Numerical and Experimental Studies of HCCI combustion

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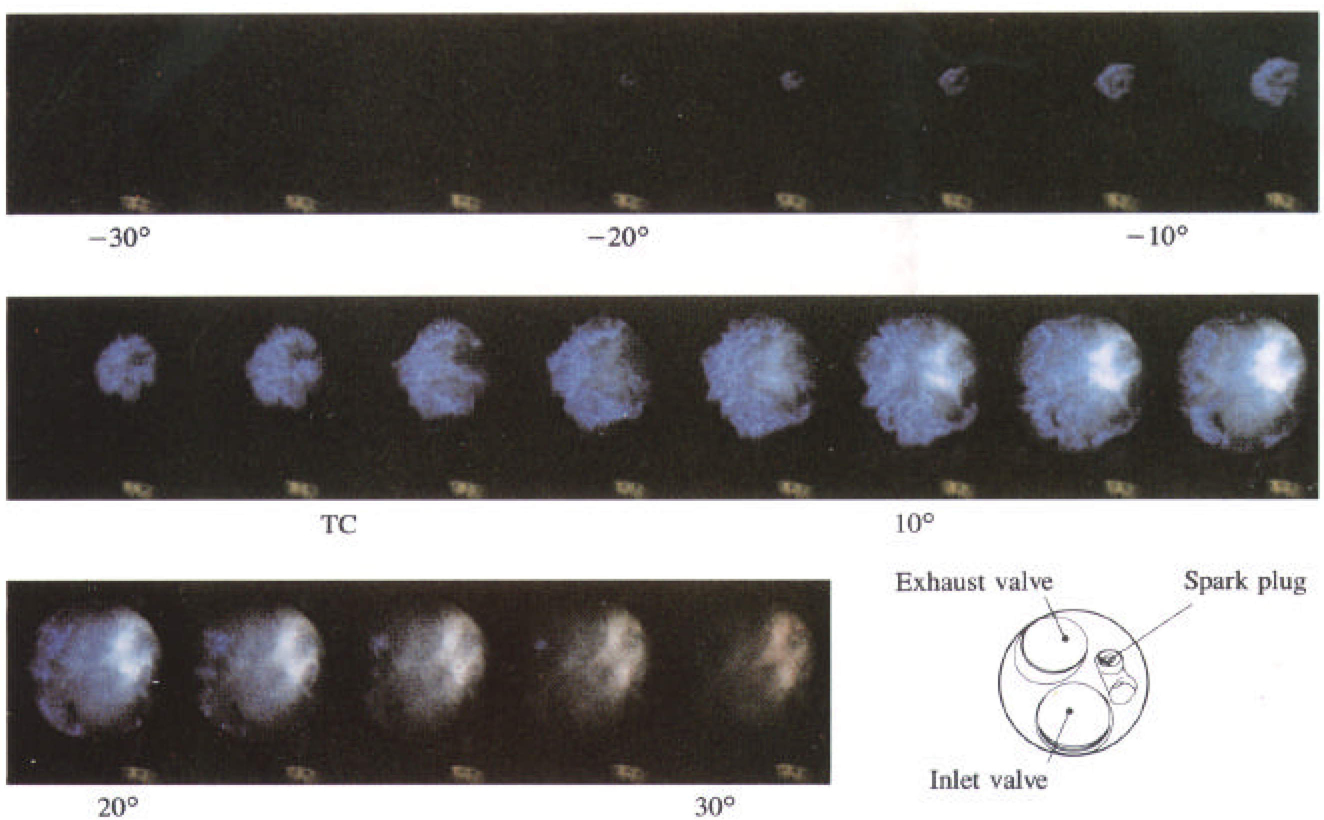
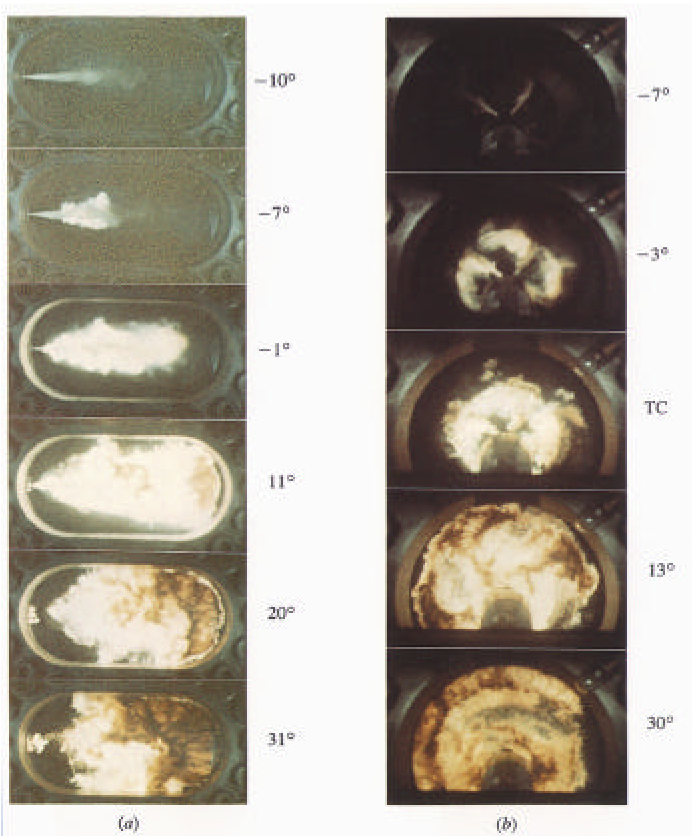
Spark ignited engine combustion

Homogeneous charge

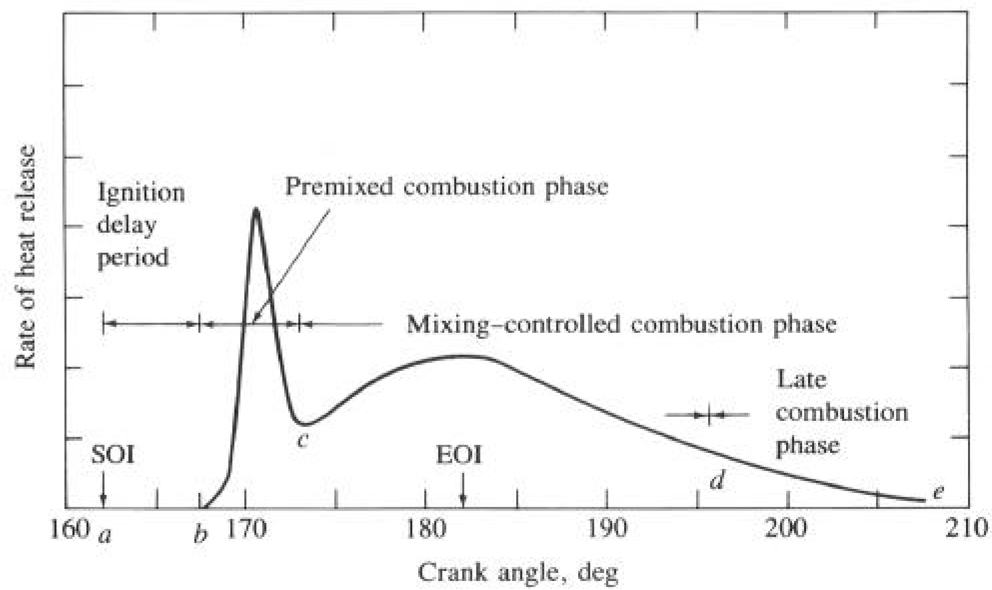
Combustion started by a spark plug and propagated by a flame spreading through the cylinder



