HCCI Combustion of FACE Diesel Fuels

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Canada

Outline

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National Research Council Canada (NRCC)

- NRCC is an agency of the Government of Canada
- NRCC employs ~4300 people across Canada
- The Institute for Chemical Process and Environmental Technology (ICPET) is one of more than 20 institutes and national programs at NRCC
- ICPET's fuels chemistry research effort supports sustainable development of Canada's oil sands

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Research Facilities

HCCI Combustion

Cooperative Fuel Research (CFR) engine
with air-assist port fuel injector/vaporizer

Clean Diesel Combustion

Caterpillar SCOTE engine with
Ganser CRS fuel injector

Objectives

- Develop a fundamental understanding of fuel chemistry effects on the compression ignition behavior of homogeneous mixtures of diesel fuel, air and recycled exhaust products
- Develop HCCI fuel rating methods, if warranted and required, to support the usage of this advanced combustion strategy

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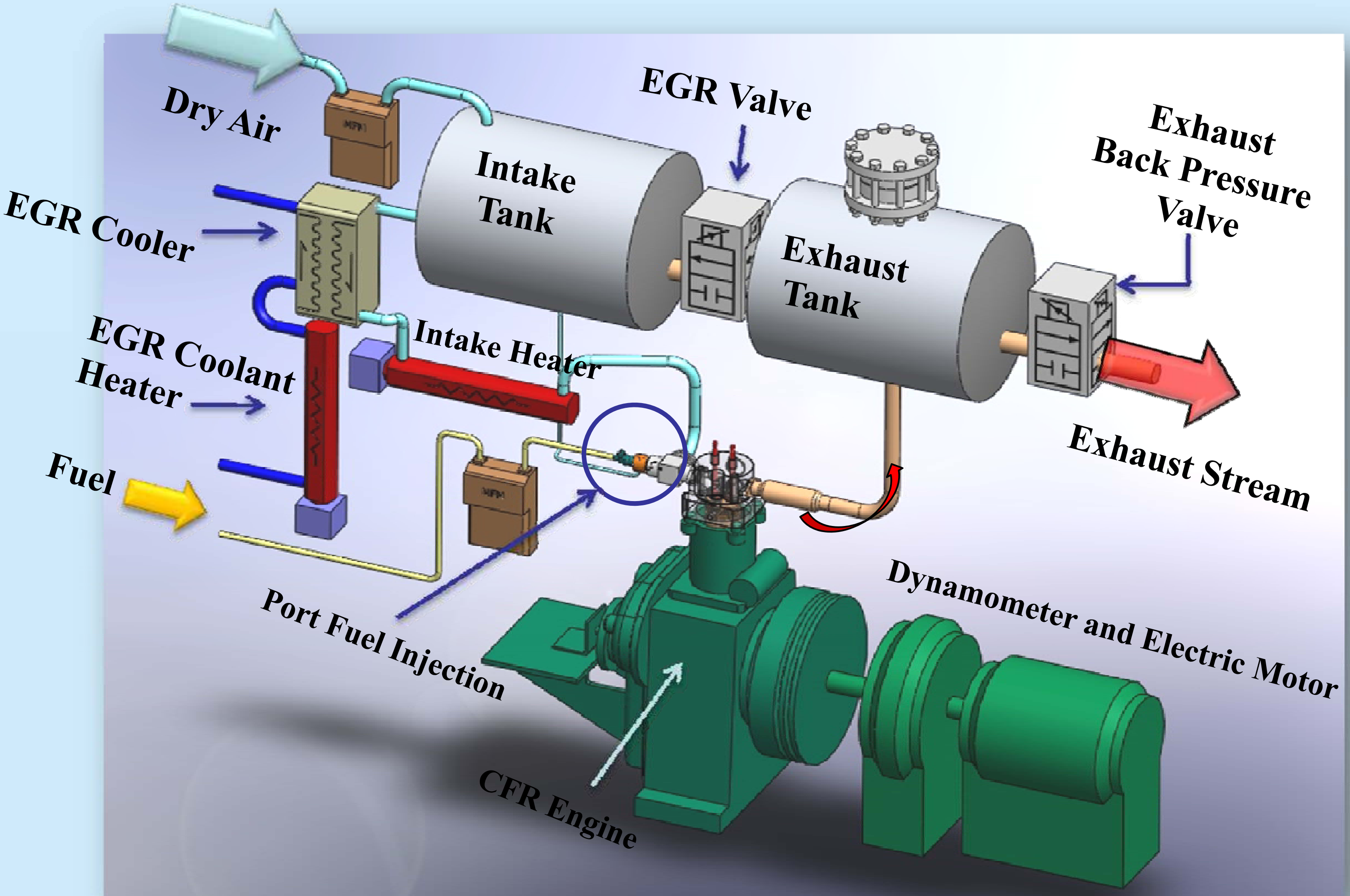
Experimental Setup

