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Advanced Oxygen Recovery via Series-Bosch Technology

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Background

■ Bosch Process:

RWGS Rxn



Boudouard Rxn



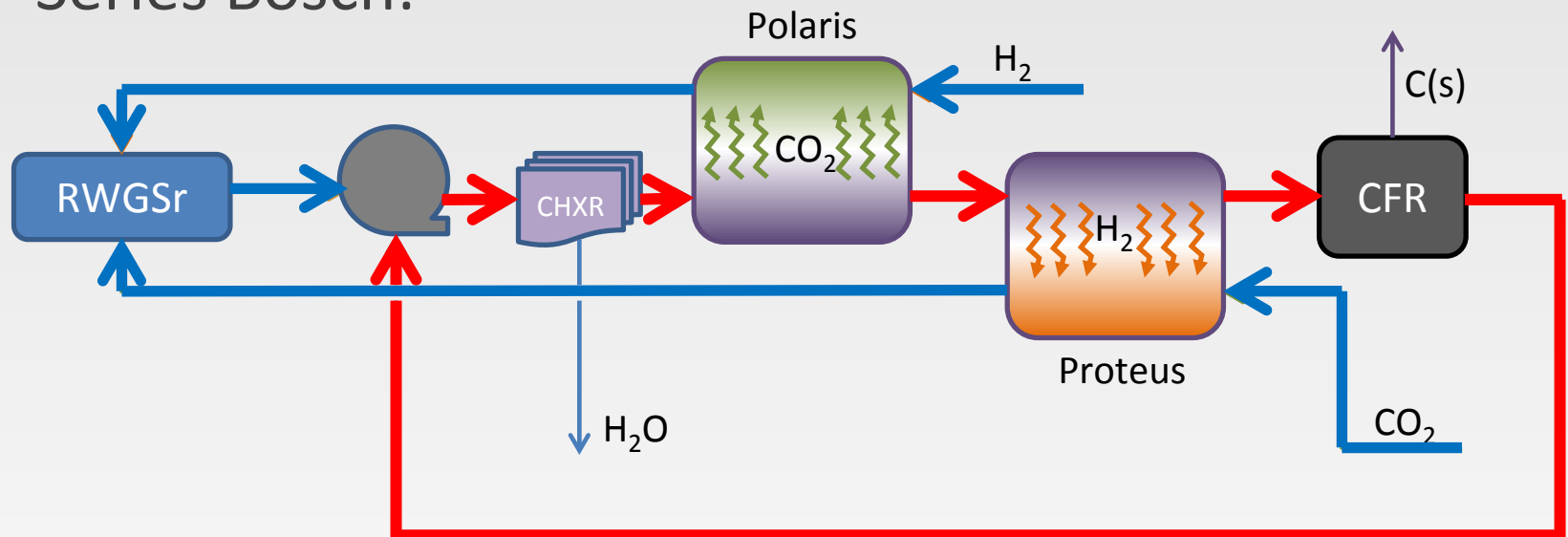
CO Hydrogenation



Bosch Process



■ Series Bosch:





■ Objective:

To evaluate the stand-alone performance of each S-Bosch sub-assembly:

- RWGSr
- Polaris Membrane (CO₂ Separation)
- Proteus Membrane (H₂ Separation)
- CFR



Methods: RWGS Reactor Performance Testing

Parameter	Values
RWGSr Heater Set Points	600°C, 650°C, 700°C
CO ₂ Feed Rates	1.41 SLPM, 2.82 SLPM
H ₂ :CO ₂ Ratios	1:1, 2:1, 3:1
RWGSr Inlet Pressure	20.7 kPa (3 psia), 34.5 kPa (5 psia), 55.1 kPa (8 psia)



RWGS IncoFoam Nickel
Foam Catalyst



RWGS Reactor (prior to
installation of insulation)



RWGS Reactor (following
insulation and containment)



Methods: Membrane Performance Testing

Parameter	Values
Membrane Process Side Pressure	55.1 kPa (8 psia), 68.9 kPa (10 psia), 89.6 kPa (13 psia)
Membrane Temperature	Ambient, 111°C (Proteus only), 130°C (Proteus only)
Sweep Gas “Low Flow” Rate	0.7 SLPM (Proteus), or 1.41 SLPM (Polaris)
Sweep Gas “High Flow” Rate	1.41 SLPM (Proteus), or 2.82 SLPM (Polaris)
Process Feed Composition	
H ₂	27-63 mol%
CO ₂	16-41 mol%
CO	15-24 mol%
CH ₄	0-0.26 mol%



