



# Technical Support Note

Title: Emissions from CNG-Fueled Equipment

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23 CNG Exhaust Emission Levels.docx

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## **Guidelines for Exhaust Gas Analysis of CNG Fueled Equipment**

### **Overview:**

CNG (Compressed Natural Gas - Methane) fueled equipment is a very hydrogen-rich fuel, and has been recognized as a preferred fuel for indoor-operated equipment. The typically achievable exhaust gas emission levels of various gases is still relatively unknown, however – to the detriment of both users of the equipment and those chartered with equipment maintenance and repair.

The purpose of this document is to provide some general guidelines regarding the expected gas concentrations in the exhaust of CNG fueled vehicles – and other general information that may be helpful to keep this equipment in proper tune and operation.

### **Non-CAT Converter Equipped Vehicles:**

This class of equipment has historically been built as gasoline fueled equipment, and then ‘converted’ to CNG by means of a pressure regulator and gas mixer, and they operate in ‘open loop’ control – which means they are highly subject to tuning variables such as mixture control, ignition timing, and spark plug condition, etc. The levels of emissions of this class of equipment is totally a function of how well the equipment is maintained and tuned.

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## Open-Loop Emissions Levels:

Gas	Idle (~650 RPM @ 17" Hg)		Medium Power (~1800 RPM @ 10" Hg)		Tilt Relief (~2500 RPM @ 5" Hg)	
	Typical Range:	Ideal Target	Typical Range:	Ideal Target	Typical Range:	Ideal Target
<b>CO:</b>	0.20% to 0.50%	0.10% - 0.30%	0.30% to 0.80%	0.30%	0.50% to 1.25%	0.50%
<b>HC: (C-1)</b>	0.030% to 0.060%	0.020% - 0.040%	0.040% to 0.080%	0.040%	0.060% to 0.100%	0.050%
<b>CO<sub>2</sub>:</b>	10.3% to 11.2%	11.2%	10.1% to 11.1%	11.1%	9.8% to 11.0%	11.0%
<b>O<sub>2</sub>:</b>	0.5% to 1.5%	<0.5%	0.5% to 1.0%	<0.5%	0.5% to 1.0%	<0.5%
<b>NO<sub>x</sub>:</b>	500 to 1000 ppm	500 ppm	1500 to 2500 ppm	1500 ppm	2000 to 3000 ppm	2000 ppm
<b>Lambda:</b>	0.950 to 1.050	1.000	0.950 to 1.050	0.950	0.900 to 1.000	0.950
<b>AFR:</b>	16.7 to 18.4	17.5	16.7 to 18.4	16.7	15.8 to 17.5	16.7
<b>CE:</b>	92.00% to 97.00%	97.0%	94.00% to 98.00%	98.0%	94.00% to 98.00%	98.0%

## CAT Converter Equipped Vehicles:

This class of equipment has not only been built specifically for operation on CNG, but has a catalytic converter installed and the associated computer controlled engine management systems built in. This class of equipment has a lambda sensor in the exhaust stream, which is used for 'closed loop' mixture control.

In essence, the levels of emissions of this class of equipment is less a function of tuning and more a function of maintenance – as the on-board computer maintains equipment tune by means of a variety of sensors, including a lambda sensor for mixture control. While there is less adjustment capability on this class of equipment, the control system sensors have to be verified and maintained in good operating condition in order to assure proper operation and CAT function. The CAT converters on this class of vehicles require

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very close mixture control, and poor CE can quickly degrade the CAT as well by causing over temperature conditions in the CAT.

## Closed-Loop Emissions Levels (Post CAT):

Gas	Idle (~650 RPM @17" Hg)		Medium Power (~1800 RPM @10" Hg)		Tilt Relief (~2500 RPM @5" Hg)	
	Typical Range:	Ideal Target	Typical Range:	Ideal Target	Typical Range:	Ideal Target
<b>CO:</b>	0.00% to 0.20%	0.05%	0.00% to 0.25%	0.05%	0.00% to 0.50%	0.05%
<b>HC: (C-1)</b>	0.000% to 0.030%	0.005%	0.000% to 0.050%	0.010%	0.000% to 0.080%	0.020%
<b>CO2:</b>	10.5% to 11.2%	11.2%	10.5% to 11.2%	11.2%	10.5% to 11.2%	11.2%
<b>O2:</b>	0.0% to 0.5%	<0.2%	0.0% to 0.7%	<0.2%	0.0% to 1.0%	<0.3%
<b>NOx:</b>	25 to 100 ppm	25 ppm	35 to 150 ppm	35 ppm	50 to 250 ppm	50 ppm
<b>Lambda:</b>	0.980 to 1.002	1.000	0.980 to 1.002	1.000	0.980 to 1.002	1.000
<b>AFR:</b>	17.2 to 17.5	17.5	17.2 to 17.5	17.5	17.2 to 17.5	17.5
<b>CE:</b>	99.00% to 99.95%	99.95%	99.00% to 99.95%	99.95%	99.00% to 99.95%	99.95%

As can be seen from the above table, the emissions levels of this class of equipment are much lower due to the oxidation and reduction capabilities of the CAT, and the engine management system control. Engine out gases (pre-CAT) are higher than the ranges above for CO, HC, and NO, but are generally lower and closer to the target values than the open-loop systems - and the gases are held to tight Lambda control with the closed-loop system to enable the CAT to function properly. The CAT reduces CO, HC, and NO engine-out gases by 80% to 90% - providing Lambda of the engine-out exhaust gas is controlled within 0.980 to 1.002 by the closed-loop system.

### NOTE – Errors in using a Gasoline-fuel analyzer on CNG fueled equipment:

Exhaust gas analyzers intended to measure the exhaust gas from gasoline fueled equipment have been commonly used to measure the exhaust of alternative fueled

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equipment. While the readings for CO, CO<sub>2</sub>, O<sub>2</sub> and NO<sub>x</sub> will be accurate, the readings for HC will be very small – about 1/20<sup>th</sup> the true value for methane. This is because analyzers for gasoline fueled equipment report HC (unburned fuel vapor) as **hexane** – the closest pure gas to the gasoline hydrocarbon mix. Hexane is C<sub>6</sub>H<sub>14</sub>, so it is much larger than Methane, which is CH<sub>4</sub> – and takes only a little Hexane much to produce the same response as Methane in the gas analyzer.

The HC value displayed when using a gasoline fuel gas analyzer is about 1/20th the true value of propane in the exhaust. The other gas readings for CO, CO<sub>2</sub>, O<sub>2</sub>, and NO<sub>x</sub> will remain accurate in conventional gas analyzers– as they are not effected by this issue – but higher level values (AFR, Lambda, CE) will be incorrect.

Bridge Gas Analyzers have fuel selection built in – so they can be set to measure Methane properly – and calculate Lambda, AFR, and Combustion Efficiency correctly to the specific fuel used.

The values for HC, Lambda, A/F Ratio, and CE given above are for an analyzer with the fuel properly selected – not for less flexible gas analyzers. They are accurate for Bridge Analyzers, Inc products set to measure the fuel as CNG (C-1).

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