HCCI Research Laboratory



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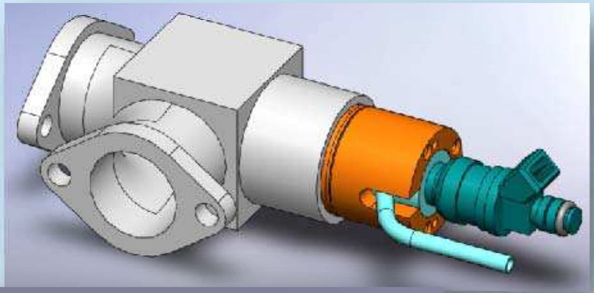
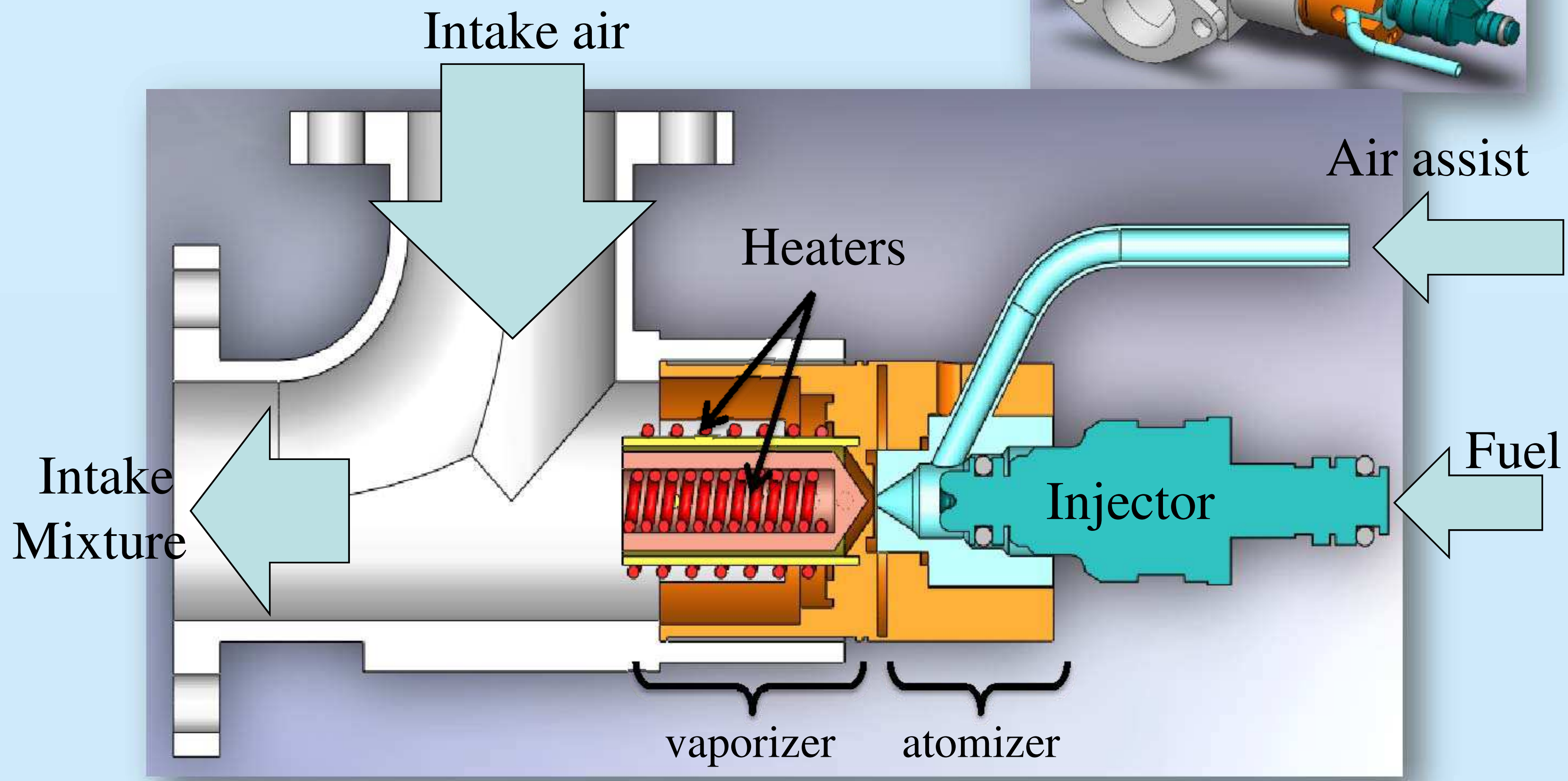
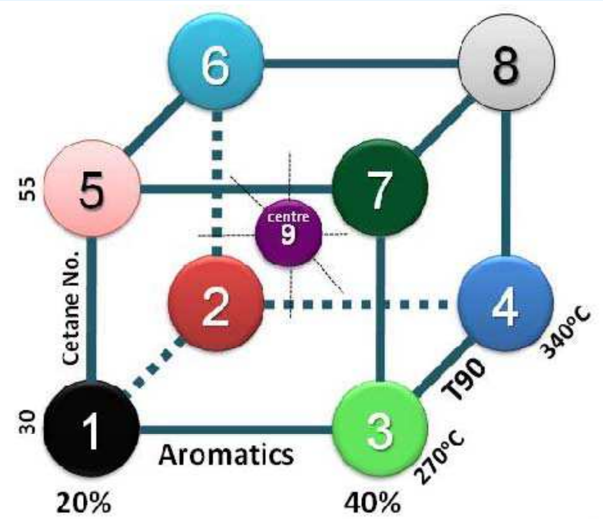
Experimental Setup

Fuel Injector/Vaporizer





FACE Fuels



FACE	Cetane Number	Aromatic Content	T90
1	Low	Low	Low
2	Low	Low	High
3	Low	High	Low
4	Low	High	High
5	High	Low	Low
6	High	Low	High
7	High	High	Low
8	High	High	High
9	Center	Center	Center

