Diesel HCCI Results at Caterpillar

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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

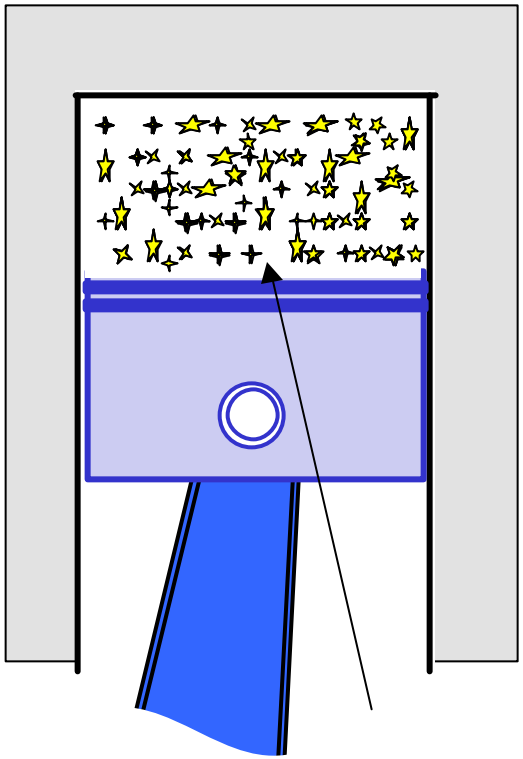
Why Diesel HCCI?

- 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 $?_{TH}$
  - 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

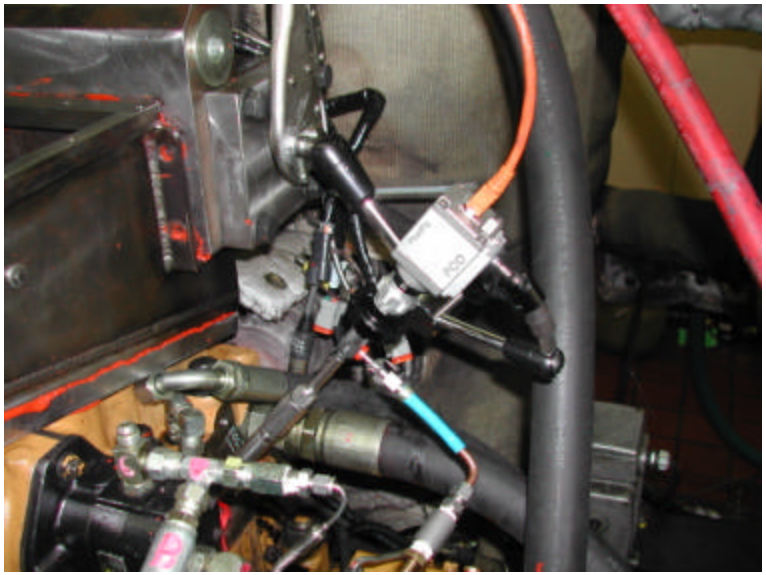
  -lowest boost possible (PR limits)

  -timing closer to TDC (fuel dilution)

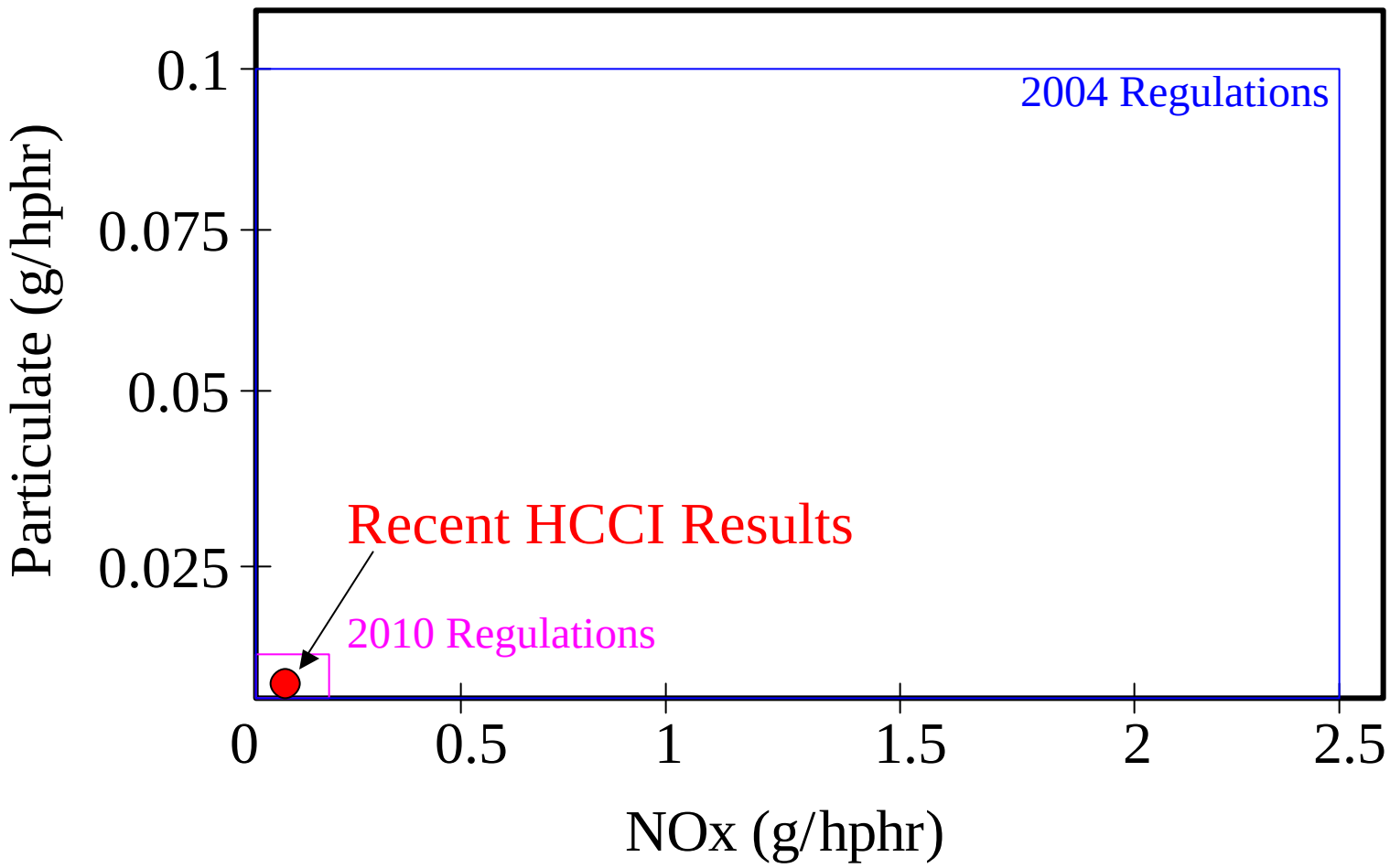
- Stay within cylinder pressure and rise rate limits of head

