Effects of Cetane Number, Aromatic Content and 90% Distillation Temperature on HCCI Combustion of Diesel Fuels

V. Hosseini, W. S. Neill, H. Guo, C. E. Dumitrescu, W. L. Chippior
National Research Council Canada

C. Fairbridge
Natural Resources Canada

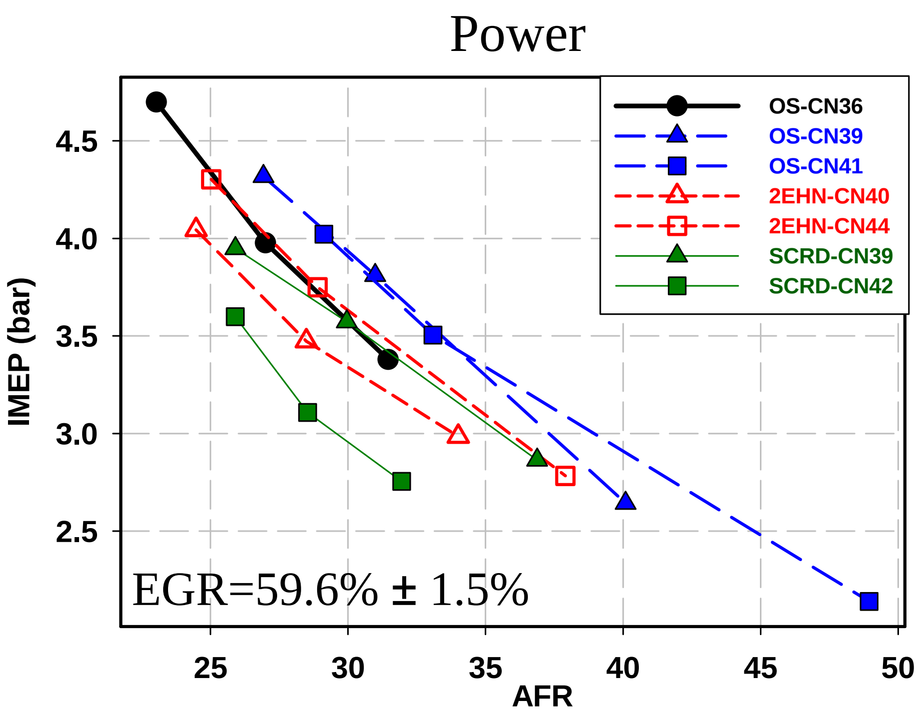
K. Mitchell
Shell Canada Limited

Introduction

IEA 2009 presentation

- Cetane number of an oil sands derived diesel fuel was increased by three methods: hydroprocessing, adding cetane improver, and blending with high cetane renewable diesel fuel

- Results: fuels with similar cetane number have different performance if upgraded by different methods



Introduction

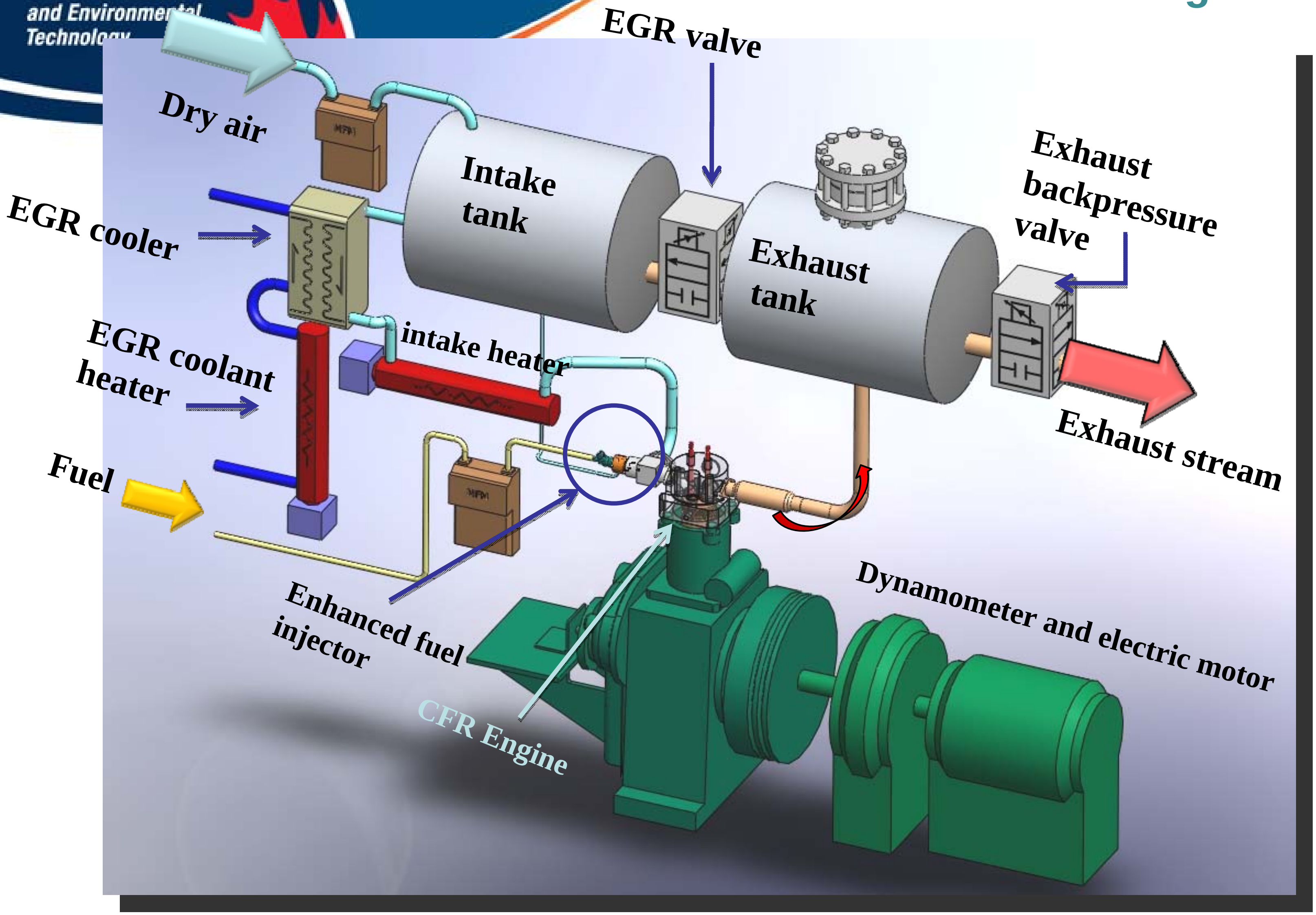
- The research continues to investigate fuel property effect on HCCI combustion
- Conventional fuel quality indicators of octane number and cetane number are not enough to reasonably rate fuels for HCCI combustion
- Other fuel properties may affect HCCI combustion
  - cetane number, distillation process, aromatics content, etc.
- ***How does each of these properties affect HCCI combustion?***

Objective

- To investigate the effects of cetane number (CN), 90% distillation temperature (T90) and aromatics content on combustion and emission characteristics of a HCCI engine