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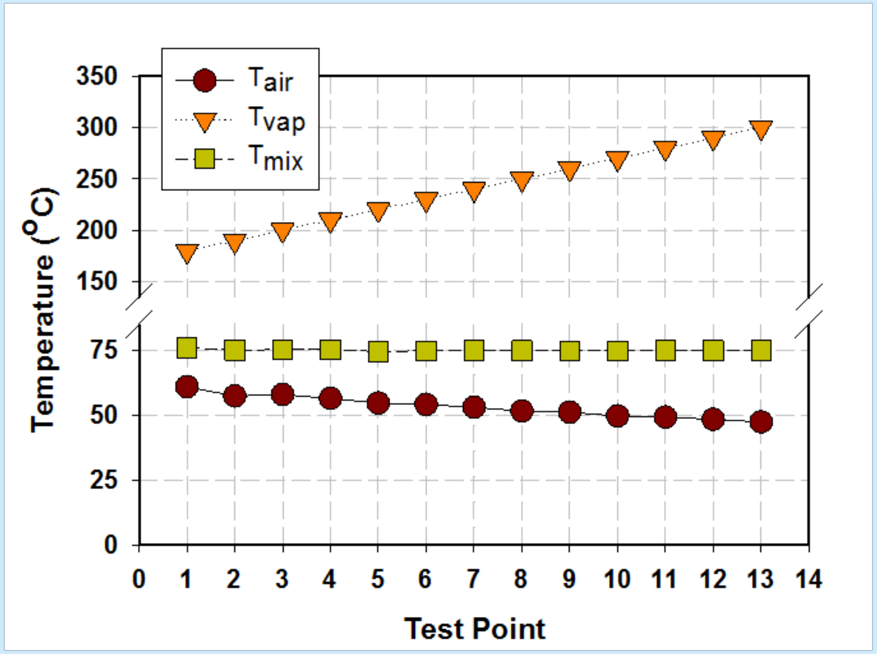
T_{vap} Experiment - I

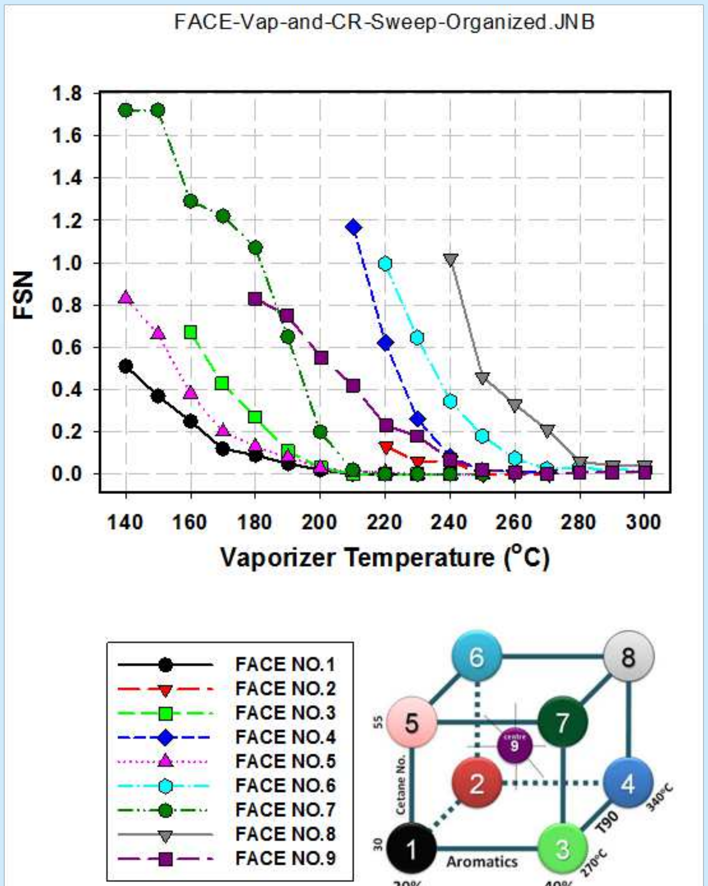
Input Parameter	Value
Speed	900 rpm
λ	3.5
CR	12.25:1
MAP	110 kPa
EGR	0 %
T_{mix}	75 °C
T_{air}	variable
T_{vap}	variable

T_{vap} Experiment - II



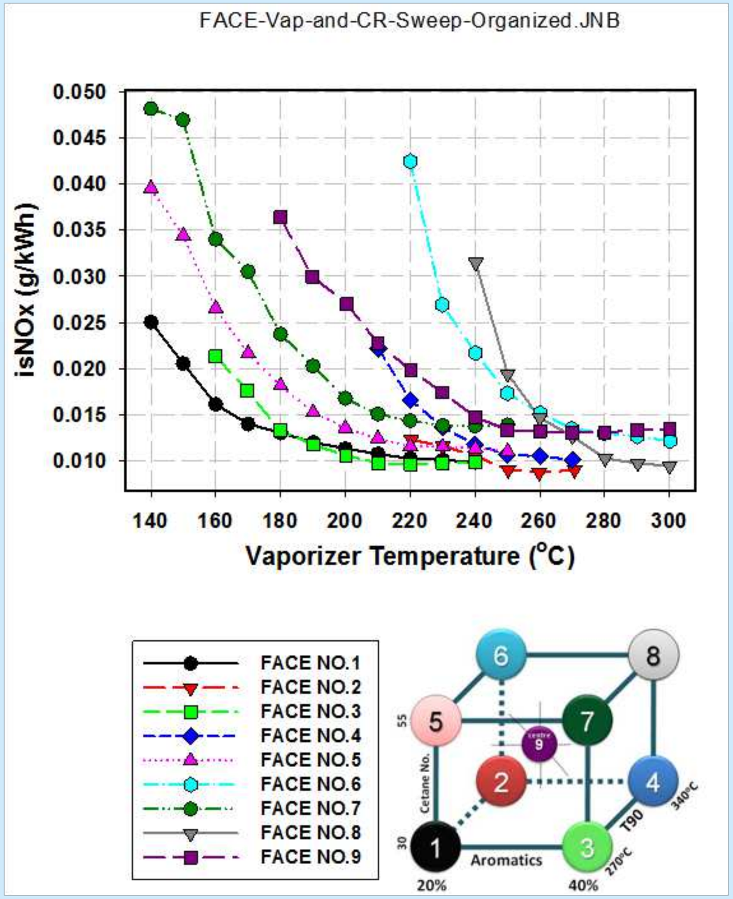
- Objective was to determine the minimum vaporizer temperature (T_{vap}) which would enable us to achieve HCCI combustion with near-zero soot and NO_x emissions for all FACE fuels
- Varied T_{vap} from 140 to 300°C while maintaining a constant fuel-air mixture temperature at the intake port

