The Scuderi Split Cycle Engine

Technical Outline

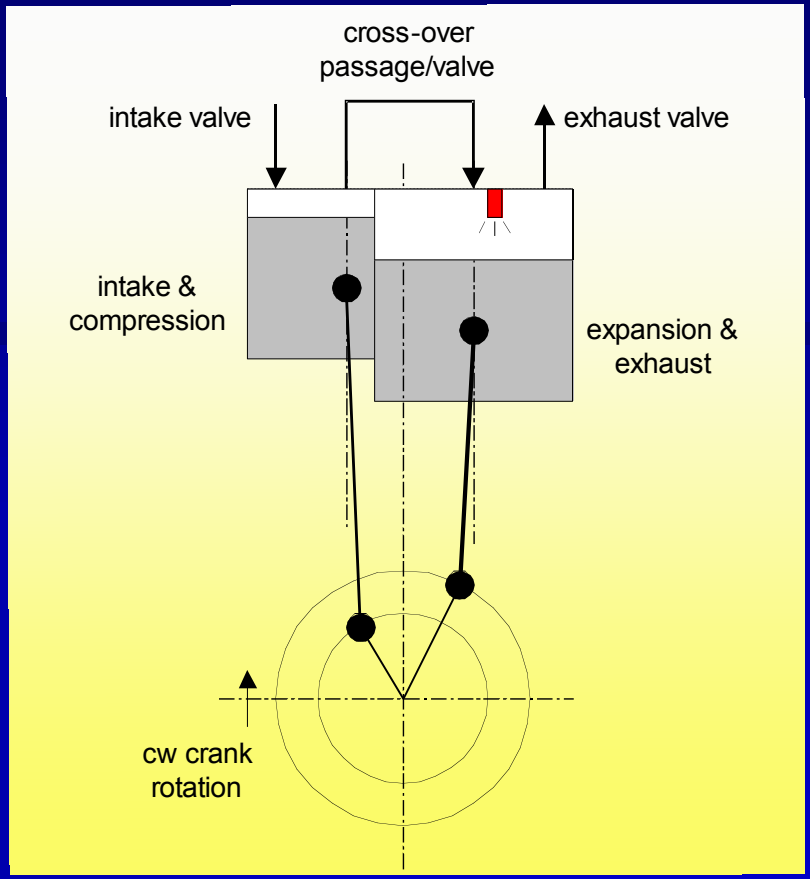
May 2010

Scuderi Split Cycle Engine Background & History

- Original concept from Carmelo Scuderi (father), using experience derived from compressor technology
- Family continue and form the Scuderi Group
- 430 Patent applications filed and 122 granted
- SwRI commenced work Sep 2002
- Initial Evaluation completed July 2003
- Proof of Concept Study commenced July 2005
- Critical Issues Evaluation (Full Load) completed July 2007.
- Valvetrain Test Rig commissioned March 2008
- Prototype Research Spark Ignition engine design commenced October 2007
- Prototype Research Spark Ignition engine first firing achieved June 25, 2009

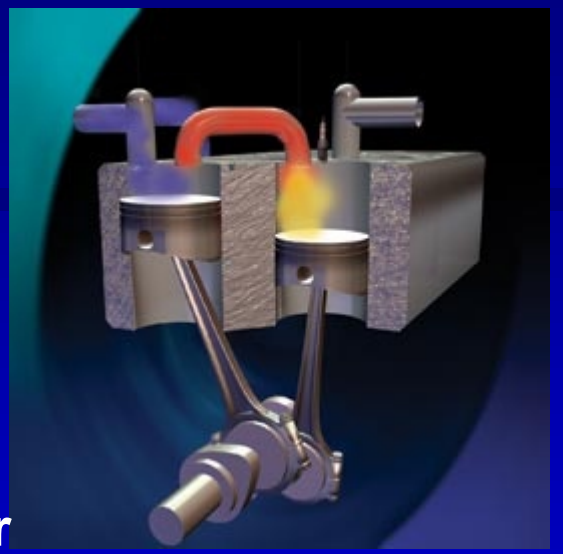
Scuderi Split Cycle Engine
Basic Concepts

- Two adjacent cylinders joined by a crossover (Xover) gas transfer passage
- One cylinder is compressor, the other an expander.
- Expander is 20°CA in advance of compressor
- Cylinders may be offset
- Combustion after TDC
- Fueling in Xover or expander cylinder
- 4-stroke cycle achieved by Split 2-cycle compressor & expander cycles



