Breakthrough Hybrid CTL Process Integrating Advanced Technologies for Coal Gasification, NG Partial Oxidation, Warm Syngas Cleanup and Syngas-to-Jet Fuel

DOE/NELT Cooperative Agreement DE-FE0023592

John Carpenter
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Overview

Breakthrough hybrid coal-to-liquids process integrating several emerging technologies and adapting some commercially available technologies to produce cost-competitive jet fuel.

- AR\GTI Compact Gasification System
- AR\GTI Partial Oxidation Unit
- RTI Warm Syngas Cleanup
- Syngas-to-Liquid System
- Axens Hydroprocessing Technology

<table>
<thead>
<tr>
<th>Technology</th>
<th>Benefits</th>
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<tbody>
<tr>
<td>Advanced gasification with dry feed (AR)</td>
<td>&gt;15%</td>
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<td></td>
<td>7-10%</td>
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<tr>
<td></td>
<td>(Cold gas)</td>
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<tr>
<td>Warm syngas Cleanup (RTI)</td>
<td>5-10%</td>
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<td></td>
<td>&gt;3% (HHV)</td>
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<td>Cumulative Impact</td>
<td>20-25%</td>
</tr>
<tr>
<td></td>
<td>7-8% (HHV)</td>
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Development Team
- RTI International
- GTI
- Aerojet Rocketdyne (AR)
1. Advance the constituent technologies of the hybrid process to TRL 5-7:
   • Demonstrate integrated operation of AR\GTI’s gasifier and POX units with RTI’s STL
     process at pilot-scale (~1 bbl/day).
   • Demonstrate the jet-fuel intermediate generated during this integrated pilot-scale test is
     suitable for upgrading into jet-fuel using commercial refinery processes.

2. Demonstrate the feasibility of the proposed hybrid process to produce cost
   competitive jet fuel and lower GHG emissions.

3. Develop a commercialization plan for commercial deployment within the next 5 to
   15 years.
Aerojet Rocketdyne\GTI Compact Gasification System

Gasifier → Syngas Cleanup

Coal → Ash

Air / Oxygen → Sulfur

Natural Gas → Partial Oxidizer → Water-Gas-Shift

Steam / Boiler Feed Water

Water Separation → Syngas-to-Liquids

CO2 Separation → Jet Fuel Upgrading

Jet Fuel

CO2

CO2
Compact Gasification System

- 90% reduction in gasifier volume
- Cold gas efficiency improvements
  - 7% - 10% versus water slurry feeders
  - 2% - 4% versus dry feed systems
- Gasifier surface temperatures of 1000°F
  - >2 year life injectors (< 4 months GE injectors)
  - >10 year life cooling liner (1-3 year for refractory)
- Dry ash recovery eliminates black water collection system and waste water treatment requirements.
  - >15% lower cost of electricity for IGGC
  - >25% lower cost for hydrogen

PWR’s Dry Solid Pump

- 32 GWh/y reduction in lock hopper power requirements (3000 tpd plant)
- Demonstrated performance with both coal and coal/biomass mixtures
Aerojet Rocketdyne\GTI Partial Oxidation Unit
Aerojet Rocketdyne\GTI Partial Oxidation Unit

• Developed with a focus on distributed gas-to-liquid production (~1,000 BPD)
• 80 hours of pilot scale (~450 MSCF/day NG feed) POX unit testing was performed in 2013
  • Validated performance and design approach
  • Demonstrated the ability to directly yield syngas with $\text{H}_2$:$\text{CO}$ molar ratios near 2.0
  • Potential to eliminate the need for downstream water-gas-shift reactors
• Designed and fabricated a prototype POX unit
  • Incorporating burner element and cooled liner designs
  • Support testing of the POX unit with natural gas using either oxygen or air.
  • Designed to enable recycle of byproduct and/or wastewater streams to the unit
• POX technology offers the potential to reduce GTL plant capital cost by 10-15%.
RTI Warm Syngas Cleanup Technology Platform

Coal -> Gasifier -> Water-Gas-Shift -> Partial Oxidizer -> Syngas Cleanup -> Sulfur

Air / Oxygen

Natural Gas

Ash

Water-Gas-Shift

Steam / Boiler

Feed Water

Water Separation

CO2 Separation

Syngas-to-Liquids

Jet Fuel Upgrading

Jet Fuel

CO2
RTI Warm Syngas Cleanup Technology Platform

- **Flexible modular approach meets:**
  - New EPA electric power generation specifications
  - Industrial production specifications
- Systems tested on actual coal-based syngas
- 50-MWe demo project with carbon capture at Tampa Electric’s Polk 1 IGCC site

