What are Water - Emulsified Fuels?

- Adding water to diesel dates back to the early 1900’s. There are hundreds of patents issued on water-diesel blends.
- Emulsified diesels are defined as emulsions of water in diesel.
- Typically made of 10-20% mass/mass water mixed with specific additives.
How do emulsified diesels work? And with what results?

- Water in diesel yields the following effects:
  - Water vaporization increases fuel dispersion in the form of smaller droplets.
  - Contact surface between fuel and air is increased.
  - Combustion is more efficient.

- Net results:
  - Reduces combustion temperature peaks (lowers NOx).
  - Particulate formation is reduced (lowers PM).
What are the benefits?

- Lower emissions:
  - Up to 25% NOx reduction.
  - Up to 60% PM reduction.
  - Up to 80% smoke reduction.
  - Up to 5% CO₂ reduction.

- Better lubricity.

- Increased thermal efficiency.

*Emulsified diesel is only emission-control fuel technology that simultaneously lowers both PM and NOx.*
Qualification of emissions reduction advantages.

• The magnitude of the emissions reductions advantage from emulsified diesels is a function of:
  • Engine type,
  • Operating conditions,
  • Properties of the baseline diesel fuel, and
  • Properties of the diesel fuel that is blended into the emulsion.
### European vs. EPA NOx and PM requirements for HD Diesel engines

<table>
<thead>
<tr>
<th></th>
<th>European Standards (g/bhp-hr)</th>
<th>EPA Standards (g/bhp-hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOx</td>
<td>5.22</td>
<td>3.73</td>
</tr>
<tr>
<td>PM</td>
<td>0.11</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Test Cycle ECE R-49.
2. Test Cycle ESC, ELR.
3. For regular engines.
4. For urban buses.
5. NOx + HC at 2.5 g/bhp-hr; HC contribution can not exceed 0.5 g/bhp-hr.
European emulsified fuel applications

- **On-Road**
  - Public fleets.
  - Mass transit fleets.
  - Private fleets.
  - Garbage collection fleets.

- **Off-Road**
  - Marine engines.
  - Locomotives.
  - Power generation.
  - Construction equipment.

- **Other**
  - Large institutional combined heat sites (apartment complexes, hospitals, universities, etc).
  - Industrial boilers.
There are four (4) companies who commercially sell emulsified diesels in Europe.

<table>
<thead>
<tr>
<th>Company Name</th>
<th>Distribution Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Cam Tecnologie*</td>
<td>With own fuel</td>
</tr>
<tr>
<td>2. Clean Fuels Technology</td>
<td>Additives Package + System</td>
</tr>
<tr>
<td>3. Lubrizol*</td>
<td>Additives Package + System</td>
</tr>
<tr>
<td>4. TOTAL*</td>
<td>With own fuel</td>
</tr>
</tbody>
</table>

* Members of the European Emulsified Fuel Manufacturers’ Association (EEFMA)
EEFMA* Objectives

- Promote the market image of emulsion fuels in Europe.
- Identify and seek to remove market barriers.
- Define and maintain high standards within the industry.

* European Emulsified Fuel Manufacturers’ Association (EEFMA)
EEFMA’s Goals

EEFMA’s market barrier removal goals are:

- Unified European standard for emulsified diesels,
- Favorable and unique fiscal treatment across the European Community.
# Emulsified diesel technology providers

<table>
<thead>
<tr>
<th>Company</th>
<th>Based in</th>
<th>Countries where sold</th>
<th>In-Field Experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAM Tecnologie</td>
<td>Pero (MI), Italy</td>
<td>France, Italy, Switzerland</td>
<td>5 yrs</td>
</tr>
<tr>
<td>Clean Fuels Technology</td>
<td>Reno, NV, USA</td>
<td>Italy</td>
<td>10 yrs</td>
</tr>
<tr>
<td>Lubrizol</td>
<td>Wickliffe, OH, USA</td>
<td>Italy, UK</td>
<td>3 yrs</td>
</tr>
<tr>
<td>TOTAL</td>
<td>Paris, France</td>
<td>France, Italy</td>
<td>8 yrs</td>
</tr>
</tbody>
</table>
# Products overview