Experimental Setup

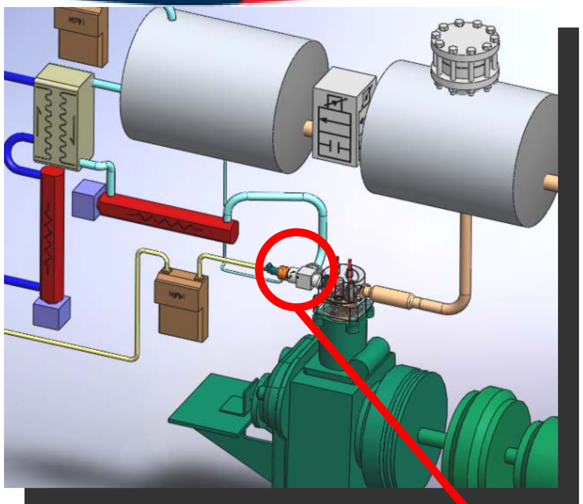
HCCI Engine laboratory



A CFR engine

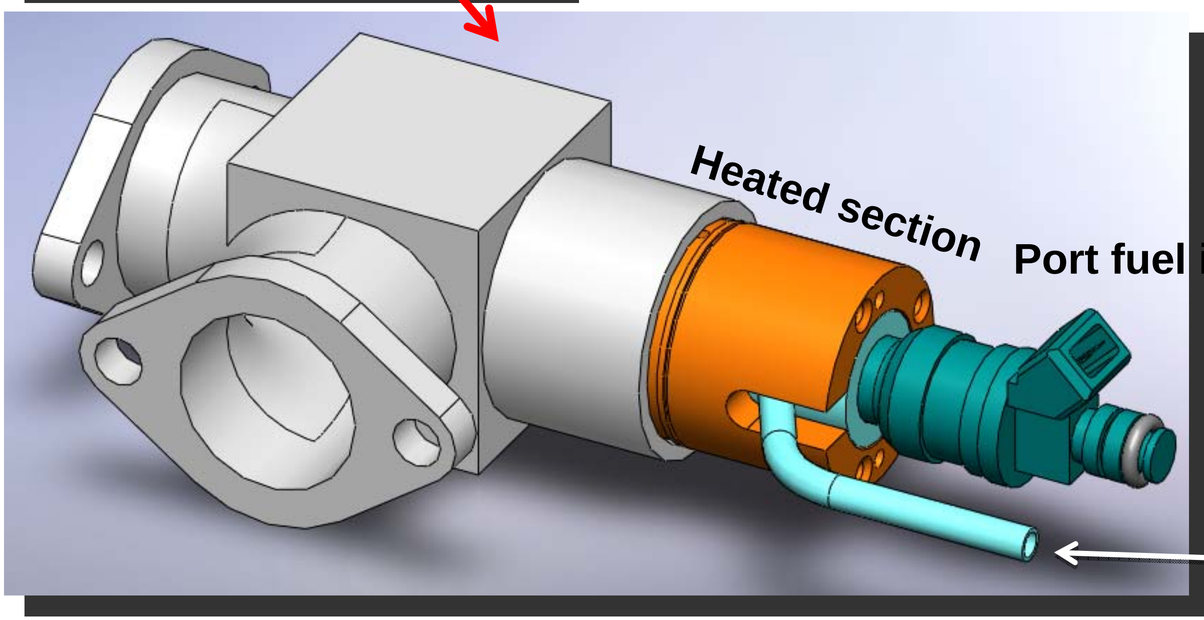
Experimental Setup

Enhanced fuel injector/vaporizer



•Enhanced fuel injector/vaporizer consisting of:

- OEM gasoline port fuel injector
- Air blast for improved atomization
- Heated section to improve vaporization



Operating Conditions

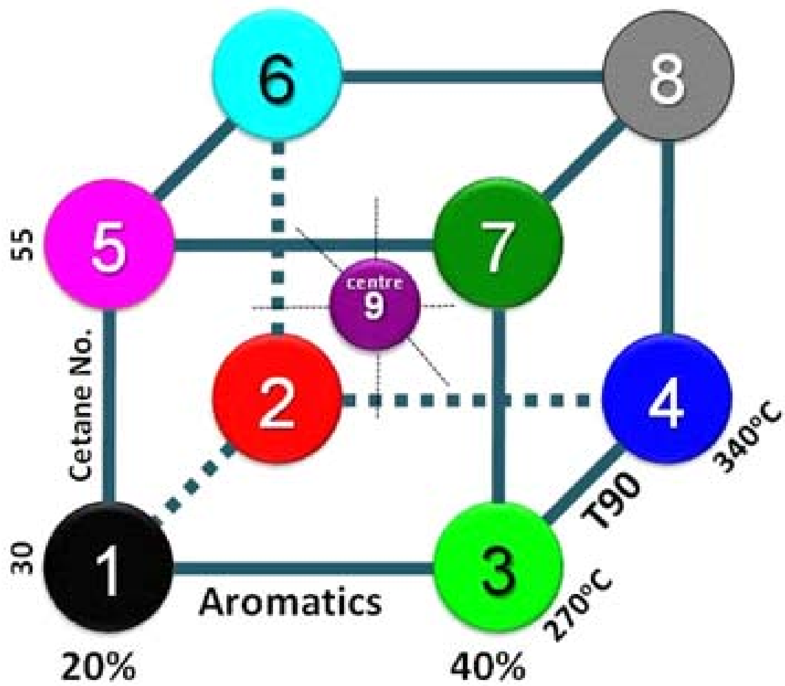
Parameter	Acronym	Value
Compression ratio	CR	variable between 9.00:1 to 15.00:1
Engine speed	N	900 rpm
Manifold absolute pressure	MAP	150 kPa
Exhaust pressure	ExhP	170 kPa
Intake mixture temperature	Tmix	75 °C
Fuel vaporizer temperature	Tvap	**270 °C**
Exhaust gas recirculation fraction	EGR	60%
relative air/fuel ratio	λ	1.2
Coefficient of variation of IMEP	COV IMEP	≤ 5%
Maximum rate of pressure rise	$(dP/d\theta)_{max}$	≤ 10 bar/°CA

Fuels

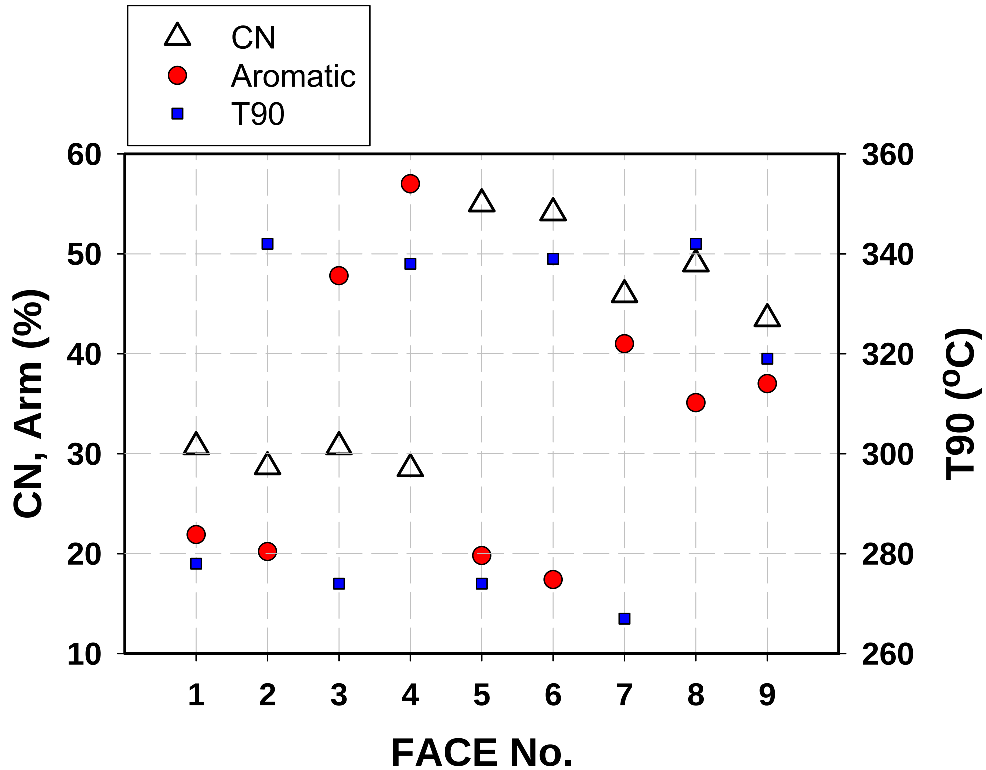
- To investigate the respective effects of cetane number (CN), distillation temperature (T90) and aromatics content, it is important to isolate these properties appropriately
- The Coordinating Research Council's (CRC) Fuels for Advanced Combustion Engines (FACE) Group designed a fuel matrix to enable researchers to isolate the effects of CN, T90 and aromatic content on advanced combustion strategies