Test Background

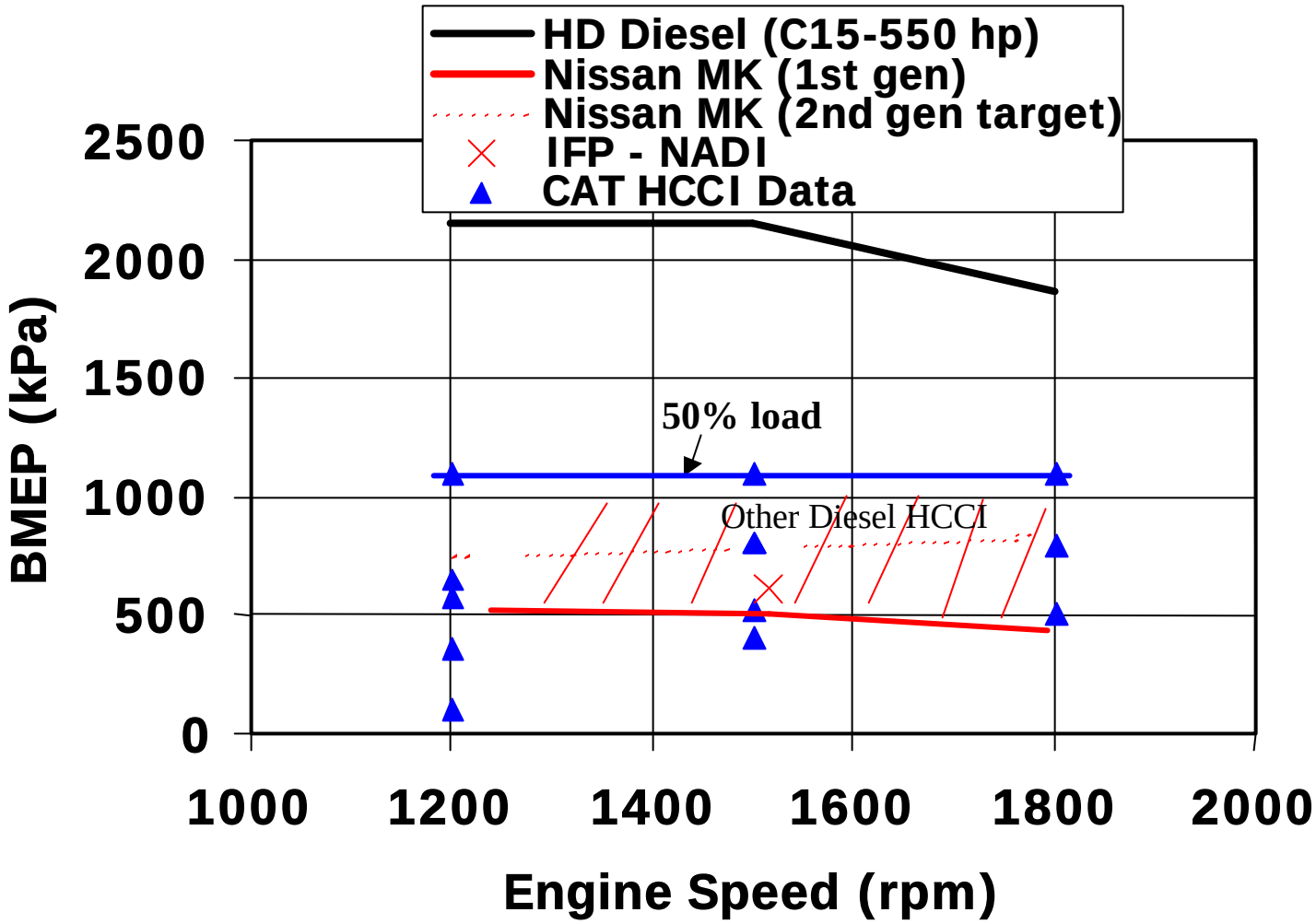
- 3401 single cylinder engine
- Low CR piston
- Multi-hole advanced nozzle
- No catalyst used
- Control variables: timing, boost, backpressure, manifold temperature



