講演番号	387

Challenges and Solutions for High-Accuracy Exhaust Gas Measurement in Carbon-Neutral Fuel Applications

Yosuke Kondo　　Yuichi Mori

HORIBA, Ltd.

2 Miyanohigashi-cho, Kisshoin, Minami-ku, Kyoto, 601-8510, Japan

KEY WORDS: **Environment・energy・resources, Emissions/emission gas**, Gas measurement, Carbon-neutral fuels (D2)

Carbon-neutral (CN) fuels are being actively developed for mobility because they can reduce net CO_2 emissions, but they also make exhaust-gas measurement more difficult. A central challenge is the much higher water vapor content in CN-fuel exhaust; for example, stoichiometric hydrogen combustion can generate roughly 35% H_2O, which increases the risk of measurement bias and requires additional technical measures for accurate emissions quantification . This paper summarizes how H_2O affects major exhaust-gas analyzer principles and outlines practical countermeasures suited to each method .

The paper first reviews representative analyzer types and target components, including Non-Dispersive Infrared Spectroscopy: NDIR (CO_2/CO/HC/N_2O), Chemiluminescence Detection: CLD (NOx/NO), Flame Ionization Detection: FID (THC/CH_4), Fourier Transform Infrared Spectroscopy: FTIR (multi-component IR gases), and Quantum Cascade Laser Infrared Spectroscopy: QCL-IR (selected gases measured with high spectral resolution) . Even when measuring the same component, the achievable accuracy under high humidity differs across these methods because the H_2O influence mechanisms are not the same .

For NDIR, H_2O causes spectral interference because it has broad infrared absorption bands that can overlap the target gas bands. Since optical filters have limited spectral resolution, complete removal of H_2O interference is fundamentally difficult . A common mitigation in pneumatic-cell NDIR is to cool the sample upstream of the detector to reduce H_2O to near saturation at 2−5° C, then convert dry readings back to wet concentrations for modal mass calculations. However, during engine cold start, the dry−wet correction can deviate from true wet exhaust behavior, so careful handling is required . If stronger suppression is needed, adding H_2O to calibration gas used for sensitivity adjustment is also described .

For CLD NOx measurement, H_2O can induce quenching shown in Fig. 1: collisions between excited NO_2* and H_2O reduce emitted light and bias readings . Countermeasures include diluting the sample or lowering pressure, dehumidifying the sample (critically downstream of the NOx converter to avoid losing water-soluble NO_2), and applying real-time correction based on directly measured or accurately estimated H_2O concentration .

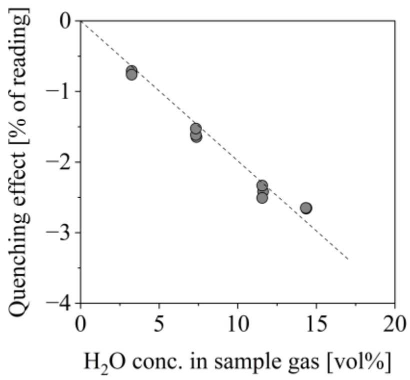

Fig. Impact of quenching effect on CLD analyzer

FID is generally insensitive to inorganic species like H_2O, but Non Mehan Cutter (NMC)-FID used for CH_4 is affected because H_2O changes catalyst combustion temperature, altering conversion efficiency and CH_4 penetration fraction . The paper notes that CFR 1065 requires pre-characterizing the H_2O–conversion relationship for gas-fueled engines and applying corrections during testing using H_2O estimated from carbon-balance calculations; alternatively, some systems remove H_2O via pre-analysis dehumidification .

For FTIR, the basic H_2O overlap resembles NDIR, and analysis typically selects regions with minimal interference and applies correction. Yet correction accuracy depends on spectral resolution (set by interferometer path difference), and may be limited under some conditions . The paper also highlights a “coexistence effect,” where H_2O changes the target gas spectrum itself; FTIR can address this by solving simultaneous equations that combine pre-characterized coexistence data with real-time measurements .

Finally, QCL-IR can reduce interference by choosing absorption lines carefully, but usually still needs correction. Because QCL-IR has higher spectral resolution than FTIR, it can enable more accurate interference correction . An example is IRLAM (Infrared Laser Absorption Modulation), which extracts features (via inner products with reference signals) and solves linear simultaneous equations for target and interfering gases; for coexistence effects such as H_2O-driven spectral broadening, broadening factors are embedded in the reference features to compensate appropriately .

Overall, accurate measurement of humid exhaust typical of CN fuels requires method-specific mitigation, and the best analyzer choice depends on the experimental objective and the required robustness of H_2O correction .

2026 JSAE Annual Congress (Spring) - Summarized Paper
Issued on May 22, 2026