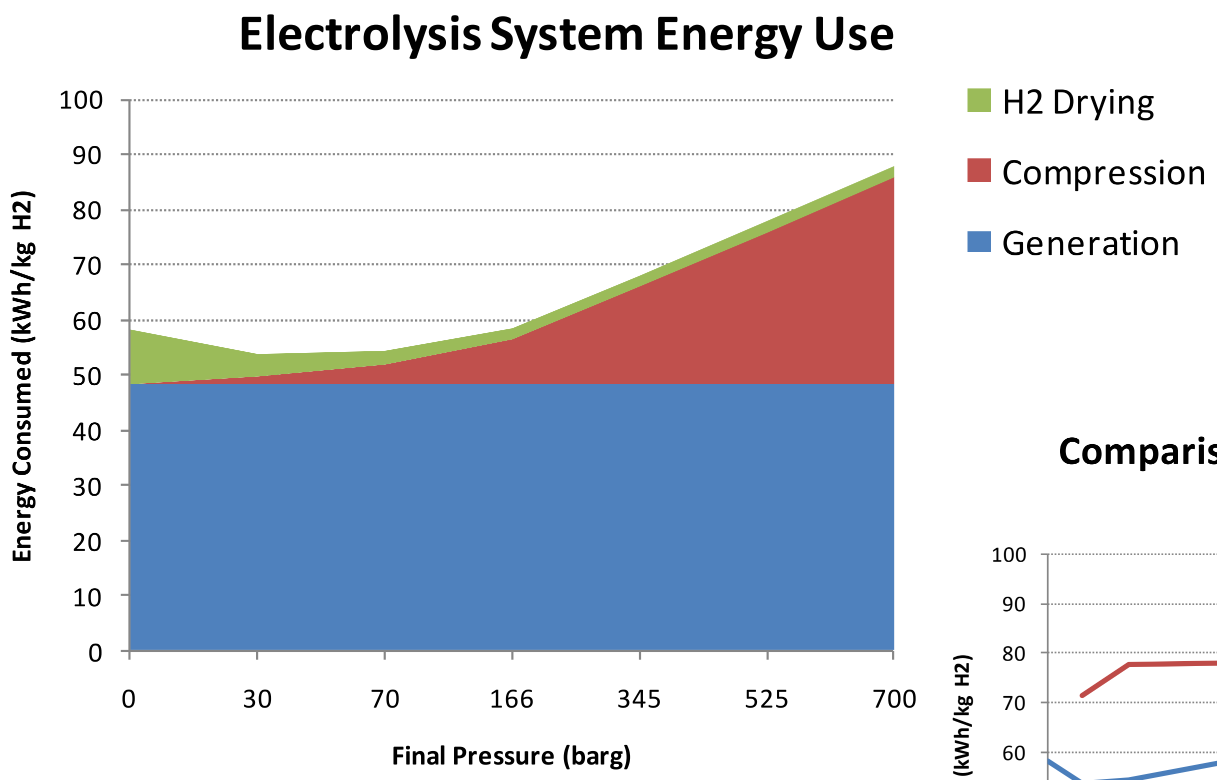
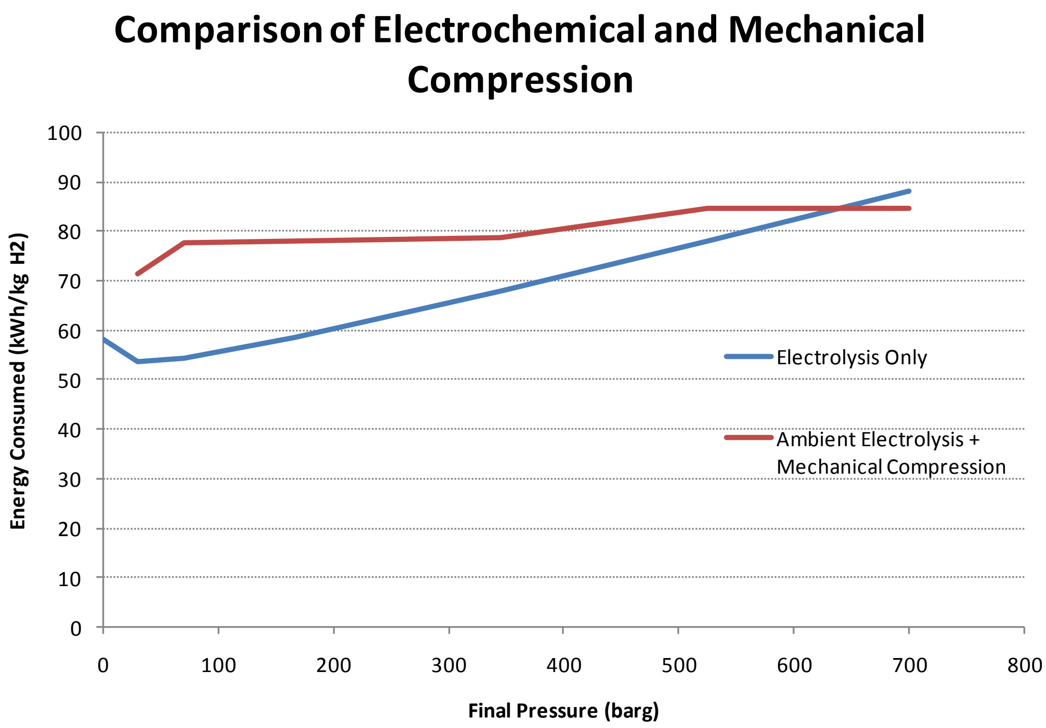
