Partially Premixed Combustion

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

RCCI

´**R**eactivity **C**ontrolled **CI**´

very high ON +very high CN

i.e. neat ethanol + Diesel

IMEP 17 bar w/o EGR reported

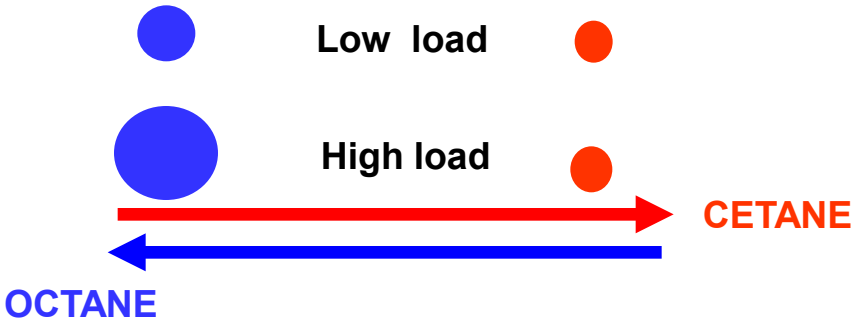
PPC

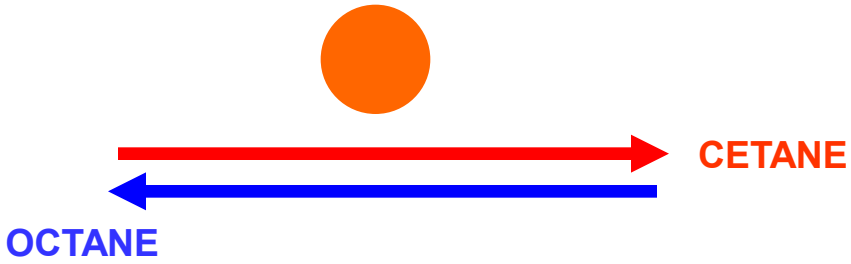
Partially **P**remixed **C**ombustion

in-between ON/CN

i.e. Naphtha or gasoline/diesel

IMEP 26 bar achieved

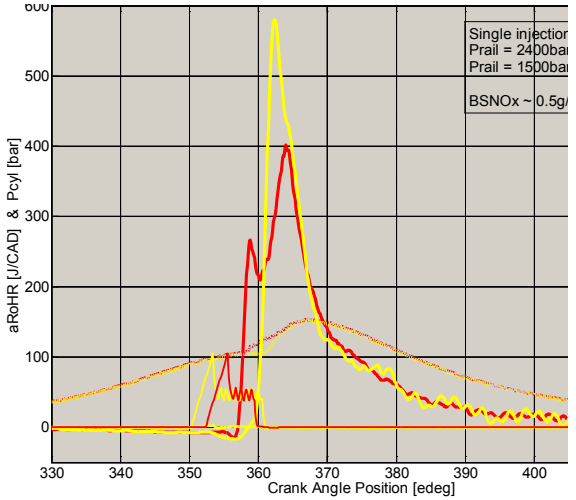




Power density - a prerequisite for downsizing and transport efficiency

PPC use a gasoline type fuel

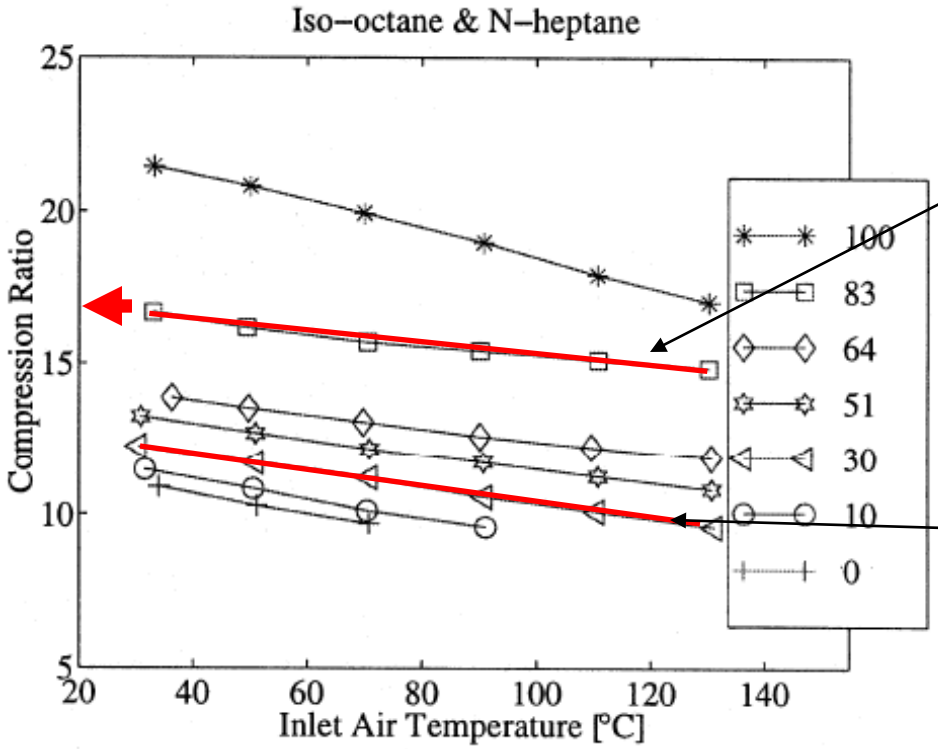
- **Low Cetane**
  - → ignition delay reduce soot (more premix)
  - → increase efficiency (faster heat release)
  - → Low load problems (noise, HC+CO)



