
Dieseline Combustion

- a logic way to expand the HCI window?

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Presentation Outline

- Research background
- Present objectives
- Research engine setup
- Results and discussion
- Conclusions
- Future prospects



CHARGE/CHASE Project Outline

CHARGE (Controlled Homogeneous Auto-ignition Reformed Gas Engine),

2 yrs DTI sponsored, Jag/total funding = £420/840K

concluded 28/04/04

- Facilitate natural gas HCCI using fuel reforming

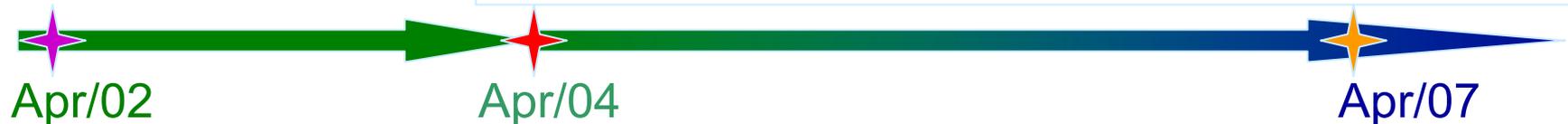
Reviewed by UK EPSRC: "Tending to International Leading"

CHASE (Controlled Homogeneous Auto-ignition Superch

3 yrs DTI sponsored, Jag/total funding = £720/1,539K)

Kicked-off 28/04/04

- Expand gasoline HCCI window



partners:

Jaguar Cars, Birmingham University

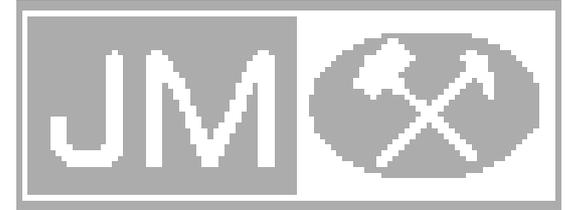
Johnson Matthey, MassSpec UK

National Engineering Laboratory

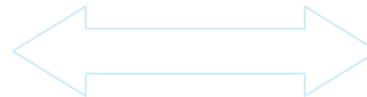
Race Technology



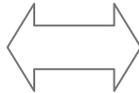
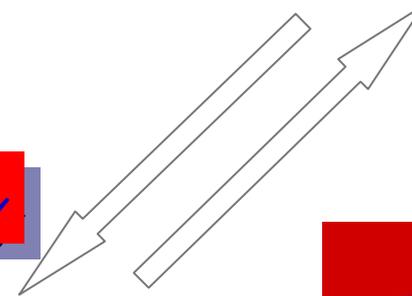
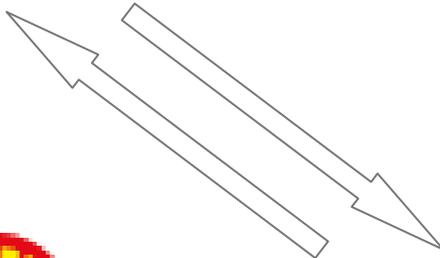
Research Partnership



Project leader, engine and optical work



Reforming catalyst development

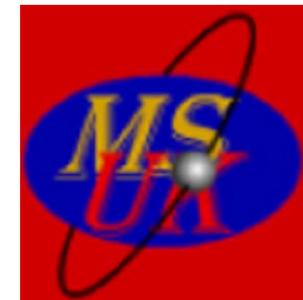


Race Technology

NEL



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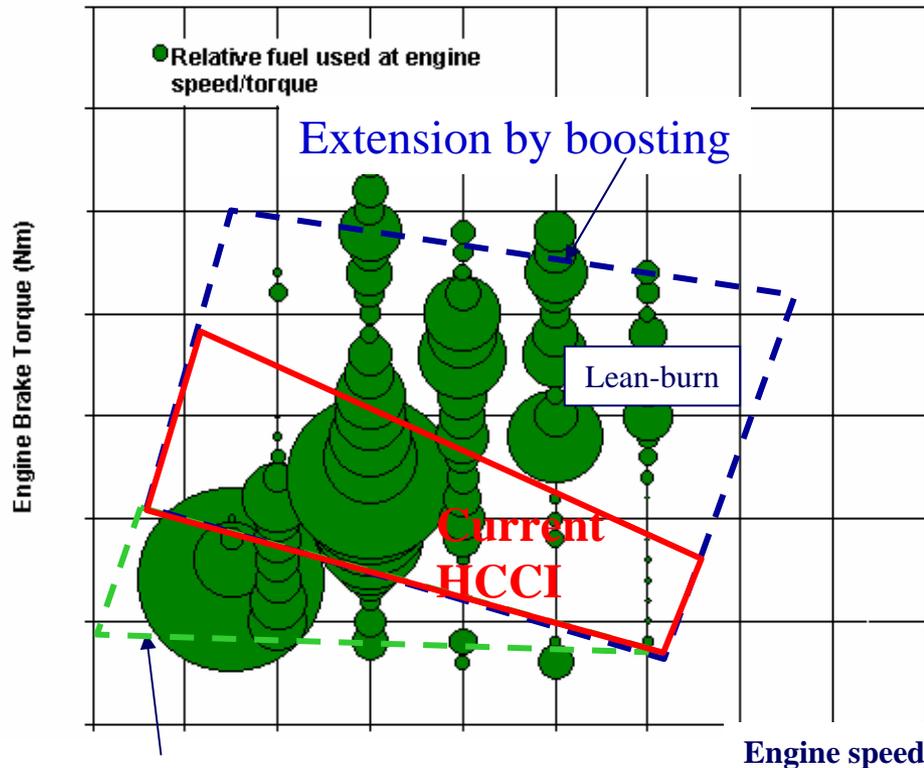


MS support

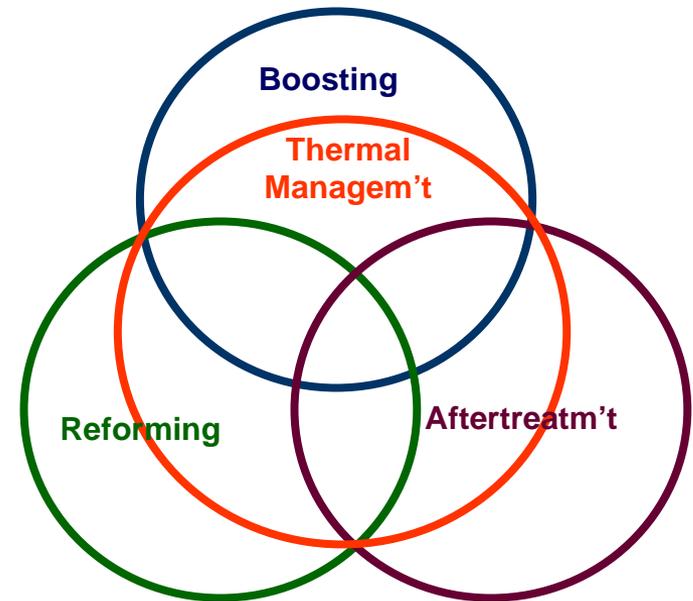
Engine and reforming experiment



CHASE Next Generation (2004-2007)



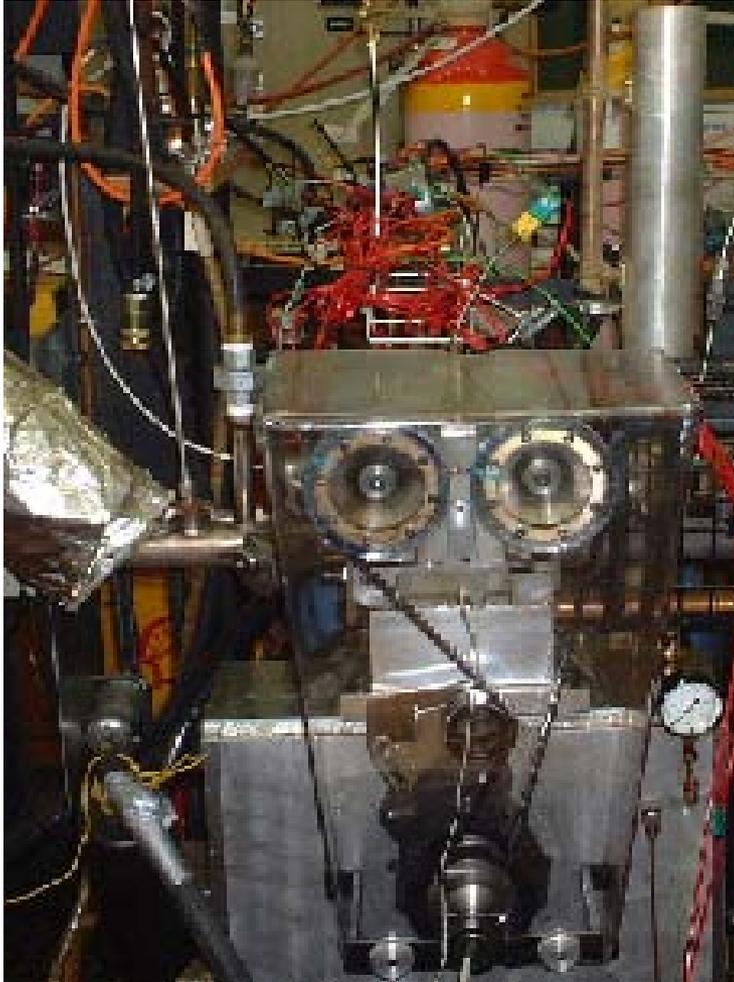
Extension by fuel reforming



Main objective – Extend the operating window of Gasoline HCCI using combination of boosting, exhaust gas fuel reforming, and total thermal management.



