White Paper

Title: Alternative Fuels – Measuring HC and Calculating Lambda and A/F Ratio on Gas Analyzers that normally measure Gasoline Fueled Vehicles
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Bridge gas analyzers prior to 'Series 3' versions (Serial numbers with a '1' or '2' at the 'X' location: 900NNXNNNN) assume the HC being used as fuel is gasoline. Real gasoline is a mix or long and short chain hydrocarbons, and the details of mix vary by 'Octane Rating' (Regular, Medium, of High Octane), geographic location, and season. The Bridge Series 1 and 2 Exhaust Gas Analyzers (Models 9003, 9004, and 9005) follow the industry standard of measuring gasoline vapor (HC) as "equivalent Hexane (C6H14)" in ppm, as opposed to attempting to deconstruct the actual mix of hydrocarbons that exist as gasoline vapor. This is in conformance with previous practice specified by BAR, OIML, and all other legislative bodies.

This practice leads to measurement errors when alternative fuels (primarily Propane (LPG) or Methane (CNG) are used as fuels, and then emissions measured. While the level of CO and CO2 are correct, the 'true' ppm of the alternative fuel (HC) is necessarily going to be different than that displayed – and Lambda and A/F ratio calculations are also effected.

HC errors when alternative fuels are used, but HC is measured by the analyzer as equivalent Gasoline (Hexane):

When alternative fuels (LPG or CNG) are used, and the analyzer is still setup to measure Gasoline (as equivalent Hexane) the HC value displayed does not represent the true HC ppm of the fuel being used. While the HC value will be considerably off, for small displayed values (200 ppm equivalent Hexane or less) a scaling factor may be used to convert the displayed HC (Hexane) into the correct ppm for alternative fuels, as shown in the table below.

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Multiplying Factors for HC:

Multiplying Factor	**Gasoline (Hexane - Default Display)**	LPG (Propane	CNG (Methane)
HC	**1.00**	2.00	20.0

The correct use for the table above using real displayed values is as follows:

Parameter	**Displayed Value Gasoline (Hexane)**	Corrected Value LPG (Propane	Corrected Value CNG (Methane)
HC	**50**	100	1000

Lambda and A/F Ratio factors as a function of Fuel:

Various fuels have differing factors used to calculate Lambda and A/F Ratio. The Lambda calculation factors as defined above vary by the gasoline blend, (and are actually different from season to season), and are significantly different for LPG and CNG as shown below.

Fuel Parameters – their values and effect on Lambda and A/F Ratio Calculation:

Fuel Factor	Non-Oxygenated Gasoline (Hexane)	American (BAR) Oxygenated Gasoline (Hexane)	European (OIML) Oxygenated Gasoline (Hexane)	Propane (LPG)	Methane (CNG)
Hcv	1.800	1.9800	1.7621	2.667	4.000
Ocv	0.000	0.0170	0.0176	0.000	0.000
Cfactor	6.000	6.000	6.000	3.000	1.000
A/F Nom	14.71	14.71	14.71	15.87	17.45

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The Bridge Analyzers use the American (BAR) Gasoline factors above, calculate Lambda using the Brettschneider equation, and report it in the Lambda display mode. When A/F Ratio display mode is selected, the lambda value calculated by this method is multiplied by 14.71 and the result is displayed. What is interesting is that the Lambda value calculated by the Brettschneider method is still accurate for alternative fuels within 1% - so it may be used regardless of the fuel. However, as the Stoichiometric A/F ratio varies by the fuel, the A/F Nom value appropriate for each fuel must be multiplied by Lambda in order to be accurate. Multiplying the displayed value of A/F Ratio (Gasoline = 14.71) by the factors below will yield the correct A/F ratio:

Multiplying Factors for HC, Lambda and A/F Ratio:

Multiplying Factor	**Gasoline (Hexane - Default Display)**	LPG (Propane	CNG (Methane)
Lambda	**1.00**	1.00	0.99
A/F Ratio	**1.00**	1.08	1.18

The correct use for the table above using real displayed values is as follows:

Parameter	**Displayed Value Gasoline (Hexane)**	Corrected Value LPG (Propane	Corrected Value CNG (Methane)
Lambda	**1.02**	1.02	1.01
A/F Ratio	**15.0**	16.2	17.7

The use of these conversion tables allows the Series 1 and 2 analyzers to be applied to alternative fuels with relative ease.

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