- **High volatility**
  - → No wall wetting; Inject anytime!

- **Low viscosity**
  - → A lubricity additive needed

CR requirement for ignition
HCCI test for PRF blends



ignition becomes demanding for ON > 80

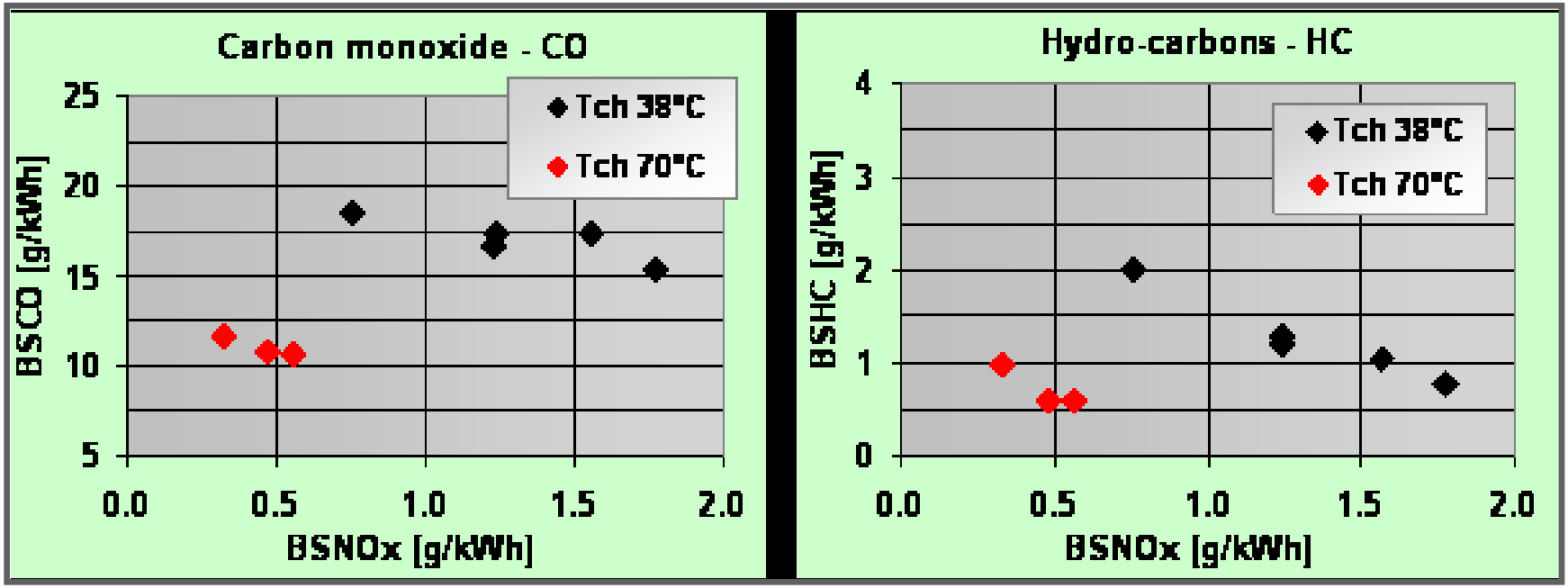
CR>17 needed for cold start?