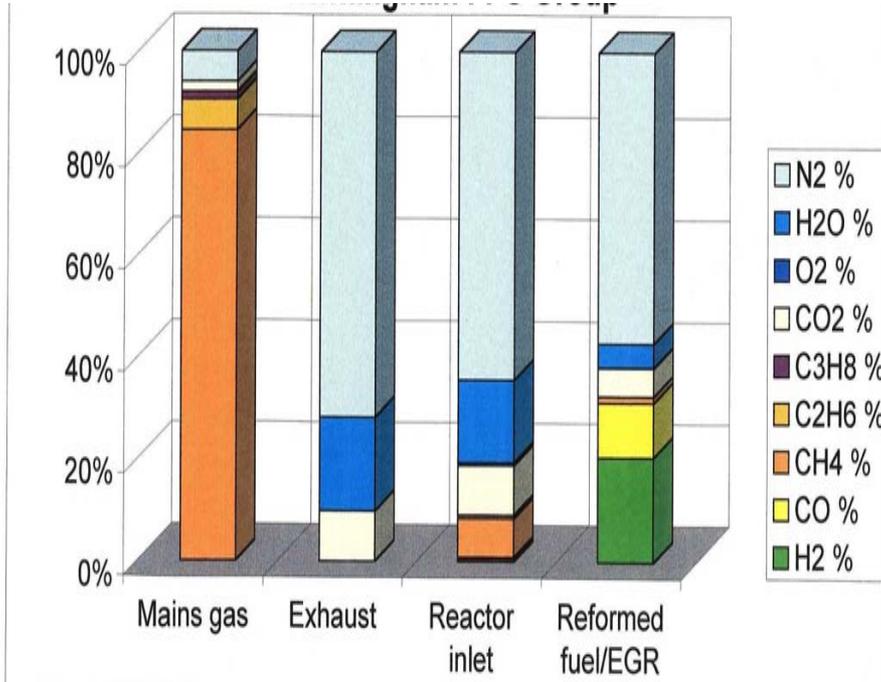
The single cylinder research engine



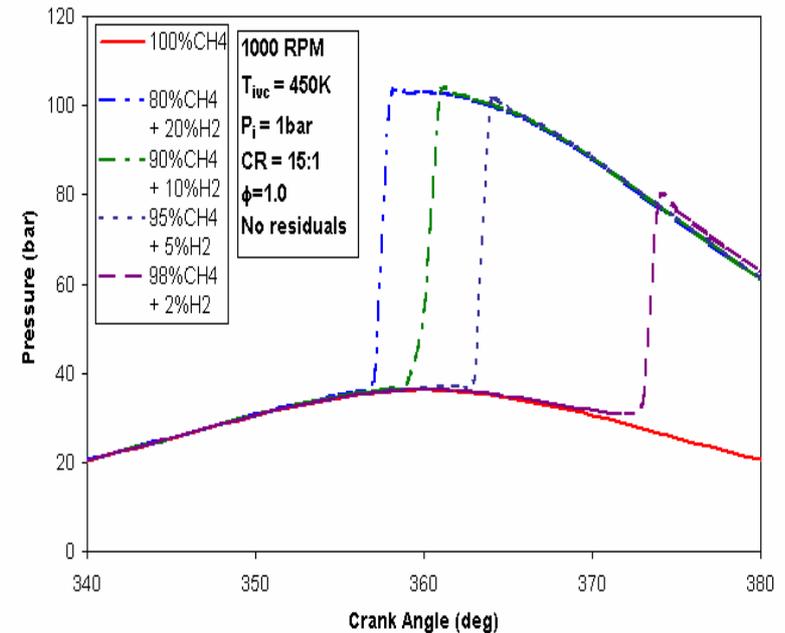
Engine type (Medusa base)	4 - stroke, single cylinder, 4 valve, pent-roof head
Bore x Stroke (mm)	80 x 88.9
Connecting Rod Length (mm)	165
Valve diameters and lift	27.7 / 24.1 mm 3 mm for NVO (8 mm standard)
Geometric Compression Ratio	10.4 for cold NVO (15.0 for heated intake standard valve events)
Fuelling type	liquid port-injected, injection at 3 bar (gauge)

Concept of CHARGE/CHASE (2002-2007)

Reformed natural gas (test data)

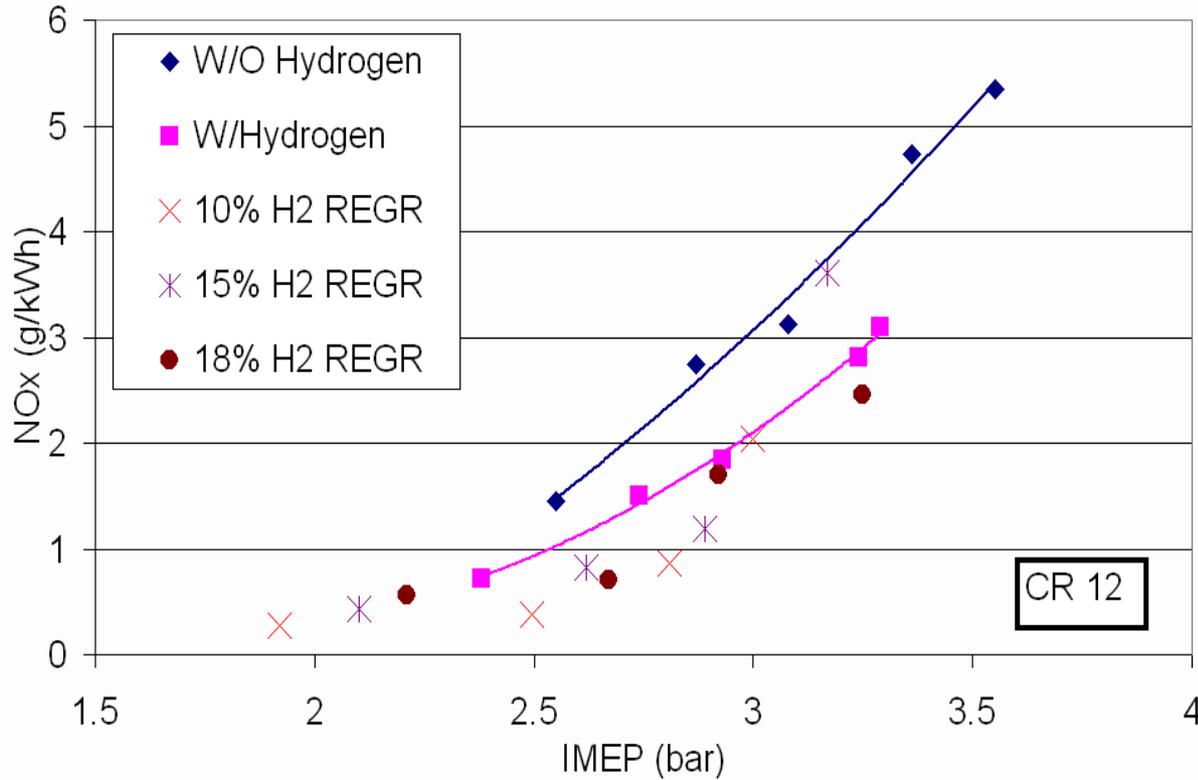


Modelling of the effect of fuel property



Main objective - Evaluate the effect of fuel composition and control of engine parameters on the auto-ignition process of natural gas in automotive engines

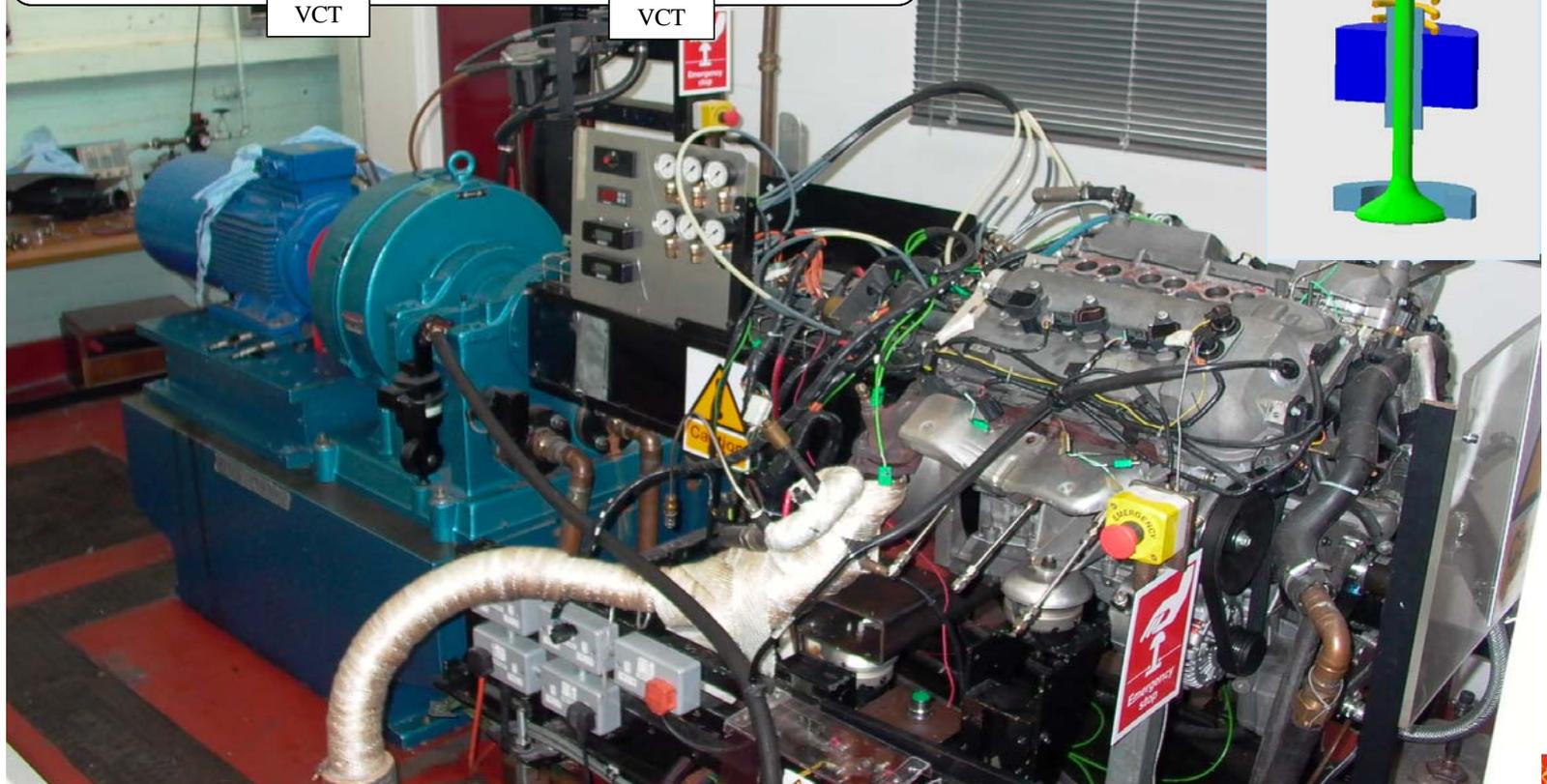
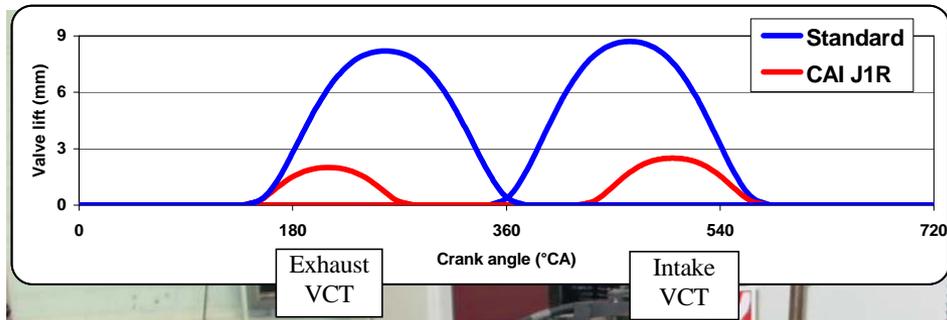
NOx emissions for HCCI – fuel reforming (NG)