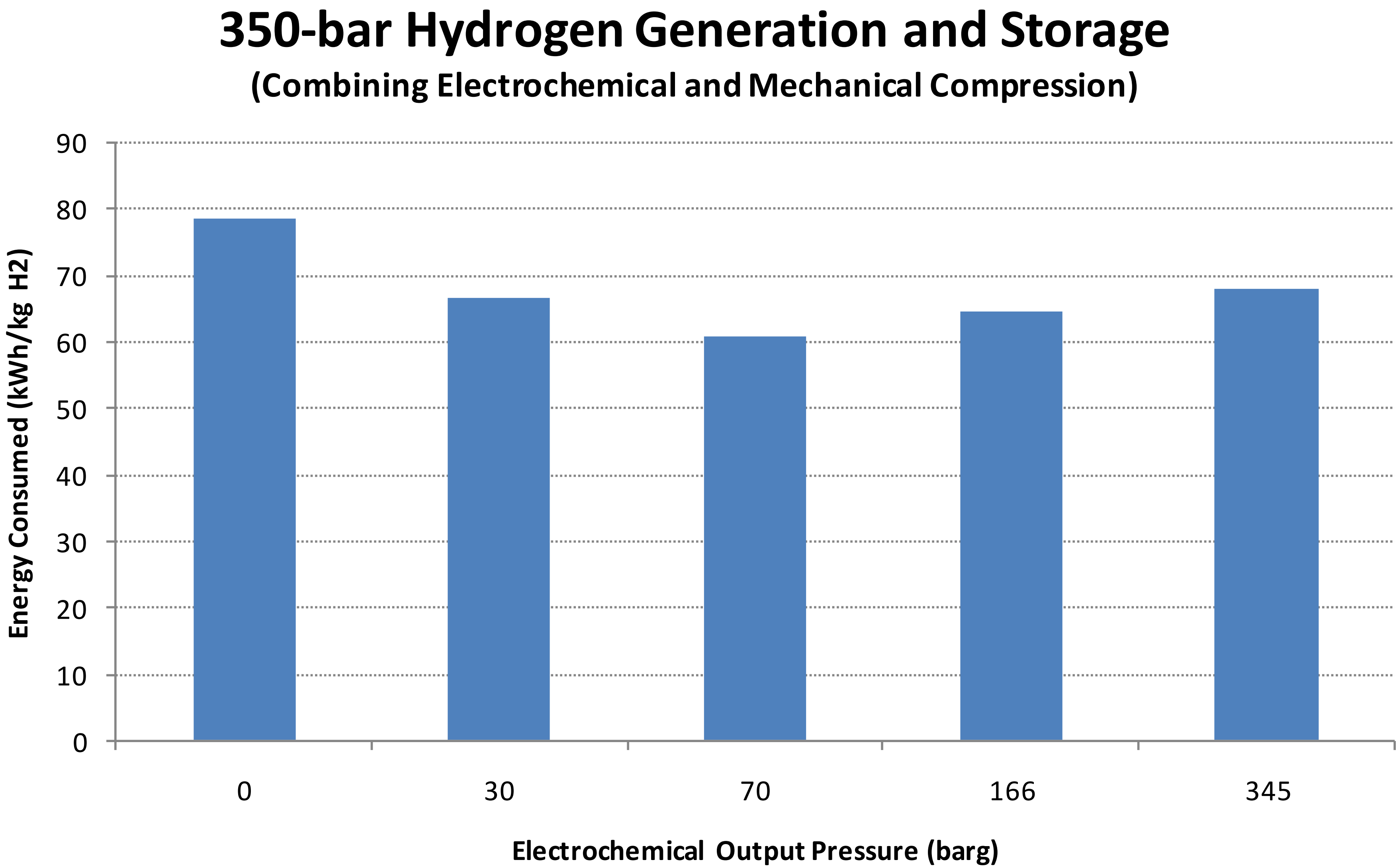
Compression Trade-off



