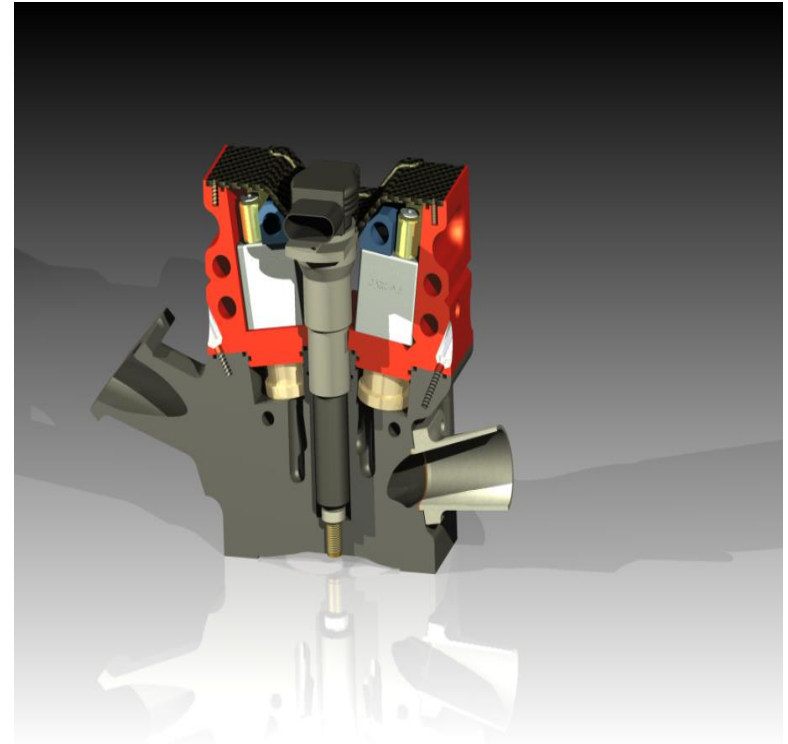


Since renamed FreeValve.com: <https://www.freevalve.com/>

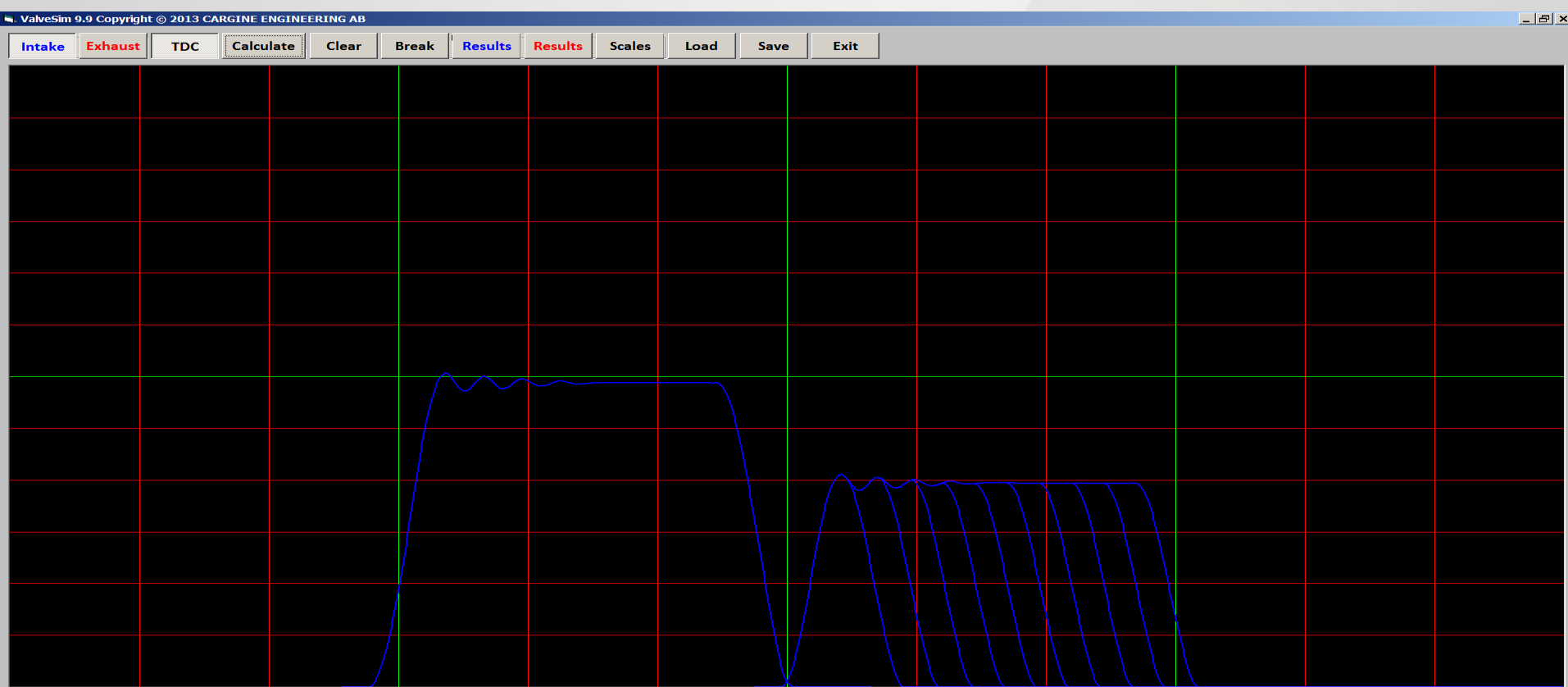
CARGINE

What is the Cargine Free Valve system?