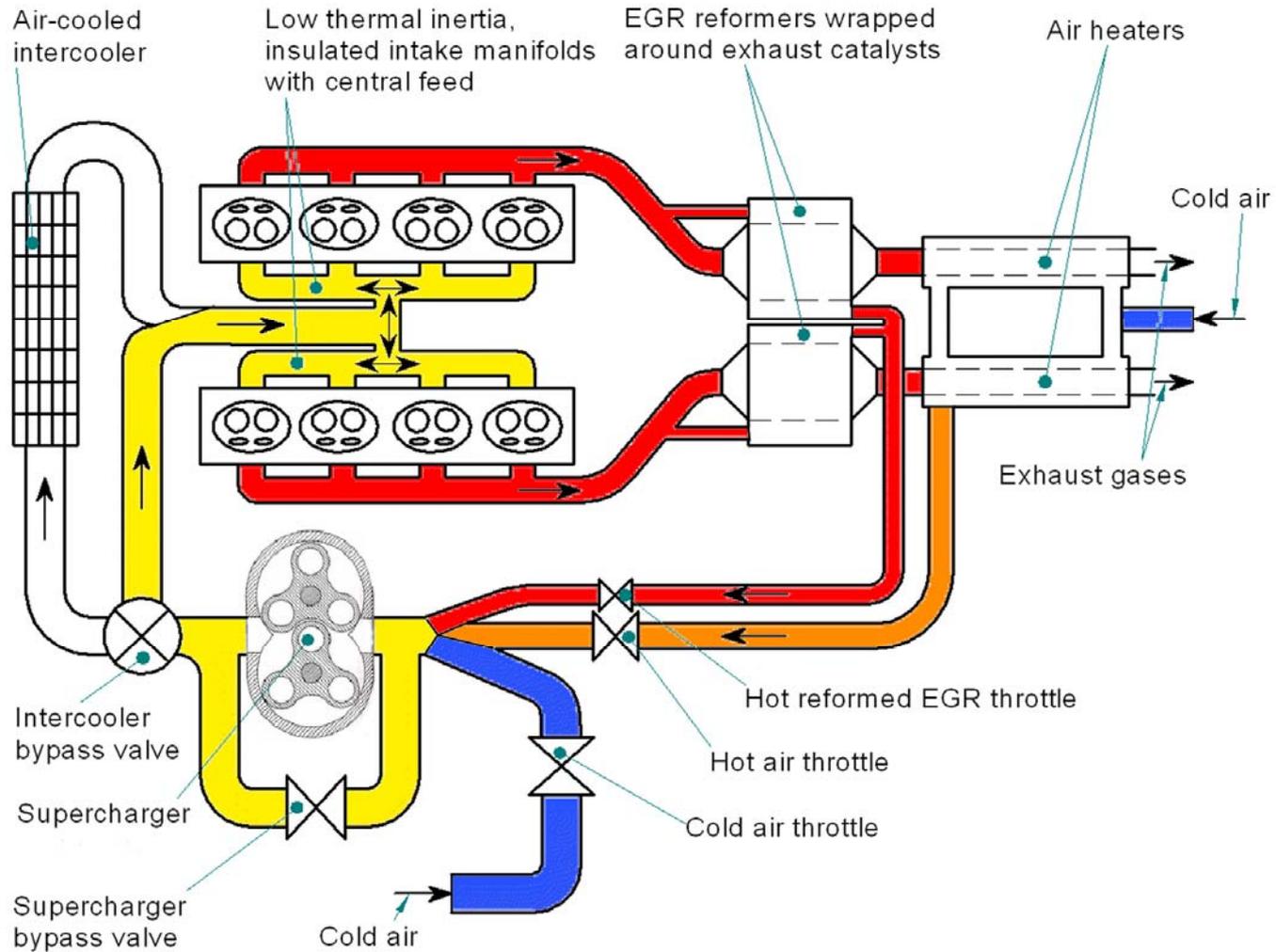
Hydrogen enriched HCCI has a lower NOx emission level and load limit than normal HCCI, with additional effect from reforming



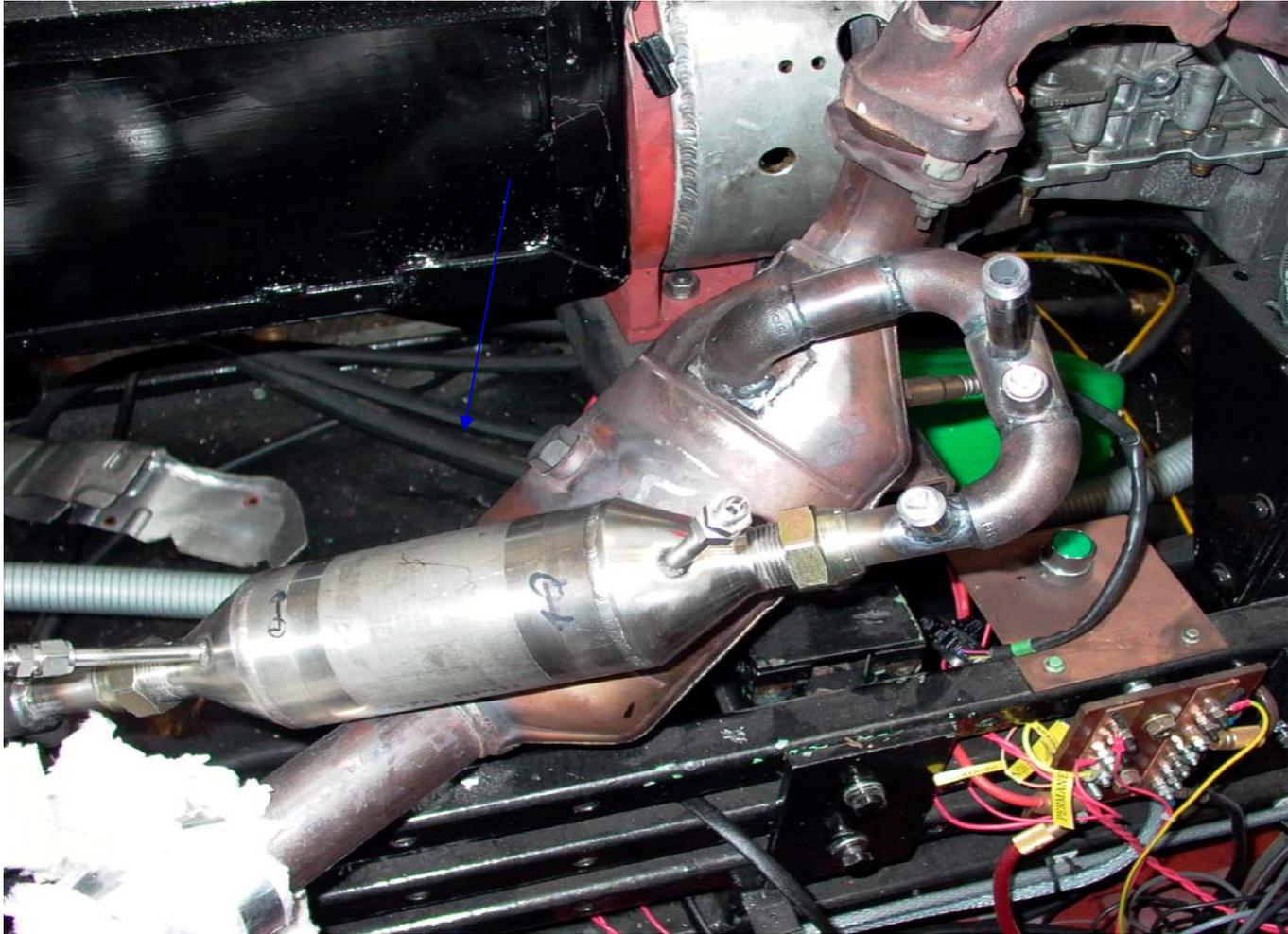
World 1st dual cam profile switching engine