FACE Fuels
Design and Measured Values for CN, Arm, and T90

FACE Design Cube



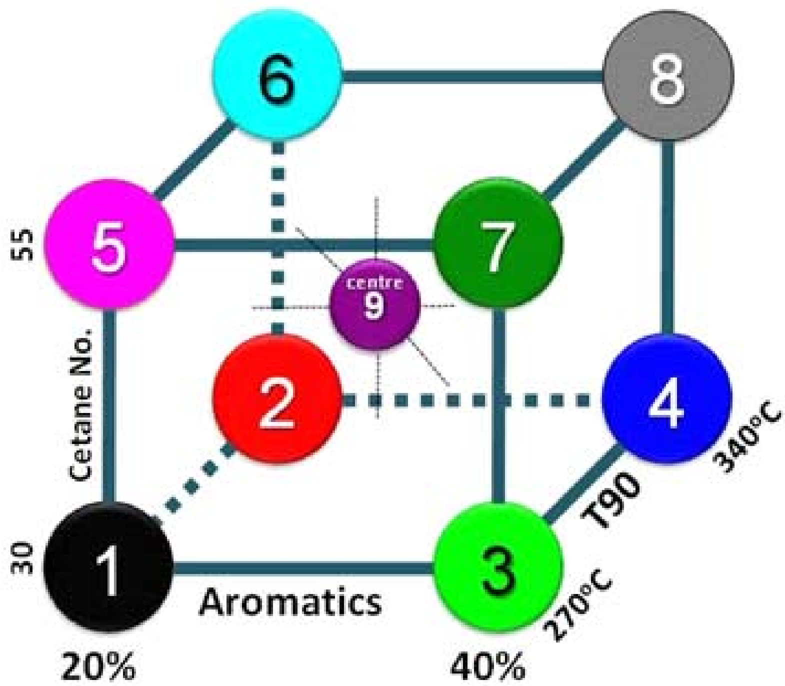
Measured Values



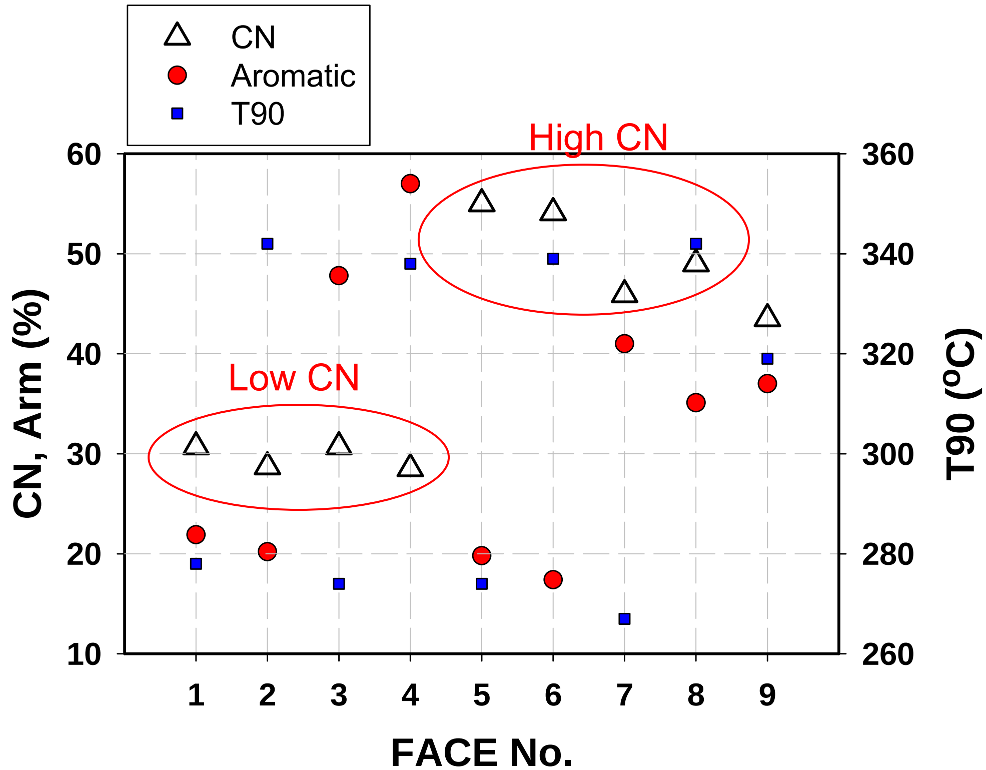
Fuels for Advanced Combustion Engines (FACE)