<table>
<thead>
<tr>
<th>Company</th>
<th>Product Name</th>
<th>Distributor/s</th>
<th>OEM Warrantee*</th>
<th>Water Content</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Clean Fuels Technology</strong></td>
<td>Aquadisel</td>
<td>IPLOM S.p.A.</td>
<td></td>
<td>13%</td>
</tr>
<tr>
<td><strong>Lubrizol</strong></td>
<td>PuriNOx™, Qwhite, Aspira</td>
<td>BP, Q8, Blanco Petroli, Green Oils, Kuwait Petroleum Italia</td>
<td>Mack, Caterpillar, Man</td>
<td>10-20%</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>Aquazole™</td>
<td>Own network</td>
<td>Irisbus, Iveco, Scania, Renault VI</td>
<td>14-17%</td>
</tr>
</tbody>
</table>

* On Engine and/or Vehicles; not exhaustive.
Equipment related market barriers*:

- Limited acceptance by engine manufacturers.
- Limited acceptance by equipment manufacturers.
- Limited acceptance due to lack of a European standard.
- Limited fleet acceptance.

* as reported by EEFMA.
Fiscal regimes in seven (7) European countries.

<table>
<thead>
<tr>
<th>Favorable</th>
<th>Neutral</th>
<th>Unfavorable</th>
</tr>
</thead>
<tbody>
<tr>
<td>France*</td>
<td>UK</td>
<td>Germany</td>
</tr>
<tr>
<td>Italy*</td>
<td>Switzerland</td>
<td>Spain</td>
</tr>
<tr>
<td></td>
<td>Netherlands</td>
<td></td>
</tr>
<tr>
<td>Special fiscal classification</td>
<td>No tax on water content</td>
<td>Taxed as diesel fuel</td>
</tr>
</tbody>
</table>

*National Standard established
The Italian model

- Tax incentive* - 36%
- Bus and Coach market size ~ 34,200
- Running on emulsified diesels ~ 8,100
- Bus and Coach market share ~ 24%

* Italian taxes on diesel fuel are ~ 5.7 x U.S. taxes
### Mass Transit use: Emulsified diesels in Europe vs. Natural Gas in U.S.

<table>
<thead>
<tr>
<th></th>
<th>Part of Europe: (France, Italy, UK, Switzerland)</th>
<th>U.S.A.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of Mass Transit Buses</strong></td>
<td>~9,900 on Emulsified Diesel</td>
<td>~ 7,300 on Natural Gas (~6,200 on CNG; ~1,000 on LNG)*</td>
</tr>
<tr>
<td><strong>Total Population</strong></td>
<td>~ 180 M</td>
<td>~ 290 M</td>
</tr>
</tbody>
</table>

* Source: American Public Transportation Association
Observations on Mass Transit use: Emulsified diesels in Europe vs. Natural Gas in the U.S.

- There are ~ 36% more buses (9,900 vs. 7,300) on emulsified diesels in four European countries than in the entire U.S. on both CNG and LNG.
- Conversion of mass transit fleets in Europe to emulsified diesels was conducted at lower cost than equivalent U.S. conversion to CNG and LNG.
Remaining emulsified diesel challenges

- Shelf life (stability).
- Power loss.
- Torque loss.
- Compliance with new engine technologies (Common rail, EGR).
- Extension to individual vehicle use (intermittent miscibility with regular diesel).
Europe vs. US comparison

- Diesel use is more prevalent in Europe.
- Fuel costs are higher in Europe (due mainly to much higher taxes).
- Impending EEC-wide tax incentive/s for use of emulsified diesel.
- $\text{CO}_2$ is a European primary air quality concern.
- There is nothing like EEFMA in the U.S.
Pertinent trends

- Much $ will continue to be spent on R&D to:
  - Satisfy engine manufacturers requirements for warrantee coverage.
  - Address Common Rail and/or EGR challenges.
  - Develop intermittent miscibility with diesel capability for use by non-fleet vehicles.
  - Sustained growth due to increased competition in Europe and to synergies between European, US and Asian markets*.
  - Harmonization of European and North American Standards.

*3 out of 4 entities are active in both Europe and North America.
Q & A
THANK YOU