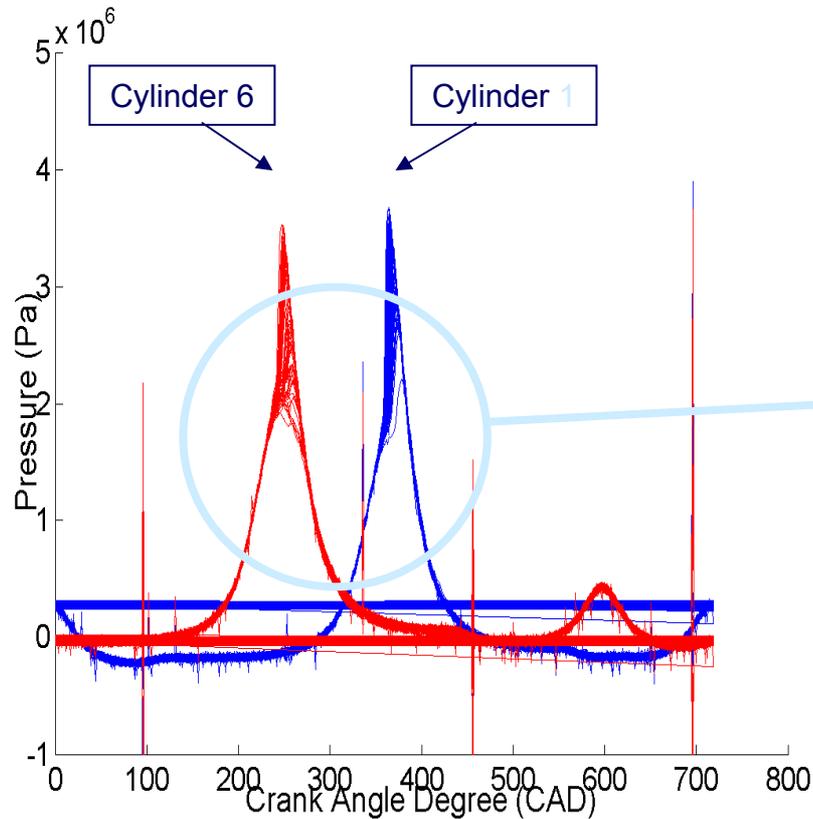
Supercharged Thermal Management System



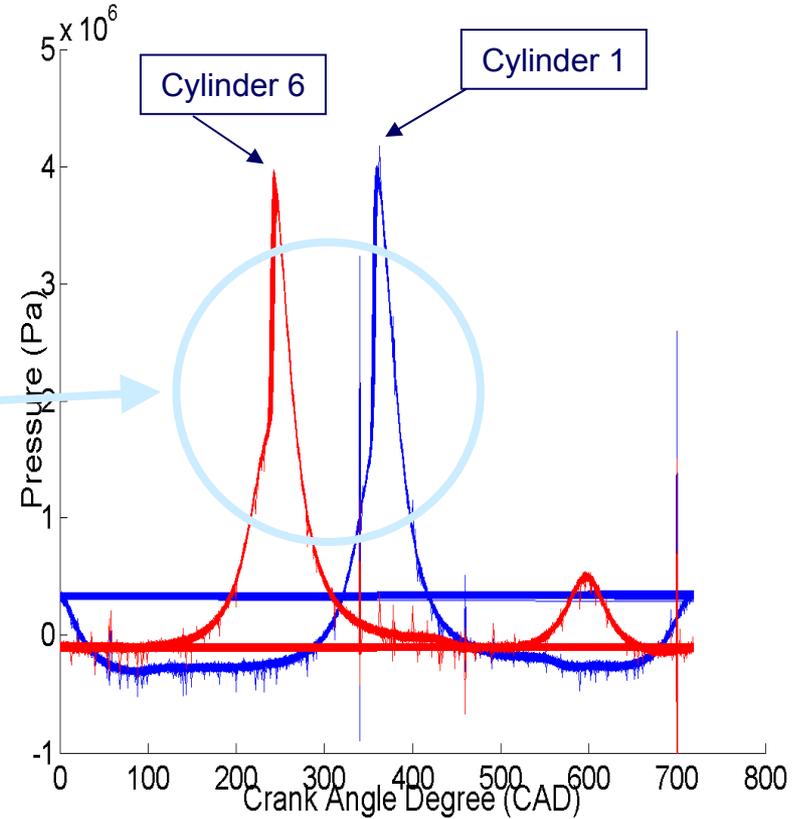
On-board reformer for the Jaguar AJV6 engine



Cycle-by-cycle & cylinder-to-cylinder variations



Without reformed gas



With on-line reformed gas



'Dieseline' research objectives

- Gasoline, diesel and a variety of alternative fuels are all possible fuels for HCCI combustion but none of them as a single fuel has proved to be able to enable a satisfactory operating window.
- Gasoline and diesel fuels, the most widely supplied main fuels, have indeed very different but complimentary properties. Gasoline, which has high volatility but low ignitability, is generally produced as a high octane number fuel.
- The Diesel fuel, on the other hand, has a high cetane number with larger carbon content and heavier molecular weight with low volatility, is better suited to auto-ignition but often requires a lower compression ratio.



Present research

- to investigate the HCCI combustion behaviour of the mixtures of gasoline and diesel as the two fuels with opposite but complementary properties.
- to investigate whether the two fuels can provide a compromise HCCI combustion where the ignitability of charge is improved
- to restrain violent knocking so as to operate the engine in a controllable HCCI combustion mode under a moderate compression ratio



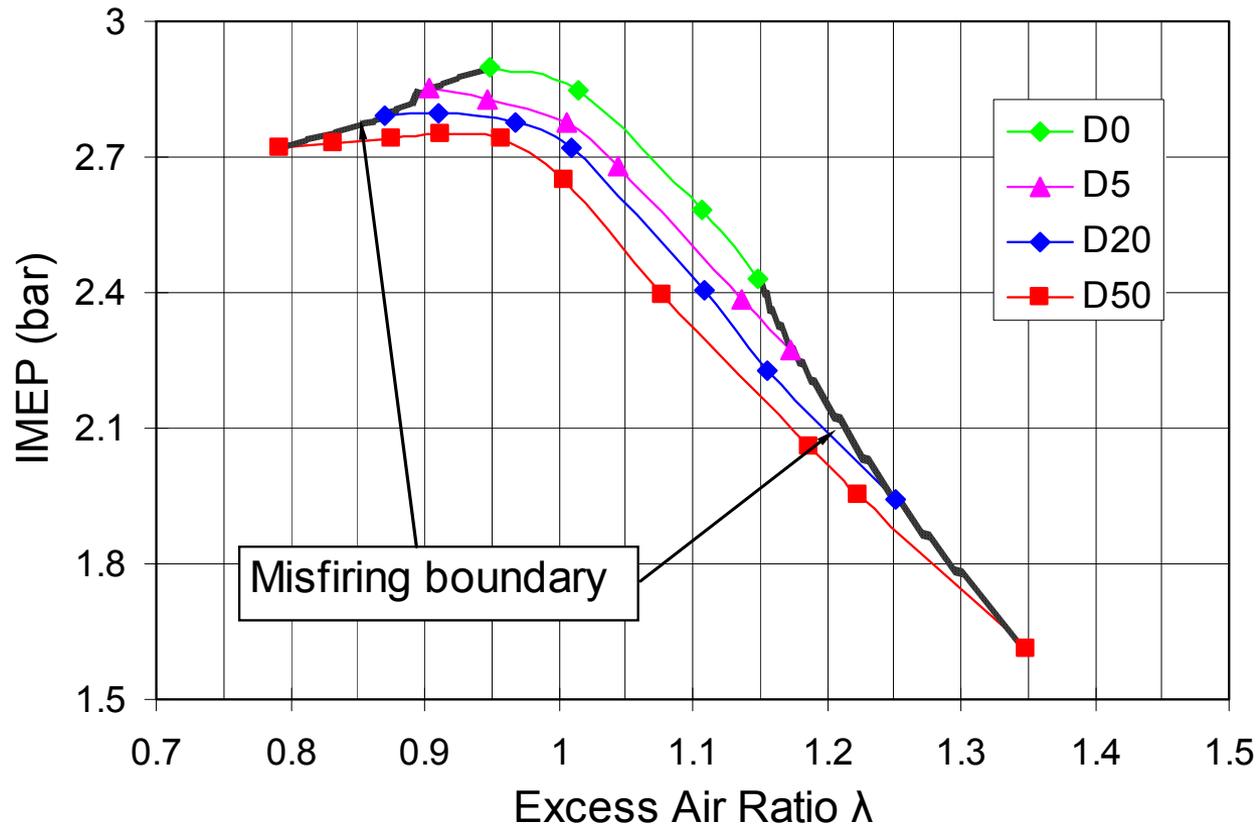
Fist Test matrix

Fuel Designation	D0	D5	D10	D20	D50
Fuel Composition Gasoline : Diesel (by mass)	100:0	95:5	90:10	80:20	50:50
Intake heating (CR=15.0)			√	√	√
NVO (CR=10.4)	√	√	√	√	√

(SAE2005-01-3733)



Air-ratio boundary with EGR trapping

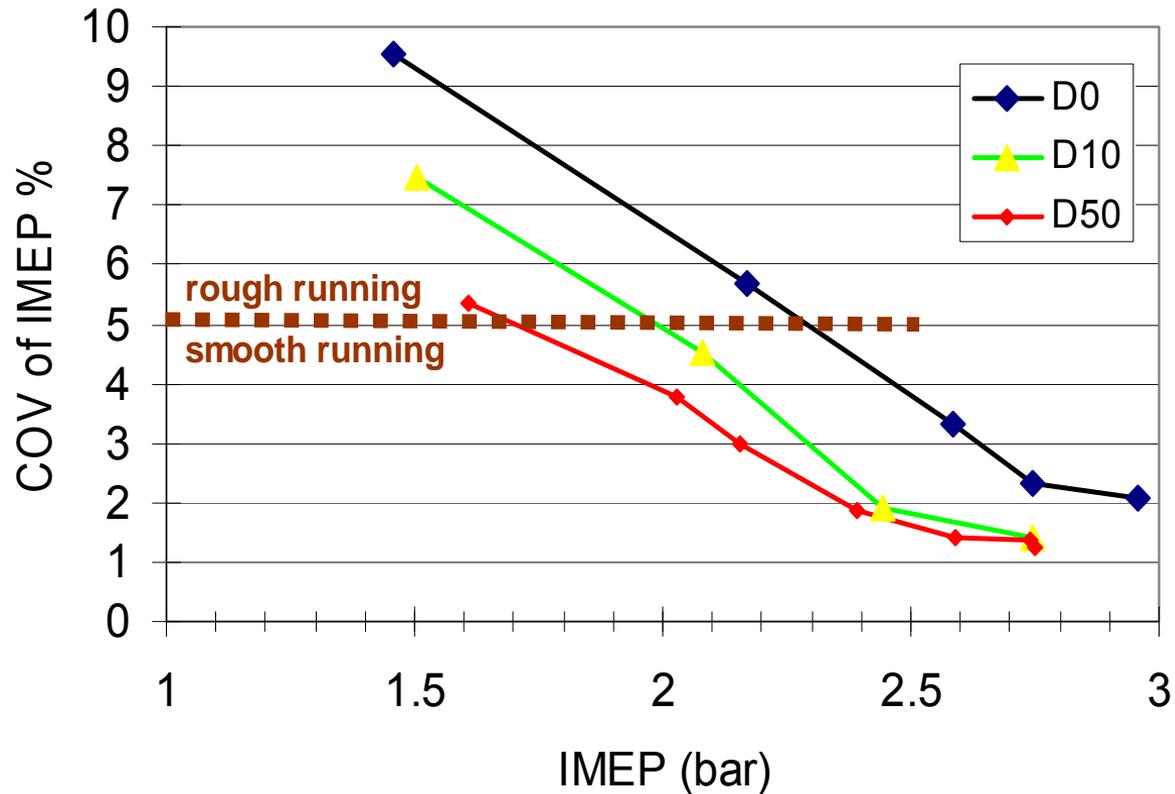


D0 (pure gasoline), D5, D10 and D50, in NVO HCCI mode, CR=10.4, 1500 rpm, unheated intake, low lift cams, NVO = -170 deg.