AVL FSN vs. T_{vap}



- HCCI combustion produced soot if the fuel was not fully vaporized and mixed with air
- The nine FACE fuels had different vaporizer temperature requirements to achieve 0 FSN
- The two high CN, high T90 fuels (6 & 8) had the highest sooting propensity
- The two low CN, low T90 fuels (1 & 5) had the lowest sooting propensity

isNO$_x$ vs. T$_{vap}$



- isNO$_x$ emissions were <0.015g/kW-hr for all FACE fuels when the vaporizer temperature was 270°C or higher
- As a reminder, EGR was not used in this experiment
- As expected, there was no trade-off between soot and NO$_x$ emissions

isHC & isCO vs. T_{vap}

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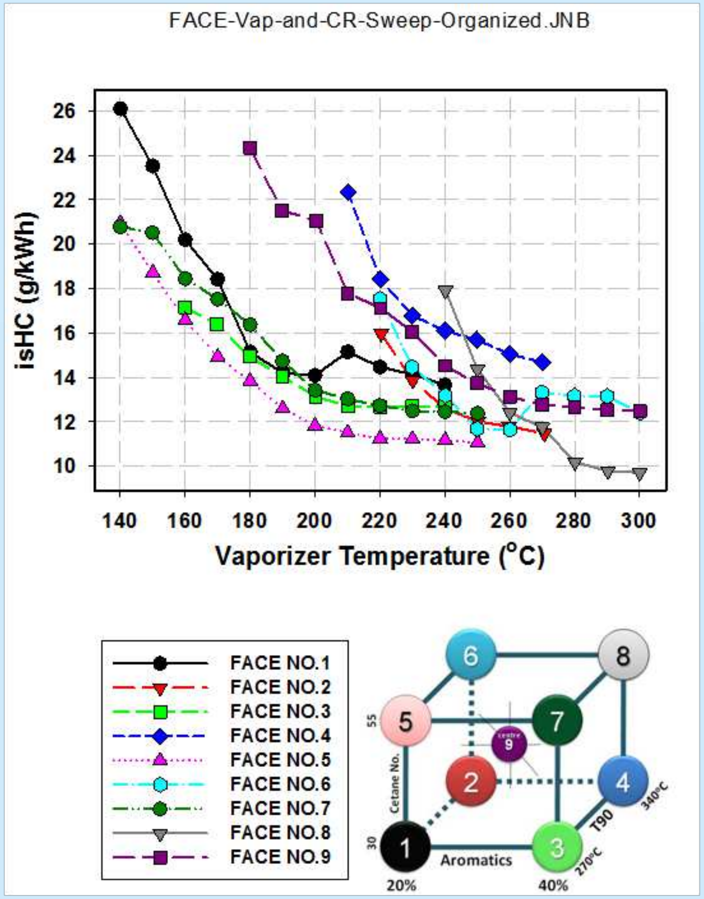
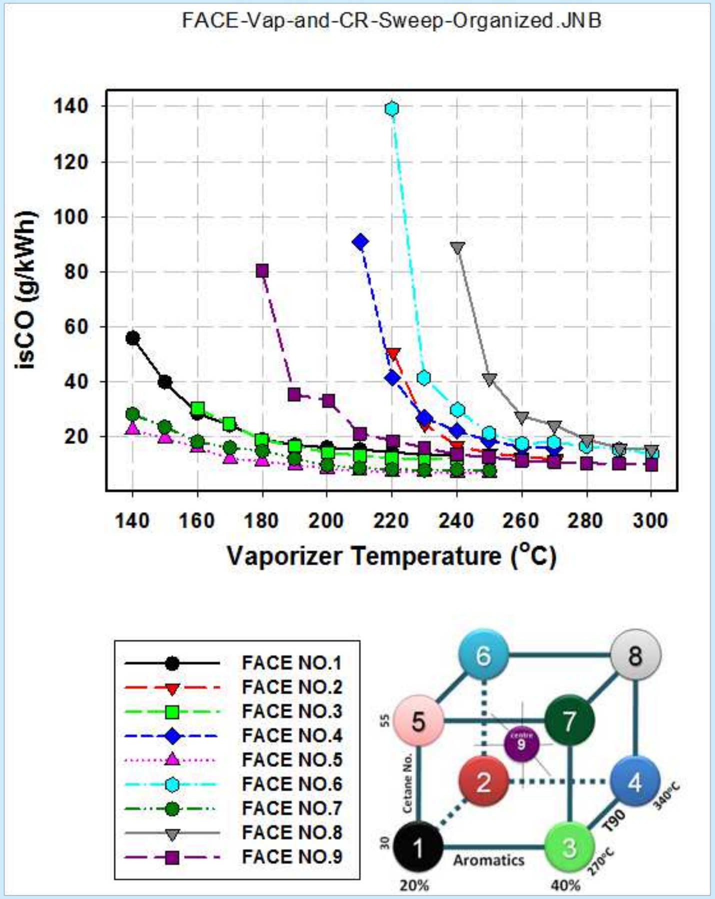




