Higher efficiency, lower NOx emissions, & new fuel options with lean-burn technology

> White paper

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Power Generation

Global warming has turned our world's attention to the **'how'** of power generation. Preferences have moved away from traditional sources like coal to new technology that is more efficient and environmentally friendly. The change is driving a trend of investing in infrastructure and replacing old power plants with natural gas-fired generators to reduce GHG emissions.

Cummins Power Generation has responded by building units with "lean-burn" technology. It is considered lean combustion because excess air is introduced into the engine along with the fuel. The technology produces two positive outcomes:

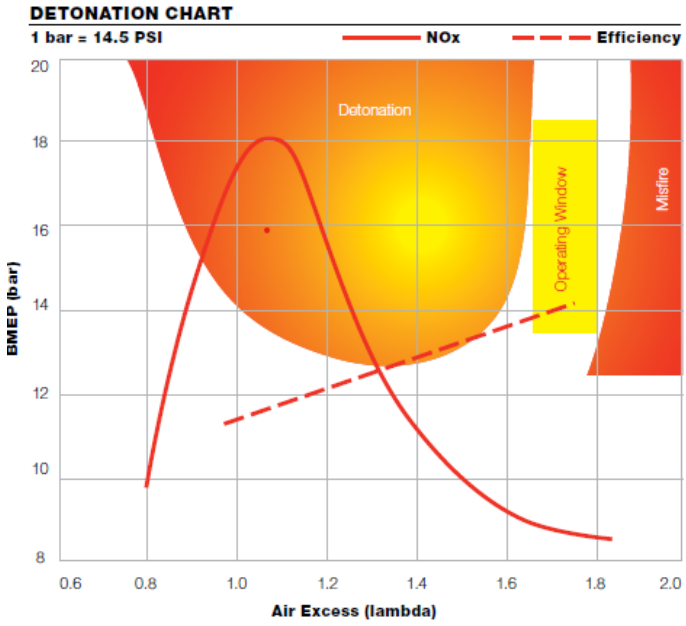
1. **Lower Combustion Temperature** - The excess air reduces the temperature of the combustion process. It reduces the amount of nitrogen (NOx) produced by nearly half, compared to a conventional natural gas engine.
2. **Higher Efficiency** - The excess oxygen available makes the combustion process more efficient. A higher amount of power is produced from the same amount of fuel.

The Combustion Process

For an energy source to initiate combustion air and fuel are needed to create a reaction. In natural gas engines, the spark plug performs this function. In lean-burn engines, the combustion process is enhanced by pre-mixing the air and fuel upstream of the turbocharger before it enters the cylinder. This creates a more homogenous mixture in the combustion chamber and reduces the occurrence of "knocking" or detonation.

Knocking or misfiring can be prevented by monitoring the narrow operating window between air temperatures and volume, and the air to fuel ratio. The microprocessor-based engine controller regulates the fuel flow, and air/gas mixture, and ignition timing.

New lean-burn engines from Cummins are designed to operate at a lean air/gas ratio of Lambda = 1.7. (Traditional stoichiometric natural gas engines have an air/gas ratio of Lambda = 1.0). The Denotation Chart (right) plots Break Mean Effective Pressure (BMEP) against Air Excess (Lambda).



The operating window is a very narrow band where efficiency peaks and NOx are near its minimum. A richer mixture (stoichiometric) can potentially produce knocking and higher NOx emissions; a leaner mixture than Lambda 1.7 may not combust reliably and cause misfiring, which raises HC emissions.

Full-authority electronic engines, sensors and micro-processors in the new lean-burn engines are critical for maintaining combustion within these boundaries.

Lean-burn Creates The Right Mixture

The design of the lean-burn engine incorporates a simple open combustion chamber housed in the piston crown. The shape of the piston crown introduces turbulence in the incoming air/fuel mixture that promotes more complete combustion by thoroughly exposing it to the advancing flame front. The is regular (flat) and the spark plug is centrally located. The air and gas fuel are correctly mixed under the control of the engine management system.

Emissions Are Reduced

One of the results of this technology is significantly reduced emissions in the exhaust. Cummins' new lean-burn gas engine generators have NOx emissions as low as .85 grams/BHP-hr., and produce low amounts of hydrocarbons (HC), carbon monoxide (CO) and particulate matter (PM). This allows the generator sets to meet the most stringent air quality regulations without after-treatment devices in the exhaust stream.

For even lower emissions, lean-burn gas engine generator sets are frequently coupled with integrated after-treatment options such as Selective Catalytic Reduction (SCR) and Oxidation Catalysts, resulting in NOx levels at or below 0.15 grams/BHP-hr. With these after-treatment options, the gas engine generators have been shown to meet the most stringent prime power emissions regulations anywhere in the world.

Landfill Gas Becomes a Fuel Option

Another advantage of the lean-burn technology with full-authority electronic engine controls is the ability to operate on gas with a wide range of quality. A measurement called the Methane Number (MN) is used to determine fuel gas suitability as an engine fuel. Most natural gas has an MN from 70 to 97, and pipeline quality gas typically has an MN of about 75.

Resource recovery gas from landfills or sewage treatment facilities is typically of lower quality but is often suitable for use in lean-burn engines. Cummins' lean-burn gas engine generators will operate on gas with an MN of 50 or greater, providing excellent fuel flexibility. However, gas with a MN below 70 may require derating of the generator output.

Lean-burn gas engine generator sets are setting a new standard for fuel efficiency, high power output for their size, and for low emissions. In regions with supplies of natural gas, these generator sets are providing highly reliable electric power for utility peaking, distributed generation, prime power and for combined heat and power systems.

For additional technical support, please contact your local Cummins Power Generation distributor. They can be found at www.cumminspower.com.