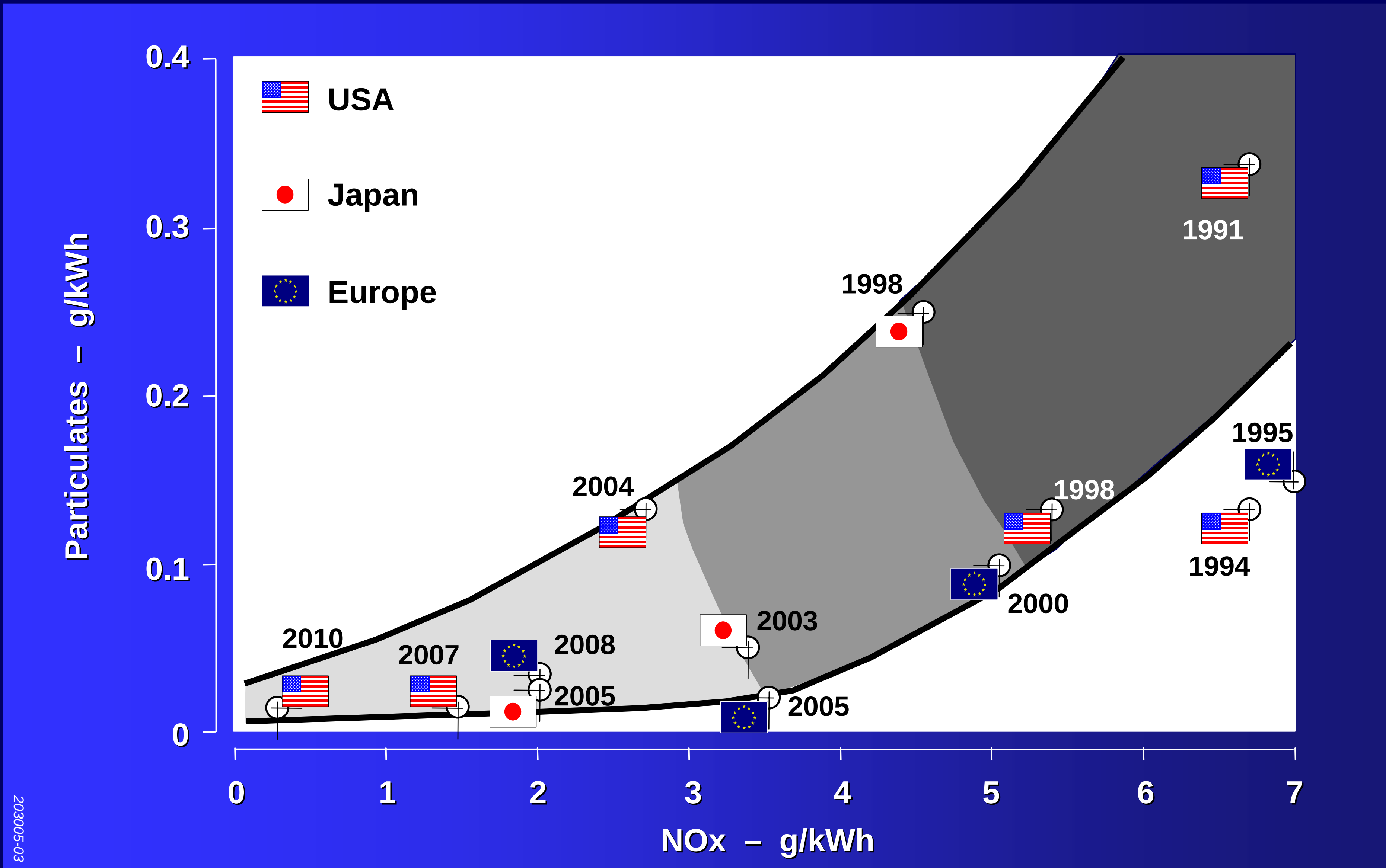
Variable Charge Motion for 2007-2010 Heavy Duty Diesel Engines

Deer Conference 2003

Presented by

Josef Maier
AVL Powertrain Engineering

Overview of Worldwide Heavy Duty Emission Regulations



ID-NR.12345-2

Technologies required

- Advanced Fuel Systems
- Cooled EGR
- Particulate Filter
- NOx Aftertreatment
- Oxidation Catalyst
- Advanced Control Strategies
- Alternative combustion?

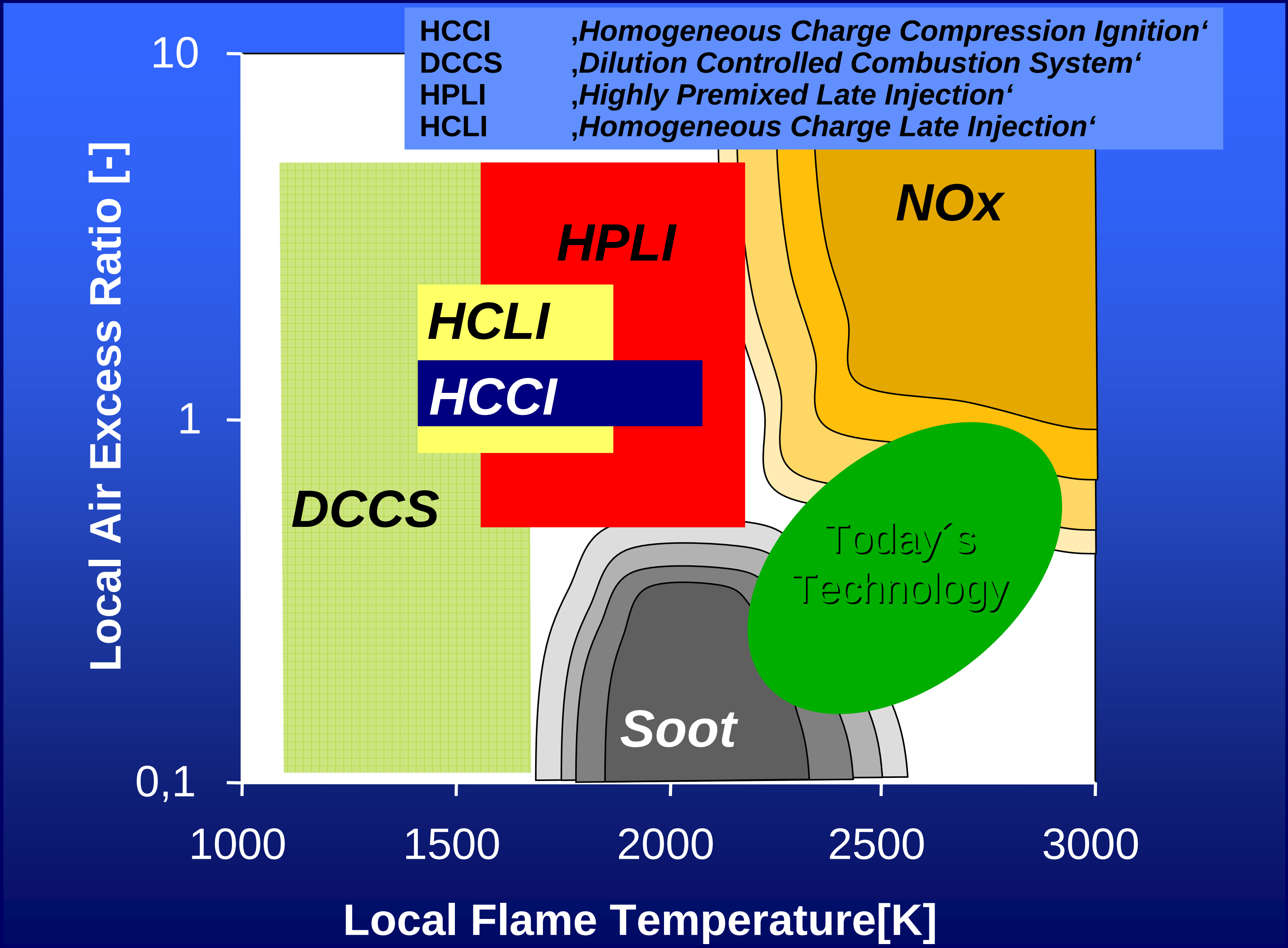
HDD Engine Range in US

• Displacement / Cyl.	0.7 - 3.0 Liter
• Rated Engine Speed	1800 - 3500 RPM
• BMEP Max	15 -23 Bar
• Spec. Power	40 - 60 hp/L
• Durability Required	300 - 1.000 K Miles
• Vehicle Mass	8.500 -150.000 lb

NOx-Soot Trade Off Improvement

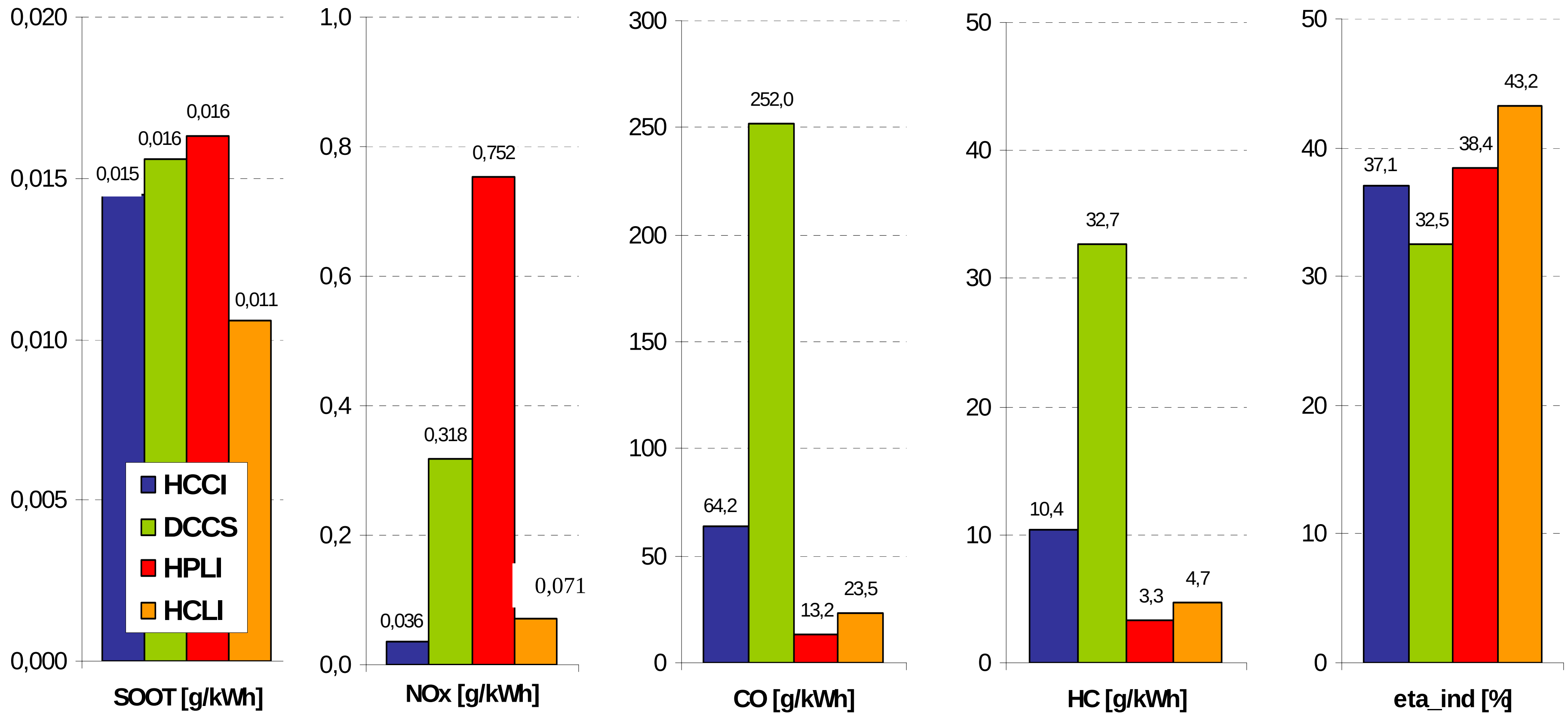
- High Pressure fully flexible fuel system
- Cooled EGR
- Variable Charge Motion
- Alternative Combustion ?

