

# Partially Premixed Combustion

# **VOLVO**

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# High Load Low Temperature Combustion - enabled by introduction of “new” fuels

## RCCI

‘Reactivity Controlled CI’

very high ON +very high CN

i.e. neat ethanol + Diesel

IMEP 17 bar w/o EGR reported

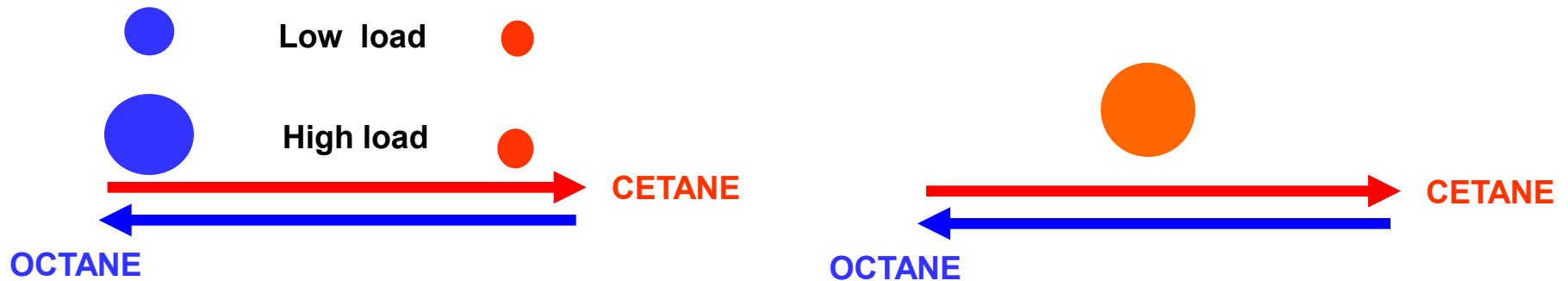
## PPC

Partially Premixed Combustion

in-between ON/CN

i.e. Naphtha or gasoline/diesel

**IMEP 26 bar achieved**



**Power density - a prerequisite for downsizing and transport efficiency**

# PPC use a gasoline type fuel

- **Low Cetane**

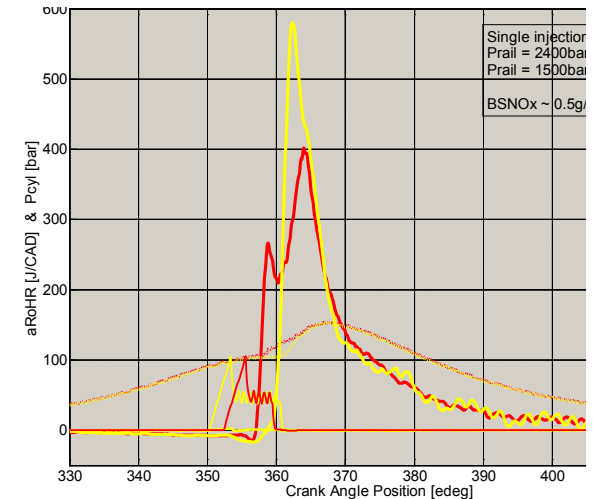
- ignition delay reduce soot (more premix)
- increase efficiency (faster heat release)
- **Low load problems (noise, HC+CO)**

- **High volatility**

- No wall wetting; Inject anytime!