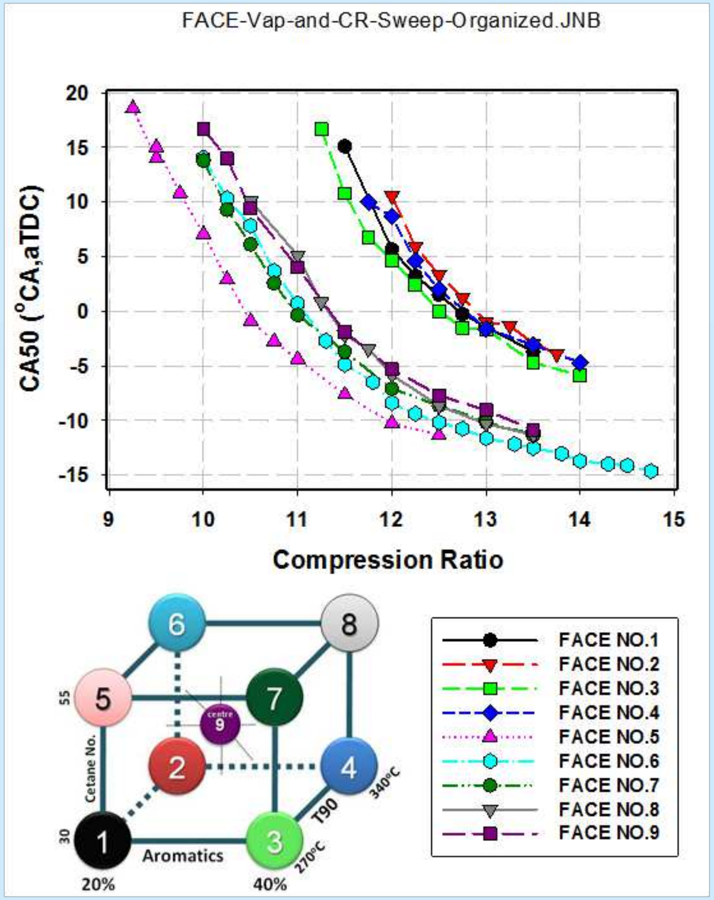
Preliminary Results

- Pure HCCI combustion with near-zero soot and NO_x emissions was realized with all nine FACE fuels when the vaporizer temperature was 270°C or higher (without EGR)
- For pure HCCI combustion, improving the homogeneity of the fuel-air mixture simultaneously reduced soot, NO_x, HC and CO emissions
- The sooting propensity of different fuels may be rated by measuring soot emissions as a function of fuel vaporizer temperature
  - The two high CN, high T90 fuels (FACE No. 6 & 8) had the highest sooting propensity
  - The two low CN, low T90 fuels (FACE No. 1 & 3) had the lowest sooting propensity

CR Sweep - I

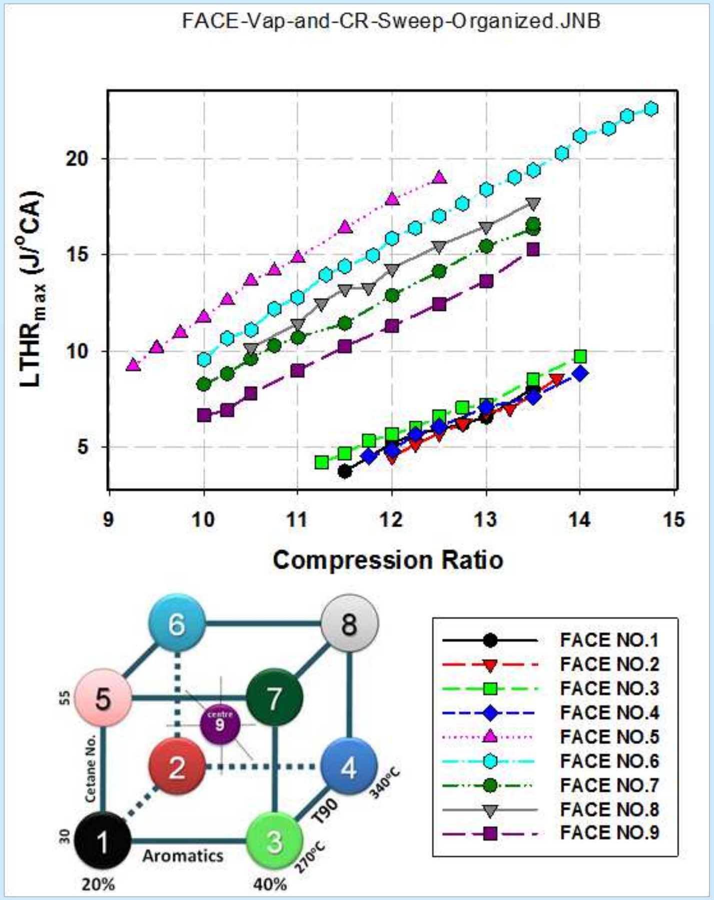
Input Parameter	Value
Speed	900 rpm
λ	**1.2**
CR	**variable**
MAP	110 kPa
EGR	**60%**
T_{mix}	75°C
T_{air}	variable
T_{vap}	**270°C**

