INVESTIGATION OF LIGHT LOAD HCCI COMBUSTION BASED ON MEASURED TEMPERATURE AND OH CONCENTRATIONS

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Introduction

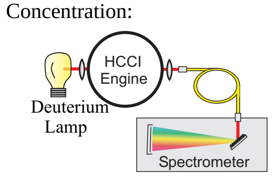
- OH is a necessary agent for the CO → CO2 oxidation reaction, which is the main heat release mechanism in the combustion process
- As equivalence ratio decreases:
  - Temperature rise is very low (1200-1300K peak temperatures)
  - OH concentration becomes too low for complete combustion
  - CO emissions become unacceptable

Intake Diluents:

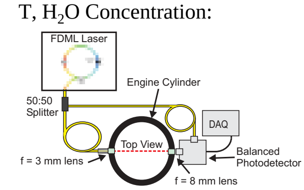
- Argon and CO_2 have specific heats lower than, and higher than air, respectively
- If we replace part of the intake air with either of these gases the temperature history of the mixture will change – T increases with Ar diluent and T decreases with CO_2 diluent
  - Ar should reach the critical acceptable peak temperature at a lower fuel mass than 100% air
  - CO_2 should reach the critical acceptable peak temperature at a higher fuel mass than 100% air
- We can show that the cutoff for marginally complete combustion is a temperature limit, not an equivalence ratio limit

Method

OH Concentration:



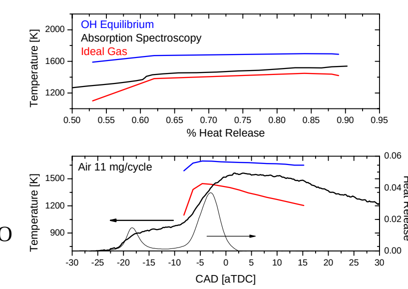
T, H_2O Concentration:



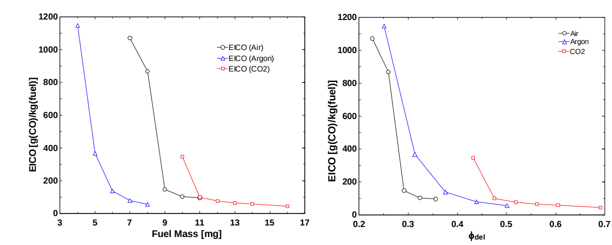
- Measure the completeness of combustion by quantitatively measuring the OH concentration and temperature (via H_2O spectroscopy)
- Measure changes in [OH] during the cycle as peak cylinder temperature is changed by varying equivalence ratio and diluent level independently

Temperature

- Phasing differences between the H_2O and OH measurements were corrected by comparing % heat release (as compared to crank angle degrees)
- Various methods for calculating temperature were used to verify H2O spectroscopic results.



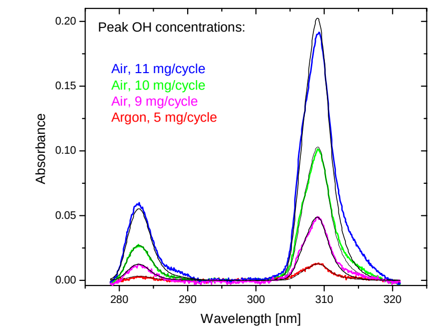
CO Exhaust



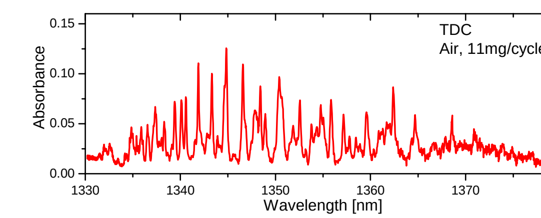
- Exhaust Index of CO (EICO) measures mass flow rate of CO exhausted per mass flow of fuel into the cylinder
  - EICO = g(CO)/kg(fuel)
- These graphs show that the argon diluent allows a lower fuel mass before the onset of incomplete combustion, consistent with the higher in-cylinder temperatures due to the low heat capacity. Likewise, the onset of high CO emissions occurs at higher load for the CO2 dilution due to the lower in-cylinder temperatures brought about by the higher heat capacity.

Spectral Results

Sample OH Measured Spectra:

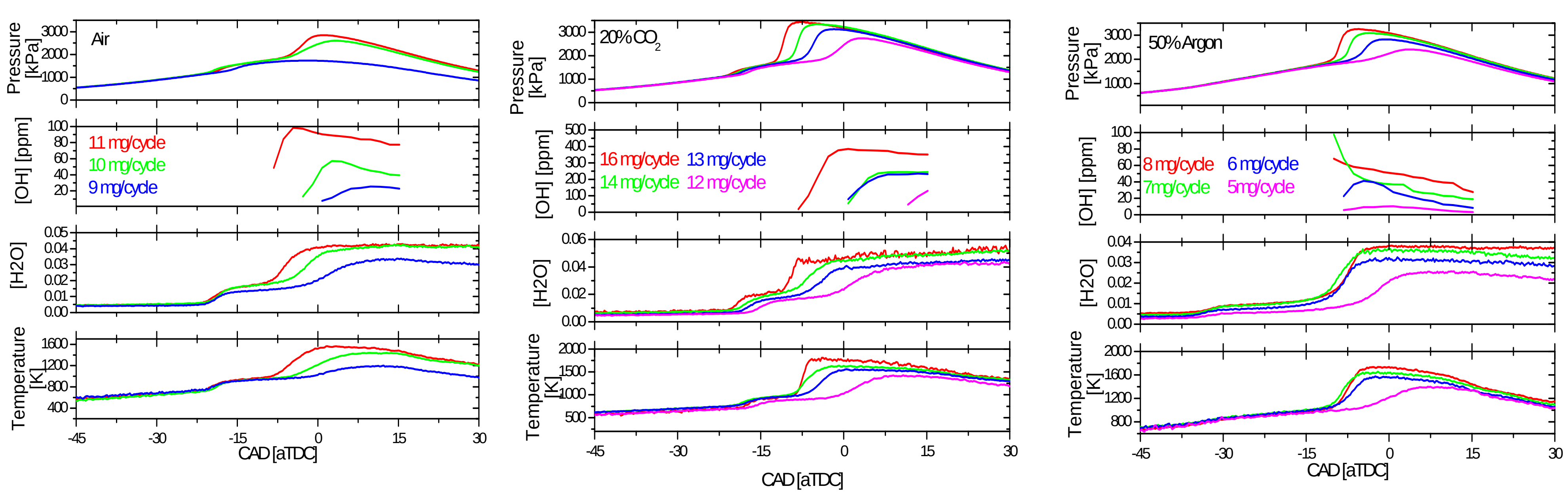


Sample H_2O Measured Spectra:



- Measured water vapor spectra were compared with a library of known water vapor spectra to determine temperature and water mole fraction

Results Overview



Conclusions

- Gaseous diluents with different specific heats confirm that the low-load limit is a temperature constraint
- Time-resolved concentration measurements show that OH forms during the second stage of heat release
- Measured [OH] was found to decrease monotonically with fuel mass
- Disappearance of OH corresponds to loss of the second-stage ignition and a rise in CO emission
- Peak temperatures were measured via H_2O spectroscopy, OH equilibrium, and ideal gas with fairly good agreement.
- H_2O temperature data shows that when the peak temperature drop below approximately 1550 K, unacceptable CO emissions occur.