Evaluation of HC, NO_x and NH_3 Mixed-Potential Sensors in Diesel and Gasoline Engine Exhaust

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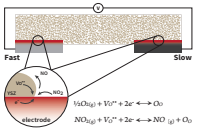
Background

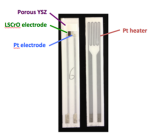
Mixed-Potential Sensors

- The non-equilibrium electric potential (EMF) developed in the presence of oxygen and a reducing/oxidizing gas is called a mixed potential.
- The magnitude of this mixed potential is a function of reducing/oxidizing gas concentrations (CO, HC, NH_3, NO_x).
- The mixed potential is dependent on the kinetics of the electrochemical reactions and is a function of the gas composition, electrode/electrolyte composition & morphology, and the operating temperature.

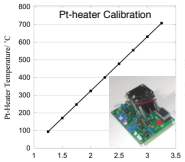


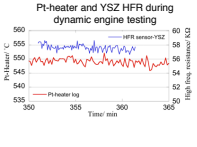
LANL Sensor design: Dense electrodes/porous electrolyte

- Minimize heterogeneous catalysis:
  Minimize diffusion path through catalytically active electrodes.
- Avoid changes in morphology- Control the interface:
  Electrolyte morphology stable and reproducible.

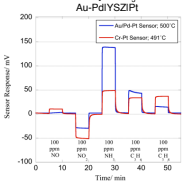


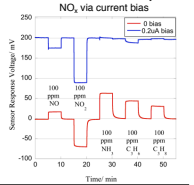
- Planar design with sensor operating temperature controlled by resistance of Pt-heater
- Heater-board developed with Custom Sensor Solutions controls Pt-heater resistance with control-loop feedback electronics
- Controlling Pt-heater resistance appears adequate for maintaining constant sensor element temperature as shown by constant high frequency resistance of YSZ electrolyte





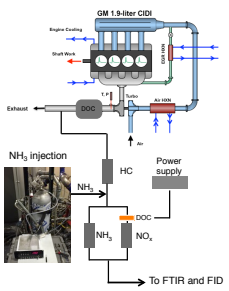
- Exploits differences in O_2 reduction kinetics of electrode materials by using dissimilar electrodes
  - Common platform allows selectivity to be altered by changing electrode materials only
- Interfacial resistance dominates: Sensor response dominated by electrochemical reactions.
  - Allows selectivity to be tuned by operation under a current bias



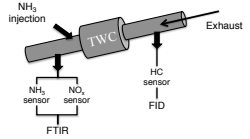


Dynamometer Sensor Testing

GM 1.9-liter CIDI

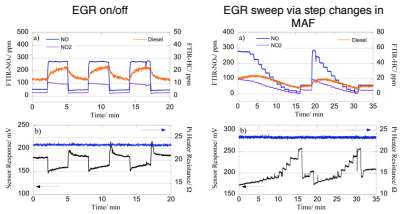


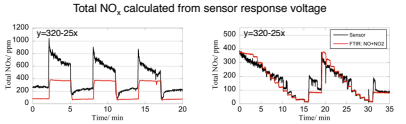
BMW 120i lean gasoline engine



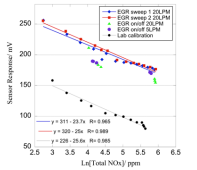
Diesel Exhaust

NO_x Sensor



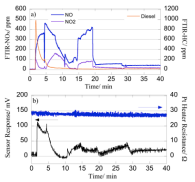


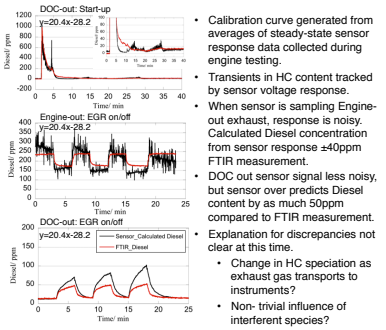
- NO_x sensor qualitatively tracks step changes in NO and NO_2
- Log-linear curves exhibit similar slopes with offset in Y-intercept between different engine experiments as well as laboratory calibration.
- *Y*-intercept likely correlated to [THC] or other interferents but not in trivial (linear) way



HC Sensor

- Data collected during engine start-up showing large variation in HC(Diesel) and total NO_x measured via FTIR.
- Sensor response qualitatively tracking HC content.
- Constant Pt-heater resistance shows that sensor element was maintained at temperature set-point under dynamic operation.