CA50 vs. CR



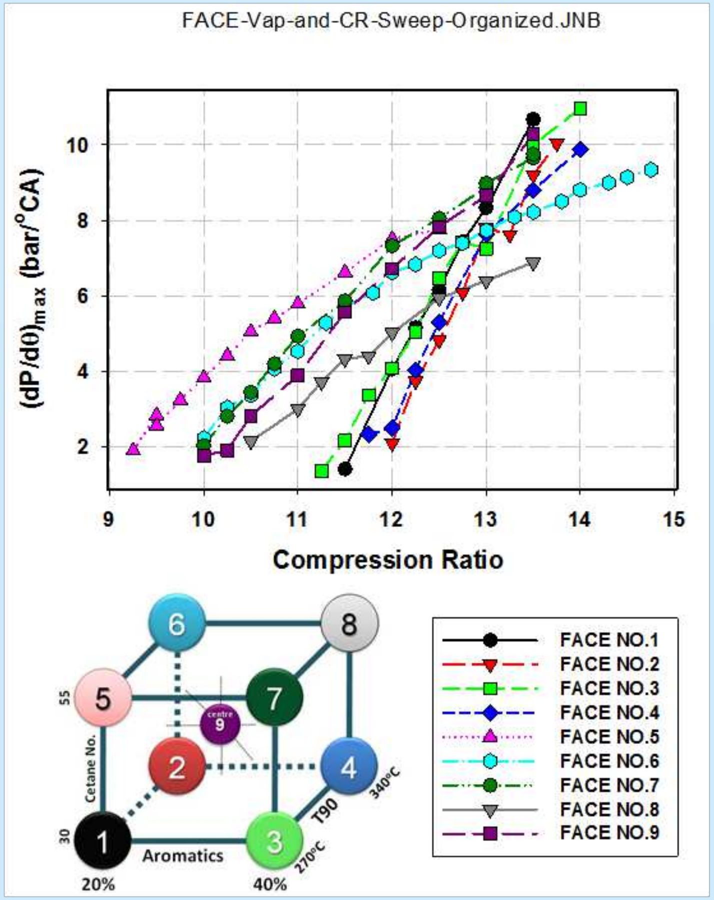
- HCCI combustion phasing (CA50) is a strong function of engine CR
- The four low CN fuels exhibited significantly delayed CA50 phasing compared to the remaining five higher CN fuels

LTHR$_{max}$ vs. CR



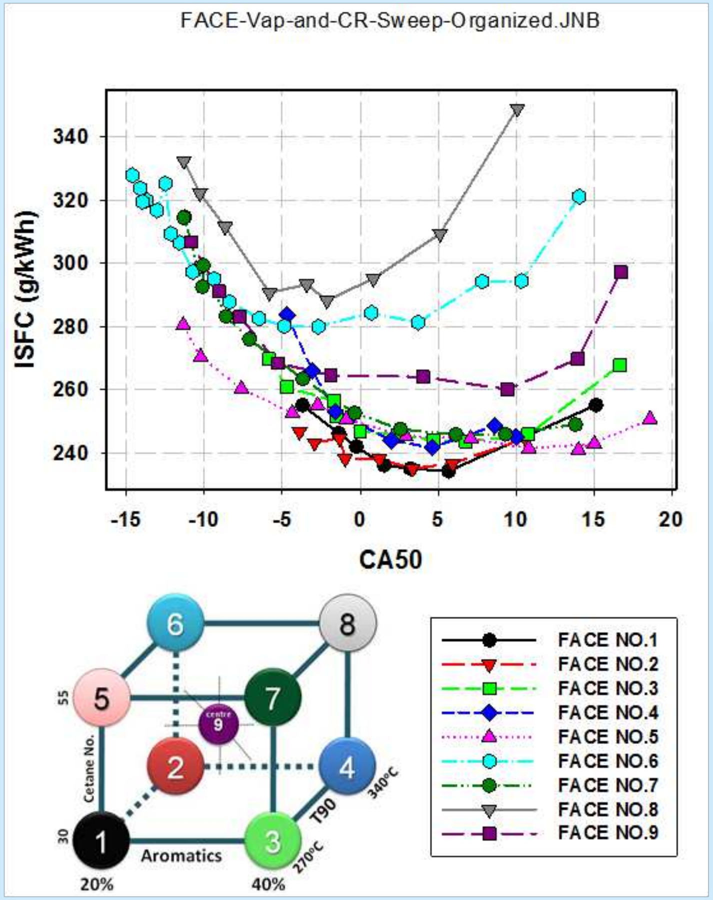
- The delayed CA50 phasing for the four low CN fuels was due to reduced low temperature heat release (LTHR) compared to the five higher CN fuels
- The LTHR$_{max}$ (or LTHR energy fraction) seems to correlate strongly with measured CN for the five higher CN fuels

$(dP/d\theta)_{max}$ vs. CR



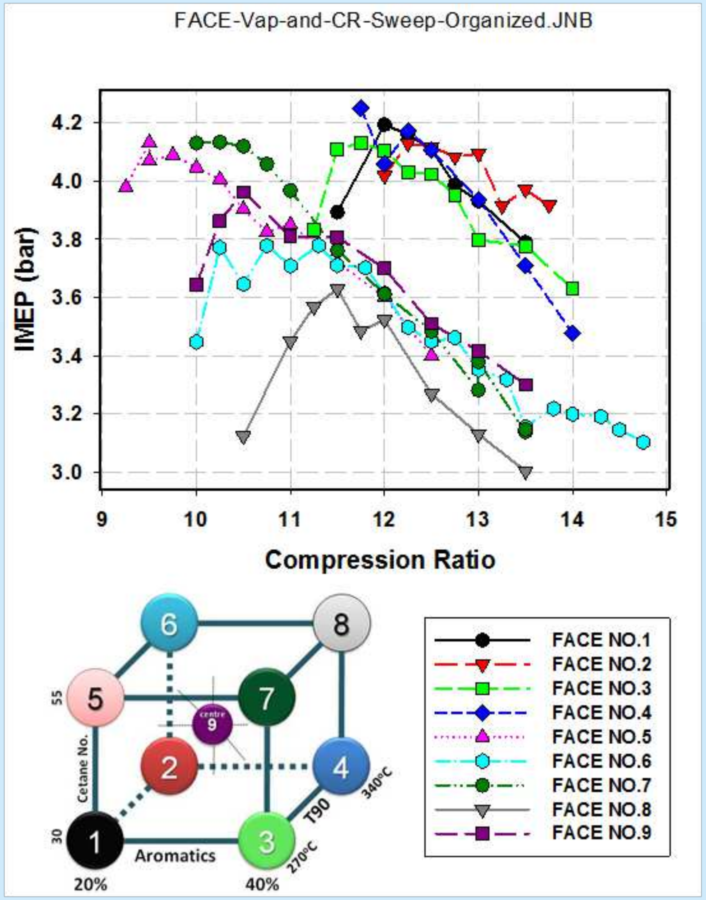
- The higher CN fuels exhibited higher rates of cylinder pressure rise for CRs up to 13
- The maximum rate of pressure rise of the lower CN fuels was more sensitive to CR changes

