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Conversion Factors for Hydrocarbon Emission Components

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Assessment and Standards Division
Office of Transportation and Air Quality
U.S. Environmental Protection Agency

NOTICE

This technical report does not necessarily represent final EPA decisions or positions. It is intended to present technical analysis of issues using data that are currently available. The purpose in the release of such reports is to facilitate the exchange of technical information and to inform the public of technical developments which may form the basis for a final EPA decision, position, or regulatory action.

Purpose

The purpose of this memorandum is to document the conversion factors for reporting hydrocarbon emissions in different forms. The general forms are total hydrocarbons (THC), total organic gas (TOG), nonmethane hydrocarbons (NMHC), nonmethane organic gas (NMOG), and volatile organic compounds (VOC), all defined in the introduction below. For reporting hydrocarbon emissions from nonroad equipment, it is helpful to provide an accepted means to estimate the hydrocarbons in the different forms. This is not a substitute for full speciation of hydrocarbon emissions.

Introduction

Hydrocarbon emissions can be reported in a variety of styles depending on the end use of the emission estimates and the measurement technique used in the underlying data. Not all emissions are measured for all engines, so a conversion from the most common measurement type to others is needed to supply an estimate in terms required by the user.

Most hydrocarbon emissions data from mobile sources is measured as total hydrocarbon (THC). THC is the measured hydrocarbon emissions using a Flame Ionization Detector (FID) calibrated with propane. The FID is assumed to respond to all hydrocarbons identically as it responds to propane in determining the concentration of carbon atoms in a gas sample. Most hydrocarbons respond nearly identically as propane with notable exceptions being oxygenated hydrocarbons such as alcohols and aldehydes commonly found in engine exhaust.

Because alcohols and especially aldehydes are chemically reactive and therefore ozone-forming hydrocarbons, the California Air Resources Board defined a measurement that adds the THC and the oxygenated components into a new measurement called total organic gas (TOG). [1] The oxygenated components are measured by collecting aldehydes on dinitro-phenylhydrazine impregnated filter traps and alcohols in chilled water impingers. The aldehydes and alcohols are extracted and measured using chromatography to determine emission rates. Each mole of aldehydes and alcohols is added by weight as formaldehyde and methanol.

Methane is an organic gas that is orders of magnitude less reactive than other hydrocarbons, so it is often excluded from emission estimations. The methane is measured by chromatographically separating the methane from the THC and analyzing the concentrations using a FID calibrated specifically for methane. The methane emissions are subtracted from the THC and TOG emission estimations to produce a nonmethane hydrocarbon (NMHC) and a nonmethane organic gas (NMOG) emission estimate. Some newer instruments can measure the NMHC directly however leading to lower uncertainty.

Some hydrocarbons are less ozone-forming than other hydrocarbons, so EPA has officially excluded them from the definition of regulated hydrocarbons called volatile organic compounds (VOC). This definition excludes methane, ethane, acetone, and compounds not commonly found in large quantities in engine exhaust like chlorohydrocarbons from consideration as VOC. For this work, the definition of VOC is the result of subtracting methane and ethane from the TOG emission estimates. Although acetone is not subtracted, it is present in smaller quantities compared to methane and ethane, and will have a negligible effect on the results.

Conversion Factors

Exhaust Emissions

Because all studies to date have measured THC, all other hydrocarbon types will be given as a proportion of THC. The ratios given in the table below were derived from those studies that measured methane, ethane, and aldehydes. Alcohols are only found if the fuel contains alcohols, so they would have been considered if data were available.

The hydrocarbon speciation data from nonroad engines is sparse. The 2-stroke engine conversions are derived from the study of only one moped engine while the 4-stroke engine results are an averaged result of 11 lawnmower engines studied. The diesel results are the average of two late 70s and early 80s vintage on-highway truck engines. The factors for compressed natural gas (CNG) and liquid petroleum gas (LPG) engines were estimated from data collected using on-highway light-duty vehicles equipped with catalysts. Nonroad equipment does not use this technology but no emissions data from nonroad CNG and LPG engines was available.

Table for Conversion Factors for Hydrocarbon Exhaust Emission Results

Engine Type	TOG/THC	NMOG/THC	NMHC/THC	VOC/THC
2-Stroke Gasoline [2]	1.044	1.035	0.991	1.034
4-Stroke Gasoline [2, 3]	1.043	0.943	0.900	0.933
Diesel [4]	1.070	1.054	0.984	1.053
LPG [5]	1.099	1.019	0.920	0.995
CNG [5]	1.002	0.049	0.048	0.004

Crankcase and Evaporative Emissions

For non-tailpipe emissions (i.e., crankcase and evaporative emissions) with fuels other than compressed natural gas, we will assume:

THC = VOC = NMHC = TOG = NMOG

Hence, all ratios will be 1.000.

For engines using natural gas fuels (CNG), we will assume that the relationship of the non-tailpipe HC emissions (i.e., crankcase and evaporative emissions) will be:

THC = TOG
and
VOC = NMHC = NMOG = 0

Hence, the ratio of TOG to THC will be 1.000 while the other ratios will be 0.0.

Conclusions

The conversion factor is applied at the end of the model calculation of total hydrocarbons, known as THC. Emission factors are generated most typically as THC, so the conversion to other hydrocarbon forms is provided for the user.

Newer data are becoming available and should be used to eventually augment and verify the data currently used in this report. Changes in engine technology needed to meet nonroad engine regulations that might affect the speciation profiles should also be considered, given available data. Acetone should also be explicitly excluded as a VOC when the newer data are analyzed.

References

[1] Air Resources Board (1996), “California Non-methane Organic Gas Test Procedure,” California Environmental Protection Agency, Last Amended June 24, 1996.

[2] Hare C.T. and White, J.J. (1991), “Toward the Environmentally-Friendly Small Engine, Lubricant, and Emission Measurement Issues”, SAE-911222.

[3] Gabele, P., (1997), “Exhaust emissions from four-stroke lawn mower engines,” Journal of the Air & Waste Management Association, pp 642-649, vol.47, Sept., 1997.

[4] Springer, Karl J. (1979), “Characterization of Sulfates, Odor, Smoke, POM and Particulates from Light and Heavy-Duty Engines -- Part IX,” Ann Arbor, Michigan: U.S. Environmental Protection Agency, Office of Mobile Sources. Publication no. EPA-460/3-79-007.

[5] ARB, (1991), “Proposed Reactivity Adjustment Factors for Transitional Low-Emission Vehicles,” Technical Support Document, Sept., 27, 1991.