Diesel is similar to PRF 30

Port injected PRF0 to PRF100

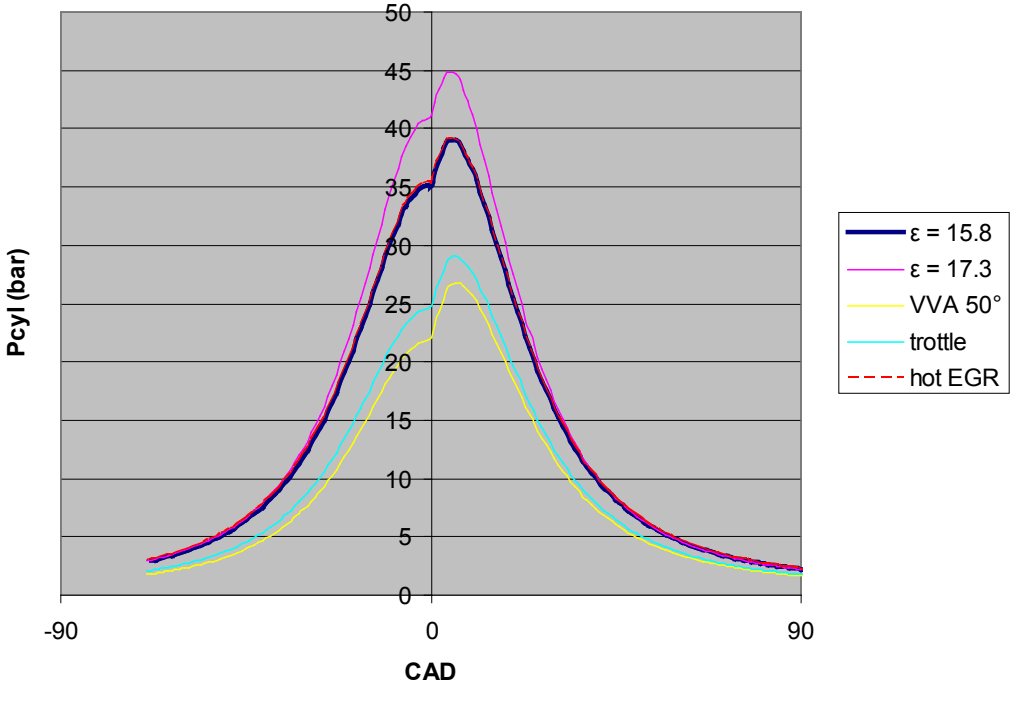
Controlling CO and HC at low load

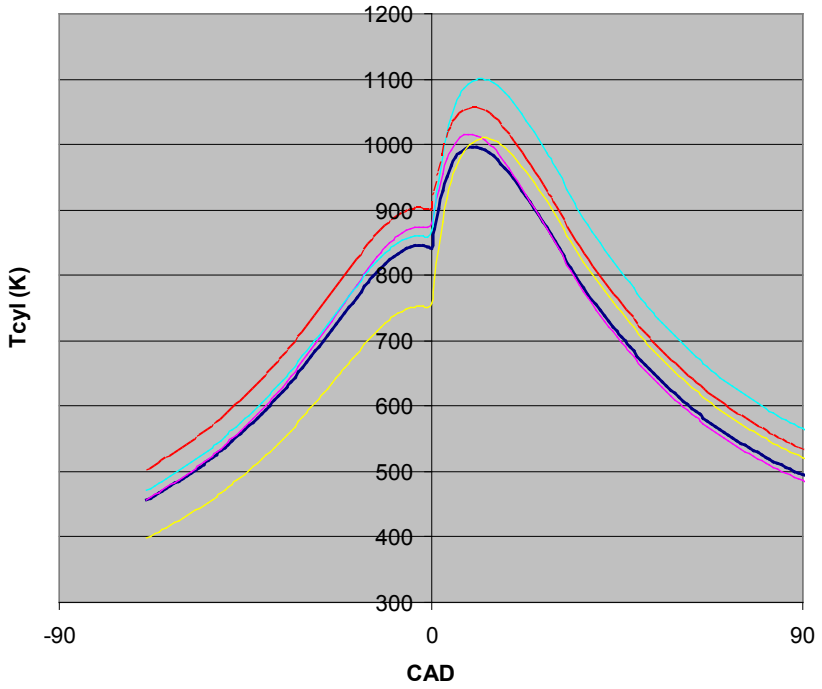
uncooled EGR setting: Inlet Manifold Temp raised from 38 to 70 C



We must do more at lower loads!