Diesel Combustion Systems for Low NOx / Soot Emission

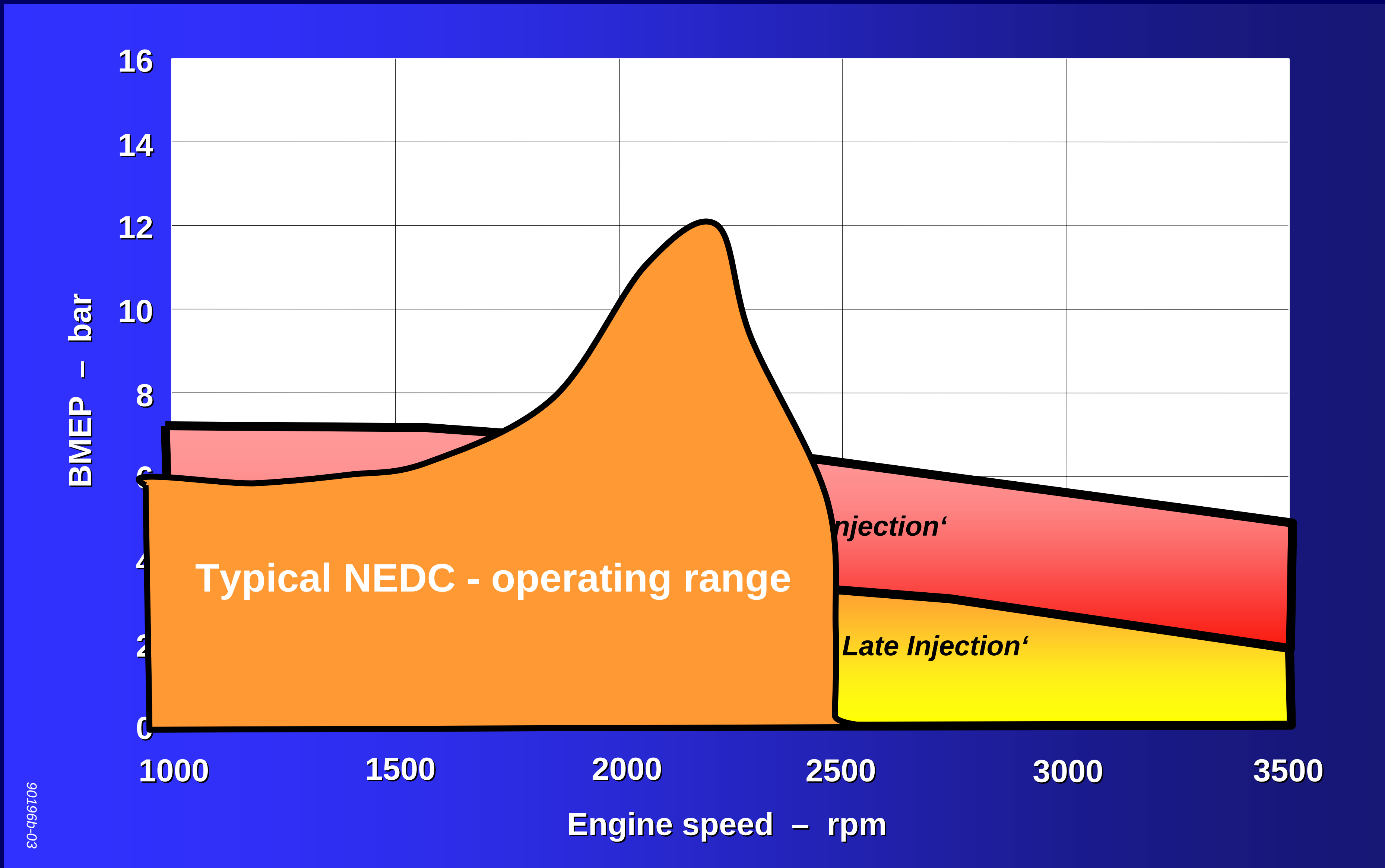


Comparison HCCI, DCCS, HPLI and HCLI Combustion
(n=1500, p_i=4bar)

HCCI DCCS HPLI HCLI

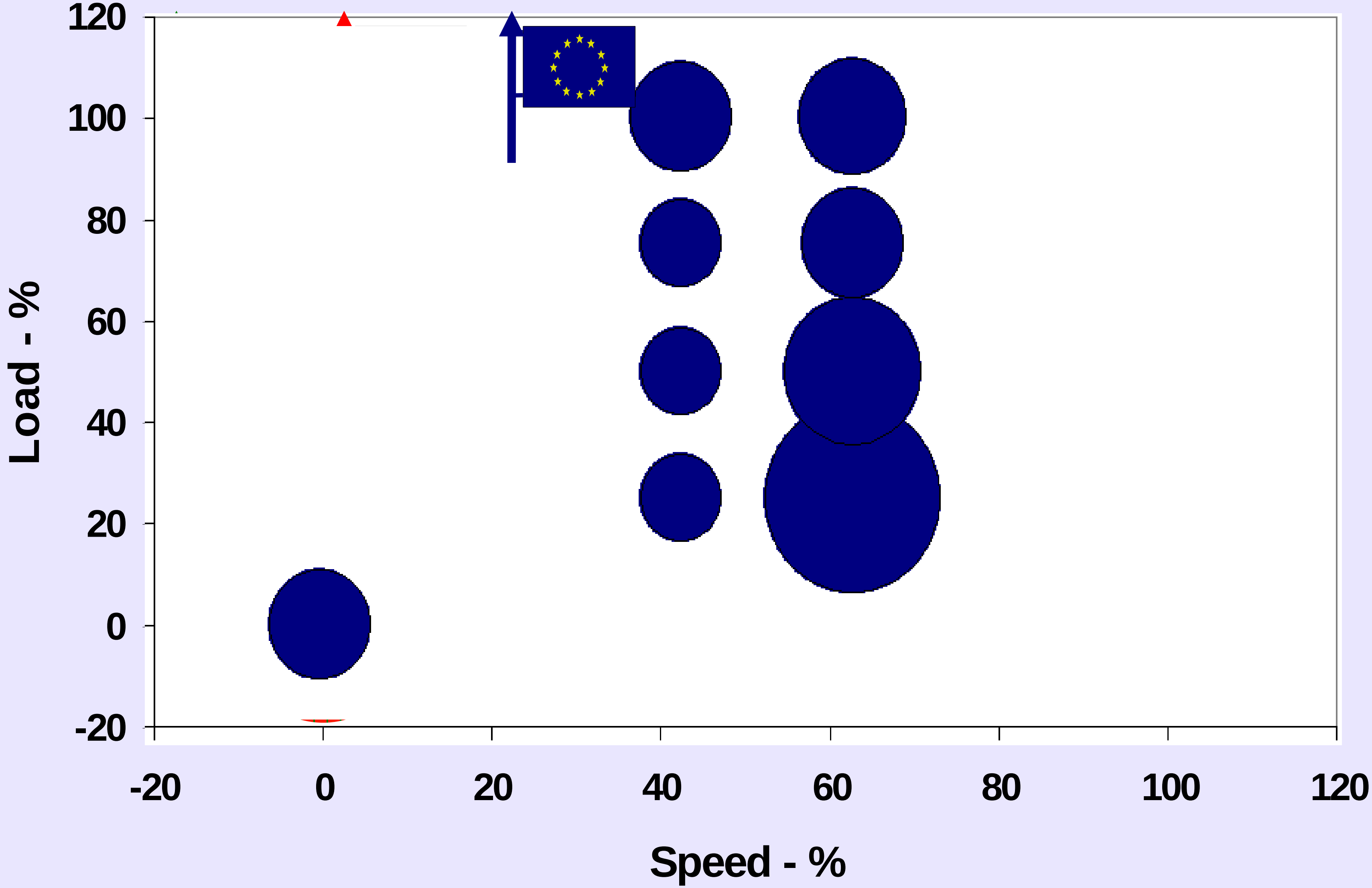


Current application strategy for alternative combustion modes with today´s TC and FIE

