Qualifying Synthetic Fuels for Military Applications

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Office of Secretary of Defense Acquisition, Technology, and Logistics Advanced Systems & Concepts

- Ms. Sue Payton - Deputy Under Secretary of Defense
- Dr. Theodore K. Barna - Assistant Deputy Under Secretary of Defense
Crude Oil: Finite Supply, Rising Demand

Proven Oil Reserves at End of 2003

Top World Oil Consumers in 2003

<table>
<thead>
<tr>
<th>Country</th>
<th>Total Demand (M BPD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>20.0</td>
</tr>
<tr>
<td>China</td>
<td>5.6</td>
</tr>
<tr>
<td>Japan</td>
<td>5.4</td>
</tr>
<tr>
<td>Germany</td>
<td>2.6</td>
</tr>
<tr>
<td>Russia</td>
<td>2.6</td>
</tr>
<tr>
<td>India</td>
<td>2.2</td>
</tr>
<tr>
<td>South Korea</td>
<td>2.2</td>
</tr>
<tr>
<td>Canada</td>
<td>2.2</td>
</tr>
<tr>
<td>Brazil</td>
<td>2.1</td>
</tr>
<tr>
<td>France</td>
<td>2.1</td>
</tr>
<tr>
<td>Mexico</td>
<td>2.0</td>
</tr>
</tbody>
</table>

World Oil Balance, 1Q04

Supply = 82.1M BPD
Demand = 82.3M BPD

International Energy Agency Oil Market Report

Source: BP Statistical Review of World Energy 2004 © BP
U.S. Demand for Petroleum Products

Many products made from petroleum

Rising Demand for Transportation Fuels
(Quadrillion Btu/yr)

Total Consumption
18.3
1975
2025
41.2

Source: Energy Information Administration (EIA)

1 Quadrillion Btu = 172M bbl oil
Increasing Reliance on Petroleum Imports

- **U.S. Consumption**: 19.8M BPD
- **U.S. Production**: 9.3M BPD
- **Imports**: 10.5M BPD
- **Total Imports**: 53%

2002:
- **Imports**: 4M BPD Finished Products

2025:
- **Imports**: 70%

Source: EIA (AEO 2004); Reference Case Scenario
[Courtesy John Winslow-DoE]
U.S. Refining Capability Is Strained
## Current Military Transportation Needs – Petroleum

<table>
<thead>
<tr>
<th>Service</th>
<th>Percent</th>
<th>BPD</th>
<th>BPY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Army</td>
<td>6%</td>
<td>18,500</td>
<td>6.7 M</td>
</tr>
<tr>
<td>Air Force</td>
<td>55%</td>
<td>166,000</td>
<td>60.8 M</td>
</tr>
<tr>
<td>Navy</td>
<td>38%</td>
<td>114,000</td>
<td>41.8 M</td>
</tr>
<tr>
<td>Marines</td>
<td>1%</td>
<td>1,500</td>
<td>0.7 M</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td>300,000</td>
<td>110.0 M</td>
</tr>
</tbody>
</table>

*Note: 75% Domestic, 25% Overseas*

Source: DESC, FY02

### Bulk Transportation Fuels

- Jet fuels, 73.5%
- Marine fuels, 7.9%
- Ground fuels, 15.1% (+3.5% heating oil)

Source: DESC Contract Awards, FY03
## U.S. Hydrocarbon Resources

- **Coal**
  - 250 B tons = 1,138 Billion BOE

- **Natural Gas**
  - 184.8 Tcf = 33.3 Million BOE

- **Petroleum Coke**
  - 798K BOE/day produced
    - 361K BOE/day exported
    - 437K BOE/day available

- **Oil Shale**
  - 270 B tons = 130 Billion BOE

- **Tar Sands**
  - 6.1 Billion BOE

- **Biomass**
  - 1.2 B tons = 31.75 Billion BOE

Equivalent to 1.3 Trillion Barrels of Oil

**BOE** = Barrels of Oil Equivalent
Fischer-Tropsch Technology

Natural Gas
Coal
Pet Coke
Biomass
Wastes

Synthesis Gas Production

Air
O2

Oxygen Plant
An Option

CO
H2

FT Liquid Synthesis

Product Recovery

Tail Gas

Power Generation

Hydrogen Separation

Wax Hydrocracking

Wax

Transportation Fuels

Liquid Fuels

Hydrogen

Hydrogen Recovery

Liquid Fuels
Emerging Global FT Industry

FT Projects in U.S.
- **BP (Nikiski, AK)**
  - 300 bpd demo plant (2003)
  - FT product to near-by refinery
- **ConocoPhillips (Ponca City, OK)**
  - 400 bpd demo plant
  - Just starting up
- **Syntroleum (Tulsa, OK)**
  - 70 bpd demo plant (late 2003)
  - DoE co-sponsor
- **Rentech (East Dubuque, IL)**
  - Convert nat. gas-fed fertilizer plant to use coal
  - Co-produce FT fuels, fertilizer, and electricity
- **WMPI (Gilberton, PA)**
  - Convert waste coal to 5000 bpd FT fuels and 41 MWe power
  - DoE co-sponsor

