Small-Scale Test Platform (SSTP) for SOFC Stacks

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Introduction:

The small-scale test platform (SSTP) will enable:

a) Evaluation of reliability and performance of SOFC stacks under realistic, long-term continuous system operation at power levels from 1 to 10 kW.

b) Identification of key R&D gaps and needs limiting long-term reliability

c) Assessment of performance and benefits of advanced stack concepts originating from FOA awards or other programs.

The SSTP incorporates a number of advanced design features, including:

- Anode recirculation loop
- External steam reforming
- High efficiency heat exchangers
- Option for electric start-up heating
- Vacuum insulation

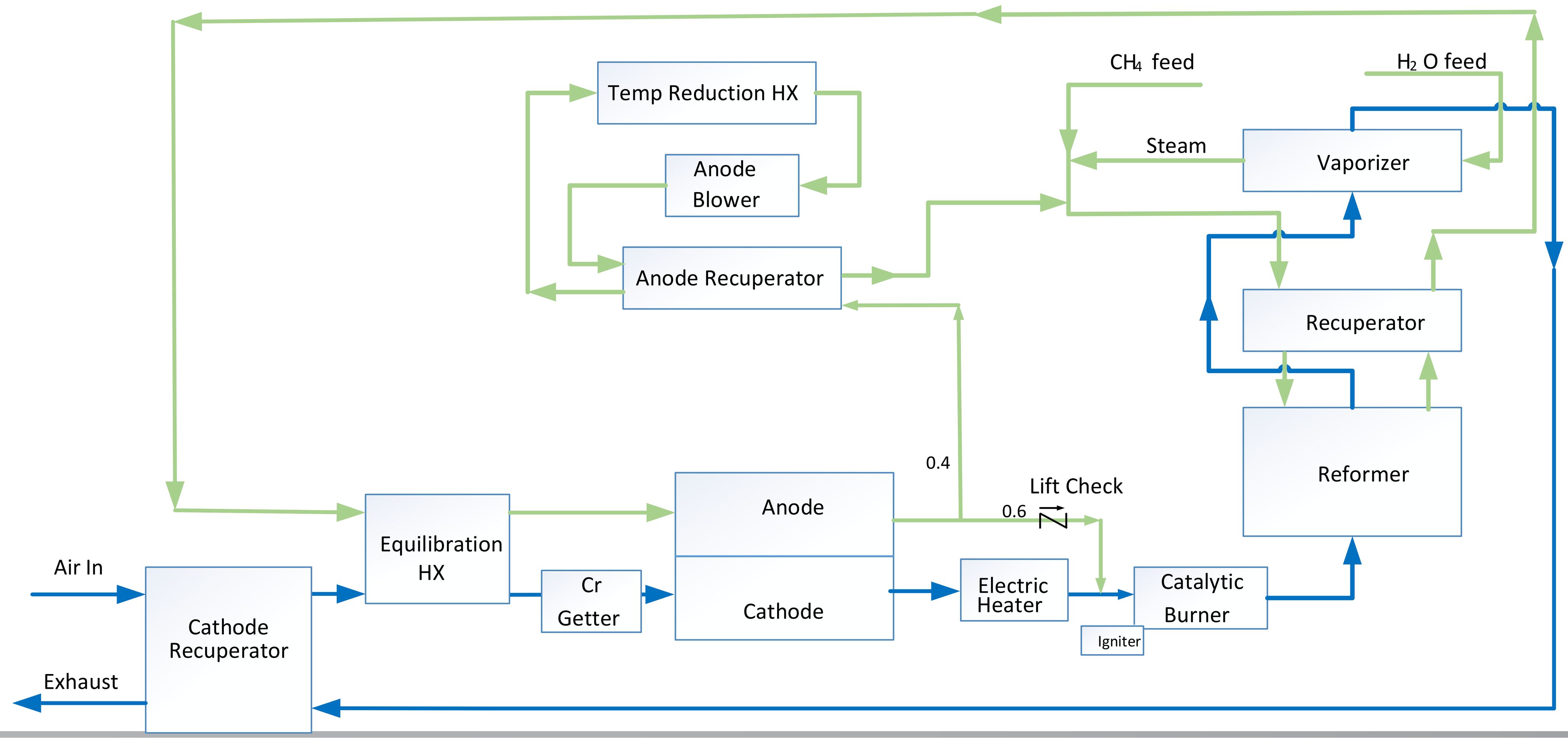
Stack Technology:

The first stack technology to be tested is a Penta 4 Stack Module from Ceres Power utilizing their SteelCell® technology.

