



Diesel HCCI Results at Caterpillar



Kevin Duffy, Jonathan Kilkenny

Gerald Coleman, Eric Fluga

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Contract Monitors – Gurpreet Singh, John Fairbanks

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Outline



- ✍ Why Diesel HCCI?
- ✍ Present challenges
- ✍ Test background
- ✍ Effects of control parameters on performance and emissions
- ✍ In-cylinder combustion movies
- ✍ Challenges ahead
- ✍ Future plans

Why Diesel HCCI?

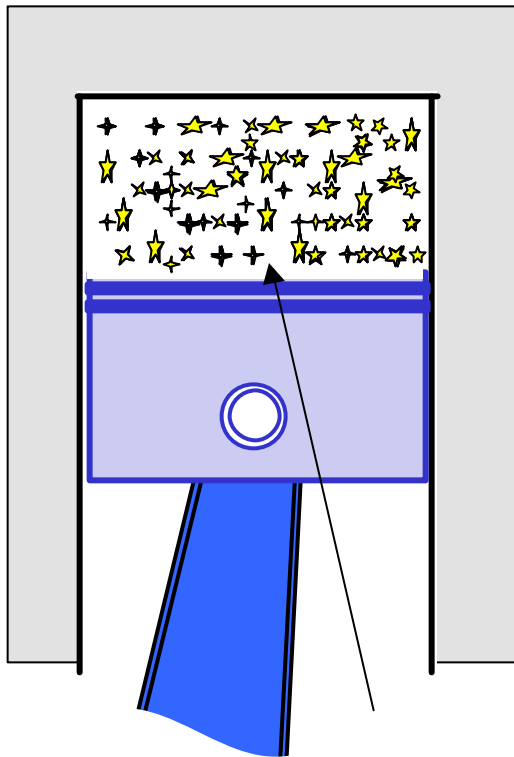


- ✍ Abundant activity on gasoline and alternative fuels HCCI at universities, national labs, etc.
- ✍ Limited development using Diesel fuel
 - Japan doing most work in this area
 - Ignition control may be harder with 2-stage ignition
 - Lower CR to prevent early ignition leads to poor η_{TH}
 - Homogeneous mixture preparation more difficult leading to high particulate emission
- ✍ If one vision is HCCI-powered trucks for 2010
 - Infrastructure, fuel availability rule out alt fuels
 - “HCCI-friendly” fuel a possibility
 - Gasoline possible, but ...

HCCI - The Challenge

HCCI Engine

(Homogeneous Charge
Compression Ignition)



Low temperature combustion
ultra low emissions

- ✍ Proper air / fuel mixing
- ✍ Combustion phasing and control
- ✍ Limited load range

Objectives

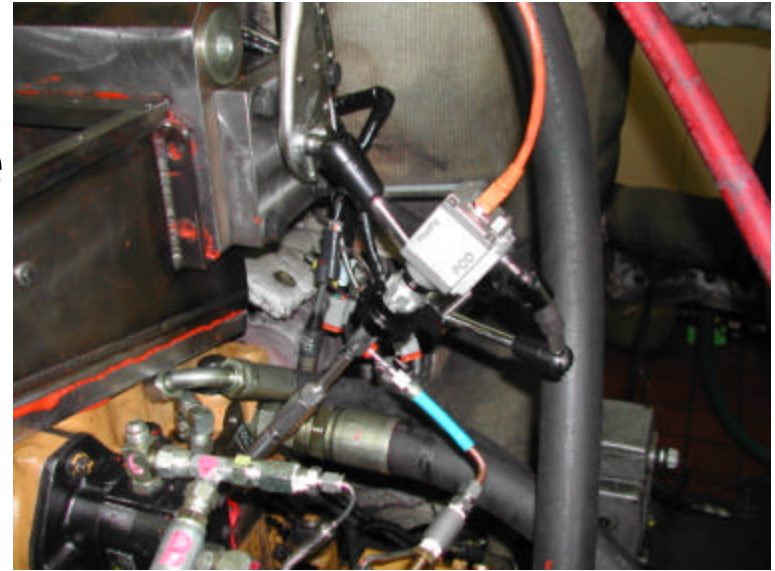


- ✍ Achieve highest load possible with ultra-low NOx and smoke and lowest HC/CO
 - lowest boost possible (PR limits)
 - timing closer to TDC (fuel dilution)
- ✍ Stay within cylinder pressure and rise rate limits of head

