Biodiesel Progress:
ASTM Specifications and 2nd Generation Biodiesel

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Detroit, Michigan
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Today’s Topics

- Biodiesel Industry Status in the US
- Summary of ASTM Biodiesel Efforts
- 2nd Generation Biodiesel
B100 Plants:
Production Locations

June 7, 2007

148 Plants
1.4 Billion Gal/yr
total capacity
9.4 MM Gal/yr
average size

Courtesy of the National Biodiesel Board
B100 Plants: Construction/Expansion

Plant Status, 6/7/2007
- Construction (96)
- Expansion (5)

1.9 Billion Gal/yr added capacity
18.7 MM Gal/yr average size

Courtesy of the National Biodiesel Board
Biodiesel Driving Forces

- Heightened awareness of the vulnerability of the US to our dependence on oil
- High prices for crude oil and its products
- Tax Incentives, both Federal and State
- Current Renewable Fuel Standard (RFS)
- A Variety of New Federal and State RFS’s
- Global Warming: Life Cycle CO2 reductions
- Ease of use in existing engines and stations
ASTM Summary for Biodiesel
Biodiesel Process

(Catalyst)

100 pounds + 10 pounds = 10 pounds + 100 pounds

Triglyceride    Alcohol    Glycerine    Mono-Alkyl Esters
(Soy Oil)       (Methanol) (Biodiesel)

- Raw Oil and Fats are NOT Biodiesel!
- Other ‘Renewable Products’ are NOT Biodiesel
- Must be long chain mono alkyl esters of fats and oils and meet ASTM D 6751
- This tight definition needed to secure OEM approvals and encourage testing
ASTM B100 spec based on existing specs for #1 and #2 petrodiesel in ASTM D 975

If #1 and #2 meet specs, blends are OK
  - No separate set of specs for blends of #1/#2

If B100 meets D 6751 and diesel meets D 975, up to 20% biodiesel may be used
  - Blends up to B20 are approved
  - No separate set of specs for the blend

This has worked well in the marketplace
<table>
<thead>
<tr>
<th>Property</th>
<th>Test Method</th>
<th>Limits</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium &amp; Magnesium</td>
<td>EN 14538</td>
<td>5 max</td>
<td>ppm (ug/g)</td>
</tr>
<tr>
<td>Alcohol control</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>either Flash Point D 93</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>or GC methanol</td>
<td>EN 14110</td>
<td></td>
<td></td>
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<tr>
<td>Flash Point</td>
<td>D 93</td>
<td>130 min.</td>
<td>Degrees C</td>
</tr>
<tr>
<td>Kin. Viscosity, 40C</td>
<td>D 445</td>
<td>0.2</td>
<td>% Volume</td>
</tr>
<tr>
<td>Sulfated Ash</td>
<td>D 874</td>
<td>93 min.</td>
<td>Degrees C</td>
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<tr>
<td>Sulfur</td>
<td>D 5453</td>
<td>1.9 - 6.0</td>
<td>mm²/sec.</td>
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<tr>
<td></td>
<td>D 5453</td>
<td>0.02 max.</td>
<td>% mass</td>
</tr>
<tr>
<td>Copper Corrosion</td>
<td>D 130</td>
<td>0.05 max (500)</td>
<td>% mass (ppm)</td>
</tr>
<tr>
<td>Cetane number</td>
<td>D 613</td>
<td>0.0015 max (15)</td>
<td>% mass (ppm)</td>
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<tr>
<td>Cloud Point</td>
<td>D 2500</td>
<td>No. 3 max.</td>
<td>degrees C</td>
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<tr>
<td>Carbon Residue</td>
<td>D 4530</td>
<td>47 min.</td>
<td>% mass</td>
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<tr>
<td>Acid Number</td>
<td>D 664</td>
<td>0.05 max.</td>
<td>mg KOH/g</td>
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<tr>
<td>Free Glycerin</td>
<td>D 6854</td>
<td>0.50 max.</td>
<td>% mass</td>
</tr>
<tr>
<td>Total Glycerin</td>
<td>D 6854</td>
<td>0.020</td>
<td>% mass</td>
</tr>
<tr>
<td></td>
<td>D 6854</td>
<td>0.240</td>
<td>% mass</td>
</tr>
<tr>
<td>Phosphorous content</td>
<td>D 4951</td>
<td>0.001 max</td>
<td>degrees C</td>
</tr>
<tr>
<td>Distillation, T90 AET</td>
<td>D 1160</td>
<td>360 max</td>
<td>ppm (ug/g)</td>
</tr>
<tr>
<td>Na/K, combined</td>
<td>EN 14538</td>
<td>5 max</td>
<td>hours</td>
</tr>
<tr>
<td>Oxidation Stability</td>
<td>EN 14112</td>
<td>3 min</td>
<td></td>
</tr>
<tr>
<td>(Visual Appearance)</td>
<td>D 4176</td>
<td></td>
<td></td>
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</tbody>
</table>