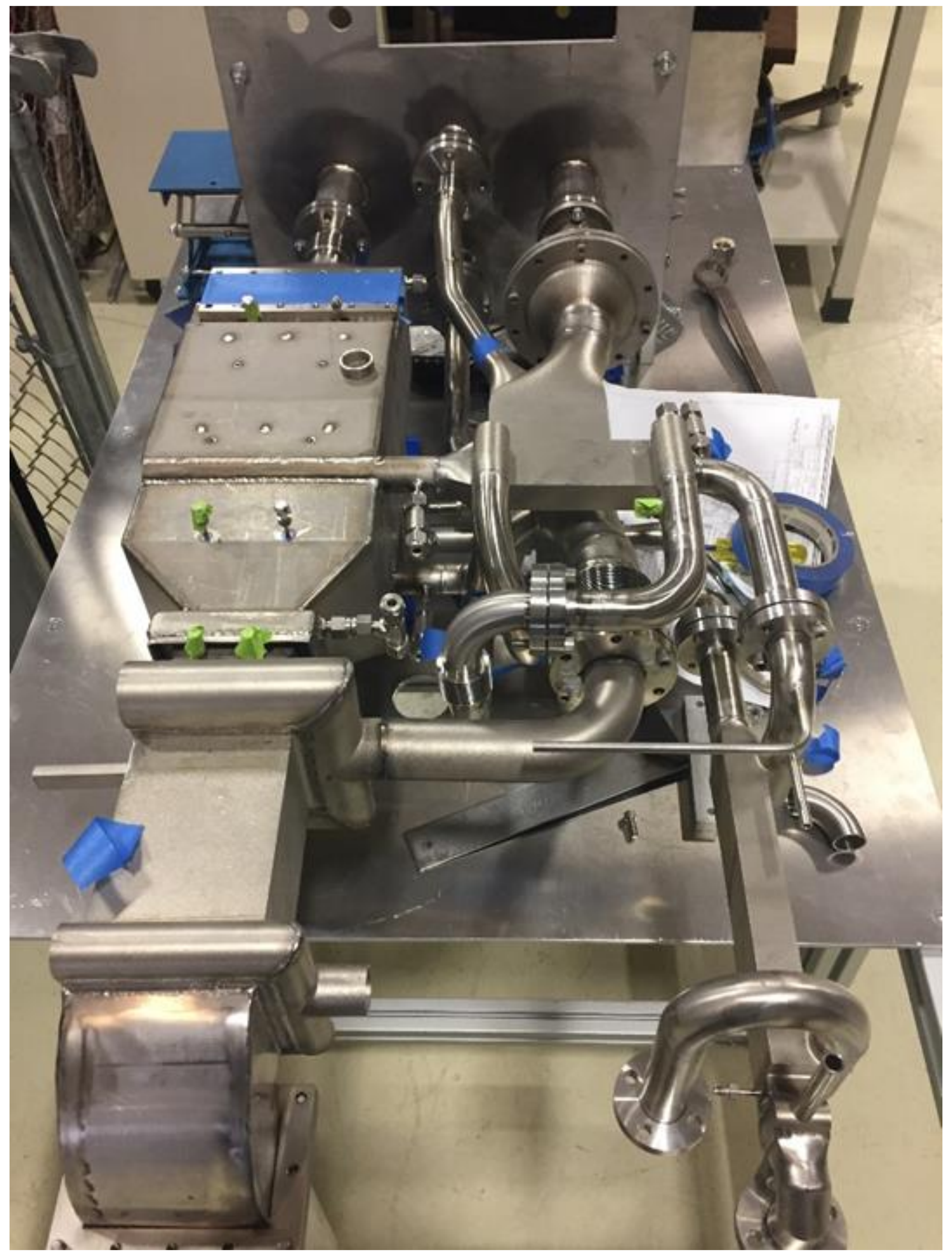
- Rated at 3.7 kW
- 9 Amps per stack, 36 Amps total
- ~105 V, with four stacks in parallel
- ~600C operating temperature

Flow Diagram:

The flow diagram shows the key components of the SSTP. 40% of the spent anode stream is recycled, while 60% is fed to a burner.

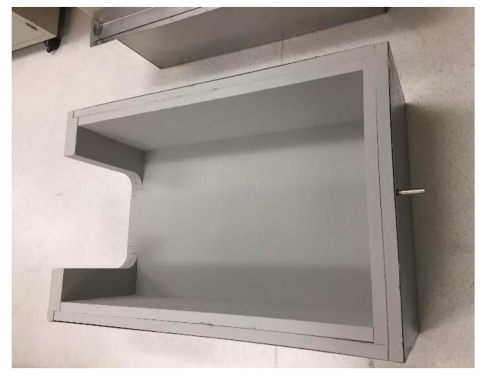


Overall Component Layout:



Vacuum Insulation:

A vacuum insulation box covers the hot BOP components. The box is constructed of a stainless steel shell filled with microporous insulation. Removing air provides excellent insulation performance in a small footprint.