Ultra-Low Emissions

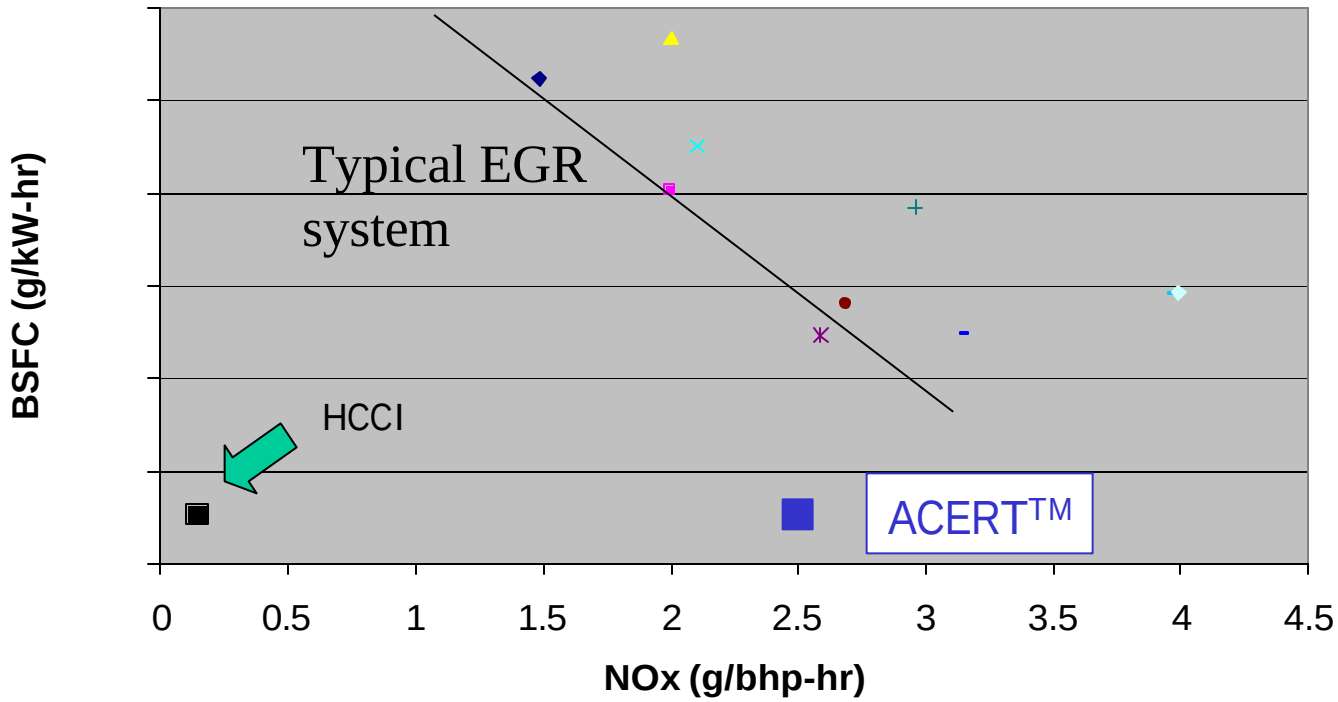


Climbing the BMEP Ladder

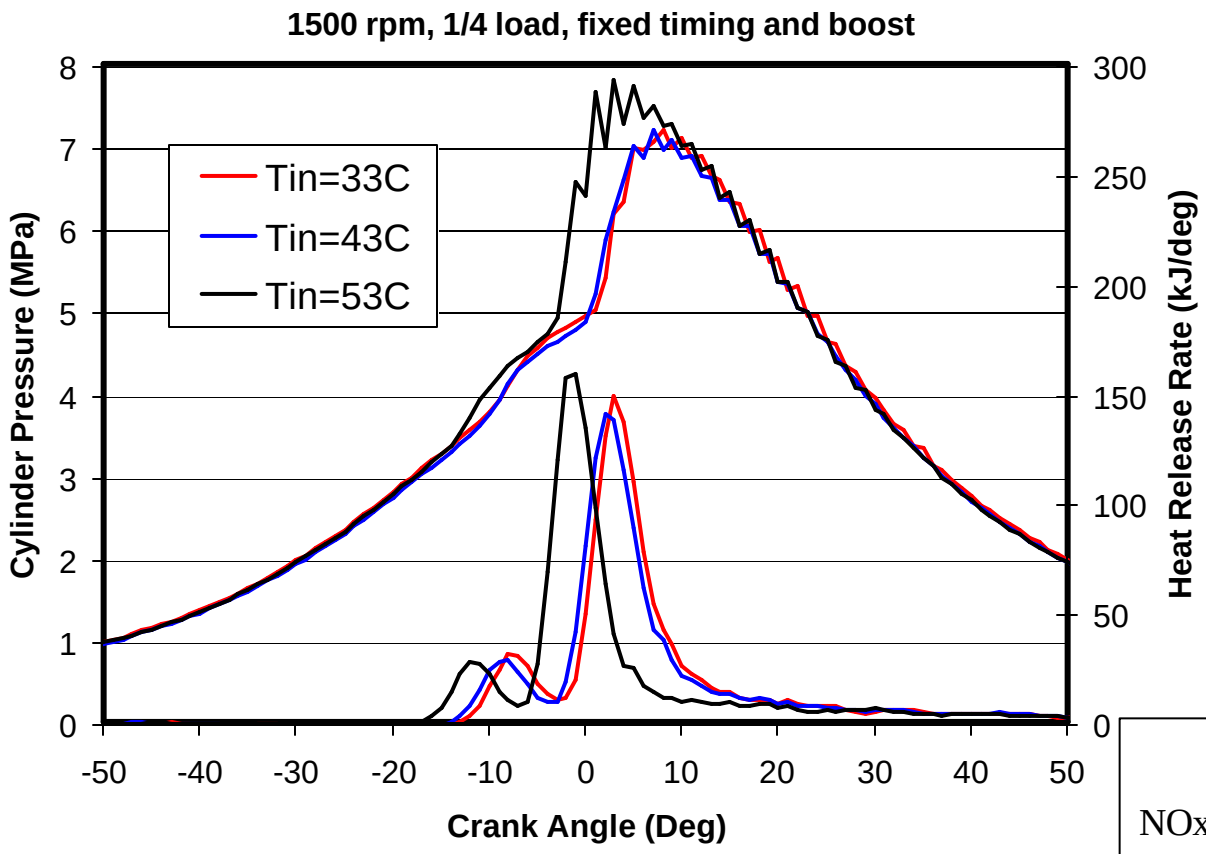


Competitive Fuel Consumption, Ultra-Low NOx

Part Load Operating Condition



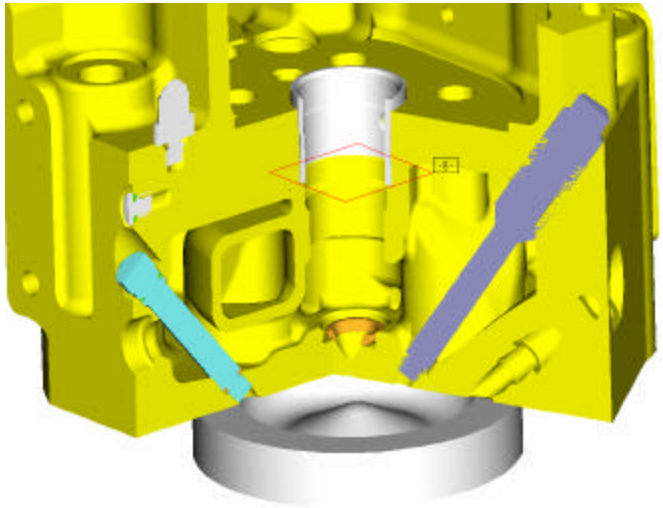
Effect of Manifold Temperature

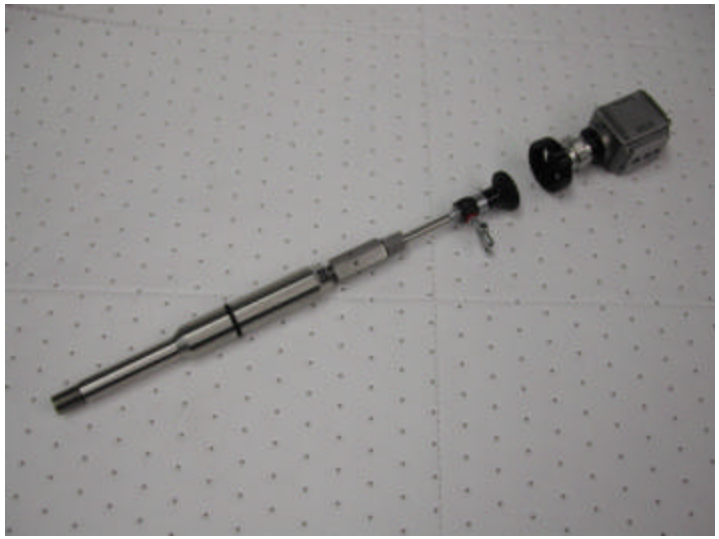


	33C	43C	53C
NOx (ppm)	2	2	8
Smoke (AVL)	0.2	0.16	0.07
HC (ppm)	1219	1014	715
BSFC delta (%)	0	-2	-7

