Sasol Synthetic Fuels
Coal to Liquids
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Overview

- Synthetic Fuels Industry in South Africa today
- Sasol Synthetic Fuels technology
- Sasol’s CTL & GTL experience
- Approval Process for Sasol Fully Synthetic Jet Fuel
  - Components
  - Properties (Def Stan 91-91)
  - Fit for Purpose Tests (Def Stan 91-91 Annex D)
  - Component tests
  - Research reports
- Establishing a CTL industry is not without challenges
- Summary
Synthetic Fuels Industry in South Africa today

**Sasol Synfuels**
- Coal-fed, supplemented with natural gas
- Capacity: 160 000 bpd crude oil equivalent

**PetroSA**
- Natural gas-fed, some condensate
- Capacity: 45 000 bpd crude oil equivalent

Total Capacity:
205 000 bpd (~ 10 million tpa) crude oil equivalent

Synfuels industry supplies ~30% of SA transport fuel consumption
Sasol Synthetic Fuels Technology

Gasification
- Coal or Biomass
- Synthesis gas

High Temperature Synfuels Technology
- LPG
- Gasoline
- Kerosene
- Diesel
- Chemicals
- Product upgrading

Reforming
- Natural gas
- Synthesis gas
- Olefins (to plastics)

Low Temperature Synfuels Technology
- Current LPG
- Naphtha
- Diesel
- Future Kerosene
- Base oils
- Product upgrading
Product Slate

- LPG
- Naphtha
- Gasoline
- Kerosene
  - Jet A1 / JP8
- Diesel
- Base Oils
- Chemicals
Sasol’s CTL & GTL experience

Sasol is the leader in gas-and-coal to liquid technologies and their application

- 50 years experience in developing technology, designing and operating plants
- more than 1.5 billion barrels of synthetic fuels produced
- currently ~25% of South African fuel is derived mostly from coal
- South Africans drive and fly on coal – today
- Synthetic jet fuel blends in commercial use for last 10 years
- Sasol Fully Synthetic Jet Fuel first 100% synthesized jet fuel approved as commercial aviation turbine fuel (Def Stan 91-91)
- Writing Sasol Fully Synthetic Jet Fuel into ASTM D1655 as a specific approval is in process

Sasol’s technology offers a technically proven, commercially viable option - TODAY
Approval Process for Sasol Fully Synthetic Jet Fuel

Component tests
- Combustor Rig
- Emissions
- Ignition
- Altitude relight
- LBO

Fuel Specification Properties Def Stan 91-91/ASTM D1655
- Fit-for-Purpose Properties UK MOD
- Def Stan 91-91
- Annex D

Engine Manufacturer Approval
- Incorporated into fuel spec (Def Stan 91-91 & ASTM D1655)
### Selected Fuel Specification Properties (Def Stan 91-91)

<table>
<thead>
<tr>
<th>Property</th>
<th>Test Method</th>
<th>Limit</th>
<th>FSJF blends</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aromatics, vol%</td>
<td>D1319/IP156</td>
<td>8 – 25</td>
<td>7.2 – 16.9</td>
</tr>
<tr>
<td>Total Sulphur, mass%</td>
<td>IP336</td>
<td>0.3 max</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>T10, °C</td>
<td>D86/IP123</td>
<td>205 max</td>
<td>175 – 189</td>
</tr>
<tr>
<td>FBP, °C</td>
<td>D86/IP123</td>
<td>300 max</td>
<td>245 – 279</td>
</tr>
<tr>
<td>Flash point, °C</td>
<td>IP170</td>
<td>38 min</td>
<td>51 – 69</td>
</tr>
<tr>
<td>Density @ 15 °C, kg/m3</td>
<td>D4052/IP365</td>
<td>775.0 – 840.0</td>
<td>0.776 – 0.802</td>
</tr>
<tr>
<td>Freezing point, °C</td>
<td>D2386/IP16</td>
<td>-47 max</td>
<td>-55 to -61</td>
</tr>
<tr>
<td>Viscosity @ -20 °C, cSt</td>
<td>D455/IP71</td>
<td>8.0 max</td>
<td>3.48 – 4.69</td>
</tr>
<tr>
<td>Smoke point, mm</td>
<td>D1322/IP57</td>
<td>25 min</td>
<td>25 – 40</td>
</tr>
<tr>
<td>Specific energy, kJ/kg</td>
<td>D4809</td>
<td>42.8 min</td>
<td>43.1 – 43.8</td>
</tr>
</tbody>
</table>