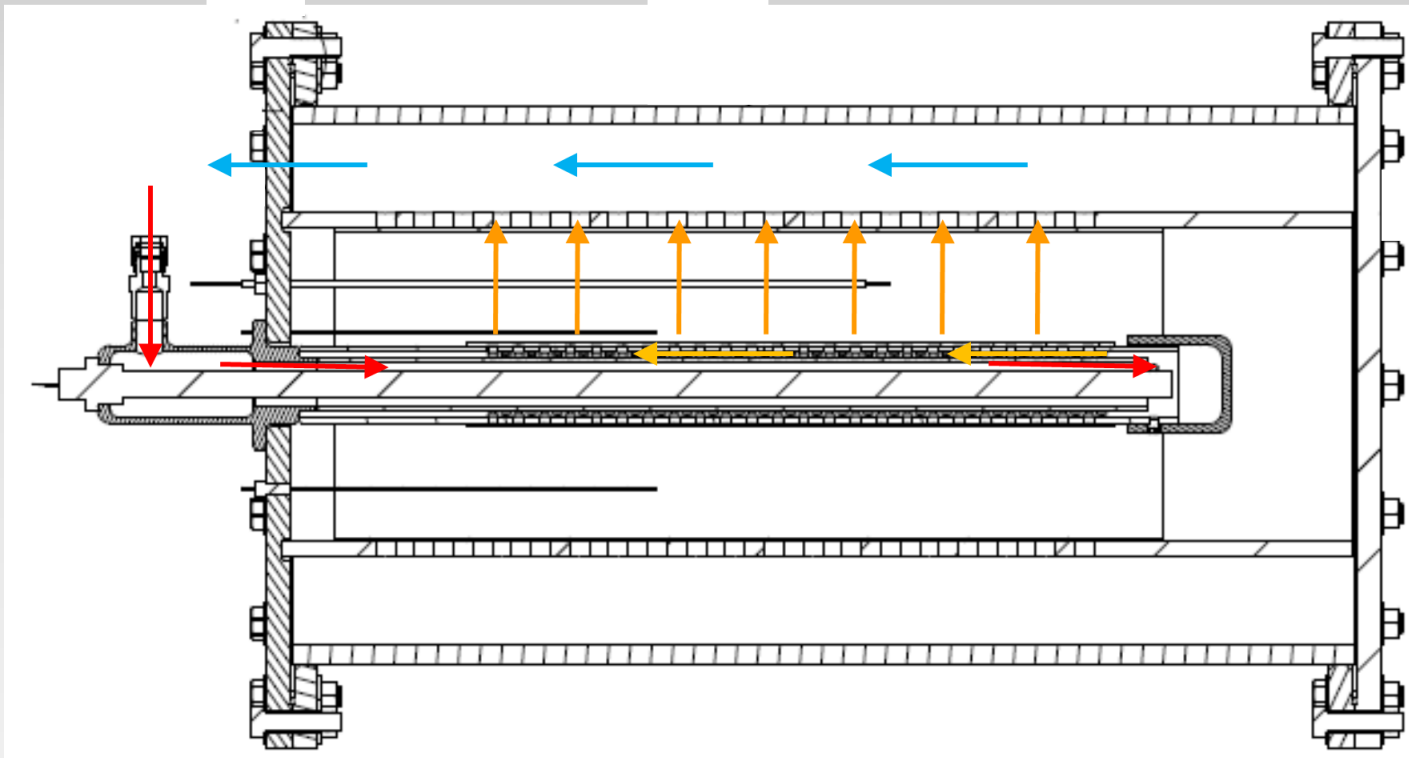
MTR Proteus Membrane
(with special packaging)



MTR Membranes
(in COTS packaging)



Methods: CFR Performance Testing



CFR Internal Flow Path

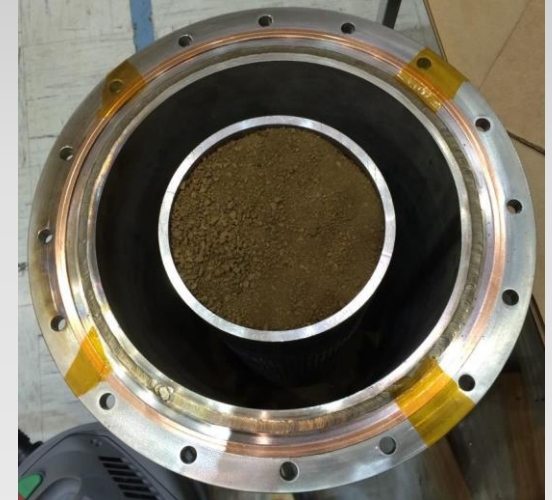


Methods: CFR Performance Testing

Orbitec JSC–Mars 1A Martian Regolith (Surface Catalyst)

Testing Parameters:

Parameter	Values
CFR Heater Temperatures	700°C, 750°C
CFR Pre-Heater Temperatures	0°C, 150°C, 400°C
CO Feed Rates	0.195-1.000 SLPM
H ₂ Feed Rates	0.195-1.000 SLPM