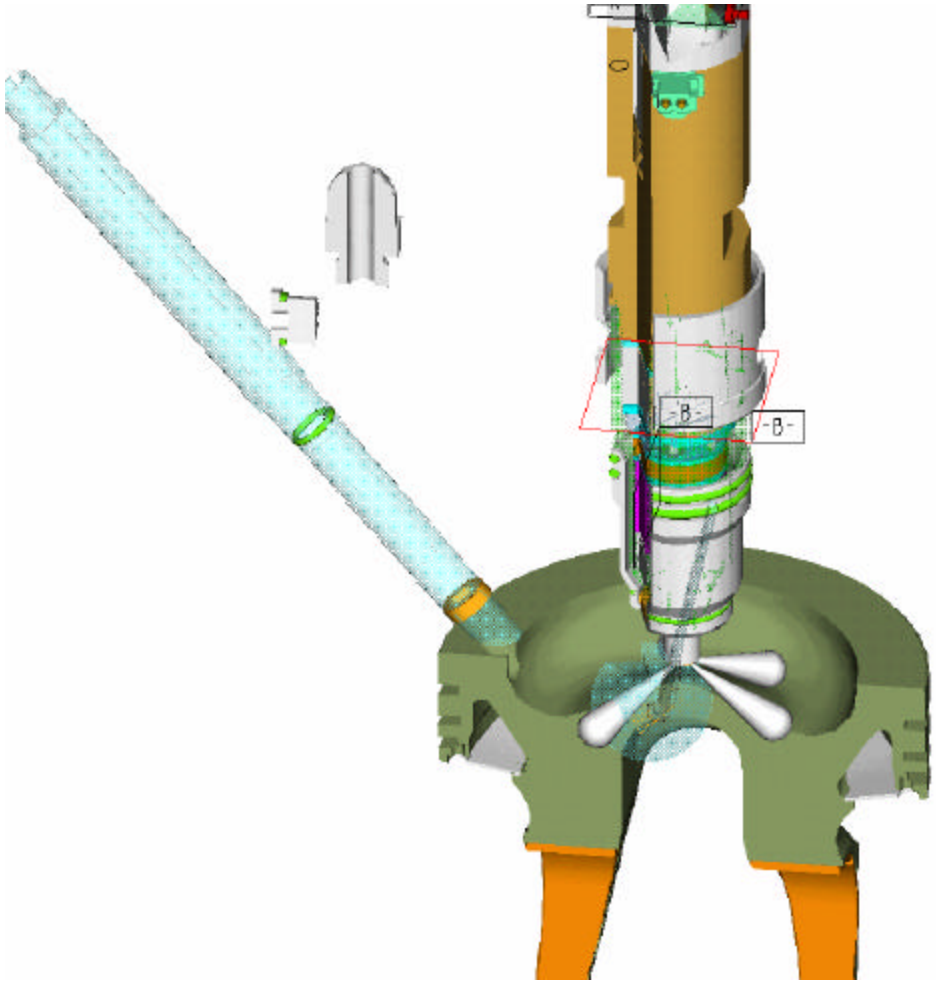
A View Inside the Combustion Chamber

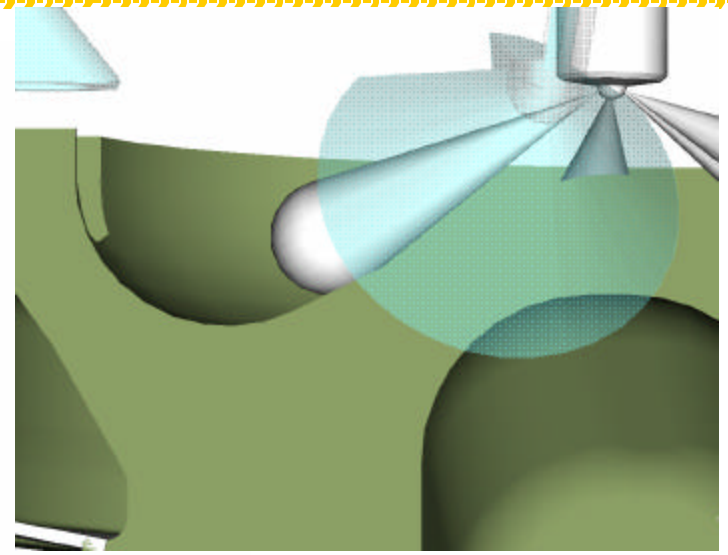
- VisioScope™ evaluation in 3401 under actual operating conditions
- Optical access to cylinder through 10 mm passages
- 2 locations (edge of bowl, halfway into cylinder)