BOLD = BQ-9000  Critical Specification Testing Once Production Process Under Control
Some users, regulators and OEM’s wanted blended fuel specs for biodiesel blends
  - What do you measure if the parent fuel quality is not known? Bid specs, enforcement easier

Blended fuel specifications are being set so blends will always be in-spec if two good parent fuels are used

The key is getting B100 that meets D 6751

Buying from BQ-9000 companies provides added assurance B100 will meet D 6751
- ASTM D 6751 is the approved standard for B100 to be used for blending up to B20 in the US
  - ASTM has approved D6751 for B100 use only for up to B20 in the final blend
  - Higher blends upon consultation with the OEM
- B5 being balloted into the petrodiesel specifications: D 975, D 396 (heating oil)
  - No changes to D975, D 396
  - B100 must meet D 6751 prior to blending
- B6 to B20 for on/off road diesel engines will be a stand alone specification
  - Widest of #1/#2 specifications, T-90 5 C increase
  - Addition of stability and acid number for final blend
Changes to D 6751 so that no change is needed for B5 in D 975, D 396
- Completed: lower acid number; add stability parameter, add Ca/Mg, Na/K

Precipitate above the cloud point issue identified in the market in 2005:
- Most due to out of specification biodiesel
- Small portion could be caused by minor components not controlled in the spec

ASTM is in process of adding a specification to D 6751 that will address this issue in D 6751

Once addressed, blended fuel ballots can move forward for approval
New ‘Blended and Alternative Fuels’ category for D 975 and D 396

All non-petroleum fuels would fall into this category, which would identify:
- ASTM spec for the blend component
- Maximum allowable concentration
- Test method for measuring the component

No parameters added and none changed compared to current D 975 or D 396
Category was needed to address deficiencies in blend stocks not covered by D 975 or D 396
- i.e. 5% raw vegetable oil could be blended into D 975 and meet properties of D 975 but could have severe problems not prevented by existing D 975 parameters
- Biodiesel is covered through meeting D 6751 prior to blending

Issue: Where do mostly hydrocarbon fuels like FT and hydrotreated oils/fats fall?
- Are they already ‘covered’ by existing D 975 or D 396?
- Do they need an ASTM spec prior to blending?
- Are there minor components in these fuels that can cause problems which are not covered by D 975 or D 396?

Task Force set up by ASTM to address these questions
- Larger issue than just biodiesel, FT, hydrotreated oils/fats
- Avoid one bad apple spoiling it for all renewables
2nd Generation Biodiesel
Biodiesel originally developed as a niche, high value added product

Early 1990’s, Soybean Farmer Research:
- Excess soy oil was drain on soybean prices
- If biodiesel could reach 30 million gallons per year, it could raise soybean prices 5 to 9 cents per bushel

Raw oils cause problems, efforts focused on low cost processing (i.e. methyl esters) and setting specifications for existing oils/fats
- No optimization of for oil yields or oil profile
- Volumes insufficient to drive new, better fats/oils
148 plants, over 1.4 billion gal/yr capacity
Over 100 more plants on the horizon
Potential annual capacity over 3 billion gpy
President’s ‘20 in 10’ would like to see more
Existing and planned capacity, combined with government signals for the future, are sufficient to consider optimizing crops and their make-up for biodiesel
Biodiesel from traditional oilseed crops, fats, and waste oils can be significant
- Entire US soybean crop could supply ~6% of 60 billion gallon diesel market

But a ‘2nd Generation’ biodiesel is needed to help meet the Presidents ‘20 in 10’ goals
- Optimistic scenarios up to 25% of diesel fuel
- This would require 15 billion gallons of biodiesel