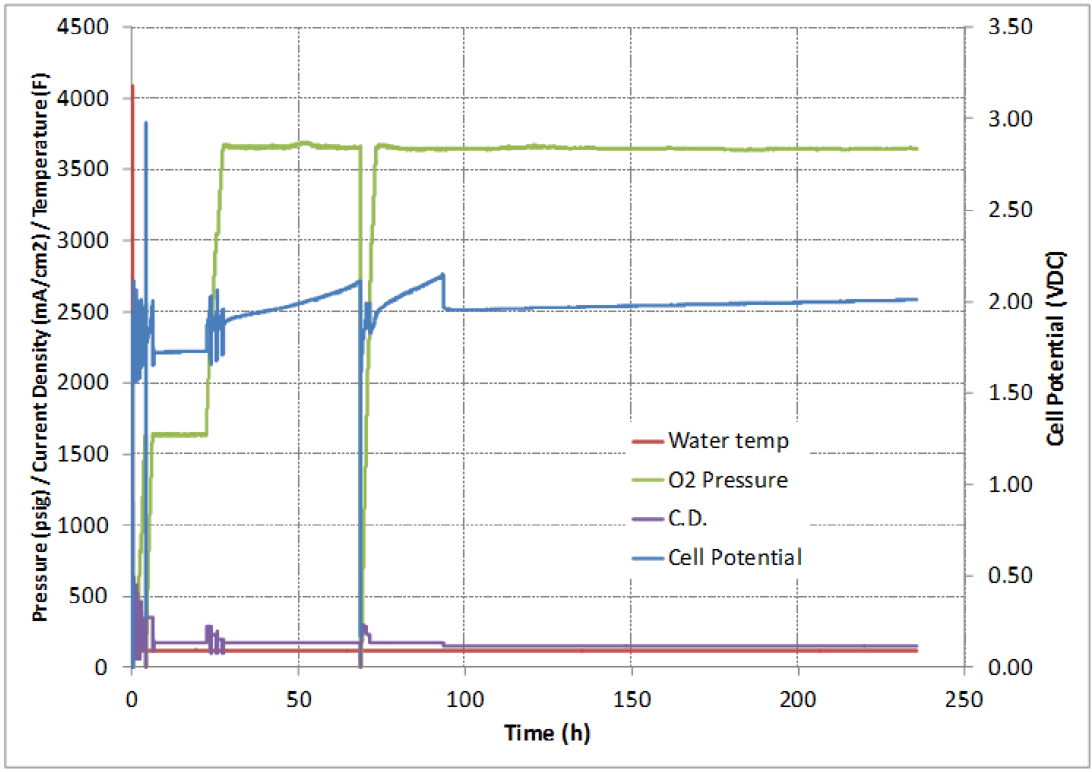


Compression Trade-off

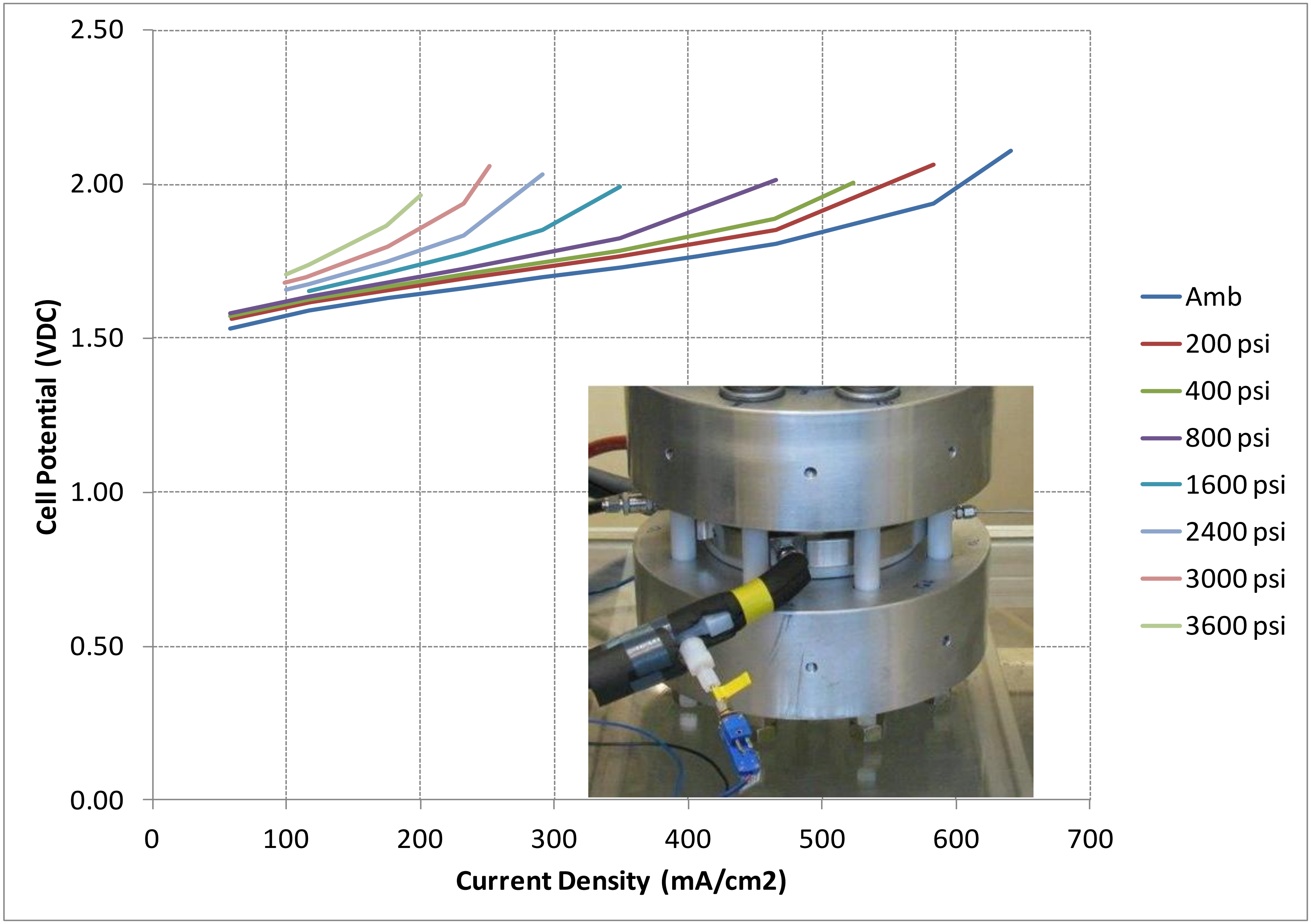


High Pressure Oxygen Generation:
NASA Phase II SBIR, via Contract # NNX15CM01C

- NASA application for atmosphere revitalization and EVA storage for exploration missions
- Eliminates need for oxygen compressor and associated reliability and redundancy concerns
- 3600 psi oxygen requirement
- Cathode feed design, rather than anode water feed
- Directly leverages design elements from the 350 bar H_2 stack