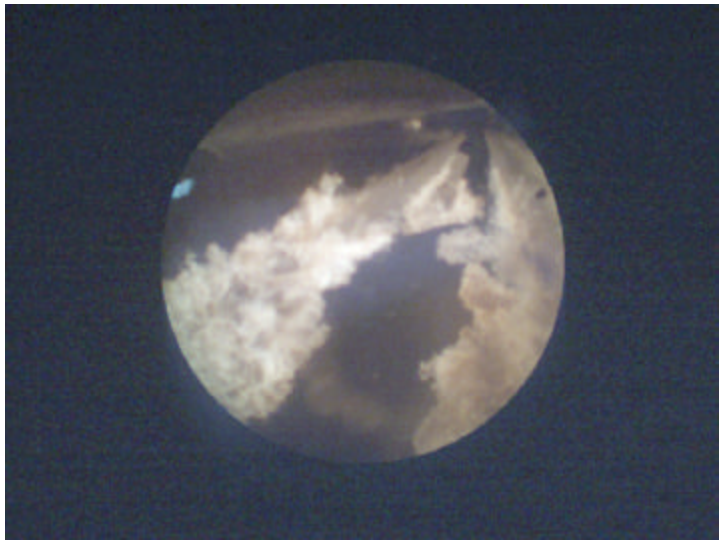




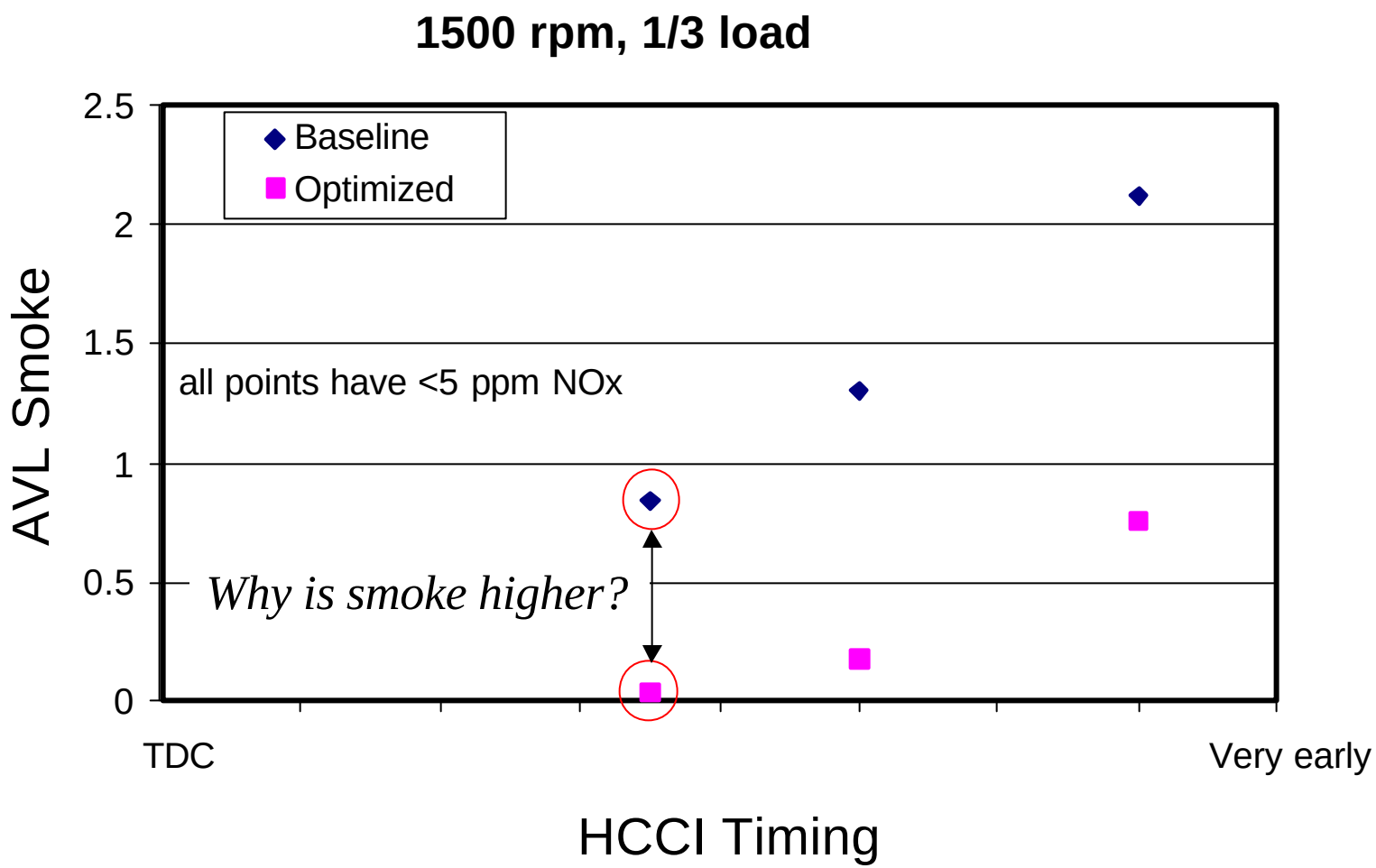
VisioScope™ View of Plumes



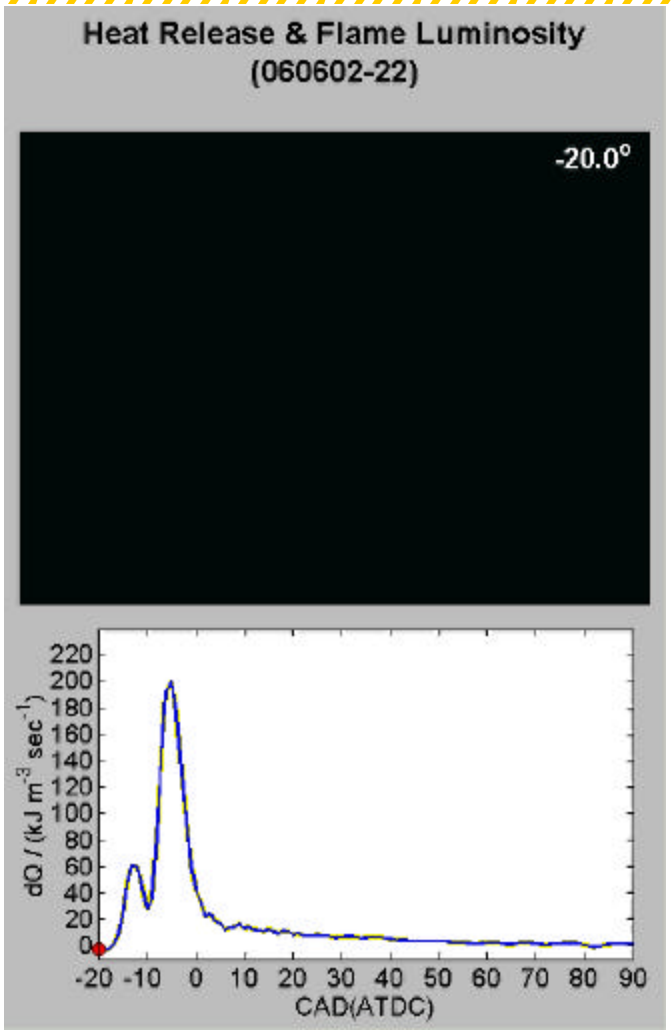




High and Low Smoke Results

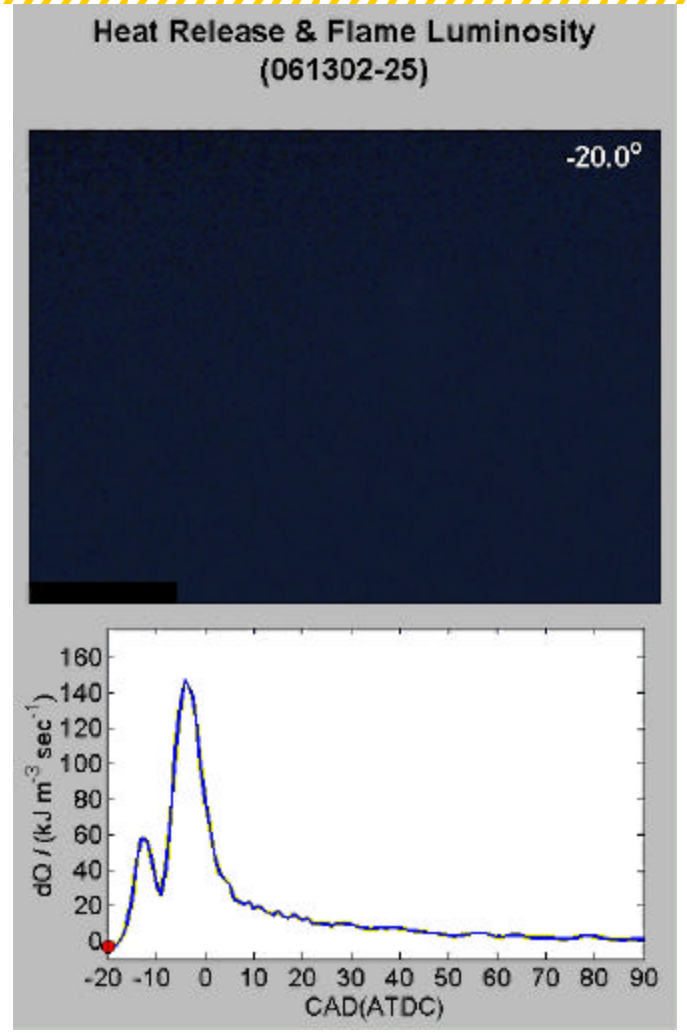