- **Fully Flexible Valve System**
 - Individual valve control
 - Fully Flexible Timing
 - Valve Opening
 - Valve Closing
 - Fully Flexible Lift Control
- **Pneumatic Closed Loop System**
 - Reduced Temperature
 - Low Energy Consumption
 - Oil Mist Lubrication
- **Hydraulic Valve Latch**
- **Hydraulic Valve Damping**

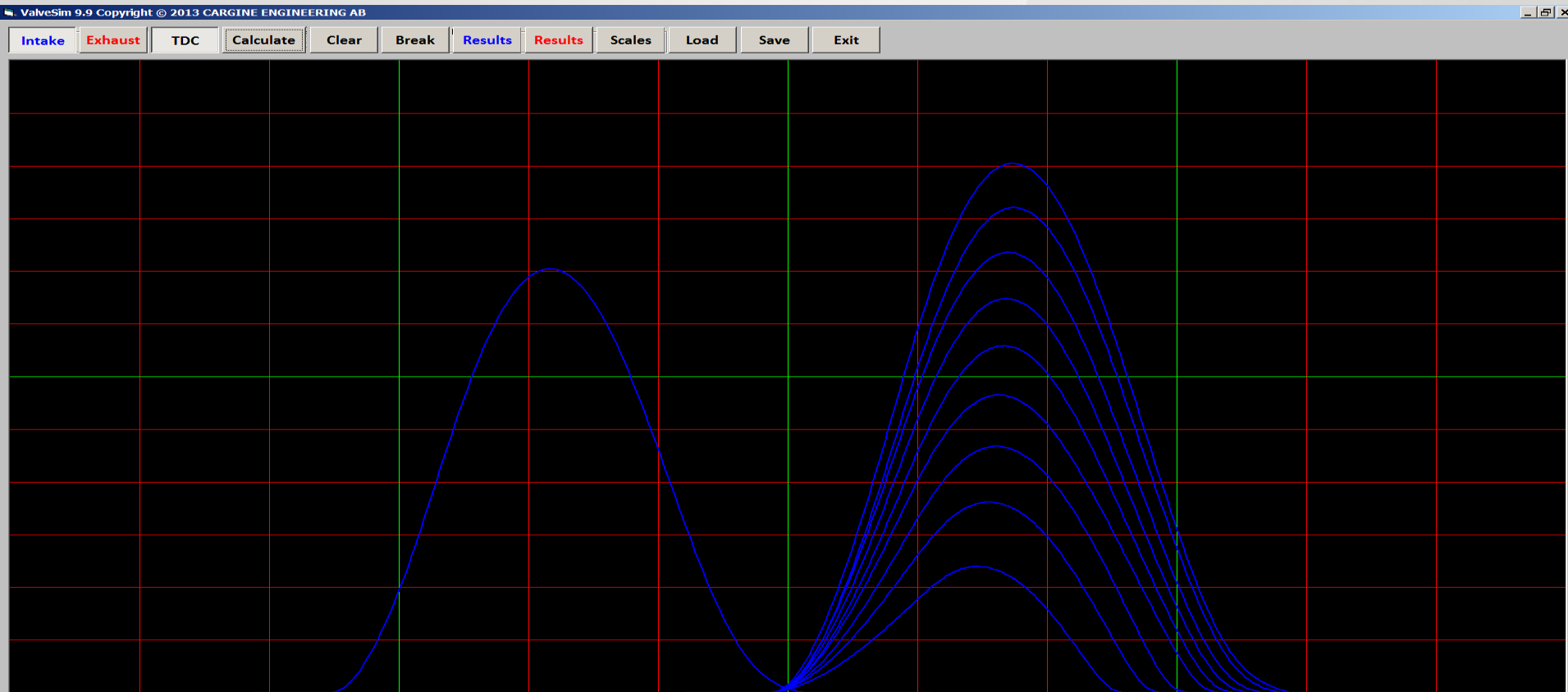


Fully Flexible Valve Opening and Closing Time