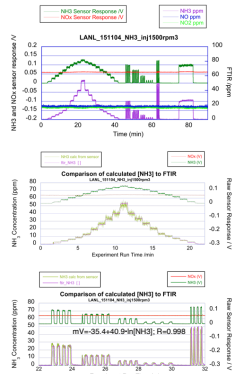




- Calibration curve generated from averages of steady-state sensor response data collected during engine testing.
- Transients in HC content tracked by sensor voltage response.
- When sensor is sampling Engine-out exhaust, response is noisy. Calculated Diesel concentration from sensor response ±40ppm FTIR measurement.
- DOC out sensor signal less noisy, but sensor over predicts Diesel content by as much 50ppm compared to FTIR measurement.
- Explanation for discrepancies not clear at this time.
  - Change in HC speciation as exhaust gas transports to instruments?
  - Non- trivial influence of interferent species?

NH_3 Sensor

- Steady-state engine operation with NH_3 injected upstream of sensors



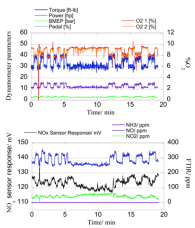
- Bench reactor data was used to generate a calibration curve for NH_3.
- NH_3 sensor clearly tracks injected ammonia.
- NO_x sensor (RED line) reflects steady state NO/NO_2 levels during injection of ammonia.

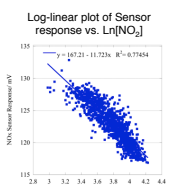
Gasoline Exhaust

NO_x Sensor

- NO_x sensor response during λ switching, sampling downstream of TWC.

λ adjusted from 1.86 to 1.62: Vary engine load

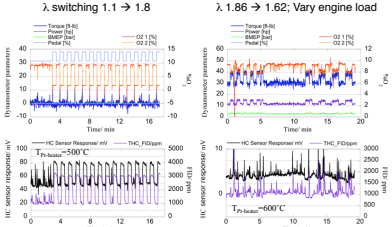




- Raw data with no averaging or signal processing
- NO_x sensor exhibits log-linear correlation to [NO_2].

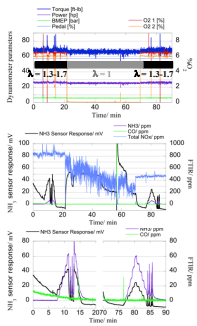
HC Sensor

- HC sensor response during λ switching, sampling upstream TWC. Exhaust from sensor sent to FID for THC analysis.
- Sensor qualitatively tracks THC measured via FID.



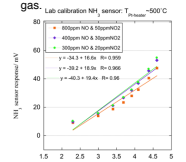
NH_3 Sensor

- Sensor response during lean-homogeneous and stoichiometric engine operation.

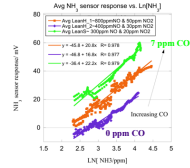


- NO_x and pO_2 influence sensor response during stoichiometric operation.
- Sensor exhibits strong preferential selectivity towards NH_3 during lean-homogeneous operation.

- Comparison of lab calibrations to sensor response in exhaust gas.



- Lab calibration revealed minimal influence of NO & NO_2 on NH_3 sensor response.



- "Baseline" shift between varying NH_3 staircases: CO, even at low levels (<10 ppm), is likely the dominant interferent species.

Acknowledgements

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