Cr Poisioning Prevention and Monitoring:

Haynes 214 alloy steel, an alumina former, is used on all hot components in contact with the air stream. A chrome getter (an alumina honeycomb coated with LSC) is placed just upstream of the SOFC cathode inlet. Removable flat coupons of similar composition will be placed before and after the getter, as well as at the SOFC cathode exit. The LSC coating can be dissolved and analyzed via ICP for chromium content periodically.

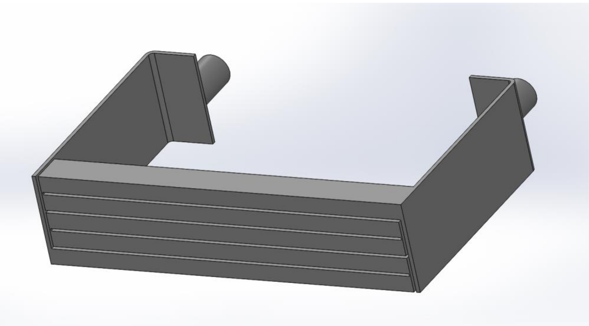
Control Scheme:

The SSTP will be fully instrumented including gas sampling for GC analysis. The following variables will be used as shown for system control:

1) Cathode blower speed ➔ Fuel cell stack temperature
2) Voltage set point➔ System power
3) Stack current ➔ Fuel and water feed rates
4) Anode blower speed ➔ Recirculation rate

Electrical Startup Heater:

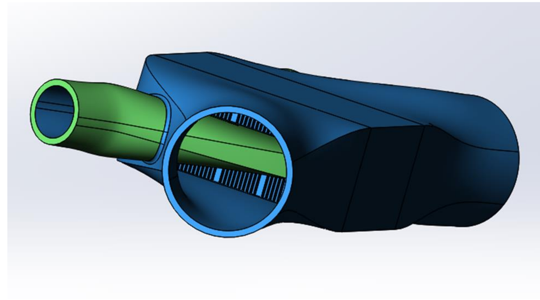
A proven electrical heater design is incorporated upstream of the burner to provide heat during startup. Fecralloy foam is cut into a serpentine electrical path with solid Fecralloy conductors. An SCR controller provides variable control over heat input.



Heat Exchangers:

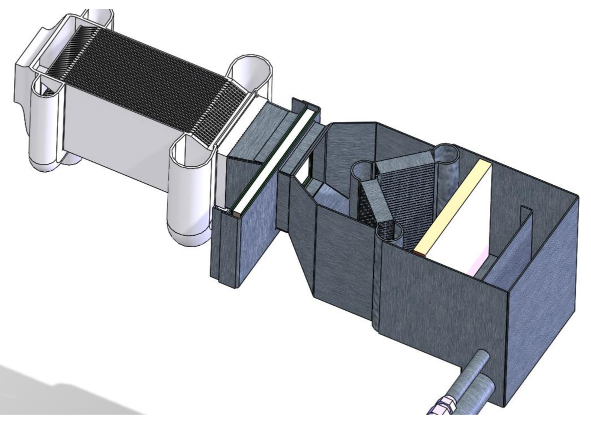
PNNL has produced many compact and efficient microchannel heat exchangers, traditionally produced by a shim lamination process. For the SSTP, direct metal laser sintering (DMLS) was used instead (i3D MFG in The Dalles, OR). Both Haynes 214 and Inconel 625 parts were printed.

The equilibration heat exchanger incorporates a unique design with intersecting headers for smooth flow paths for both the air and fuel streams.



Reformer Unit:

The reformer unit incorporates several components in one enclosure for efficient use of heat. From right to left shown here: the burner; the catalytic burner to react unburned fuel (white panel); the reformer reactor; the water vaporizer; the cathode recuperator.



Test Plan:

1) Initial system shakedown
2) Heat up to 600C
3) Continuous Operability Test
    a) 500 hours at 9A per stack and 40% recycle rate
    b) 20 or more thermal cycles, one per day
    c) 10 or more emergency stop cycles, one per day
    d) Recycle rate experiments at 30%, 35%, 45%, and 50% recycle rate

Project Status:

System assembly is nearly complete with target system shakedown and testing commencement in May, 2019.

Future stack technologies can be tested with the SSTP. Future modifications to the flow sheet and certain components may be necessary for different stack architectures due to operational requirements.

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