- **Low viscosity**

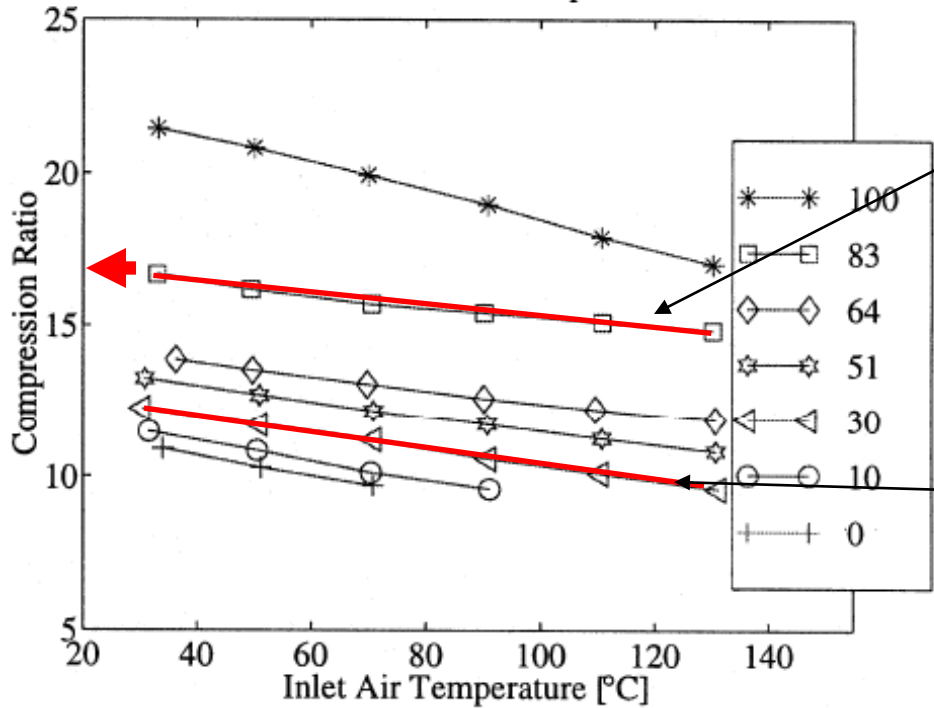
- **A lubricity additive needed**



# CR requirement for ignition

## HCCI test for PRF blends

Iso-octane & N-heptane



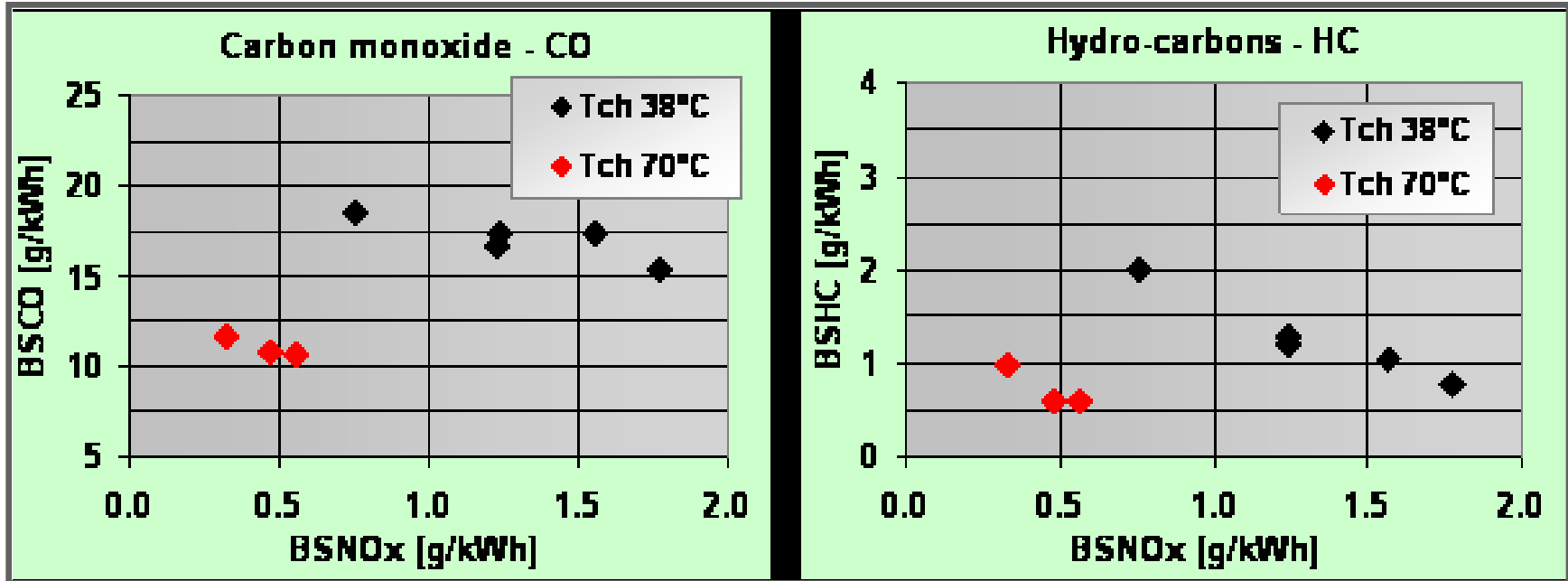
ignition becomes demanding for ON > 80  
CR > 17 needed for cold start?