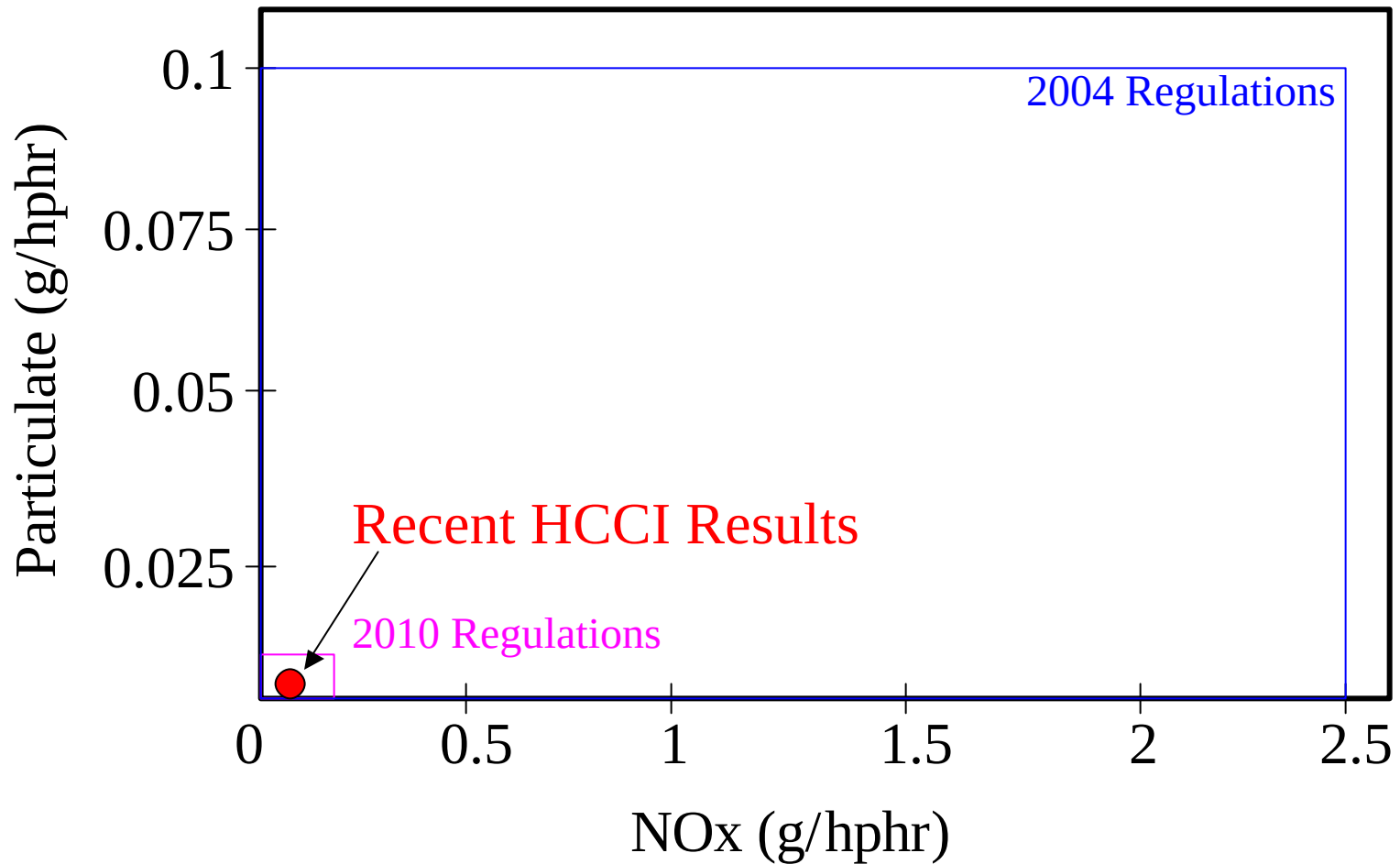
Test Background



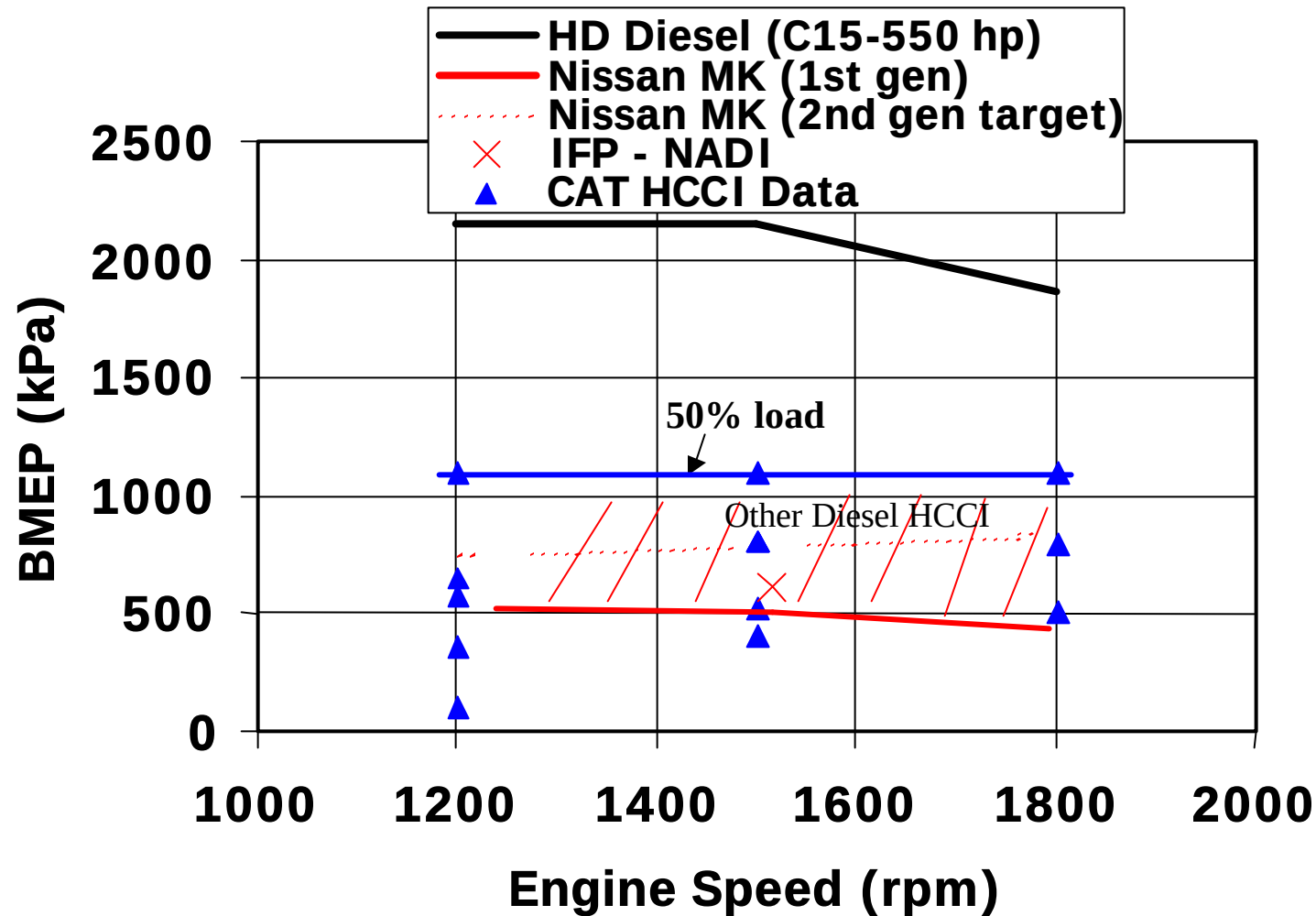
- ✍ 3401 single cylinder engine
- ✍ Low CR piston
- ✍ Multi-hole advanced nozzle
- ✍ No catalyst used
- ✍ Control variables: timing, boost, backpressure, manifold temperature