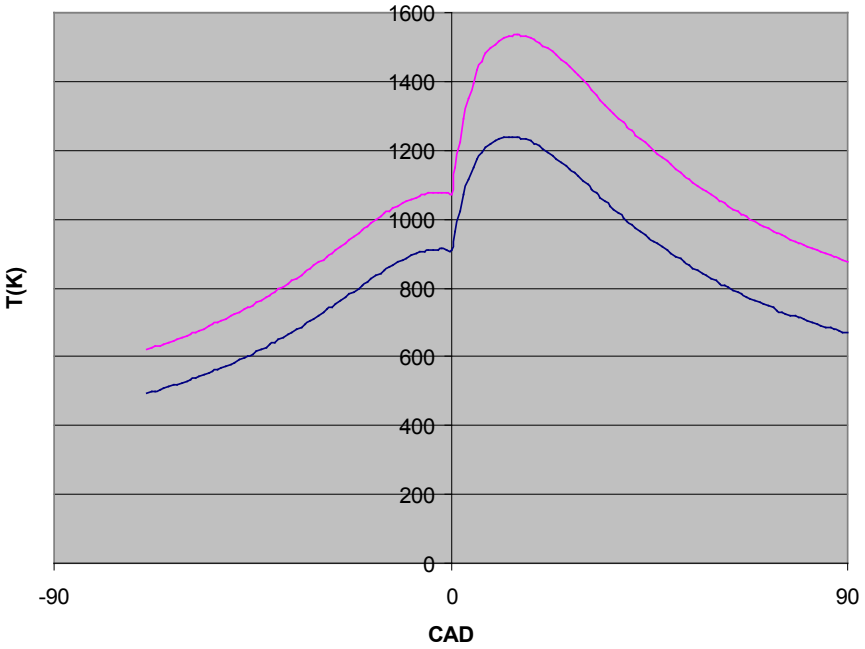
Ways to improve temperature at TDC





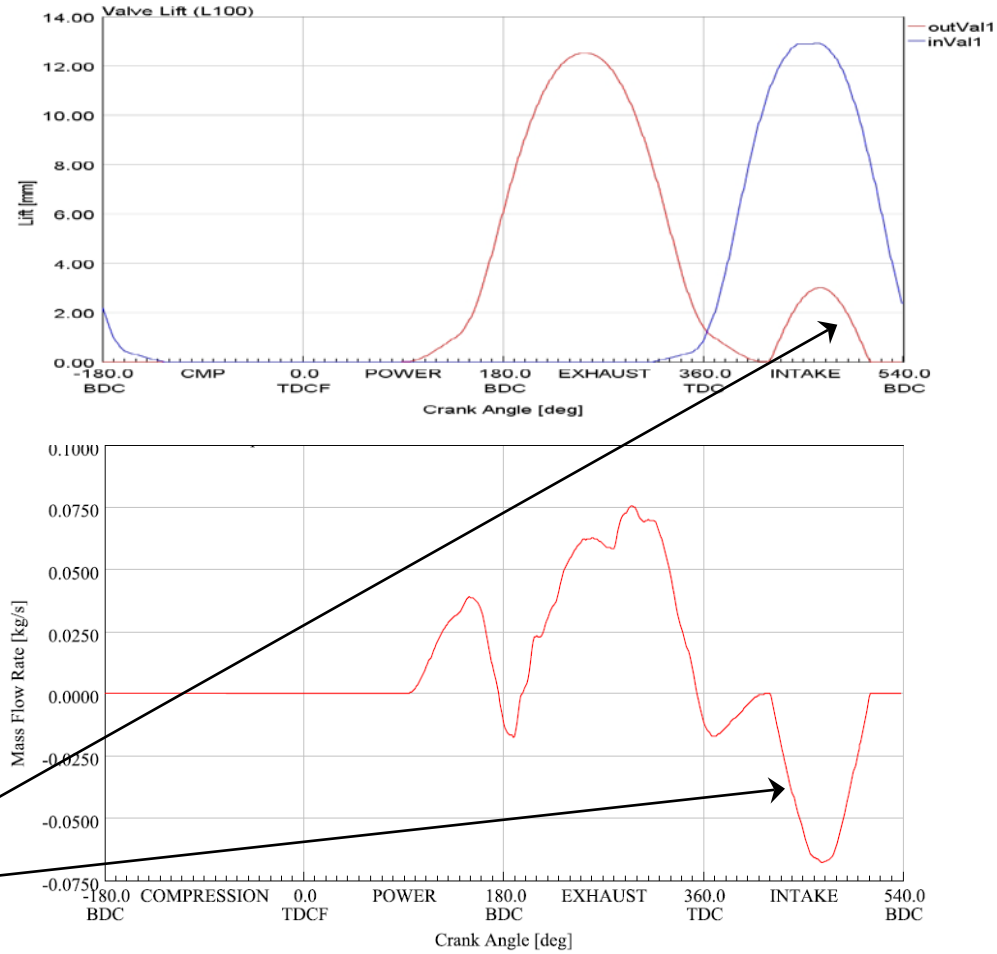
Influence on in cylinder temperature at TDC by:
increased compression ratio, Miller, intake throttling and hot EGR
Hot EGR still the best