(SAE2005-01-3733)



Improvement in combustion stability

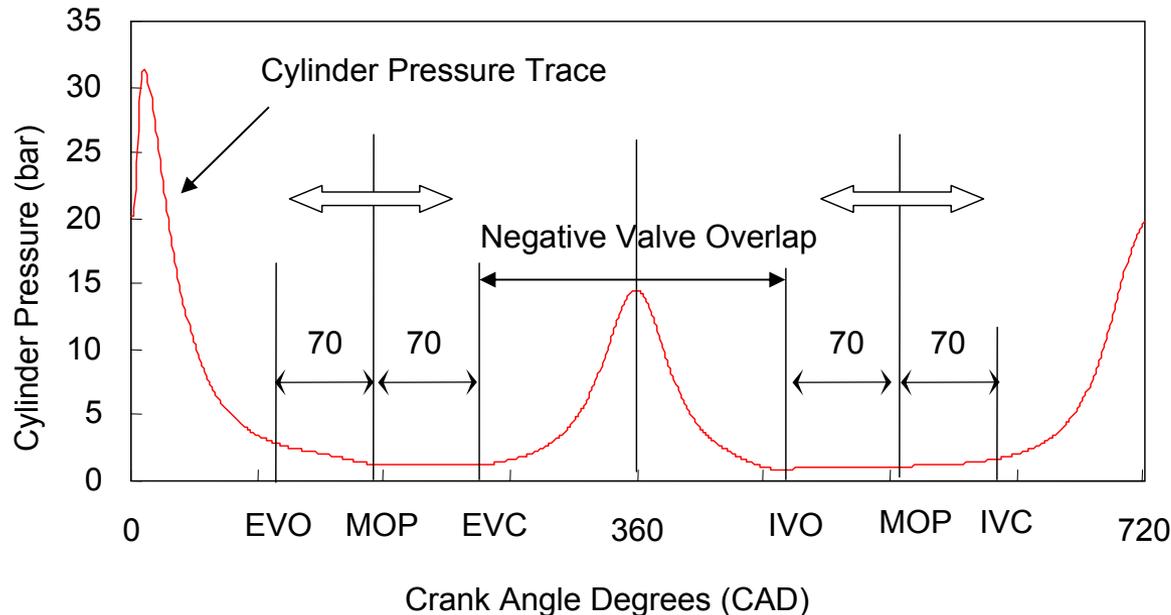


D0 (pure gasoline), D10 and D50 when engine worked with unheated NVO HCCI mode, CR= 10.4, 1500 rpm.

(SAE2005-01-3733)



Valve timing – case study

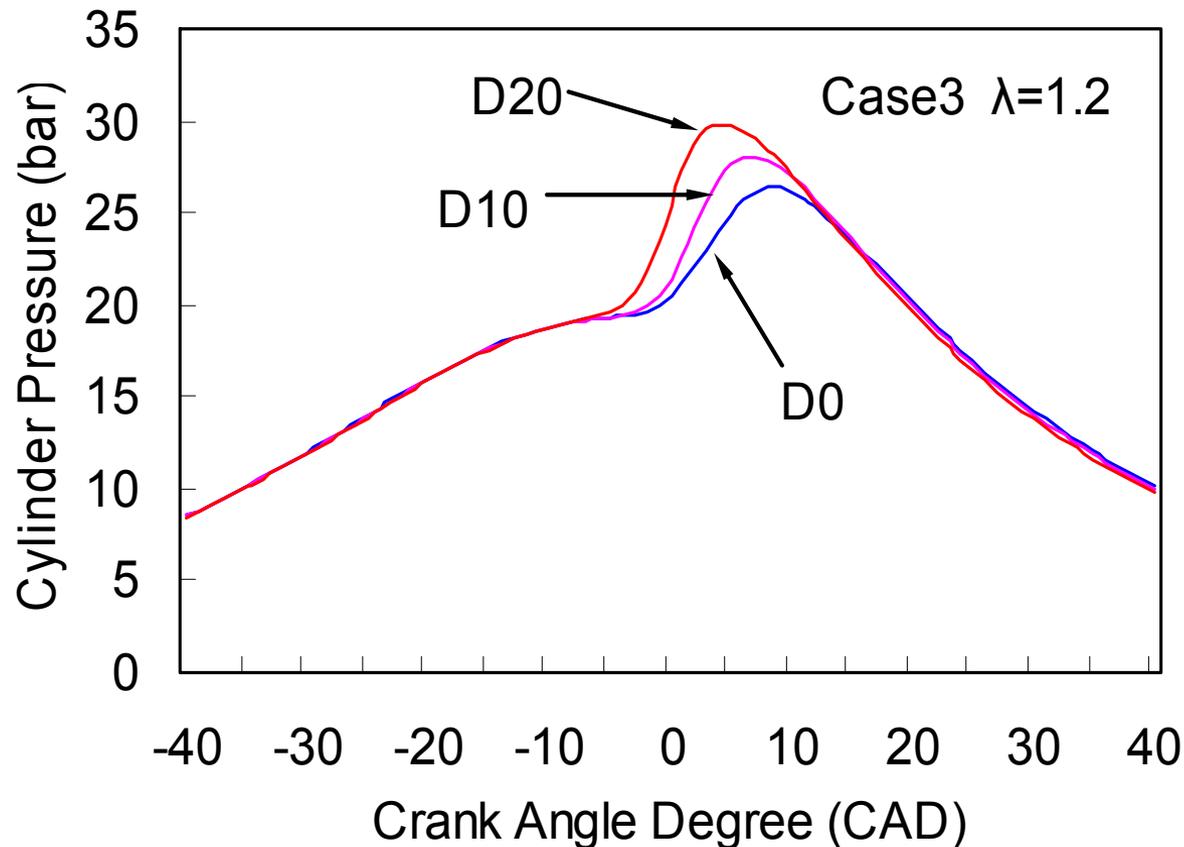


Valve timing used in HCCI engine operated in NVO (negative valve overlap) mode. "0" crank angle degrees indicates TDC in the compression / combustion revolution. All IV/EV timings are symmetrical w.r.t. TDC

Conditions	Inlet valve MOP (CAD aTDC)	Exhaust valve MOP (CAD bTDC)	Valve Overlap (CAD)
Case 1	130	130	-120
Case 2	140	140	-140
Case 3	150	150	-160
Case 4	160	160	-180
Case 5	170	170	-200



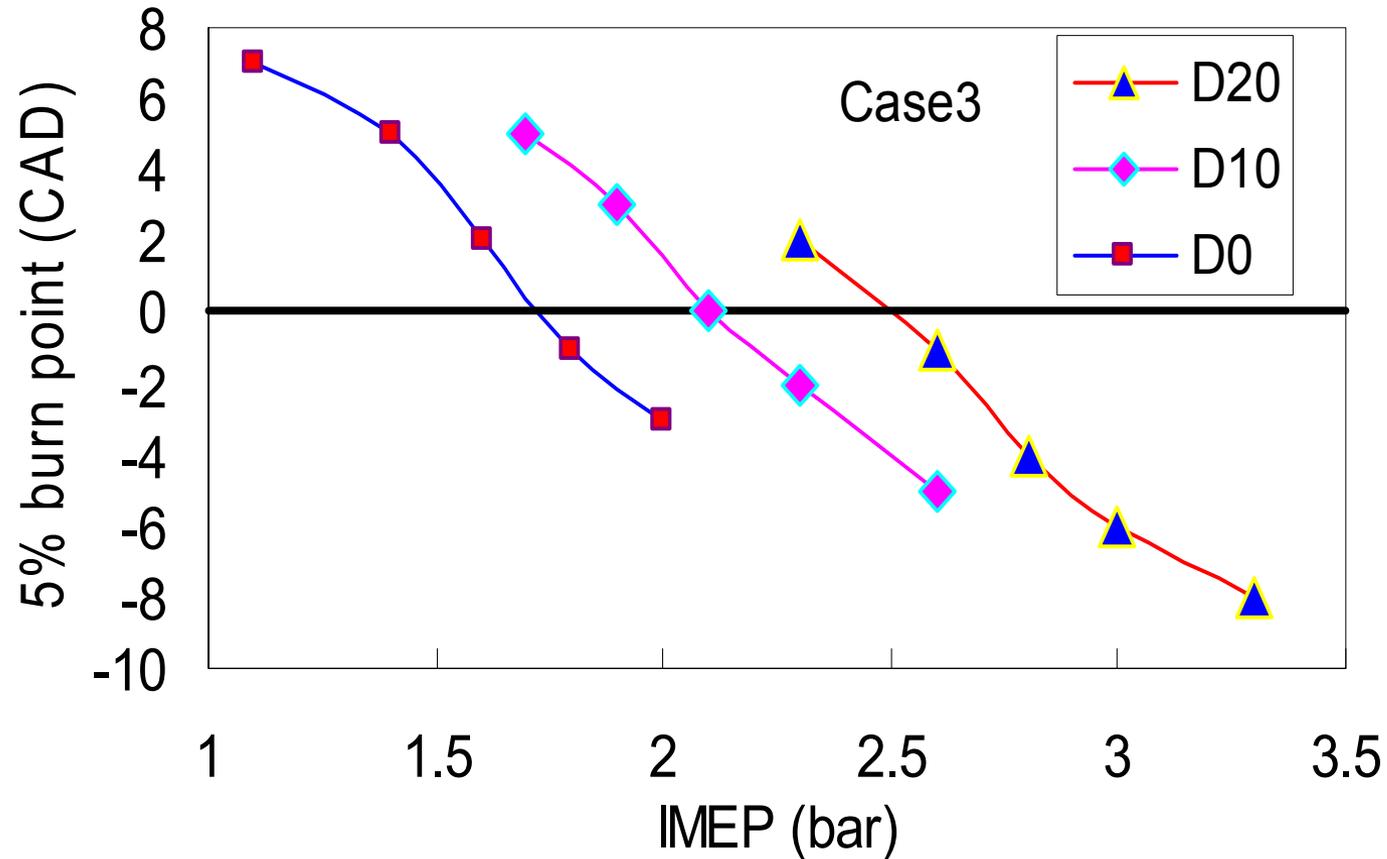
Increasing diesel content, $\lambda = \text{const}$, NVO = const



