Selective Conversion of Syngas to JP-8 Jet Fuel

Andrew Lucero, Brittany Basu, Brandon Cline, Patrick Woolcock, Curtis Thompson, Kevin McCabe, and Santosh Gangwal

Presentation for
Gasification & Syngas Technologies Council
2017 Syngas Technologies Conference
October 15-18, 2017
Agenda

- SR Overview
- Project goals and objectives
- Project team
- CTL process concept
- Hybrid selective FT synthesis
- Summary
- Recommendations and path forward
QUICK FACTS

- Founded in 1941 in Birmingham, Alabama
- Proven Team of 450 Scientists, Engineers and Technicians
- Discovered 7 FDA Approved Cancer Drugs
- Developing Drugs for Cancer, Alzheimer’s, Diabetes, Kidney Disease, Parkinson’s, Tuberculosis and ALS
- Developed an HIV Treatment that is Changing History
- Worked With NASA Since the First Manned Space Flight
- Deep history in air and water emissions control technologies
- Operating the state of Alabama’s first solar research center
SOUTHERN RESEARCH
-FOUR OPERATING DIVISIONS-

DRUG DISCOVERY

DRUG DEVELOPMENT

ENERGY & ENVIRONMENT

ENGINEERING
Jet Fuel Project Goals

• Develop process intensification approaches to reduce the cost of CTL/CBTL for production of JP-8 jet fuel.
  – Autothermal reforming (ATR) of raw syngas from gasification
  – Advanced hybrid Fischer-Tropsch synthesis does not produce waxes

• Prepare for integrated pilot / demo scale efforts, accelerating potential commercialization of CTL and CBTL.

• Demonstrate significant cost savings for CTL/CBTL for jet fuel production
PROJECT TEAM

- Southern Research (lead, ATR catalyst development)
- Chevron (Co-zeolite hybrid FT catalyst supplier)
- IntraMicron (FT heat exchange reactor technology)
- National Carbon Capture Center (testing host site)
- Southwest Research Institute (product qualification support)
CTL Process Concept

Diagram of the CTL process concept showing the flow of coal or coal/biomass to the gasifier, which produces hot gas. The gas is then directed to the ATR (Autothermal Reactor) where oxygen is added. The output from the ATR goes to a cooler, followed by a sour shift (if required). The gas then goes to the acid gas removal and finally to the CO₂ sequestration or utilization. The CO₂ is removed for further processing. The sulfur is recovered and directed to the Fischer-Tropsch reactor where C₅-C₂₀ hydrocarbons are produced, which fall within the 65% jet fuel range. The tail gas is sent back to the reactor.
Technical Approach for 2017

• ATR catalyst testing using a laboratory-scale steam reformer with TRIG gasifier syngas at NCCC
  – Reform tar and light hydrocarbons to additional syngas
  – Decompose ammonia in the presence H$_2$S and other coal syngas contaminants
  – Deliver the required hydrogen (H$_2$) to carbon monoxide (CO) ratio for Fischer-Tropsch (FT) synthesis

• Testing Chevron’s hybrid cobalt-zeolite FT catalyst in a 4 inch ID bench-scale reactor tube with IntraMicron MFEC technology*
  – Demonstrate jet fuel selective FT catalyst with >75% liquid selectivity, >65% jet fuel, little or no solid wax, and >0.7 g C5+/gcat/hr

*Previous FT tests in microreactor and 2 inch ID MFEC reactor
Lab Reformer Installed in Cabinet for Operation in Class 1 Div. 2 Industrial Environment
Lab Reformer Installed at NCCC
Accomplishments: ATR Catalyst Testing

- High conversion of methane in the presence of 380 ppm H₂S – tars and ammonia not detected in effluent
- Ability to control H₂:CO ratio
- Strong effect of temperature on methane conversion
- No evidence of permanent poisoning

*Catalyst developed in DE-FE0012054 (Gasification Program)*
FT Catalyst Testing

- Chevron hybrid cobalt-zeolite catalysts
  - Highly selective: ~75% hydrocarbon liquids
  - >65% jet fuel
  - 5x greater yield than traditional catalysts
  - Eliminate production of undesirable wax
  - CAPEX and OPEX reductions