HCCI Combustion – Direct Luminosity



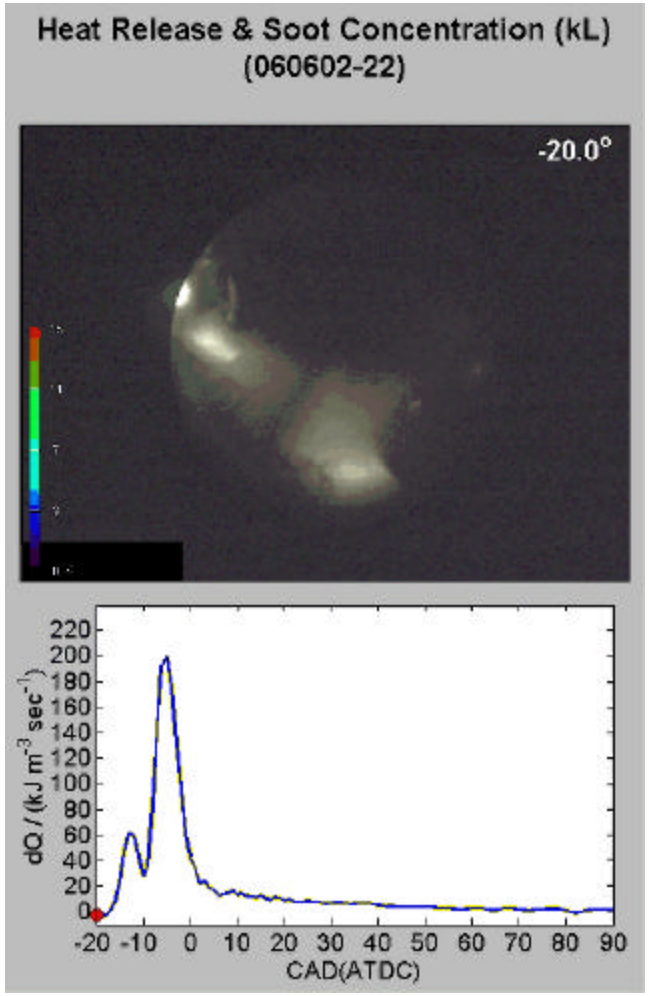
0.03 AVL Smoke

Both zero NOx



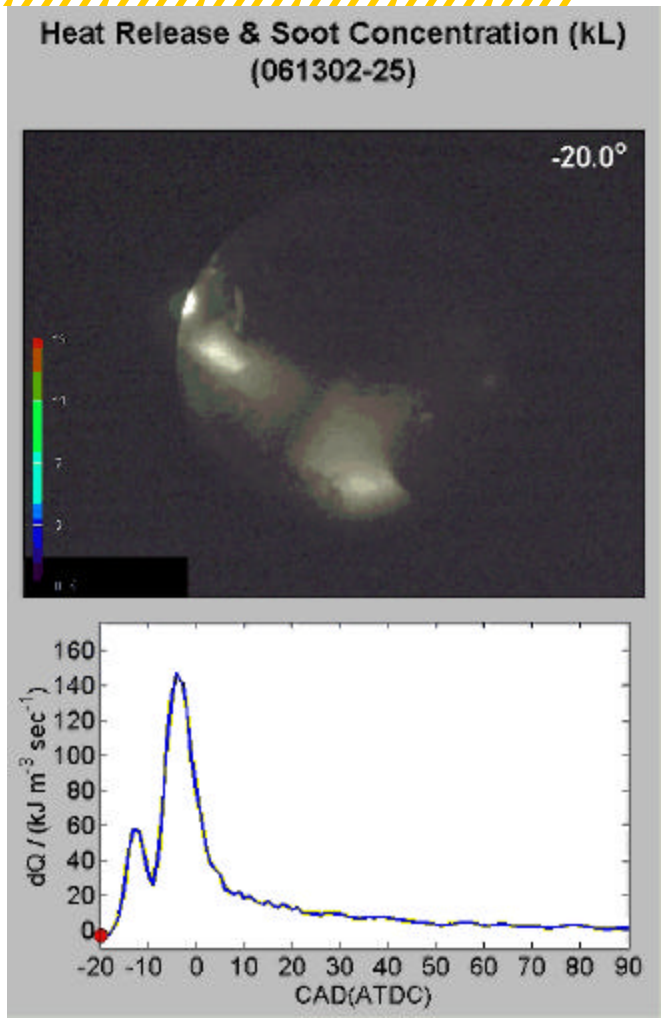
0.84 AVL Smoke

HCCI Combustion – KL Soot Concentration