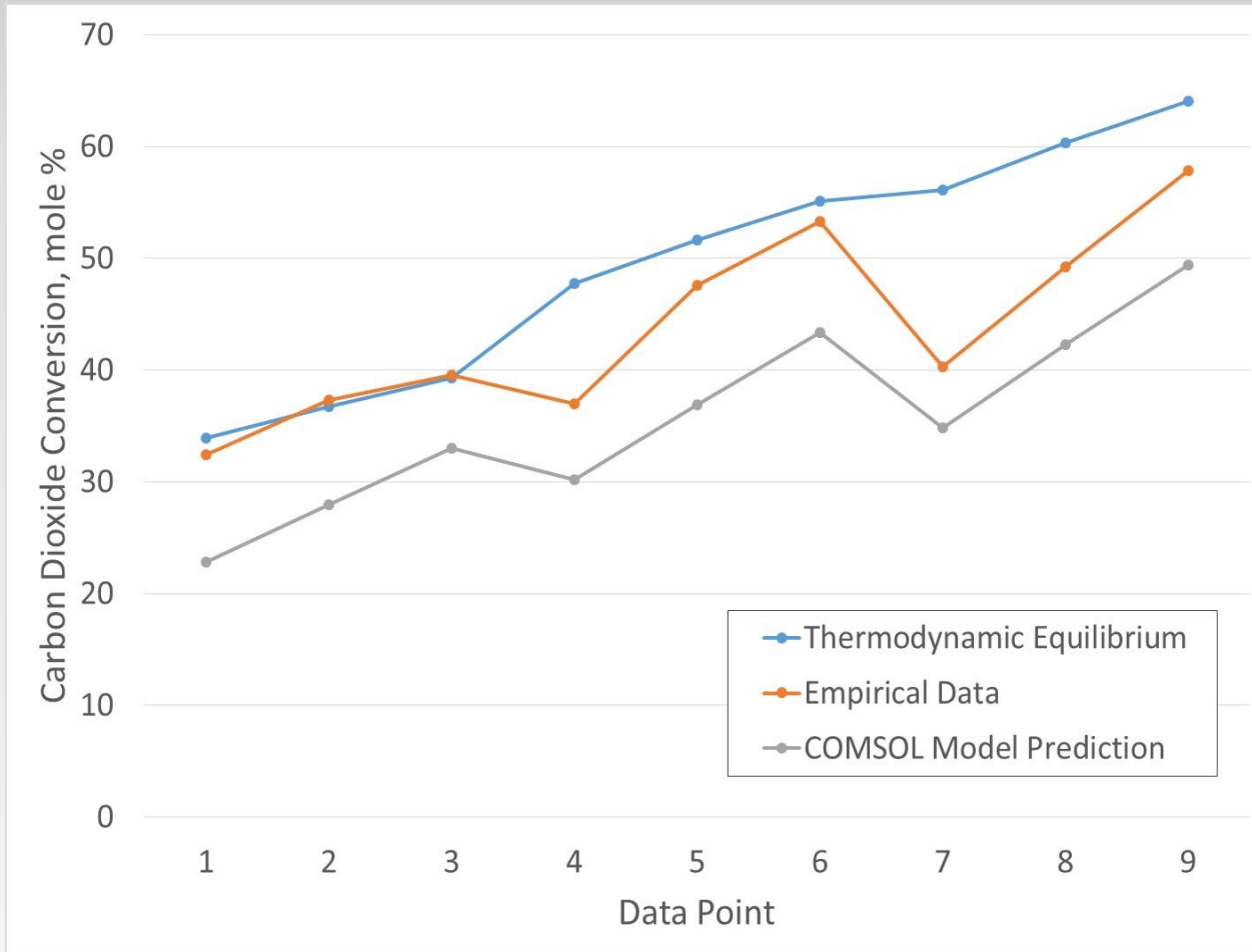


Amasteel S-660 Steel Bead (Transit Catalyst) Testing

Parameter	Values
CFR Heater Temperature	750°C
CFR Pre-Heater Temperatures	400°C
CO Feed Rates	0.195-2.000 SLPM
H ₂ Feed Rates	0.195-2.080 SLPM



