

Integrated Testing of a CPOX Reformer & SOFC

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Remote Alaska electric issues

- Diesel is a preferred fuel because of energy density
 - Diesel has about 17,000 BTU per pound
- Most remote electric is from diesel generator sets
- Cost can be very high in remote villages
 - In Kotzebue, cost is about \$.20 per kWh
 - In small villages the cost exceeds \$.40 per kWh
 - Transportation of fuel can be a significant cost
- Grid power does not exist in remote areas
- Alternatives that are more efficient and have lower environmental impact are of interest

Remote power generation in Alaska

- Two diesel generators
 - 25 kW
 - 35 kW
- Access by river or aircraft
- Low winds
- Under 400 people – average for Alaska ~450 people
- Environment is a consideration



Aerial View of Lime Village

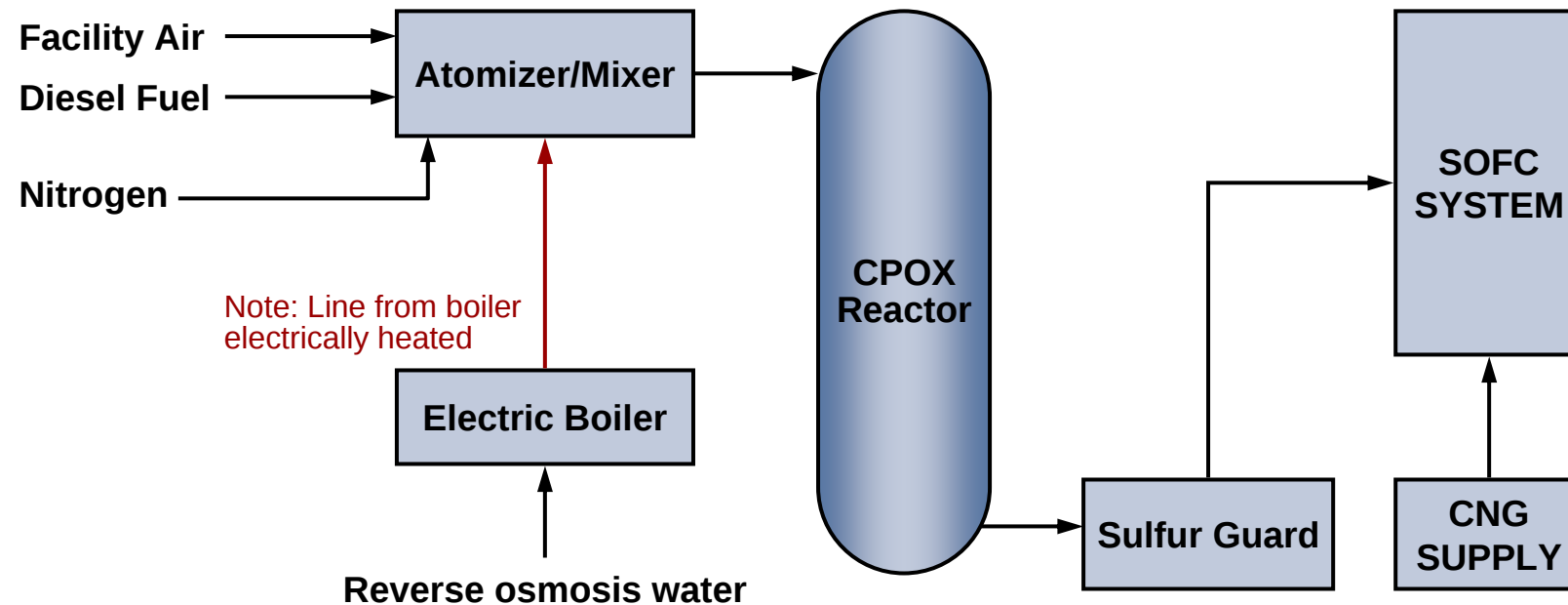
Technical Issues

- Fuel cell operation at altitude
 - Lower pressure
 - Higher volumetric flow for the same mass flow
 - Higher pressure drop
 - Lower residence time
 - Lower oxygen content reduces reaction rates
- Use of liquid fuels
 - Liquid fuel reformation versus natural gas
 - Results in high volumetric flow rates for the same energy input
 - High pressure drops
 - External reforming affects thermal management
 - Endothermic natural gas versus exothermic reformat
 - Temperature profile changes
 - Additional cooling required in the front part of the cell stack