Ultra-Low Emissions



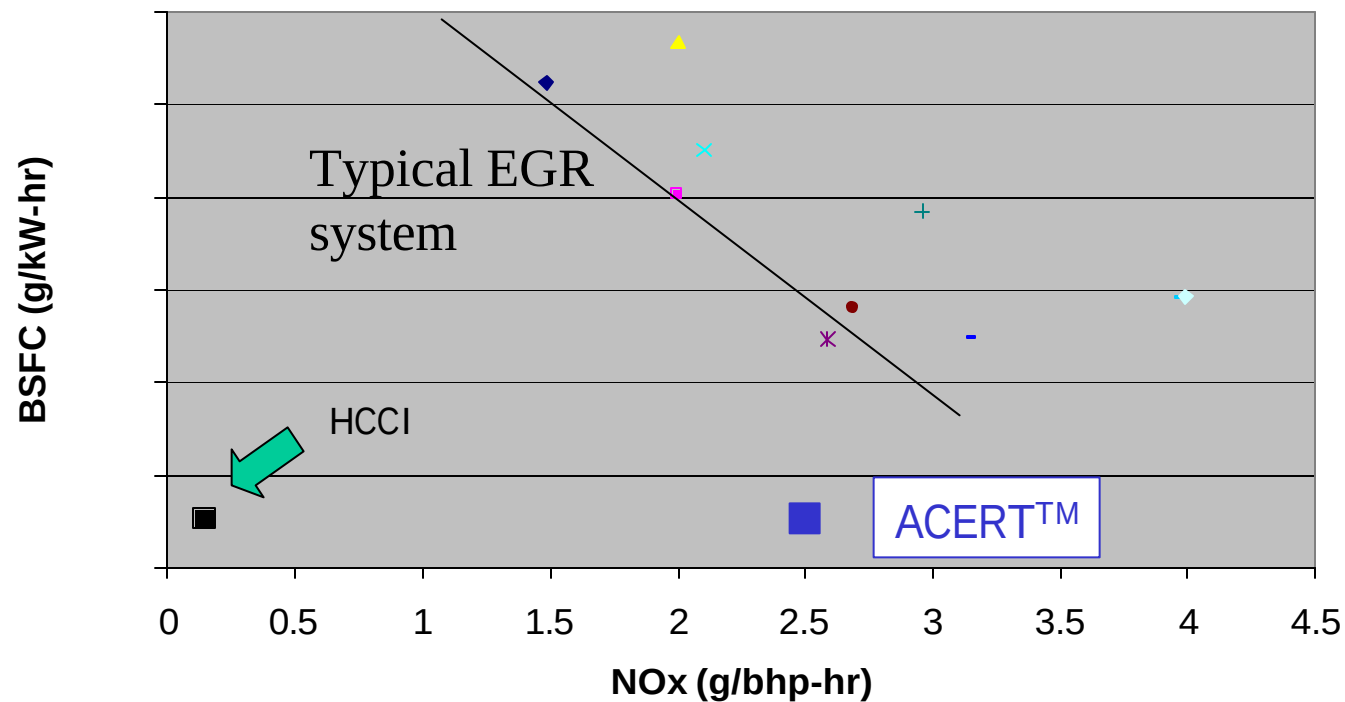
Climbing the BMEP Ladder



Competitive Fuel Consumption, Ultra-Low NOx



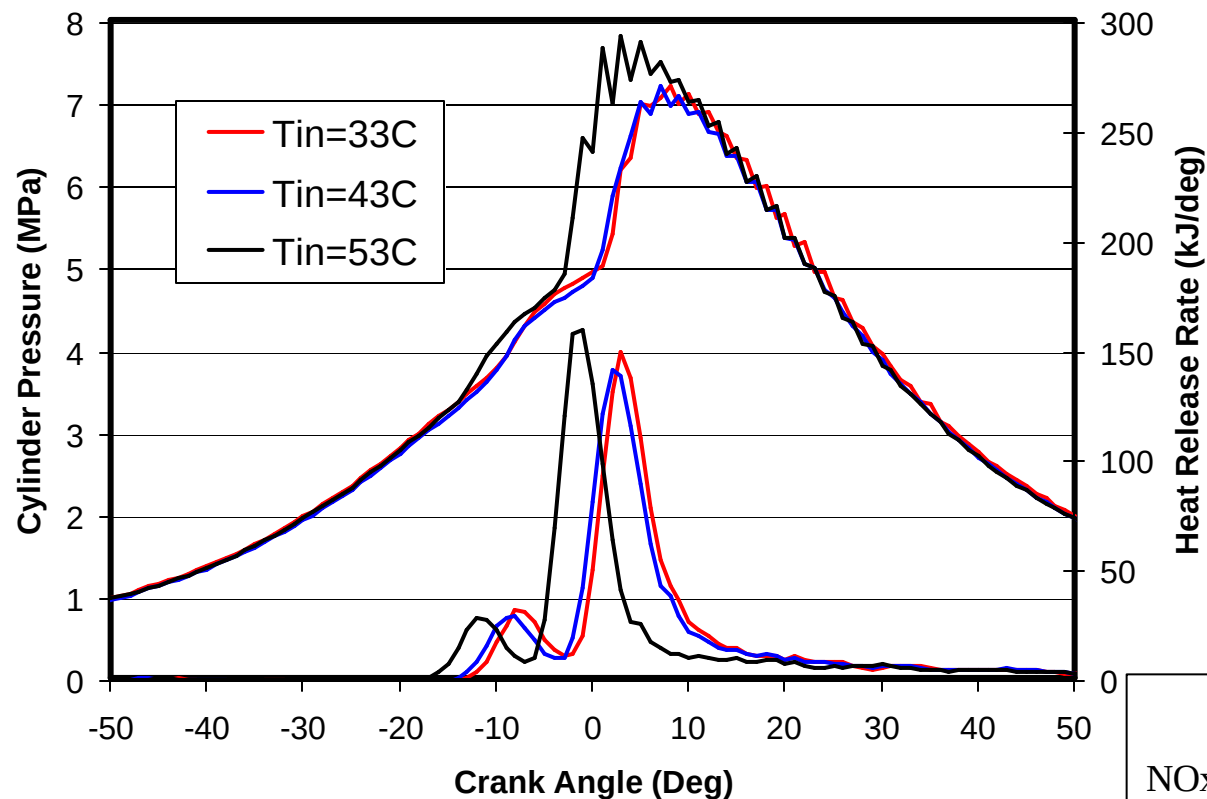
Part Load Operating Condition



Effect of Manifold Temperature



1500 rpm, 1/4 load, fixed timing and boost

