

Lean-burn engine technology increases efficiency, reduces NOx emissions

> White paper

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Internal combustion engine-powered generator sets fueled by natural gas are commanding more attention these days as interest grows in on-site power production equipment that is both efficient and environmentally friendly.

In response to this interest, manufacturers have introduced natural gas engine-powered generator sets that feature “lean-burn” technology. The combustion is considered “lean” when excess air is introduced into the engine along with the fuel.

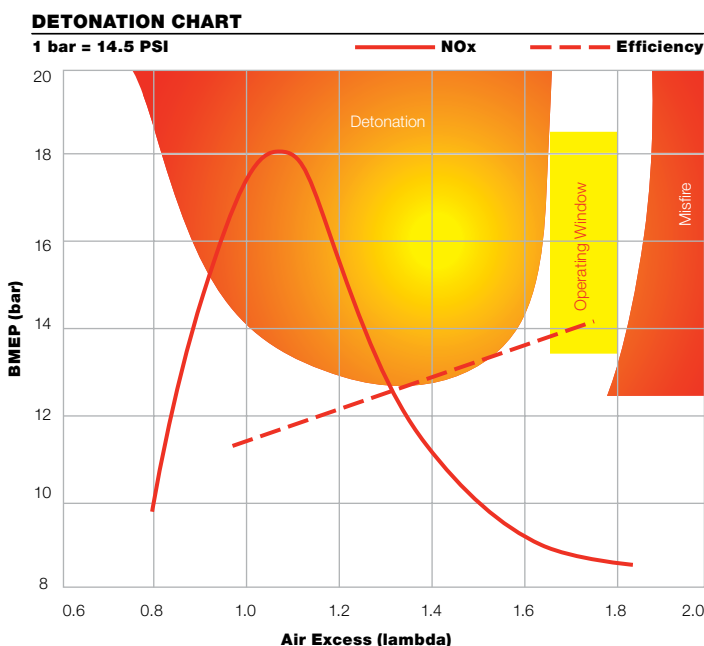
This produces two positive effects. First, the excess air reduces the temperature of the combustion process and this reduces the amount of oxides of

nitrogen (NOx) produced by nearly half, compared to a conventional natural gas engine. Second, since there is also excess oxygen available, the combustion process is more efficient and more power is produced from the same amount of fuel.

Combustion process

Any air/fuel reaction requires an energy source to initiate combustion. 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 introduction into the cylinder. This creates a more homogenous mixture in the combustion chamber and reduces the occurrence of “knocking” or detonation. To prevent either knocking or misfiring, the combustion process must be controlled within a narrow operating window. Charge air temperatures and volume, together with air to fuel ratio, are constantly monitored. 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 $\text{Lambda} = 1.7$. (Traditional stoichiometric natural gas engines have an air/gas ratio of $\text{Lambda} = 1.0$). In the chart (at left) that plots Break Mean Effective Pressure (BMEP) against Air Excess (Lambda), the operating window is a very narrow band where efficiency peaks and NOx is near its minimum. A richer mixture (stoichiometric) can potentially produce knocking and higher NOx emissions; a leaner mixture than $\text{Lambda} 1.7$ may not combust reliably and cause misfiring, which raises HC emissions. Full-authority electronic engines, sensors and microprocessors in the new lean-burn engines are critical for maintaining combustion within these boundaries.



About the author



Keith Packham is Gas Applications Manager for Cummins Power Generation, and provides expert technical advice and support to the global Energy Solutions Business team on the design, installation and operation of gas fuelled energy plants. He has been involved with

the design, installation, maintenance, and operational aspects of combined heat and power (CHP) plants, boiler plants for steam or hot water, power generation and distribution, refrigeration, water and effluent treatment plants and their optimum performance. He holds a Bachelor's degree in Energy Engineering from Southbank University in England.

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 flame plate of the cylinder head 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.

Reduced emissions

One of the results of this technology is significantly reduced emissions in the exhaust. Cummins' new lean-burn gas engine generators have NO_x 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.

One of the results of this technology is significantly reduced emissions in the exhaust.

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 NO_x 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.

Fuel flexibility

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.

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