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



In Cylinder temp with and without re-breathing

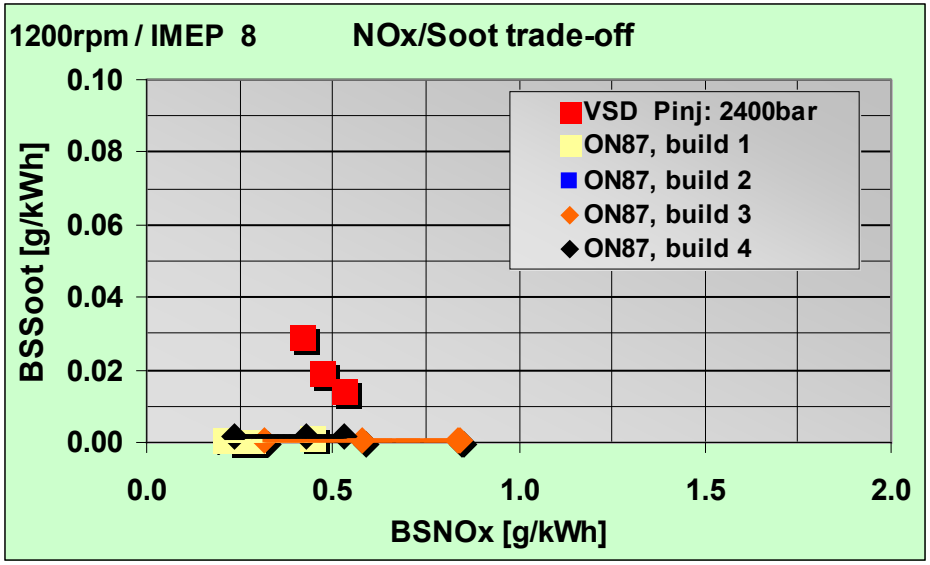
Re-breathing

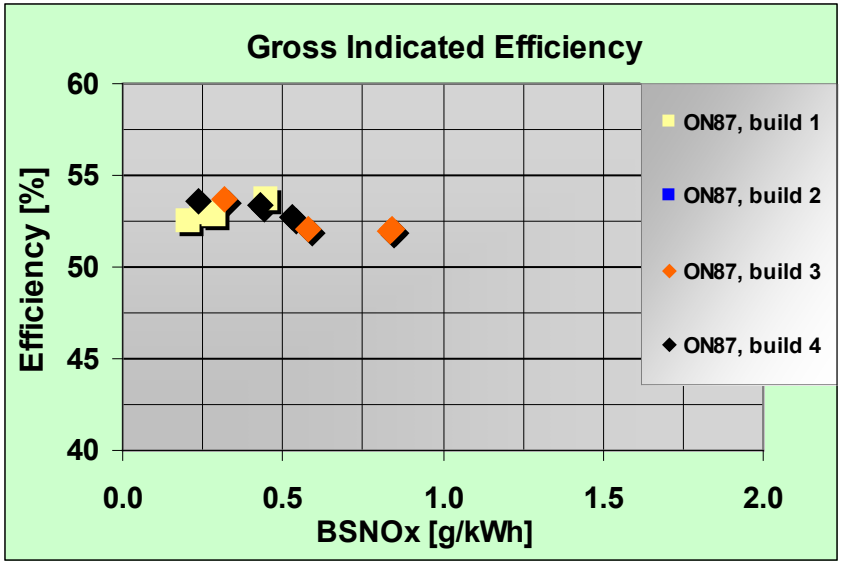


PPC test results with single stage turbo boundary conditions

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

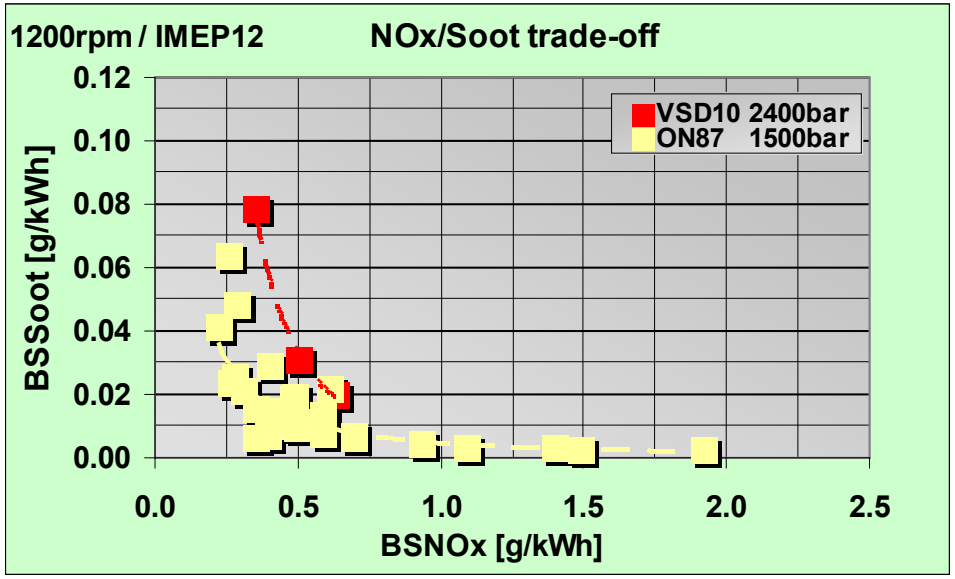
1200rpm/IMEP8, soot free combustion at very low NOx

