# Organic Gas Speciation Profiles for Buses Running on Compressed Natural Gas (CNG)—OG2401 & OG2402

Wenli Yang, PhD; Paul Allen

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## 1. Introduction

Two organic gas speciation profiles for compressed natural gas (CNG) buses running exhaust emissions (OG2401 and OG2402) were developed in this work to complement the current CARB organic gas speciation database. The profiles were created based on test data of a 40-passager New Flyer bus running on CNG during Steady-State (SS) cruise cycle and Central Business District (CBD) cycle. Profile OG2401 was made for SS cycle and OG2402 was for CBD cycle. The test bus was equipped with a 2000 Detroit Diesel (DDC) Series 50G engine without any after-treatment system. This engine is a diesel engine converted to run on CNG; and it is not a high compression engine one expects for a diesel as it is spark-ignited. The emissions of regulated (hydrocarbons) and non-regulated (gas-phase toxic hydrocarbons, carbonyl compounds, polycyclic aromatic hydrocarbons) pollutants were measured in the source tests [1-3].

## 2. Methodology

The emission factors for light-end hydrocarbons, selected toxic hydrocarbons, and carbonyls are obtained from Ayala et al. [3]. However, the emission factors of PAHs are only reported in Kado et al. [2], in which carbonyls and selected toxic hydrocarbons were also measured. Since the same bus was tested under similar conditions in these two studies and the test results of the common species (i.e., carbonyls and selected toxic hydrocarbons) are comparable between the two sets of test data, the emissions of volatile PAHs obtained from Kado et al. [2] are used along with emissions of other species from Ayala et al. [3] to generate the speciation profiles for the CNG buses.

## 3. Results

The details of the speciation profiles are provided in Table 1. The ratios of TOG/THC (total organic gas/total hydrocarbon) are 1.105 for OG2401 and 1.097 for OG2402. The ratio can be used to convert THC emission mass to actual weight TOG. The ROG/TOG ratios are 0.1604 and 0.1471 for OG2401 and OG2402, respectively.

The profiles show that methane dominates the TOG emissions from both CBD and SS cycle. It is over 82% of TOG in both profiles. Formaldehyde is the second abundant species in the profiles and it is about 10% of the TOG.

**Table 1. OG Speciation profiles for CNG buses**

| *Species Name* | *SAROAD* | *Weight Percentage, %* | |
|---|---|---|---|
| | | *OG2401 CNG Bus Steady-State Cruise* | *OG2402 CNG Bus CBD Cycle* |
| (1a,2a,3b)-1,2,3-trimethylcyclopentane | 91038 | 0.007916 | 0.025709 |
| 1,3-butadiene | 43218 | 0.002843 | 0.004214 |
| 1-butene | 43213 | 0.021888 | 0.020099 |
| 1-methylnaphthalene | 91124 | 0.000007 | 0.000270 |
| 1-pentane | 43220 | 0.003695 | 0.007996 |
| 1-pentene | 43224 | 0.004548 | |
| 2,6-dimethylnaphthalene | 98185 | 0.000003 | 0.000151 |
| 2-methylbutane | 98132 | 0.015350 | 0.022476 |
| 2-methylnaphthalene | 91123 | 0.000011 | 0.000432 |
| 2-methylpropene | 43215 | 0.005685 | 0.008645 |
| acenaphthene | 97002 | 0.000001 | 0.000040 |
| acenaphthylene | 97001 | 0.000003 | 0.000130 |
| acetaldehyde | 43503 | 0.361012 | 0.547860 |
| acetone | 43551 | | 0.059541 |
| acrolein | 43505 | 0.048893 | 0.042251 |
| benzaldehyde | 45501 | | 0.017938 |
| benzene | 45201 | 0.041786 | 0.024205 |
| biphenyl | 99317 | | 0.000100 |
| butyraldehyde | 43510 | 0.003127 | 0.017938 |
| crotonaldehyde | 98156 | 0.019046 | |
| ethane | 43202 | 1.810744 | 2.344883 |
| ethylbenzene | 45203 | 0.005685 | 0.001513 |
| ethylene | 43203 | 4.519753 | 3.695621 |
| ethyne | 43206 | 0.187612 | 0.179378 |
| formaldehyde | 43502 | 10.148125 | 9.293083 |
| m&p-xylenes | 99024 | 0.008812 | 0.013724 |
| methane | 43201 | 82.151491 | 82.881330 |
| methyl ethyl ketone | 43552 | 0.012223 | |
| methylpropane | 43214 | 0.015350 | 0.044845 |
| naphthalene | 98046 | 0.000010 | 0.000335 |
| n-butane | 43212 | 0.018761 | 0.045169 |
| o-xylene | 45204 | 0.003695 | 0.001081 |
| propane | 43204 | 0.185054 | 0.337144 |
| propionaldehyde | 43504 | 0.009096 | 0.039117 |
| propylene | 43205 | 0.358169 | 0.314452 |
| styrene | 45220 | 0.002558 | |
| toluene | 45202 | 0.034964 | 0.012427 |
| valeraldehyde | 98200 | | 0.021612 |
| | | *100.000000* | *100.000000* |

**References:**

1. Ayala, A.; Kado, N. Y.; Okamoto, R. A.; Holmén, B. A.; Kuzmicky, P. A.; Kobayashi, R.; Stiglitz, K. E., Diesel and CNG Heavy-duty Transit Bus Emissions over Multiple Driving Schedules: Regulated Pollutants and Project Overview. *SAE Trans. J. Lubr. Fuels* **2002**, 735-747.
2. Kado, N. Y.; Okamoto, R. A.; Kuzmicky, P. A.; Kobayashi, R.; Ayala, A.; Gebel, M. E.; Rieger, P. L.; Maddox, C.; Zafonte, L., Emissions of Toxic Pollutants from Compressed Natural Gas and Low Sulfur Diesel-Fueled Heavy-Duty Transit Buses Tested over Multiple Driving Cycles. *Environmental Science and Technology* **2005,** *39*, (19), 7638-7649.
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