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HCCI Combustion of FACE Diesel Fuels

Neill, W. Stuart; Hosseini, Vahid; Chippior, Wallace L.

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HCCI Combustion of FACE Diesel Fuels

W. Stuart Neill, Vahid Hosseini and Wallace L. Chippior

Presented to Diesel Cross-Cut Team January 21, 2010

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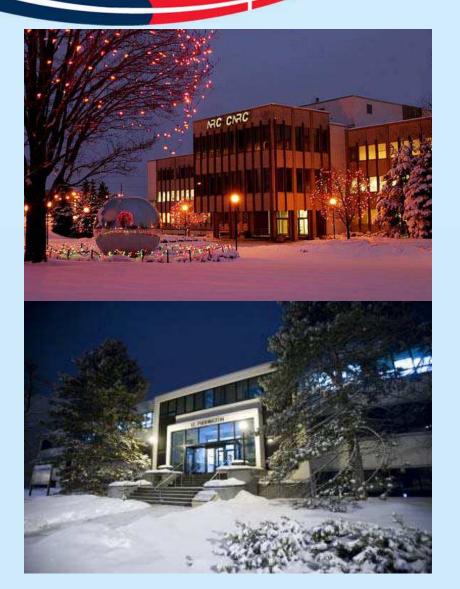
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Outline

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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

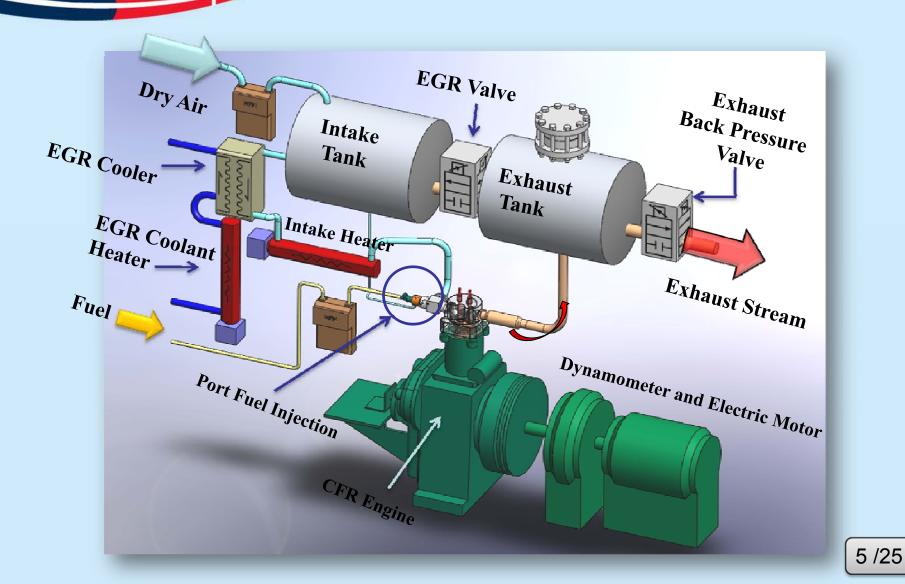
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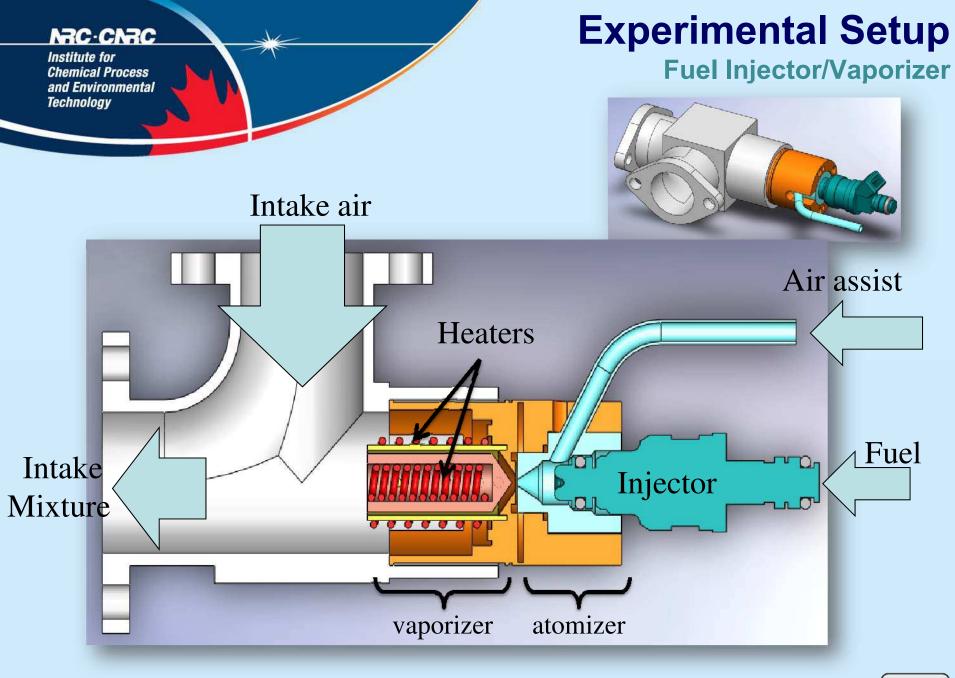
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- Develop a fundamental understanding of fuel chemistry effects on the compression ignition behavior of homogeneous mixtures of diesel fuel, air and recycled exhaust products
- Develop HCCI fuel rating methods, if warranted and required, to support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

