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TEXAS TECH
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Series-Bosch Technology For Oxygen Recovery During Lunar or Martian Surface Missions

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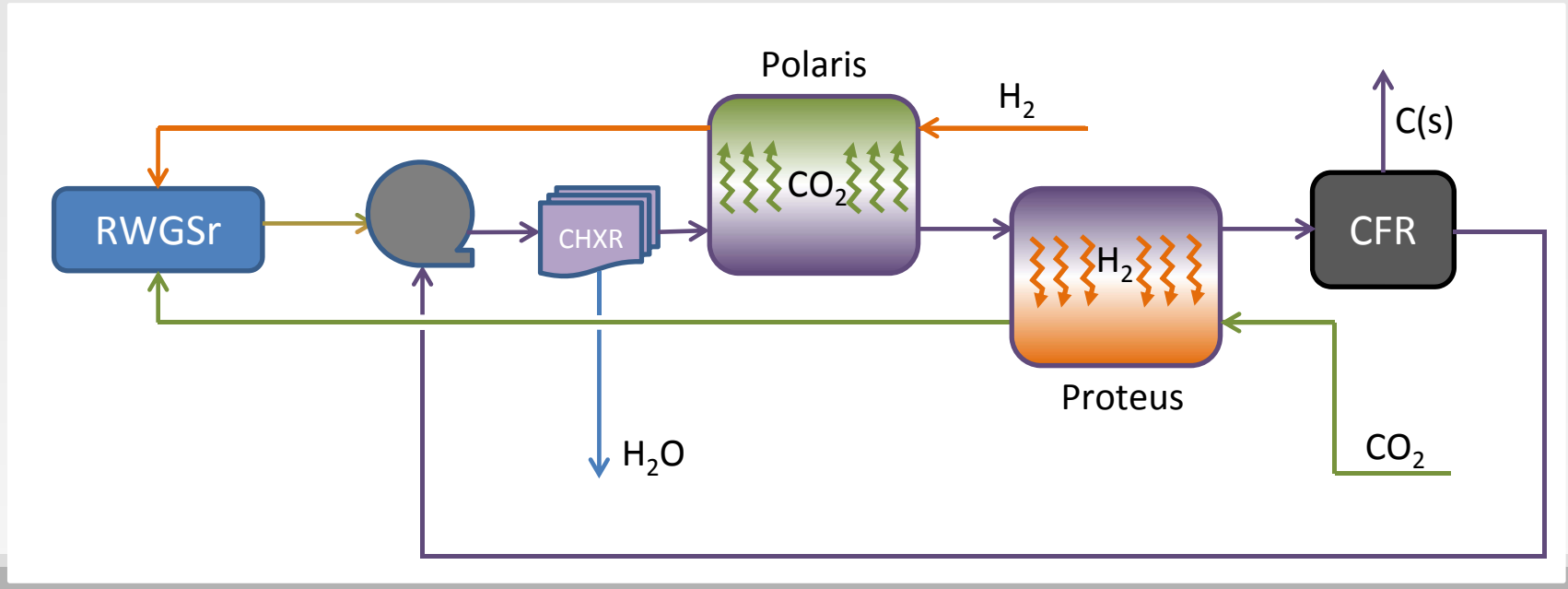
Series-Bosch Technology

Reverse Water-Gas Shift (RWGS)	$CO_2 + H_2 \leftrightarrow H_2O + CO$
CO Hydrogenation	$CO + H_2 \leftrightarrow H_2O + C(s)$
Boudouard	$2CO \leftrightarrow CO_2 + C(s)$
Bosch Process	$CO_2 + 2H_2 \leftrightarrow 2H_2O + C(s)$

