Bi-fuel Technology

By: Daniel Barbersek
Power Solutions Manager
Generac Power Systems, Inc.
What is Bi-fuel?

- Simultaneous combustion of two fuels
  - Diesel & natural gas
  - Compression ignition engine
  - Diesel is the igniter (pilot fuel)
  - Up to 90% of the energy can be generated from the natural gas

- Most applications the engine can run 100% diesel
- Engine cannot run on 100% natural gas
- Not dual fuel or Bio-fuel
How Long Has Bi-fuel Been Around?

- Concept is as old as the diesel engine
- Implementation back in 1940’s
  - Engines specially built for bi-fuel operation
  - Used for the municipal prime power
  - Low speed engine technology
  - Lacked integrated control technology
- High capital cost
Bi-fuel Technologies

- Low Pressure Injection
  - Port level injection - 50 psi
  - Standardized on 6 – 10% pilot fuel
  - Intake valve cam or rocker arm or poppet valve
  - Low RPM prime mover applications
  - Engines specially built for bi-fuel operation
Bi-fuel Technologies

- High Pressure Injection
  - Cylinder level injection – 3000 psi
  - Could achieve pilot fuel levels of only 1%
  - Pre-chamber diesel injection combustion
  - High energy chemical spark plug
Bi-fuel Technologies

- Combustion Air gas Integration
  - Gas injected pre-turbo 2 – 5 psi
  - Pilot levels of 10 – 25%
  - Can run 100% on diesel fuel
  - More common approach for the stand-by power market segment
  - More commonly referred to as fumigation
Implementation of Fumigation

- Engine is started on Diesel
  - Runs on diesel until loaded

- Gas is mixed into air intake
  - Pre-turbo
  - Turbo helps mix gas & air
  - Designed for pipe line gas
  - Gas pressure as low as 2 psi
  - Internal pressure regulator generally included
  - Control system controls gas flow (dynamic gas ramping)
Fumigation Technology

Natural Gas
Supply 3-5 PSI

Pressure Regulator
Adjusted To
30 Inches H2O
Output

Flow Meter

Butterfly Valve

Inlet Air

Turbo Charger

Charge Air Cooler

Coolant Sensor

Temp. Sensor

Knock Sensors

Radiator

Engine A/F Control
(Mapping)

Bi-Fuel Control
Board

Generator
Controller

Generator
Governor

Load Meters

Crank

Shaft

Position Sensor

Cylinders

Governor / Frequency
Control

KW

KW

KW
### Fuel Usage

#### Diesel vs Gas

<table>
<thead>
<tr>
<th>kW</th>
<th>Gal/Hr Diesel w/Nat Gas</th>
<th>Gal/Hr Straight Diesel</th>
<th>% Nat Gas</th>
<th>Cu.Ft./hr. Nat Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>8</td>
<td>8.9</td>
<td>10%</td>
<td>125</td>
</tr>
<tr>
<td>200</td>
<td>8.5</td>
<td>17.0</td>
<td>50%</td>
<td>1187</td>
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<tr>
<td>300</td>
<td>7.5</td>
<td>24.8</td>
<td>70%</td>
<td>2431</td>
</tr>
<tr>
<td>400</td>
<td>8.5</td>
<td>31.4</td>
<td>73%</td>
<td>3206</td>
</tr>
<tr>
<td>500</td>
<td>9.7</td>
<td>37.2</td>
<td>74%</td>
<td>3843</td>
</tr>
<tr>
<td>600</td>
<td>11</td>
<td>43.3</td>
<td>74%</td>
<td>4480</td>
</tr>
</tbody>
</table>
Run Times

Diesel vs. Bi-Fuel™ Run Times
(600 kW genset at 75% load)

<table>
<thead>
<tr>
<th>Diesel Tank Capacity</th>
<th>Diesel-Only Run Time</th>
<th>Bi-Fuel™ Run Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>20” tall / 469 gallons</td>
<td>10 hours</td>
<td>33 hours (1.3 days)</td>
</tr>
<tr>
<td>30” tall / 936 gallons</td>
<td>20 hours</td>
<td>66 hours (2.7 days)</td>
</tr>
<tr>
<td>40” tall / 1349 gallons</td>
<td>29 hours</td>
<td>94 hours (3.9 days)</td>
</tr>
</tbody>
</table>

Diesel Fuel Gallons

Run Hours

Diesel Fuel Requirement

Diesel Fuel Requirement Using Bi-Fuel
Advantages - Compared to spark ignited engines

- Lower capital cost
- Higher power density
- More efficient (function of compression ratio)
- No spark plug maintenance
- Diesel benefits
  - Transient response of a diesel
  - Seamless transition to full diesel operation
    - NFPA 110
    - NFPA 20, Fire Pumps requires NFPA 110, Level 1
**Advantages – Compared to diesel Engines**

- **Gas benefits**
  - Extended operation without re-fueling (for extended outages)
  - Potential for less on-site diesel fuel storage
  - Lower fuel cost

- **Lower Emissions**
  - NO$_x$ & PM
  - CO does increase during bi-fuel operation
  - Oxidizing catalyst should be installed

- **Enhanced engine life**
  - Softer Ignition, lower peak cylinder pressures
  - Cleaner oil
  - Longer maintenance cycles (oil cleanliness)
Primary Target Applications

- Extended run time applications
  - Hurricane areas
  - Areas with a history of extended outages
  - Customer preference for 48+ hour run times

- Minimizes on-site fuel requirements
  - Indoor applications (660 gallons)
  - Diesel maintenance

- Environmentally more responsible