Single Battlefield Fuels (SBF) Made From Unconventional Resources

Material Issues – An Army Perspective

National Materials Advisory Board Meeting
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Plenary Session II – Materials for Power and Energy

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<th>Standard Form 298 (Rev. 8-98)</th>
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Kerosene-type fuels
- JP-8/F-34
  - MIL-DTL-83133
- JP-5/F-44
  - MIL-DTL-5624
- Jet A-1/F-35
  - ASTM D 1655 (U.S.)
  - Defence Standard 91-91 (most ROW)

Diesel fuels
- No. 2-D and No. 1-D
  - A-A-52557 (CID*)
    - ASTM D 975
- F-76 (mil-spec marine distillate fuel)

*Commercial Item Description
- Tactical/combat vehicle fleets
- CE & MHE
- Other Equipment
  - Fuel storage, distribution, handling
  - Power generation
  - Future
- Army aircraft and watercraft
Petroleum-derived fuels will be around for years, such as JP-8 (current SBF).

However, non-petroleum derived fuels will increasingly make their way into the fuels supply, typically as blends:
- Semi-synthetic jet fuel (partly FT IPK*) used at Johannesburg International Airport
- E-85 ethanol fuel, biodiesel fuel blends (B1 - B20)

Key reasons for blends (excluding energy policy drivers):
- Limited volumes of unconventional fuels
- May allow an otherwise unfit-for-use fuel to be used in existing equipment (or slightly-modified equipment)

* FT IPK is Iso-Paraffinic Kerosene – discussed in separate slide
Unconventional SBF on the Horizon

• Fischer-Tropsch (FT) derived

• BioJet
  – Synthesized from crop oils via thermal, and/or catalytic, and/or enzymatic processing [BioJet per DARPA BAA 06-43]
  – How compatible will this fuel be with existing equipment? Need samples for characterization of fuel – starting point to determining compatibility

• Other?
FISCHER-TROPSCH (FT) TECHNOLOGY

Coal + Biomass
Natural Gas
Coal
Pet Coke
Biomass Wastes

Synthesis Gas Production

FT Liquid Synthesis

Product Recovery

Power Generation

Tail Gas

Oxygen Plant

An Option

CO

H₂

Hydrogen Separation

Liquid Fuels

Wax

Hydrocracking

Wax

Hydrogen Recover

Liquid Fuels

Transportation Fuels

CO₂ to Sequestration

O₂

Air

Hydrogen
Fischer-Tropsch Derived Kerosene

• FT synthesis step – product variations possible based on FT reaction parameters (catalyst, temperature, pressure, etc.)
  – Product typically contains only paraffins, mostly normal paraffins; many paraffins of long chain lengths (“waxy”)
  – Possible to produce product containing other species such as aromatics, olefins

• Upgrading step
  – Hydrocracking breaks up long chains into kerosene boiling range compounds
  – Hydroisomerization rearranges chains from n-paraffins to isoparaffins yielding kerosene meeting JP-8 freeze point requirement

• FT kerosene compositions meeting JP-8 freeze point requirement
  – FT Iso-Paraffinic Kerosene (FT IPK) – containing no aromatics
  – Possible to also produce FT-derived kerosene that containing aromatics
Fuel Leaks Possible From Sudden Switch to Lower Aromatic Content Fuel

- Some elastomers affected by change in fuel solvency (esp. aromatics in fuel)
  - Swelling: absorption of aromatic solute
  - Shrinkage: purging of aromatic solute
- Affected elastomers include Nitrile, common in Military fuel distribution system sealing applications
- Low aromatic fuels becoming more prevalent
  - Ultra-low sulfur diesel fuel
  - FT fuels
- Introducing lower aromatic fuels into existing equipment may result in some fuel leaks
- Mitigate risk of leaks through use of
  - Unaffected elastomers
  - Fuel blends

![Graph showing volume changes with switches between Synthetic FT "JP-8" & JP-8](image)

Switch # | Average Volume Change (%) | Fuel Aromatic Content
--- | --- | ---
1 | FT "JP-8" | 0% vol.
2 | JP-8 | 18% vol.
3 | FT "JP-8" | 0% vol.
4 | JP-8 | 18% vol.
5 | FT "JP-8" | 0% vol.
6 | JP-8 | 18% vol.

Data courtesy TARDEC Lab

SAE Paper No. 2007-01-1453, April 2007
“The Effect of Switch-Loading Fuels on Fuel-Wetted Elastomers”
(by TARDEC and SwRI™ authors)
Hydrocarbon Types In FT IPK (Iso-Paraffinic Kerosene)

- n-alkanes (10%)
- Alkanes, branched (90%)
- Zero aromatics
- Zero sulfur
- No heteroatoms

FT IPK is paraffinic – contains mostly isoparaffins whereas Petroleum-derived fuels are rich in aromatics, cycloparaffins, and hetero-compounds

Some of these are polar compounds (N, O), typically trace amounts, responsible for much of a fuel’s inherent lubricity
Fuel Lubricity Critical for Performance of Fuel-Lubricated Rotary Injection Pumps

- Some vehicles have fuel-lubricated fuel pumps
  - HMMWV (high density vehicle in Army ground vehicle fleet)
  - Some others (smaller populations in Army fleet)

- Test rig testing
  - HMMWV pump with hardened components: FT IPK lubricity appears adequately improved with use of Military approved lubricity improver
  - Other fuel-lubricated pumps (testing in progress—one common to Army and Navy)

### HMMWV Rotary Injection Pump Test Results

<table>
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<tr>
<th>Test</th>
<th>Pump</th>
<th>Duration (hours)</th>
<th>Pre-test (mm)</th>
<th>Post-test (mm)</th>
<th>Change (mm)</th>
<th>Lubricity additive (CI/LI) treat level in FT IPK</th>
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<tr>
<td>1</td>
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<td>95.6</td>
<td>5.017</td>
<td>5.113</td>
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*= Roller-to-Roller Dimension Pump Assembly Specification is 5.017 cm ± 0.001 cm

**Treated fuel tests run 500 hrs with minimal wear – indicative of acceptable field performance**

**chipped roller shoe**

Excessive wear occurred with untreated fuel.

Data courtesy of SwRI™
Concluding Remarks

• Fueling-up with unconventional SBF
  – Early use most likely in blends with petroleum fuel
    • Use of blends minimizes/eliminates fitness-for-use issues
    • Early acceptance by users critical when introducing new fuel
  – Strategic fueling flexibility would be enhanced by establishing the capability for freely interchangeable use of current SBF (JP-8) and unconventional SBF (not as a blended fuel)

• Determining fitness-for-use in existing equipment
  – Current SBF specifications evolved from history of use with petroleum-based fuels; are not performance-based specifications
  – An unconventional fuel may have properties meeting the chemical / physical property requirements found in these specifications, but not be fit-for-use