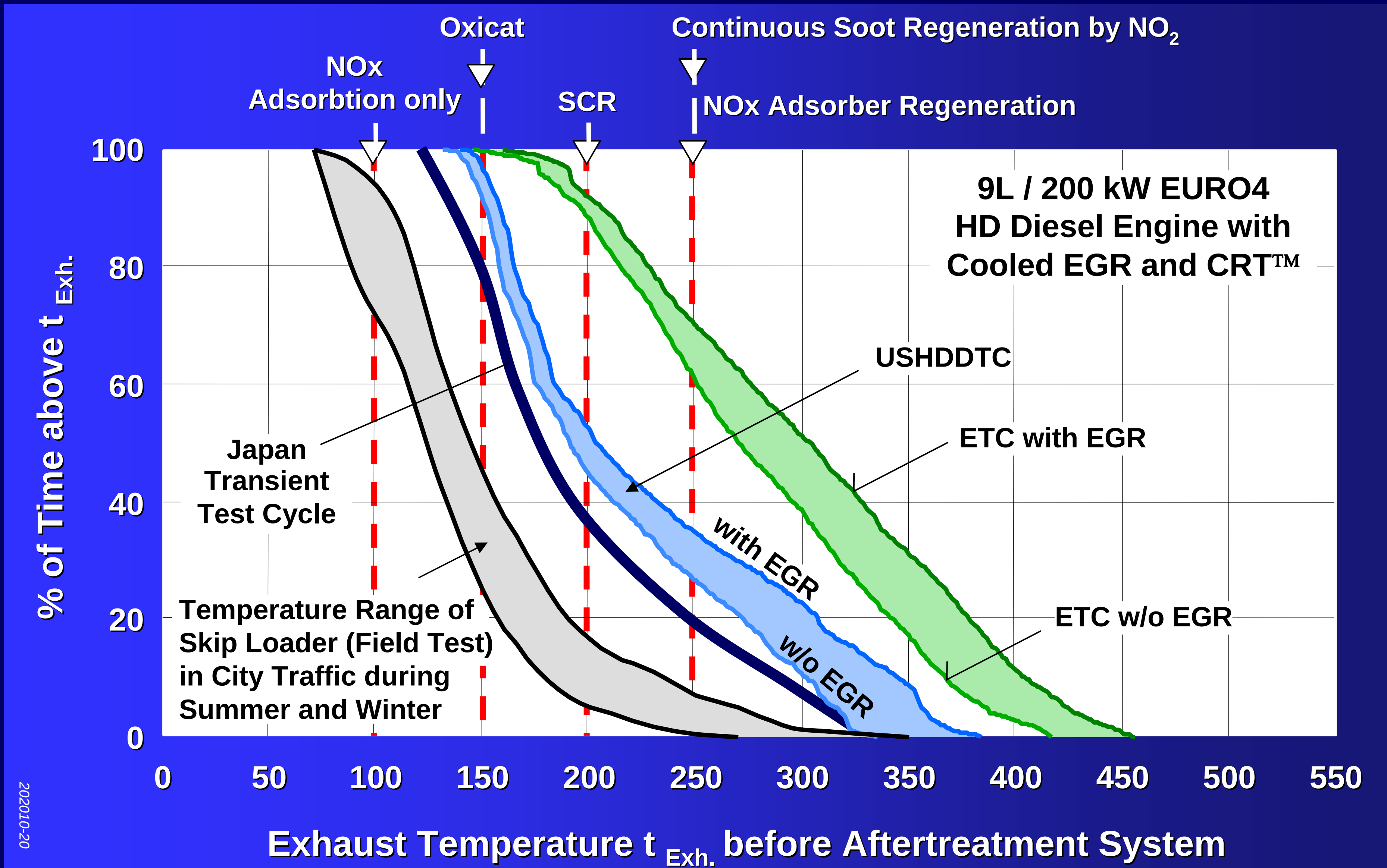


ID-NR.12345-8

Steady state simulation of transient test cycles

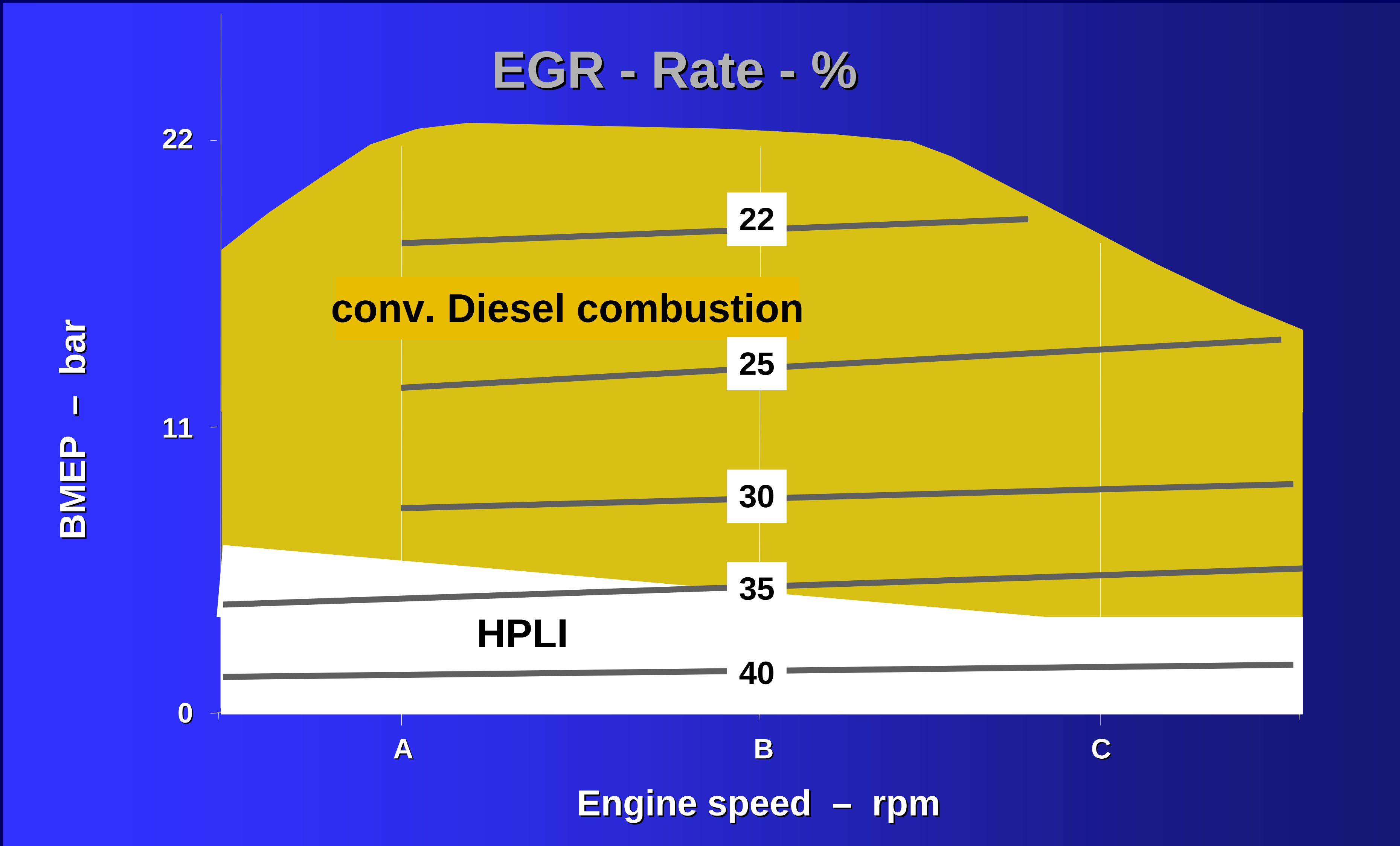


Cumulative Exhaust Temperature and Critical Temperatures for Aftertreatment

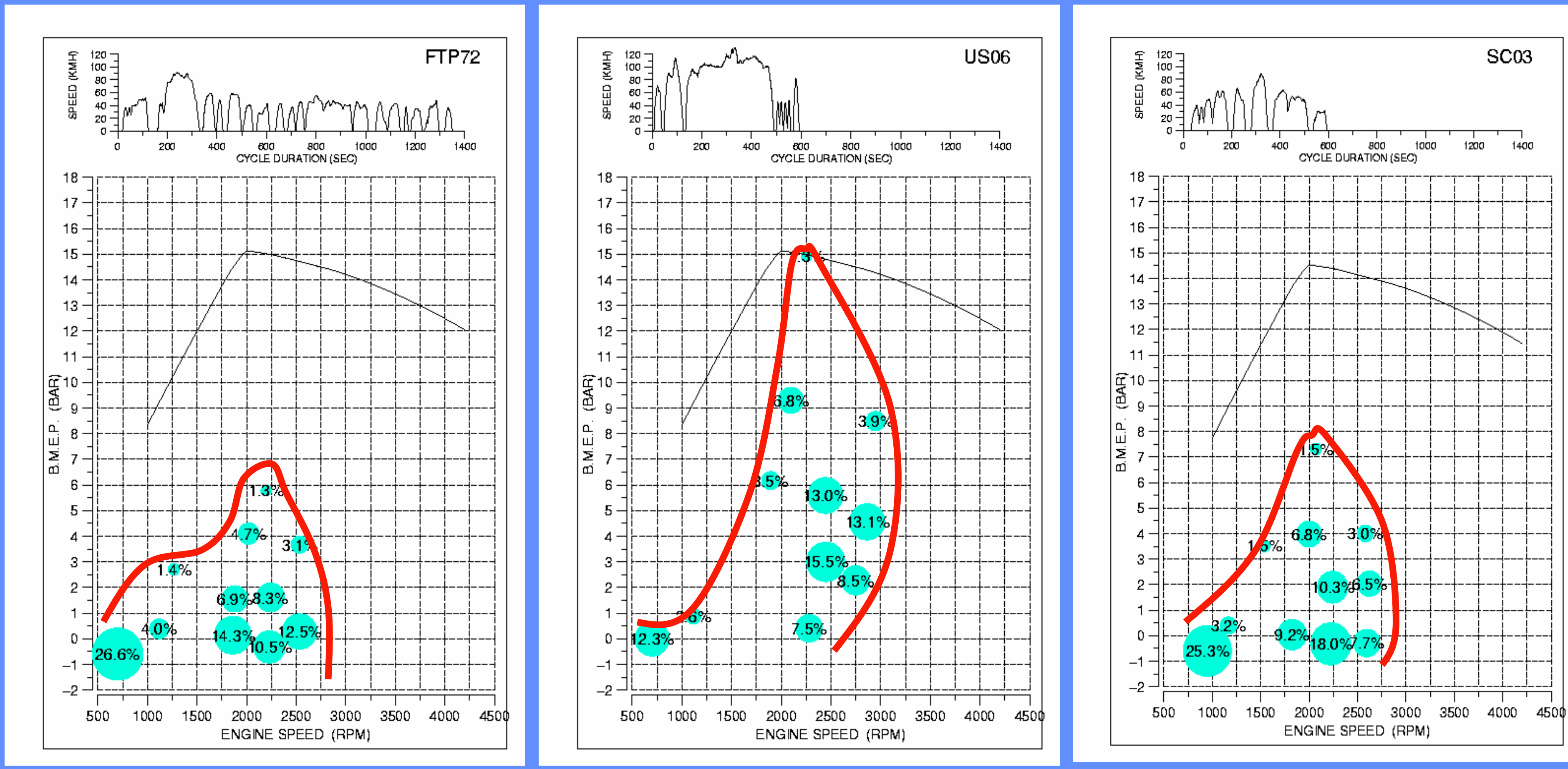


Dual - Mode Operation for Future HD Diesel Engines

Japanese NLTR , Euro 5 and US 2007 Engines



Emission test cycle simulation
FTP72 / SC03 / US06 - Example



Alternative Combustion - Conclusions

- All combustion systems show high potential for lowest emission limits of soot and NOx
- All the strategies applied cover low load operating conditions only. A combination with a conventional DI System is necessary
- HPLI and HCLI offer high potential for lowest NO_x and Soot emissions
- Only moderate hardware changes in comparison to an actual DI TCI engine, thus enabling a combination with today's standard diesel combustion

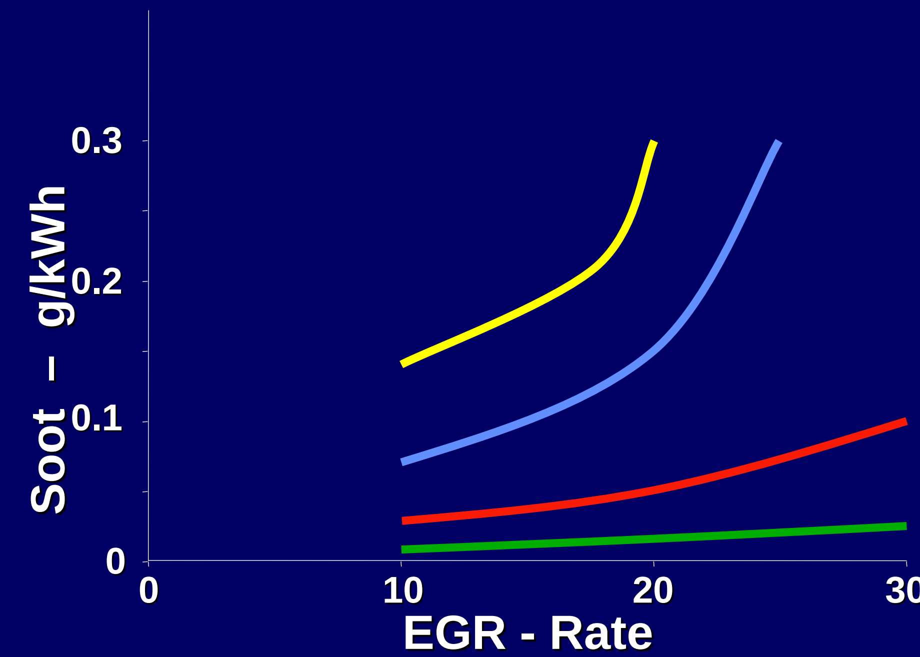
NOx-Soot Trade Off Improvement

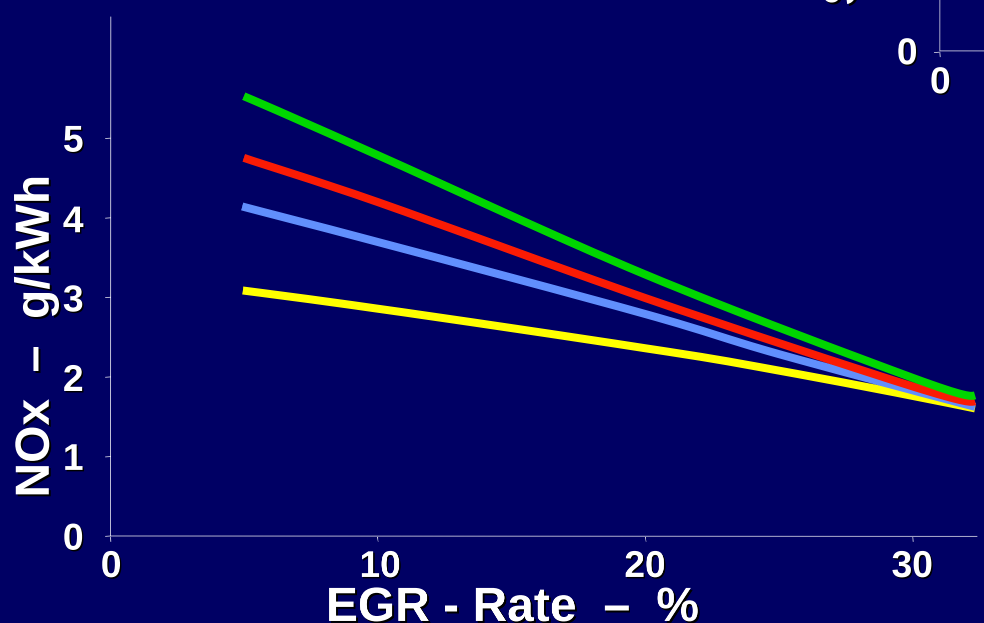
- High Pressure fully flexible fuel system
- Cooled EGR
- Variable Charge Motion
- Alternative Combustion ?

Relation between EGR Rate, Injection Pressure and NOx

(Diesel mode)

Injection timing = const.
BMEP = 15 bar
Speed = 1500 rpm
λ = 2.2
Single cyl. = 2 l



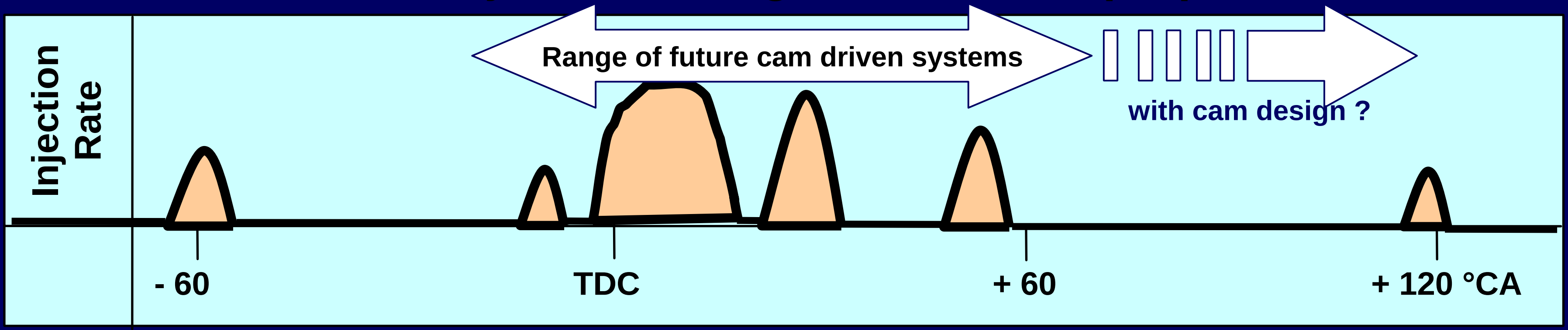


Injection Pressure

- 1000 bar
- 1400 bar
- 1800 bar
- 2200 bar

Benefits of Multiple Injection for Diesel Combustion

Possible injection timings for different purposes



- Early pilot injection for alternative combustion
- Close pilot injection for emissions and noise control
- Main injection
- Close post injection for NOx/Soot control
- late post injection for control of lambda < 1 operation (EGAS)
- very late post injection for HC-enrichment and / or

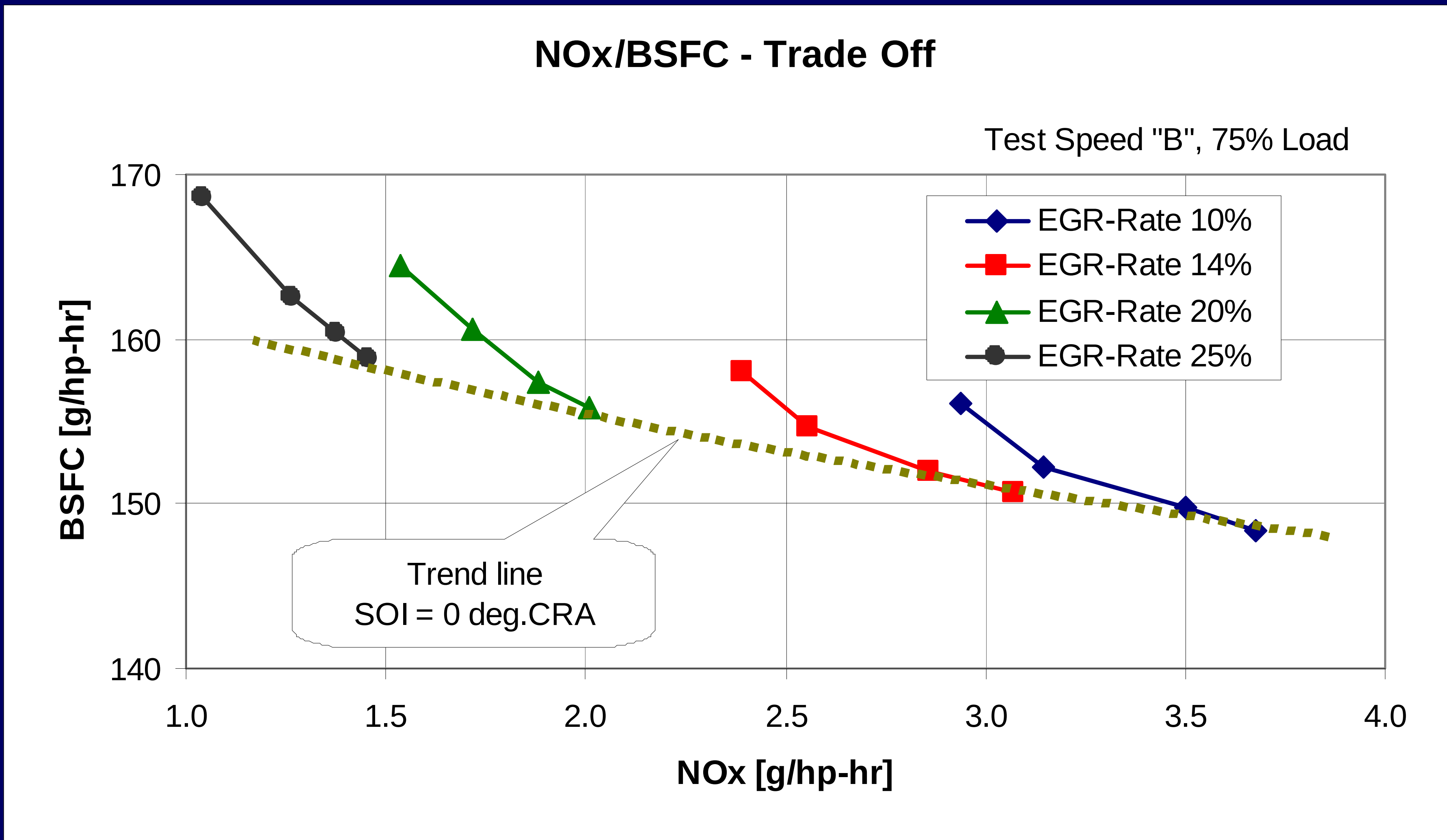
  exhaust gas temperature management (EGAS)

NOx-Soot Trade Off Improvement

- High Pressure fully flexible fuel system
- Cooled EGR
- Variable Charge Motion
- Alternative Combustion ?

