Technical Support Note

Title: Quebec Forklift Emissions Program
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Guidelines for Annual Tailpipe Testing of LPG Fueled Equipment.

Overview:

The Canadian OSHA equivalent in certain Provinces of Canada require annual tailpipe inspection of exhaust gas – using a protocol developed in Quebec in conjunction with the L'Institut de recherche Robert-Sauvé Health and Safety (IRSST). This protocol requires the use of a 4 or 5 gas analyzer, and is a practical implementation of a working standard for tailpipe testing.

Specified Emissions Levels:

	Idle (~650 RPM @ 17" Hg)	**High RPM (~1800 RPM @ 10" Hg)**
Gas	**Specification:**	**Specification:**
CO:	**0.10%** to 0.80%	**0.50%** to 0.80%
O2:	0.80% to 2.00%	0.80% to 2.00%
HC:	Less than 200 ppm (Hexane) Less than 400 ppm (Propane)	Less than 200 ppm (Hexane) Less than 400 ppm (Propane)
CO2:	Equal or Greater than 11.0%	Equal or Greater than 11.0%

Note: Oxygen readings above 2.00% indicate air dilution of the exhaust gas sample due to improper probe insertion, sampling system vacuum leak, etc., which will cause the CO, HC, and CO2 readings to be incorrectly reduced.

Inadvertent air dilution will also be indicated by a low CO2 reading – which is the reason the 'Equal or Greater than 11.0% CO2" is specified.

See Bridge TSN # 37 for more details on the correction of high exhaust gas readings in Bridge EGA analyzers.

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CAT Converter Equipped Vehicles:

This class of equipment has been built specifically to EPA specifications for operation on LPG, and has a closed-loop computer controlled propane injection system with a catalytic converter for exhaust gas after treatment.

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 very close mixture control, and poor combustion efficiency (CE) can quickly degrade the CAT by causing over temperature conditions in the CAT.

Closed-Loop Emissions Levels (Post CAT):

	Idle (~650 RPM @17" Hg)		**Medium Power (~1800 RPM @10" Hg)**		**Tilt Relief (~2500 RPM @5" Hg)**	
Gas	**Typical Range:**	**Ideal Target**	**Typical Range:**	**Ideal Target**	**Typical Range:**	**Ideal Target**
CO:	0.00% to 0.25%	0.05%	0.00% to 0.25%	0.05%	0.00% to 0.50%	0.05%
HC:	0 to 100 ppm (Propane)	25 ppm	0 to 150 ppm (Propane)	35 ppm	0 to 150 ppm (Propane)	40 ppm
CO2:	12.0% to 13.0%	13.0%	12.0% to 13.0%	13.0%	12.0% to 13.0%	13.0%
O2:	0.2% to 0.8%	0.2%	0.2% to 0.8%	0.2%	0.2% to 0.8%	0.2%
NOx:	25 to 100 ppm	25 ppm	35 to 150 ppm	35 ppm	50 to 250 ppm	50 ppm
Lambda:	0.980 to 1.002	1.000	0.980 to 1.002	1.000	0.980 to 1.002	1.000
AFR:	15.6 to 16.1	15.9	15.6 to 16.1	15.9	15.6 to 16.1	15.9
CE:	99.00% to 99.95%	99.95%	99.00% to 99.95%	99.95%	99.00% to 99.95%	99.95%

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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 an Automotive (Gasoline-Fuel) analyzer on LPG fueled equipment:

Conventional exhaust gas analyzers intended to measure the exhaust gas from gasoline fueled equipment have been commonly used to measure the exhaust of propane fueled equipment. While the readings for CO, CO2, O2 and NOx will be accurate, the readings for HC will be ½ the true value for propane. 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 C6H14, so it is about twice as large as the C3H8 propane molecule – and takes only half as much to produce the same response in the gas analyzer.

The HC value displayed when using a gasoline fuel gas analyzer is ½ the true value of propane in the exhaust.

The values for HC, Lambda, A/F Ratio, and CE given above are for an analyzer with propane properly selected as the fuel being used. Because of the chemical difference between the fuels, the values of AFR, Lambda, and CE will also be somewhat off if these are reported on a gasoline-fuel gas analyzer if it is used to evaluate propane fueled equipment.

Errors in using a CO Only gas analyzer on LPG fueled equipment:

CO only gas analyzers cannot ‘see’ air dilution of exhaust gas – and as exhaust from an internal combustion engine is pulsating in nature, there can be significant air pulled in between power strokes, and this will cause the CO readings to appear to be much lower than they actually are. We have typically seen air dilution of 25% to 50% - which means the CO readings displayed on single gas analyzers can commonly be ½ of their correct value in undiluted exhaust. Only gas analyzers with air dilution correction capability should be used to assess the CO level in tailpipe exhaust.

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