Diesel is similar to PRF 30

Port injected PRF0 to PRF100

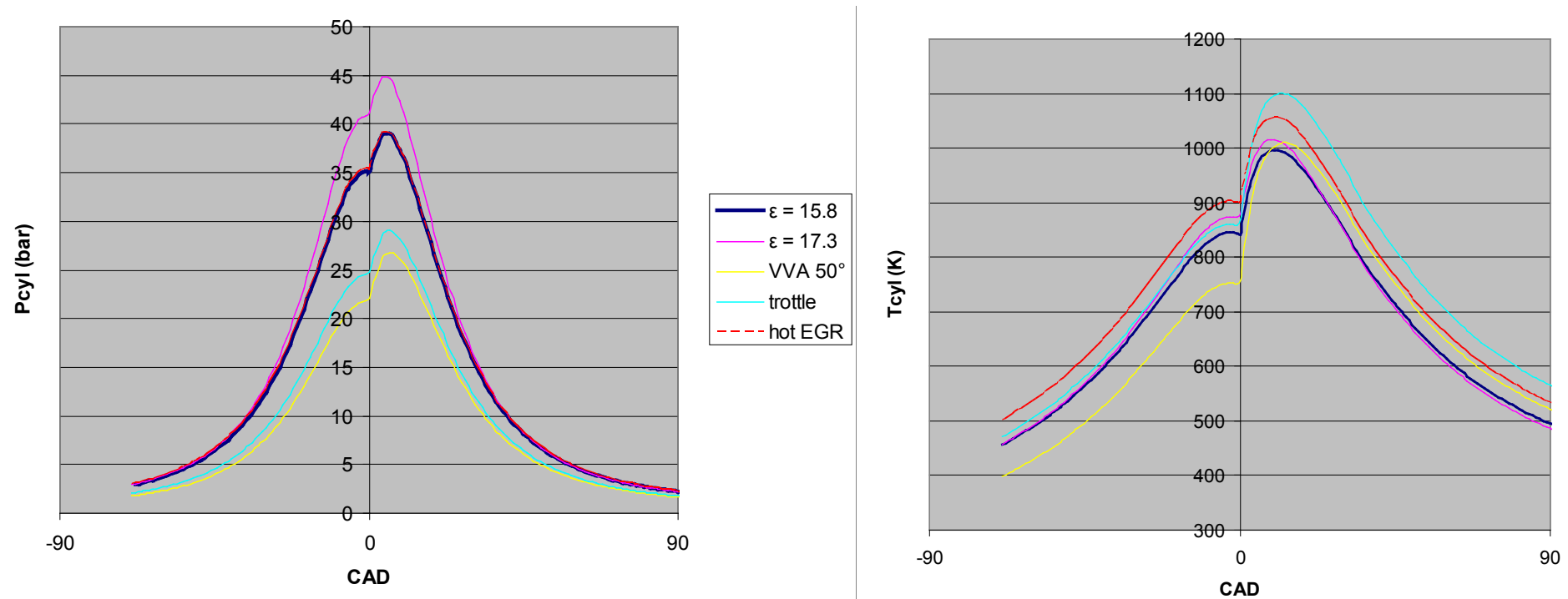
# Controlling CO and HC at low load

uncooled EGR setting: Inlet Manifold Temp raised from 38 to 70 C



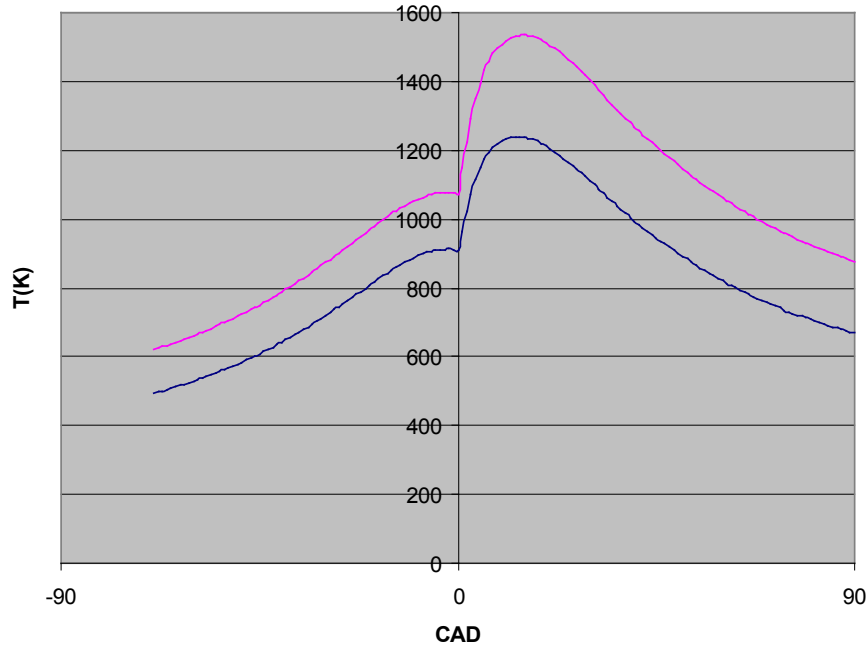
We must do more at lower loads!