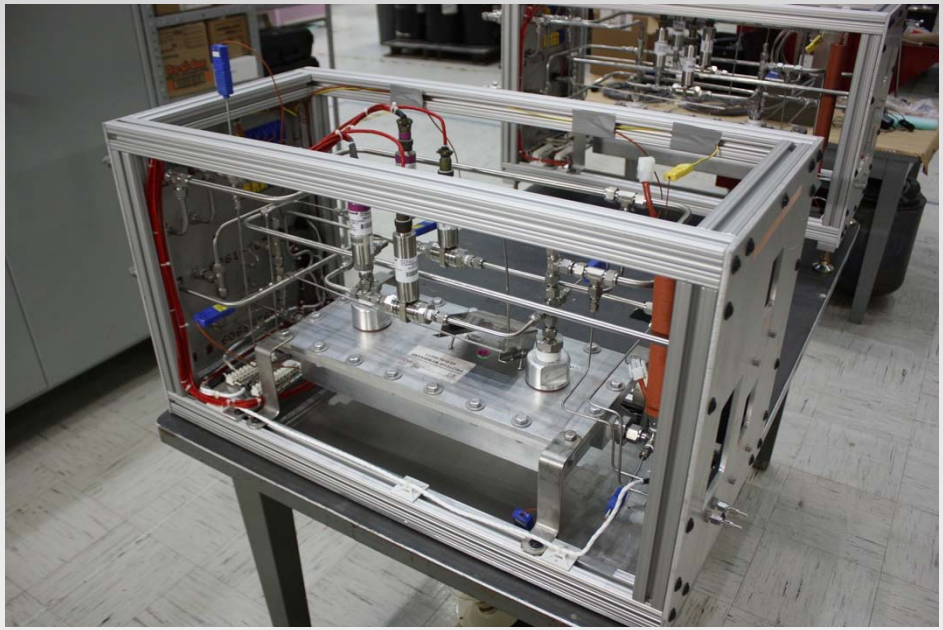


Hardware Description

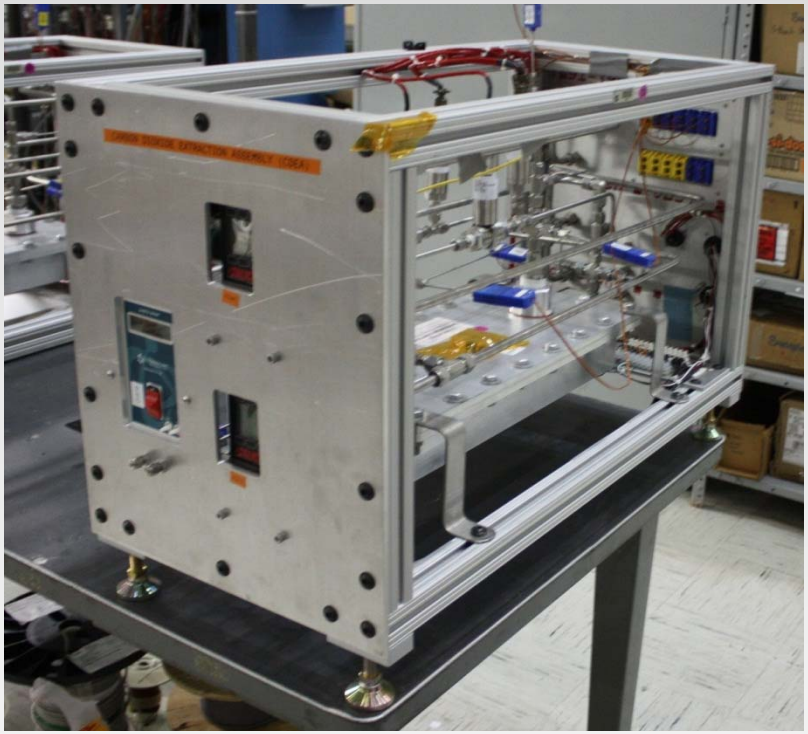
S-Bosch Test Stand

RWGS Reactor (with band heaters and thermocouples, no insulation)

Hardware Description



Proteus Membrane Sub-Assembly (H_2 Separation)