Test overview

- Use existing infrastructure for fuel (diesel)
- Use a commercially available reformer and SOFC
 - Reformer provided by SOFCO-EFS
 - SOFC provided by Acumentrics
- Test reformer and SOFC at origin
 - Reformer on diesel (low sulfur and synthetic)
 - SOFC on natural gas
- Test each unit independently at INL
- Test the units in integrated operation on diesel
- Gather data for designing a “for purpose” unit

Schematic of CPOX Reformer



Initial tests with methane and diesel

	<i>METHANE</i>	<i>LOW SULFUR DIESEL</i>	<i>SYNTHETIC DIESEL</i>
Hydrogen %	31%	30%	33%
Carbon Monoxide %	14.6%	12.4%	12%
Fuel type	Natural gas	Phillips	Syntroleum
Hours tested	2000 +	4	4
Conversion of hydrocarbons	93%	99%	99%
Reformer efficiency	77%	82%	80%

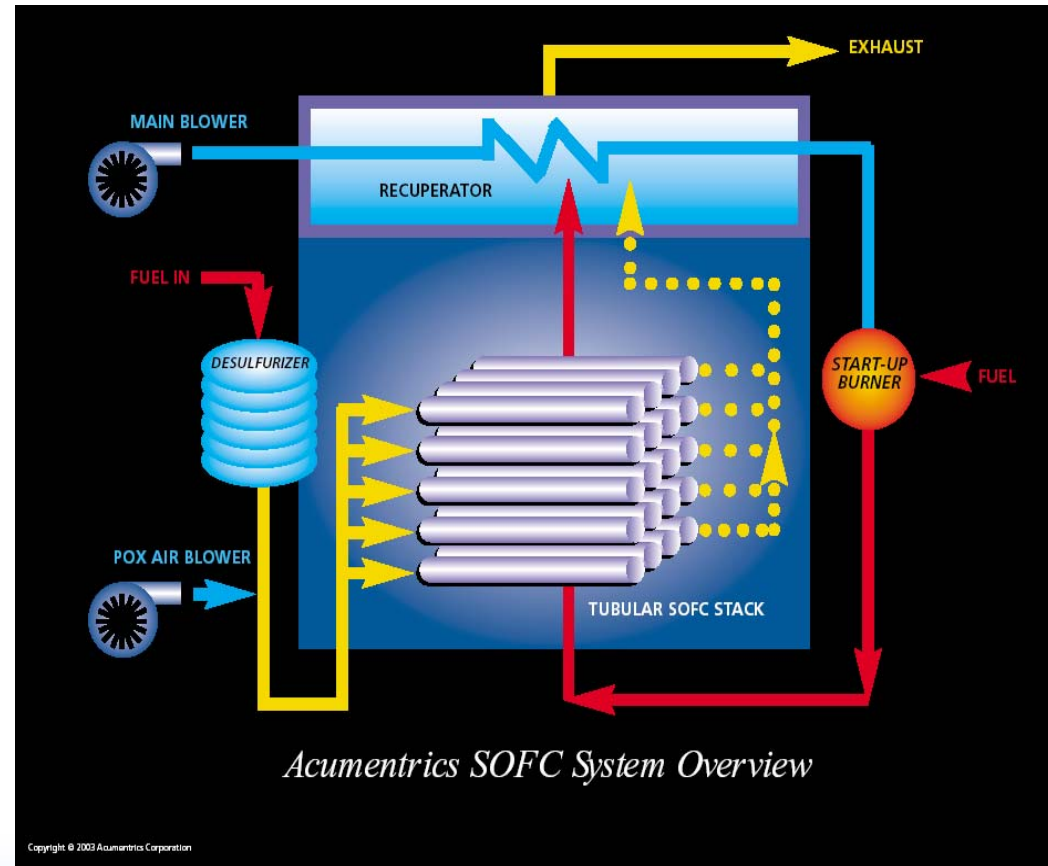