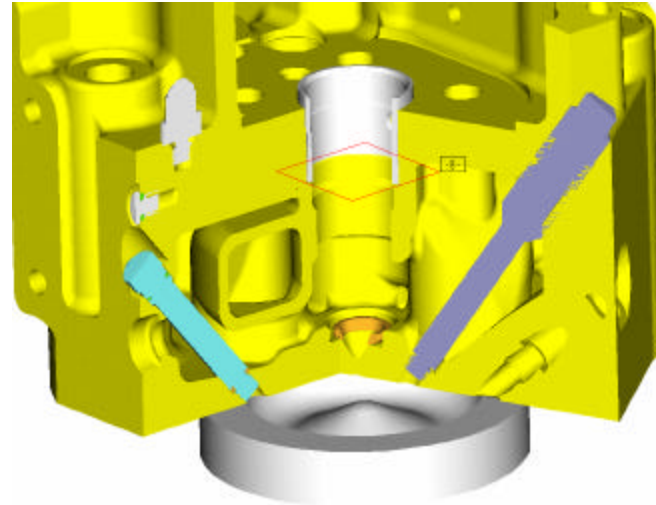


	33C	43C	53C
NOx (ppm)	2	2	8
Smoke (AVL)	0.2	0.16	0.07
HC (ppm)	1219	1014	715
BSFC delta (%)	0	-2	-7

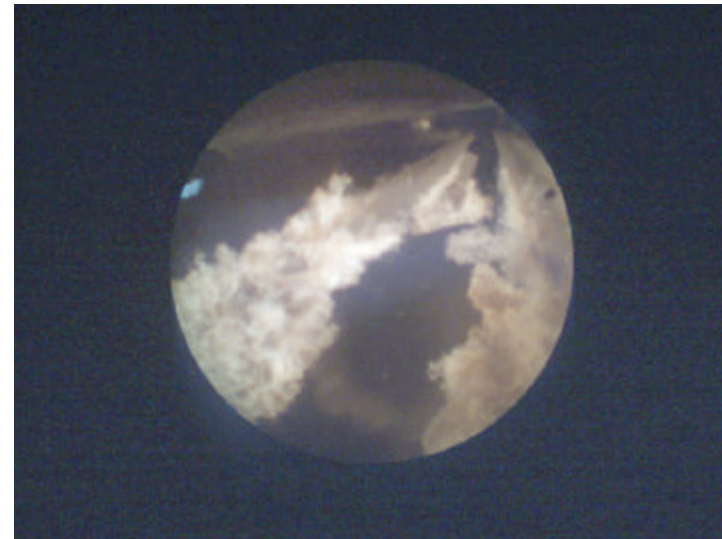
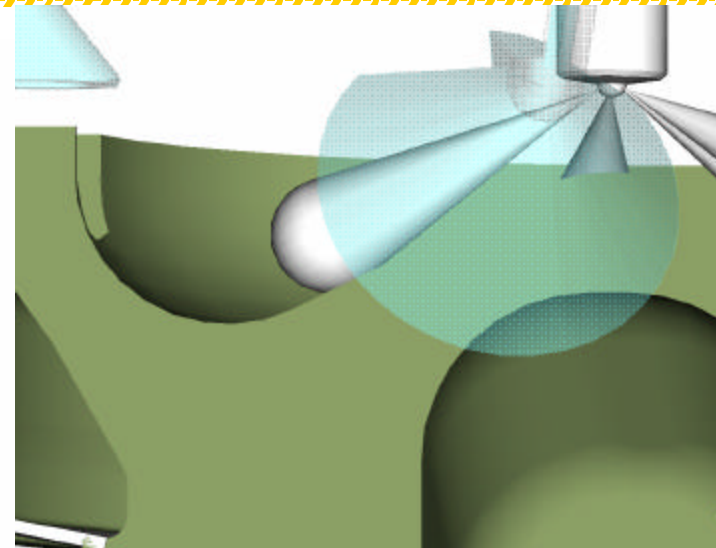
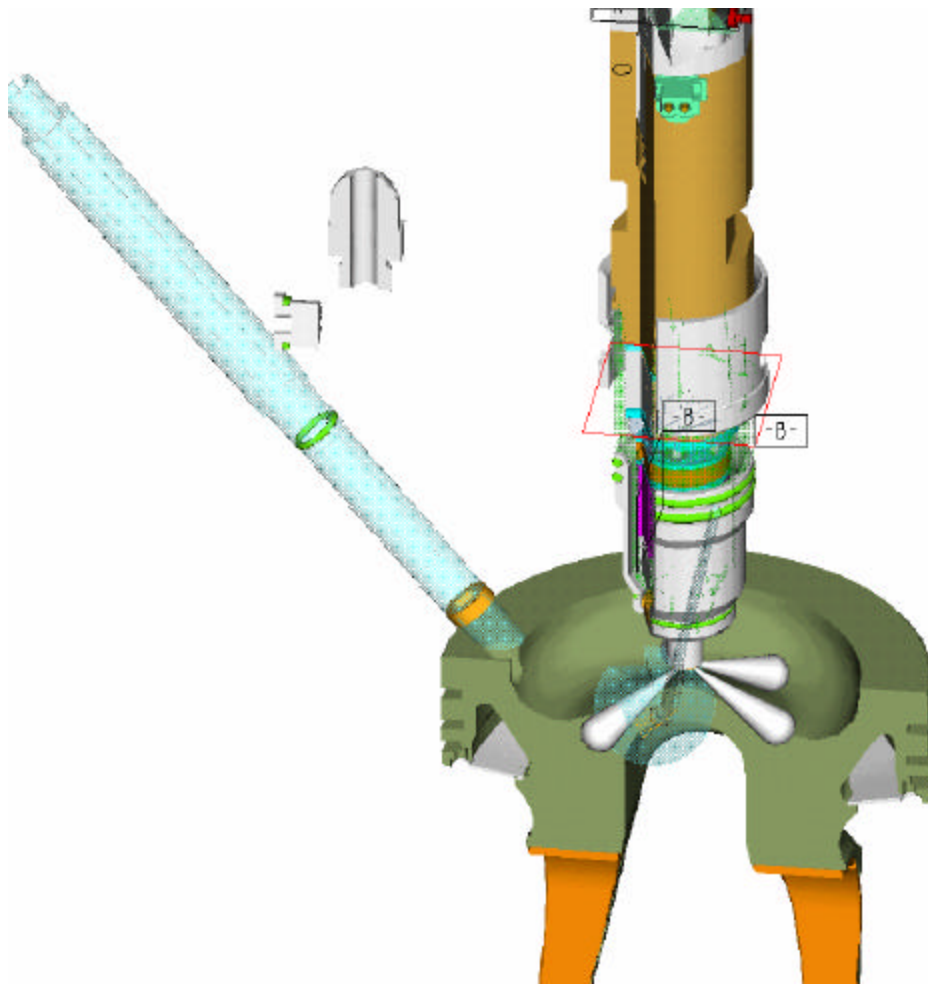
A View Inside the Combustion Chamber