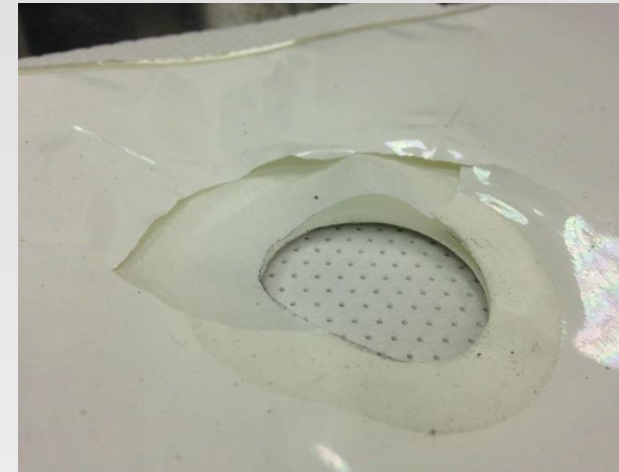
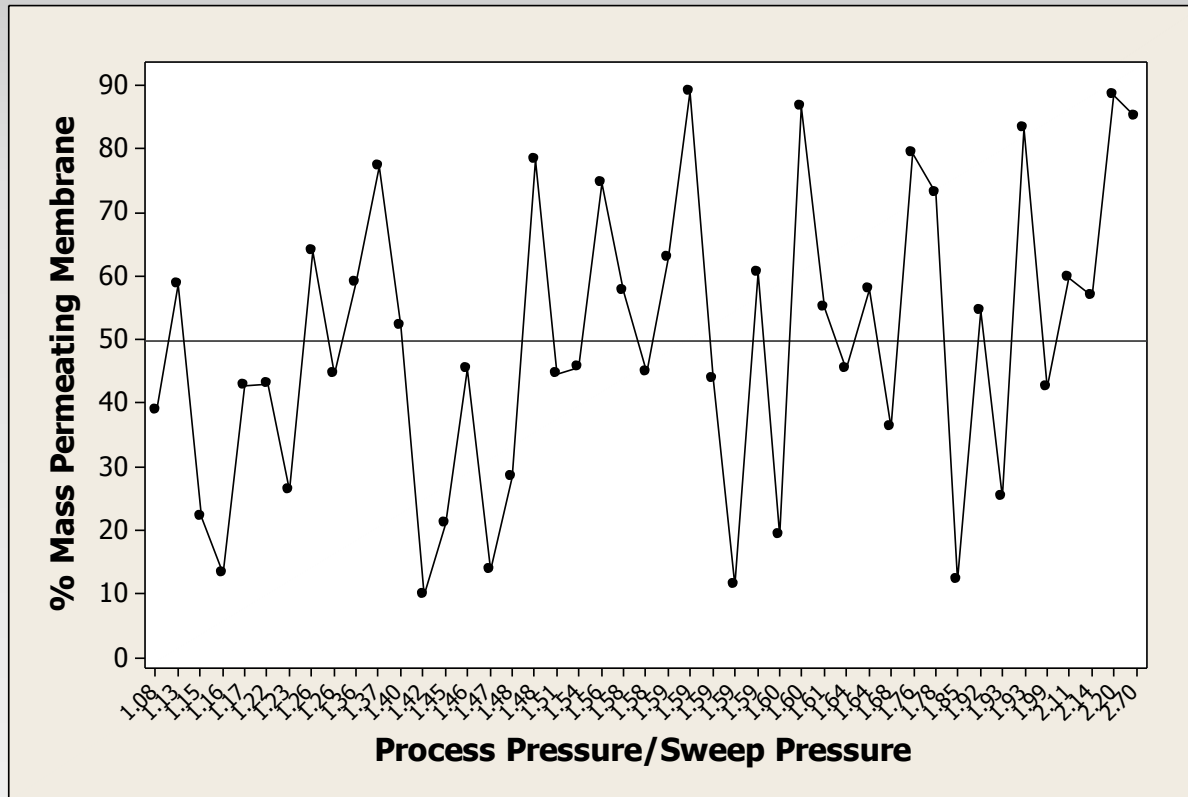
Results: RWGS Performance Testing



Test Point	Ratio of H ₂ :CO ₂	Temp (°C)
1	0.81	600
2	0.81	650
3	0.81	700
4	1.66	600
5	1.66	650
6	1.66	700
7	2.51	600
8	2.51	650
9	2.51	700