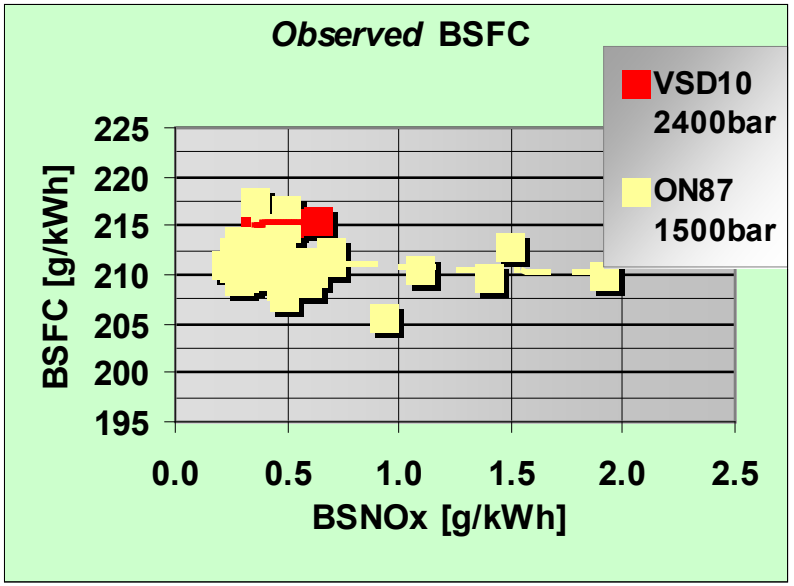




Soot free due to premixing
Note that diesel is injected at 2400 bar

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

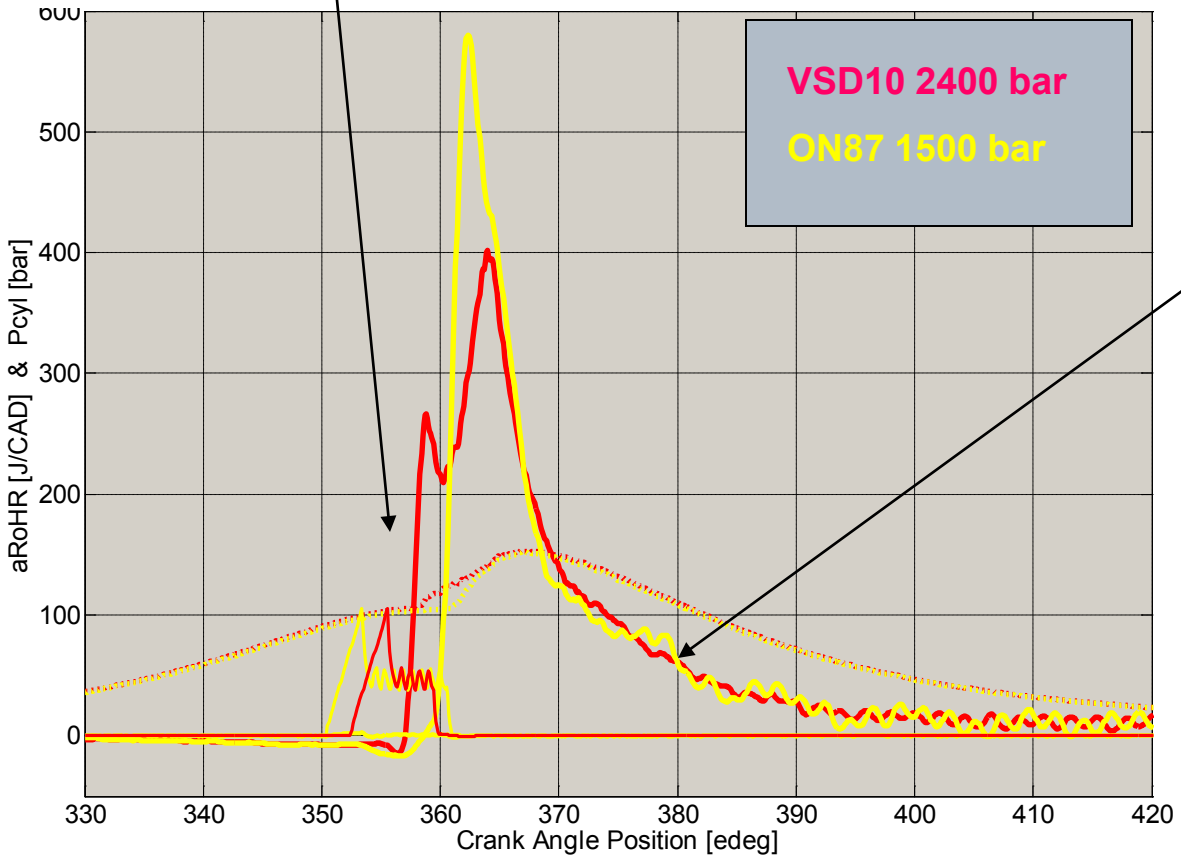




One reason for improved BSFC is shorter combustion duration

IMEP12 – Rate of Heat Release example

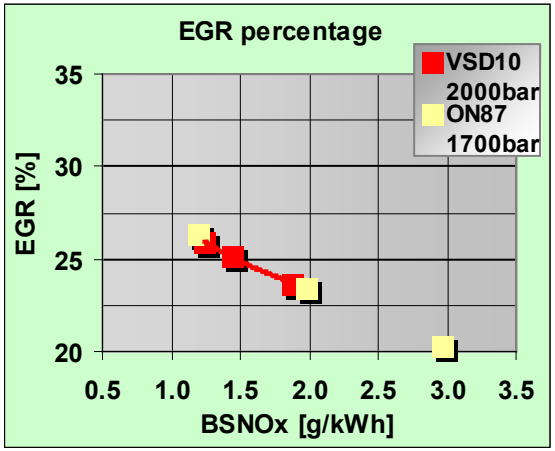