CPOX unit

- Unit takes about 30 minutes to reach operating temperature
- Steam provided by auxiliary electric boiler
- Fuel controlled at average of 1.134 Kg/hr
- Steam controlled at 1 – 1.5 ratio to carbon
- Temperature of reformat $\sim 800^{\circ}\text{C}$
- Cooled for Sulfur guard ($\sim 600^{\circ}\text{C}$) & SOFC ($\sim 50^{\circ}\text{C}$)
- Efficiency $\sim 80\%$



Overview of the Acumentrics system

- Schematic of system
- Designed for pipeline natural gas
- Burner provides preheat and adds heat to maintain
- Produces 5 kWe at sea level on natural gas

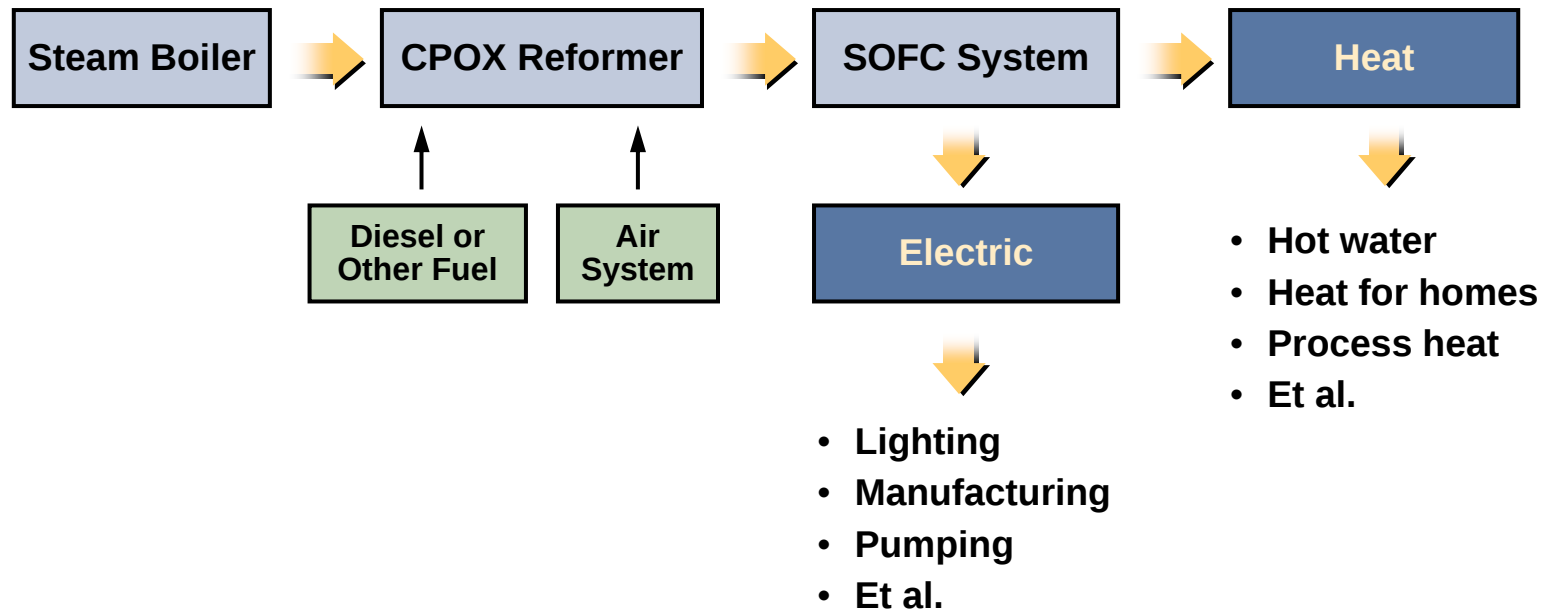


Fuel Cell system at Acumentrics

- **Successfully operated on natural gas**
- **Consists of four tubular SOFC stacks**
- **No previous tests on diesel fuels**