# Ways to improve temperature at TDC



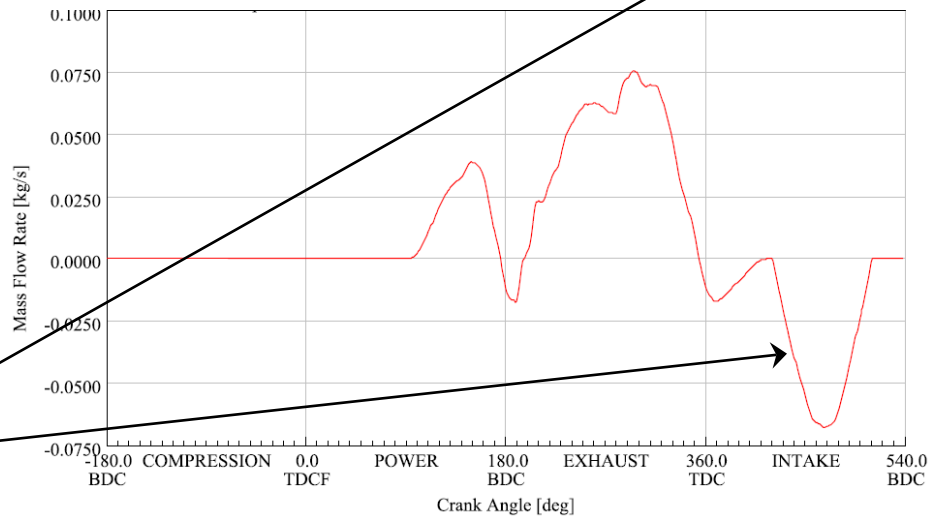
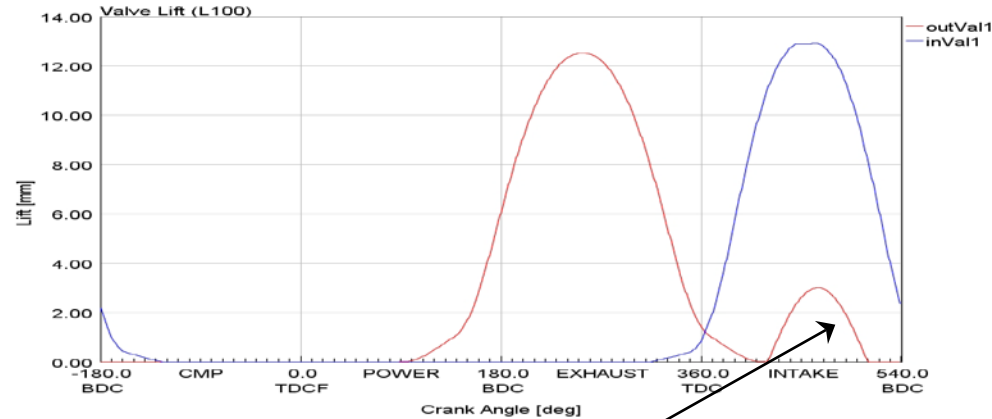
**Influence on in cylinder temperature at TDC by:  
increased compression ratio, Miller, intake throttling and hot EGR  
Hot EGR still the best**

# Exhaust re-breathing is another way to increase in cylinder temperature



In Cylinder temp with and without re-breathing

Re-breathing

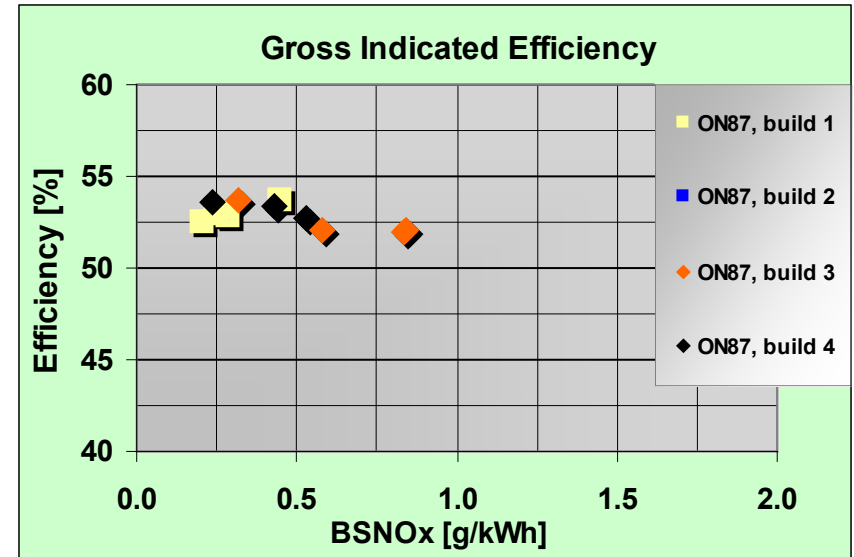
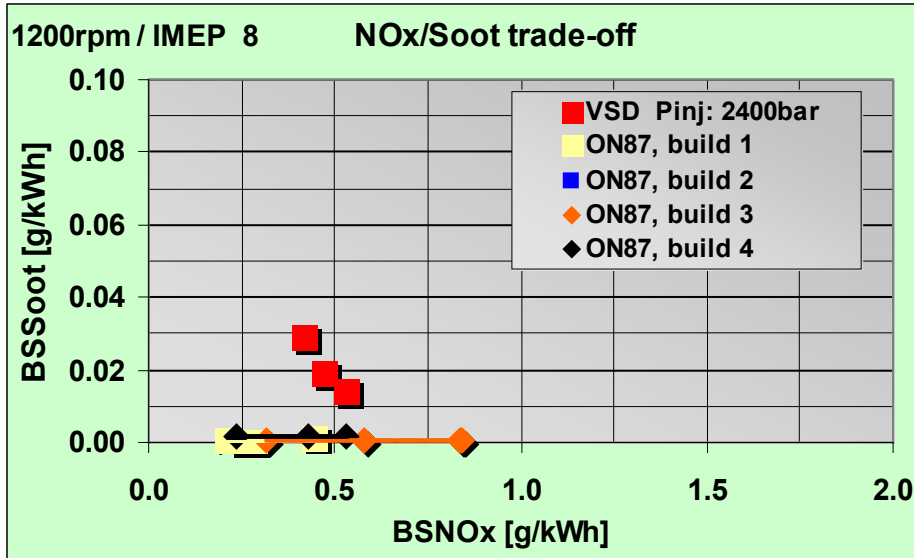