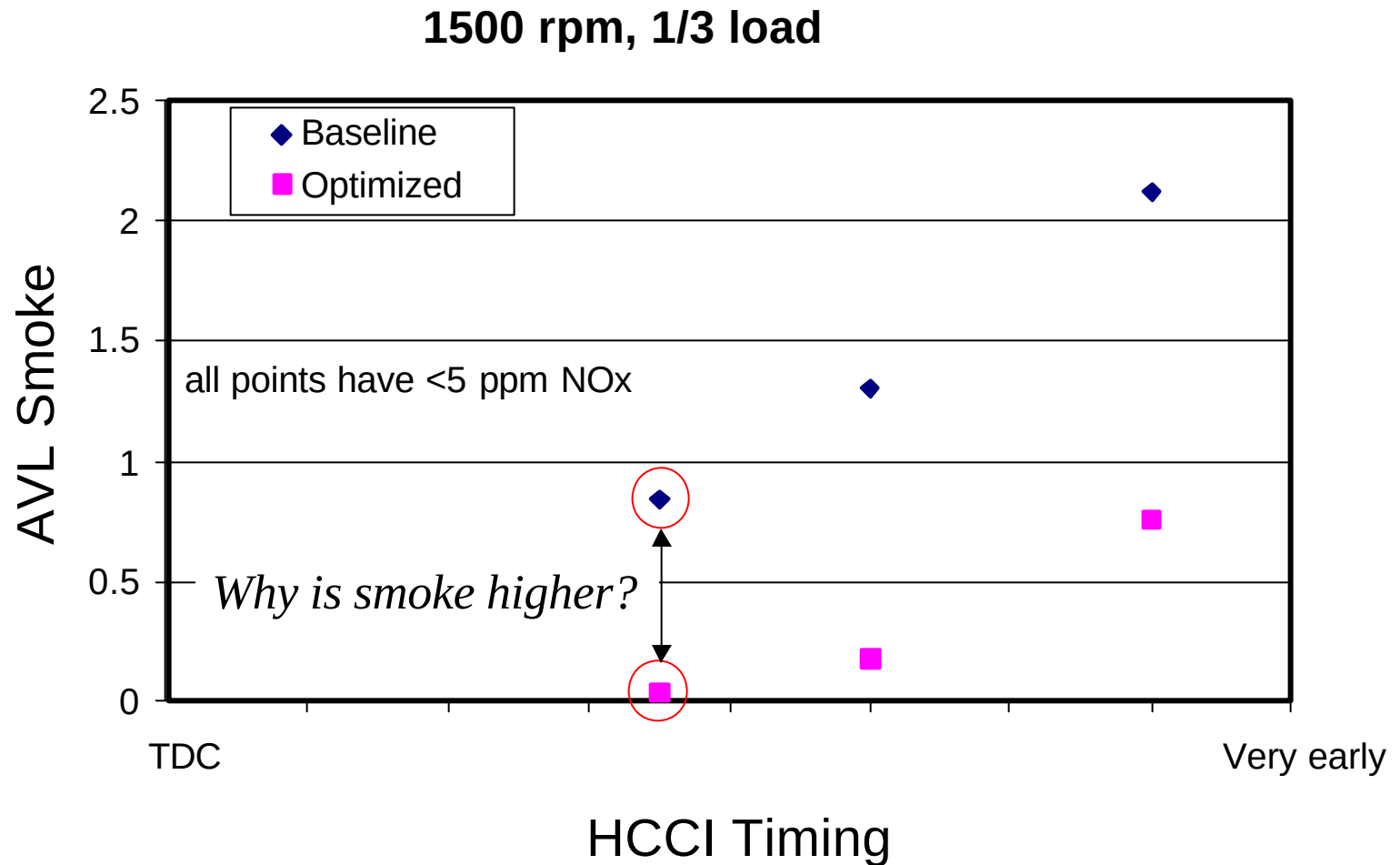
- ✍ VisioScope™ evaluation in 3401 under actual operating conditions
- ✍ Optical access to cylinder through 10 mm passages
- ✍ 2 locations (edge of bowl, halfway into cylinder)