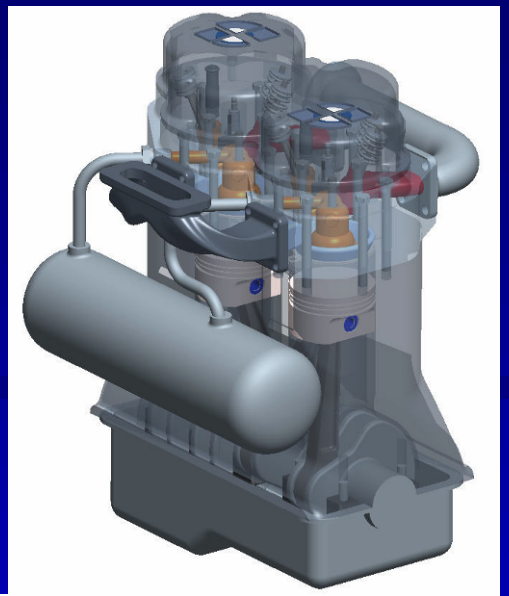
Scuderi Split Cycle Engine Operating Principle

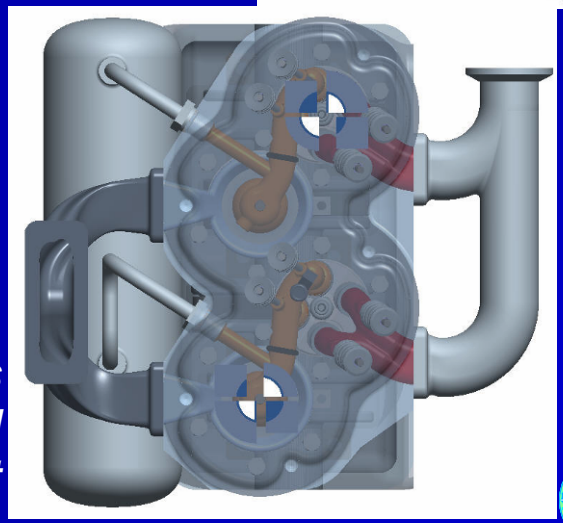
- Intake charge is drawn into compressor cylinder
- Charge is compressed and driven into crossover gas passage via valve system
- Pressurized charge is admitted to expander cylinder near TDC, together with fuel
- Combustion takes place in expanding cylinder
- Exhaust gases are expelled from expander cylinder (as 4-stroke)



Scuderi Split Cycle Engine Operating Principle

- Split Cycle engine adapts very well to Air Hybrid operation
  - An air storage tank is connected to the cross-over gas passage by a control valve
  - Can operate in air motor mode with compressor cylinder disabled, consuming stored air from tank
  - Can operate in air braking mode with expander cylinder disabled, compressing air into tank (i.e. regenerative braking)