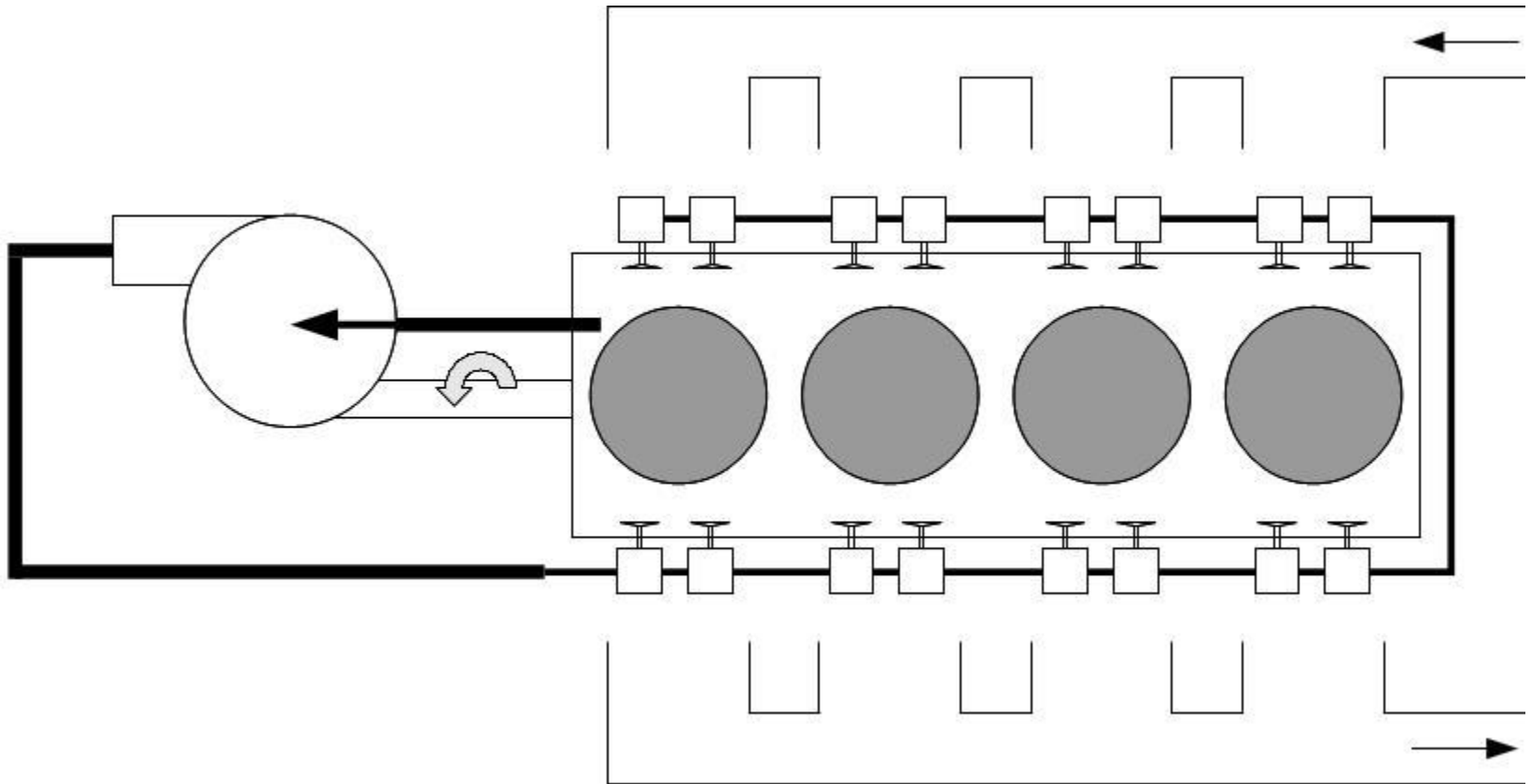
Valve lift curves at 2000 r/min engine speed
X-scale: 60 degCA/div, Y-scale: 1 mm/div, TDC at center

Fully Flexible Valve Lift



Valve lift curves at 6000 r/min engine speed
X-scale: 60 degCA/div, Y-scale: 1 mm/div, TDC at center

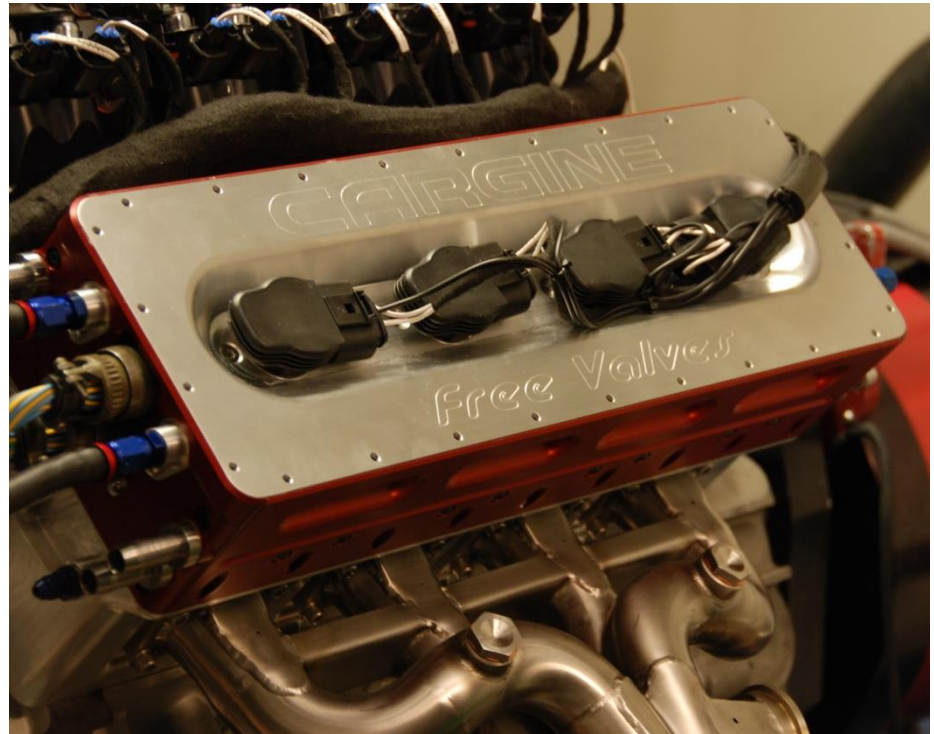
Closed loop air supply system with elevated return pressure for reduced temperature losses