The oils/fats industry needs to begin to immediately focus on growing more oils/fats

Source: Bob McCormick, National Renewable Energy Laboratory
“2nd Generation Biodiesel”

- A new biodiesel industry initiative that is just at the beginning stages
- Optimize existing ‘traditional’ crops for higher oil content and modified fatty acid profile to improve stability and cold flow
- Investigate non-traditional crops for higher oil output and improved fatty acid profile
- Look at novel crops or other sources for oils/fats, i.e. biodiesel’s ‘cellulosic ethanol’
## Crop Oil Yield

### Gallons/acre

<table>
<thead>
<tr>
<th>Crop</th>
<th>Oil Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>18</td>
</tr>
<tr>
<td>Cotton</td>
<td>35</td>
</tr>
<tr>
<td>Soybean</td>
<td>48</td>
</tr>
<tr>
<td>Mustard seed</td>
<td>61</td>
</tr>
<tr>
<td>Sunflower</td>
<td>102</td>
</tr>
<tr>
<td>Rapeseed/Canola</td>
<td>127</td>
</tr>
<tr>
<td>Jatropha</td>
<td>202</td>
</tr>
<tr>
<td>Oil palm</td>
<td>635</td>
</tr>
<tr>
<td>Algae</td>
<td>“10,000”</td>
</tr>
</tbody>
</table>

Source: NREL; Wikipedia.org
Micro-Algae for Biodiesel

- Existing crops will continue to be used and need to increase oil production and improve FA profile.
- New crops like algae will be investigated and have much promise for the future:
  - Much greater per-acre productivity possible with algae
  - Non-food resource
  - Use otherwise non-productive land
  - Can utilize saline water
  - Can utilize waste CO₂ streams
- Micro-algae could be biodiesel’s version of cellulosic ethanol
Biodiesel presents a way forward to meet performance, environmental, economic, and energy security needs.

Oilseeds contain both food (i.e. soy meal) and fuel (biodiesel from soy oil).
- Food vs. fuel is not a major factor for biodiesel.

Legumes (soybeans) are nitrogen fixing and no-till planting practices can be used.
- Minimizes environmental issues of farming.
- Use agricultural land in production for years.
The Ideal Path Forward

- Independent USDA/DOE life cycle study shows biodiesel from soybeans has:
  - Fossil energy balance of 3.2 to 1
  - Life cycle CO2 reduction of 78%

- 10% oxygen in biodiesel (B100) has benefits that pure hydrocarbons don’t:
  - Imparts lubricity at low concentrations
  - Biodegradable, non-toxic
  - Significant Particulate Matter (PM) reductions
  - Reduced temperatures needed for PM trap regeneration due to character of biodiesel soot
The Ideal Path Forward

- Optimize the fatty acid profile
  - Plant selection, breeding, genetics
- Totally saturated is not desirable
  - Cold flow issues but good stability and cetane
- Totally un-saturated is not desirable
  - Stability issues but good cold flow and cetane
- Optimize for mono-unsaturated
  - Excellent stability, cetane and cold flow
  - Also desirable for edible applications
The Ideal Path Forward

- Methyl ester process has low capital, operating and energy costs compared to other processes
  - Glycerine by-product further displaces crude oil products

- Medium size, decentralized plants are possible, compared to huge petroleum refineries
  - Adds new refining capacity, higher number of plants
  - High paying manufacturing JOBS
  - In rural parts of the country that are hurting
  - More companies involved, reduces monopolies

- More plants helps to insure energy security by minimizing impact if one plant becomes inactive
  - Natural disaster (hurricanes on the gulf, flooding, etc.)
  - Man made disaster (terrorist attack or bombing)
  - ‘Normal’ accidents or shut downs
Educational Resources

- BEN: Biodiesel Education Network
- Web-based resource specifically for petroleum marketers
- Partnership between NBB/PMAA
- www.pmaa.org
- www.biodiesel.org
Other Biodiesel Resources

- Biodiesel Magazine
  - A MUST HAVE’ magazine

- Biodiesel Industry Directory On-Line
NBB Resources

- www.biodiesel.org
- Technical Library
- Biodiesel Bulletin
- Educational Videos Available
- Informational Resources
- Technical Resources
- On-line Database & Spec Sheets