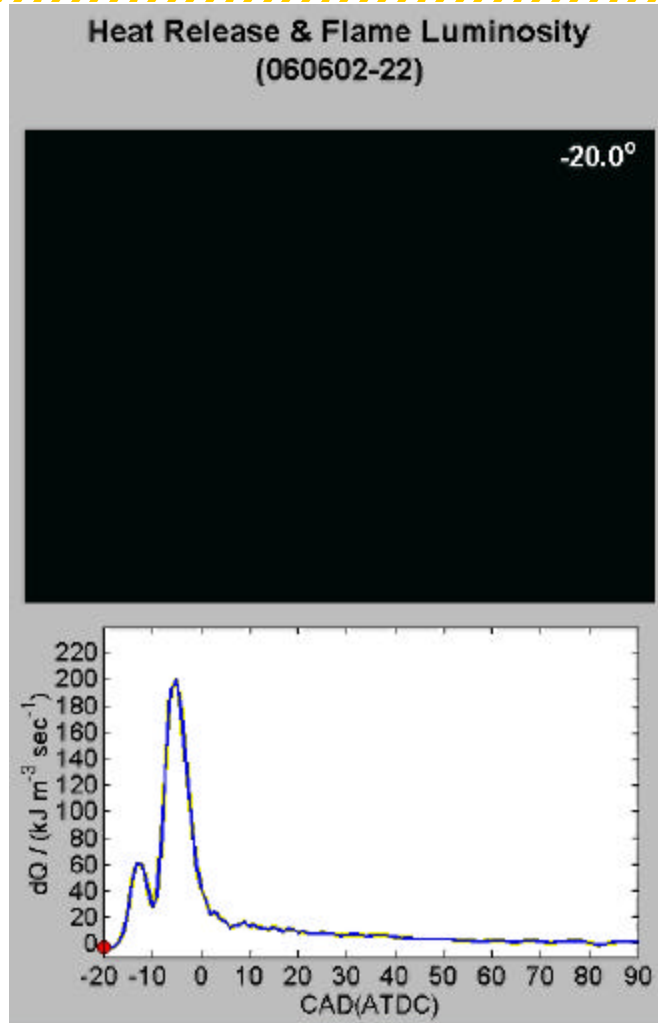
VisioScope™ View of Plumes



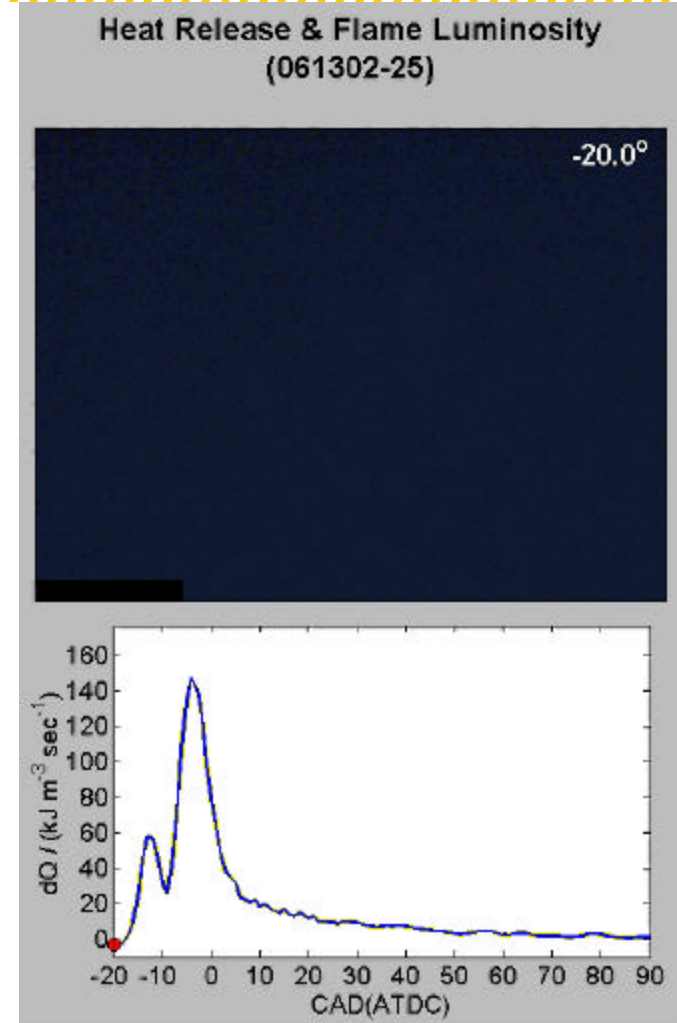
High and Low Smoke Results



HCCI Combustion – Direct Luminosity



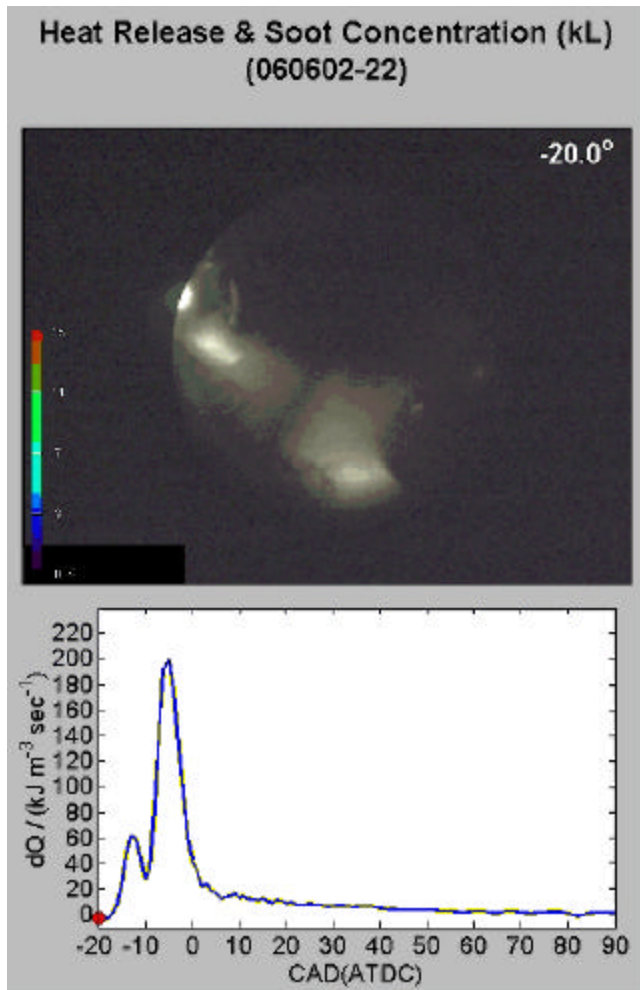
0.03 AVL Smoke