source:AVL, P.Kapus paper, SIA Conf Nov 2006

Cargine Free Valves Advantages

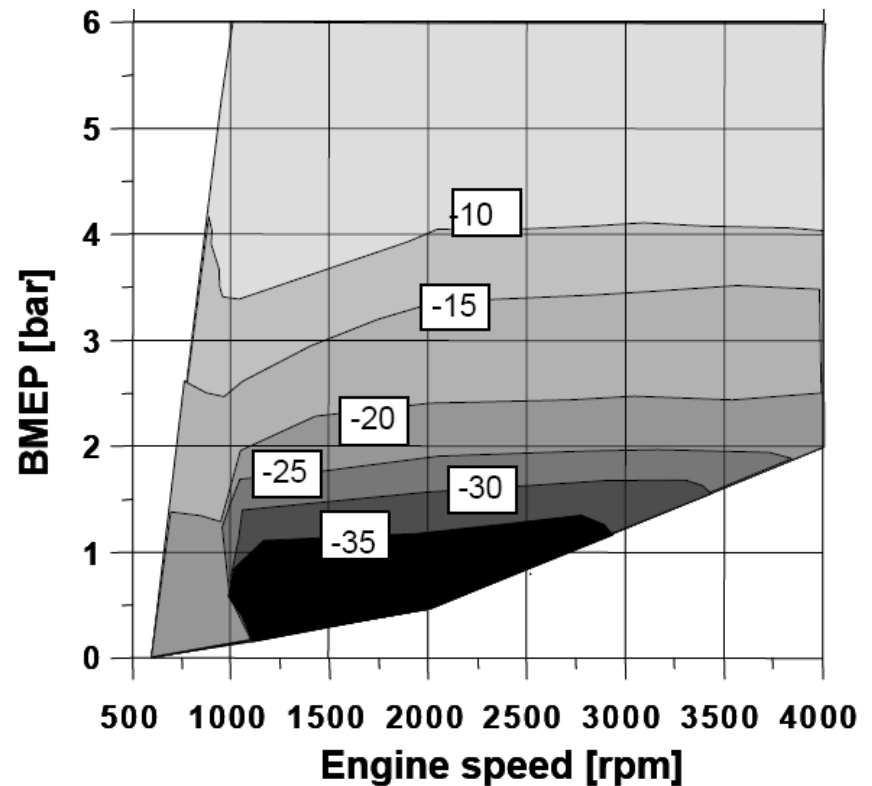
- *Reduced*
 - Fuel Consumption
 - Emissions
 - Noise Level
- *Increased*
 - Torque
 - Peak Power
- *Improved*
 - Packaging
 - Weight



Reduced Fuel Consumption, SI Engine with Free Valves

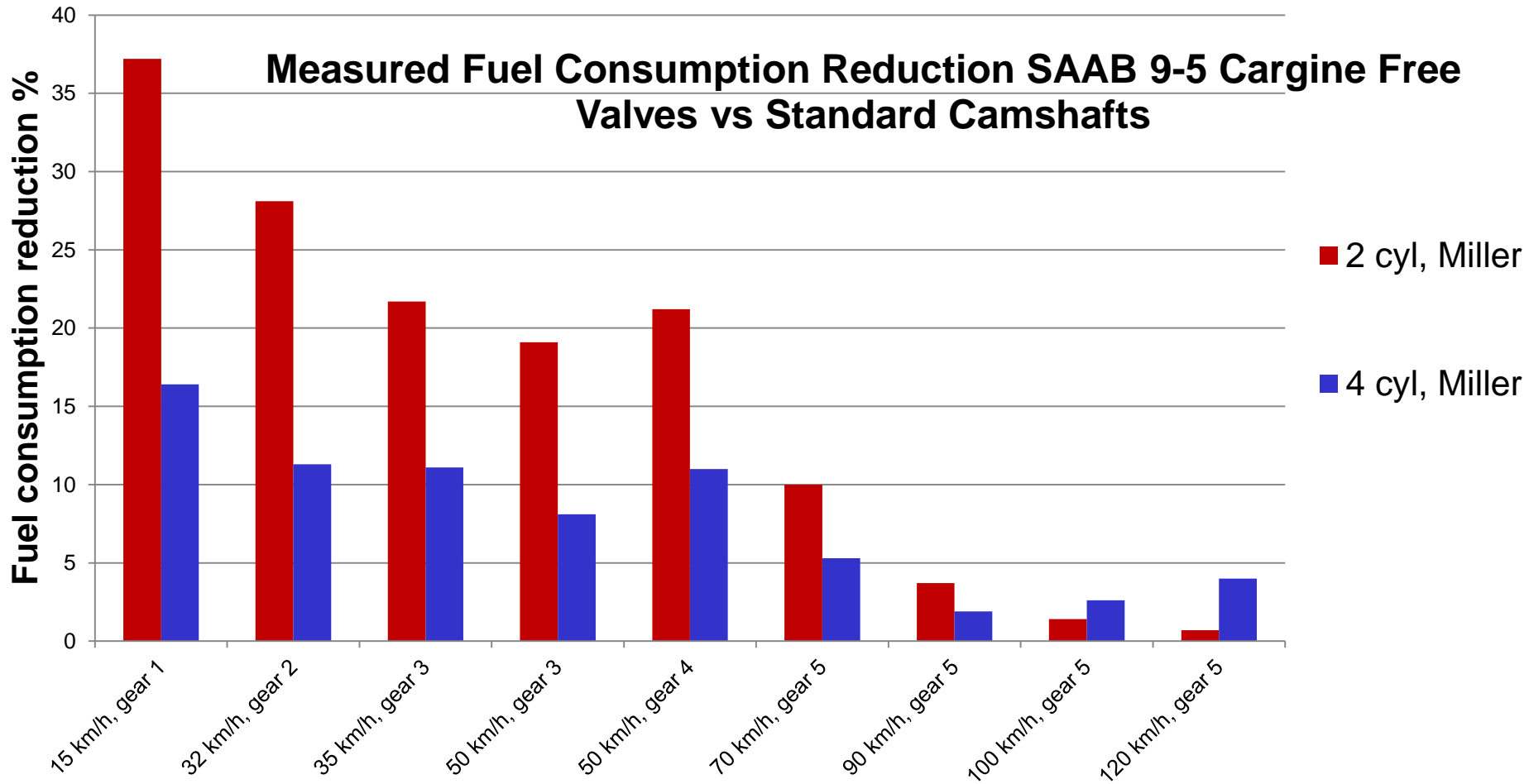
With Free Valves and Cylinder
Deactivation:

*10 - 35 % Fuel consumption
reduction (1 - 4 bar BMEP)*



source:AVL, P.Kapus paper, SIA Conf Nov 2006

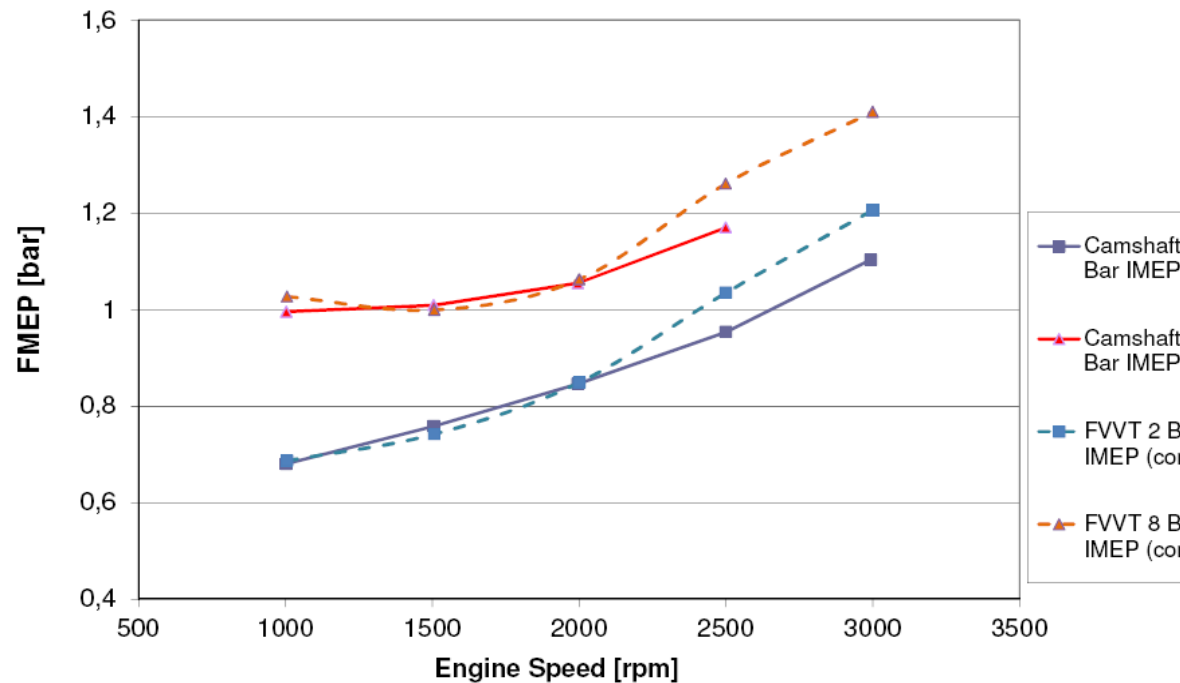
Measured Fuel Consumption Reduction SAAB 9-5 Free Valves vs Standard Camshaft