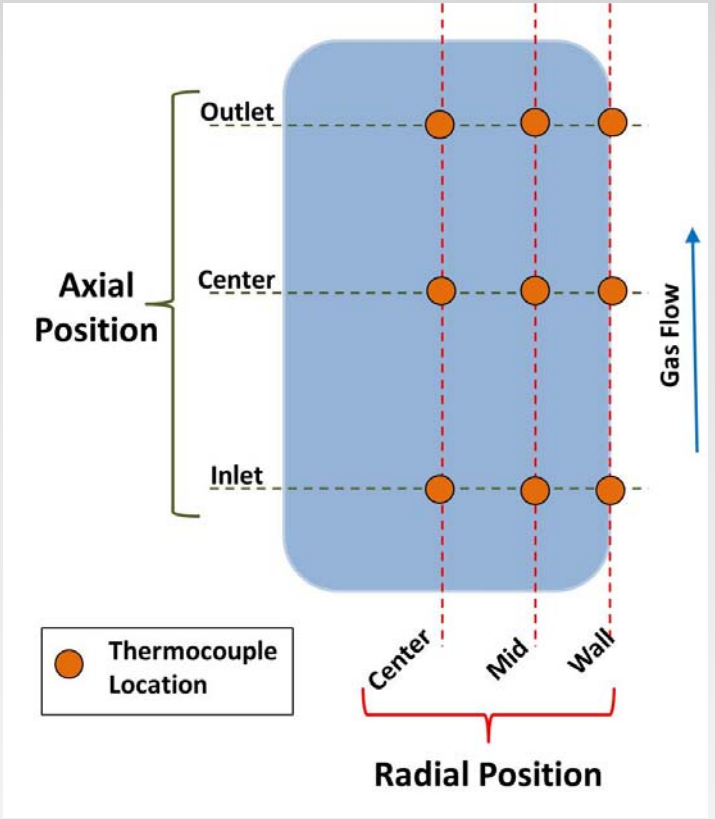
Polaris Membrane Sub-Assembly (CO_2 Separation)

Development Path

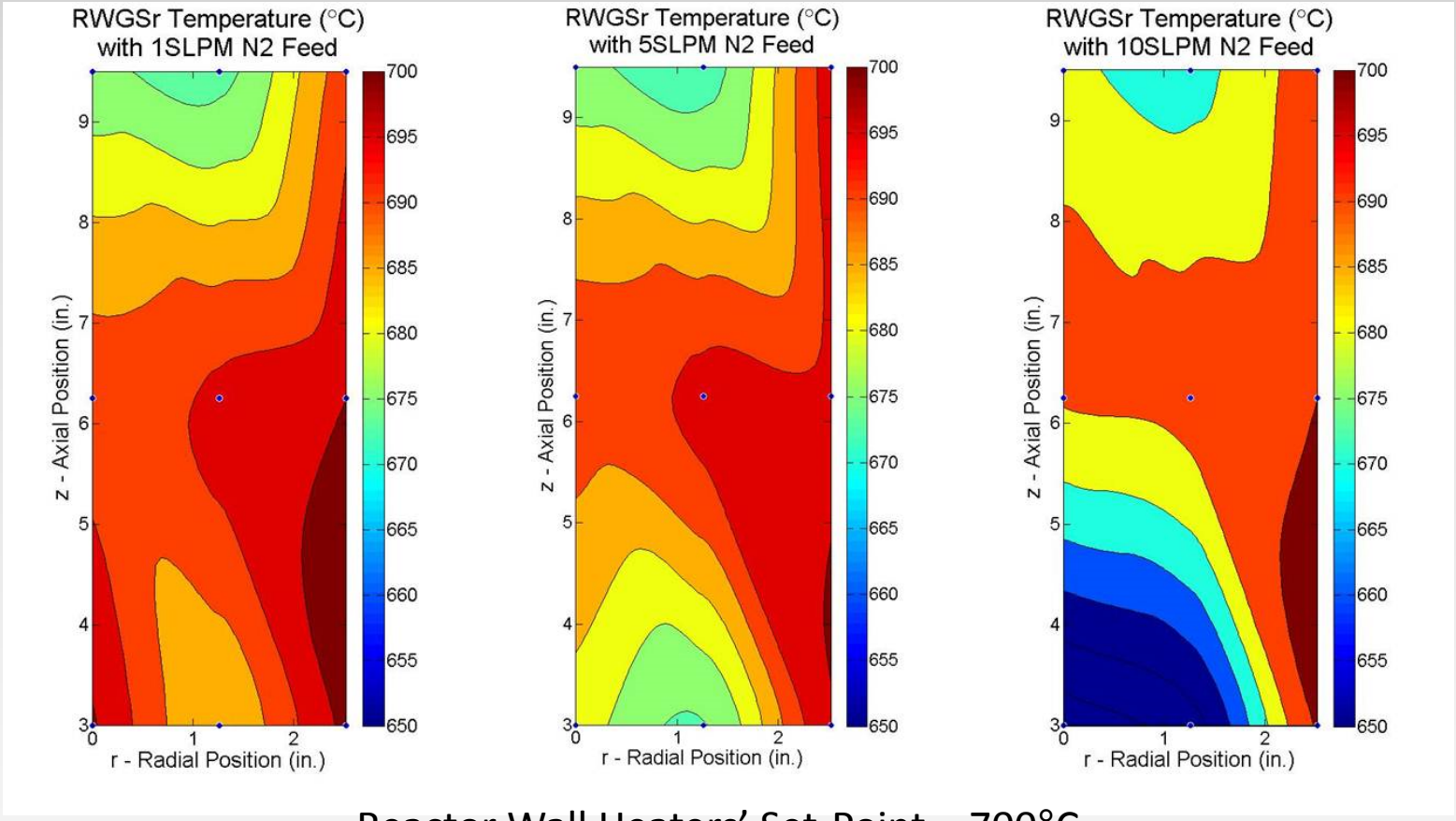
1. RWGS Reactor Thermal Profile Testing
2. Regolith-based CFR Concept Development
3. Regolith + Carbon Brick Testing