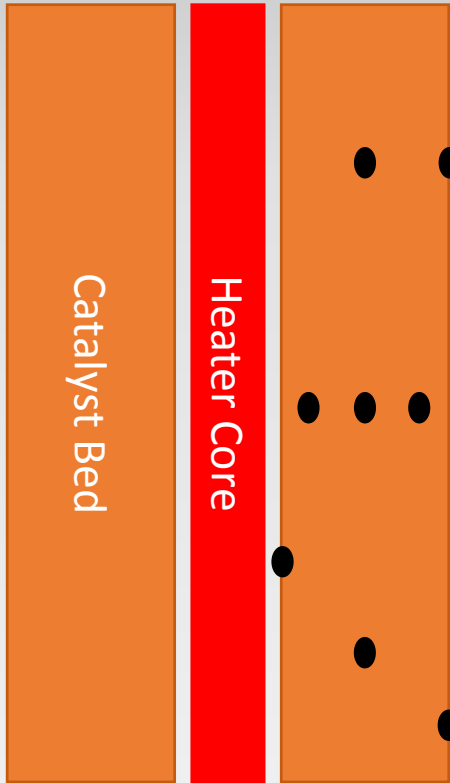
Results: Membrane Performance Testing



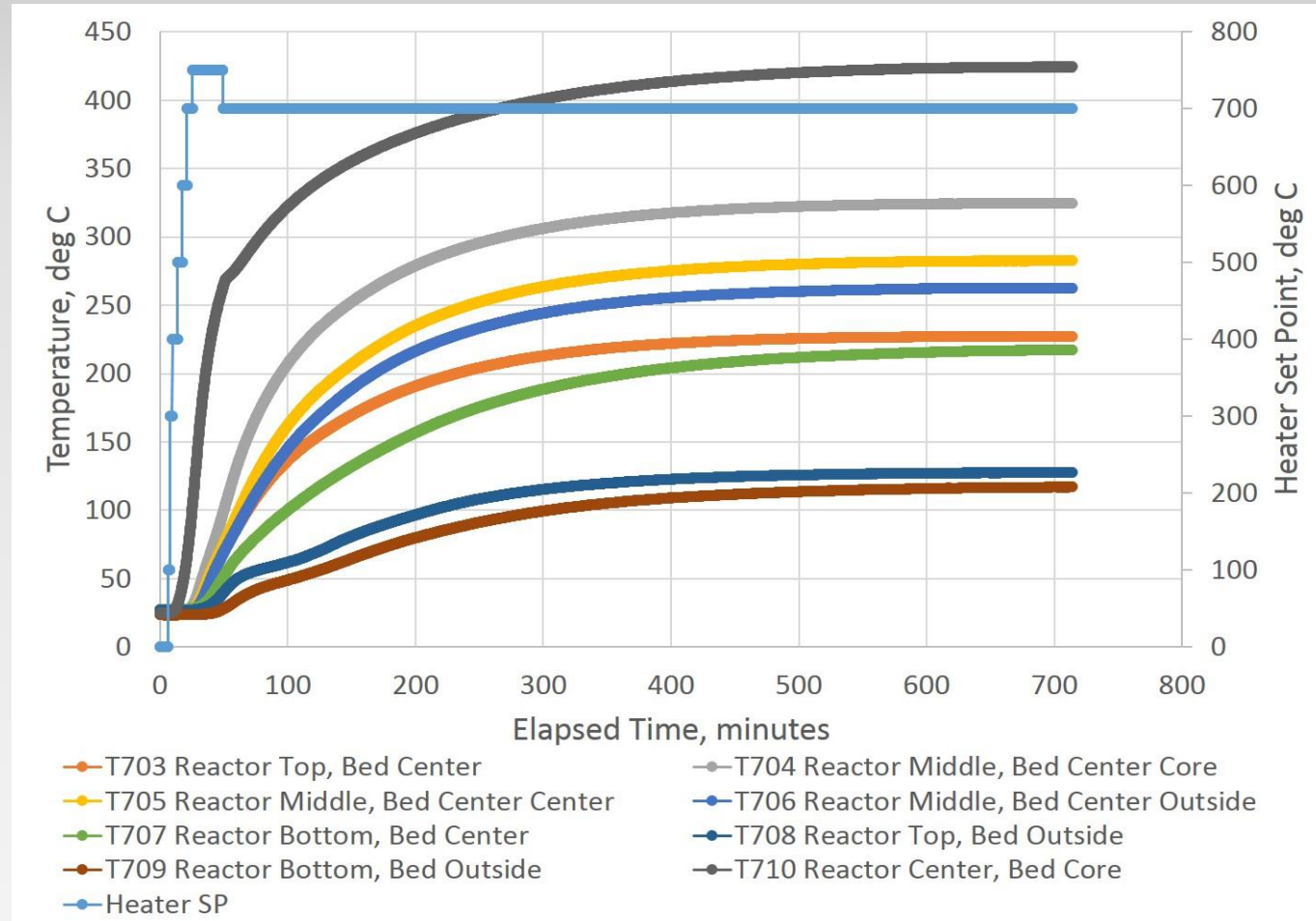
- No effect of dP across the membrane
- No effect of concentration gradient across the membrane
- Indicative of damage to the membrane