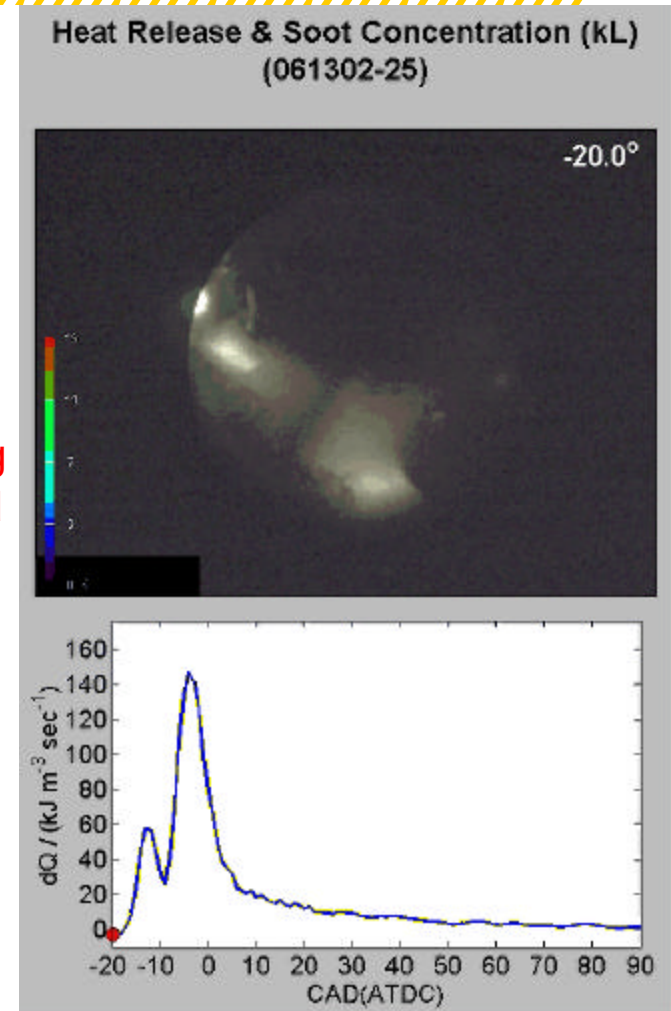
0.84 AVL Smoke

Both
zero
NOx

HCCI Combustion – KL Soot Concentration



Mechanism: Fuel deposited in oil during early injection evaporates off during expansion stroke and burns to generate high smoke



