



**CHEMICAL COMPOSITION OF THE EXHAUST
FROM LOW-NO_x LOW-PM DIESEL COMBUSTION**

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SUMMARY

This paper describes the exhaust chemistry of combustion modes exhibiting simultaneous low-NO_x and low-PM emissions. An improved understanding of the exhaust constituents in these modes is necessary not only in the understanding of the combustion process but also in the evaluation of the potential environmental impact from these modes. While a number of papers have described the basic emissions phenomena of low-NO_x low-PM combustion regimes, a thorough characterization of the exhaust chemistry under these conditions is missing from the literature. The objective of this investigation is to improve the understanding of the exhaust chemistry and consequently the combustion processes associated with operating in low-NO_x low-PM combustion regimes.

Numerous experiments were performed on a Mercedes 1.7 liter common-rail diesel engine using a California low-aromatic certification diesel fuel. This engine was operated with a rapid-prototype, full-pass engine controller. Combustion regimes that exhibit a simultaneous reduction in NO_x and PM emissions were achieved using two approaches. The first approach utilizes a throttle to increase exhaust gas recirculation rate (EGR) rate beyond the maximum rate possible with sole use of the EGR valve. The second approach does not use a throttle, but rather uses a combination of EGR and manipulation of injection parameters.

Detailed characterizations of gas-phase hydrocarbons, particulate soluble organics, and aldehydes are discussed for both approaches. Comparing aldehydes from the two approaches shows that the emissions of formaldehyde and acetaldehyde were more than 6 times higher for Approach 1 as compared to Approach 2, with formaldehyde being the

dominant species for both approaches. Overall, the formation of aldehydes is an indicator of partial oxidation of the fuel hydrocarbons. Propene, cyclopentadiene, and benzene were also observed for both approaches. The presence of these species is an indicator of fuel cracking and reforming occurring in the engine, despite the fact that the engine was operating fuel-lean for both approaches. Large increases in unsaturated compounds such as alkenes is indicative of hydrogen abstraction, and thus the potential for H₂ formation. A significant increase in the soluble organic fraction (SOF) of the particulate matter was also observed for both approaches.

The results presented in this article focus on the chemistry of these combustion regimes using a single fuel. Additional fuels are currently being investigated to provide further understanding of the mechanisms at work.

CONCLUSIONS

- There are chemical markers present in the exhaust that verify a change in the fundamental combustion process when an engine enters low-NO_x, low-PM combustion.
- Entering a low-NO_x, low-PM combustion regime through aggressive dilution of the intake charge with EGR produces increases in fuel cracking compounds.
- Low-NO_x, low-PM combustion has been shown to exhibit relatively high PM-SOF.
- Further study is needed, both in terms of inclusion of chemical species and in terms of fuels.