U.S. ARMY

DEVCOM C5ISR CENTER

U.S. ARMY COMBAT CAPABILITIES DEVELOPMENT COMMAND C5ISR CENTER

Fuel Cell Power Sources for the Dismounted Soldier	MAY - 2023

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SMALL UNIT POWER REQUIREMENT

THE NEED

- **When power is needed for long durations in "austere locations" there is a need for a power generation source that can be used to recharge batteries.**
- **Ability to recharge batteries "on-the-move" will facilitate operations to continue uninterrupted without requiring the operation to be halted for recharging batteries.**
- **A wearable power generation system can facilitate recharging of batteries "on-the-move".**
- **In the absence of the ability to recharge batteries either additional batteries must be carried or one has to rely on battery resupply to meet the power and energy demands.**

What is needed is a Power generation source that is scalable for individual or group needs that is at a reduced weight, size, noise and emissions for battery charging or as a direct power source.

POTENTIAL TECHNOLOGY OPTIONS

Power Generation Technology

- Fuel Cell Systems
- Thermo Electric Generators,
- Thermo Photo Voltaic Generators
- Thermionic Systems

Fuel Cell Technology and Fuel Options

- PEM, High Temperature PEM, SOFC
- Hydrogen, Chemical Hydrides, Methanol, Ethanol, Propane, JP-8

FUEL SELECTION

Large Choice of materials available as Hydrogen carriers

- Weight % Hydrogen
- Volumetric Considerations
- Safety during Use, Storage and Transport
- Environmental Stability,
- Controllable Release of Hydrogen

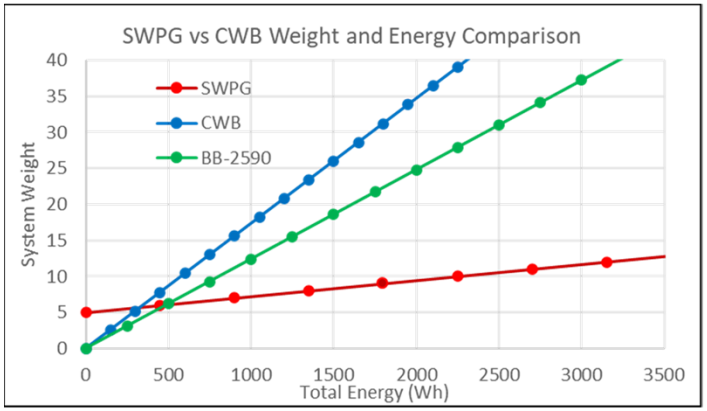
Technology	EDAB	NH3 Borane	Na Silicide	Na Borohydride
Theoretical Fuel Energy Density (Wh/kg)	3697	6722	3025	7058
Cartridge (Wh/kg)	< 500	< 1000	< 200	< 700
Comments	Pentaborane by product	Ammonia by product	Low Energy Density	Difficult Reaction Control

Technology	RMFC	DMFC	AlH_3
Theoretical Fuel Energy Density (Wh/kg)	2907	5538	3361
Cartridge (Wh/kg)	< 800	< 1000	< 1000
System Power Density (W/kg)	< 25	< 15	< 30
System Vol. Power Density (W/kg)	< 25	< 15	< 40
TRL	~ 6	~ 8	~ 6

Soldier Wearable Power Generator (SWPG)