Integrated Reformer and Fuel Cell System



5kW Diesel Fueled Acumentrics SOFC

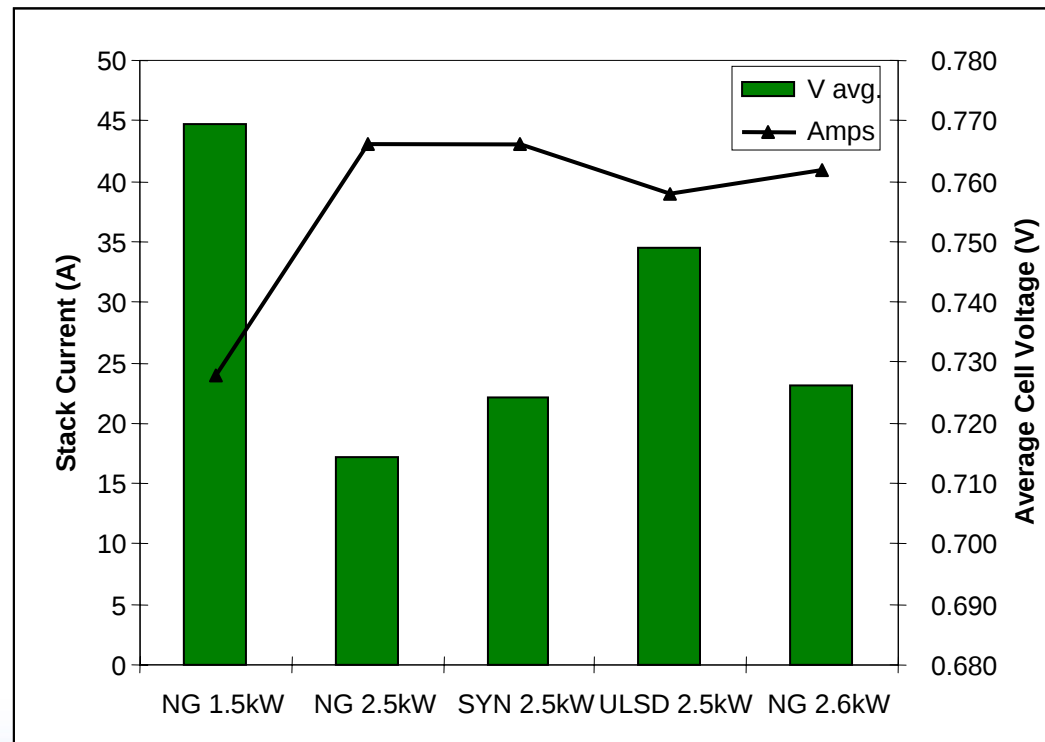


Preliminary results on system

<i>Fuel Type</i>	<i>Hydrogen</i>	<i>Carbon Monoxide</i>	<i>CH₄ – C₃H₈ ppmv</i>	<i>Load</i>
Synthetic Diesel	20%	18%	987	2.5 kW
Low Sulfur Diesel	16%	15%	657	2.5 kW

- Notes:*
- 1. Amounts shown are on a dry basis*
 - 2. Samples were drawn and had oxygen contamination, amounts are corrected*
 - 3. Some drift on steam flow between samples that may have affected numbers*
 - 4. Carbon monoxide was in the expected range but hydrogen was low*
 - 5. System efficiencies about as expected for non-optimized system*
 - 6. Synthetic diesel ~120 BTU/SCF; Low Sulfur ~108 BTU/SCF*

