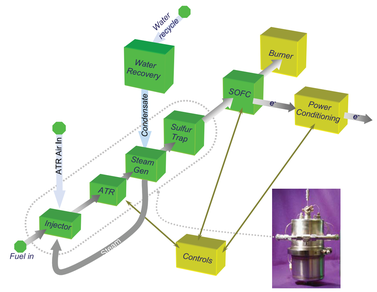
Recent Progress in Developing Reliable, Cost Effective Fuel Reformers & Fuel Processors

Subir Roychoudhury, Christian Junaedi, Jeff Weissman, Saurabh Vilekar

Autothermal Reformer (ATR) Schematic



Size: 3 liters; Weight: 5.2 kg

Room-temp start-up; No preheat required

Off-the-shelf pumps & blowers implemented

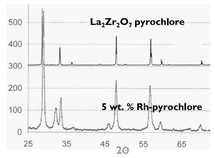
Automated "push button" start, load changes & shutdown

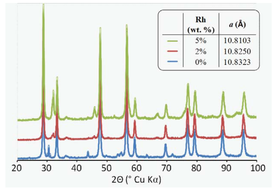
Control logic/algorithm implemented via PC-based interface

Readily integrated w/SOFC, PEM, H_2 generation systems

Fuel sulfur converted to H_2S in ATR and sorbed in downstream sulfur trap

DOE NETL Pyrochlore Catalyst Synthesis & Coating





- Prepared as powder according to NETL method
  - Reproducible performance demonstrated at NETL
  - XRD analysis on as prepared material corresponds closely to pyrochlor PXRD pattern
- Detailed characterization at PNNL-EMSL via Rapid Access
  - Relate Rh structural parameters & particle morphology to performance & durability
  - Trends in lattice parameter vs. Rh loading

Rh Pyrochlore Coating Development & Test Results

- Optimize coating of 5 wt.% Rh pyrochlore catalyst on PCI's Microlith substrate.
- Maximize loading, dispersion & adhesion; minimize cost & processing time.
- To date, 4 iterations have been performed by adjusting washcoat formulation & catalyst application method.
- Catalyst performance tests were performed with 1.6-ppm sulfur JP 5 (similar aromatics w. Tier II Diesel).

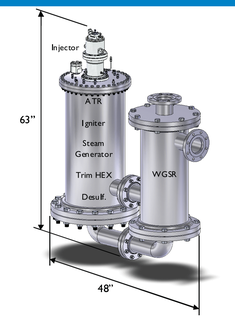
Iteration #	Conversion to C1s (%)	LHV-based Efficiency (%)	Ethane + Ethylene (ppmv, wet basis)	Propane + Propylene (ppmv, wet basis)
1	94.1	73.9	1175	260
2	97.1	75.5	1100	290
3	~100	79.3	634	64
4	~100	78.8	198	0
5*	100	85	0	0

*Target values as achieved by non-pyrochlore catalyst

- Reduced coke precursors (i.e., higher hydrocarbons, including C2s & C3s) from >1000 ppm$_v$ to 200 ppm$_v$
- Increased fuel conversion to C1 products (i.e., CO, CO_2, CH_4) & reforming efficiency.

ATR

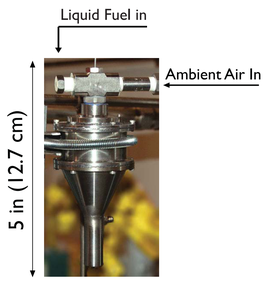
ATR Scale-up: 1 MWth ATR System

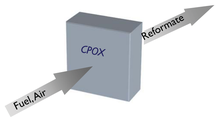


Modular, 250 kW$_e$ Fuel Processing System consisting of fuel/air/steam injector, ATR steam generator hex, and downstream sulfur clean-up

Catalytic Partial Oxidation Reactor (Waterless CPOX)

5 kWth CPOX reactor w. fuel/air injector, igniter





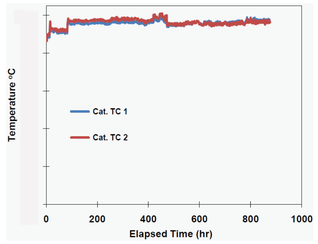
- Operates at O/C ≈ 1And S/C = 0
- Direct partial oxidation (w/o deep oxidation)
- High H_2 selectivity
- Startup time <1min (ambient to steady state).
- Collaboration w. automotive OEM

Reformate composition (mole %) for operation w. distillate fuel:

H_2	O_2	N_2	CH_4	CO	CO_2	C_2H_4	C_2H_6	C_3H_6	C_3H_8
22	0	54	0.4	21	2	0.3	0.0	0.1	0.0

T Profile from CPOX Test
(w. Distillate Fuel containing Sulfur)

CPOX reactor peak temperature profile vs. time



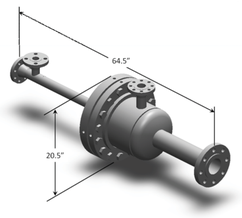
- Catalyst durability test w. distillate fuel containing sulfur.
- Stable T observed for 900 hrs without catalyst replacement or regeneration.
- Minimal change in Oxygen-to-carbon (O/C) ratio during the test.

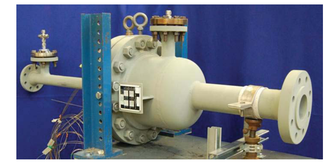
CPOX

CPOX Scale-up 5 MWth Natural Gas Reformer

5 MWth reactor to reform natural gas to produce syngas

Prototype tested & delivered





- Performance testing successfully completed.
- 1000 hrs of sub-scale durability completed (Target 8000 hrs).

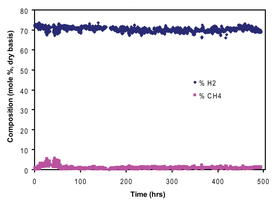
Heat-Integrated 3 kWth Steam Reformer (CSR) Prototype

Performance Summary:

- Include exothermic (burner) & endothermic (steam reformer) sections
- Up to 3 kWth CSR operation
- Prototype size: 12 inches long, 1.5 inches diameter
- 500 hr operation at S/C of 3.0 with low sulfur fuel without coke formation
- Product composition in good agreement with thermodynamic prediction
- ~10x higher overall heat transfer coefficient vs. conventional HEX
- Fuels tested: n-C12 & synfuel S-8

500-hr Durability of Heat-Integrated CSR

Product composition vs. time



- Operation w. distillate fuel containing 2-5 ppm$_w$ Sulfur

	Expd Product Mol%, S/C=3.0, P = 1 atm	Equilibrium Mol%, S/C=3.0, 1 atm, 650°C
H_2	69-71	70.8
CO	10.7-14.0	11.8
CO_2	14.0-19.3	15.6
CH_4	0.8-4.0	1.9
LHV-based efficiency (w. CH_4)	~119% (synfuel)	115%

CSR

CSR Scale-up: 7.5 kWth Operating at 10 atm

7.5 KWth CSR for up to 10 atm operation w. low sulfur diesel

- CSR prototype consists of catalytic exothermic (burner), catalytic endothermic (CSR), HEX & mixer.
- Catalytic burner instead of flame -stabilized burner increases thermal uniformity, distribution, durability & control.

PCI
Precision Combustion, Inc.
www.precision-combustion.com
tech@precision-combustion.com