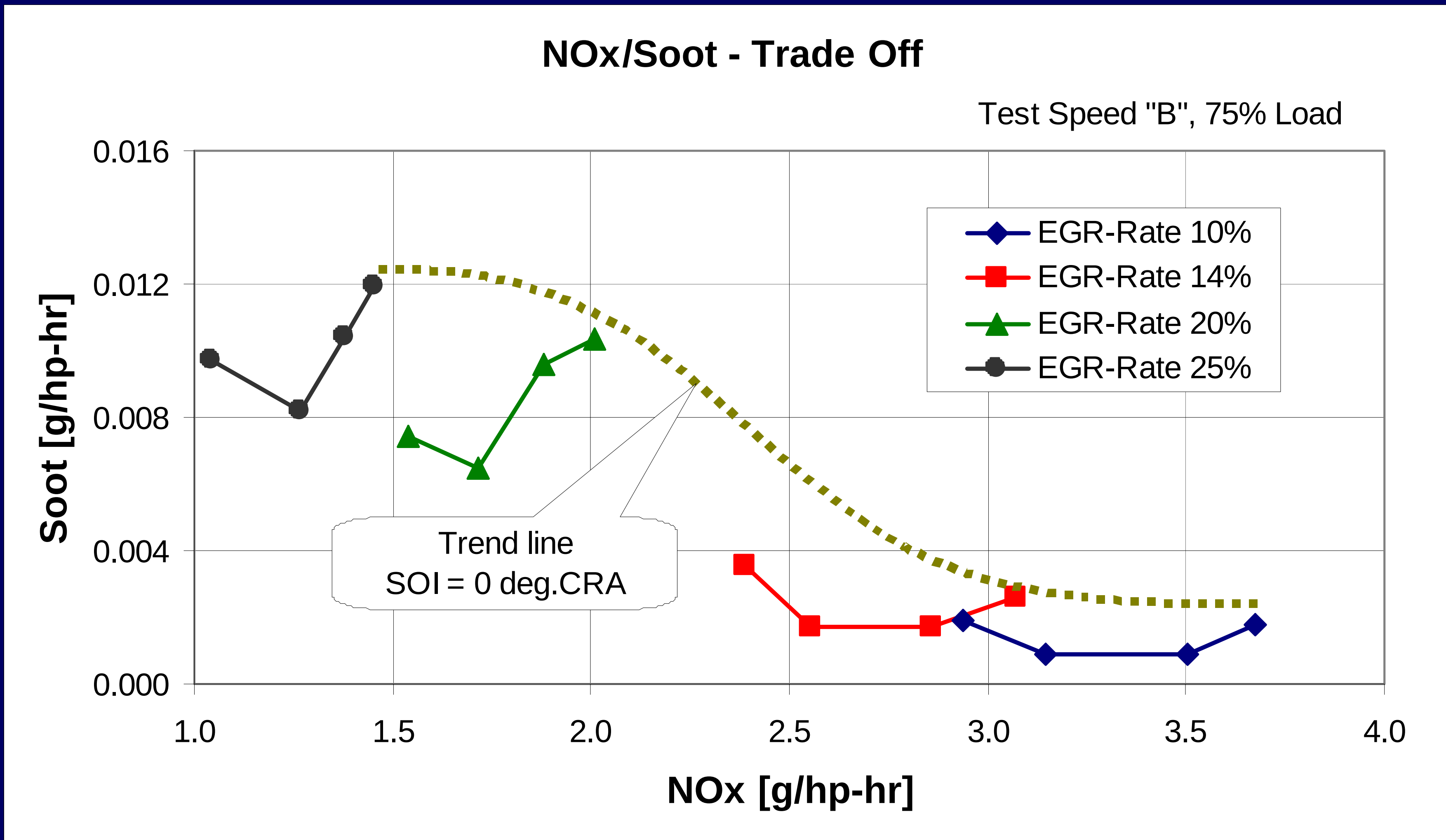
Conventional Diesel Combustion

AVL R&D engine, 6 cyl. in-line DI/TCI, 4V, 300 kW, 1.8 l/cyl. class



Conventional Diesel Combustion

AVL R&D engine, 6 cyl. in-line DI/TCI, 4V, 300 kW, 1.8 l/cyl. class



NOx-Soot Trade Off Improvement

- High Pressure fully flexible fuel system
- Cooled EGR
- Variable Charge Motion
- Alternative Combustion ?

Influence of different Swirl Levels

Engine 0,75 l / Zyl.

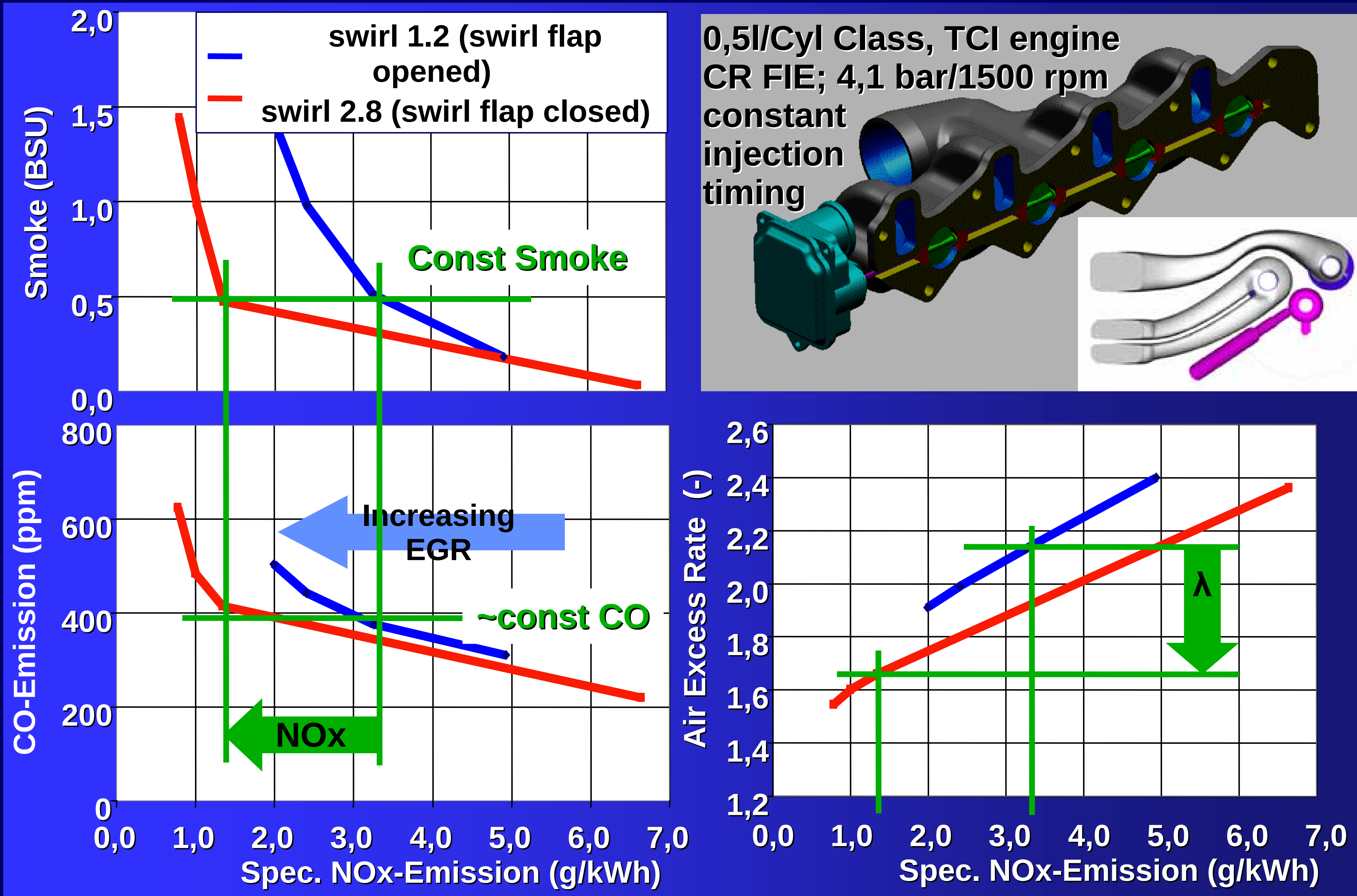
Swirl Influence on Performance and Emissions

Increase of low end torque:	+ 12% (1000-1500RPM)
Reduction of NOx and PM in FTP cycle:	up to -30% (Base = EU4)
Decreased smoke values at low Lambda figures	load response benefits

Split port 2V engine, 0.5L/Cyl.

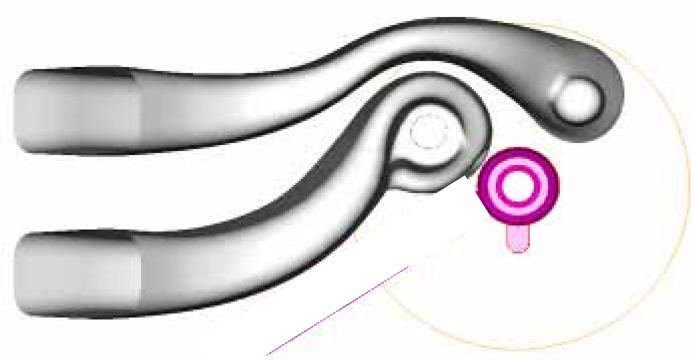
Low Swirl: 1.2 / High Swirl: 3.2 (Paddle Wheel Method)

