



Technical Support Note

Title: Tailpipe Testing of Emissions Control Retrofit Kits

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Overview:

Beginning in 2009, the California Air Resource Board (CARB) is requiring fleet operators in California to maintain minimum emission standards. The regulation may require a portion of their fleet to be retrofitted to have a state-certified retrofit emission control systems (See <http://www.arb.ca.gov/msprog/offroad/orspark/orspark.htm> for more information.) Retrofitters and fleet operators are often interested in establishing a method to verify the operating state of forklifts prior to and after retrofitting.

This Technical Support Note establishes a method to verify operation of the retrofitted emission control system by means of tailpipe emissions testing using a Bridge 2-Gas, 4-Gas, or 5-Gas exhaust gas analyzer.

The method provides a non-invasive and simple verification that the tailpipe emissions are being correctly reduced by the retrofit kits by comparing the retrofitted tailpipe exhaust gas readings to those found in uncontrolled forklift tailpipe exhaust.

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Forklift Tailpipe Exhaust Gas Levels Before and After Retrofitting:

Measured Gas	Idle (~650 RPM @ 17" Hg)		Medium Power (~1800 RPM @ 10" Hg)		Tilt Relief (~2500 RPM @ 5" Hg)	
	Before Retrofit:	After Retrofit:	Before Retrofit:	After Retrofit:	Before Retrofit:	After Retrofit:
CO:	0.20% to 1.50%	0.00% to 0.20%	0.50% to 1.50%	0.00% to 0.20%	1.00% to 2.50%	0.00% to 0.40%
HC: (Propane)	100 to 200 ppm	0 to 80 ppm	150 to 250 ppm	0 to 100 ppm	200 to 300 ppm	0 to 150 ppm
CO2:	11.5% to 12.5%	12.0% to 13.0%	11.0% to 12.0%	12.0% to 13.0%	10.5% to 11.5%	12.0% to 13.0%
O2:	1.0% to 3.5%	0.2% to 0.8%	0.5% to 2.5%	0.2% to 0.8%	0.5% to 2.0%	0.2% to 0.8%
NOx:	500 to 1000 ppm	25 to 100 ppm	1500 to 2500 ppm	35 to 150 ppm	2000 to 3000 ppm	50 to 250 ppm
Lambda:	0.920 to 1.080	0.980 to 1.002	0.920 to 1.080	0.980 to 1.002	0.900 to 1.000	0.980 to 1.002
AFR:	15.1 to 16.7	15.6 to 16.1	15.1 to 16.7	15.6 to 16.1	14.3 to 15.9	15.6 to 16.1
CE:	92.00% to 97.00%	99.00% to 99.95%	94.00% to 98.00%	99.00% to 99.95%	94.00% to 98.00%	99.00% to 99.95%

900323 2-Gas EGA (Yellow Cells)

900403 4-Gas EGA (Yellow and Blue Cells)

900503 5-Gas EGA (Can use the Yellow, Blue, and Green Cells)

As can be seen from the above table, the emissions levels for CO and HC (unoxidized gases) are significantly lower after retrofit, and can be measured at the tailpipe using a **Model 900323** 2-Gas analyzer. This method will assess the oxidation enhancement of the retrofit emission system compared to a non-retrofitted system – providing an overall assessment of both fuel control system as well as the catalytic converter function.

NOTE: The Model 900323 is a basic 2-gas analyzer which assumes that the exhaust gas is not air-diluted – which can cause a large variability in readings. To avoid this, consider using a Model 900403 instead, as it can detect and correct air dilution of the

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exhaust gas, resulting in more consistent and accurate readings in the field. For more details on the comparison of the two analyzers, see Bridge TSN# 29.

The **Model 900403** has the additional benefit of measuring CO₂ and O₂. Because of this it can detect air dilution as well as directly calculating Lambda, AFR, and Combustion Efficiency from tailpipe gases. Lambda and AFR can be used to determine the effectiveness of the closed-loop fuel control system separately from the catalytic converter, while Combustion efficiency can be used to validate the catalytic converter function. As these are the primary control parameters used by the retrofit emission control system to reduce emissions, they confirm that the closed loop fuel control system is operating properly, and the catalytic converter is working correctly in the oxidation mode.

The **Model 900503** has the addition of NO_x measurement, which enables the measurement of the NO_x gas reduced by the 3-way catalytic converter. This analyzer allows assessment of the primary closed-loop fuel control parameters (Lambda, AFR and Combustion Efficiency), the effectiveness of the catalytic oxidation of CO and HC, and the effectiveness of the catalytic reduction of NO_x.

As can be seen above, the degree of evaluation of retrofitted emission control systems is a function of the analyzer used, but even the most basic evaluation using the Model 900323 2-Gas analyzer can provide valuable indications of the effectiveness of retrofit emission control systems.

Note:

These guidelines should provide general verification of system performance and are not intended to represent equipment specifications. Retrofit emission control systems which yield tailpipe gas values indicating a malfunction should be further diagnosed using the manufacturer recommended diagnostic and repair procedures.

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