Diesel 2º CAD ignition delay
Gasoline 8º CAD ignition delay



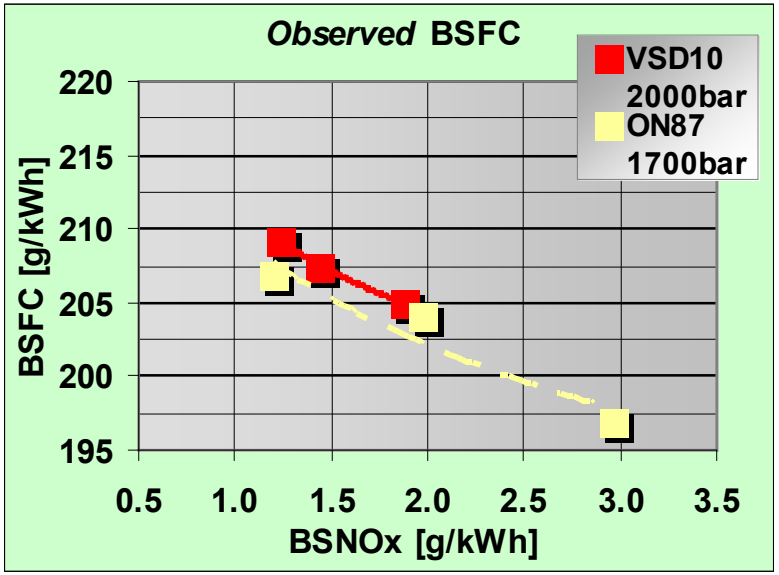
RoHR tail is identical! The later part of the combustion is mixing controlled

Global mixing is still a major design target!

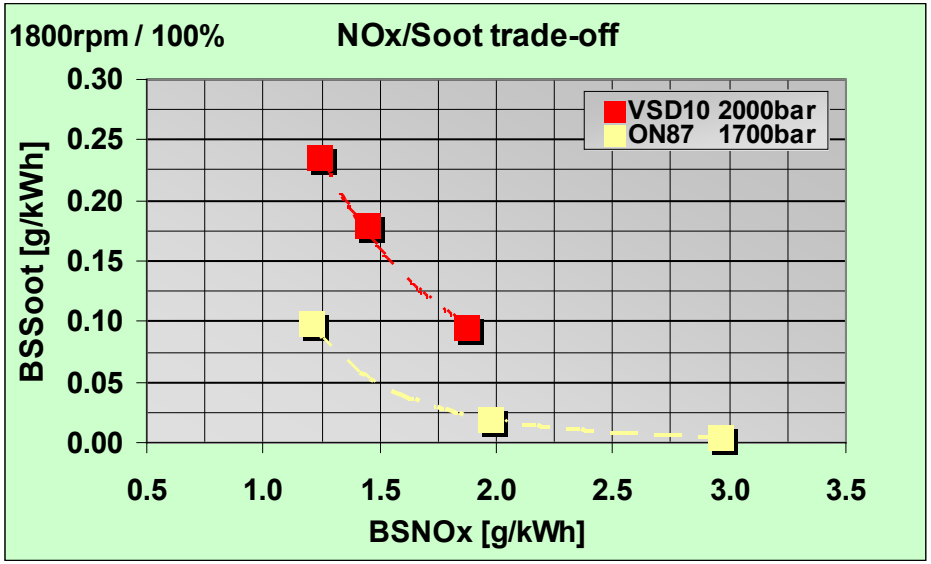
1800rpm /IMEP21



Same
EGR level



Slightly improved BSFC



Still almost soot free at 2 g NOx!