Design and Measured Values for CN, Arm, and T90

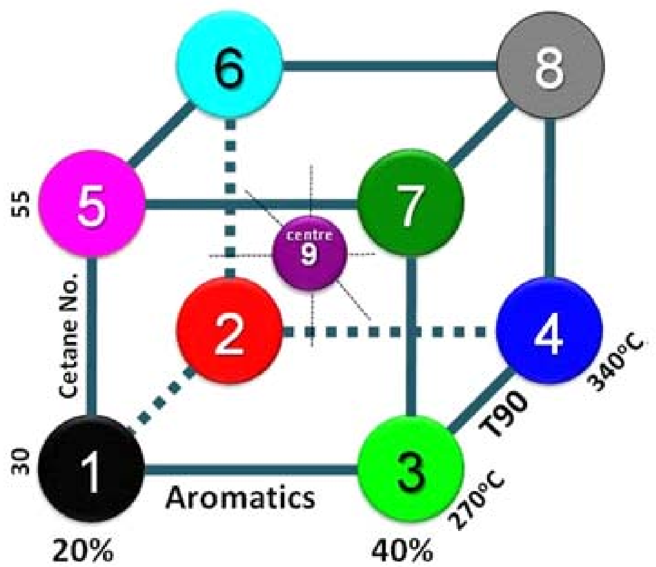
FACE Design Cube

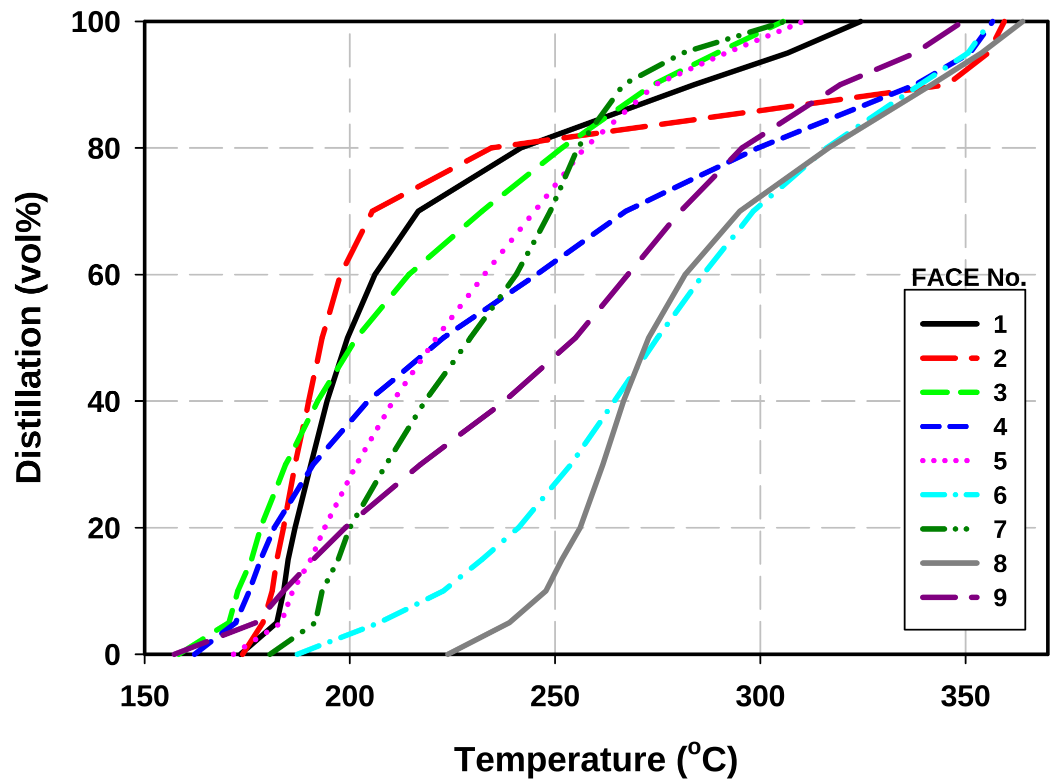


Measured Values

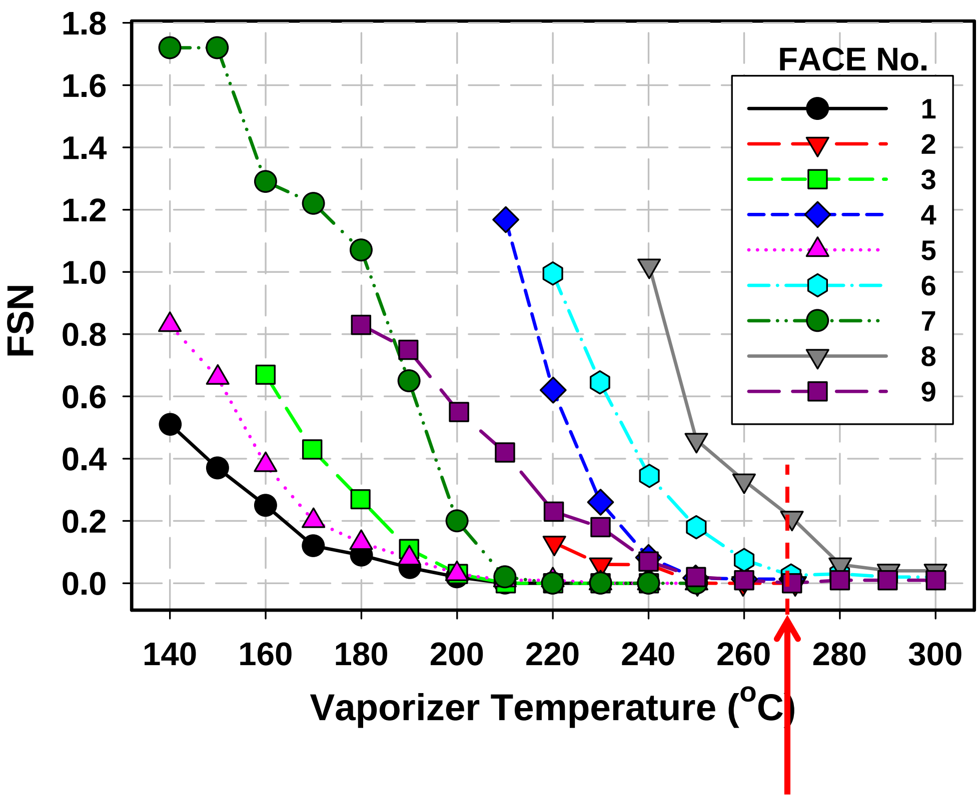


FACE Fuels
Distillation Curves

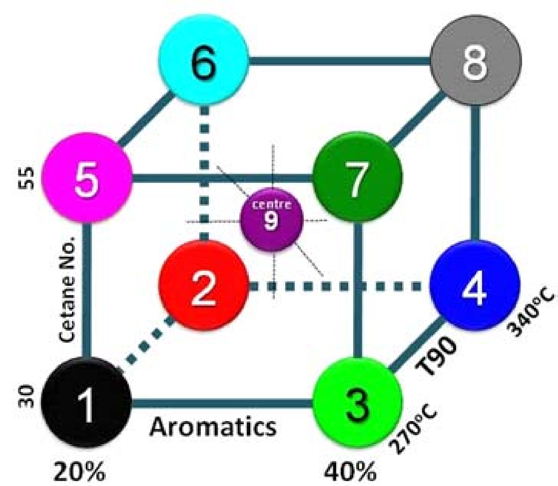




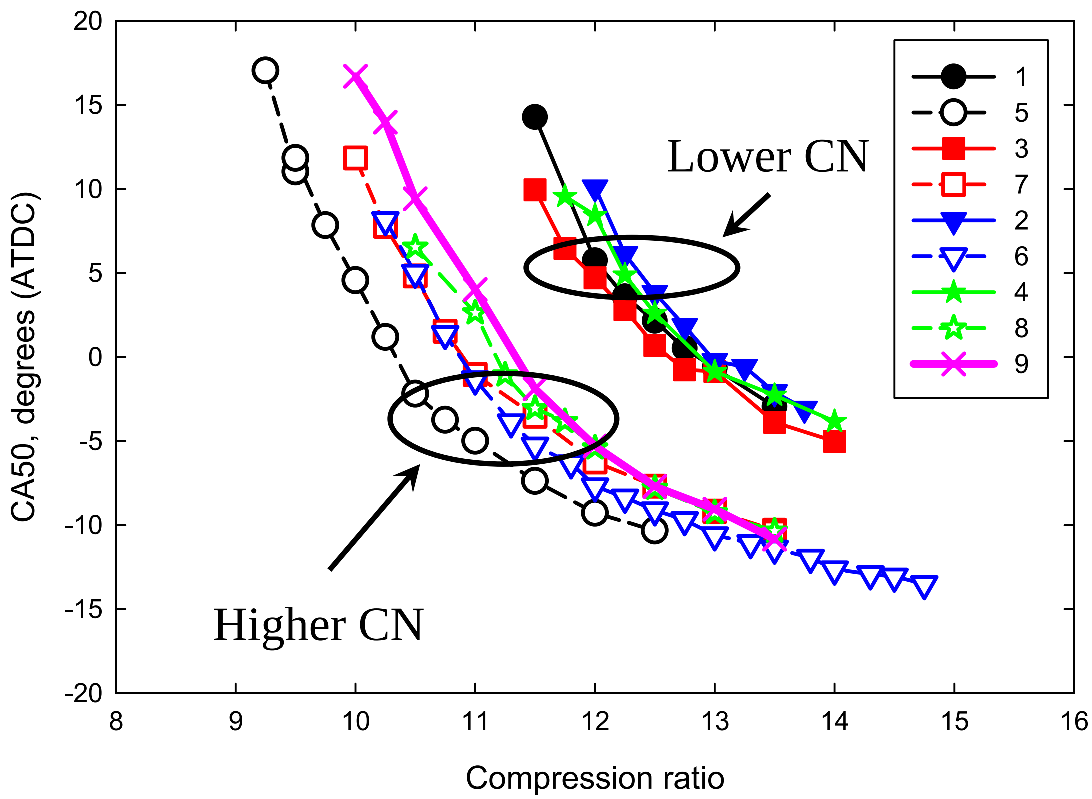
Vaporizer Temperature



- Determined based on sooting propensity
- T_{vap} range was limited at the low side by engine unstable operation.
- High T90 fuels (FACE No. 2, 4, 6, 8, and 9) produced the most soot emissions.
- T_{vap}=270 ˚C was selected for the rest of experiments.



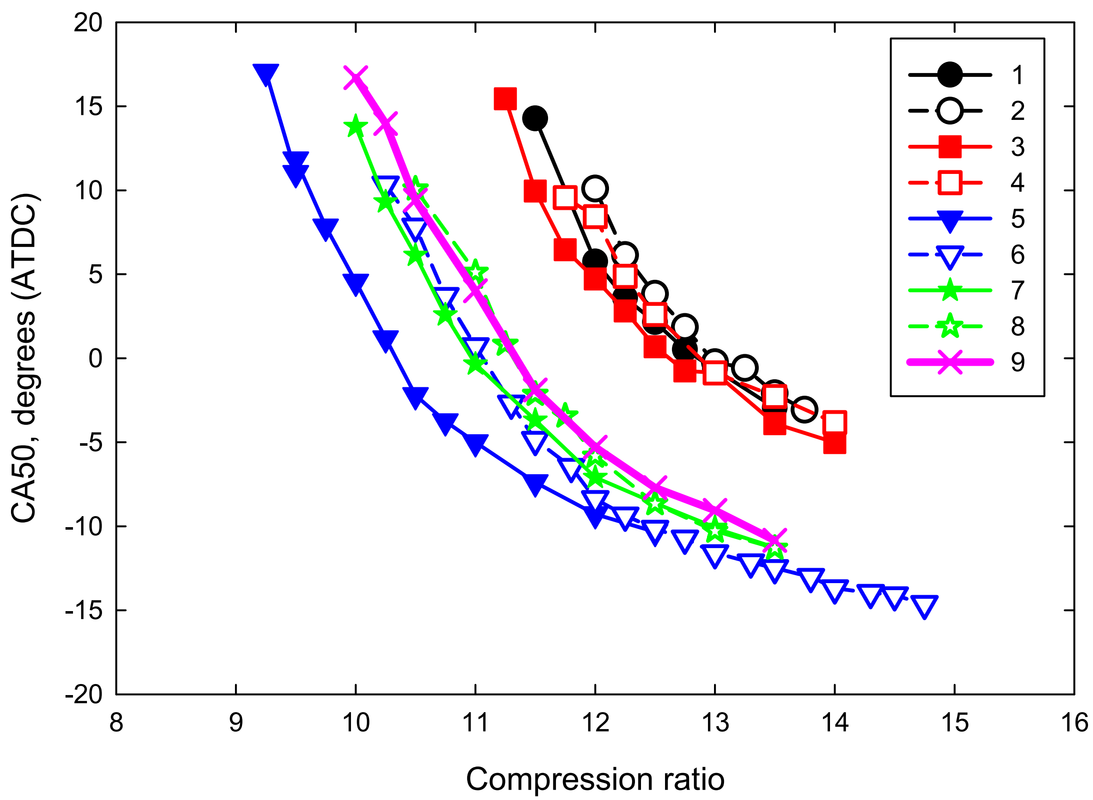
Combustion Phasing (CA50) – CN Effect



Open: **higher CN**
Filled: **lower CN**

- The higher the CN, the earlier the combustion phasing, suggesting that CN does play significant role in predicting ignition