Diesel engine combustion

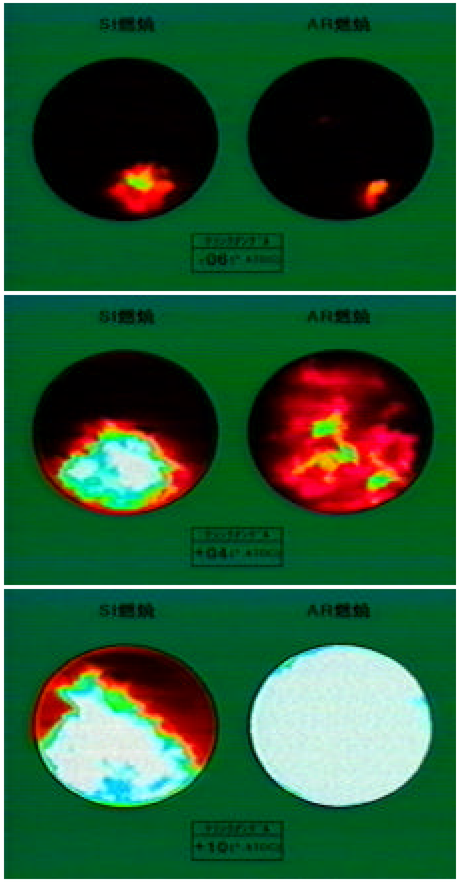


- Fuel injected late in compression stroke
- Combustion controlled by mixing between the air and fuel



Homogeneous Charge Compression Ignition (HCCI) combustion

- Homogeneous charge, similar to SI engine
- Compression ignition, similar to a diesel engine
- Ignition controlled by chemical kinetics, no flame propagation
- Very sudden combustion