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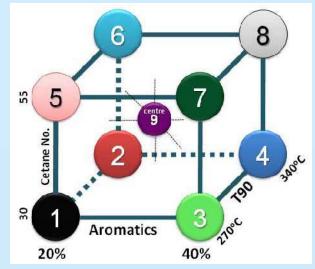
Experimental Setup HCCI Research Laboratory





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FACE Fuels



FACE	Cetane Number	Aromatic Content	Т90
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

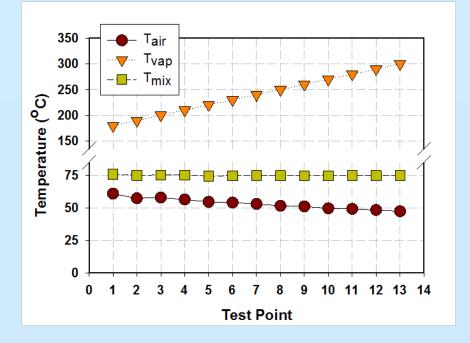
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T_{vap} Experiment - I

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

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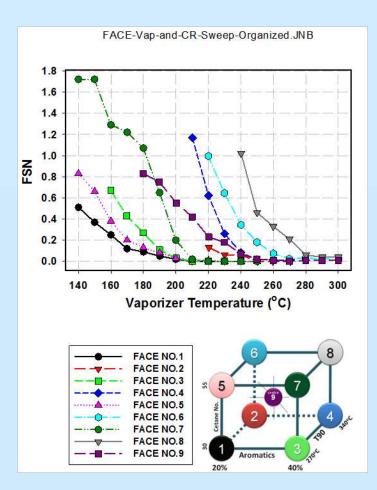
T_{vap} **Experiment - II**



- 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

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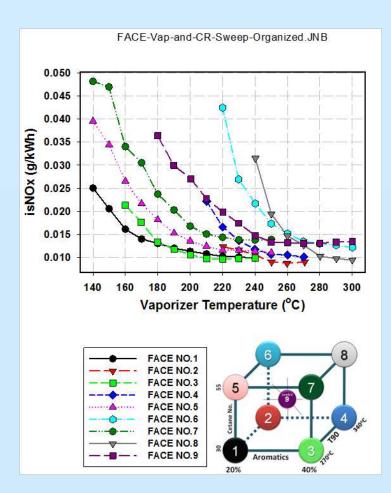
AVL FSN vs. T_{vap}