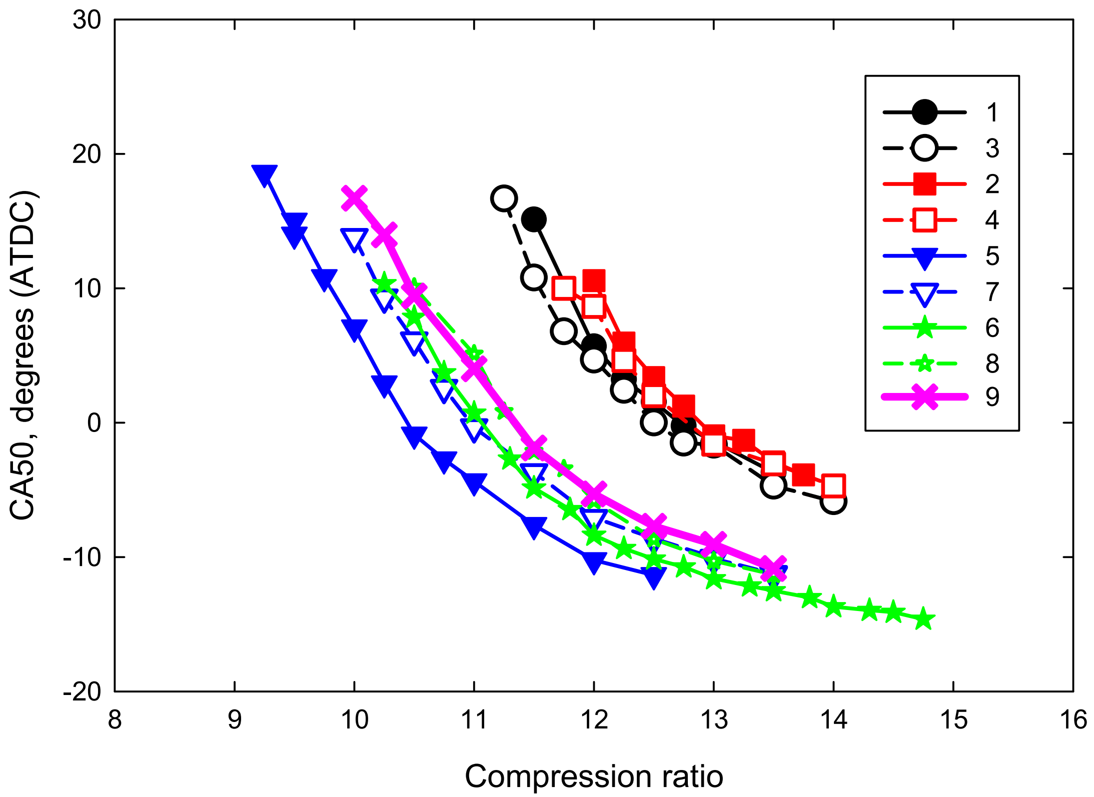
Combustion Phasing (CA50) – T90 Effect



Open: higher T90
Filled: lower T90

- The lower the T90, the earlier the combustion phasing, suggesting that T90 may also affect ignition

Combustion Phasing (CA50) – Aromatics Effect



Open: higher Arom.
Filled: lower Arom.

- No clear trend can be observed for the effect of aromatics content on ignition

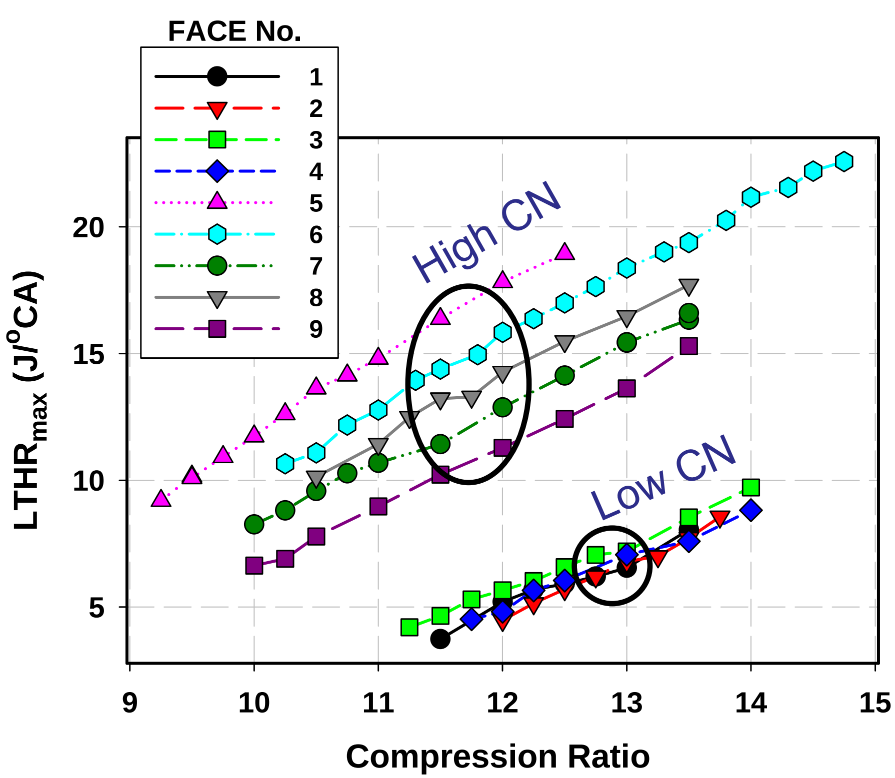
Combustion Phasing (CA50)

Regression analysis for CA50

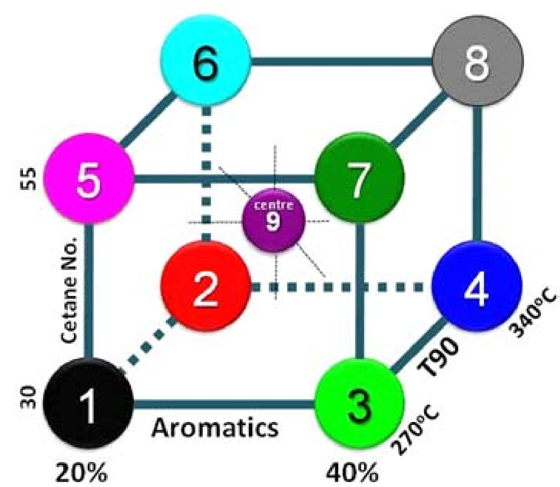
$$CA50=269.545-37.345\,CR+1.292\,CR^{2}-\mathbf{0.525}\,CN+\mathbf{0.038}\,T90+\mathbf{0.013}\,Arom$$

- The absolute values of the coefficient are in the order of b_{CN} (0.525) > b_{T90} (0.038) > b_{Arom} (0.013)

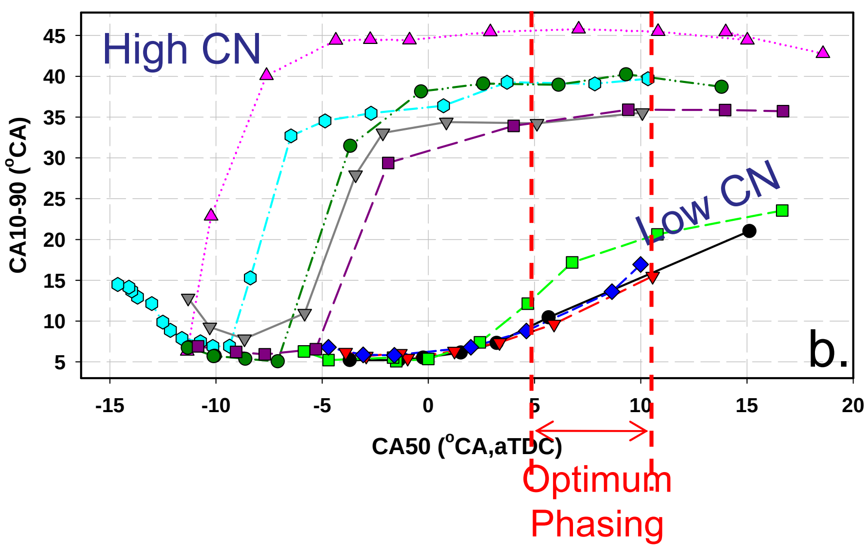
Low Temperature Heat Release (LTHR)



- Higher CN fuels released more energy during LTHR.
- T90 and Aromatic content did not significantly affect LTHR.