600 Wh of Energy

4 x CWBs = 1 x Methanol Cartridge = 1 x Alane Cartridge

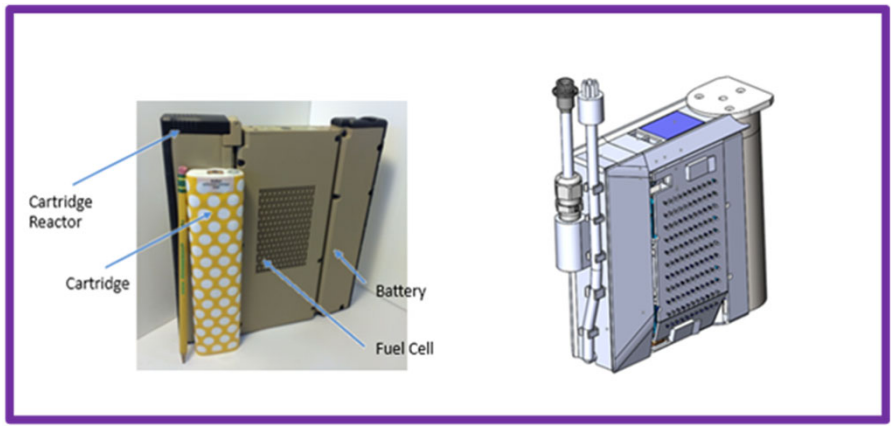


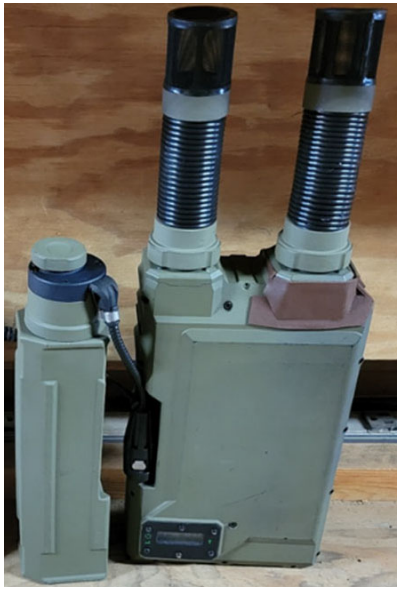
Significant Weight Reduction for Extended Missions

On-The-Move Charging Configuration

- Empowers Soldiers to be more “energy independent”
- Fuel cartridges have lower weight/volume than spare batteries
- Enables extended duration operation without increasing Soldier burden

SOLDIER WEARABLE POWER GENERATOR DETAILS





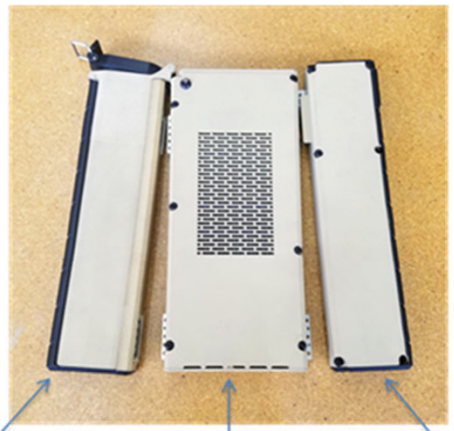
Soldier Wearable Power Generator (SWPG)

- Nominal Power Output > 20 W
- Cartridge Energy > 200 Wh
- Weight (including fuel) < 6 lbs. (T)
- Operating Temperature - 20 C to 55 C
- Ruggedization MIL-SPEC compliant

EVOLUTION OF THE ALANE FUEL CELL SYSTEM

2010

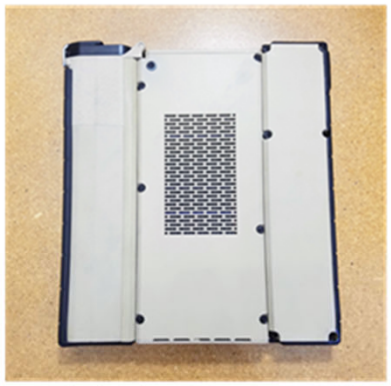
Cartridge



Reaction Chamber:

Fuel Cell System: (Fuel cell:)

Battery Chamber



Fully integrated System

Next Gen System

EVOLUTION OF THE REFORMED METHANOL FUEL CELL SYSTEM

- Progressive reduction in size and weight
- Improved Ruggedization
- Improved Manufacturability and Reliability