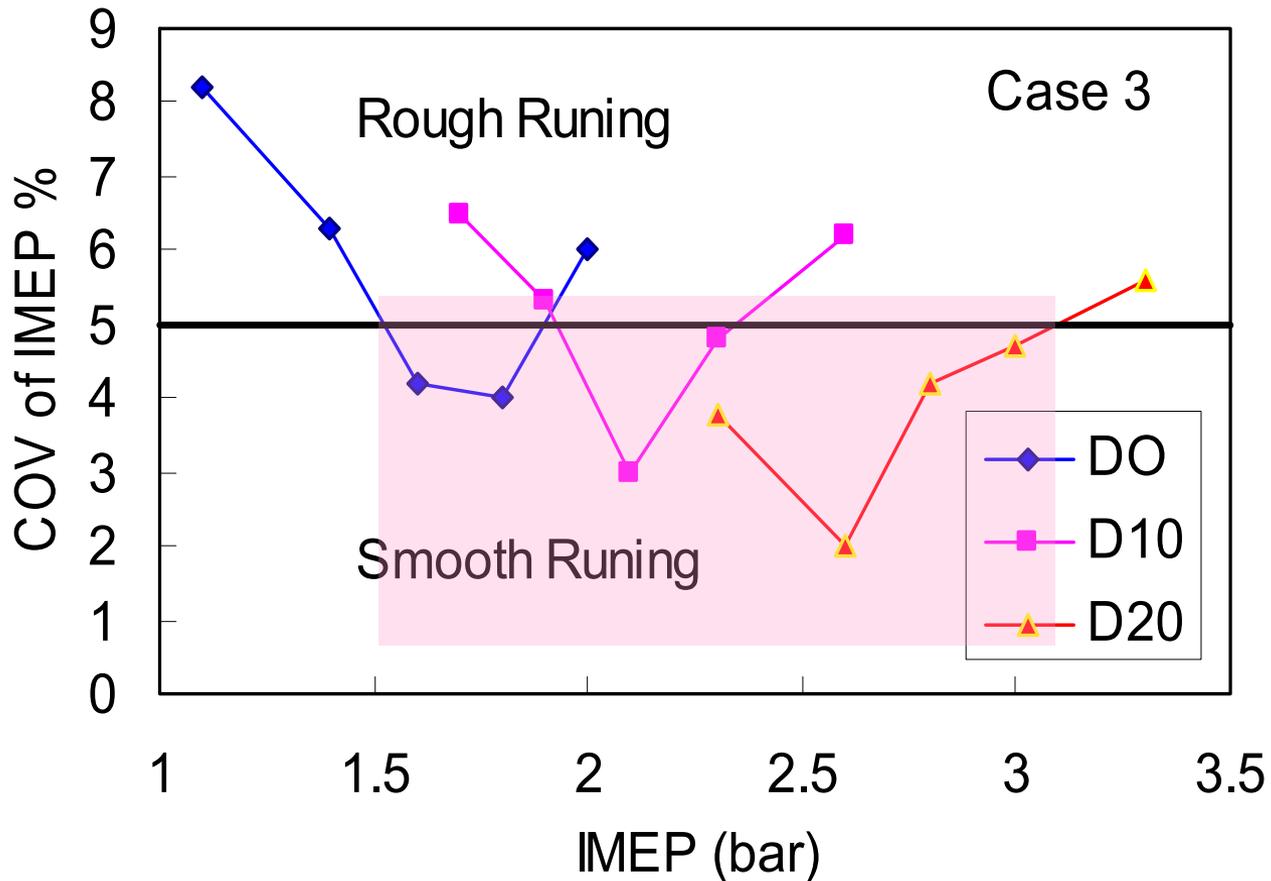
D0, D10, D20 fuels
Case3
NVO = -160 CAD
1500 rpm,
 $\lambda = 1.2$



Ignition advances with increased load and diesel content



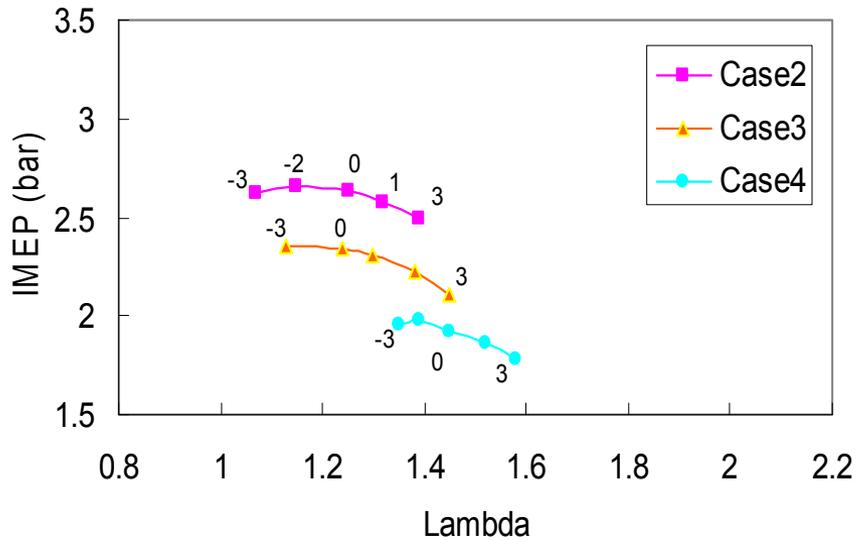
IMEP boundary with Variable diesel content



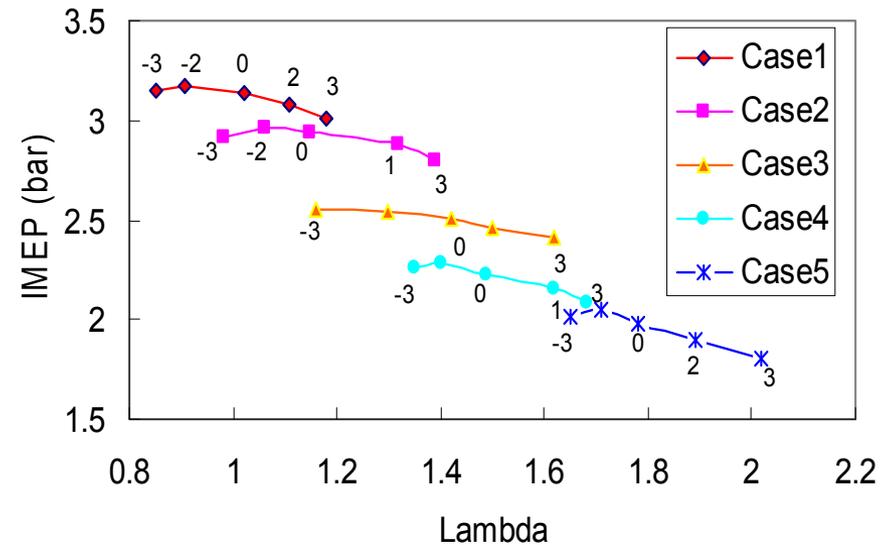
- combustion stability for pure gasoline D0 is poor, particularly at lower loads, this is also due to retarded combustion phasing
- D20 offers a very respectable and acceptable COV below 5% over practically its whole range of IMEP



Comparison of load boundary



D0 fuel (gasoline)