RWGS Reactor Thermal Testing

- Purpose: To observe the thermal profile of the reactor at various wall temperature set-points both with and without a pre-heater
- Test Parameters
  - Nitrogen flow = 1, 5, or 10 SLPM
  - Wall Temp = 25-800°C
  - Pre-Heater Temp = 25-250°C
  - Pressure = 8 psia
- Thermocouples used to measure temperature at various locations in the reactor

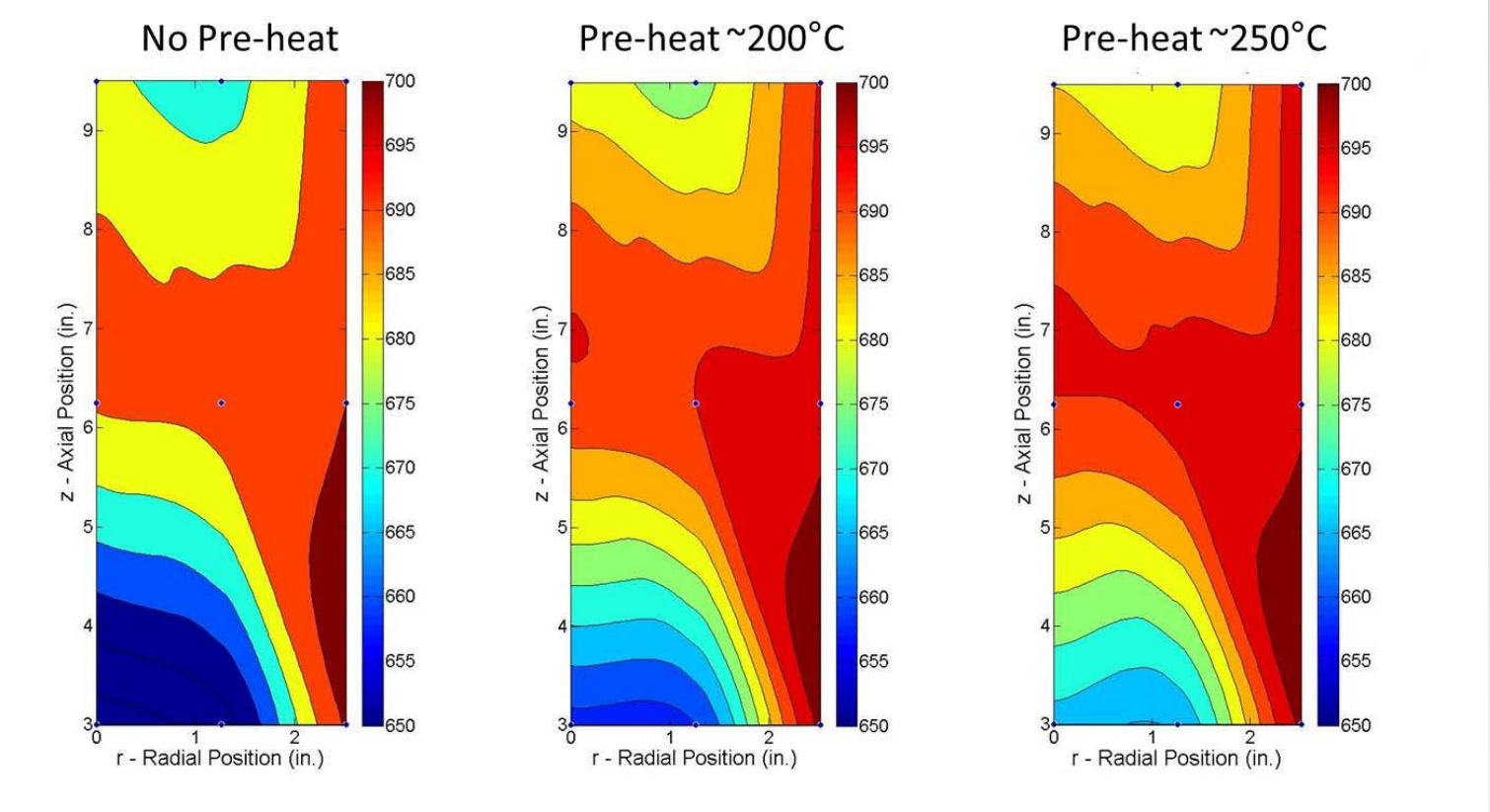


RWGS Reactor Thermal Results



Reactor Wall Heaters' Set-Point = 700°C
No Gas Pre-Heating

RWGS Reactor Thermal Results



Reactor Wall Heaters' Set-Point = 700°C

CFR Concept Development

- Considerations:
  - Regolith Specifications – Martian Regolith
    - Iron in all mapped Martian soil = 10-20 wt%
    - Majority of Lunar soil contains <5 wt% Fe (although some areas ~20 wt%)
    - Mars a targeted destination for manned space exploration
    - CO_2 in Martian atmosphere could be used to obtain O_2 because no H_2 is consumed in the Bosch process (when water electrolysis is used to recovery H_2)
  - Gravity Dependence