DISCUSSION ON HYDROGEN AS POTENTIAL FUEL

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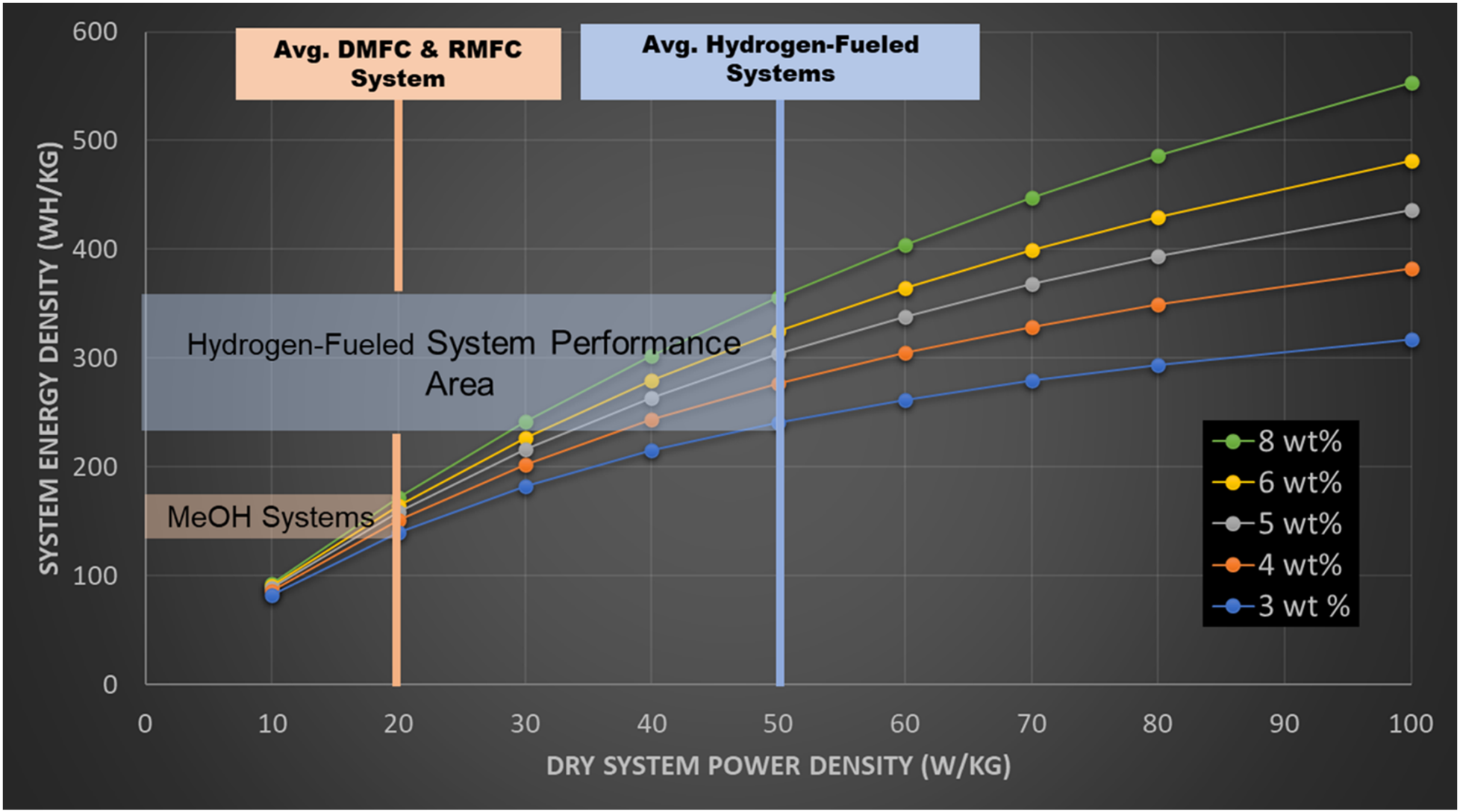
GASEOUS HYDROGEN VS OTHER FUEL CARTRIDGES

600 WH of Cartridge Energy Storage				
	Weight	Volume	Equivalent Hydrogen	
Fuel Option	Kg	Liters	wt/wt%	wt/L
RMFC Cartridge	> 0.80	~ 0.75	< 5.0%	~ 52
DMFC Cartridge	< 0.60	~ 0.80	> 7.0%	~ 43
Alane Cartridge	< 0.60	~ 0.70	> 7.0%	~ 55
350 bar Hydrogen	> 1.00	~ 1.70	< 4.0%	~ 23