Challenges of High Load HCCI

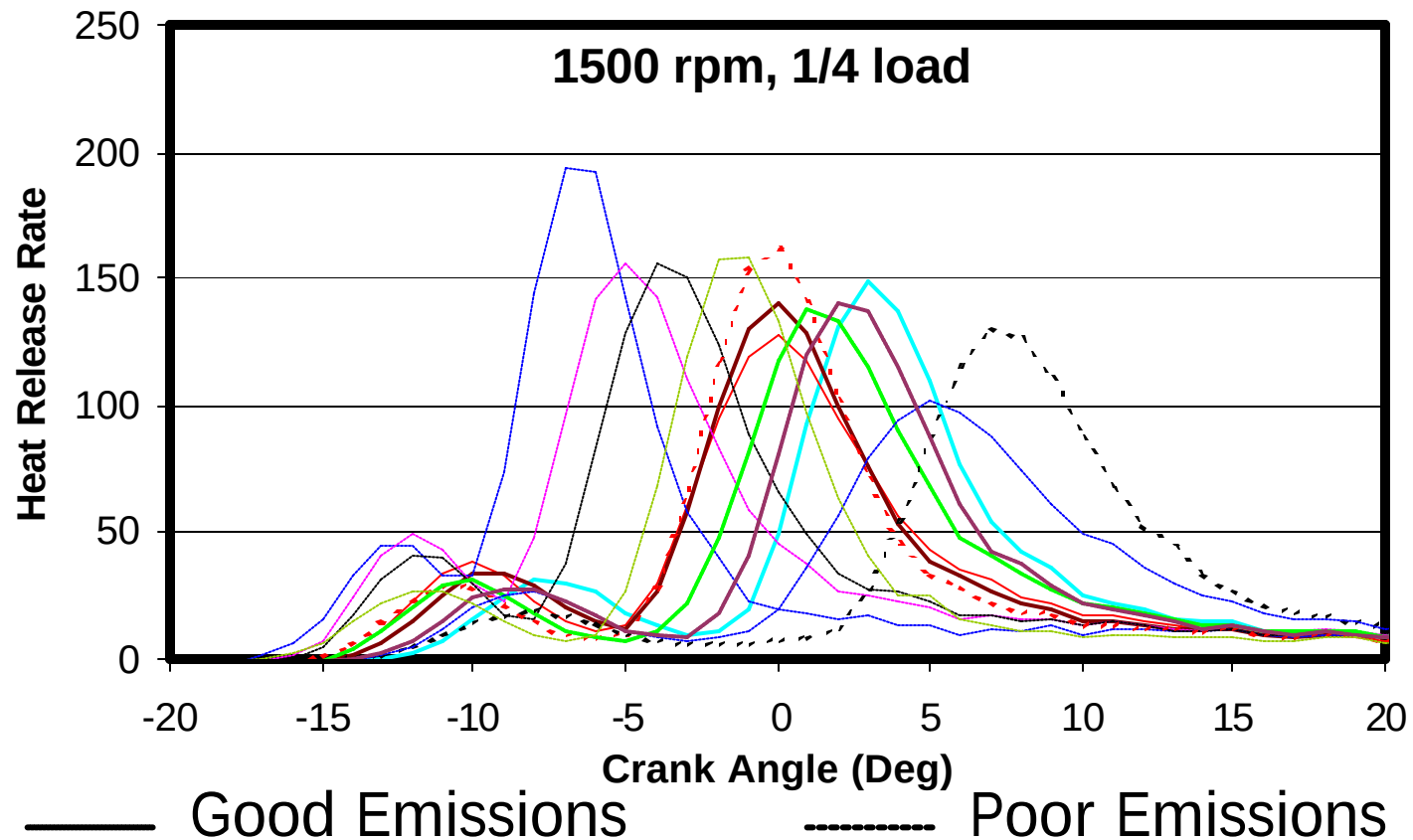


- Combustion Control
- Pressure Rise Rates (~ 2 MPa/deg)
- Air System (maintain AFR, lower T_{exh})
- HC and CO conversion
- Cold Start

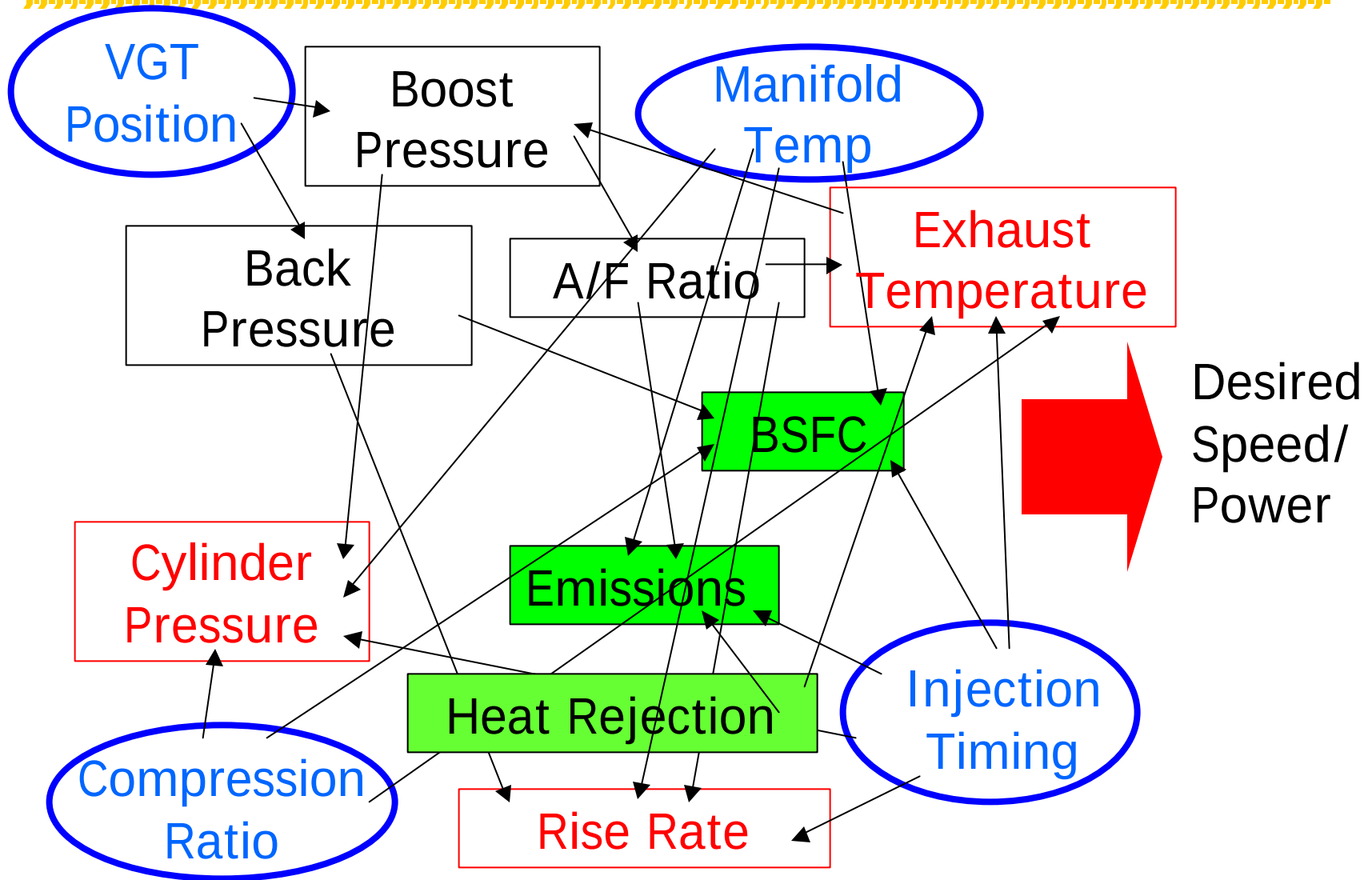
Combustion Control



Cylinder pressure feedback alone may not be sufficient for control



Combustion Control – System Interaction



Future Plans



- ✍ Further investigate load limits at other engine speeds
- ✍ Other methods to control combustion
- ✍ Multi-cylinder demo
- ✍ Advanced control algorithm development