Variable Swirl - Effect on Exhaust Emissions

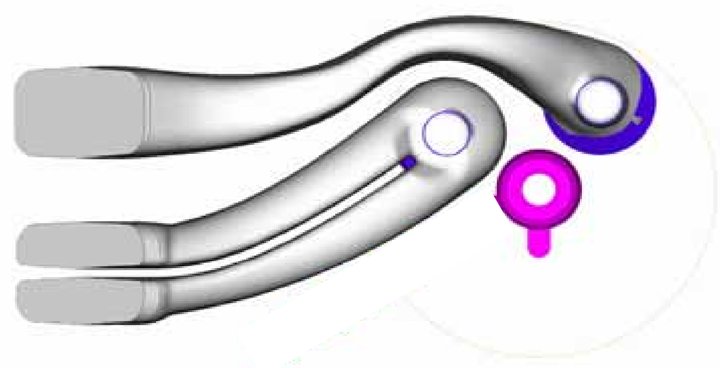


Variable Swirl Concepts
Split Port vs. Deactivated Port

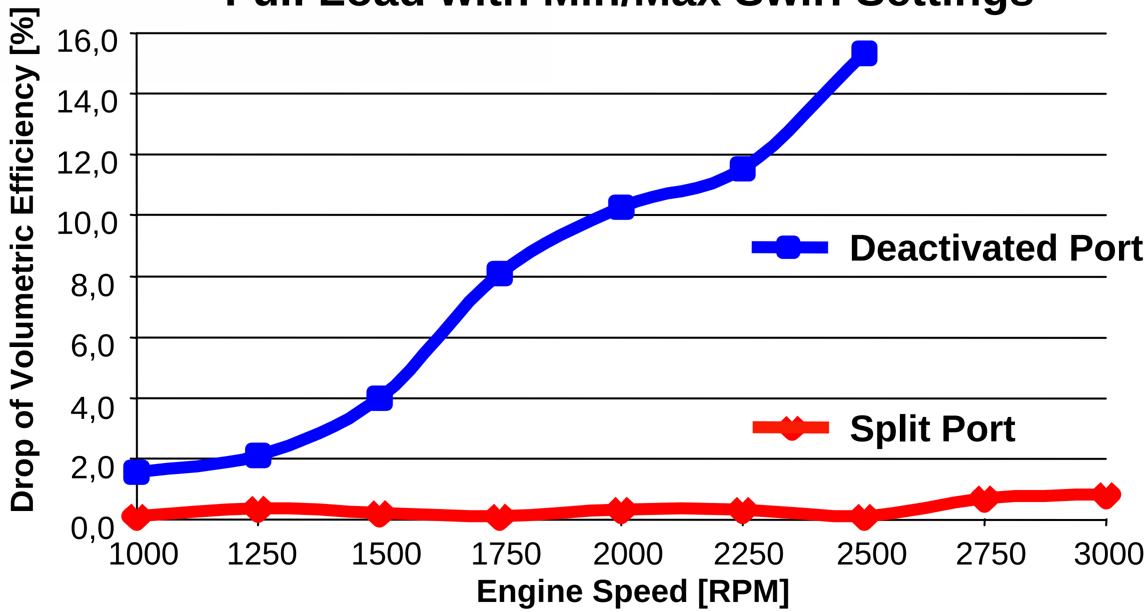
Standard with port deactivation



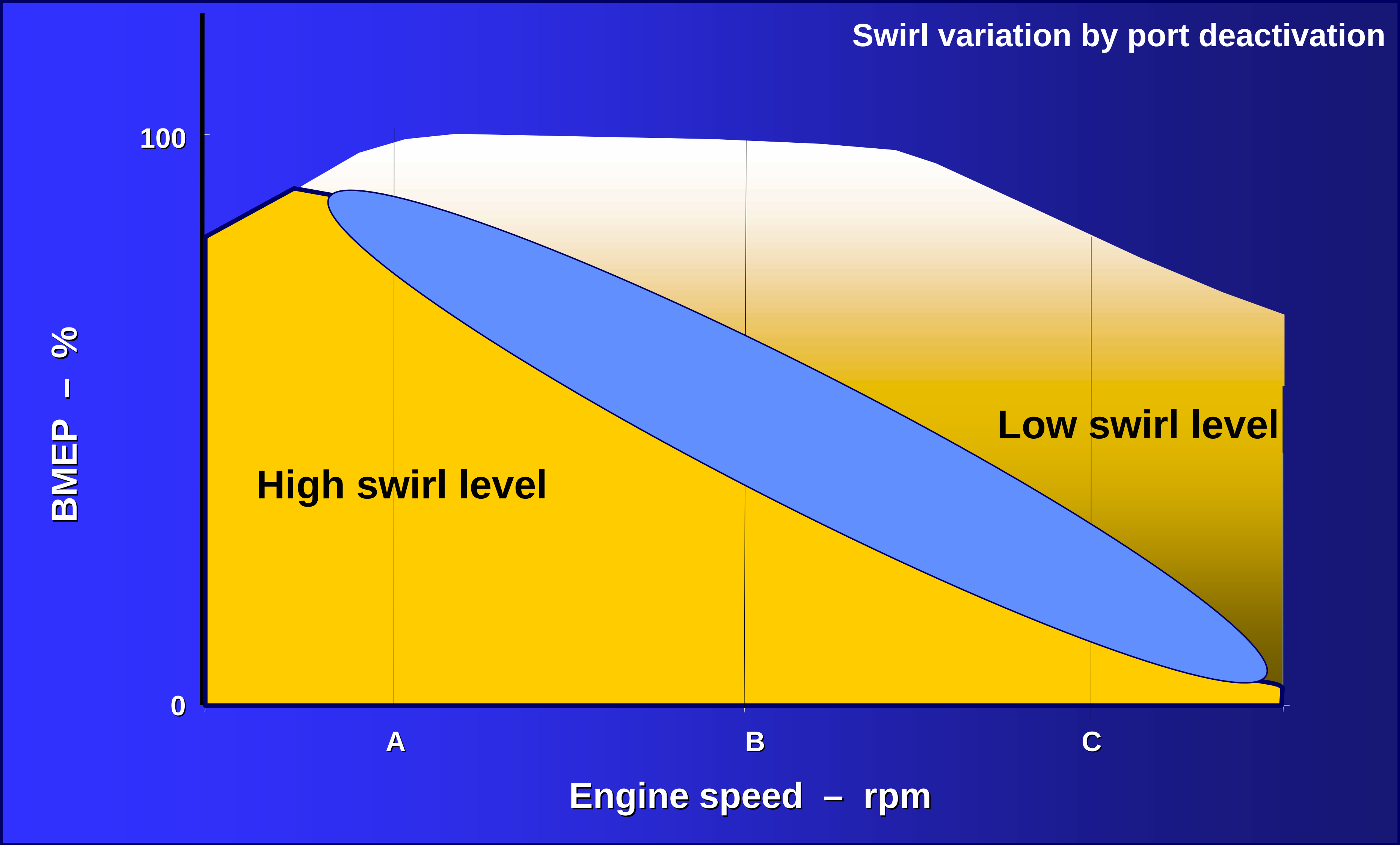
Split port design



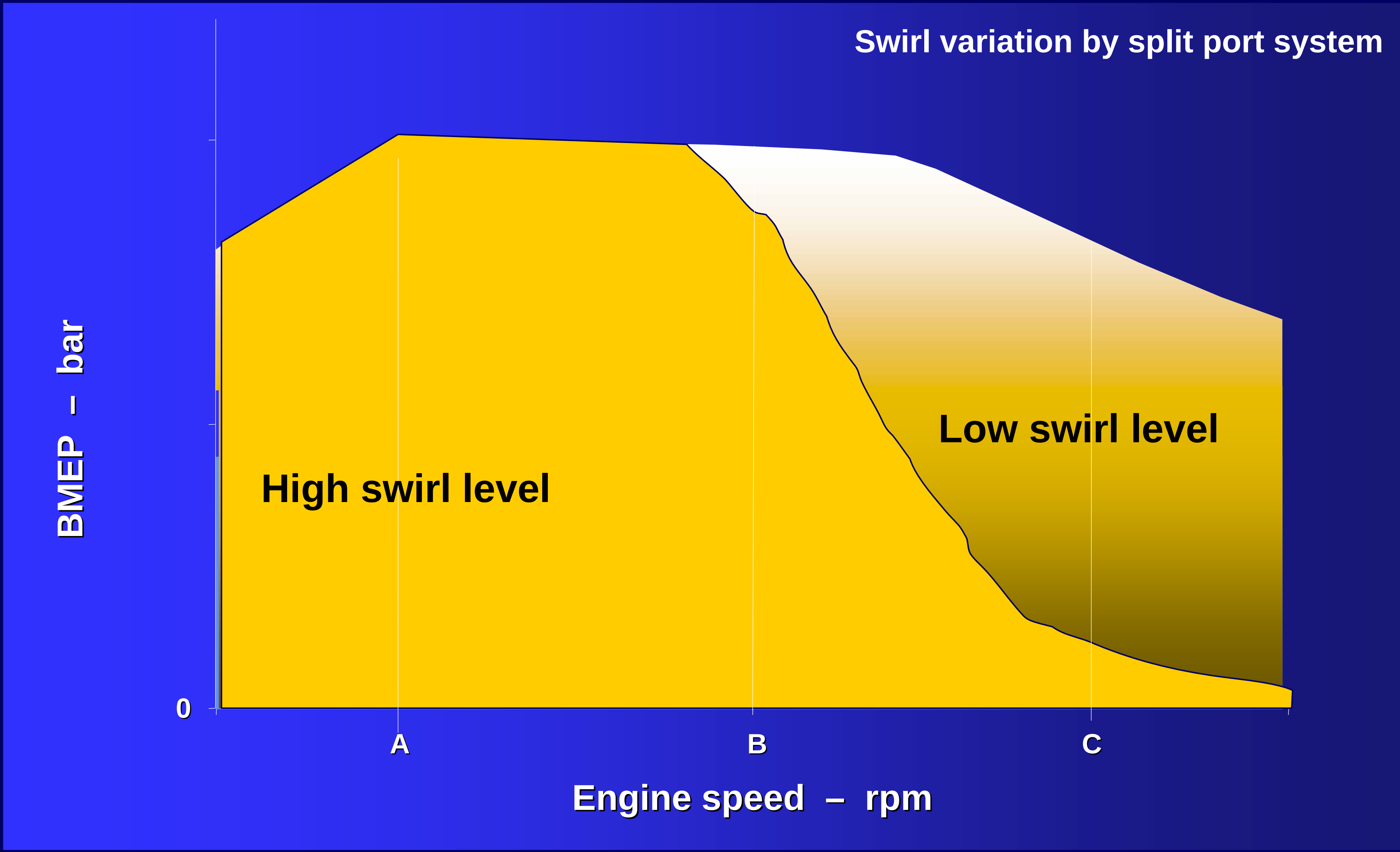
Full Load with Min/Max Swirl Settings



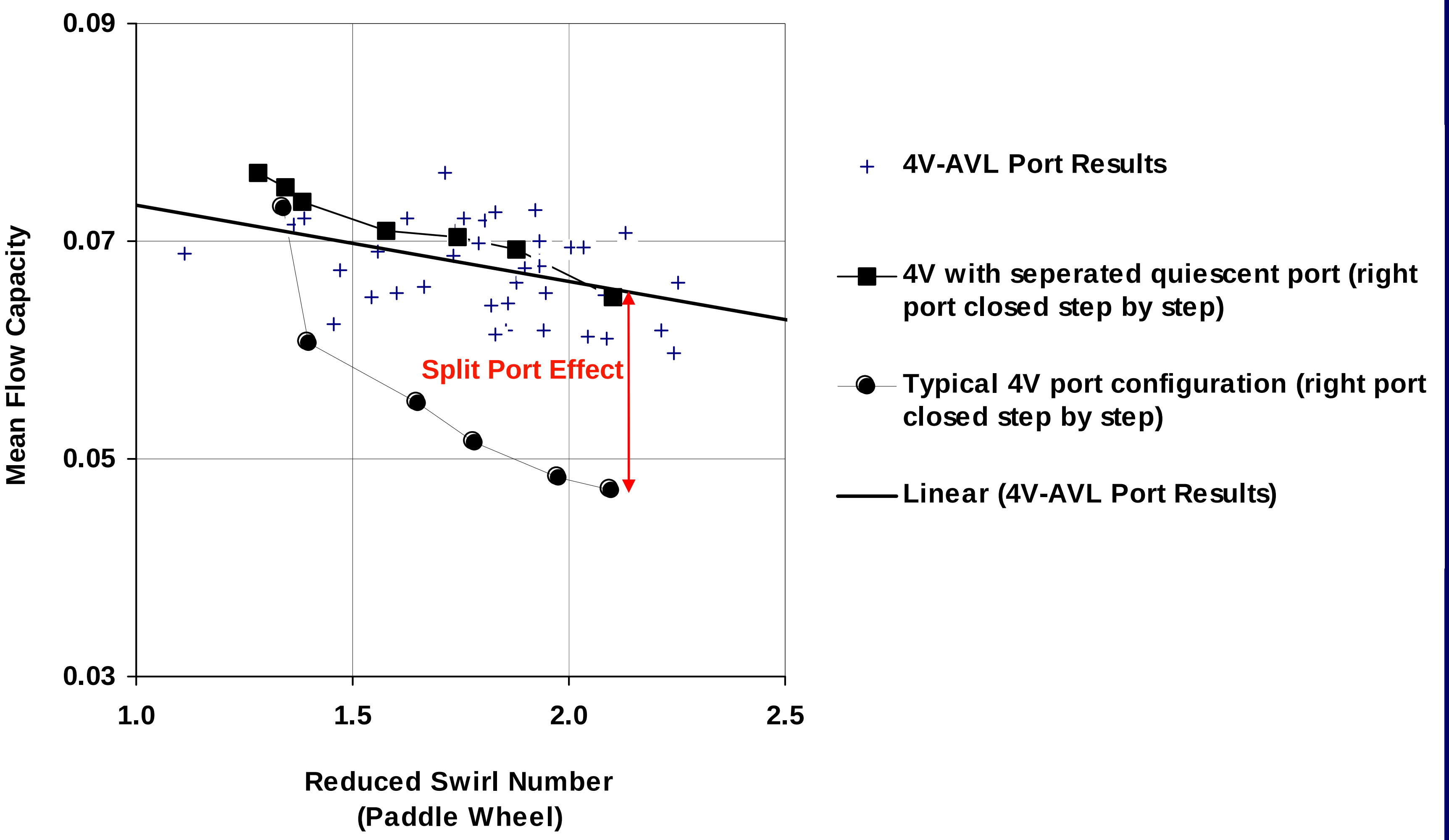
Distribution of High and Low Swirl Level(2/2)



Distribution of High and Low Swirl Level(1/2)