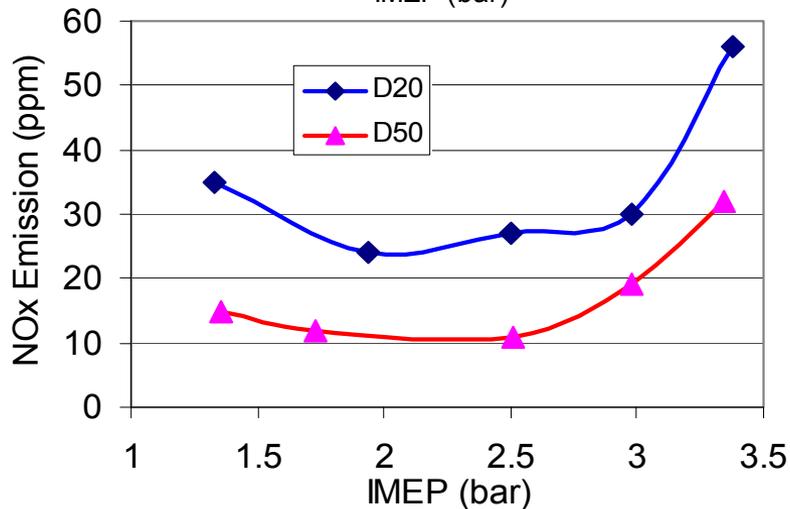
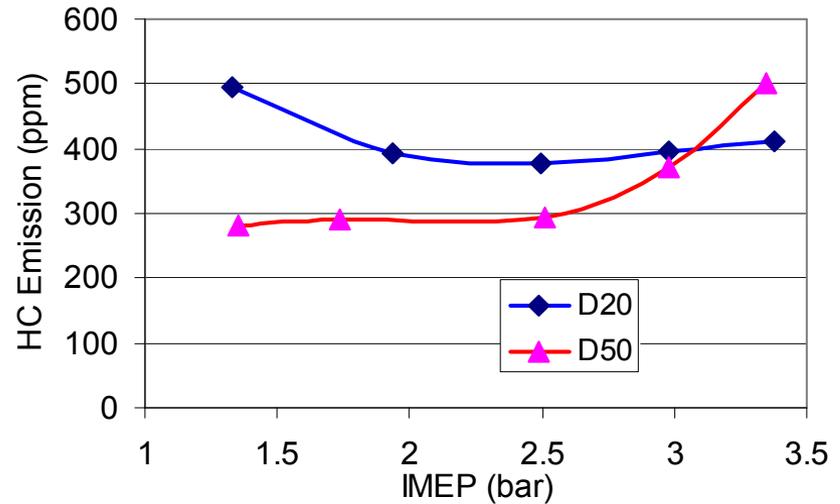
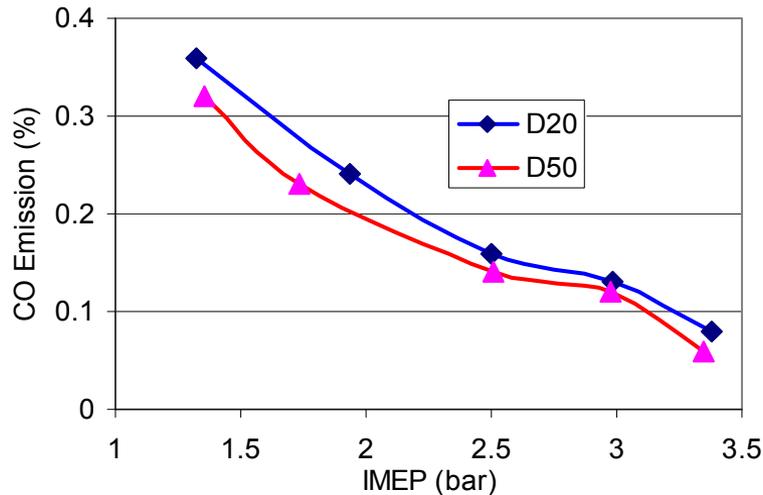


D20 fuel

- with D20 fuel, a substantial increase in the upper limit of engine load and a wide lean limit of lambda was achieved compared with D0 fuel.
- diesel fuel addition at the same Case of NVO also enables richer mixtures and higher loads with sustainable combustion



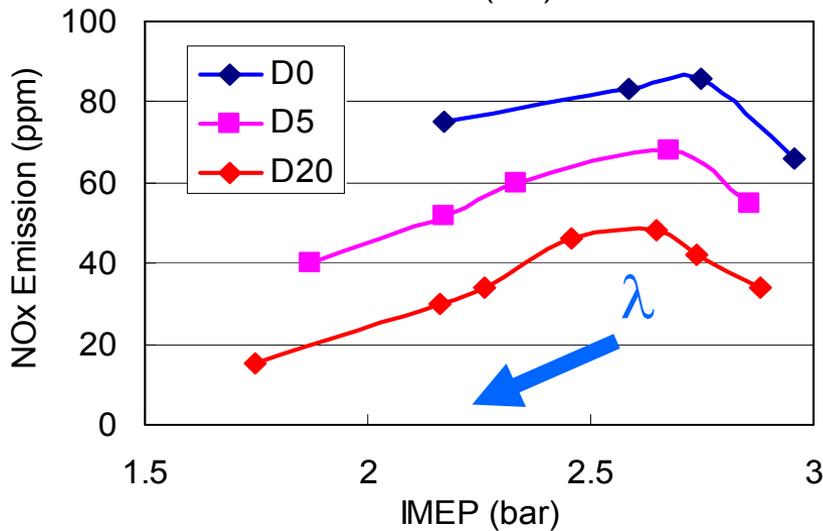
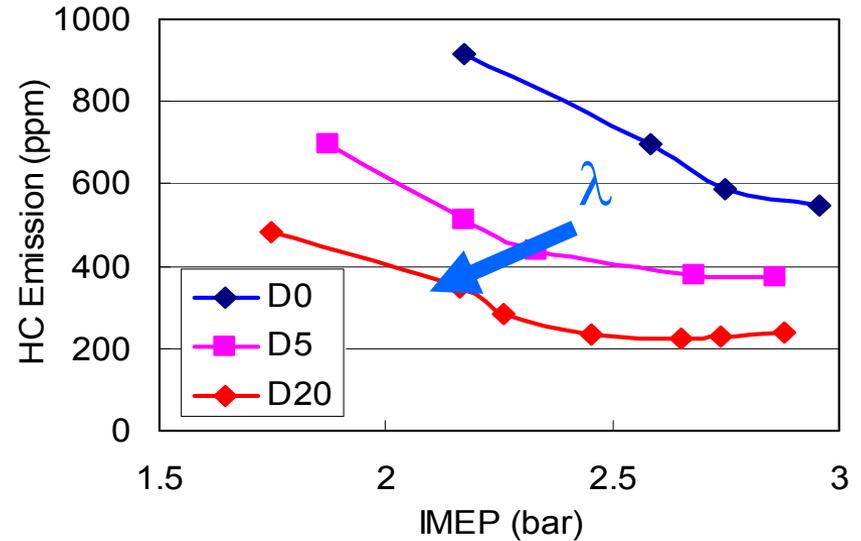
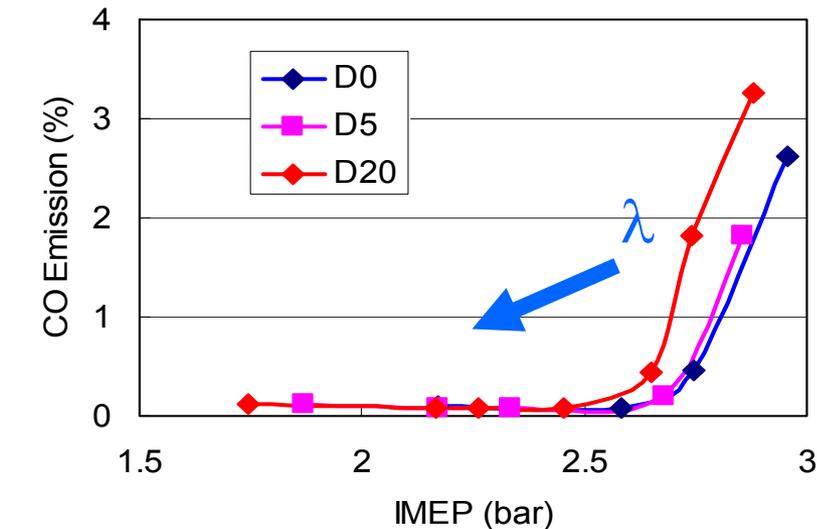
Comparison of emissions



1500 rpm, intake temperature
380 K, intake pressure = 0.1
MPa (abs), CR = 15.0,
standard camshaft with positive
valve overlap



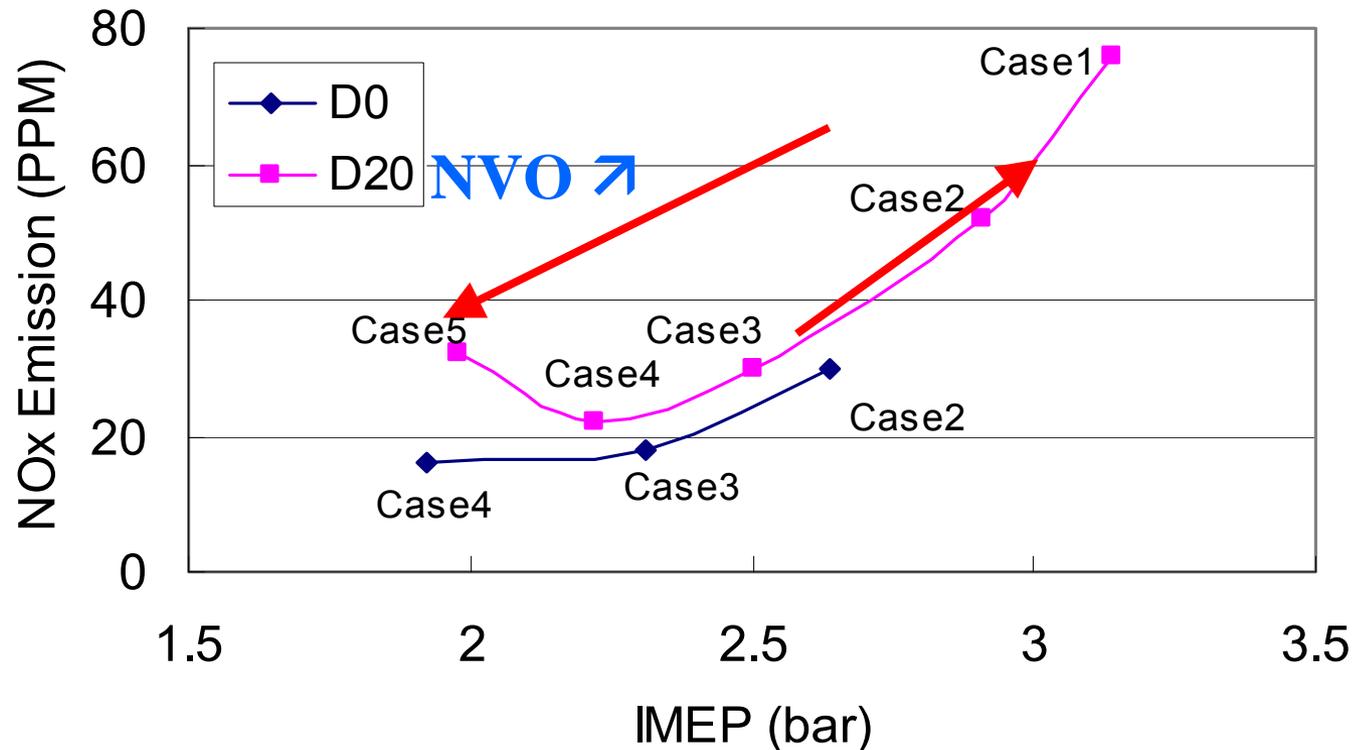
Comparison of emissions with varied λ and load