Combustion Duration ($CA_{10\text{-}90}$)



- At the optimum combustion phasing of CA50=5-10 ˚CA,aTDC, high CN fuels exhibited long combustion duration.
- An abrupt CA10-90 reduction was observed for high CN fuels around -5 ˚CA,aTDC.
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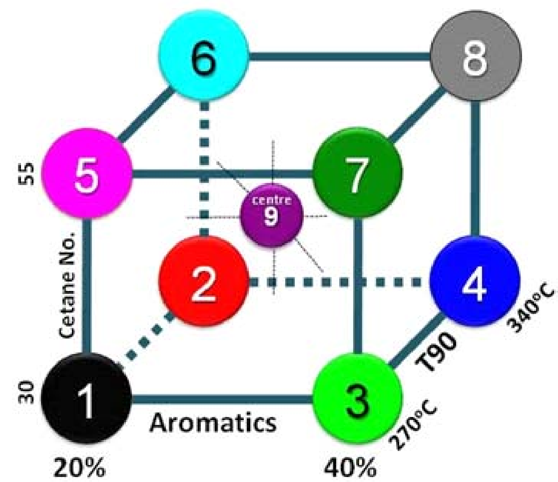
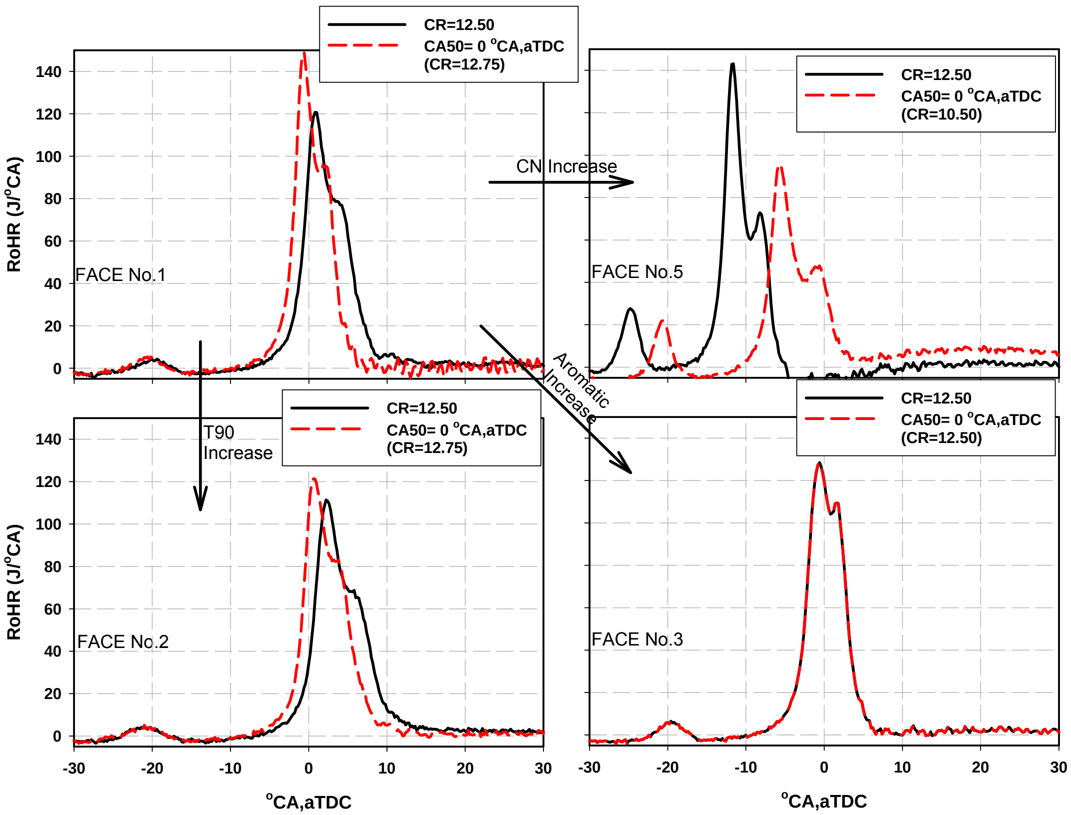
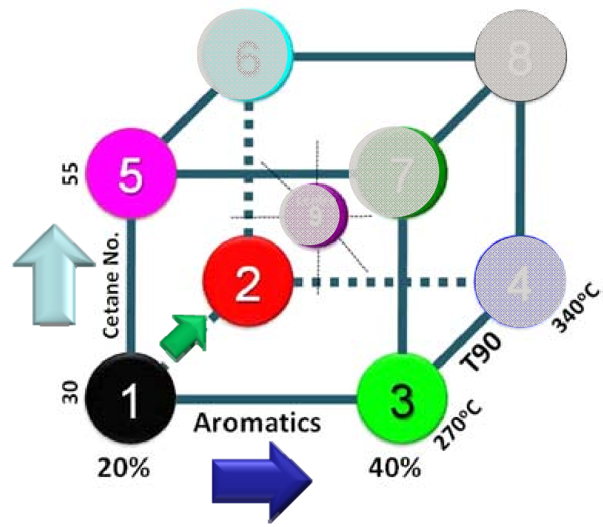


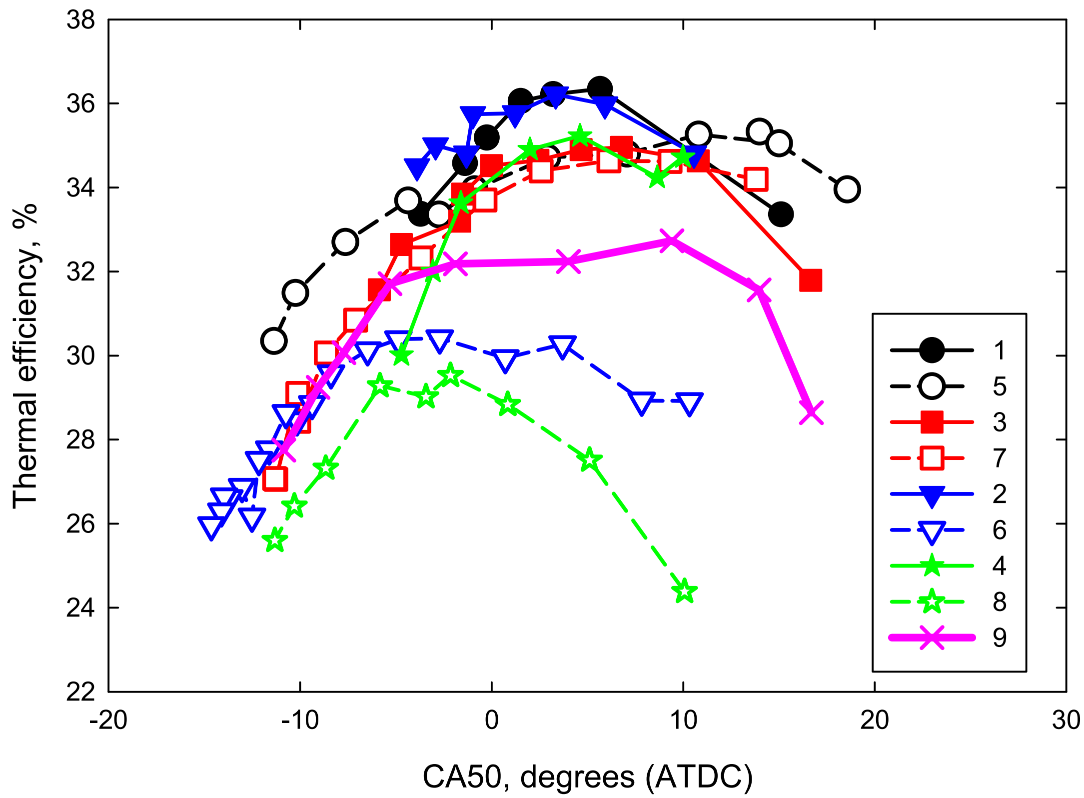
Rate of Heat Release (RoHR)



- RoHR was faster for low CN fuels.
- Strong dual stage HTHR was observed for high CN fuels resulted in prolonged CA10-90.