AVL (third party) Power Consumption Measurements

Cams vs Cargine Free Valves

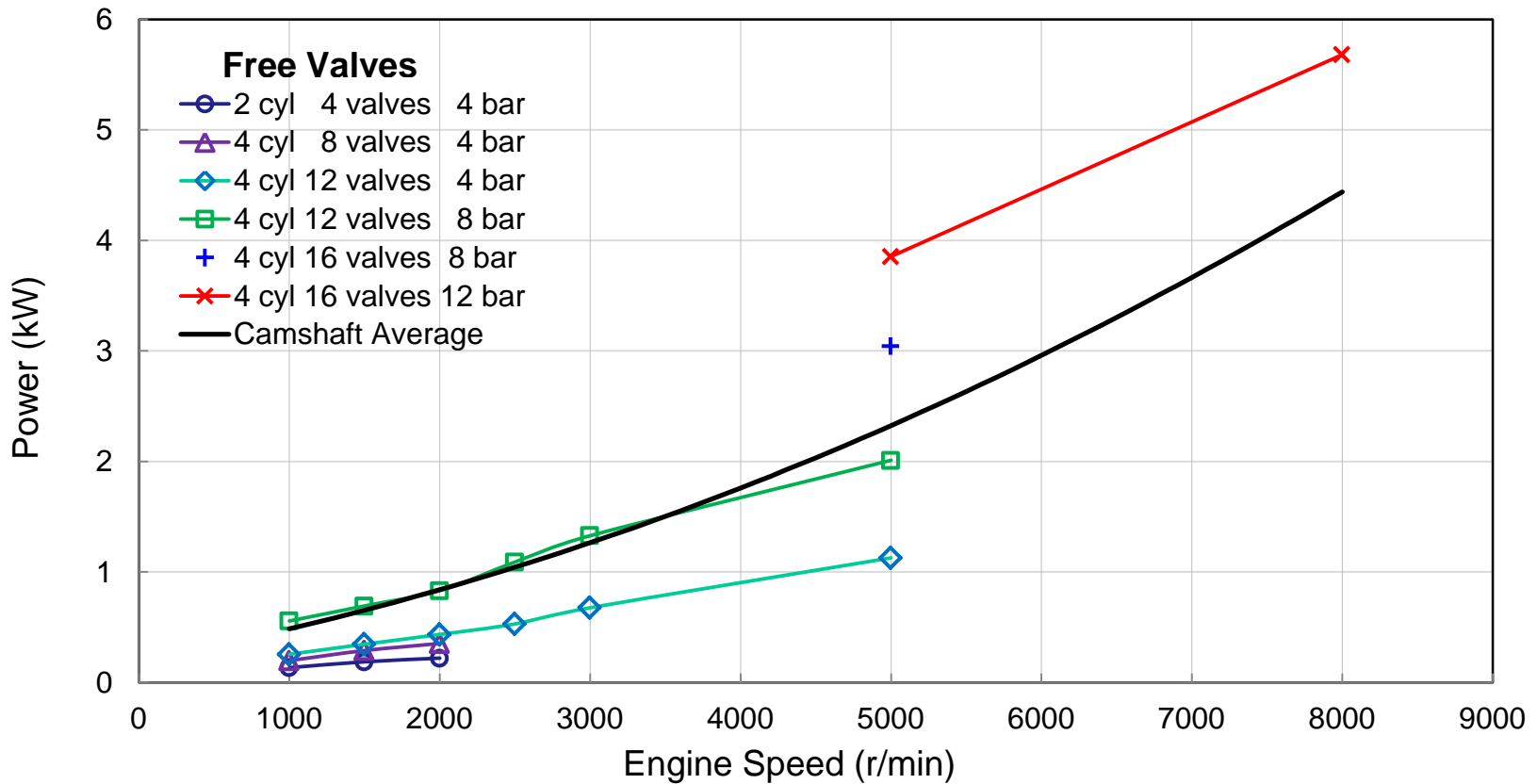
- **Reference** – 4 cyl, 2 liter GM engine with low-friction roller-rocker cam system (single cylinder)
- **Measured** parasitic losses with standard camshafts and with Cargine Free Valve system (same single cylinder engine)
- **Parasitic losses comparable with standard camshafts up to 2000 rpm for same PV diagram (4 valve operation)**
- With optimal 3 valve operation – parasitic losses 25% lower compared to camshafts



Source: AVL SPEAB

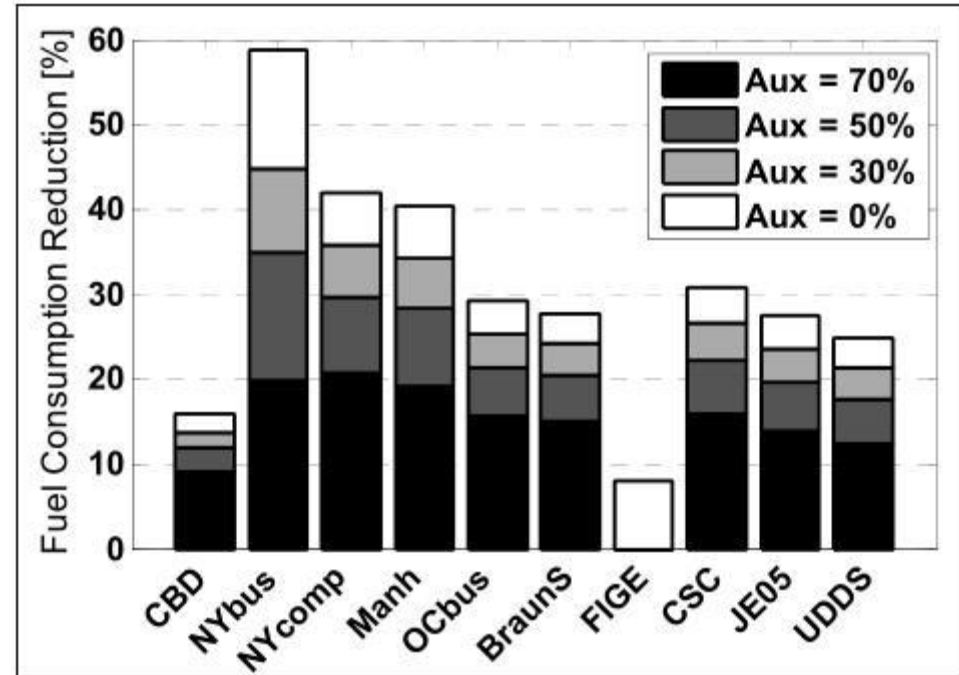
Free Valve Power Consumption Measurements

Free Valve System Power Consumption vs Engine Speed



Cargine Air Hybrid project 2005-2011 results

- Engine lab test with
 - Free Valve System
 - 2 L displacement
 - 50 L air tank
- Vehicle simulation performed
- FC reduction 8-58 % (30 % average)
- Low-cost
- Light-weight
- Robust
- Improved performance
- Engine efficiency gains due to camless operation **not included** in above figures. Only regenerative braking and start/stop benefits.