ISFC vs. CA50



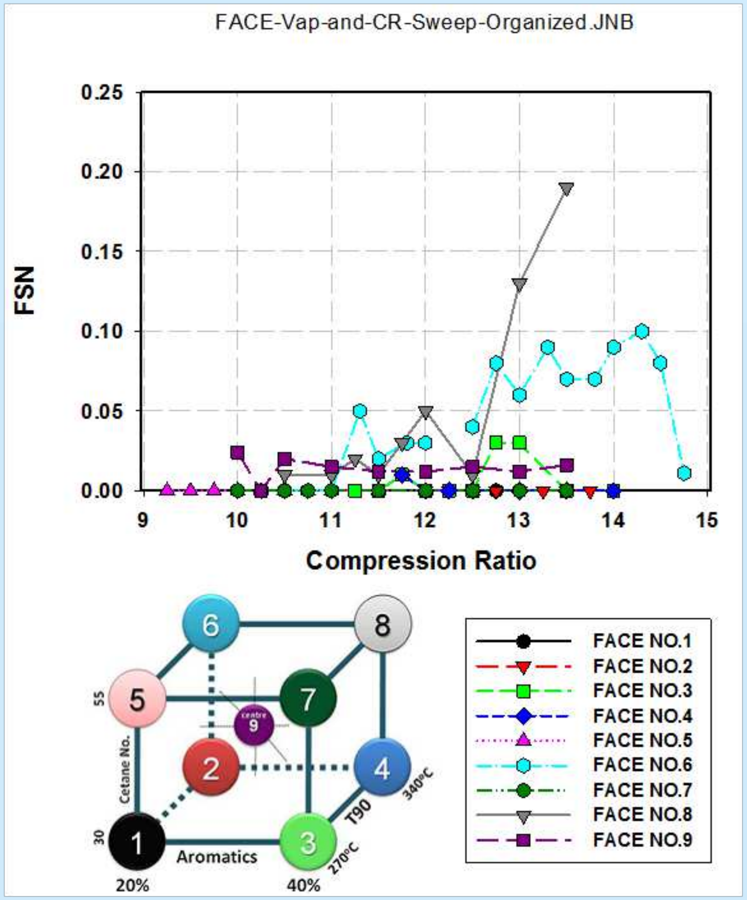
- The minimum ISFC for the four low CN fuels occurred when CA50 was ~5°ATDC
- The minimum ISFCs for the lower CN fuels were better than those for the high CN fuels, but ISFCs of the low CN fuels seemed to be more sensitive to CA50 phasing
- The two low CN, low aromatic fuels (FACE No. 1 & 2) had the lowest minimum ISFCs
- The two high CN, high T90 fuels (FACE No. 6 & 8) had the highest minimum ISFCs

IMEP vs. CR



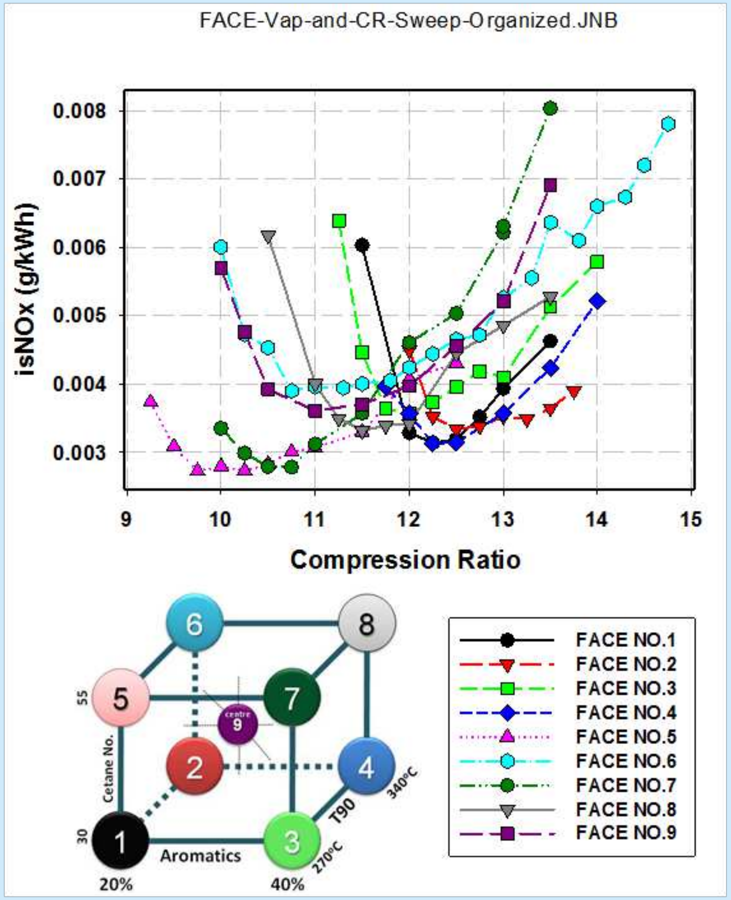
- The four low CN fuels (Face No. 1-4), as well as the two high CN, low T90 fuels (Face No. 5 & 7) were able to achieve the highest peak IMEPs at fixed MAP, λ and EGR
- The operating range, in terms of CR, was wider for the high CN fuels
- The high CN, high aromatic, high T90 fuel (FACE No. 8) had the lowest achievable peak IMEP at fixed MAP, λ and EGR

