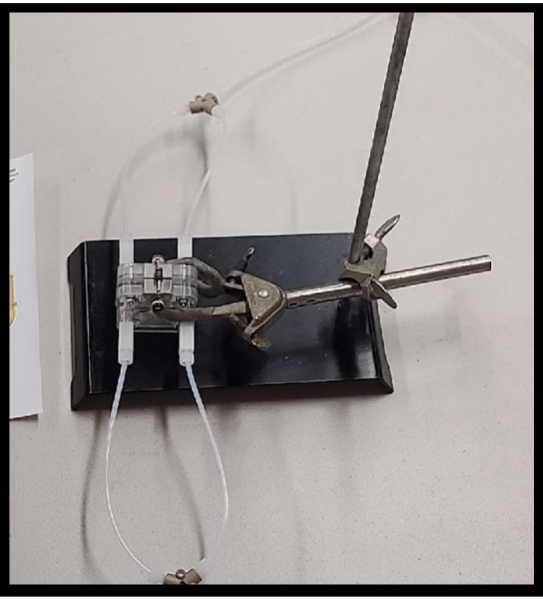

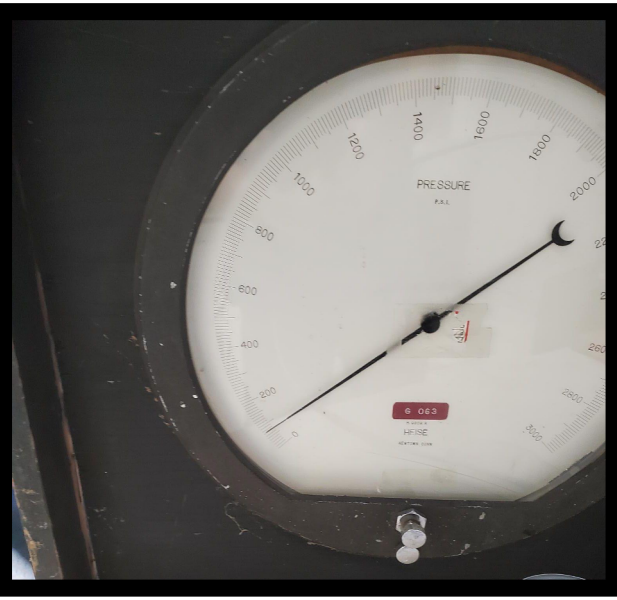

System Design for a Polymer Electrolyte Membrane Hydro-Proof Test Apparatus