# PPC test results with single stage turbo boundary conditions

A load sweep from IMEP 8 to 21 bar  
From premixed to diffusion combustion



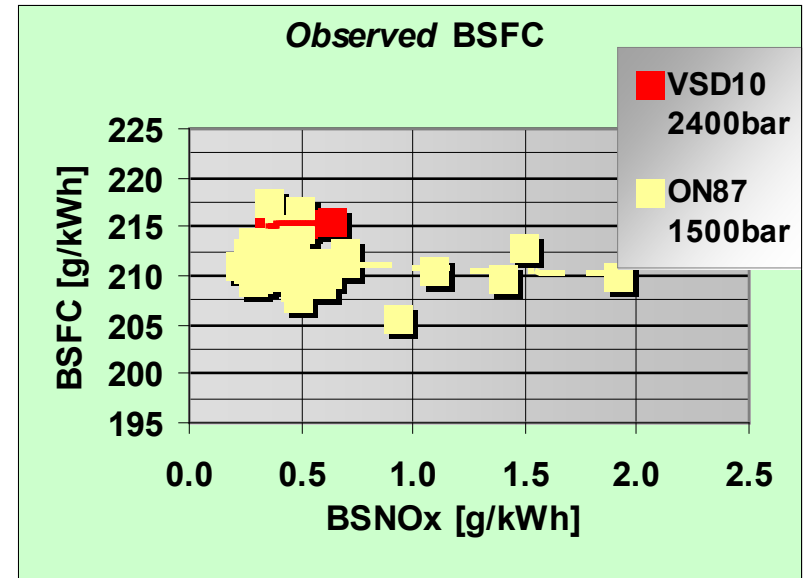
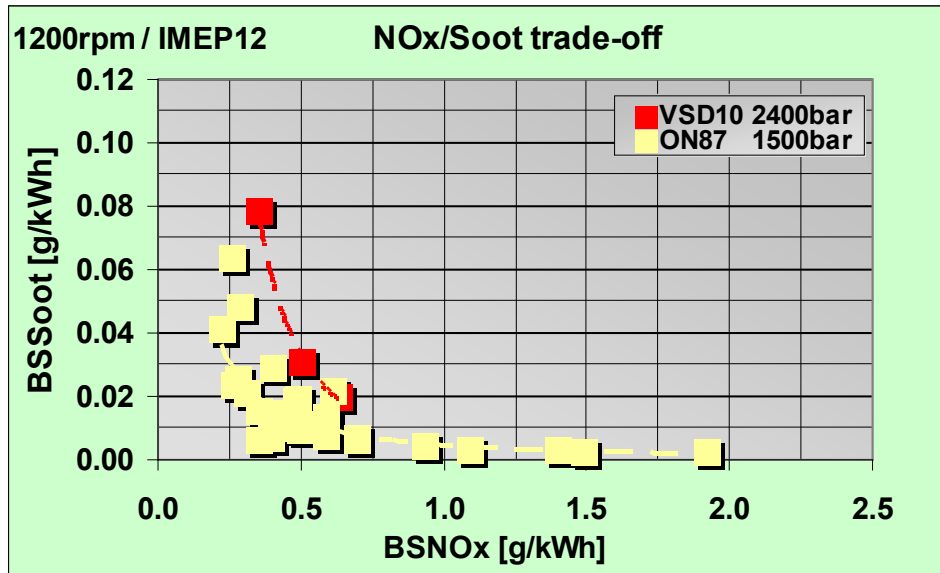
# 1200rpm/IMEP8, soot free combustion at very low NOx