**History of Commerically Operated FT Plants**

<table>
<thead>
<tr>
<th>Company</th>
<th>Years Operated</th>
<th>Capacity (BPD)</th>
<th>Feed Stock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sasol (S. Africa)</td>
<td>44</td>
<td>160,000</td>
<td>coal</td>
</tr>
<tr>
<td>MossGas (S. Africa)</td>
<td>10</td>
<td>22,500</td>
<td>nat. gas</td>
</tr>
<tr>
<td>Shell (Malaysia)</td>
<td>7</td>
<td>15,000</td>
<td>nat. gas</td>
</tr>
</tbody>
</table>
FT Plants
U.S. Energy Security

US COAL BASINS

Source: GRI
Benefits to Domestic Production of Non-petroleum Fuels

- Provides Secure Supply
  - U.S. Military & Homeland Security
  - Transportation Market
  - Co-production of Electricity and Fuels

- Promotes Diversity of U.S. Energy Supply
  - Uses most plentiful domestic resources
  - Increases number of suppliers worldwide
  - Encourages monetization of worldwide non-petroleum resources

- Provides Stimulus for U. S. Economic Growth
  - New industry = new jobs
  - Offsets crude oil trade deficit ($200 billion/year)
  - Downward pressure on global energy pricing
Fischer-Tropsch (FT) Fuels
Fuels for the 21st Century

• Can use existing distribution infrastructure

• Cleaner Air – Healthier Lives
  – Exceed EPA 2006 regulations for ultra-low sulfur fuels
    • No sulfur
  – Cleaner burning
    • No aromatics, no sulfur
    • Lower engine exhaust emissions

• Less toxic
  – No aromatics, no heteroatoms
  – Biodegradeable
FT Fuels Being Evaluated

• FT diesel fuel evaluations in bus fleet demonstrations
  – Denali National Park
  – Washington DC WMATA

• Fuels produced at Synthroleum Tulsa Port of Catoosa Demonstration Plant
  – DoE is co-sponsor
    • Ultra-clean Transportation Fuels Program
    • National Energy Technology Laboratory (NETL)
  – Marathon is co-sponsor
  – ICRC Program Manager
DoD-DoE Joint Agency Program for FT Fuels

- FY03 program start
  - Continuing FY04, FY05
- FT jet fuel supplied by Syntroleum Corp. from Tulsa demonstration plant
- Define FT fuel formulations needed to allow use in all DoD equipment
- Coordination of military/commercial aviation communities through Coordinating Research Council (CRC)

Managed by:

[ UNITED STATES ARMY NAC ]
[ NATIONAL AUTOMOTIVE CENTER ]
Research Participants

- Air Force
  - Air Force Fuels Research Laboratory/NAFRC
  - University of Dayton Research Institute
- Army
  - TARDEC Fuels & Lubricants Laboratory
  - Southwest Research Institute
- Navy
  - NAVAIR Fuels and Lubricants Laboratory
  - Naval Fuels and Lubricants Integrated Product Team
- DoE
  - National Energy Technology Laboratory
- Syntroleum Corp.
FT Fuels Reduce Emissions

- Less Pollutant Emissions
  - 2.4% less CO₂
  - 50% to 90% less particulate matter (PM)
  - 100% reduction in SOₓ
  - ~1% less fuel burn (increased gravimetric energy density)

Hydrocarbon types in Syntroleum S-5
- Zero aromatics
- Zero sulfur
- No heteroatoms

Highly Paraffinic Fuel – normal and isoparaffins
Petroleum derived fuels are rich in aromatics, cycloparaffins, and heteroatoms
Even moderate fractions of FT fuel blended in JP-8 significantly reduce exhaust emission particulates in T63 turbine engine testing.

*Note: Results are highly dependent on engine model/year and composition of baseline fuel.
FT Fuel for the Military

Reduced Exhaust Emissions with FT Fuel Relative to Low-Sulfur Diesel Fuel

FT fuel burns more completely and emissions are significantly cleaner than EPA certified low-sulfur diesel fuel tested in 6.5L diesel engine.