    - Regolith-based reactor requires gravity
    - Mars transit version of the reactor would be operable in microgravity
  - Reactor Approach – Radial Flow Moving Bed Reactor
  - Heating Method – Core Heater
    - Core heating allows a temperature gradient to occur which pushes equilibrium toward solid carbon
    - Minimal insulation is needed due to the insulating properties of the regolith material

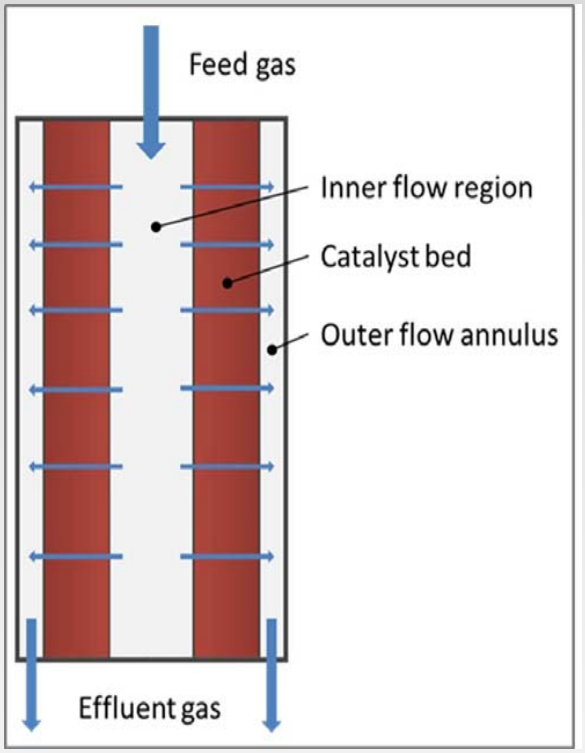


Diagram of Radial Flow Moving Bed Reactor

Regolith Brick Testing

- Purpose: To determine the best method of producing bricks from regolith containing carbon and to determine the effect of carbon on the brick mechanical properties
- Brick Production Methods
  - Sintering (2 hrs @ 500°C, 2 hrs @ 1100°C)
  - Sulfur-Binding (80 vol% Simulant + Carbon, 20 vol% Sulfur, 30 min @ 160°C)
  - Polyethylene-Binding (70 vol% Simulant + Carbon, 30 vol% Polyethylene, 4 hrs @ 150°C)
- Mechanical Properties Testing
  - Compressive Strenth
  - Tensile Strength
  - Modulus of Elasticity (3-point bending test)
  - Freeze-Thaw Cycling