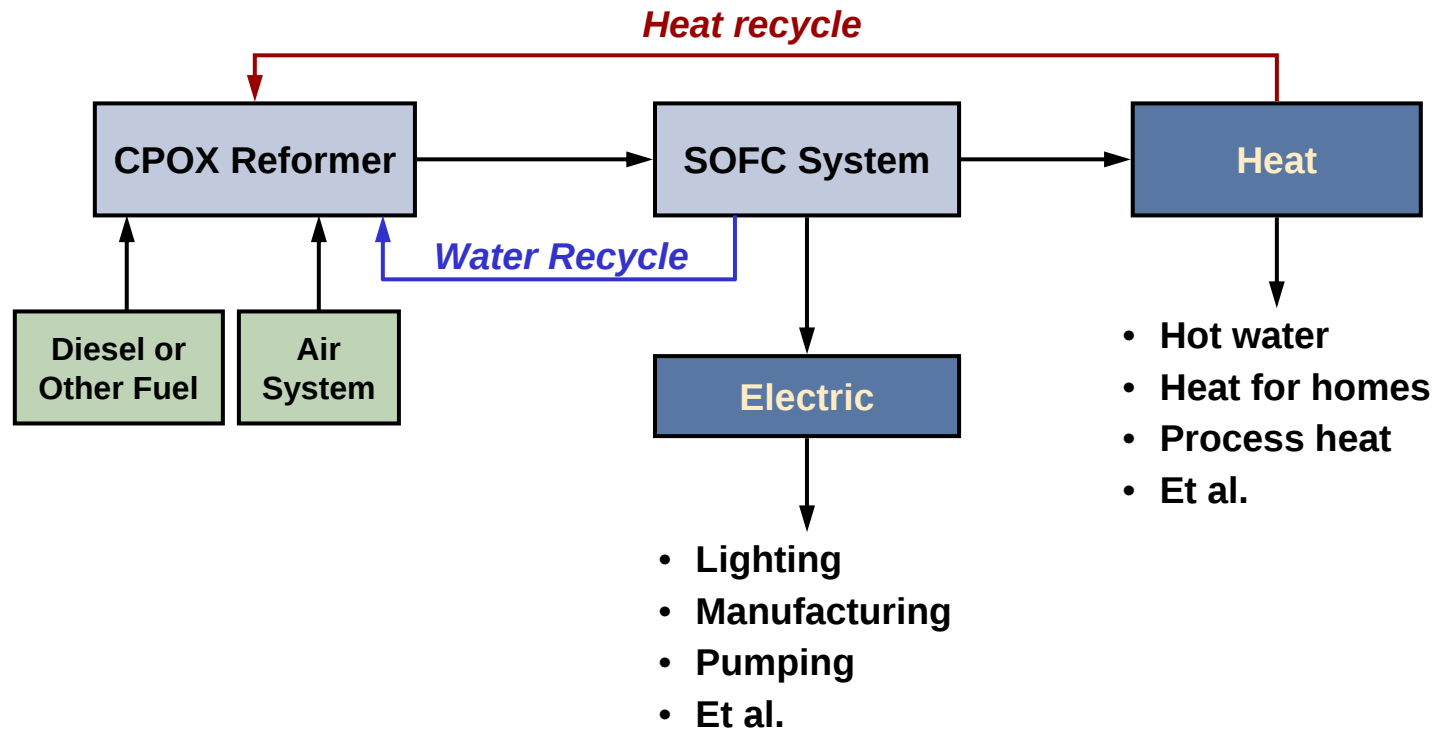
Diesel Fueled SOFC Performance



Graph courtesy of Acumentrics

Preliminary “for purpose” System

BLOCK DIAGRAM OF COMBINED HEAT & POWER SYSTEM



Preliminary observations

- **CPOX reformer system**
 - Can successfully reform low sulfur diesel and synthetic diesel
 - More stable operation on synthetic diesel
 - Less drift in mass flow
 - Temperature has narrower range
- **SOFC system**
 - Can successfully operate at altitude (~5000 feet)
 - Adjustments to air flow needed for diesel reformat
 - Performance is slightly better on synthetic diesel

Comparison of fuel costs

<i>SYSTEM TYPE</i>	<i>EFFICIENCY</i>	<i>FUEL USED</i>	<i>COST / YEAR</i>
DIESEL	25%	~49,000 GAL	\$194,000
SOFC	50%	~24,000 GAL	\$97,000

Notes: 1. Costs are for one year of operation

2. Fuel cost delivered of ~\$4/gallon

3. Three (3) 35 kW generators as basis

4. No adjustment for transportation, storage, maintenance, etc

- Potential exists for other savings from combined heat and power units