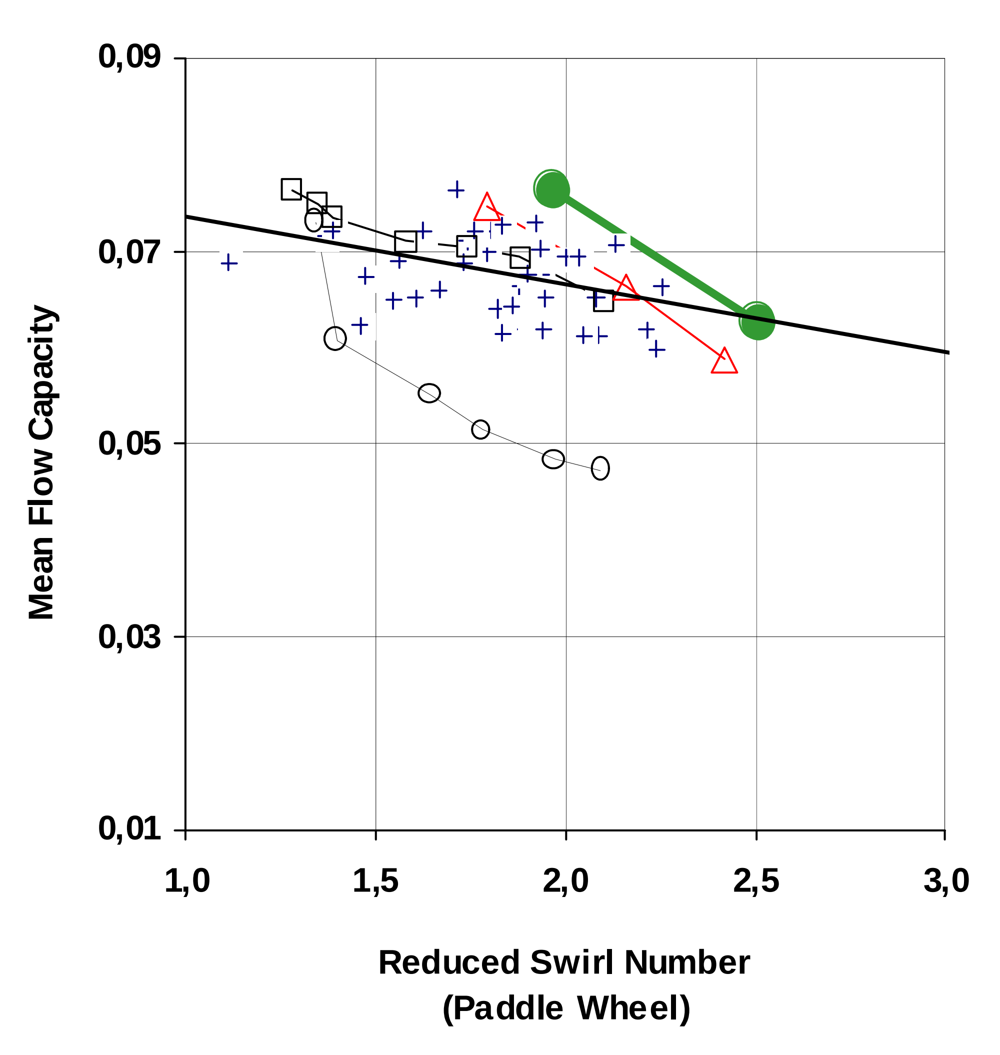


4V - Port Capacity Diagram



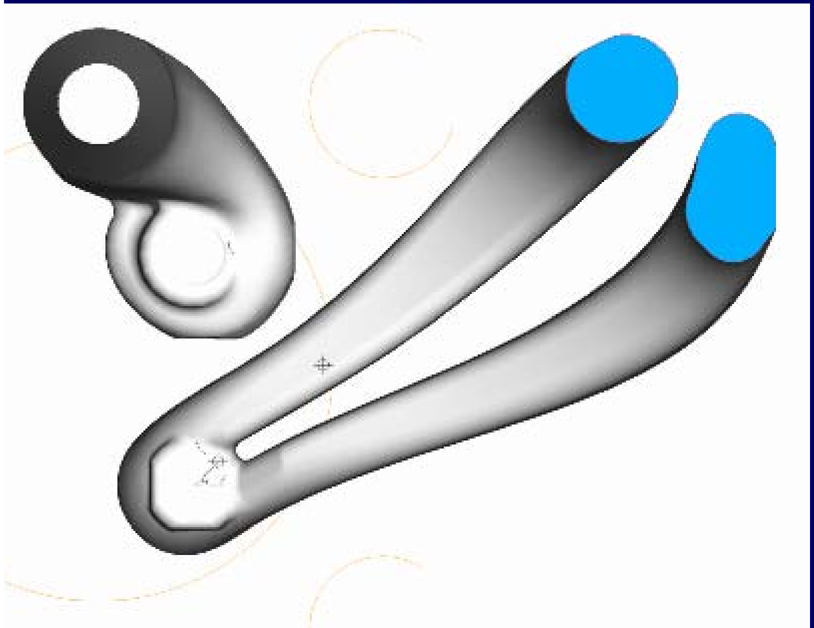
B0349G

4V - Intake Ports - Parallel Valve Pattern

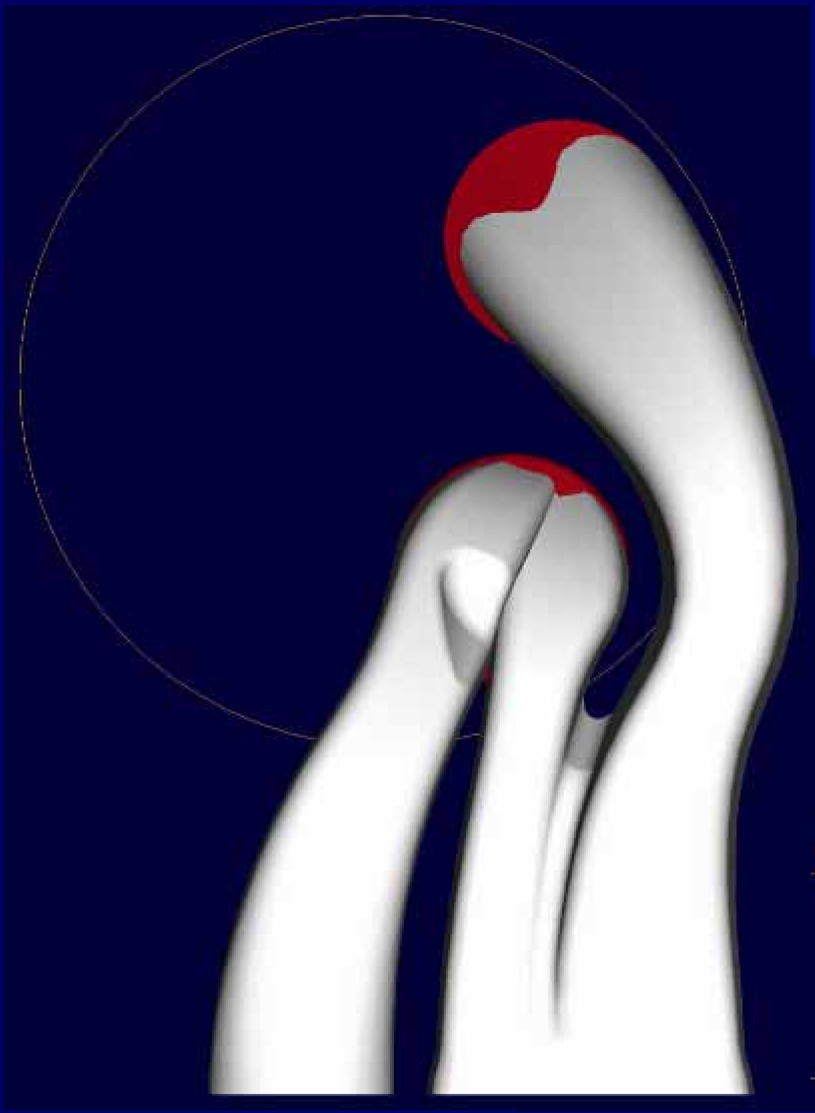


Separated Quiescent Port

Parallel Valve Pattern

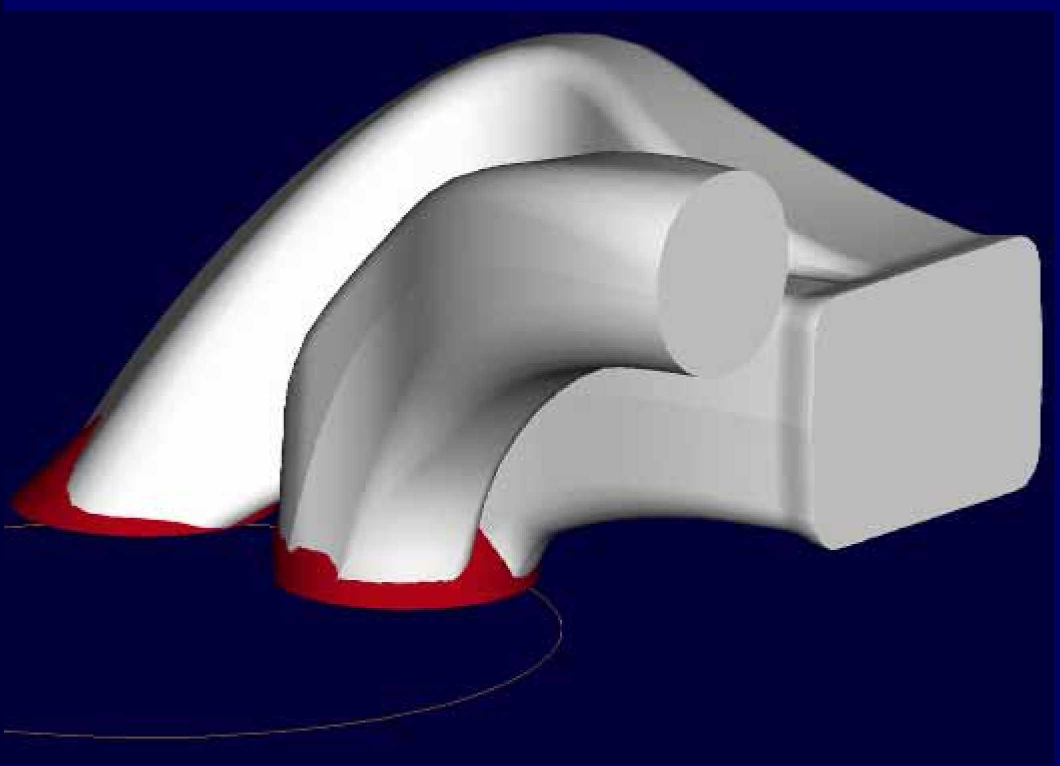


Alternative Split Port Concept

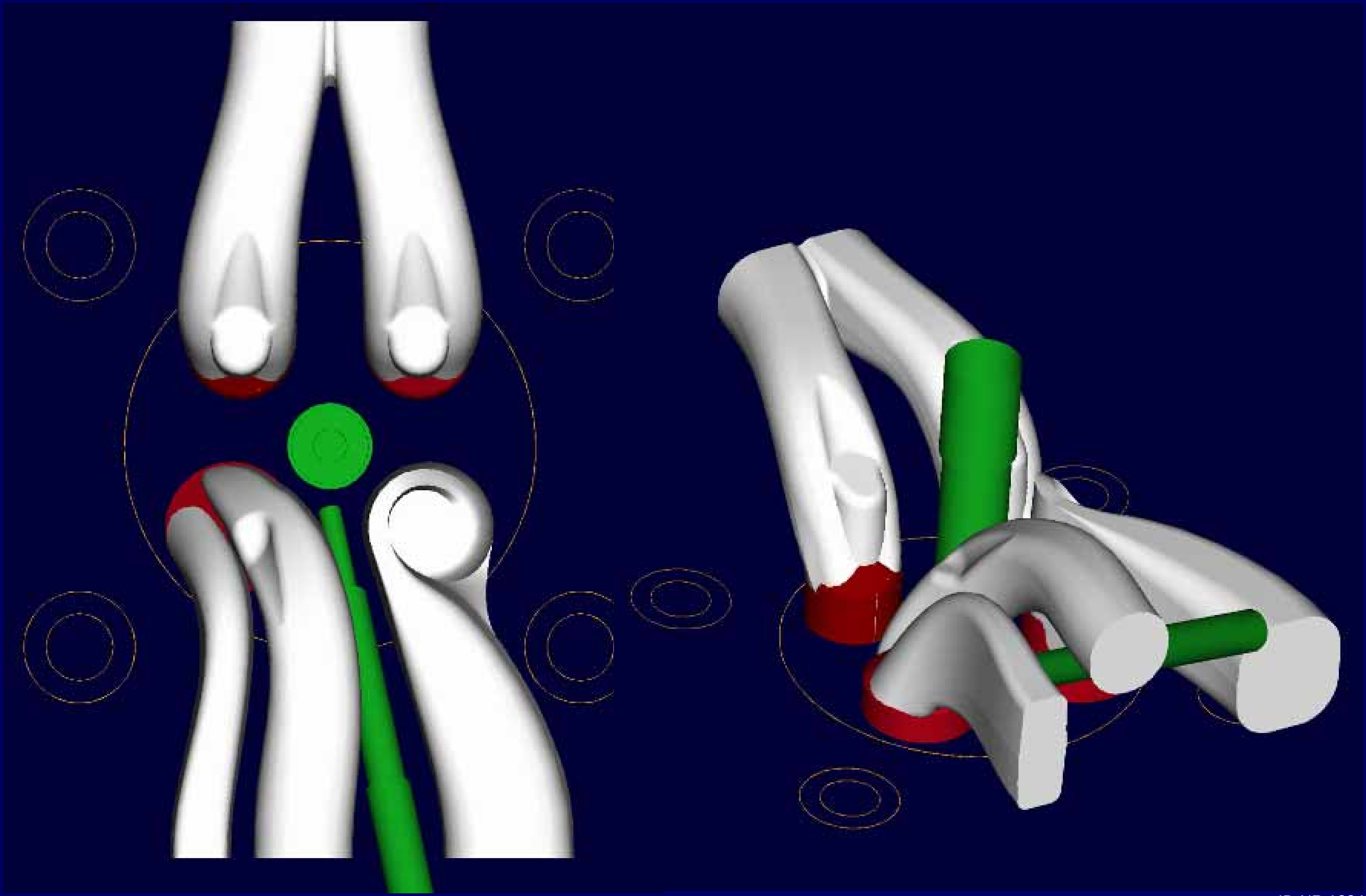


Skewed valve pattern

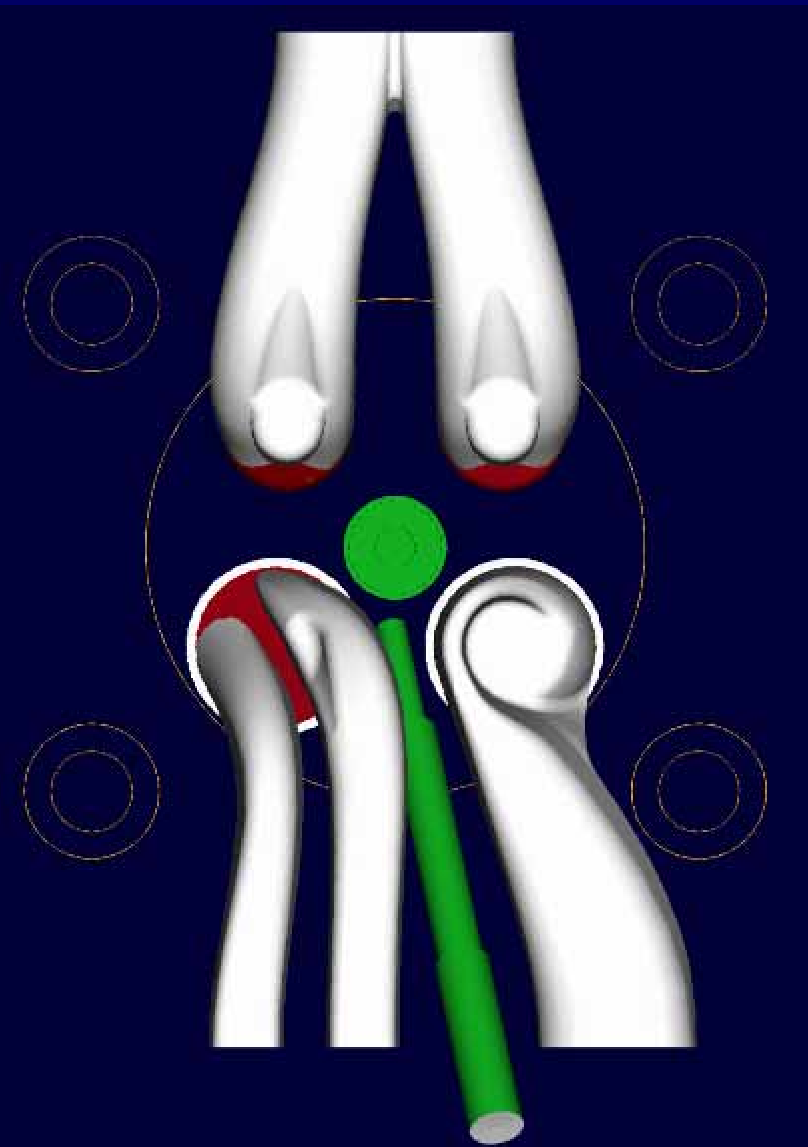
flap deactivation



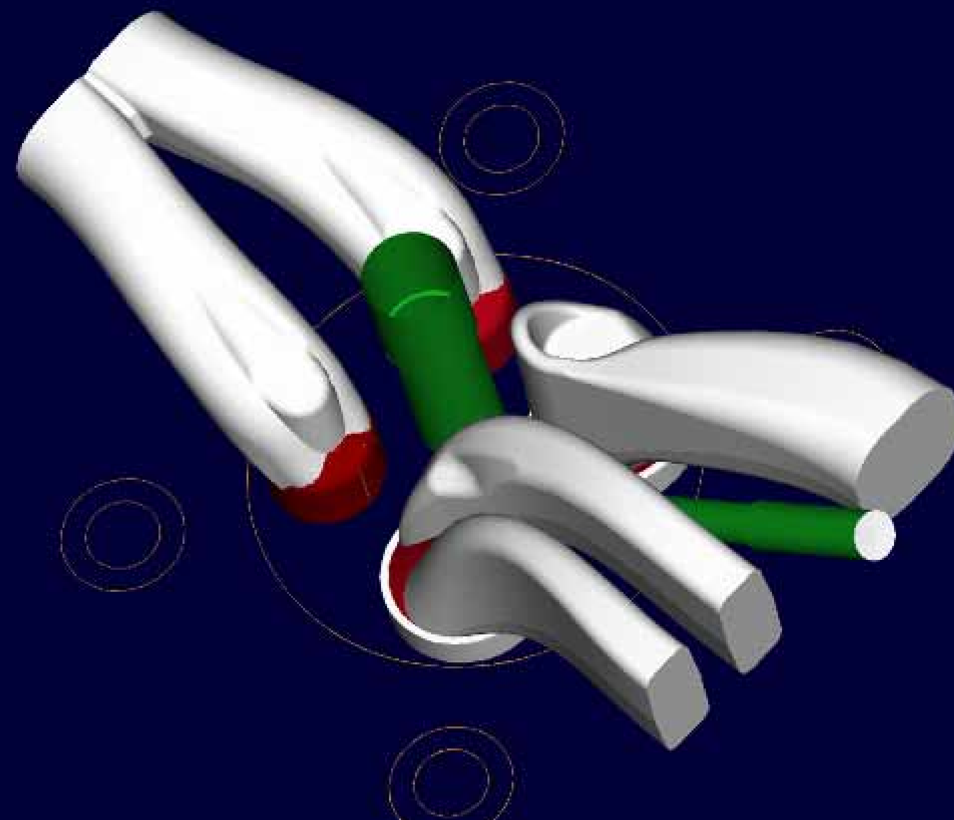
Split Port Concept – Parallel Valve Pattern



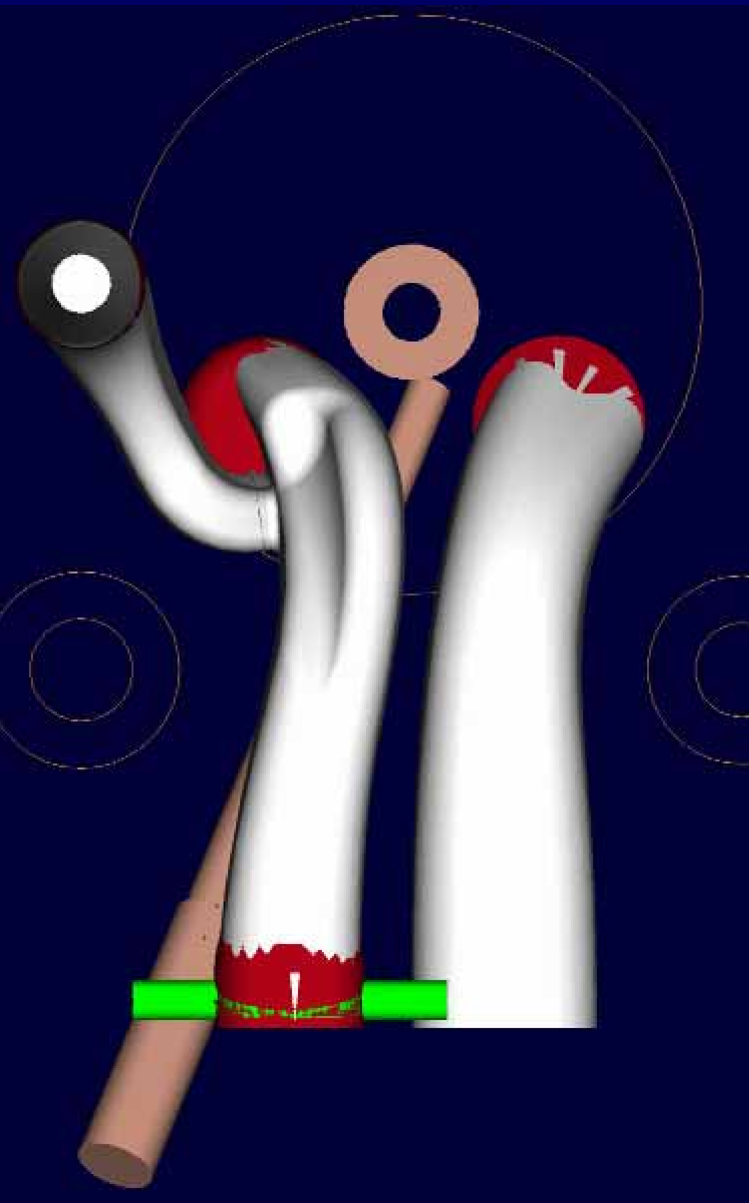