- 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

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isNO_x vs. T_{vap}

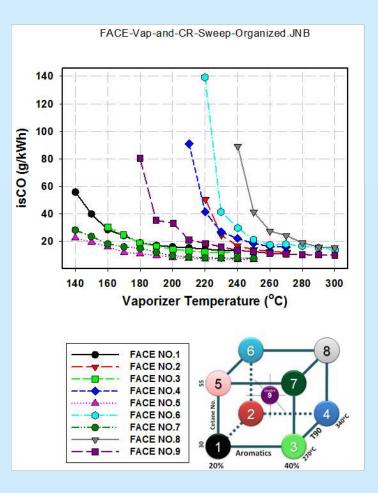


- isNO_x emissions were <0.015g/kW-hr for all FACE fuels when the vaporizer temperature was 270°C or higher
- As a reminder, EGR was not used in this experiment
- As expected, there was no trade-off between soot and NO_x emissions

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isHC & isCO vs. T_{vap}

FACE-Vap-and-CR-Sweep-Organized JNB 26 24 22 isHC (g/kWh) 20 18 16 14 12 10 140 160 180 200 220 240 260 280 300 Vaporizer Temperature (°C) FACE NO.1 FACE NO.2 FACE NO.3 5 5 FACE NO.4 FACE NO.5 FACE NO.6 FACE NO.7 FACE NO.8 - FACE NO.9 Aromatics 20% 40%



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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

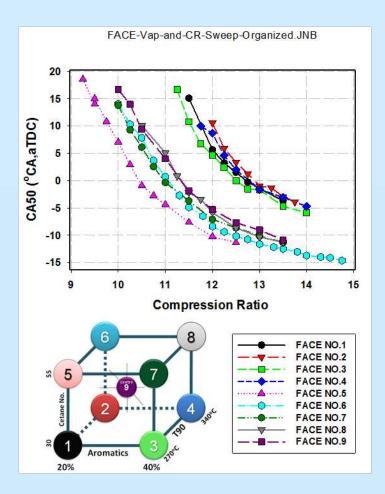
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CR Sweep - I

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	

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CA50 vs. CR

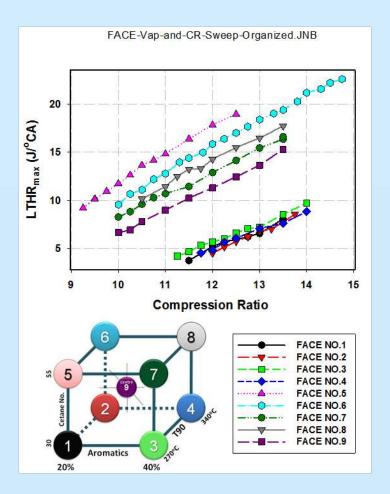


- HCCI combustion phasing (CA50) is a strong function of engine CR
- The four low CN fuels exhibited significantly delayed CA50 phasing compared to the remaining five higher CN fuels



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LTHR_{max} vs. CR

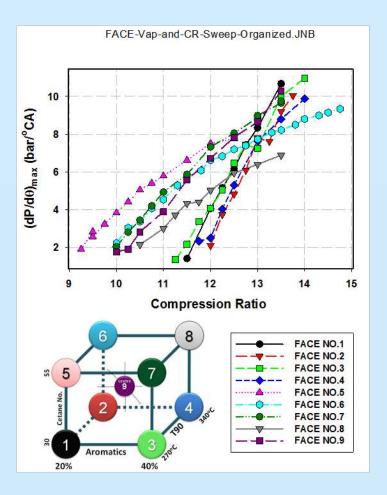


- The delayed CA50 phasing for the four low CN fuels was due to reduced low temperature heat release (LTHR) compared to the five higher CN fuels
- The LTHR_{max} (or LTHR energy fraction) seems to correlate strongly with measured CN for the five higher CN fuels



