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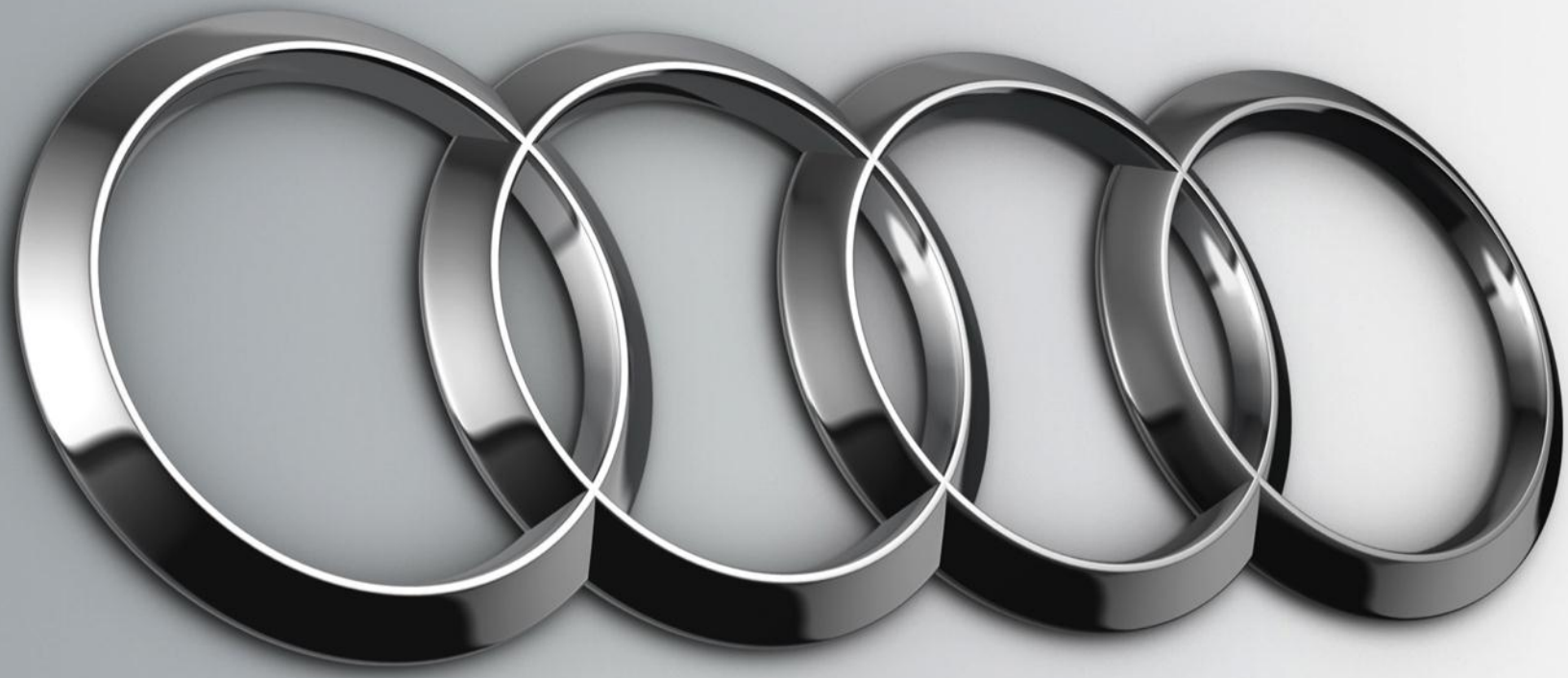

Additional Pollutants: Estimation of oxygenated hydro-carbon (OHC) emissions by using scaling factors between OHC and NMHC for ethanol-blended fuels up to E25

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OHC emissions in GTR

- **Reference Measurement Techniques in GTR**
  - Carbonyls: DNPH cartridge or DNPH solution and HPLC-UV
  - Alcohols: Impingers and GC-FID

- **Disadvantages**
  - No convenient (stand-alone) test cell analyser
  - Results delayed for several days
  - Chemical laboratory required
  - High costs for analysis
  - Error-prone
  - Results close/below detection limit for fuels with no/little ethanol content

OHC: Oxygenated Hydrocarbon
DNPH: Di-Nitro Phenyl Hydrazine
HPLC-UV: High Performance Liquid Chromatography with Ultraviolet Detector
GC-FID: Gas Chromatography with Flame Ionisation Detector

OHC emissions in U.S. legislation (1)

- **E0 fuel**

  In the U.S. vehicle emission regulation oxygenated hydrocarbons (OHC) have been regulated for a long time. Therein, OHC are limited to ethanol, formaldehyde and acetaldehyde. These 3 compounds have to be determined and reported as sum value together with NMHC. This sum value is called NMOG (“Non-Methane Organic Gases”). Since the OHCs are generally small compared with NMHC for gasoline-fueled vehicles, **EPA has previously allowed manufacturers to estimate the emissions** of NMOG as an alternative to conducting measurements for every emissions certification test when E0 fuel is used. This approach resulted in application of a multiplier of 1.04 to the NMHC mass emissions meaning that the sum of ethanol, formaldehyde and acetaldehyde is estimated to be 4% of NMHC.