Results: CFR Performance Testing

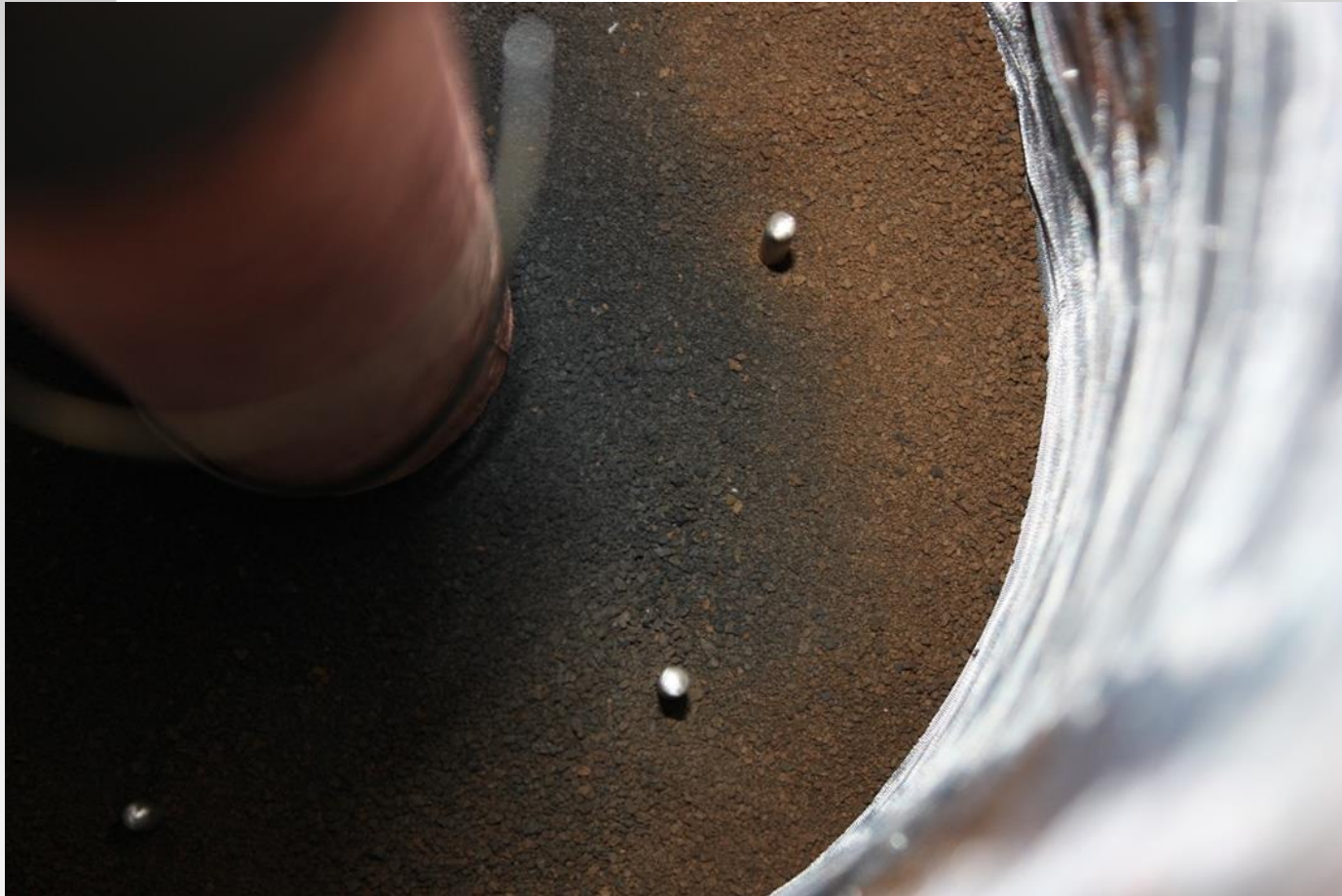


CFR Thermocouple Placement





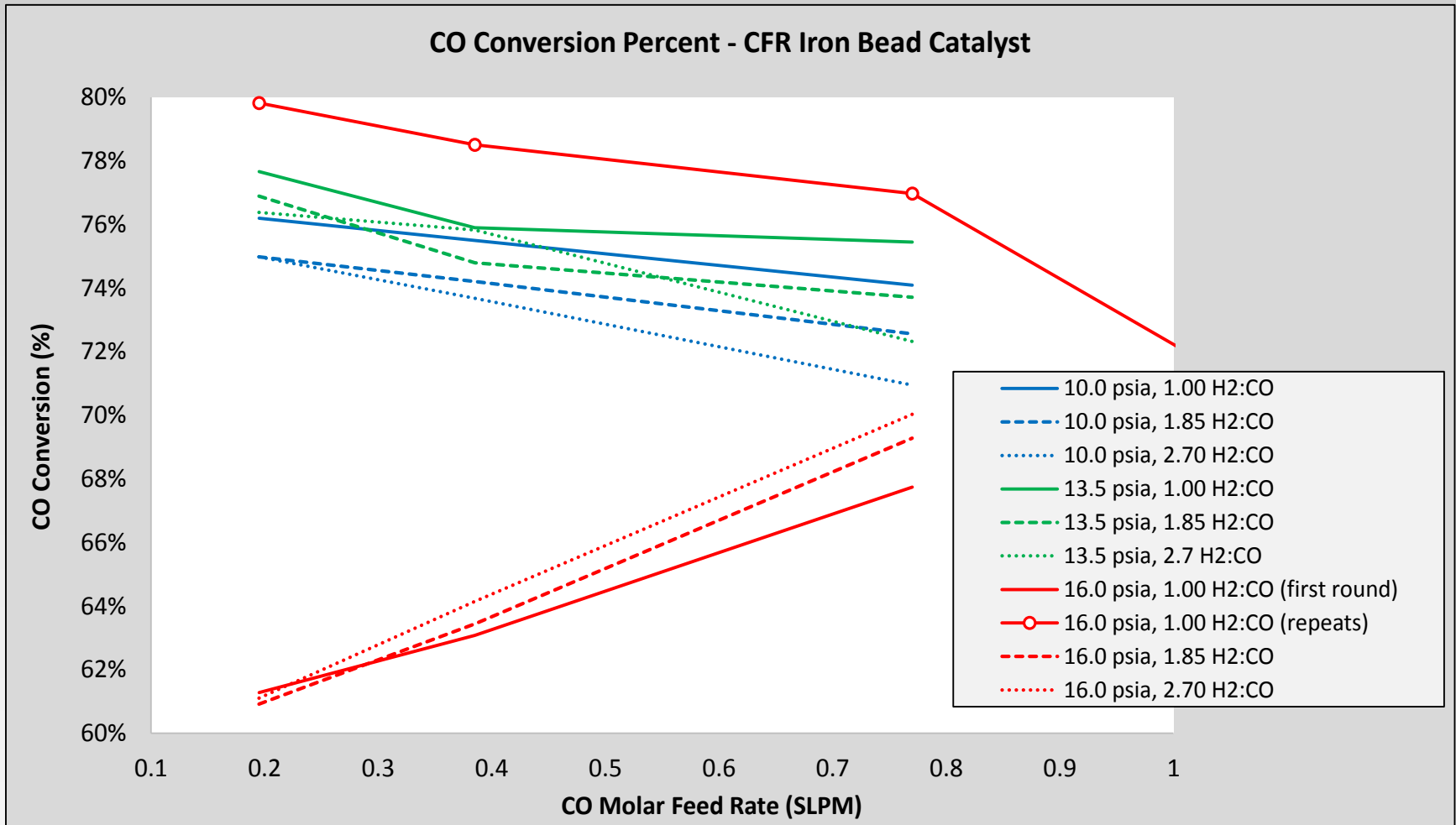
Results: CFR Performance Testing



CFR Performance with Martian Regolith Stimulant