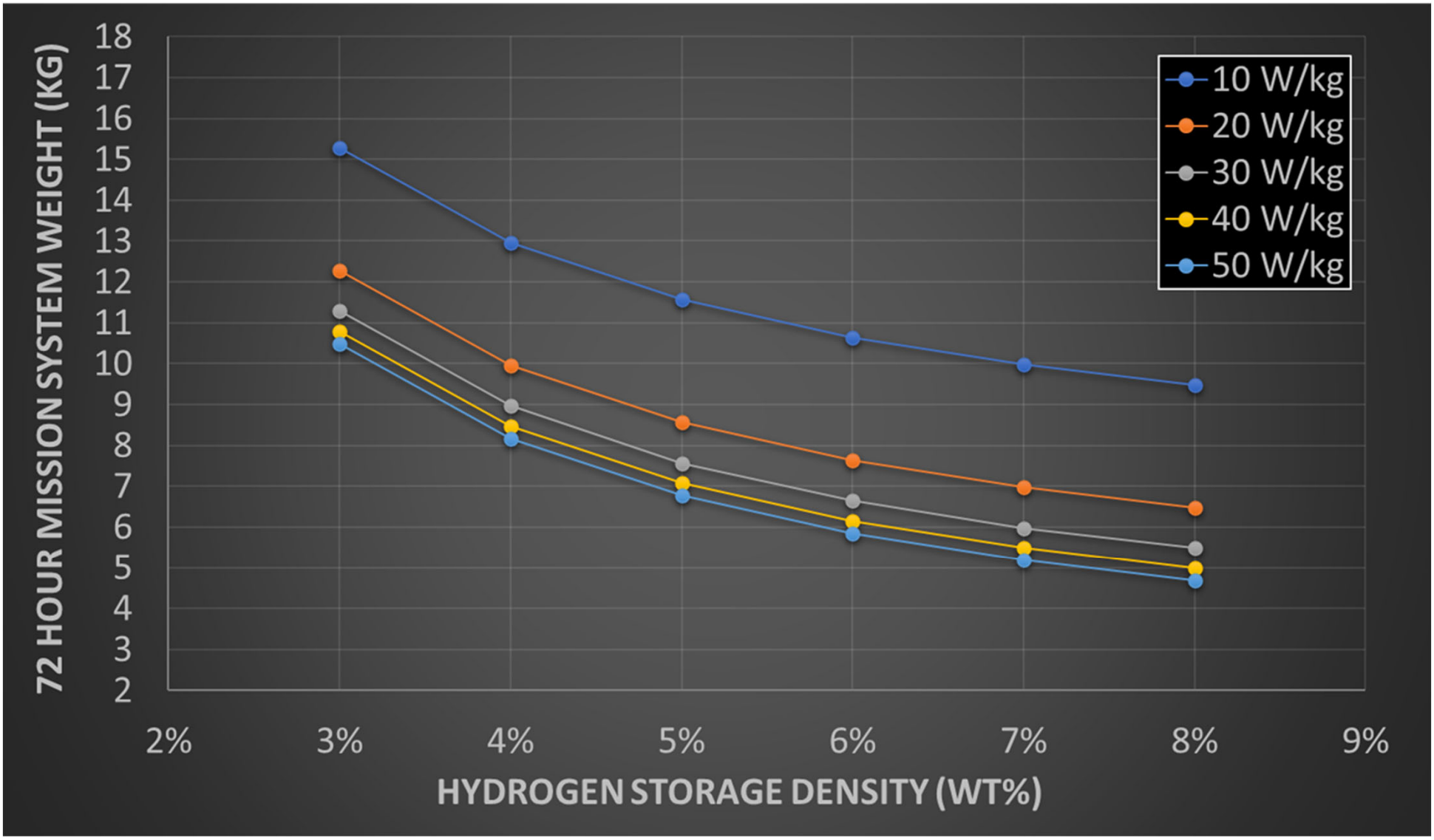
Gaseous Hydrogen Storage can be competitive with liquid and/or solid fuels if storage tanks can be built to withstand pressures > 350 bar

THEORETICAL IMPACT OF DRY POWER DENSITY ON ON SYSTEM METRICS



Hydrogen-Fueled systems warrant further investigation for portable power generation applications