Soot free due to premixing

Note that diesel is injected at 2400 bar

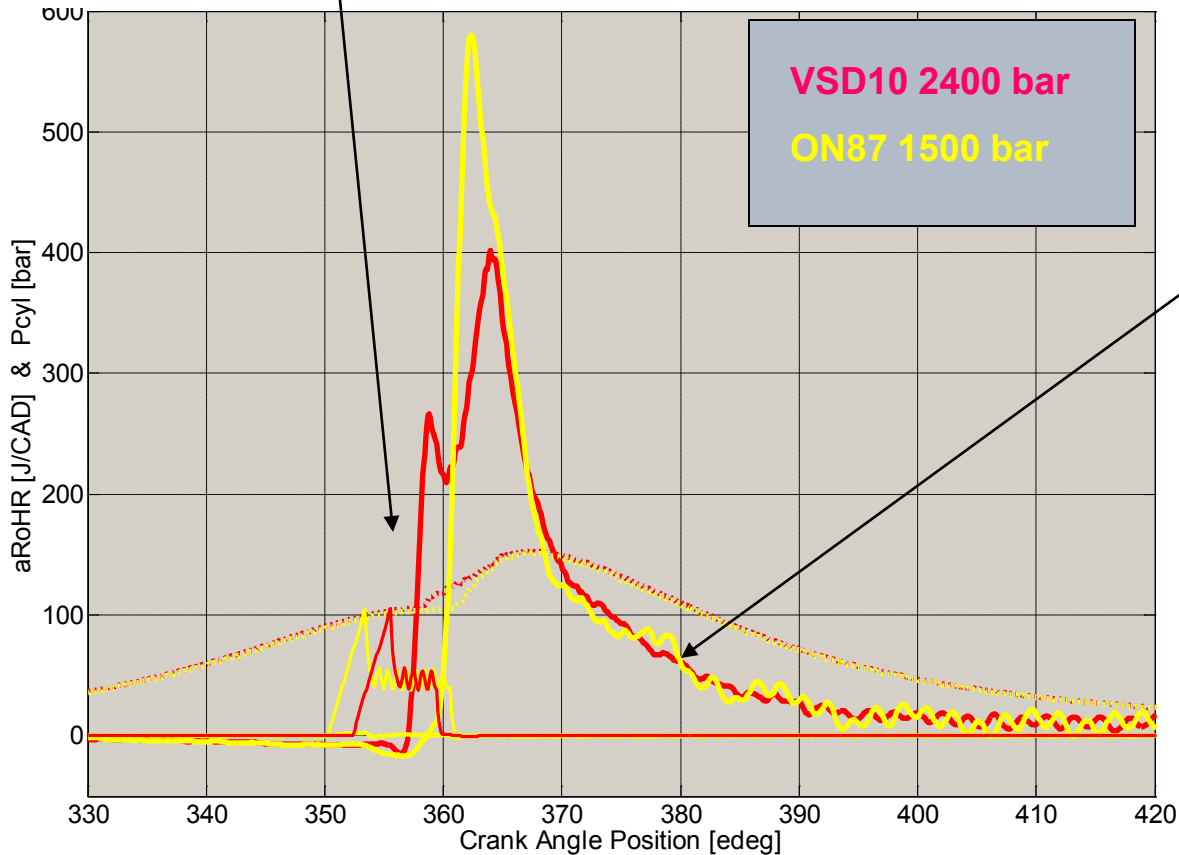
# 1200rpm/IMEP12, significant potential on soot and BSFC with gasoline type fuel



One reason for improved BSFC is shorter combustion duration

# IMEP12 – Rate of Heat Release example

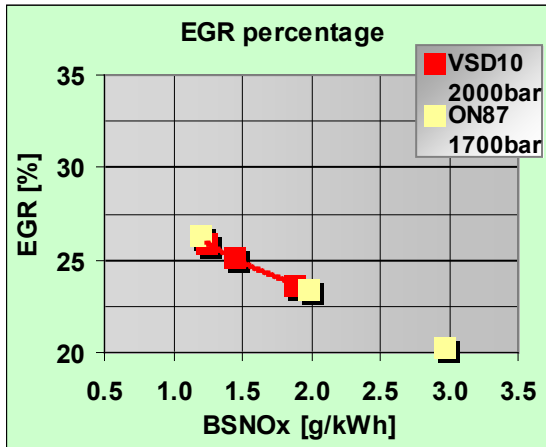
Diesel 2° CAD ignition delay  
Gasoline 8° CAD ignition delay