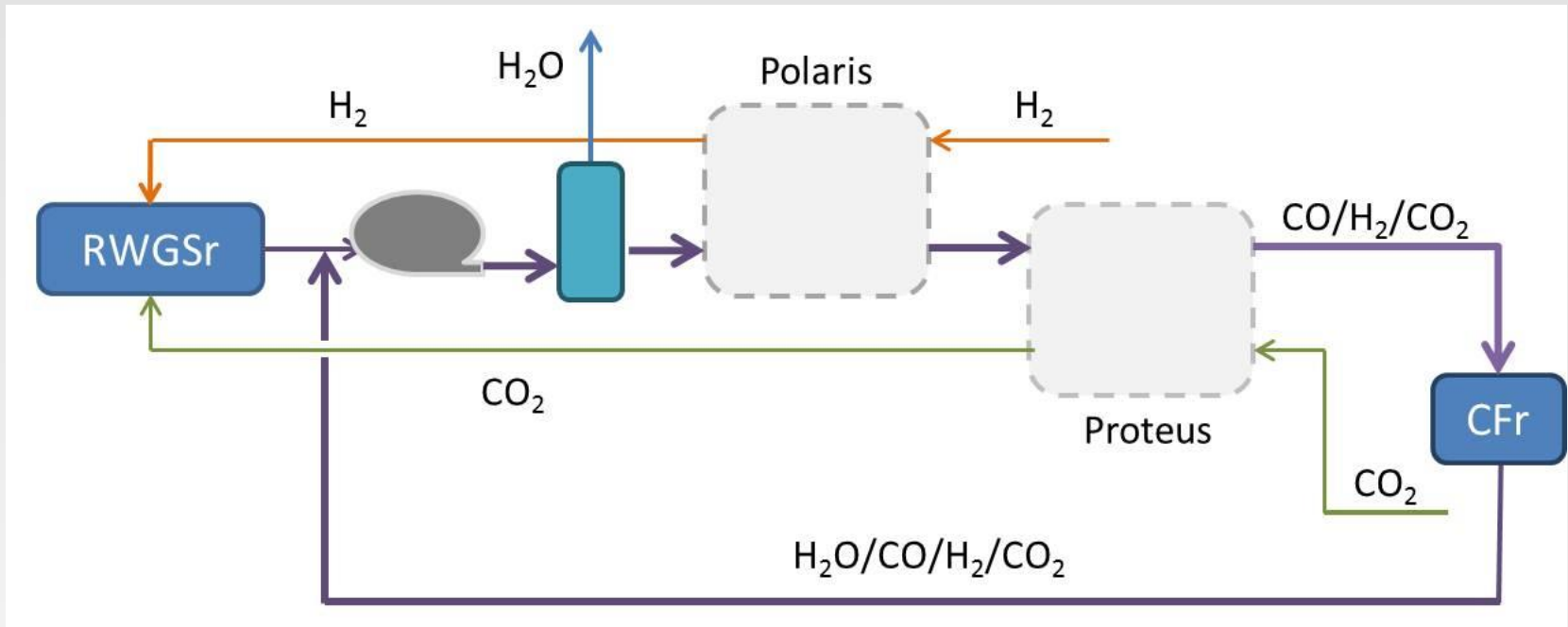
Results: CFR Performance Testing





Discussion: Advantage of Architecture: Robustness

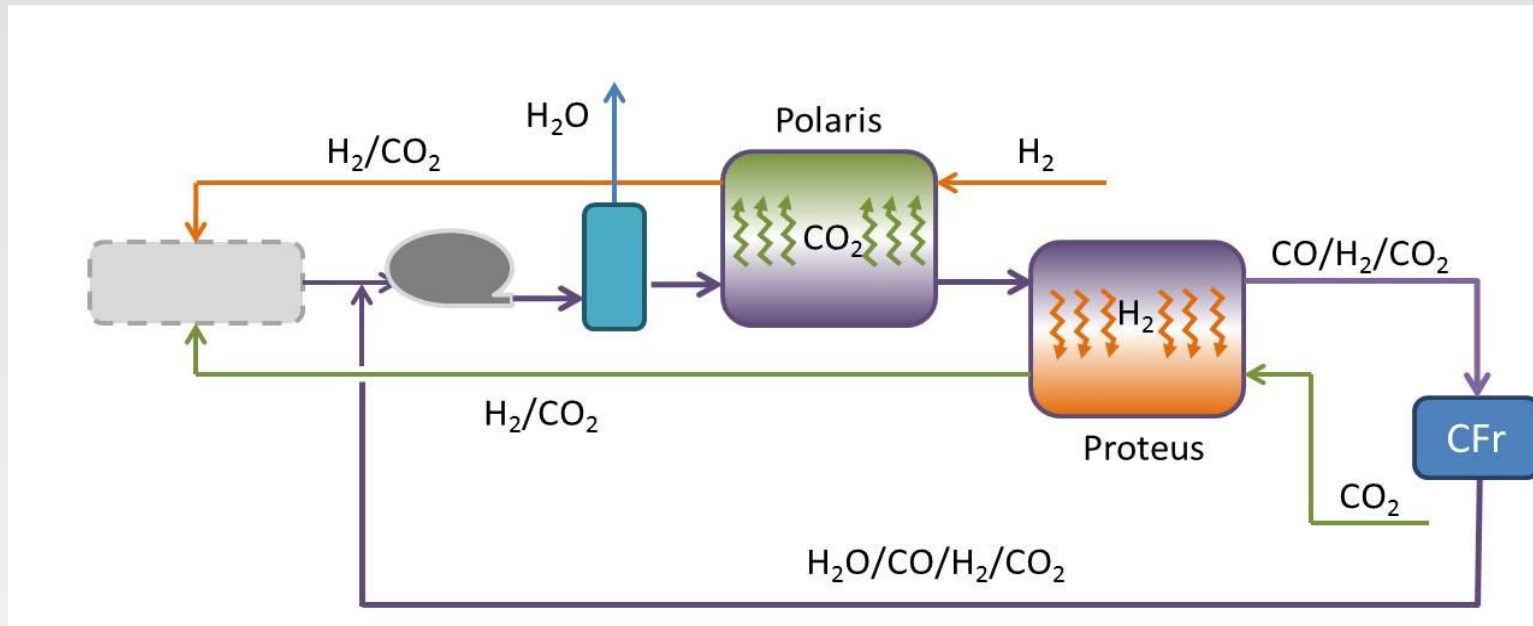
- Potential Failure 1: Membranes
 - Potential fouling
 - Potential tearing