- 6

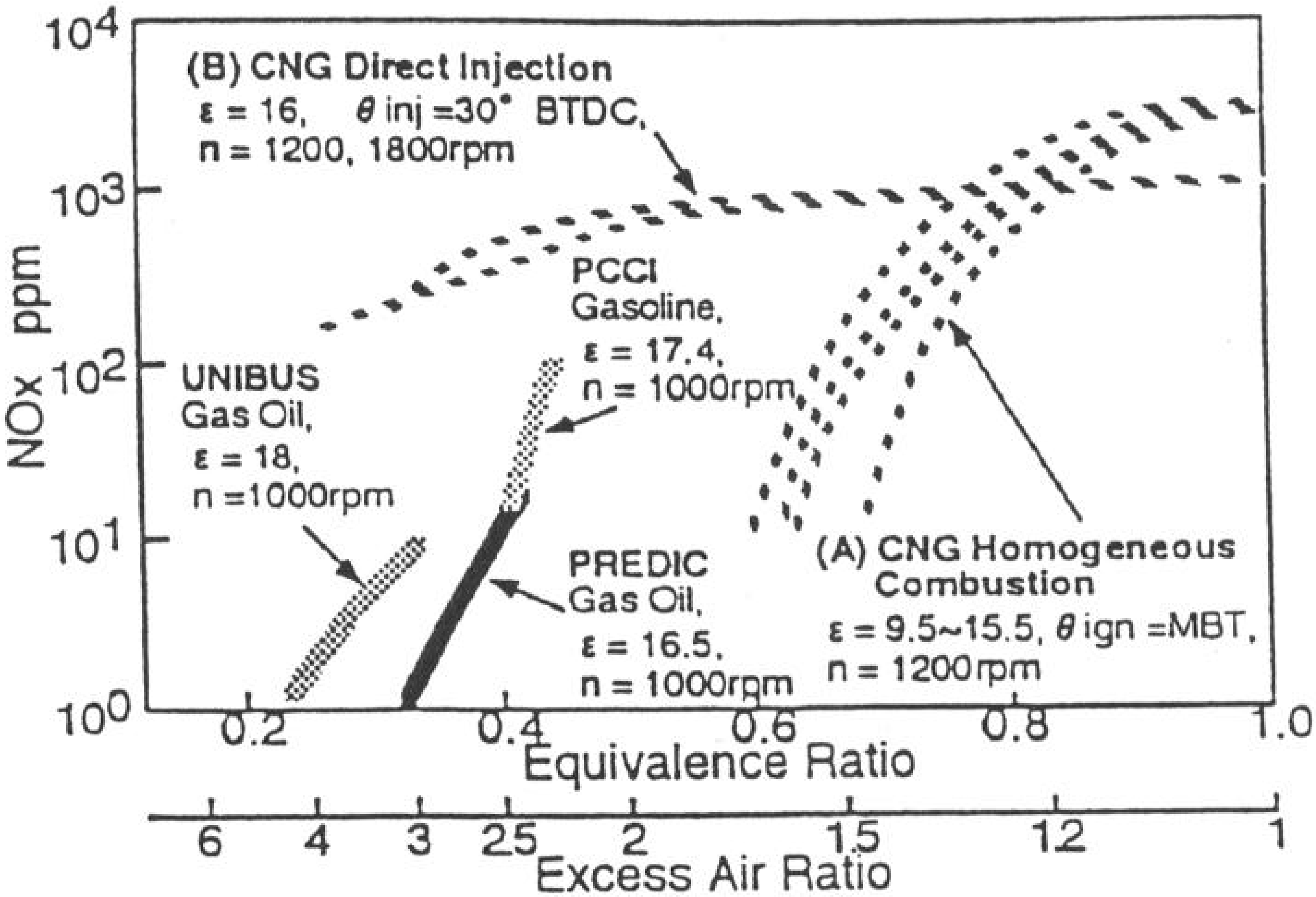
+ 4

+ 10

Spark ignition HCCI

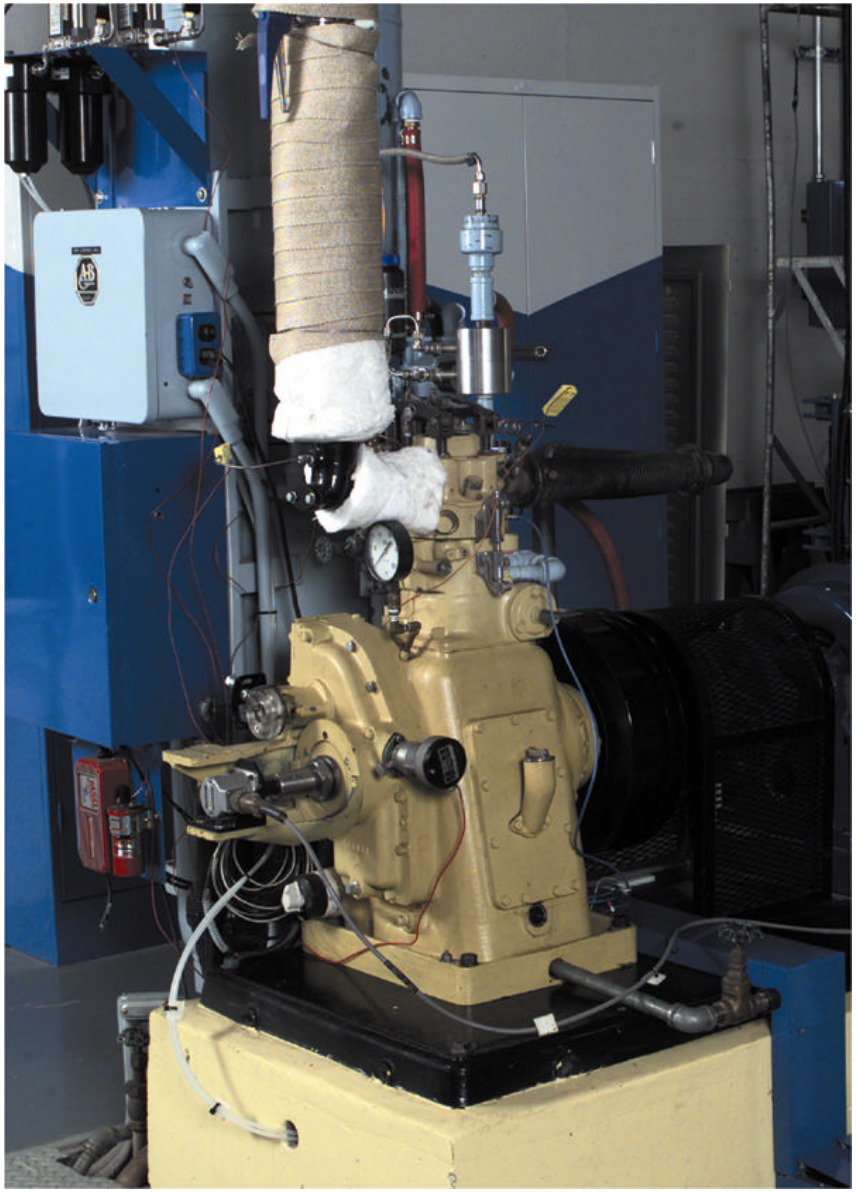
Recent HCCI experiments by Honda

NO_x reduction potential with HCCI combustion

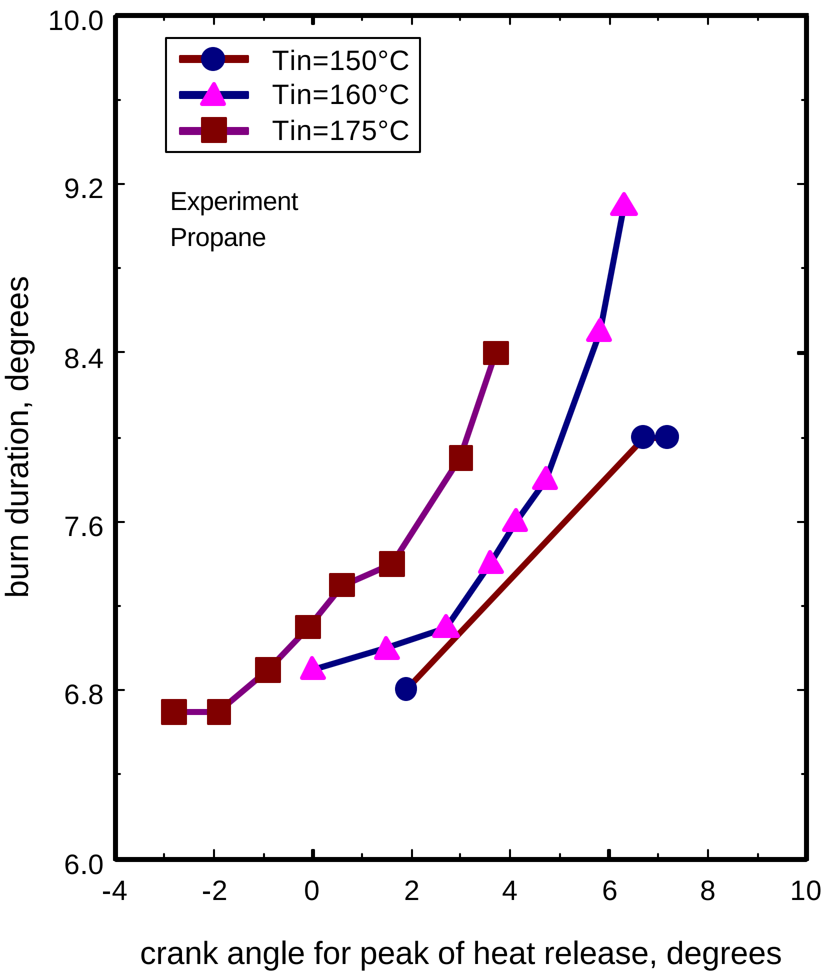


We have completed a set of experimental runs with the CFR engine

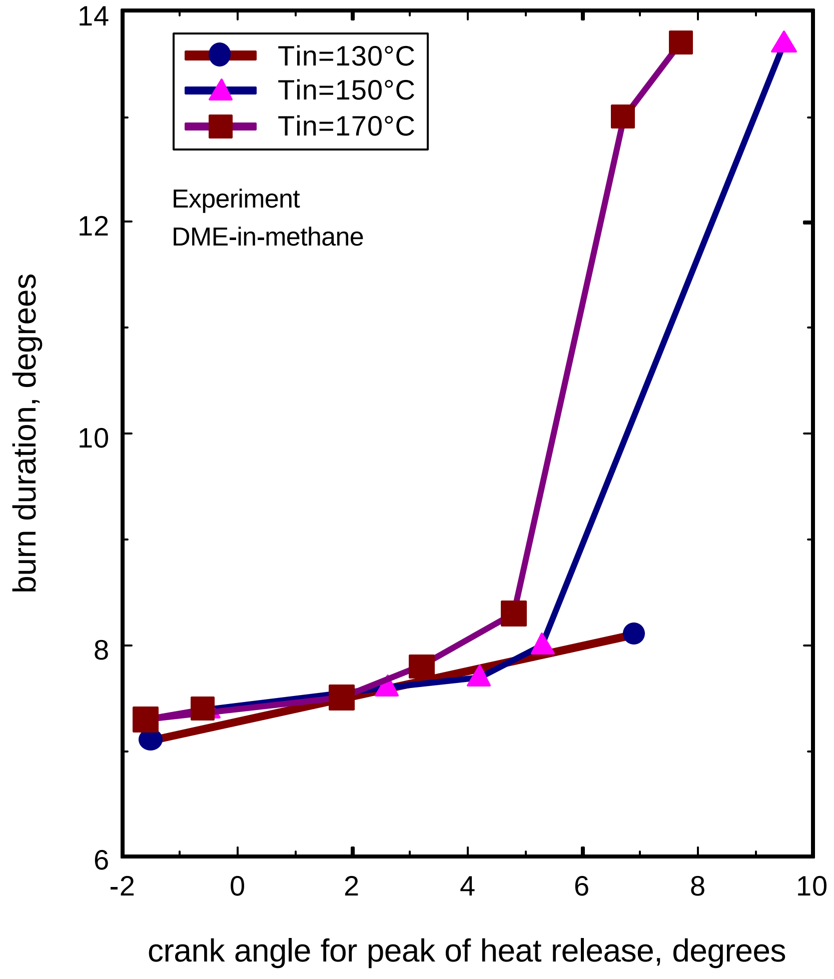
- Fuels: methane, propane and a mixture of methane and DME
- Studied conditions for optimum operation
- Demonstrated satisfactory operation at very low NO_x
- Obtained good agreement between experimental results and detailed chemical kinetics model (SAE 2000-01-0328)



Single-cylinder experiments in the CFR engine have provided insight into the HCCI combustion process