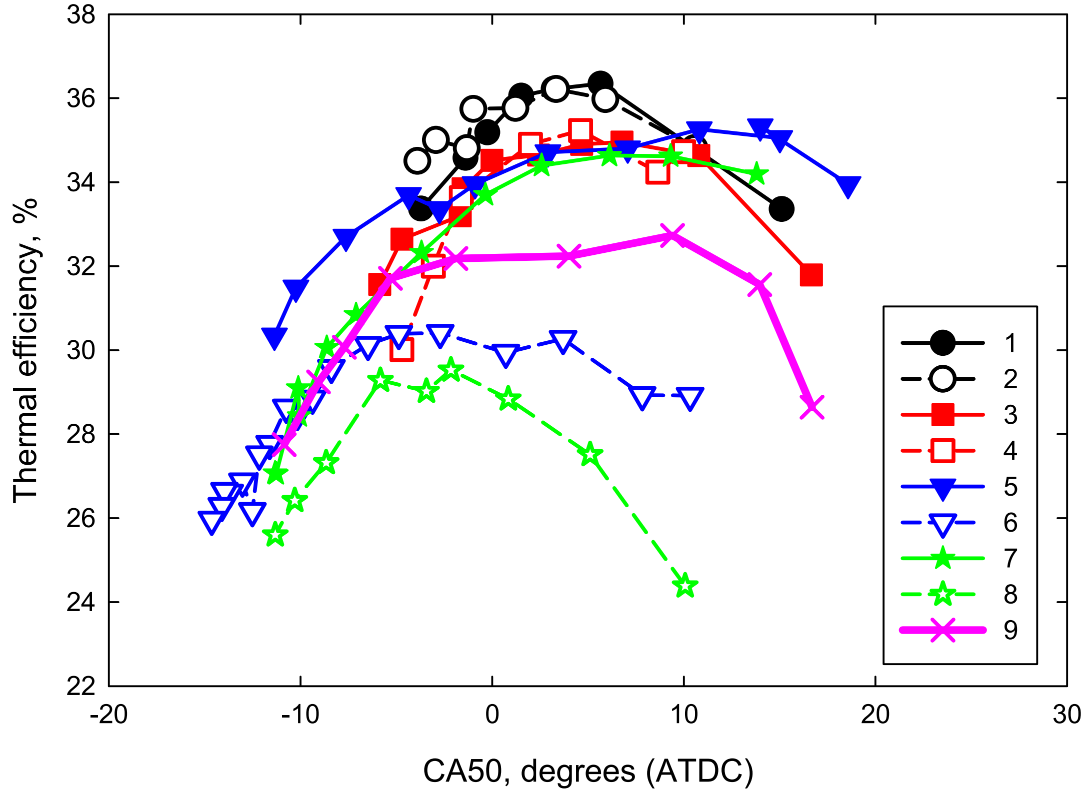
Thermal Efficiency – CN Effect



Open: higher CN
Filled: lower CN

- Lower CN fuels offer higher thermal efficiency, possibly due to optimized combustion phasing and shorter combustion duration

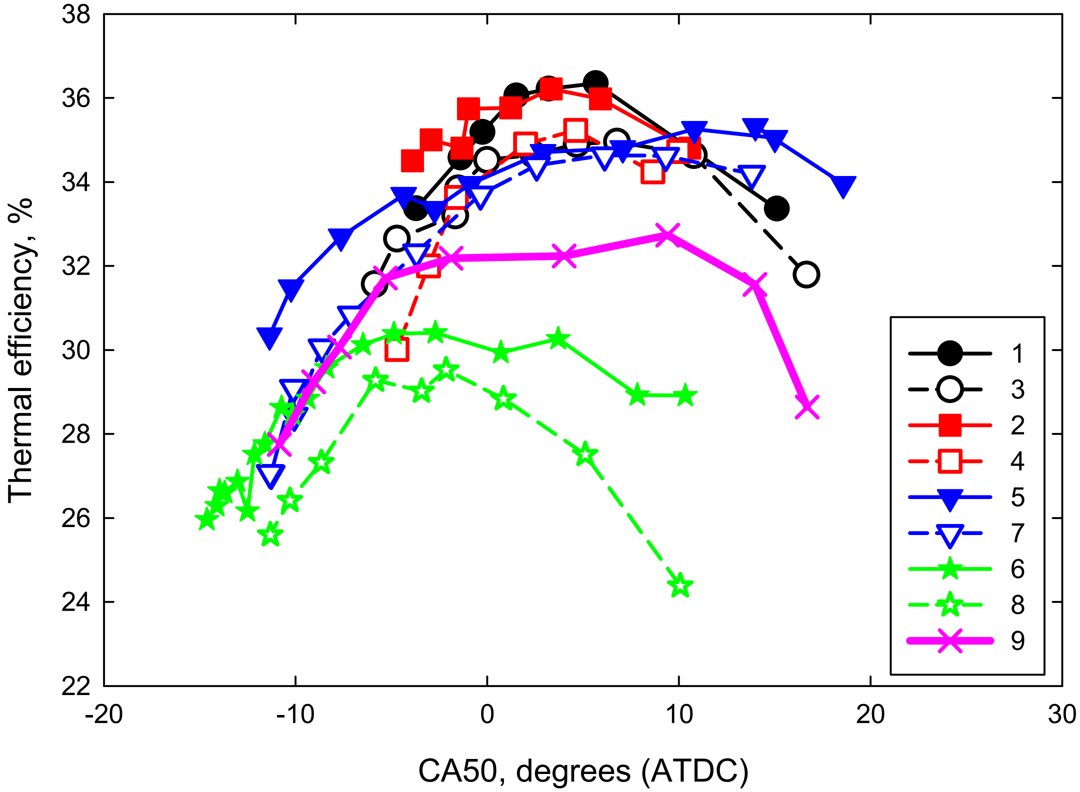
Thermal Efficiency – T90 Effect



Open: higher T90
Filled: lower T90

- For higher CN fuels (blue and green), the higher the T90, the lower the thermal efficiency
- For lower CN fuels (black and red), effect of T90 on thermal efficiency is negligible (possibly the effect is offset by CN effect)

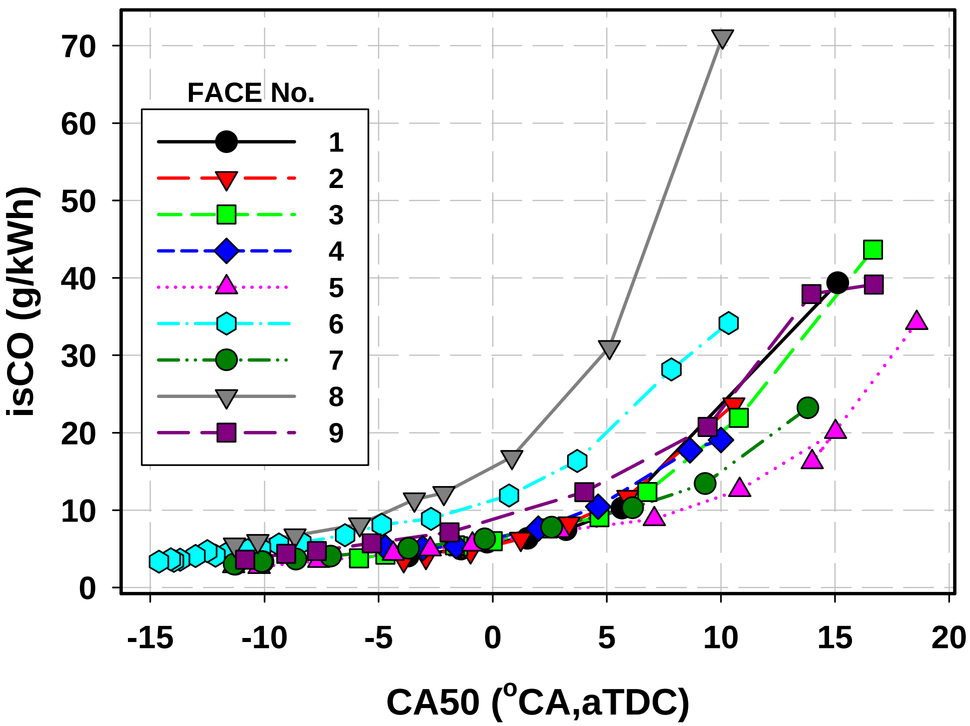
Thermal Efficiency – Aromatics Effect



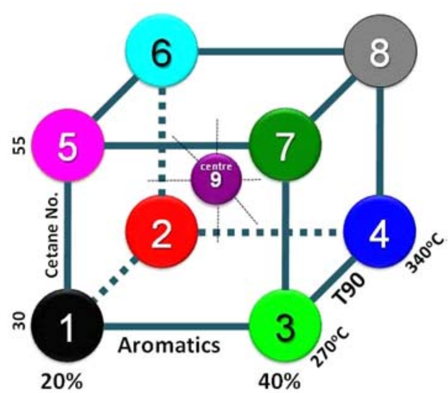
Open: higher Arom.
Filled: lower Arom.