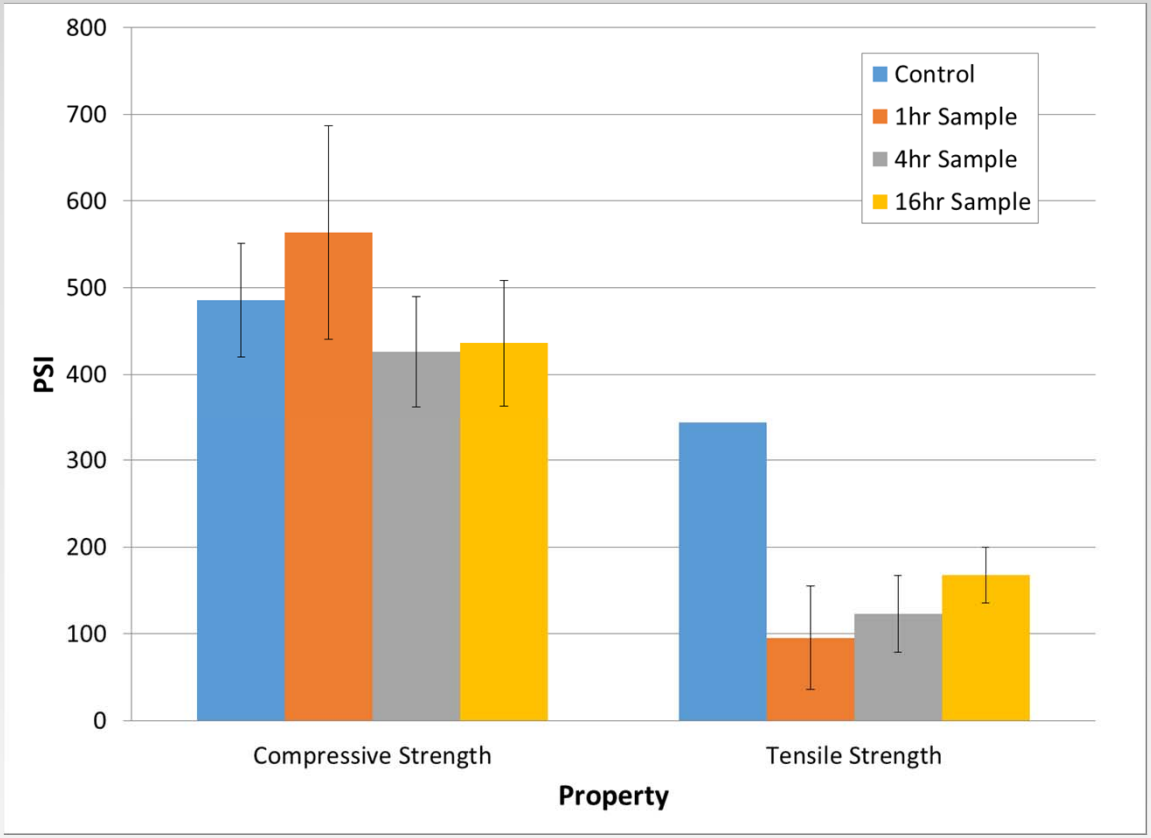
Regolith Brick Testing Results

Sintered bricks – repeatability concerns (outer bricks not heated enough, center bricks heated too much within the same furnace)

Sulfur-Bound bricks – Sublimation of sulfur resulted in insufficient content in bricks, bricks highly brittle

Polyethylene-Bound bricks – Repeatable method, uniform bricks, not entirely homogenous

Regolith Brick Testing Results



No measureable reduction in Compressive Strength compared to pure polyethylene, other results inconclusive

Future Work

- Carbon Formation Reactor Development
  - Microgravity design
  - Martian gravity design
- Carbon Handling Development
- Membrane Testing
- Repeated Mechanical Testing

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