Split Port Concept – Parallel Valve Pattern

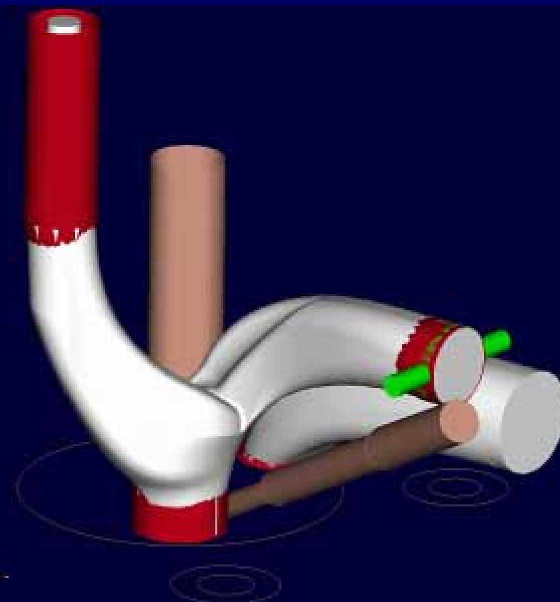


Flap in the manifold (rotating slider, circular flap....)



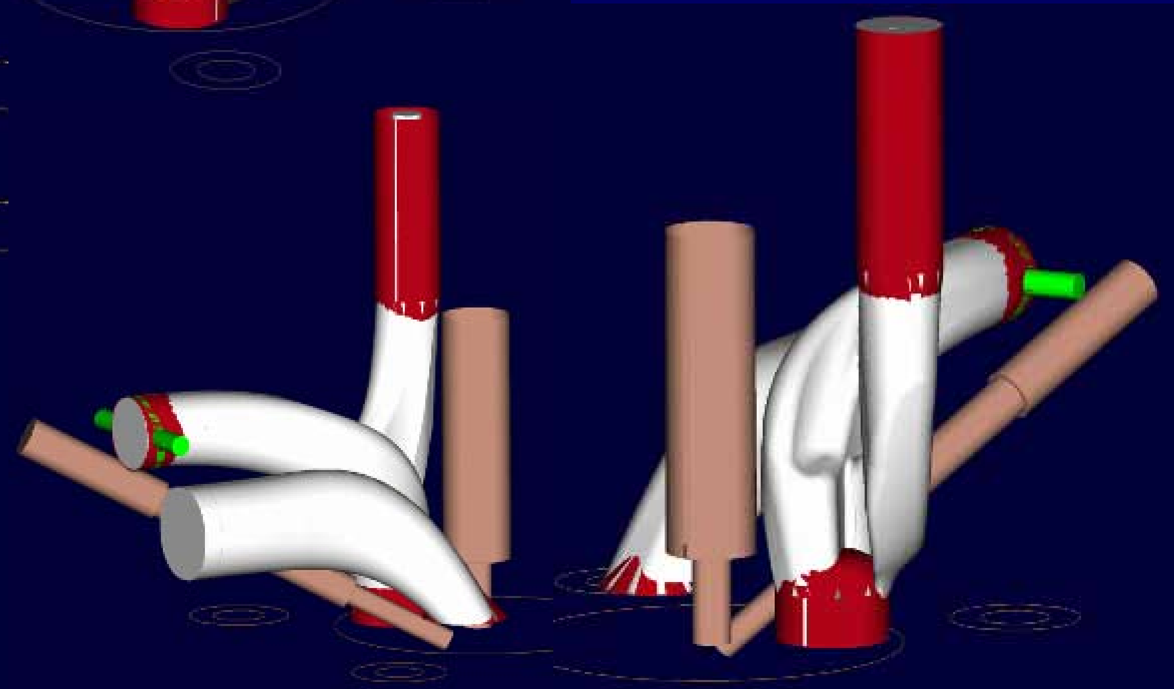
Split Port Concept – Parallel Valve Pattern





Helical component from the top.

Flap deactivation in the cylinder head or in the manifold.



Conclusions:

4V ⇒ low swirl skewed: ß = 0.195

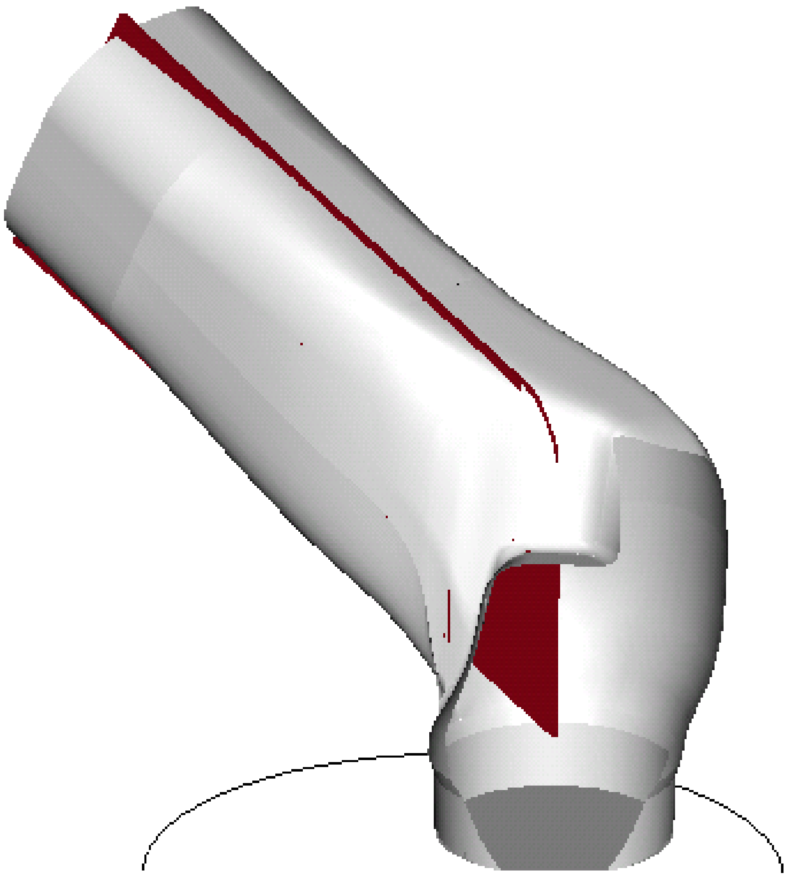
parallel: ß = 0.215

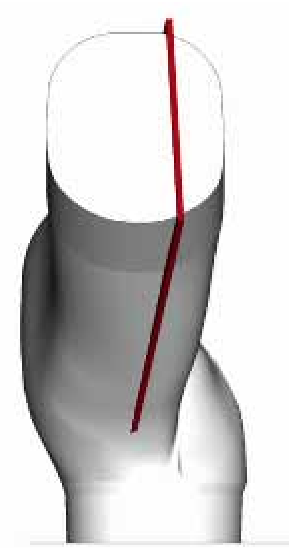
Split port => high swirl: +40% ⇒ +60% flow capacity

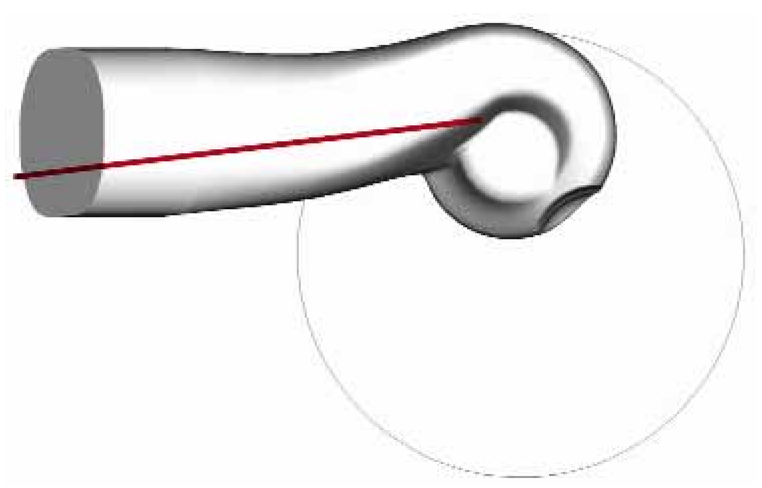
High swirl can be used up to higher engine speeds