AVL FSN vs. CR



- The two high CN, high T90 fuels (FACE No. 6 & 8) produced measurable soot emissions at high CRs
- The same two fuels (FACE No. 6 and 8) were found to require the highest fuel vaporizer temperatures to achieve near-zero FSN in the previous experiment

$isNO_x$ vs. CR



- The $isNO_x$ emissions were extremely low for all FACE fuels with 60% EGR
- The two high CN, low T90 fuels (FACE No. 5 & 7) had the lowest minimum $isNO_x$ emissions

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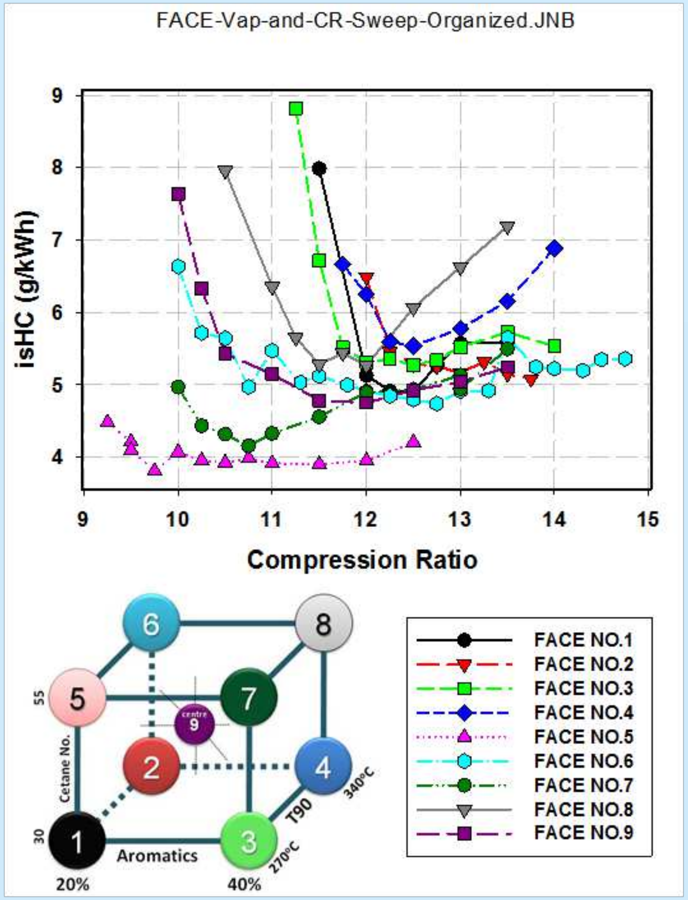
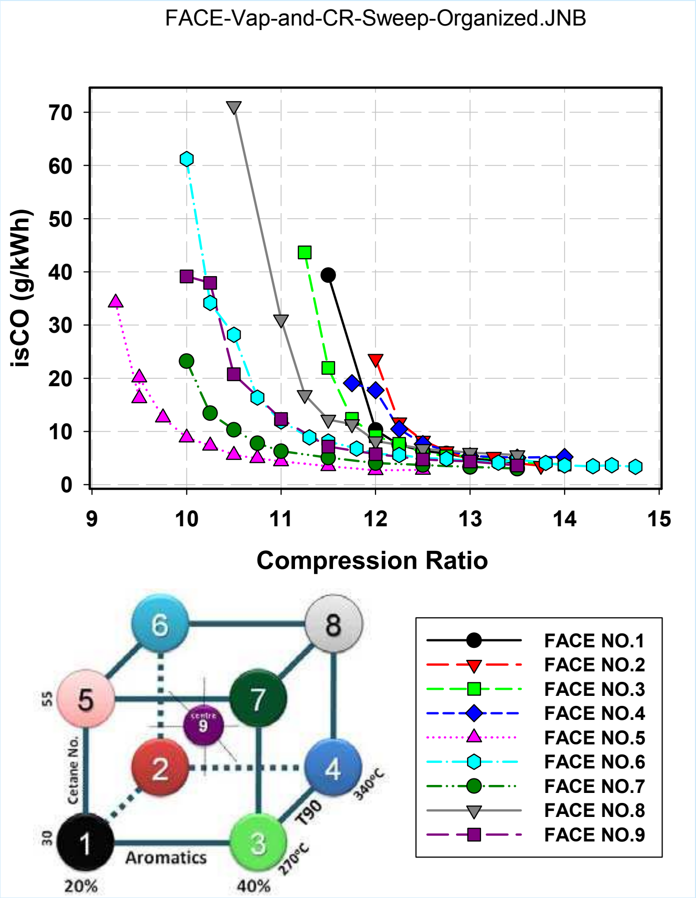
isHC vs. CR



- isHC emissions showed a strong dependence on fuel chemistry
- The two high CN, low T90 fuels (FACE No. 5 & 7) had the lowest minimum isHC emissions

isCO vs. CR



- isCO emissions were relatively independent of fuel chemistry at high CR
- At low CR, isCO emissions increased due to retarded combustion phasing that caused incomplete combustion

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Conclusions

Preliminary

The preliminary findings from our pure HCCI combustion experiments using the FACE fuels are as follows:

- The sooting propensity increased with increasing CN and T90
- The four low CN fuels (Face No. 1-4), as well as the two high CN, low T90 fuels (Face No. 5 & 7) were able to achieve the highest peak IMEPs at fixed MAP, λ and EGR
- The two low CN, low aromatic fuels (FACE No. 1 & 2) had the lowest minimum ISFCs
- The operating range, in terms of CR, was wider for the high CN fuels

Future Work

- Collect replicate data and perform statistical analyses of the experimental data
- Investigate HCCI combustion of fuels derived from oil sands and renewable sources
- Investigate PCCI combustion of FACE fuels under both low and moderate load conditions
  - comparison with HCCI combustion results
- Other suggestions?

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