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Presentation Outline

Big Picture

Background

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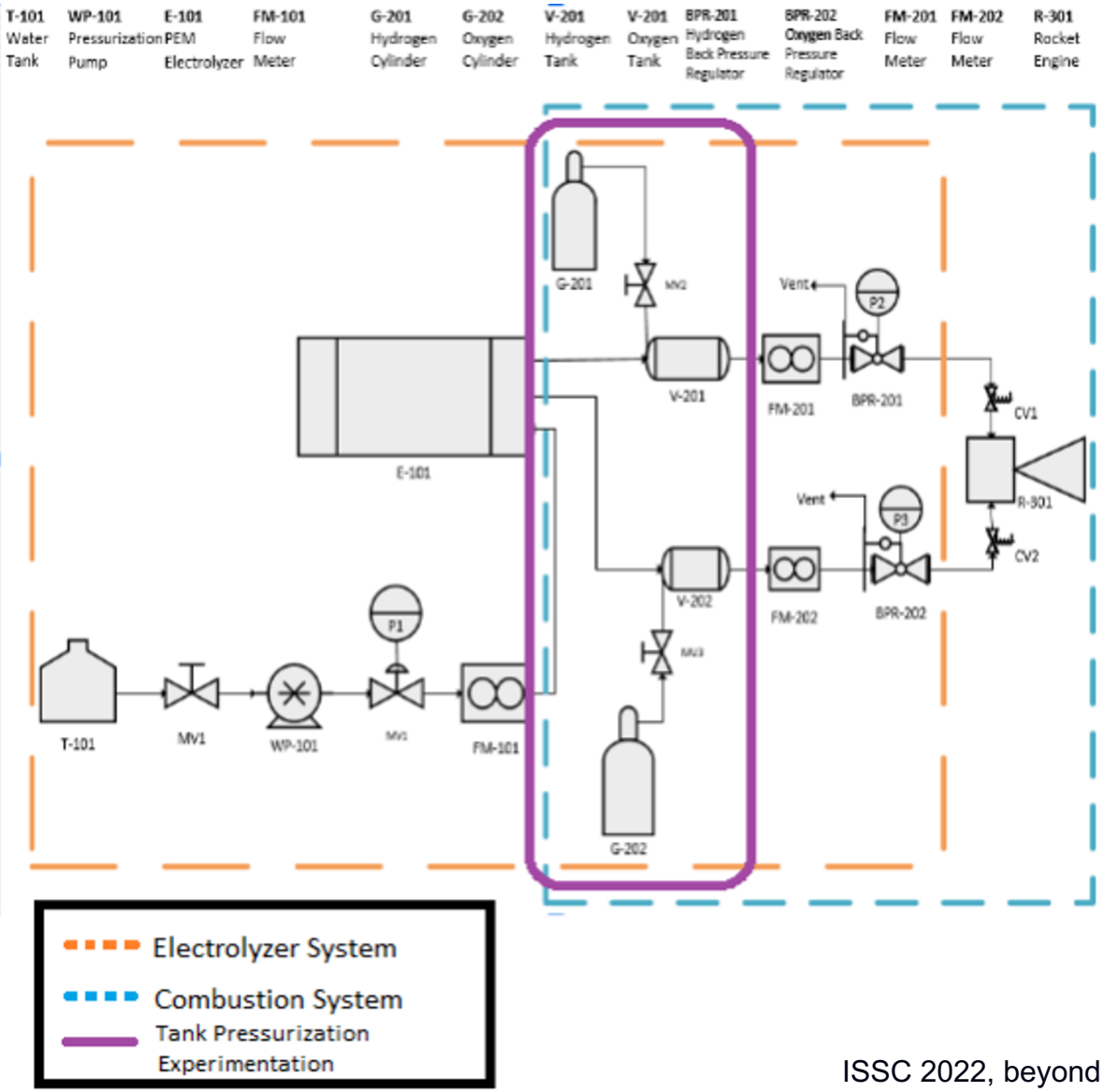