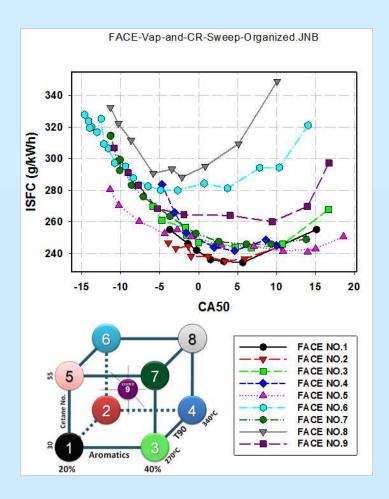
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(dP/dθ)_{max} vs. CR



- 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

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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

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FACE-Vap-and-CR-Sweep-Organized.JNB 4.2 4.0 IMEP (bar) 3.8 3.6 3.4 10-00 3.2 3.0 q 10 11 12 13 14 15 **Compression Ratio** ACE NO.2 ACE NO.3 FACE NO.7 FACE NO.8 FACE NO.9 Aromatics 40% 20%

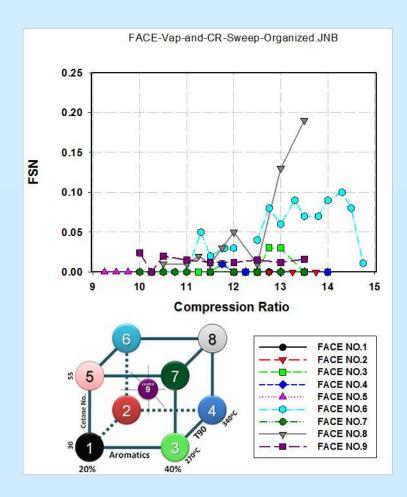
IMEP vs. CR

- 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

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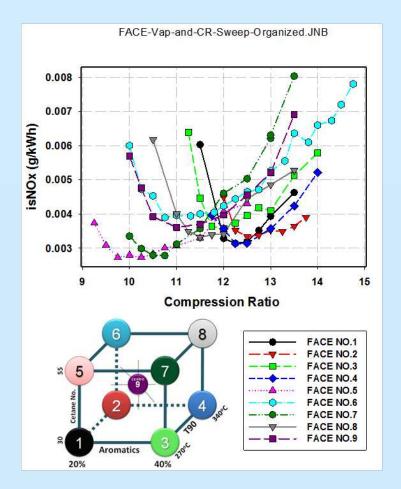


- The two high CN, high T90 fuels (FACE No. 6 & 8) produced measurable soot emissions at high CRs
- The same two fuels (FACE No. 6 and 8) were found to require the highest fuel vaporizer temperatures to achieve nearzero FSN in the previous experiment



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isNO_x vs. CR

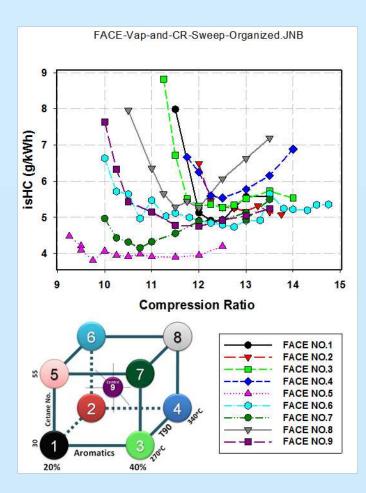


- The isNO_x emissions were extremely low for all FACE fuels with 60% EGR
- The two high CN, low T90 fuels (FACE No. 5 & 7) had the lowest minimum isNO_x emissions



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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

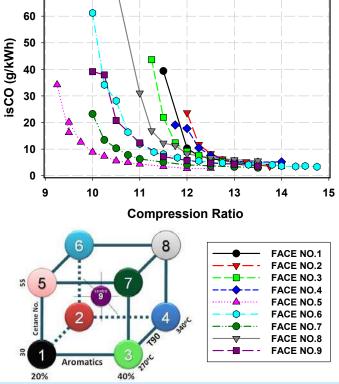


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isCO vs. CR



FACE-Vap-and-CR-Sweep-Organized.JNB



- 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

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- 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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