OHC emissions in U.S. legislation (2)

- **E0 – E25 fuel**

  In current U.S. legislation EPA allows to estimate NMOG for fuels up to E25:

  40 CFR §1066.635 NMOG determination.

  (c) For ethanol-gasoline blends with less than 25 % ethanol by volume, you may calculate NMOG from measured NMHC emissions as follows:

  (1) For hot-start and hot-running test cycles or intervals other than the FTP, you may determine NMOG based on the NMHC emission rate using the following equation:

$$NMOG_{EST} = NMHC_{MEAS} \times 1.03$$

  (2) You may determine weighted composite NMOG for FTP testing based on the weighted composite NMHC emission rate and the volume percent of ethanol in the fuel using the following equation:

$$NMOG_{EST} = (1.0302 + \%\text{-Ethanol} \times 0.0071) \times NMHC_{MEAS}$$

%-Ethanol: Volume percentage of Ethanol in fuel
$NMOG_{EST}$: Non-Methane Organic Gases_estimated
$NMHC_{Meas}$: Non-Methane Hydrocarbons_measured

Scaling factors for various fuels

- **Conversion of linear equation from „NMOG“ to „OHC“**

$$OHC_{EST} = (0.0302 + 0.0071 \times \%\text{-Ethanol}) \times NMHC_{MEAS}$$

- **Examples**

0.0302	when	**E0**	→ OHC: **3.0%** of $NMHC_{MEAS}$
0.0657	when	**E5**	→ OHC: **6.6%** of $NMHC_{MEAS}$
0.1012	when	**E10**	→ OHC: **10.1%** of $NMHC_{MEAS}$
0.1864	when	**E22**	→ OHC: **18.6%** of $NMHC_{MEAS}$

OHC: Formaldehyde + Acetaldehyde + Ethanol

OHC_{EST}: Oxygenated Hydrocarbons_estimated

Harmonization with U.S. & Application to WLTP

- **Proposal for GTR - WLTP testing**

Permission of estimation approach based on scaling factors between OHC and NMHC as alternative to conducting measurements of ethanol, formaldehyde and acetaldehyde for ethanol-blended fuels up to E25.

Underlying equation:

$$OHC_{EST} = (0.0302 + 0.0071 \times \%\text{-Ethanol}) \times NMHC_{MEAS}$$

OHC: Formaldehyde + Acetaldehyde + Ethanol

Additional Information

- Additional Pollutants subgroup (chaired by C. Astorga, JRC) supports proposal

- VW-group proposal to Brazilian authority (CETESB) to adopt estimation approach pending: in-house study comprising 104 emissions tests from VW Wolfsburg, AUDI Neckarsulm and AUDI Ingolstadt with E22 fuel

Background Material

Study from ORNL

- The estimation approach is based on a study published from the Oak Ridge National Laboratory (ORNL). Therein, the estimation of NMOG is based on a scaling factor for NMHC that is dependent on the fuel ethanol content.

  Emissions tests were conducted by Southwest Research Institute (SwRI), San Antonio, Texas and Transportation Research Center Inc. (TRC), East Liberty, Ohio.

  The data used were gathered from over 600 cold-start Federal Test Procedure (FTP) tests conducted on 68 vehicles representing 21 models from model years 2000 to 2009. Most of the vehicles were certified to the Tier-2 emissions standard, but some Tier-1 and other vehicles were also included. The test fuels E0, E10, E15, and E20 were blends of ethanol and emissions certification gasoline from Chevron-Phillips and Haltermann Products.

ORNL: Oak Ridge National Laboratory
SwRI: Southwest Research Institute
TRC: Transport Research Center
FTP: U.S. Federal Test Prodedure

Comments from ORNL report

- „In general, the formaldehyde emissions from ethanol-blended fuels are on the same order as for ethanol-free fuel“
- “Another potential concern is error associated with the measurement of such small quantities of individual OHC species. Measurements of ethanol at substantially less than 1 mg/mile accuracy require exceptionally high fidelity gas chromatography methods. [...] Similar measurement concerns exist for the DNPH analysis of carbonyl species.”
- “It is worth noting that the results from this study affirm that the characteristic NMOG/NMHC ratio for cars tested using an ethanol-free fuel is approximately 1.03, in general agreement with the 1.04 factor currently allowed by EPA.”

Results from ORNL report

- NMOG for fuels with ethanol content lower than 25% (E25) can be described by following equation:

$$\mathbf{NMOG_{EST} = (A + \%\text{-}Ethanol \times B) \times NMHC_{MEAS}}$$

For cold-start FTP tests **A** and **B** come to **A = 1.0302** and **B = 0.0071.**

References

- Sluder, C. and West, B., "NMOG Emissions Characterizations and Estimation for Vehicles Using Ethanol-Blended Fuels," *SAE Int. J. Fuels Lubr.* 5(2):721-732, 2012, doi:10.4271/2012-01-0883.