- 20,000 hours of tests with several catalysts in micro-reactor
- Optimum candidate selected for >300 hours of experiments in a 2 inch ID bench-scale reactor in 2015
- Scaled up for ~125 hours of experiments in a 4 inch ID bench-scale reactor in 2017
IntraMicron’s Microfibrous Entrapped Catalysts (MFEC)

Cu-entrapped FT Catalyst Particles

**MFEC Allows**
- Use of simpler fixed beds
- Large diameters up to 2-6 inches
- Very high activity catalyst particles
- Isothermal operation

**Resulting in**
- High productivity and selectivity
- Shorter and fewer tubes
- Reduced cost

Images from http://www.intramicron.com
Bench-scale FT Reactors
Technical Approach for 2017 Experiments

• Design and fabricate larger diameter reactor
• Upgrade systems to allow for additional catalyst in larger reactor
  – Syngas feed
  – Reactor cooling
  – Sampling system
• Goal - Duplicate or improve on FT catalyst performance targets in 4 inch ID bench-scale reactor tube with MFEC technology
  – >75% liquid selectivity,
  – >65% jet fuel, little or no solid wax
  – >0.7 g C5+/gcat/hr
Southern Research Fischer-Tropsch Skid Installed and Commissioned at NCCC
CO Conversion and Liquid Selectivity during 2017 FT Experiments
Accomplishments FT Synthesis

• ~75% selectivity to liquid hydrocarbons
• ~86% of liquid hydrocarbons in jet fuel range
• Improved Economics!

![Bar chart showing weight percent of carbon number distribution for C4 to C24, with weight percent values for C8-C16 shown as 86.0, 87.8, 86.1, 87.2.](image)
SUMMARY

• Advanced process intensification approaches are being used to reduce cost to produce low cost jet fuel using XTL
  – ATR to reform hydrocarbons and tar, and decompose ammonia in the presence of sulfur for gasification based processes
  – Cobalt-zeolite wax-free jet selective catalyst with high productivity and selectivity
  – Heat exchange reactor technology to allow large diameter reactor to be used for exothermic FT reaction; to enable reduction in reactor tube height.
  – 4 inch ID FT reactor was successfully tested with Chevron catalyst and IntraMicron MFEC technology in SR thermosyphon reactor
    – ~75% selectivity to liquid hydrocarbons
    – ~86% of the liquid hydrocarbons in the jet fuel range
• Goal is to be ready for integrated pilot / demo scale efforts by the end of the project (2017), accelerating potential commercialization of XTL, ultimately allowing smaller plants to become cost effective.
Recommendations and Path Forward

• Long term testing
• FT product upgrading to collect jet fuel fraction and certify for ASTM D7566
• Pilot scale testing
Acknowledgements

• Funding Provided by Air Force /US Department of Energy/National Energy Technology Laboratory and Southern Research under Co-operative Agreement # DE-FE0024083
• Venkat Venkataraman, John Rockey of DOE/NETL
• Chevron: Kandaswamy Jothi and Bob Saxton
• Intramicron: Paul Dimick, Hongyun Yang and Bruce Tatarchuk
• Southern Company/NCCC: Scott Machovec, Barry Shirley, Frank Morton and entire Southern Company/NCCC staff and contractors
• Southern Research E&E Department Senior Staff, Engineers, and Chemists
Disclaimer

The Government reserves for itself and others acting on its behalf a royalty-free, nonexclusive, irrevocable, worldwide license for Governmental purposes to publish, distribute, translate, duplicate, exhibit and perform this paper. Neither Southern Research Institute nor the United States Department of Energy, nor any person acting on behalf of either: makes any warranty or representation, express or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or assumes any liabilities with respect to the use of, or for damages resulting from the use of, any information, apparatus, method, or process disclosed in this report. Reference herein to any specific commercial products, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Department of Energy. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Department of Energy.
Questions?