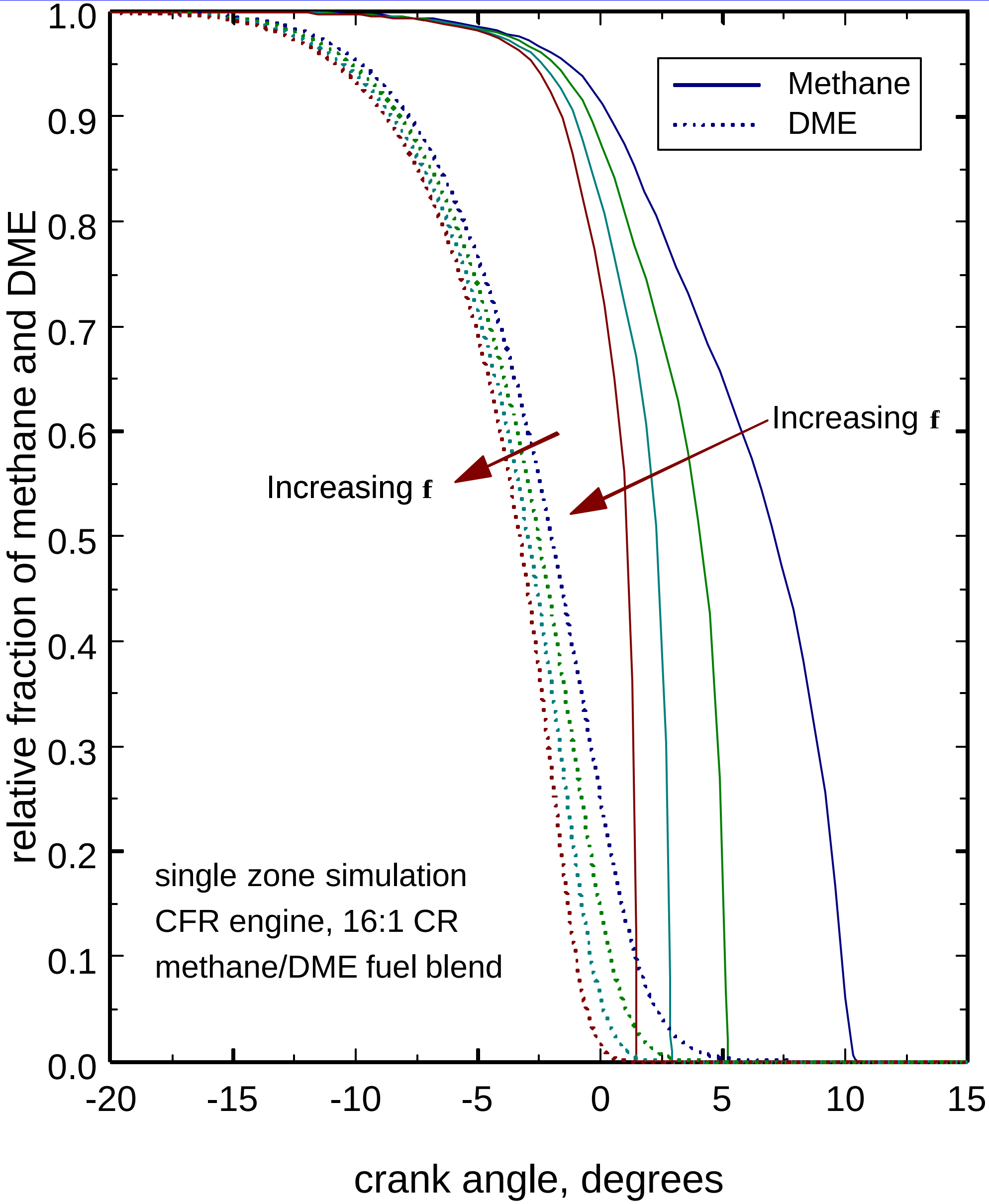


Propane



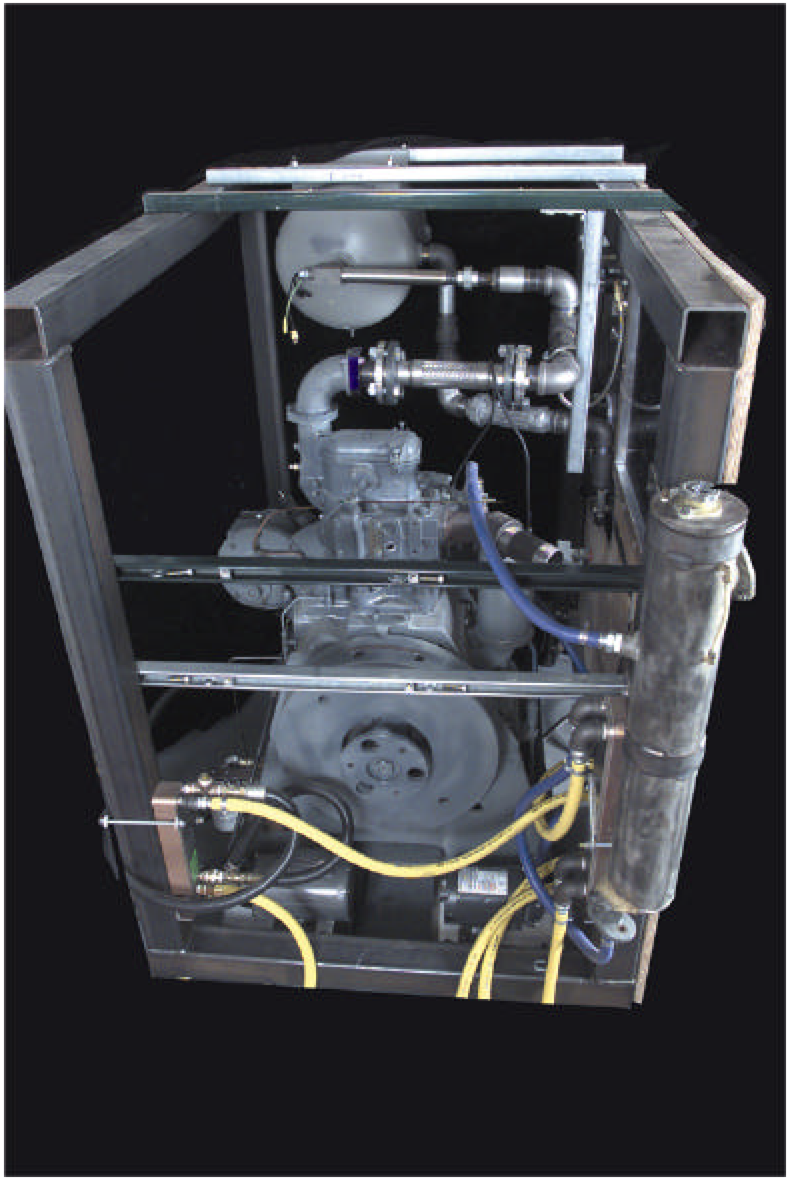
15%DME-in-methane

Chemical kinetics provides us with an understanding of experimentally observed phenomena



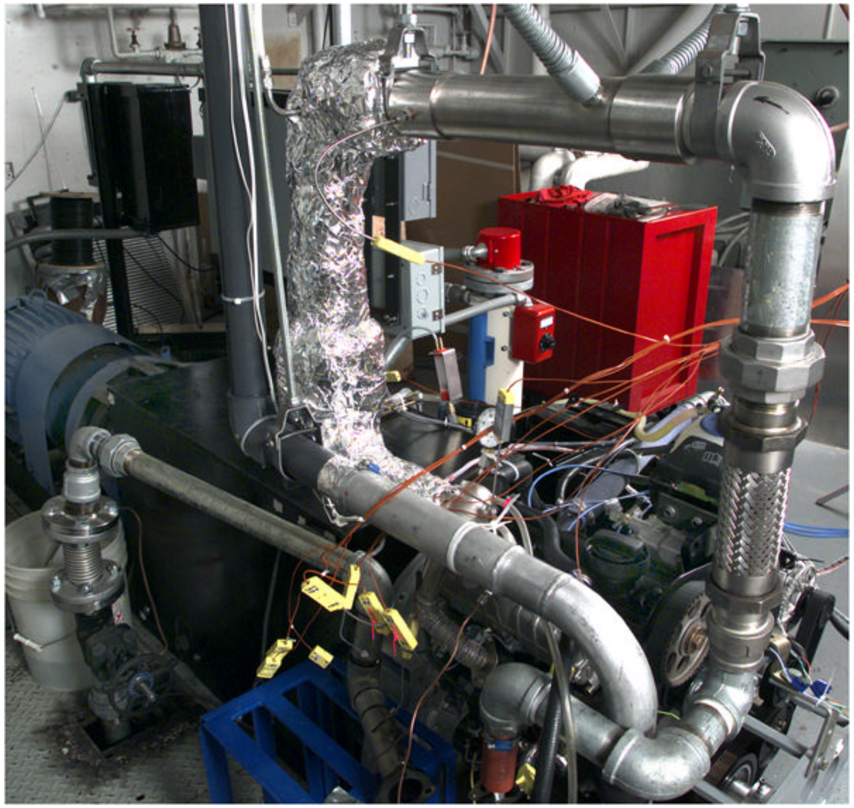
We are installing a Caterpillar 3401 2.2L single cylinder engine at UC Berkeley