Source: University of Lund

Reduced Cold Start Emissions

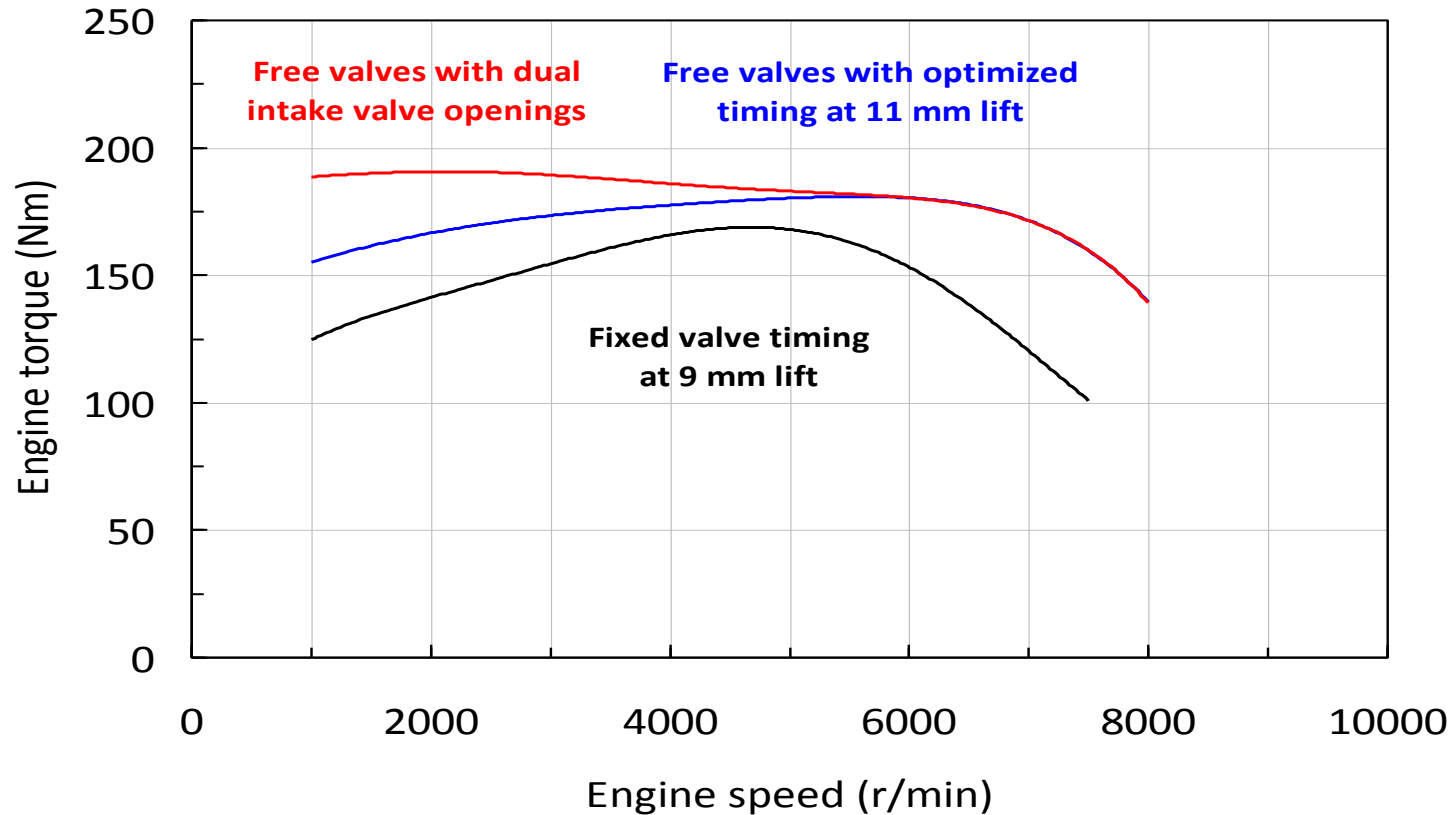
- Cold start emissions can be reduced more than 75 % by:
 - Cylinder deactivation
 - Early exhaust valve opening
 - Increased turbulence
 - Improved fuel vaporisation
- Demonstrated ability to start at low temperatures with 100 % ethanol.