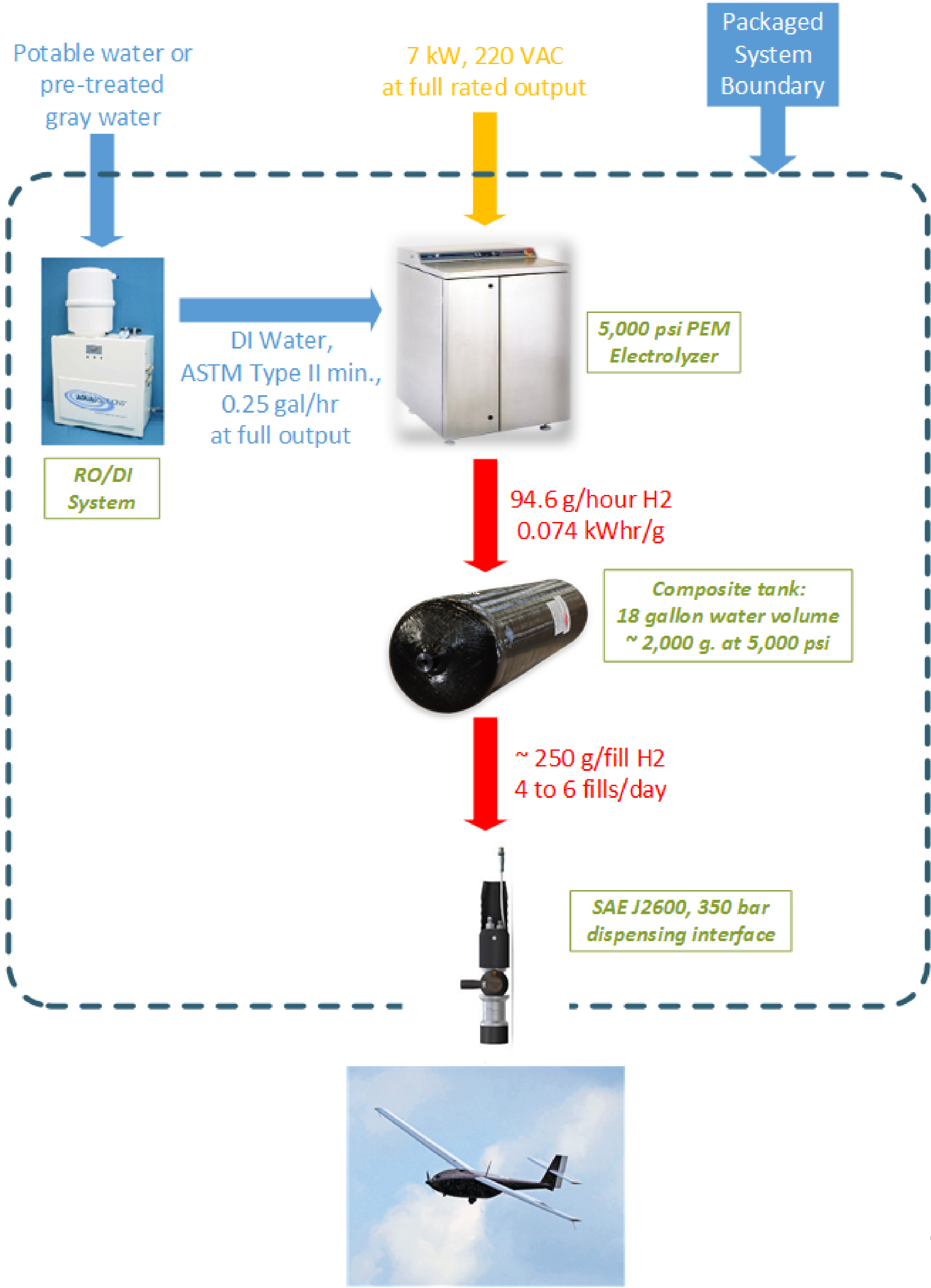
Voltage vs. O_2 pressure



Integration Considerations

Example concept for deployable UAV fueling:

simple integration of COTS components and designing for environment and CONOPS



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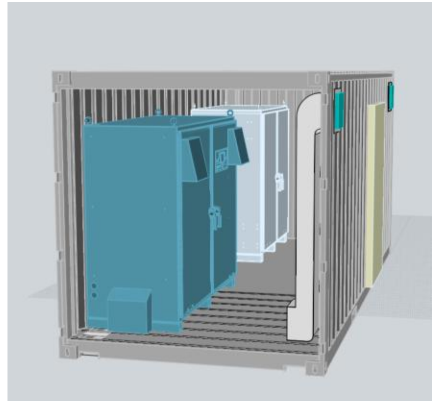
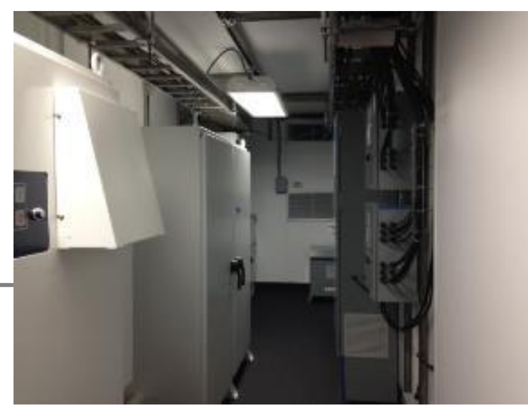
Containerized Hydrogen Solutions:
established capability for ease of installation





Design Considerations for In-Theater Needs

- Flexible power conversion and control
- Design for the environment
- High efficiency water treatment
- Packaged systems, readily transported
- Site ready, rapid integration features
- Leverage other high value uses for hydrogen
- Generation capacity needs to be traded against storage
- Where will the power come from?

Electrolysis technology addresses real world military operational needs:

Lifting gas

Oxygen generators

Tactical vehicles

UAV's and UUV's

Mobile power

FOB Energy Storage

Thank you!

Sponsors/Collaborators:
DOE/FCTO
NASA/MSFC
ERDC/CERL
TARDEC

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