Over 50% reduction in particulate emissions in transient mode.
FT Fuels Improve Aerospace Propulsion and Power Systems

- **FT iso-paraffinic kerosene (100%)**
  - low emissions, high stability
  - 2.2X – 9X increase in cooling
  - No sulfur, no aromatics
  - 1200 Btu/lb cooling
  - No poisoning, less coking of reformer catalyst
  - High thermal stability, high H/C
  - ISP=362.5

- **Hydrocarbon reformers**
  - (fuel cell power generation)

- **Hydrocarbon Rockets**
  - (RP-1 replacement)

- **Current and advanced gas turbine aircraft**
  - (Jet A/JP-8 replacement)

- **Hypersonic Vehicles**
  - (JP-7 replacement)
FT Fuels Benefit Air/Ground/Marine Propulsion and Power Systems

FT Fuels

Clean alternative to petroleum fuel (MADE IN USA)

E.O. 13149, EPAct

Easier starts, all climates

Reduced exhaust pollutants

Lower CO, PM, NOx

High cetane, >74

Diesel engine fleets

Fleets operating in non-attainment areas

Fuel Cell Applications (APUs in Vehicles)

Alternative Fuel Vehicles (AFVs)
(non-tactical fleets; Post, Camp & Station)

E.O. 13149, EPAct
FT Fuels Have Superior Thermal Stability

Relative Total Deposition – ECAT (6 Hrs)

Deposition, micrograms/cc

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Deposition, micrograms/cc</th>
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<tbody>
<tr>
<td>JP-8</td>
<td>350</td>
</tr>
<tr>
<td>JP-8+100</td>
<td>100</td>
</tr>
<tr>
<td>JP-7</td>
<td>50</td>
</tr>
<tr>
<td>Sasol 50/50</td>
<td>25</td>
</tr>
<tr>
<td>FT</td>
<td>10</td>
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</tbody>
</table>

Increased fuel thermal stability enables development of very fuel efficient propulsion systems
FT Fuels Have Excellent Low Temperature Properties

Scanning Brookfield Viscosity

Superior Low Temperature Properties Improve High Altitude Operations and Low Temperature Starting
FT Fuel Benefits for Navy Shipboard Use

Storage Stability Test Results (Syntroleum S-5)

<table>
<thead>
<tr>
<th></th>
<th>w/o AO</th>
<th>0 Hr</th>
<th>24Hrs</th>
<th>48Hrs</th>
<th>72Hrs</th>
<th>96Hrs</th>
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<tbody>
<tr>
<td>Saybolt Color</td>
<td>30</td>
<td>29</td>
<td>24</td>
<td>19</td>
<td>22</td>
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<tr>
<td>Peroxide, ppm</td>
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<td>&gt;240</td>
<td>&gt;240</td>
<td>&gt;240</td>
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<tr>
<td>Gums, mg/100ml</td>
<td>0</td>
<td>0</td>
<td>0.1</td>
<td>1</td>
<td>7.9</td>
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<tr>
<th></th>
<th>20 ppm AO</th>
<th>0 Hr</th>
<th>24Hrs</th>
<th>48Hrs</th>
<th>72Hrs</th>
<th>96Hrs</th>
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<td>Peroxide, ppm</td>
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<tr>
<td>Gums, mg/100ml</td>
<td>0.4</td>
<td>0.3</td>
<td>0.4</td>
<td>0.5</td>
<td>1.3</td>
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<tr>
<td>Antioxidant ppm</td>
<td>22.2</td>
<td>9.5</td>
<td>8.7</td>
<td>7.6</td>
<td>9.1</td>
<td></td>
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</table>

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<tr>
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<td>Peroxide, ppm</td>
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</tr>
<tr>
<td>Gums, mg/100ml</td>
<td>0.1</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.4</td>
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<tr>
<td>Antioxidant ppm</td>
<td>33.3</td>
<td>33</td>
<td>33.7</td>
<td>33</td>
<td>33.3</td>
<td></td>
</tr>
</tbody>
</table>

Compatibility Evaluation Test Results (2 FT fuels: F-T 1 and F-T 2)

Cu Migration Test Results

FT fuel responds well to standard antioxidant (AO) used for petroleum fuel.

Low copper uptake of FT fuel = good long-term storage stability.

- Excellent long-term storage stability
- Significant reduction in copper up-take
  - Increased thermal stability / Extended engine life
FT Fuels –
The Next Single Fuel for the Battlefield

• Clean Fuels
  – Reduced emissions
  – No aromatics

• Enables Fuel Efficient Designs
  – Increased thermal stability

• Excellent low-temperature properties allow for:
  – higher altitude operations
  – improves diesel engine cold-starting capability
Take Action—Make It Happen

**FT Plants in the U.S. converting our vast hydrocarbon resources into transportation fuels:**
- Enhances our energy security
- Promotes diversity of supply
- Stimulates U.S. economic growth
- Leads to Cleaner Air – Healthier Lives

**The U.S. Military is preparing to use FT fuels:**
- FT fuels offer advantages to the military
- DoD-DoE Joint Program is working to make possible – FT Fuel for the Military

**National Energy Security Post 9/11, June 2002**
(a study conducted by the United States Energy Association)

“More than 50% of the gasoline, aviation fuel, heating oil, diesel fuel and other petroleum products come from a dozen or more nations abroad. Some are friendly, some are not. The answer to increased energy security is diversifying our sources of supply . . .”