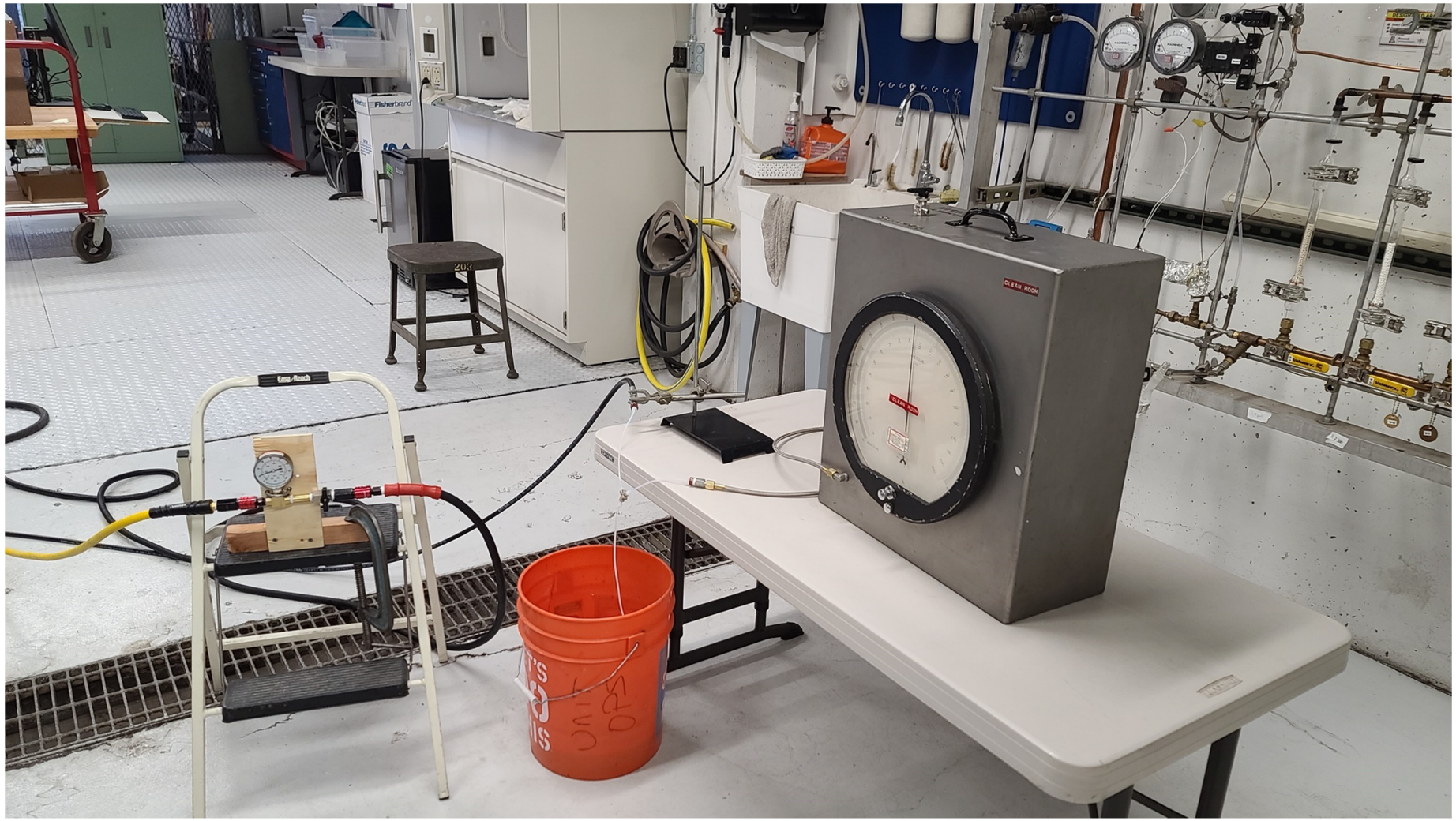
Big Picture

- **Develop a Green Propulsion System for a 1-3U Cubesat**
- **Utilize a Polymer Electrolyte Membrane (PEM) to separate Water into Hydrogen (Fuel) and Oxygen (Oxidizer)**
- **Product from burning Hydrogen with Oxygen for thrust is Water**
- **Water is a stable, nontoxic, non-polluting substance that can be collected via In-Situ Resource Utilization (ISRU)**

Background

- Determined that 3.5 atm is the optimal operating pressure for the propulsion system
- Evaluating Educational PEM Electrolyzers to stay in CubeSat paradigm of low cost access to space
- Ran hydrostatic tests to determine electrolyzer pressure limits