- This engine belongs to a class that is appropriate for heavy vehicle applications
- In operation by the fall of 2000



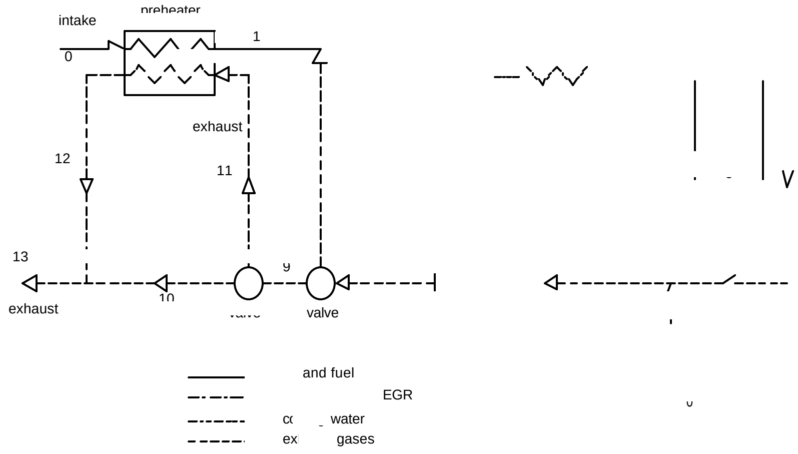
Experiments and computations on TDI engine are giving us insight into control of the HCCI combustion process