Sum up of test results

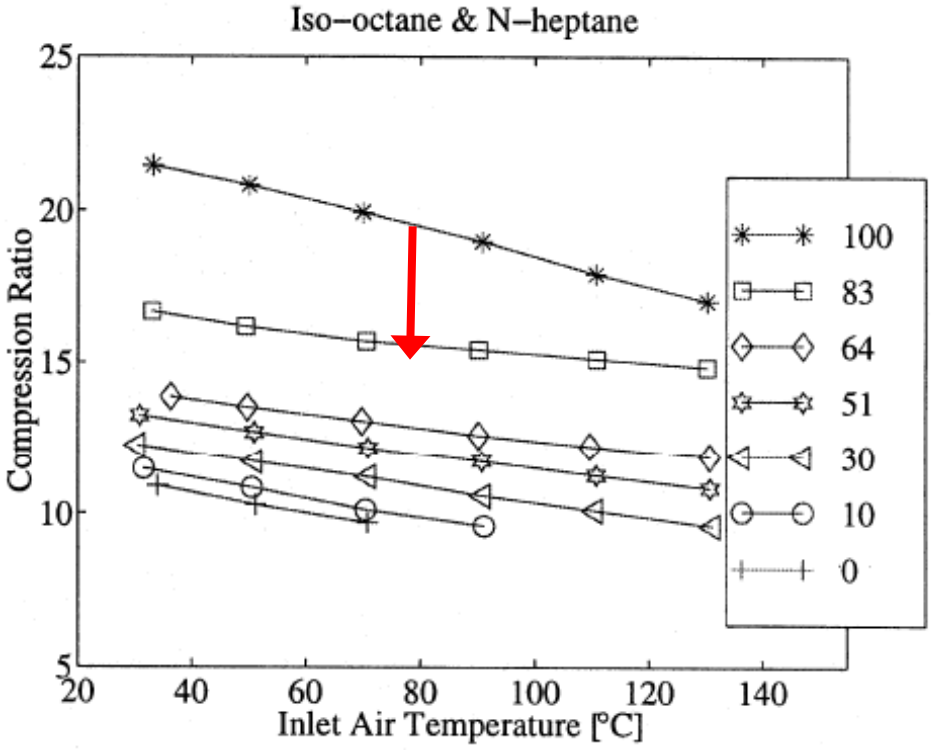
With easy to achieve boundary conditions we can:

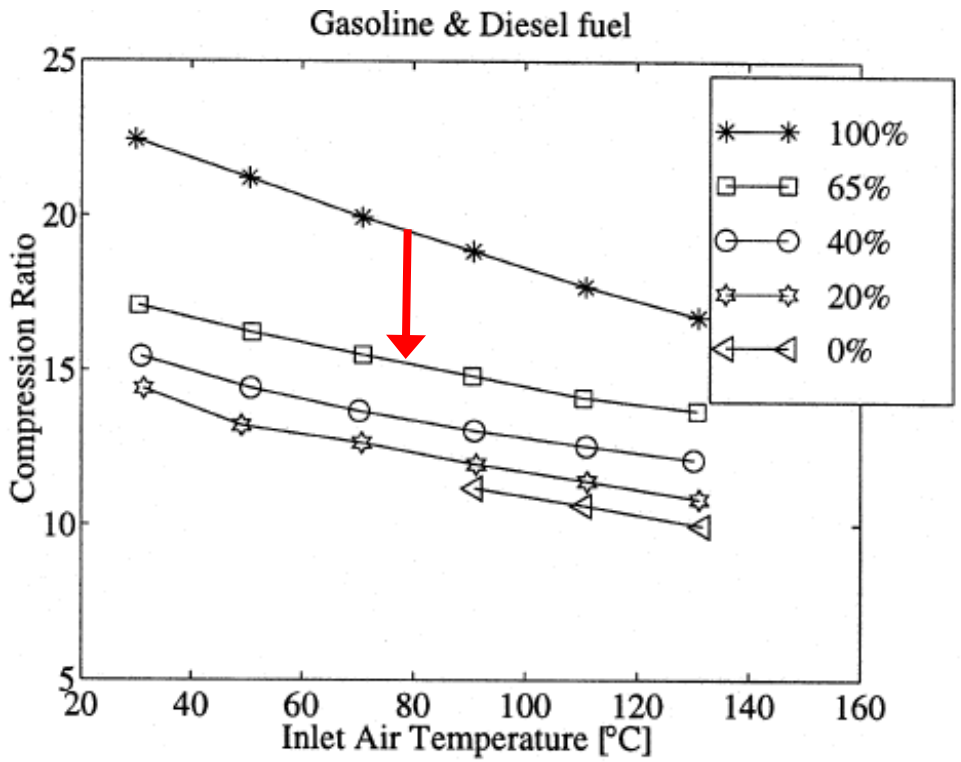
- Run almost soot free at all tested loads
- Get biggest BSFC benefits at road load
- Get very low NOx at road load

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_2	CH_4	N_2O	GHGs
10 ppm S RFG without oxygenate for DI SI engine								
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								
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

79.9%

86.4%

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

Acknowledgements

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