Increased Torque

Naturally Aspirated SI Engine

Maximum torque curves for a 2 liter 4-stroke engine

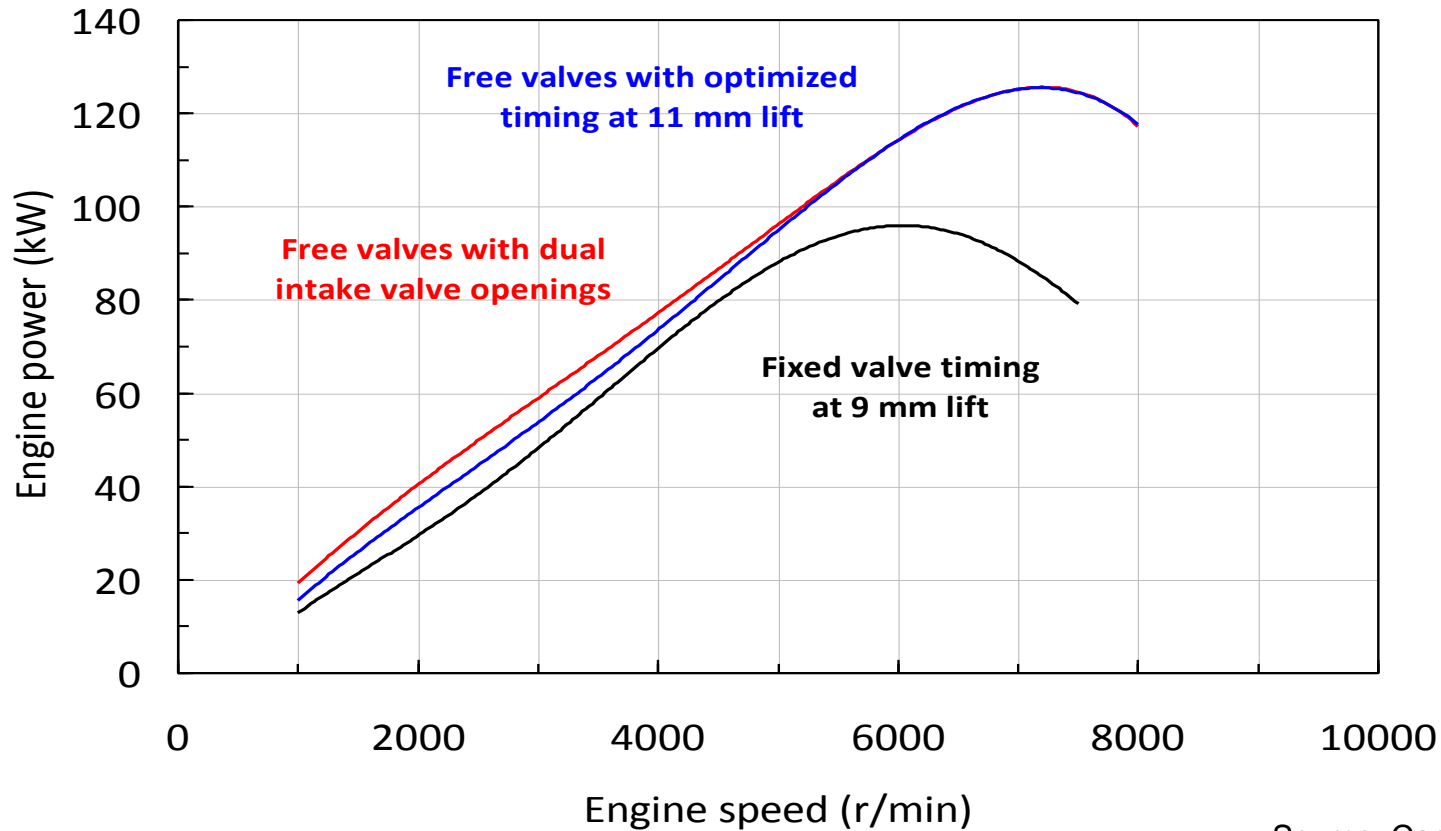


Source: Cargine simulation

Increased Power

Naturally Aspirated SI Engine

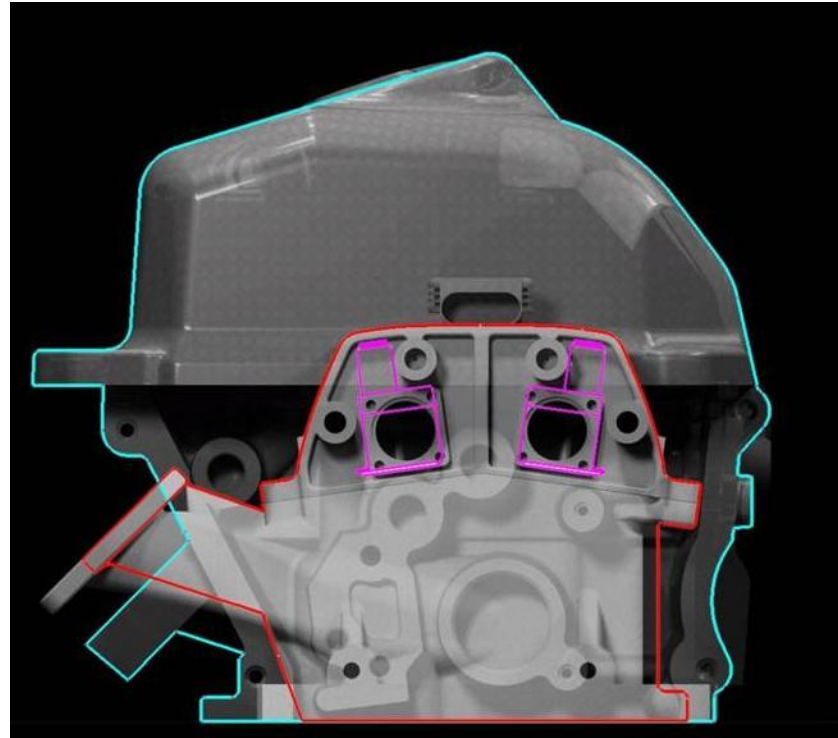
Maximum power curves for a 2 liter 4-stroke engine



Source: Cargine simulation

Improved Packaging and Reduced Weight

- Improved Packaging:
 - *Lower (50 mm)*
 - *Narrower*
 - *Shorter (45 mm)*
- Reduced Weight (5 kg)



Cylinder Head Profile DOHC vs Free Valves

Real life/Longevity test SAAB 9-5 2009-2013

- 8 Intake valves
- On-board compressor with variable displacement
- 65 000 km daily operation
- Cold starts down to -20 C
- Throttle free operation with Miller cycle (6-10 % fuel cons red)
- Very low noise level
- Very good reliability in everyday use
- Focused on functionality.



Source: Cargine

Noise Level Test SAAB 9-5 2013

- A standard SAAB 9-5 and the SAAB 9-5 modified with Free Valves were tested with a dB meter at different engine speeds. The noise level was measured at same distance and other conditions.
- **Same noise level at idle**
- **2 dB(A) lower noise level at 2000 rpm with Free Valves**
- **4 dB(A) lower noise level at 3000 rpm with Free Valves**



Source: Cargine

Cargine Free Valves

*Few people miss
carburetors today,

Even fewer will miss
camshafts tomorrow!*