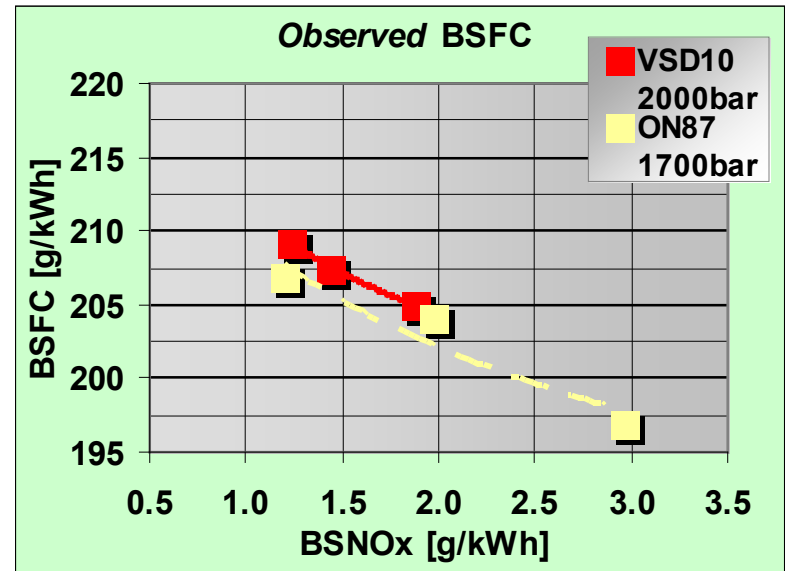
RoHR tail is identical!  
The later part of the  
combustion is mixing  
controlled

Global mixing is still a  
major design target!

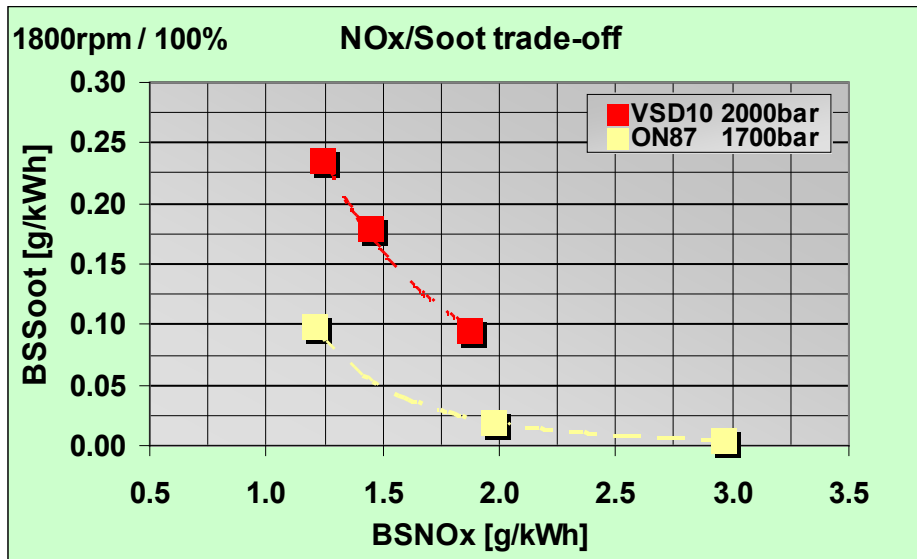
# 1800rpm /IMEP21



Same  
EGR level



Slightly improved BSFC



Still almost soot free at 2 g NOx!