0.03 AVL Smoke

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



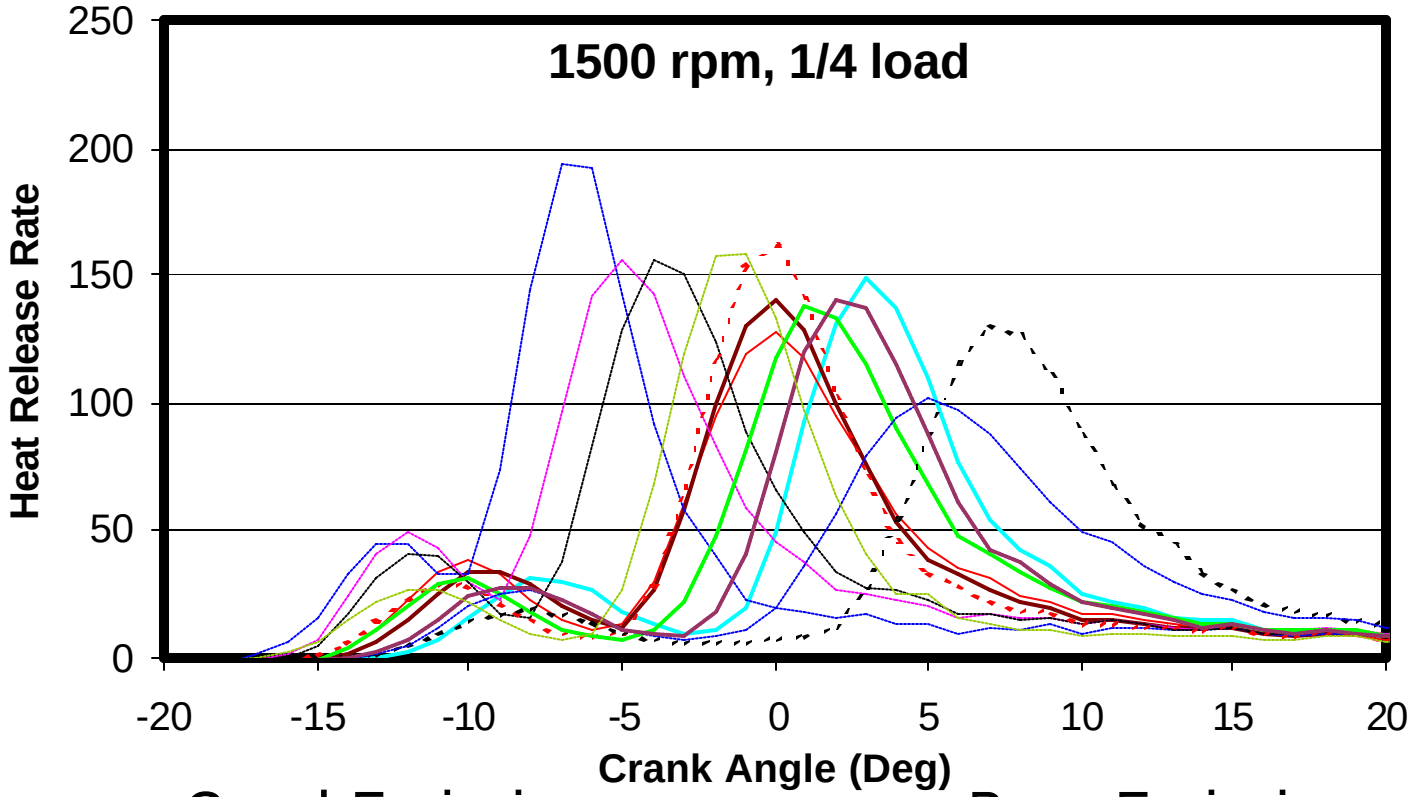
0.84 AVL Smoke

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