- **The higher the aromatics content, the lower the thermal efficiency**

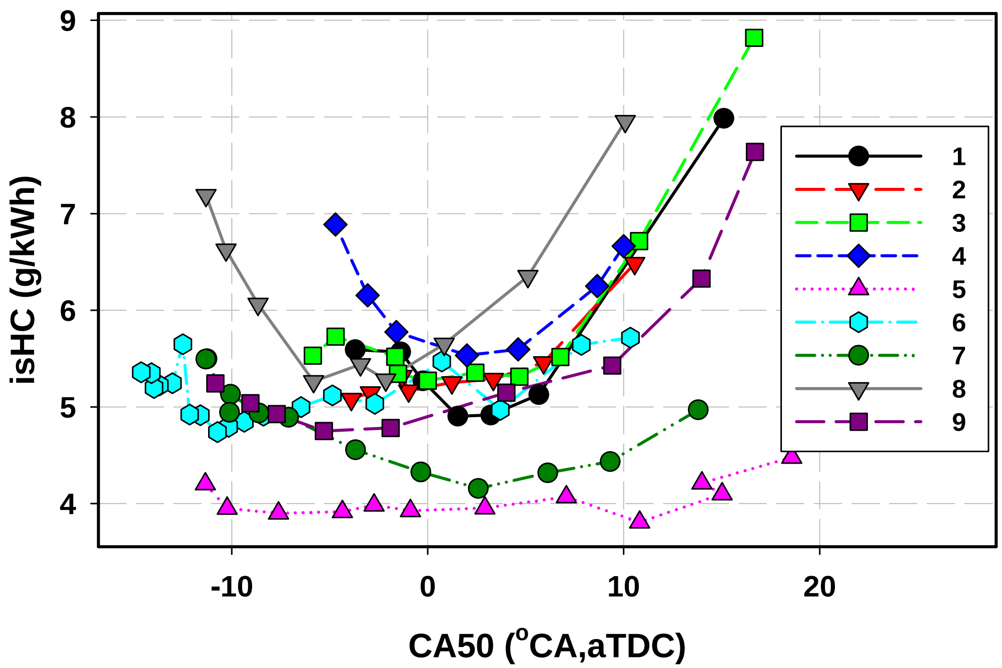
CO Emissions

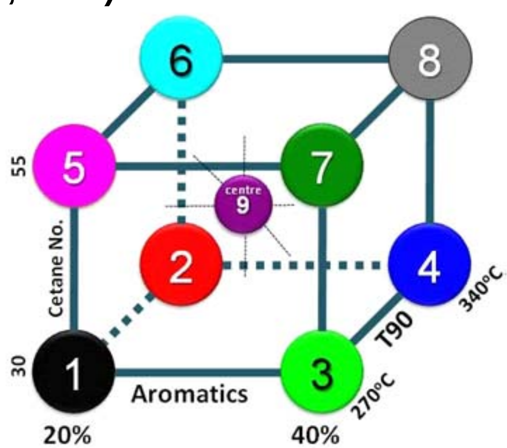


- CO emissions were mostly function of operating conditions
- Fuels No. 6 and 8 (high T90, high CN) produced more CO emissions



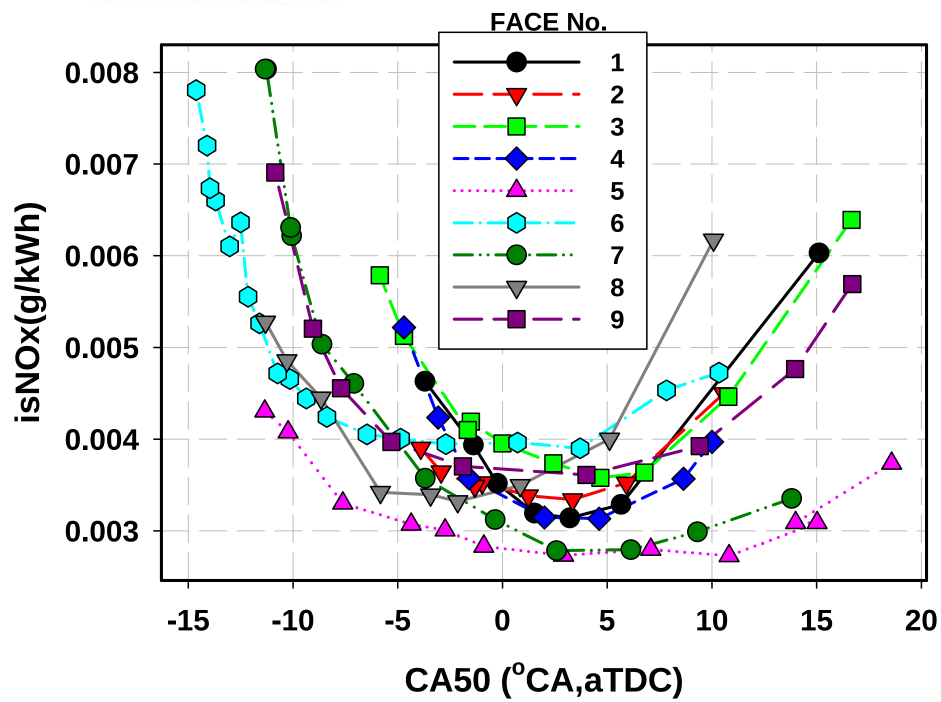
Unburned Hydrocarbon (HC) Emissions



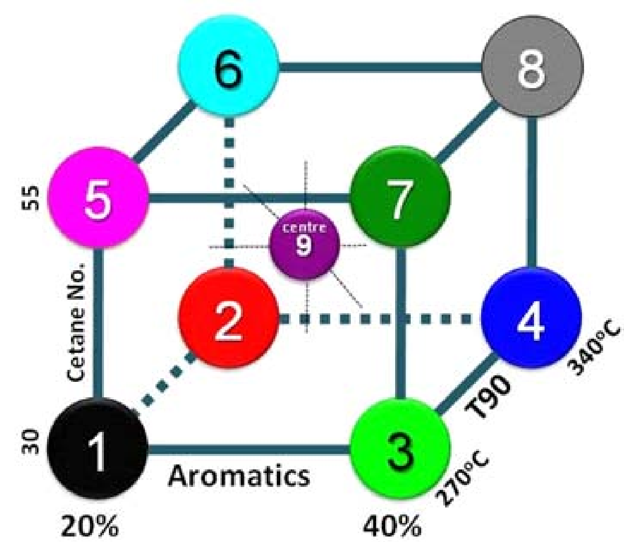


- HC emissions were a function of both operating conditions and fuel properties
- Low CN, high T90 fuels produced more HC emissions.
- High CN, low T90 fuels produced less HC emissions.

NOx Emissions



- NO_x emissions were generally low and mostly function of operating conditions.
- High CN, low T90 fuels produced the least NO_x emissions.



Conclusions

- Combustion phasing
  - Increasing CN or decreasing T90 advances the combustion phasing, with CN effect being more significant
  - The effect of aromatics content is negligible
- Combustion duration
  - High CN fuels exhibit longer combustion duration at optimized operating condition
- Thermal efficiency
  - The higher the CN, the lower the thermal efficiency
  - For higher CN fuels, the higher the T90, the lower the thermal efficiency; For lower CN fuels, T90 effect is negligible
  - The higher the aromatics content, the lower the thermal efficiency
- Emissions
  - CO emissions are basically of function of operating condition, but fuels with high CN and higher T90 emit more CO
  - Fuels with lower CN and higher T90 produce more HC
  - NOx emissions basically depend on operating conditions

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Questions?

Science at work for Canada

Thank you for your attention

(vahid.hosseini@nrc-cnrc.gc.ca)

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