# Sum up of test results

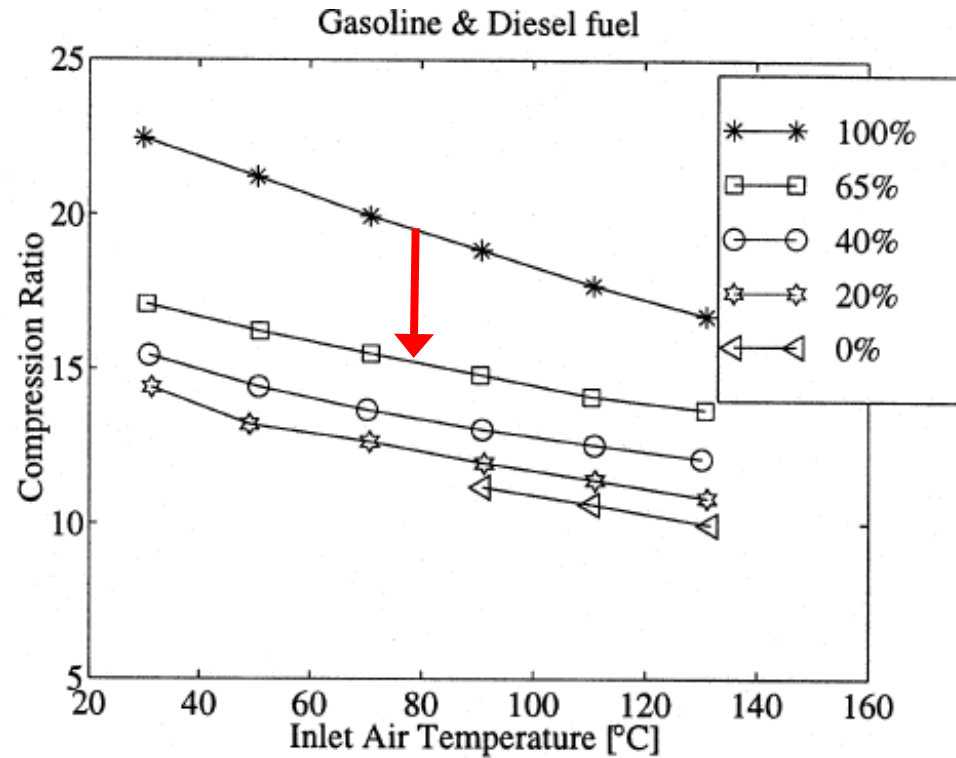
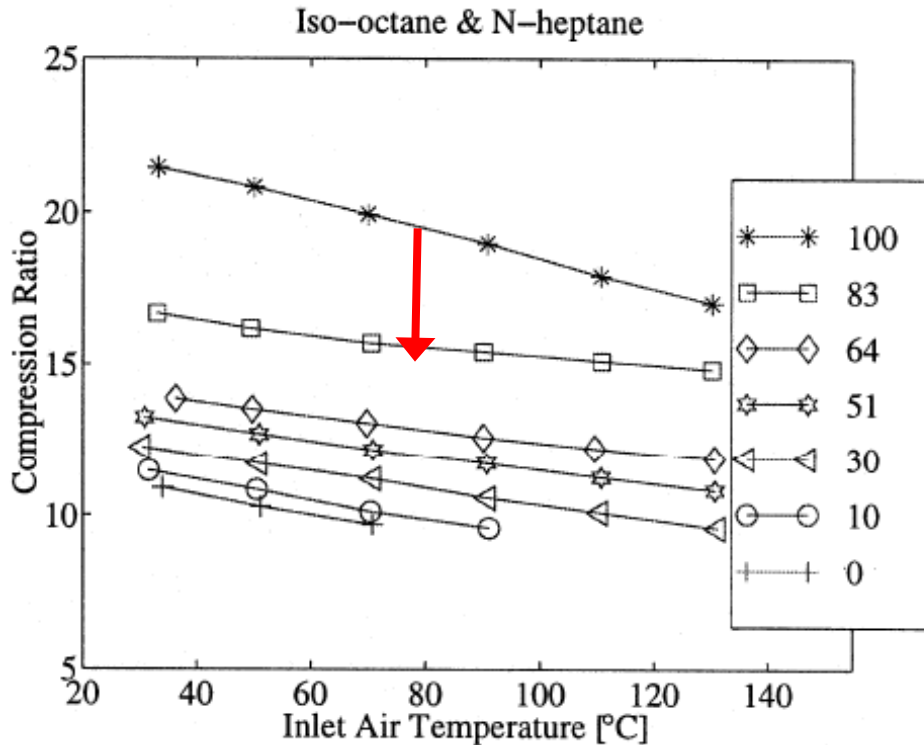
With easy to achieve boundary conditions we can:

- Run almost soot free at all tested loads
- Get biggest BSFC benefits at road load
- Get very low NOx at road load

# Transport system implications from “new” fuels need to be investigated

- Well To Tank analysis, WTT
- Availability
- Bio content capability
- .....

# Compression Ignition with Diesel/Gasoline Blends



Diesel 35% + Gasoline 65% = PRF 80 (ON)

# Well To Tank efficiency

## GM/Argonne report using GREET (2001, 2005)

	Total Energy	WTT Efficiency (%)	Fossil Energy	Petroleum	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	GHGs	
10 ppm S RFG without oxygenate for DI SI engine									79.9%
10%	224,340	78.1	220,599	105,790	17,461	106.2	0.296	19,989	
50%	252,344	79.9	247,927	118,238	19,525	108.2	0.329	22,113	
90%	280,895	81.7	275,944	130,598	21,616	110.4	0.363	24,249	
Crude naphtha									86.4%
10%	117,081	83.3	114,704	52,468	9,607	97.4	0.171	11,893	
50%	157,279	86.4	154,116	71,579	12,530	100.5	0.219	14,909	
90%	201,146	89.5	197,485	92,593	15,777	104.0	0.270	18,257	

**Naphtha**  
**8% more**  
**Efficient!**



# Conclusions

- Potentially more than 10% lower CO2 foot print with PPC/Naphtha
- Significant soot, NOx and efficiency gains from using PPC
- Significant engine design changes needed to handle low load

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