Discussion: Advantages of Architecture

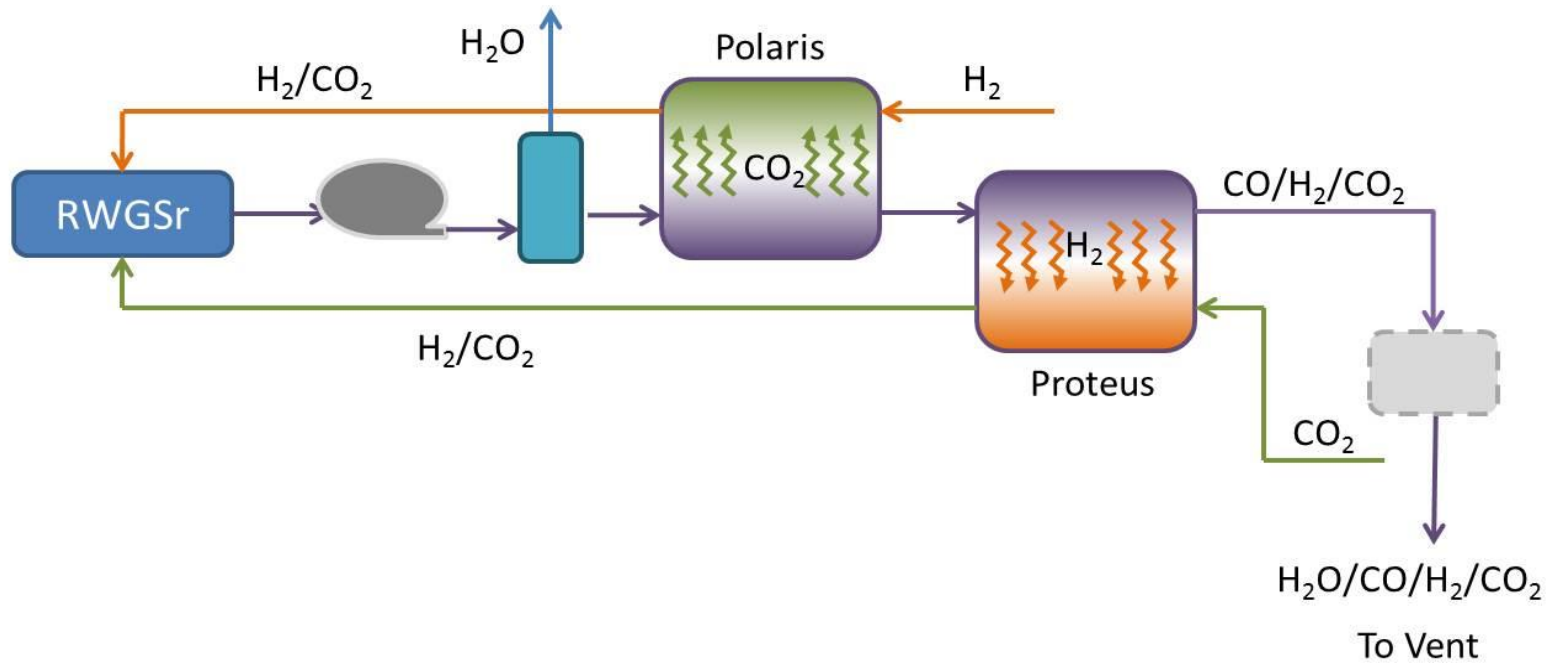
- Potential Failure 2: RWGS
 - RWGS fouled with carbon





Discussion: Advantages of Architecture

■ Potential Failure 3: CFR





Summary

- Demonstrated near-equilibrium performance of the RWGS reactor
- Membranes damaged due to special packaging
 - Long-duration performance and reliability proven in industry
- CFR shown to have thermal challenges
- CFR with Martian Regolith simulant performed significantly below target due to inadequate temperature
- CFR with steel beads performed near equilibrium despite low temperature
- S-Bosch architecture designed to be robust against failures



ICES 302: Physio-chemical Life Support- Air Revitalization Systems - Technology and Process Development