60874

2V variable swirl, low swirl helical port with inserted separation wall

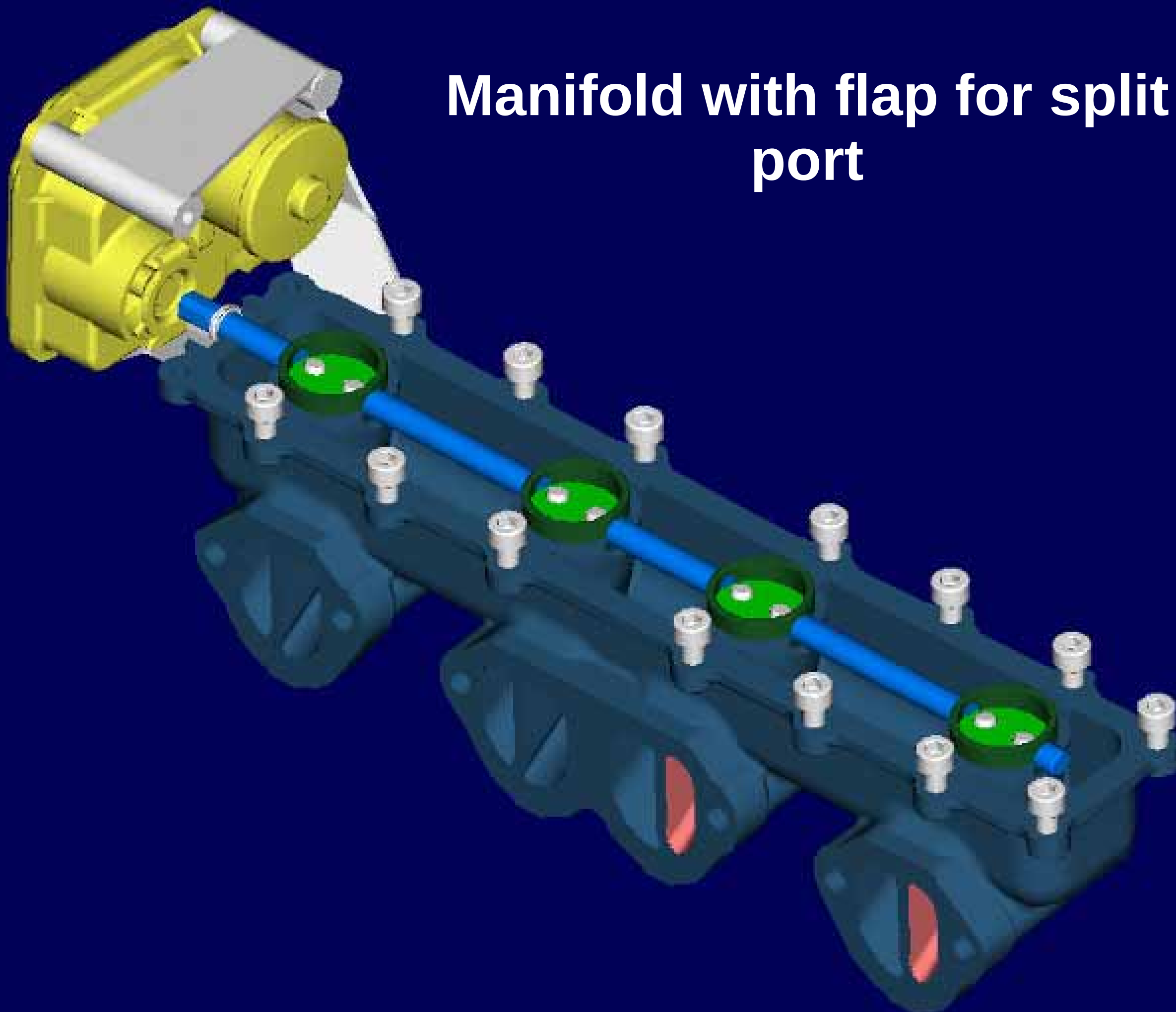




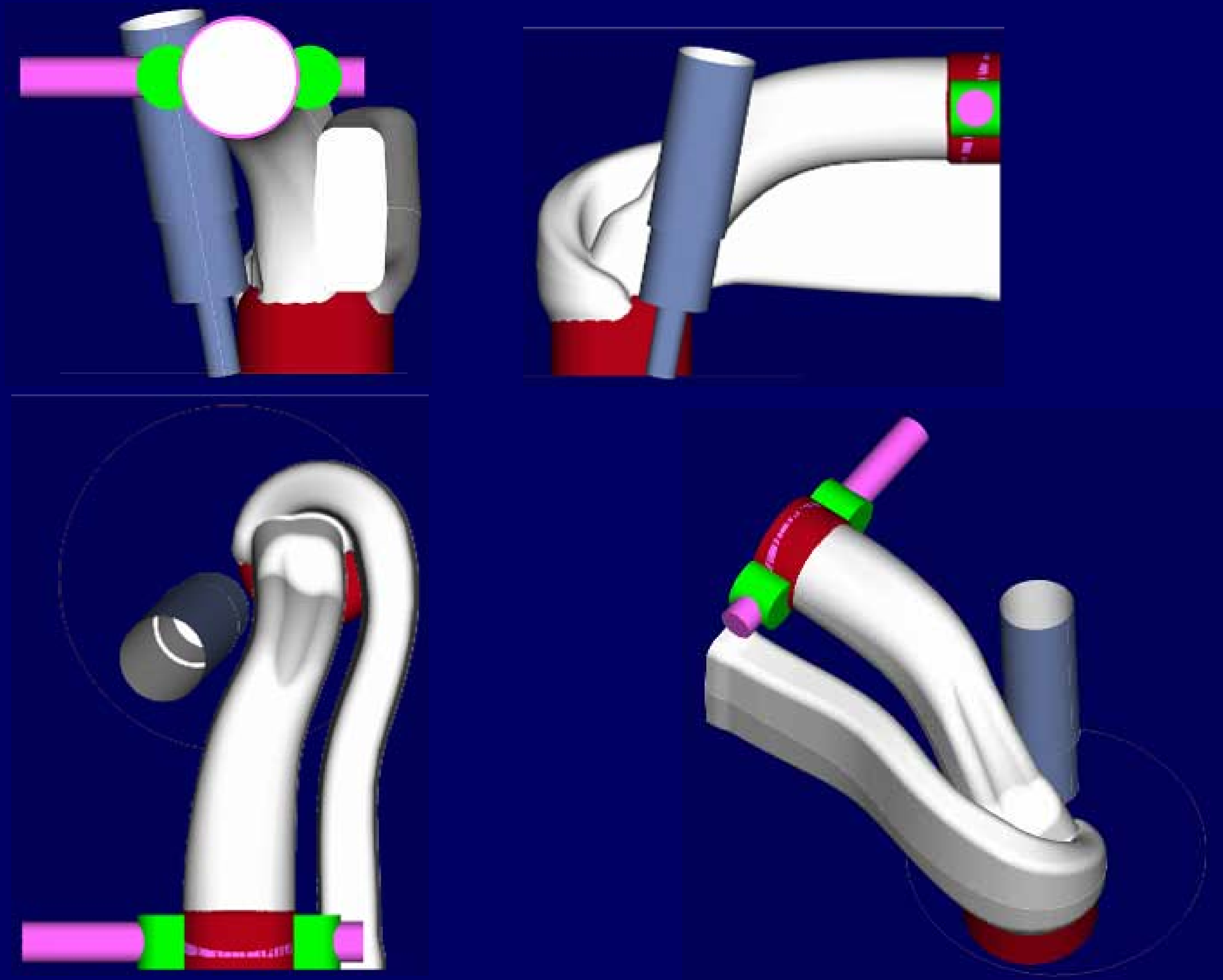


Port Design and Development

Manifold with flap for split port

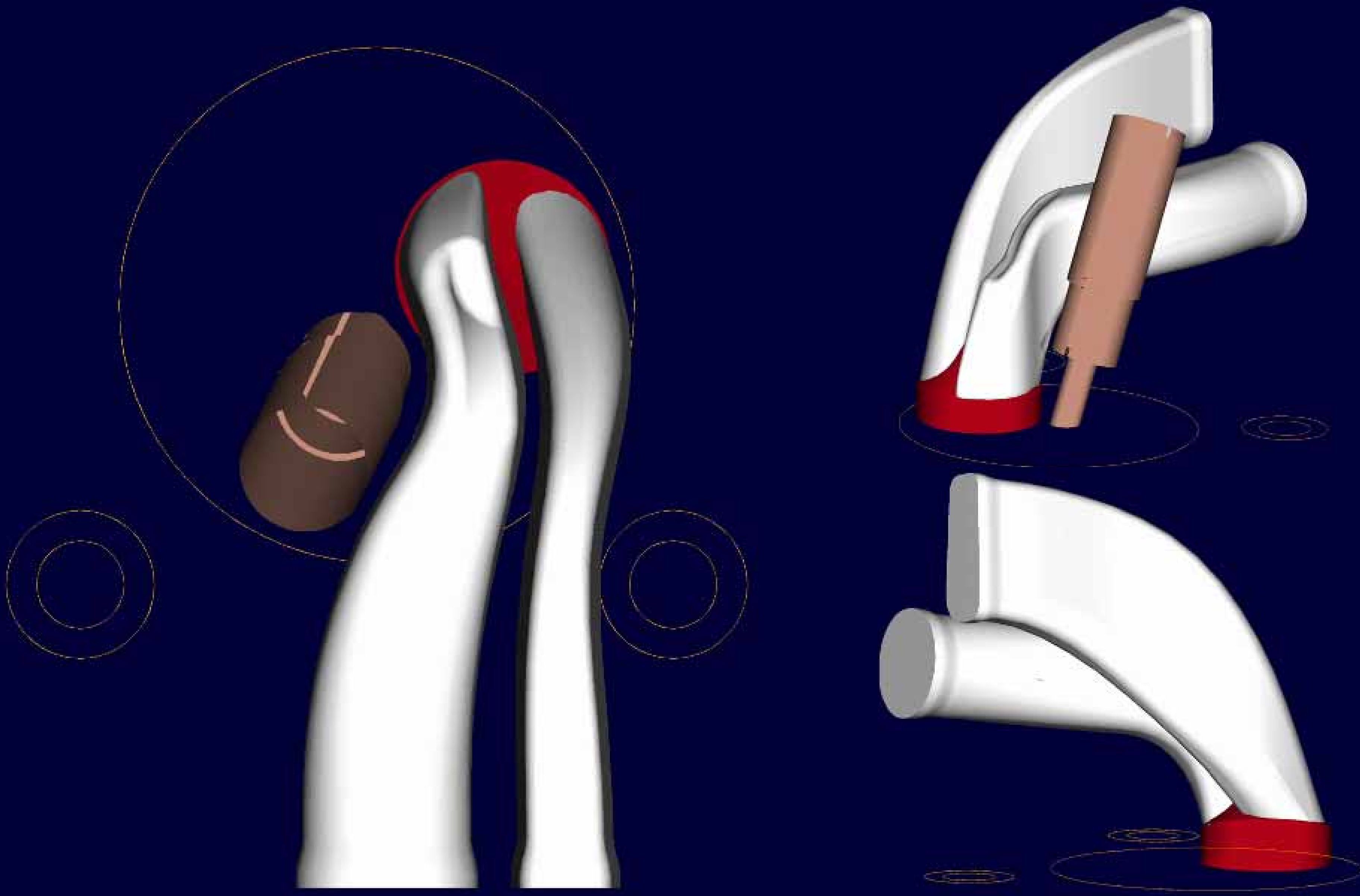


Split port (helix around quiescent) with flap optional within the cylinder head

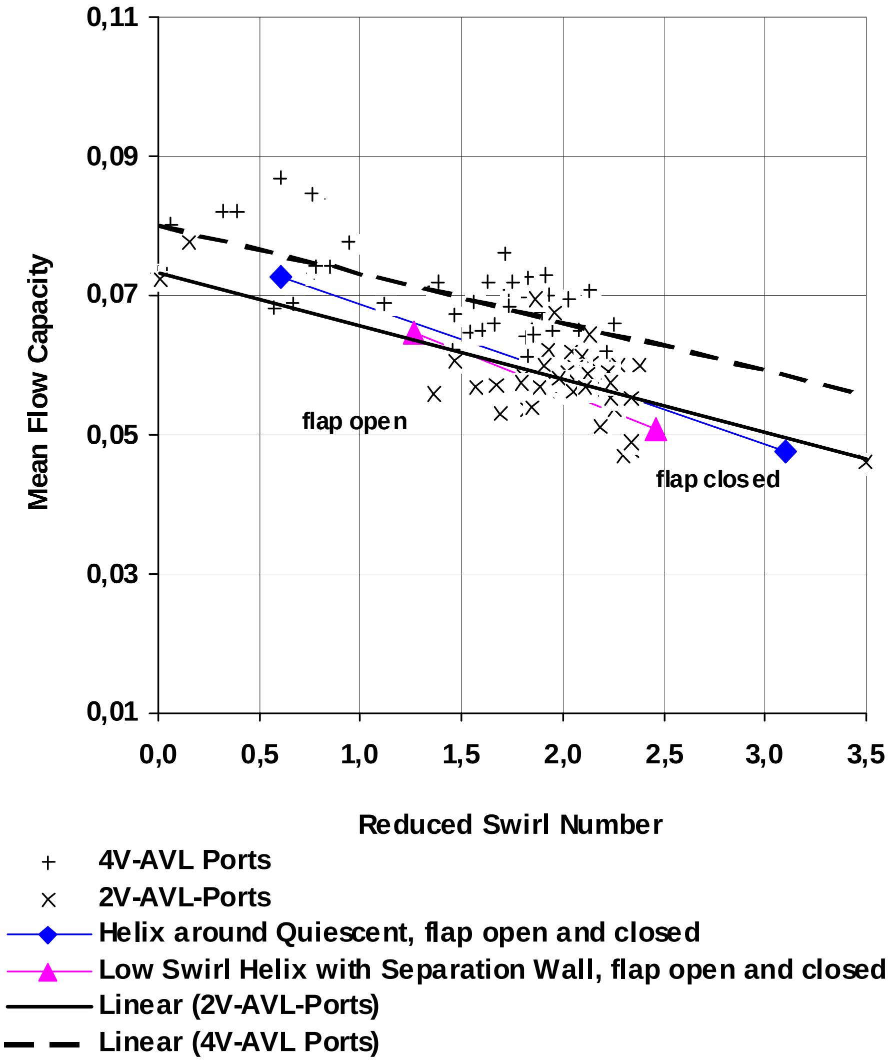


60874

2V- Split Port (tangential/quiescent)



Port Design and Development



Swirl Number-
Mean Flow Capacity -
Diagram
2V-4V-AVL - PORTS, 2V
Variable Swirl Systems

Conclusions:

There are many systems we have to tune and optimize to achieve the lowest engine out emissions such as:

- Fuel system
- Charging system
- EGR system
- Aftertreatment system

A variable swirl system, especially with a split port design applied to high speed, heavy duty engines may be a major contributor to achieve future goals.

60874