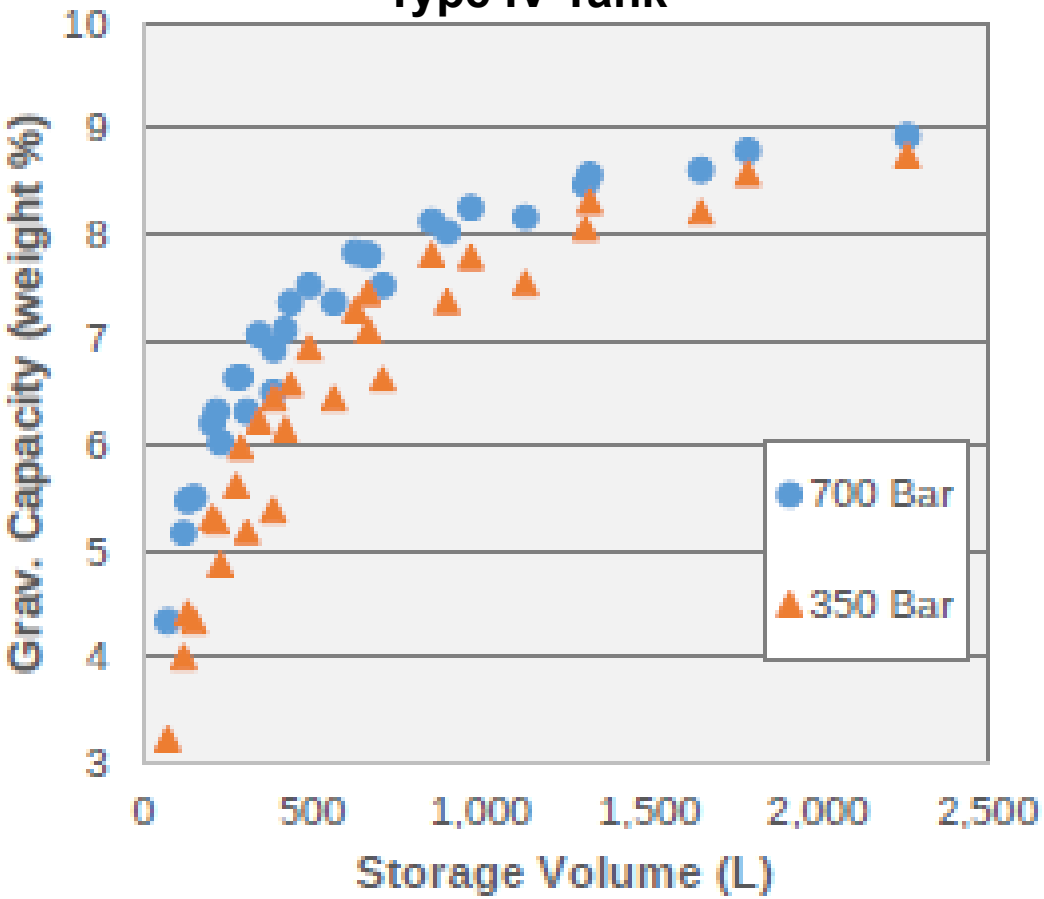
THEORETICAL IMPACT OF CARTRIDGE ENERGY DENSITY ON 72-HR MISSION WEIGHTS



- Theoretical 72-hour mission system weight ranges for various fuels:
  - Methanol: 7-10 kg
  - Hydrogen: 6-8 kg

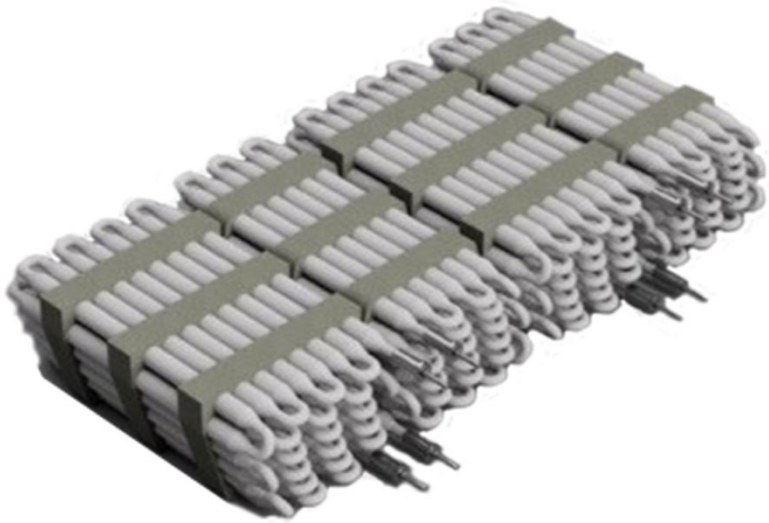
Gaseous Hydrogen Storage

Type IV Tank



"Design Space Assessment of Hydrogen Storage onboard medium and heavy duty Fuel Cell Electric Trucks", Proceedings of the 14th Fuel Cell Science, Engineering, and Technology Conference, PowerEnergy2016, June 26-30, 2016,

Potential COTS Conformal Tank



Representative Conformal H2 Tank – Vendor A

Hydrogen Content Varies from 4-8 wt% depending on system size

SUMMARY

- Presented on the development of wearable fuel cell power systems.
- Power Generation systems based on Methanol, Gaseous hydrogen, or solid hydrogen (Alane) fuels are expected to offer significant weight savings vs batteries for extended missions.
- Dry system power density is critical in achieving low mission weights.
- Small size, gaseous hydrogen storage tanks are an attractive option if they can safely store hydrogen at > 4 wt% Hydrogen.