Experiments

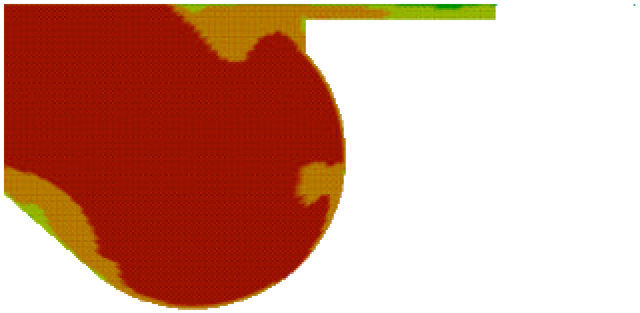


4-Cylinder 1.9L VW TDI HCCI Engine at UC Berkeley

Wide Ranging Performance Studies

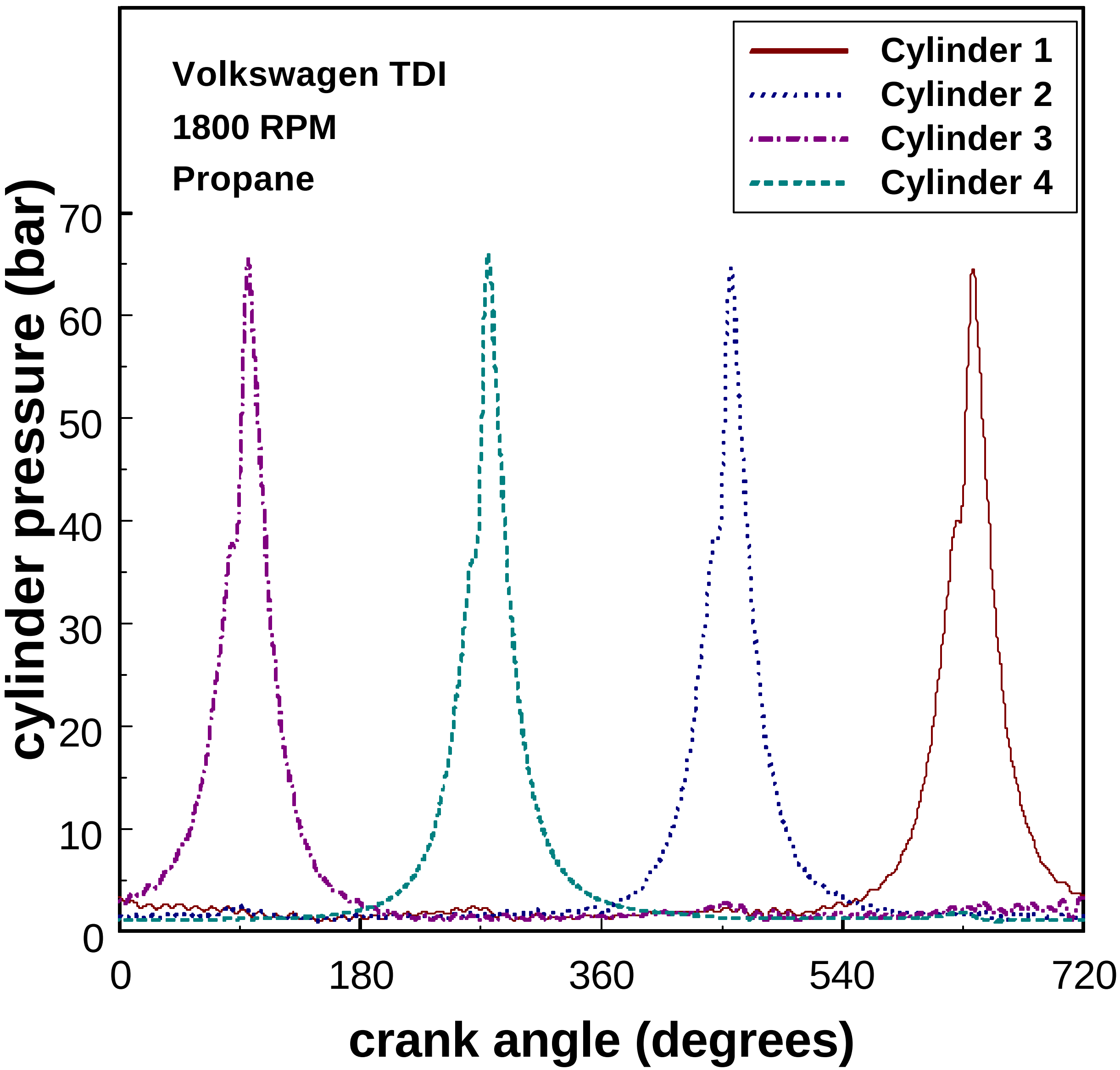


Multi-zone Modeling

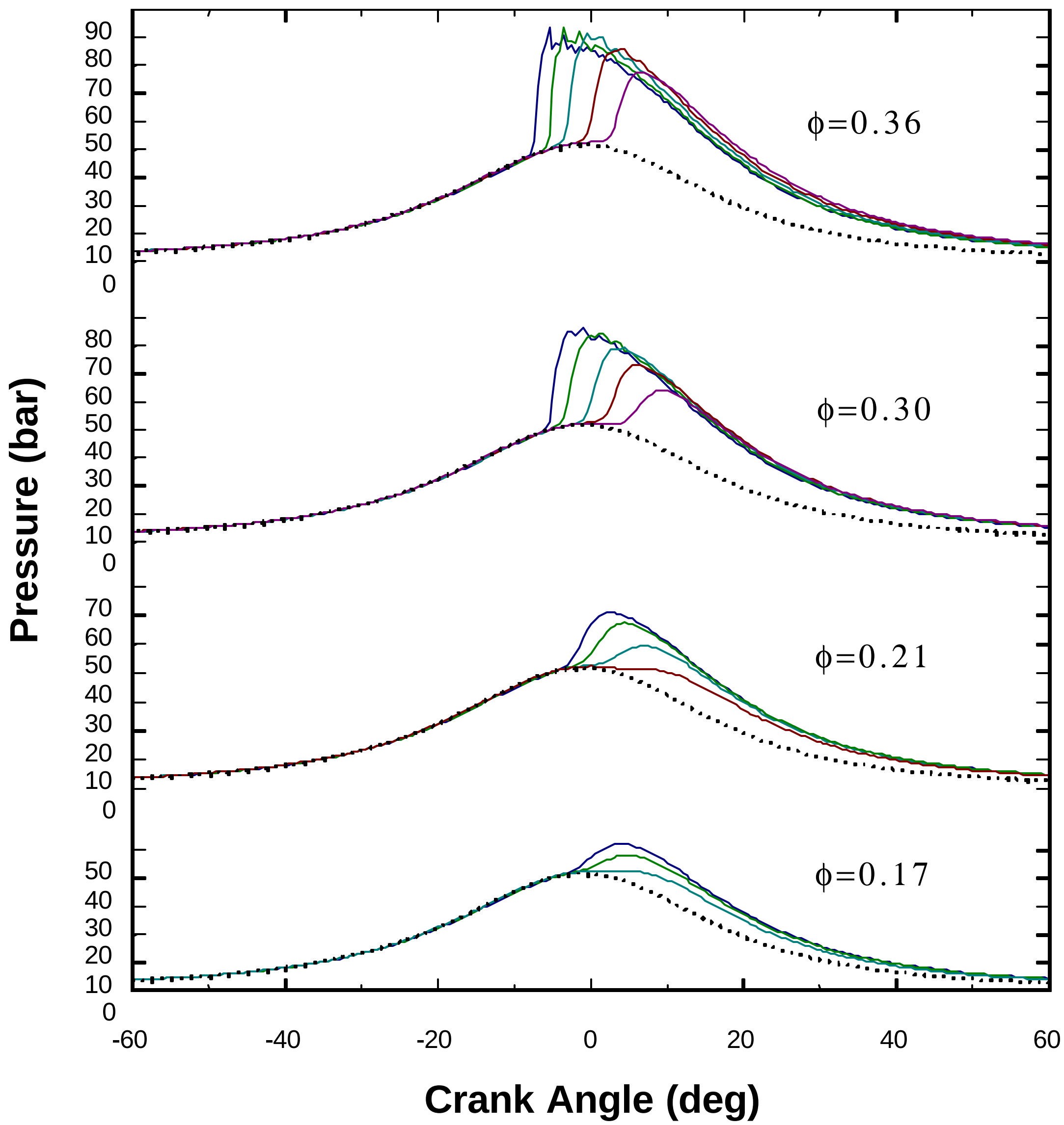


Temperature distribution in Volkswagen TDI combustion chamber at TDC (KIVA-IIIV)

We have achieved satisfactory combustion in all cylinders of the TDI 4-cylinder engine



Experiments are being conducted on the TDI 4-cylinder engine to look at optimum combustion timing

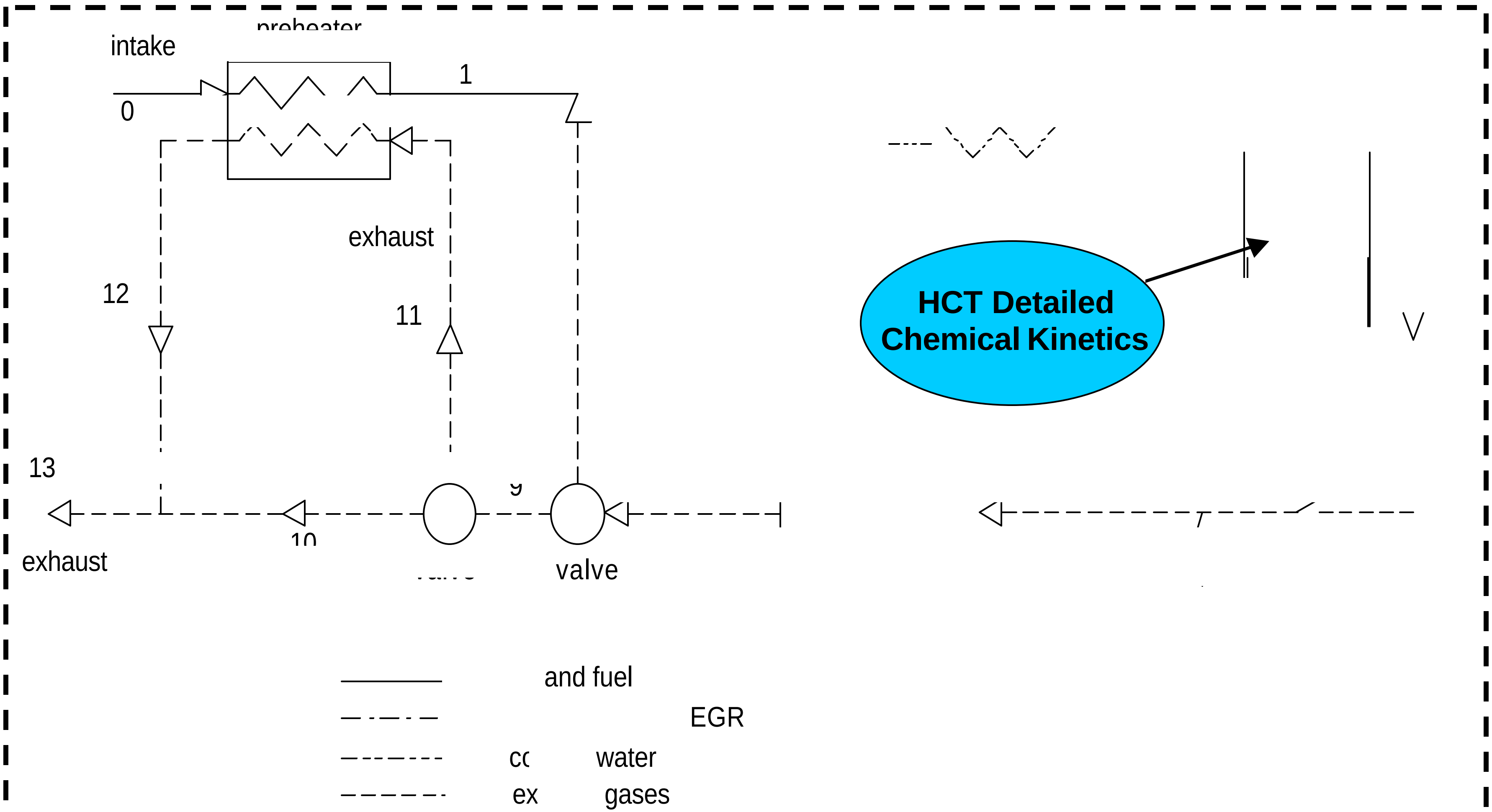


Analysis of HCCI combustion

- Assuming truly homogeneous charge, HCCI is dominated by chemical kinetics, with little effect from turbulence and no flame propagation
- Use a detailed chemical kinetics code (HCT: hydrodynamics, chemistry, and transport) for prediction of HCCI combustion
- Single-zone engine model being used to develop a thermal control system for the TDI engine running on natural gas
- Engine model linked to SuperCode optimizer to determine operating conditions for maximum efficiency and maximum power, under restrictions of low NO_x (<100 ppm) and peak cylinder pressure (<250 bar)