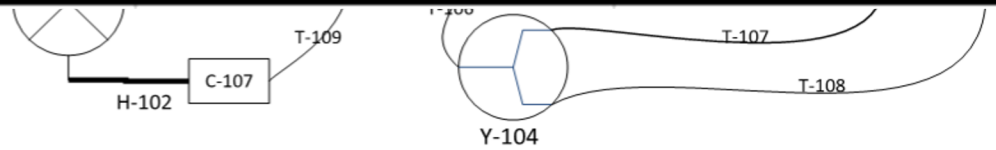
PEM Testing



PEM Pressure Tests

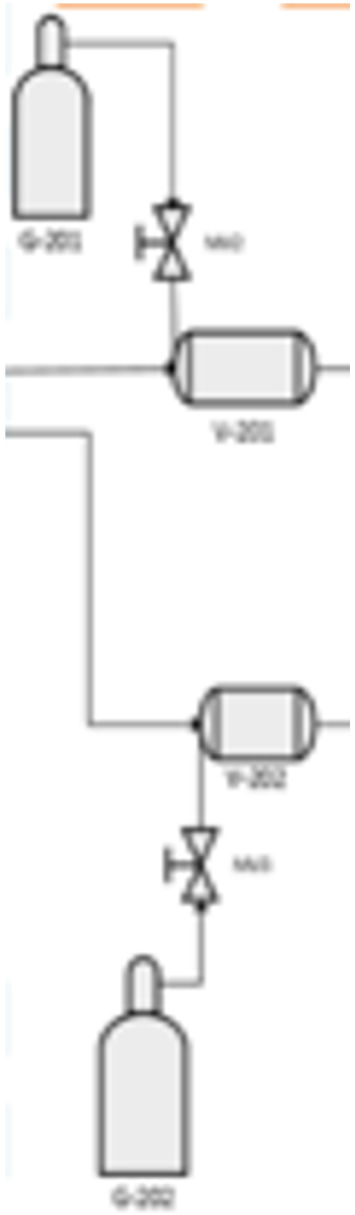
P-101 Water pipe	**MV-101** Water Manual Valve	**G-101** Flexible Garden Hose	**F-101** Water filter	**WP-101** Water pump	**C-101** ¼" NPT to 6AN M fitting	**H-101** 6AN F to F Hose Assembly	**C-102** 6AN M to 1/8" IDEX Coupling	**T-101-109** 1/8" Teflon	**Y-101-104** Y connect to 1/8" Teflon (2)	**C-103-106** 1/8" to ¼" Quick Connect	**E-101** H-Tec PEM Double Electrolyzer	**C-107** 1/8" IDEX to 4AN M Coupling	**H-102** 4AN F to F Hose Assembly	**PG-101** Pressure Gauge

Summary Table of Maximum Pressures			
Electrolyzer	Maximum Pressure (psi)	Pressure at Failure (psi)	Time of Failure (at pressure range)
H-Tec Double (test 1)	74.3	73.75	5:51
H-Tec Double (test 2)	72.2	71.7	4:43
H-Tec Single	46	42.5	1:19
Horizon Educational (w/RTV)	31.5	29.4	4:00
Horizon Educational (no RTV)	24.5	24.5	8:25
H-Tec Rebuildable (test 1)	72.5	-	no failure
H-Tec Rebuildable (test 2)	69.75	-	no failure



Further Background

- Obtained gas storage tanks that are rated to 2000 psi
- Determined that it would be beneficial to hydrostatically test these storage tanks up to their rated pressure
  - In case of accidental over pressurization
  - In case future research pursues higher operating pressures
- Initially conducted experiments on low-cost, low-pressure containers (large soda bottles)



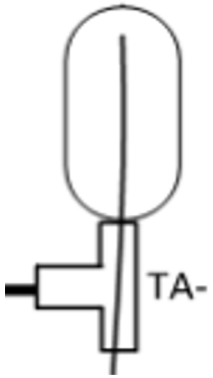
Objectives

- Develop a hydrostatic test system which can be used to pressure test storage tanks
- Design the system to be capable of withstanding pressures up to 2000 psi.
- Follow the KISS mentality

Challenges

- **Bulkhead fitting**
  - **Creating sufficient seals on bottle caps**
    - **Overcame this issue by**
      - **Soda bottle threads are universal across all brands**
      - **But some have Inner Protrusions**
      - **Made gaskets that worked with caps that had no inner protrusion**
      - **Developed one interchangeable cap seal for all tests**

- **Air in the system**
  - **Designed a way to vent the air while filling the bottle with water**
    - **Developed a system with the water inlet and air outlet at the bottom**
    - **Air outlet was a teflon tube that drew out of the top**



Experimental Methods

- Tested containers at various pressures
- Held each pressure for 60 seconds
  - Tested for leaks frequently using dry paper towels and monitoring the pressure gauge
- Increased the pressure in approximately 10 psi increments until failure