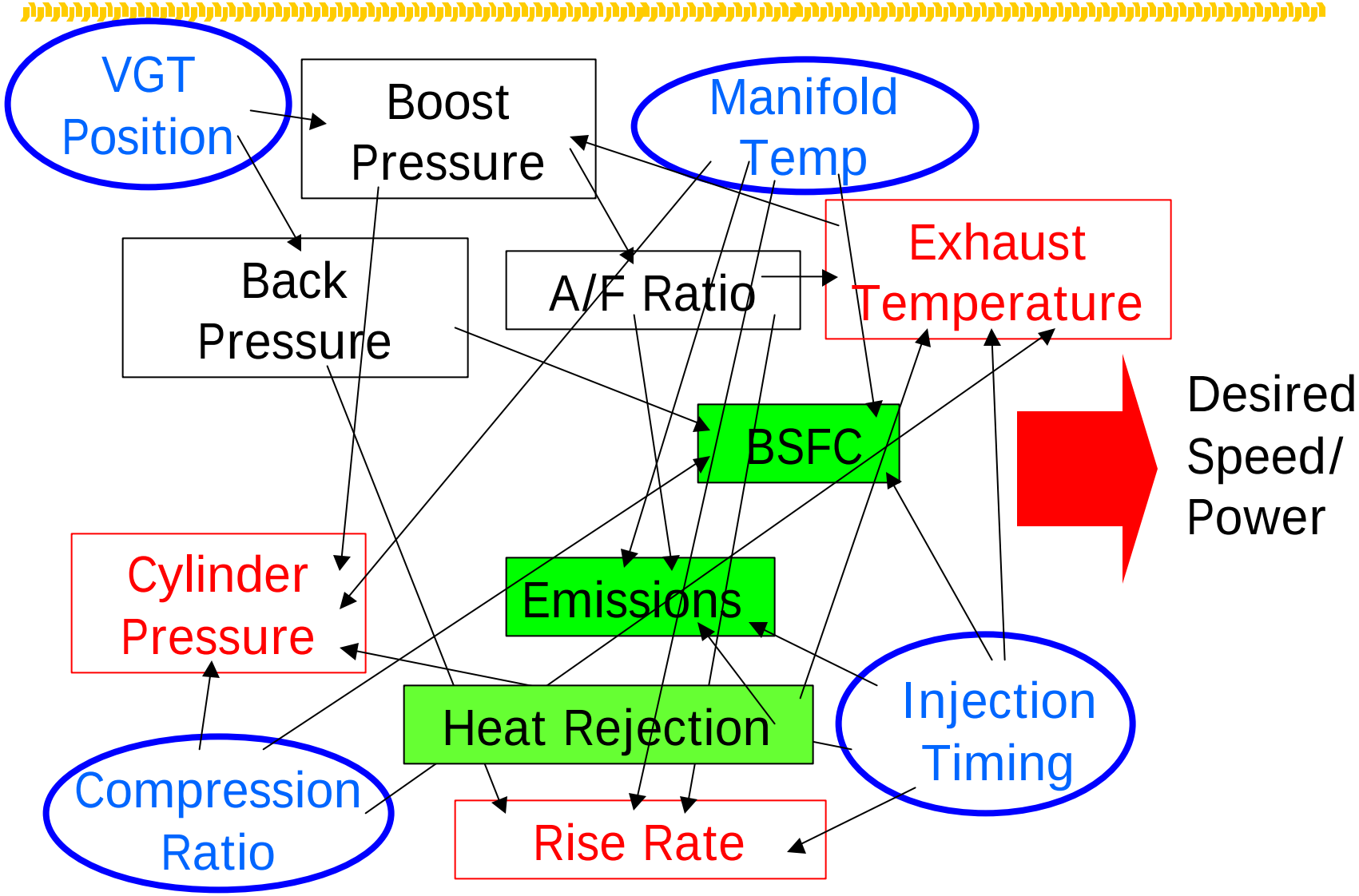
Combustion Control

Cylinder pressure feedback alone may not be sufficient for control



—— Good Emissions ---------- Poor Emissions

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