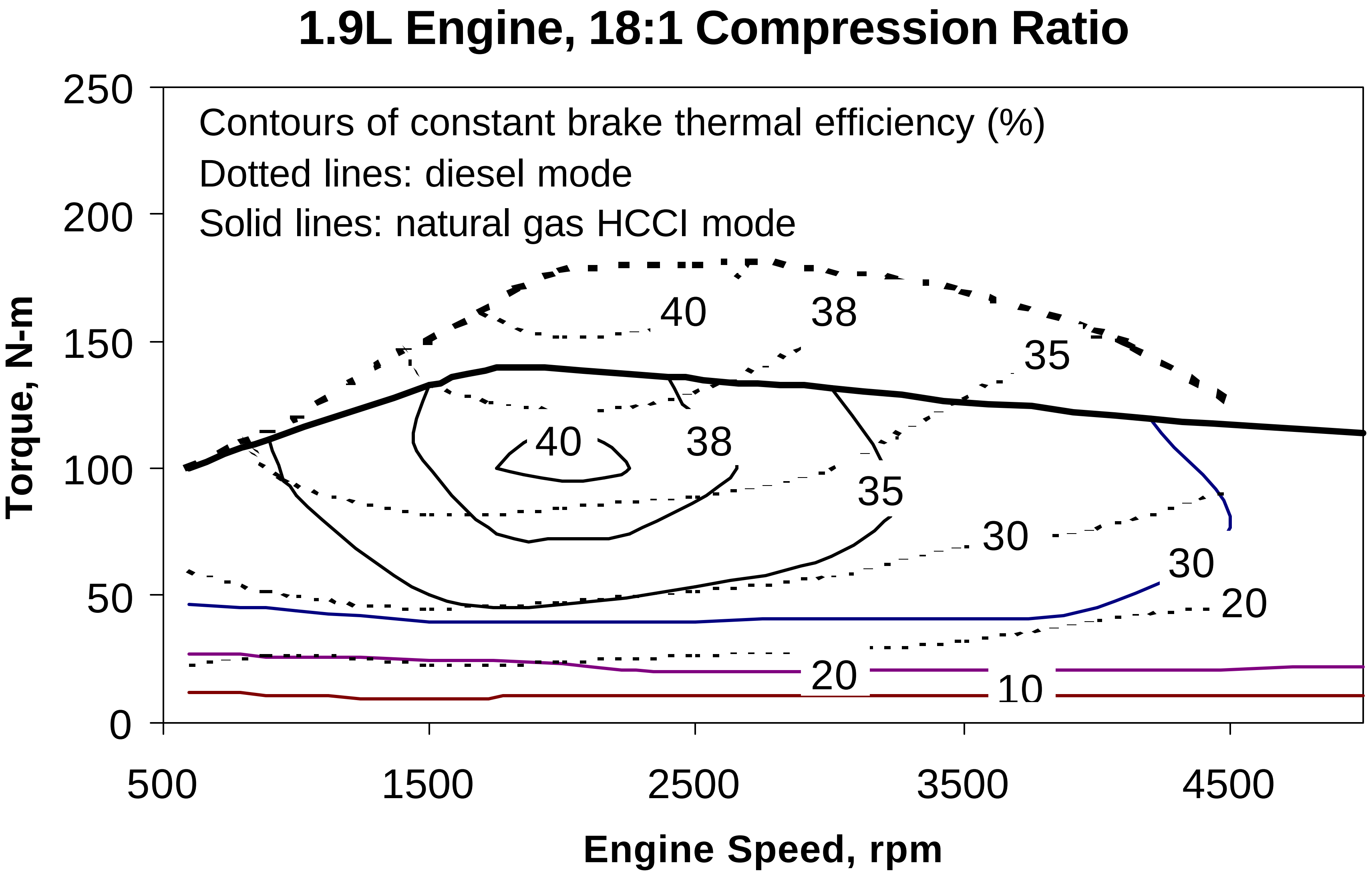
We have developed an HCCI engine system simulation and optimization tool

Example of thermal control system

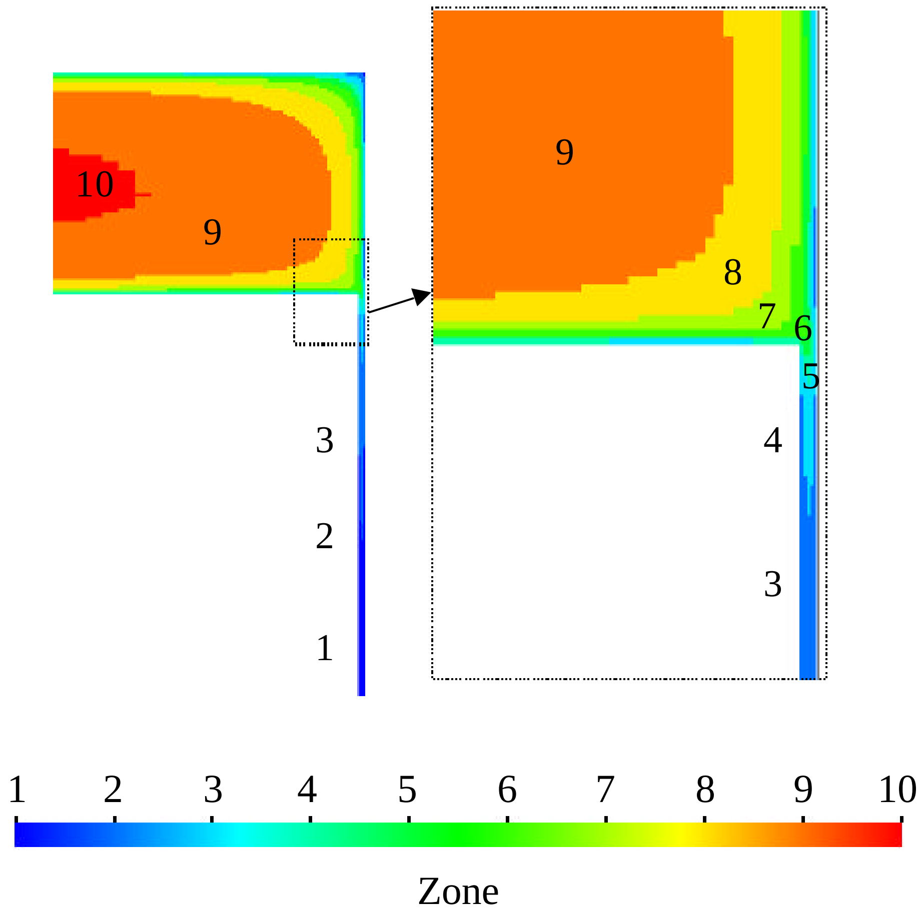


SuperCode Optimization

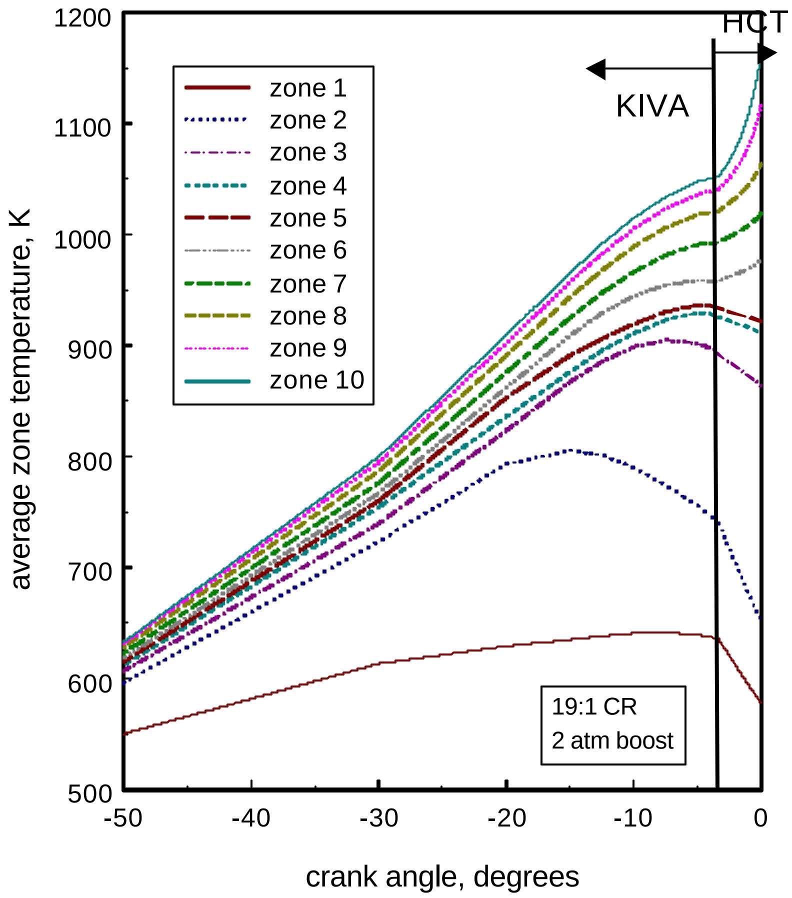
The efficiency of the HCCI engine is higher than the TDI engine operated as a diesel for the same torque