Results

P-101 Water pipe | **MV-101** Water Manual Valve | **G-101** Flexible Garden | **F-101** Water filter | **WP-101** Pneumatic Water | **H-101** 6AN F to F Hose | **TA-101-102** T-assembly | **ST-101** storage tank | **T-101-102** 1/8" Teflon | **BV-101** Ball valve | **H-102** 4AN F to F Hose | **PG-101** Pressure Gauge

Bottle Pressurization Tests Summary

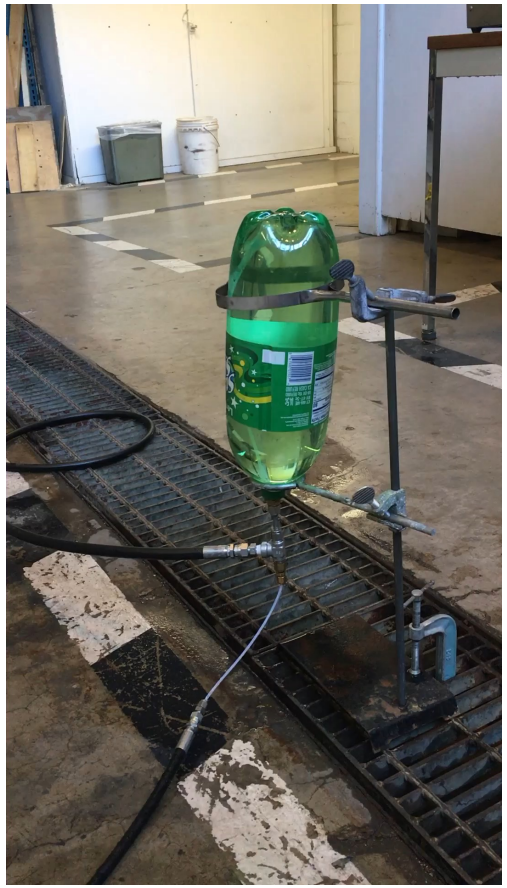
Bottle number	Bottle Size (L)	Pressure at Failure (PSI)	Time of Failure (sec) (At Pressure)
1	1.25	185	2
2	2.00	135	78
3	2.75	148	6
4	2.00	135	27

WP-101

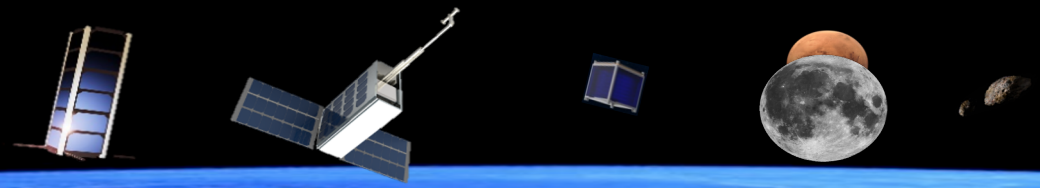
BV-101

Results

Bottle 3
Rupture



Bottle 2
Hydroforming



Findings

- Developed a system that can be used to safely and accurately pressure test a container
- Had persistent leaks and had to modify the fabricated cap seal several times
- Reached a Maximum pressure of 185 psi (with Bottle 1) out of all the experiments
- Bottle 1 failed at the cap, indicating that the walls of the bottle could have withstood higher pressures
- All containers had significant hydroforming prior to rupture

Discussion

- Proof of concept in the system
  - Can move onto testing the higher pressure storage tanks
- Modular System
  - Can add alternate components for unique configurations including using 3000 psi rated gauge
- Hydroforming should not be an issue with the stainless steel gas storage tanks rated to withstand up to 2000 psi

Next Steps

- Hydrostatic testing of the gas storage tanks
  - Utilizing most of the current experimental setup with some changes
    - No need for fabricated seals since pipe fittings can directly attach to the tanks
    - Different hydraulic line setup since the tanks have separate inlet and outlet ports
  - Designing a system to prevent implosion of lightweight balloon tanks during draining
    - Determined several potential solutions
      - Solenoid valve
      - Motorized ball valve
      - Vacuum breaker valve

Questions

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