Sasol 100% synthesized jet fuel meets all commercial Jet A1 specifications
Fit for Purpose Tests (Def Stan 91-91 Annex D)

- Physical properties vs. T
  - Density
  - Viscosity
  - Specific heat
  - Thermal conductivity
  - Bulk modulus
  - Surface tension
- Thermal stability
- Density vs. dielectric
- Lubricity
- Storage stability

- Hydrocarbon composition
- Trace materials
  - Organics
  - Inorganics
  - Metals
- Water separation
- Additives
- Materials compatibility
  - Elastomers
  - Metals
  - Other non-metals

Sasol 100% synthesized jet fuel properties and characteristics indistinguishable from conventional jet fuel
Component tests

- **Endurance Engine Test**
  - Evaluation of impact of Sasol FSJF on engine performance and operation
  - Fresh JT9-D engine
  - 500 commercial cycles

- **Combustor Rig Tests**
  - Low-temperature atomization
    - Honeywell
    - Addressed APU start on cold-soaked fuel (-40C)

- **Emissions**
  - Pratt & Whitney Talon combustor

- **Cold Start & altitude relight**
  - Main engine: R-R Trent combustor

- **Altitude Lean Blow Out**
  - Honeywell combustor rig

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No degradation of engine performance

Combustion characteristics are normal for viscosity and boiling point distribution; synthetic hydrocarbons are not different
EVALUATION OF SASOL SYNTHETIC KEROSENE FOR SUITABILITY AS JET FUEL

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DECEMBER 2003

PHASE II: ENGINE AND COMBUSTOR TESTS

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SwRI® Project No. 08-04438

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September 2007
D.4 Specific Approvals

D.4.2 Sasol Fully Synthetic Jet Fuel

D.4.2.1 Sasol synthetic kerosene, see clause D.4.2.4, is currently the only fully synthetic jet fuel which has been approved for use.

D.4.2.2 The aromatic content of Sasol fully synthetic fuel shall not be less than 8.0% nor greater than 25.0% by volume when using method IP 156, or less than 8.4% nor greater than 26.5% by volume when using method IP 436. The fuel shall exhibit a maximum wear scar diameter of 0.85 mm when tested by ASTM D5001. Analysis for these properties shall be made at the point of manufacture. These results shall be included on the batch certificate for the fuel.

D.4.2.3 The flash point shall be no greater than 50°C. The boiling point distribution shall have a minimum slope defined by T50-T10 ≥ 20°C and T90-T10 ≥ 40°C when measured by IP 123 / ASTM D86.

D.4.2.4 Sasol fully synthetic kerosene is defined as that material blended from light distillate, heavy naphtha and iso-paraffinic kerosene streams manufactured at the Secunda plant as described in the SwRI reports number 08-04438 and 08-04438-2. The batch certificate for the fuel shall state that the fuel contains 100% synthetic components.
Establishing a CTL industry is not without challenges

The Challenges in the Global Market

- World energy markets are volatile
- Competition for resources
- Investment decisions on large capital projects are risky
- Uncertainty of global Greenhouse Gas framework
- Objections to coal use

The cost of projects are high
In summary

- CTL has been demonstrated as source of jet fuel for the future
- CTL can be a significant part of a portfolio of measures to address future energy security
- Sasol leads GTL and CTL operations and development globally
- South Africa's government and economy are being handsomely rewarded for enabling a CTL industry
- A number of countries are at various stages of development of a CTL industry
- There is an urgent need for objective debate by decision makers to ensure sustainable energy solutions for the future