- Enhance overall process efficiency and lower costs by operating at temperatures of 250°C to 600°C with small footprints!
- Pressure independent
- Effective for all forms of sulfur
- Fully compatible with conventional and warm CO₂ capture

**RTI PILOT PLANT TEST UNITS AT EASTMAN COAL GASIFICATION PLANT**
Syngas-to-Liquids System

- **Coal** → **Gasifier**
- **Air / Oxygen** → **Partial Oxidizer**
- **Natural Gas** → **Gasifier**
- **Coal** → **Partial Oxidizer**
- **Gasifier** → **Syngas Cleanup**
- **Partial Oxidizer** → **Syngas Cleanup**
- **Syngas Cleanup** → **Ash**
- **Syngas Cleanup** → **Sulfur**
- **Water-Gas-Shift** → **Syngas Cleanup**
- **Steam / Boiler Feed Water** → **Syngas Cleanup**
- **Syngas Cleanup** → **Syngas-to-Liquids**
- **Syngas-to-Liquids** → **CO2 Separation**
- **CO2 Separation** → **Jet Fuel Upgrading**
- **Jet Fuel Upgrading** → **Jet Fuel**

**Processes:**
- **Water Separation**
- **CO2 Separation**
- **Syngas-to-Liquids**
- **Jet Fuel Upgrading**
RTI is developing an STL process with the following features:

- Produces a targeted narrow carbon range distribution of fuel products
- Achieves heat management through reduced reactant partial pressure
- Utilizes commercial and emerging F-T catalyst compositions

Single pass CO conversion efficiencies of over 60% with selectivity to C$_8$-C$_{18}$ liquid products of 65% have been achieved.
1BPD Pilot-Scale STL System

System to demonstrate STL technology with relevant syngas from gasifier and POX systems.
1 BPD Pilot Plant Testing with Syngas at GTI

GTI’s Gasification Pilot Plant
Axens Hydroprocessing Technology

Coal → Gasifier → Syngas Cleanup
  ↓ ↓
  Ash Sulfur

Air / Oxygen → Partial Oxidizer → Water-Gas-Shift
  ↓ ↓
  Steam / Boiler Feed Water

Syngas Cleanup

Water Separation → Syngas-to-Liquids → CO2 Separation → Jet Fuel Upgrading

Jet Fuel

CO2
Axens’ technologies have been developed to ensure:

- Minimum production costs by careful balancing of the hydrotreatment reaction pathway (hydro-isomerization vs hydro-cracking).
- Minimum impact of CO/CO₂ inhibition
- Fine tuning of product cold flow properties
- Superior fuel stability in operation

<table>
<thead>
<tr>
<th>Property</th>
<th>Typical Vegan Jet Product</th>
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<tbody>
<tr>
<td>Density, kg/m³</td>
<td>766</td>
</tr>
<tr>
<td>D86 T10, °C</td>
<td>169</td>
</tr>
<tr>
<td>D86 FBP °C</td>
<td>272</td>
</tr>
<tr>
<td>Freezing point °C</td>
<td>-57</td>
</tr>
<tr>
<td>Flash point °C</td>
<td>68</td>
</tr>
<tr>
<td>BRW00</td>
<td>Case A: Advanced CTL (no POX)</td>
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<td>-------</td>
<td>------------------------------</td>
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<tr>
<td>Total Owners Cost $/bpd</td>
<td>$135,640</td>
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<tr>
<td>Capital Charge $/bbl</td>
<td>$70.00</td>
</tr>
<tr>
<td>O&amp;M $/bbl</td>
<td>$44.50</td>
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<tr>
<td>Plant Gate Fuel Cost $/bbl</td>
<td>$114.50</td>
</tr>
<tr>
<td>Cost of Oil Equivalent $/bbl</td>
<td>$95.40</td>
</tr>
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The hybrid CTL process provides potential savings for both capital and operational costs that can remain cost-competitive with petroleum-based jet fuel and when crude oil prices are at or above $70/bbl.
Reduction in total generated CO$_2$ as a function of coal in the total feedstock calculated using AR’s coal gasifier and partial oxidation technologies.

At a 51% coal, 49% natural gas split, only 60.5% (vs. 84% for conventional CTL) of the non-fuel-bound carbon is required to be captured in order to meet EISA 2007 §526 requirements for our hybrid CTL process.
• Leverages ongoing parallel activities in other DOE and commercialization projects on many of the technology components

• Furthers the TRLs of the less mature STL and partial oxidation technologies

All of the key technologies should be ready for integrated hybrid CTL demonstration testing, and within 3-5 years of full commercial readiness, by project end.
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