Multi-zone model: divide cylinder into 10 isothermal zones and use temperature histories for detailed kinetics model

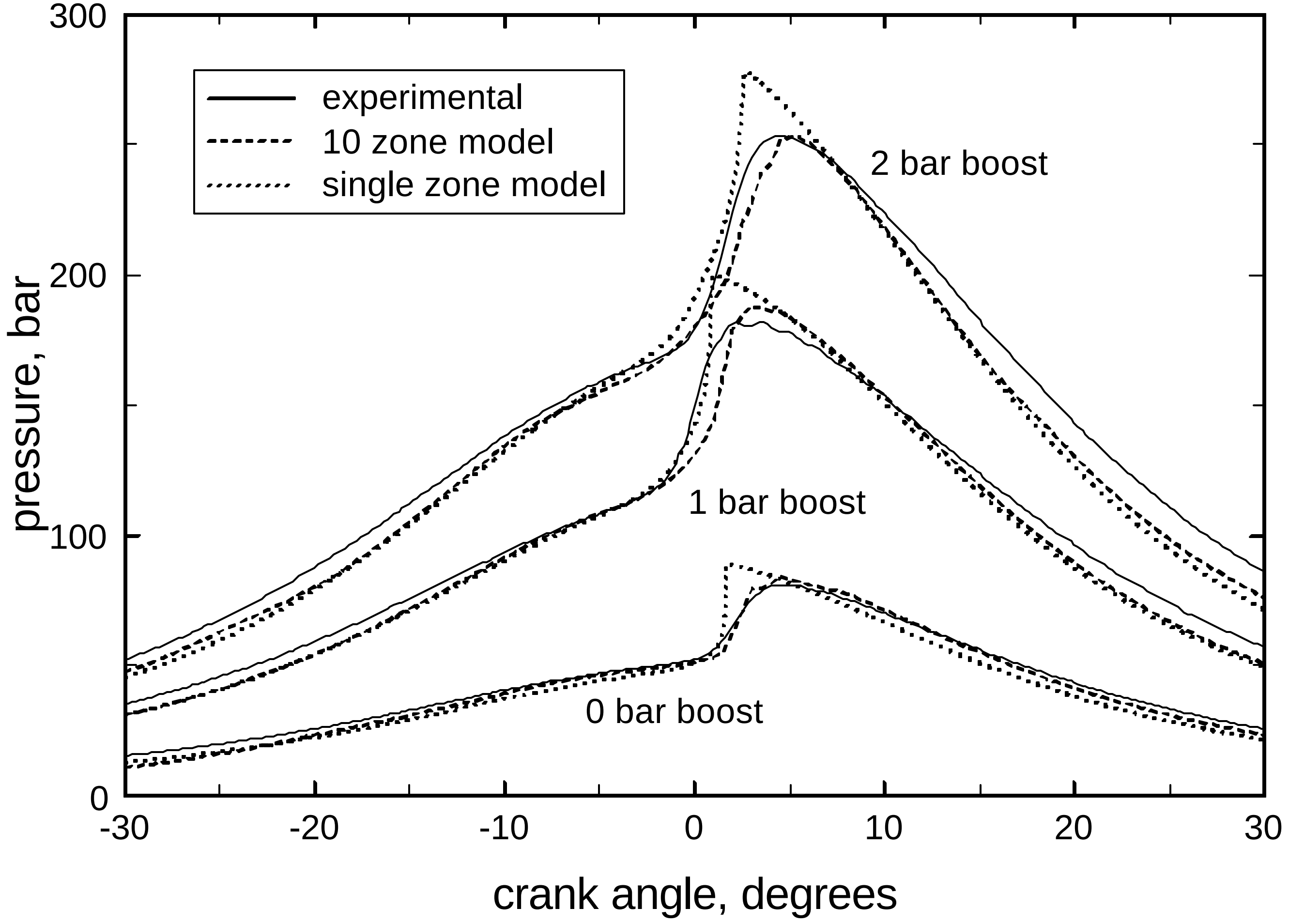


Location of isothermal zones in cylinder



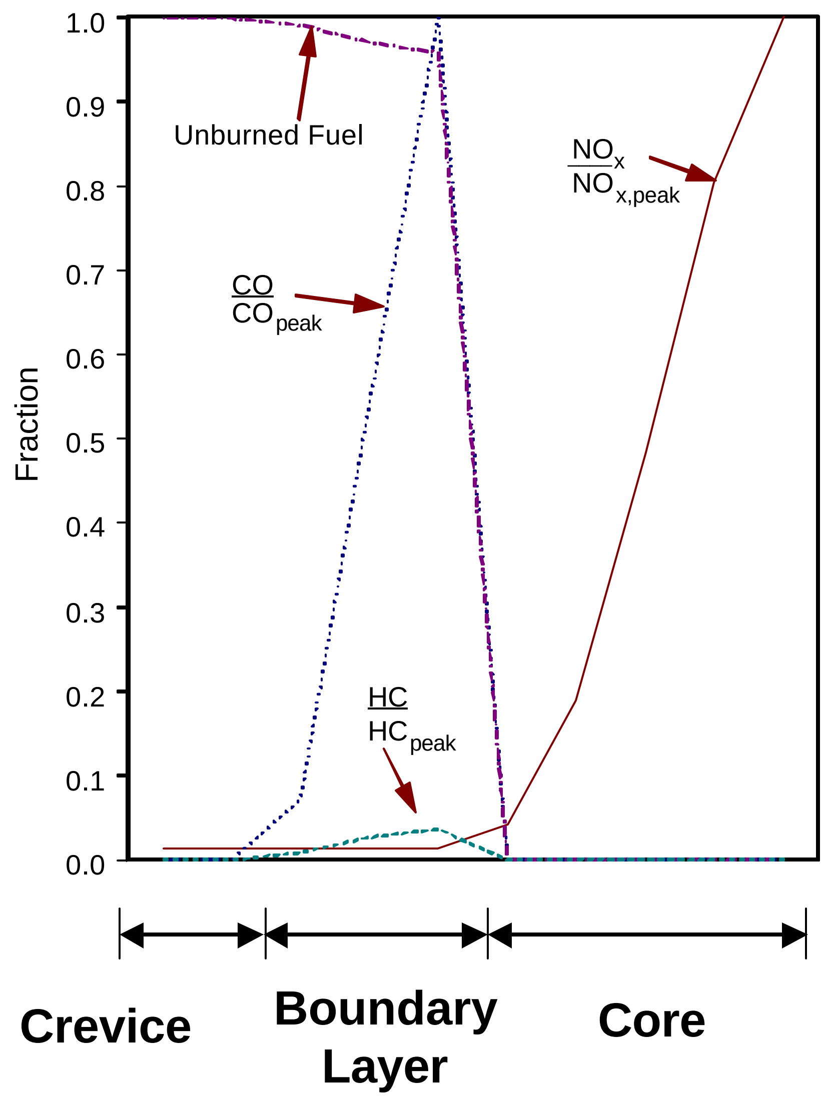
Temperature history of 10 zones during compression stroke

Multi-zone model yields excellent agreement with experimental pressure traces for natural gas (SAE 2000-01-0327)



Multi-zone methodology also yields predictions for HC and CO emissions

Multi-zone HCCI analysis determines that HC emissions originate at crevices, CO at the boundary layer, and NO_x at core



Multi-zone HCT analysis gives us insight into the initiation of the HCCI combustion process

HCCI combustion occurs at 1050 - 1100K due to the decomposition of H_2O_2 into OH

H_2O_2 (+M) ® OH + OH (+M)