1500 rpm, unheated intake, low lift cams, NVO = -170 deg, varied λ



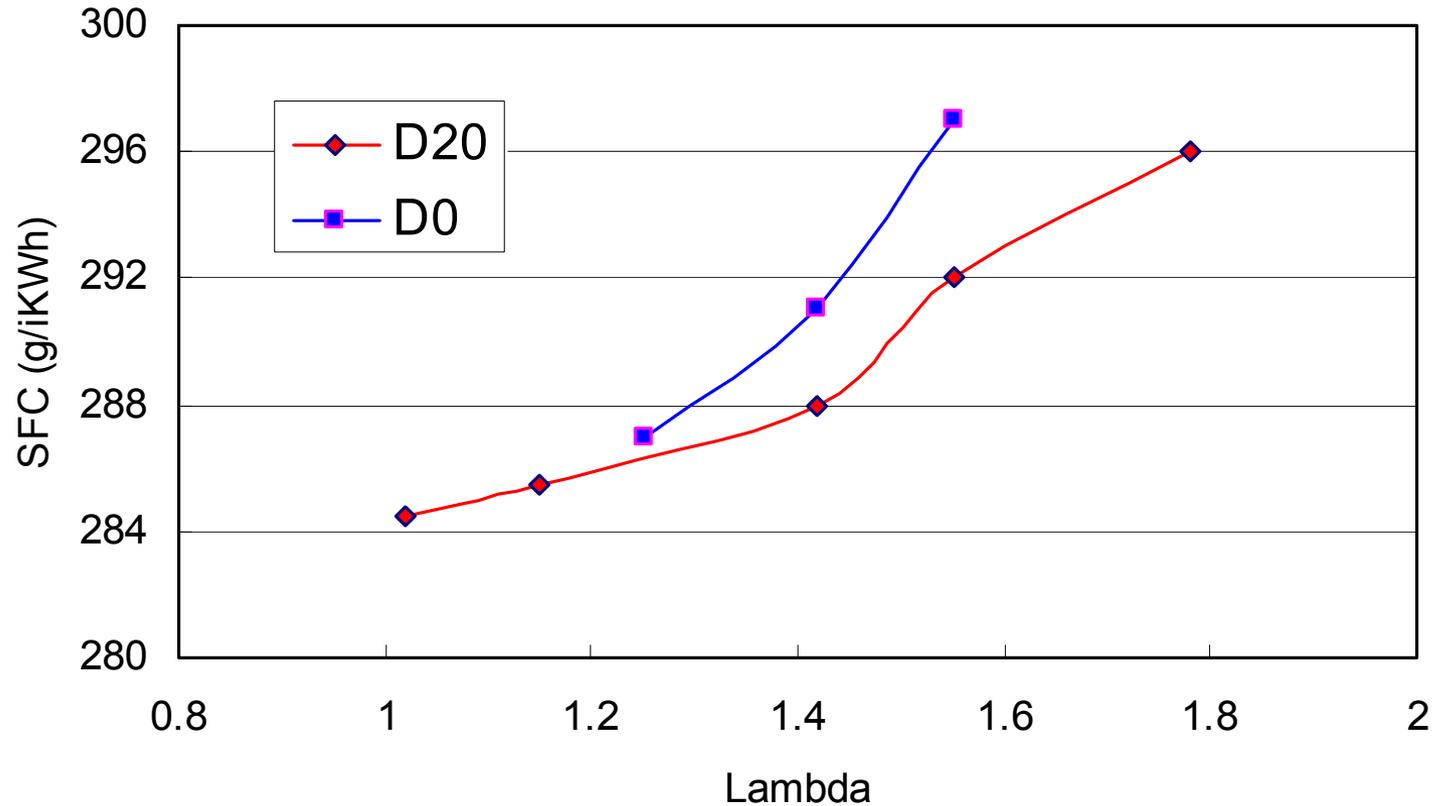
NOx variation when 5% burn kept at TDC



Case 5 has large NVO, more residual gases in cylinder, higher in-cylinder temperature during the next consecutive cycle. Over-advanced combustion phasing may also be partially responsible for higher NOx.



Comparison of fuel consumption



1500 rpm, 5% burn at TDC, stable combustion



Summary and conclusions

- The blended fuel namely 'dieseline' makes compromised and optimal offer to the desired ignition quality, which reduces the dependence of HCCI on EGR trapping or intake heating.
- For 'dieseline' HCCI, the required intake temperature heating can be lowered by at least 10 degrees compared with pure gasoline operation. With diesel addition, appropriate engine conditions can be achieved for gasoline HCCI with EGR trapping for a wide range of CR.
- The HCCI operating region for the unheated NVO can be significantly extended into lower IMEP values and the audible knocking is restrained to the highest values of λ at high load boundary for the highest mixture temperatures. The resulting effects make it possible to reduce the NVO interval required for stable combustion.
- The possible scale of NVO was extended by up to 40 CAD, the lean limit of lambda can almost reach up to 2.0 when engine is operated with a moderate compression ratio (10.4). However this might cause a CO emission penalty at the leanest limit due to lower combustion temperature.

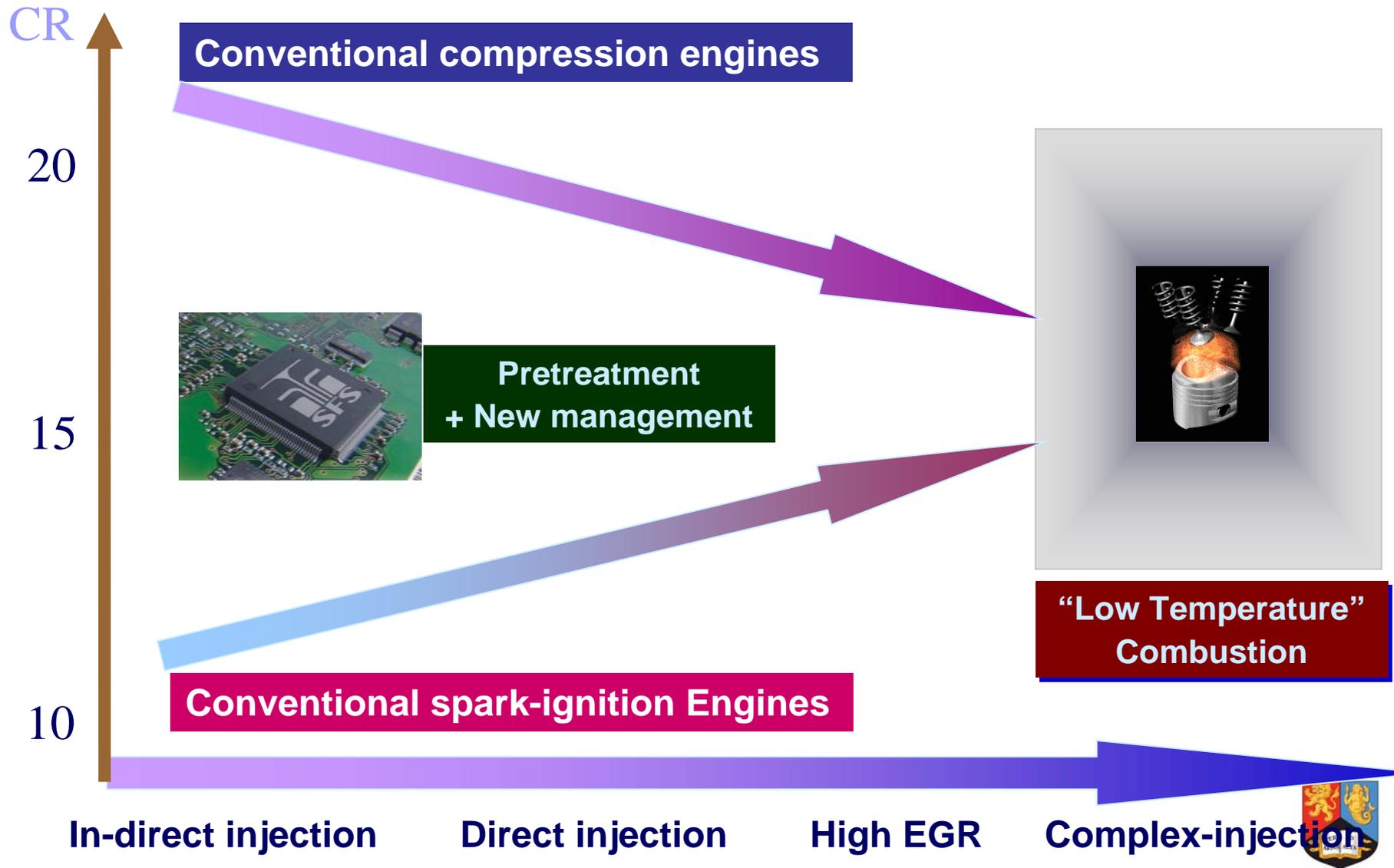


Summary and conclusions

- The indicated specific fuel consumption and CO emissions decrease due to decreased pumping losses of recompression and higher combustion efficiency.
- Emissions of HC and NO_x show an interesting improvement compared with gasoline HCCI with optimized engine operating conditions.
- A substantial increase in the upper limit of load range will be achieved without intake heating because of higher volumetric efficiency resulting from smaller NVO and the presence of less residual gases in cylinder. However this can result in potentially higher NO_x emissions due to the lower dilution amount present and higher combustion temperature.



Gasoline and Diesel Engine Technologies are emerging



Acknowledgements

- ≡ The authors would like to acknowledge the assistance and cooperation of the colleagues and coworkers in the Future Power Systems Group at the University of Birmingham, especially Dr S Zhong as academic visitor. The support from Jaguar in relation to the present research work is also gratefully acknowledged.