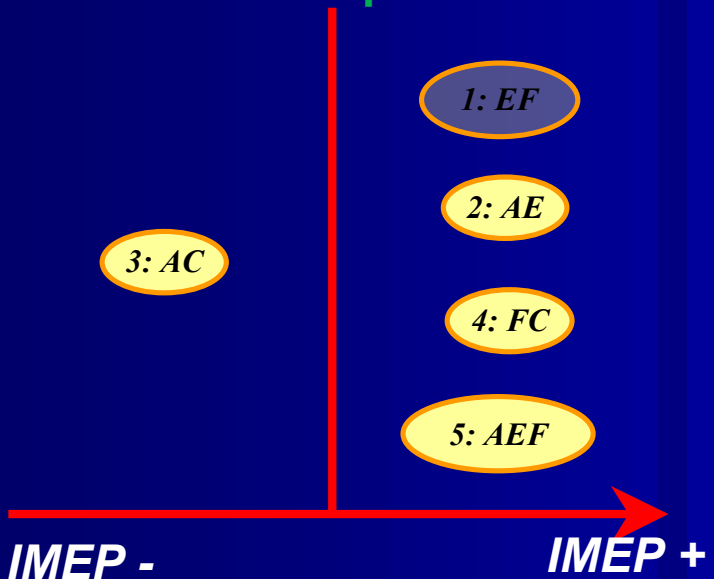




Early impressions of an air hybrid concept

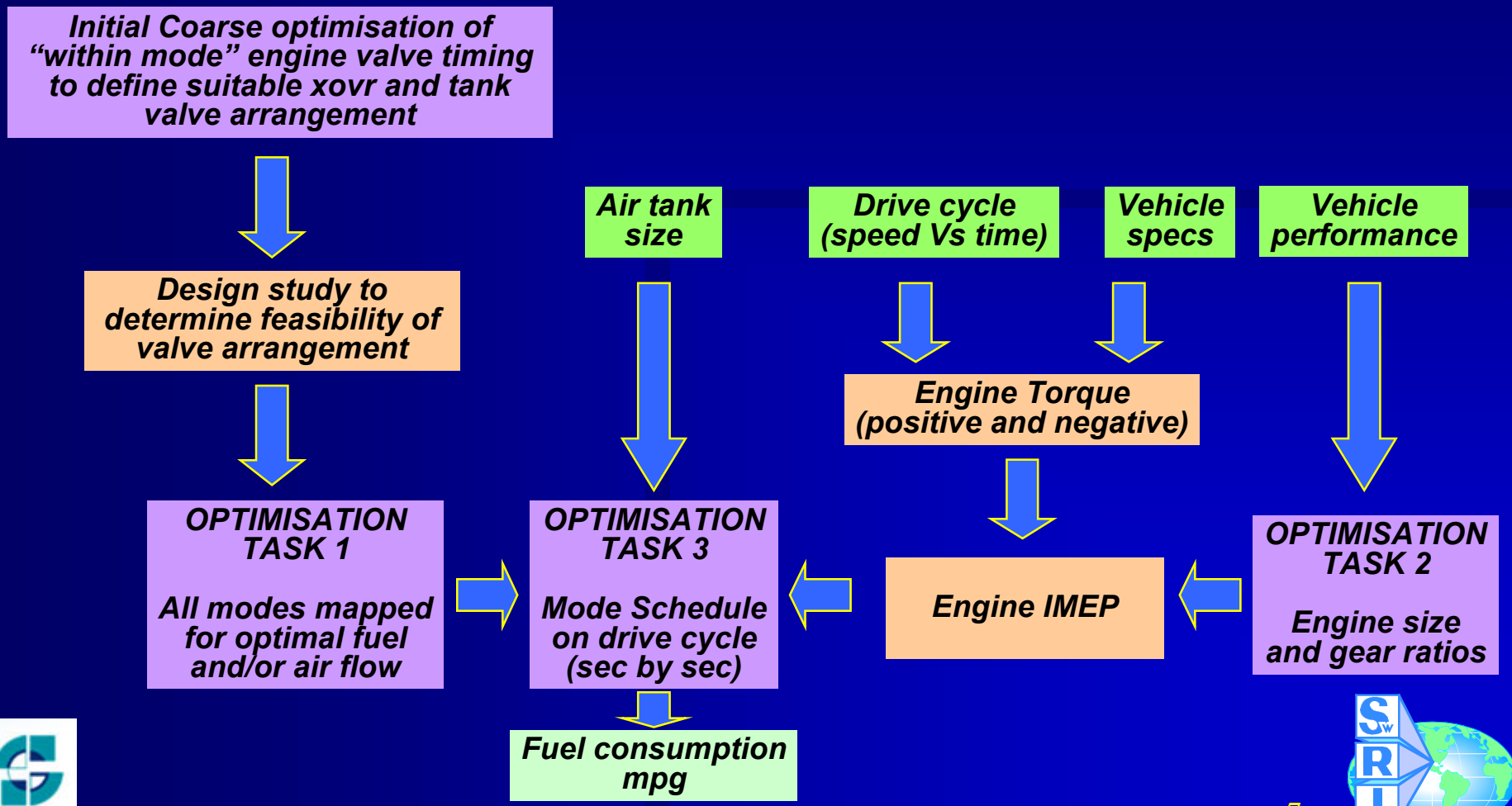
Scuderi Split Cycle Engine
Air Hybrid Operating Modes

- Engine Firing (EF) mode is to be correlated to measured data from the Prototype Research Engine
- 4 Air hybrid modes are simulated (Optimization Task 1)
  - AC Mode: Complete
  - AE Mode: Complete
  - AEF Mode: Complete
  - FC Mode: Complete



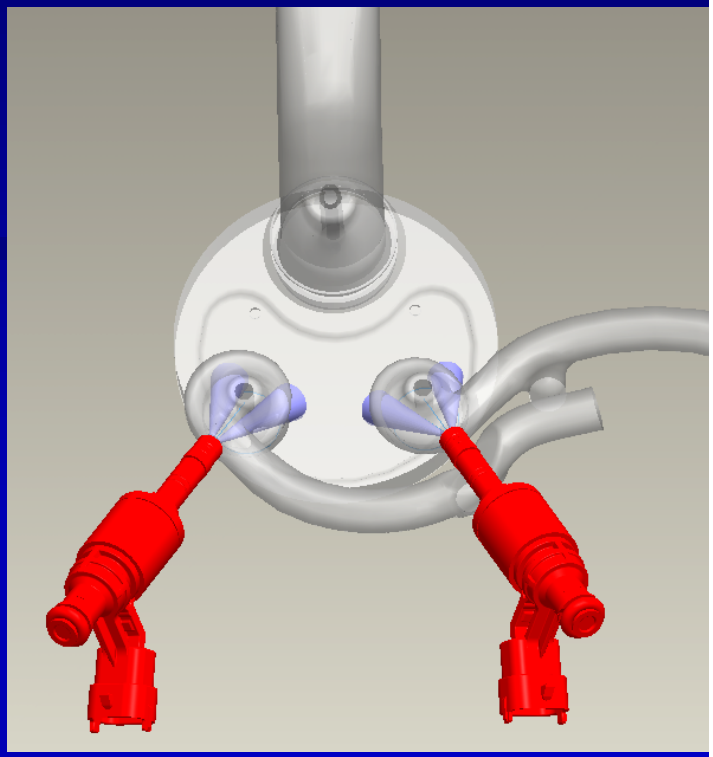
1. EF Engine Firing
2. AE Air Expander
3. AC Air Compressor
4. FC Firing and Charging
5. AEF Air Expander + Firing

Scuderi Split Cycle Engine Air Hybrid Study

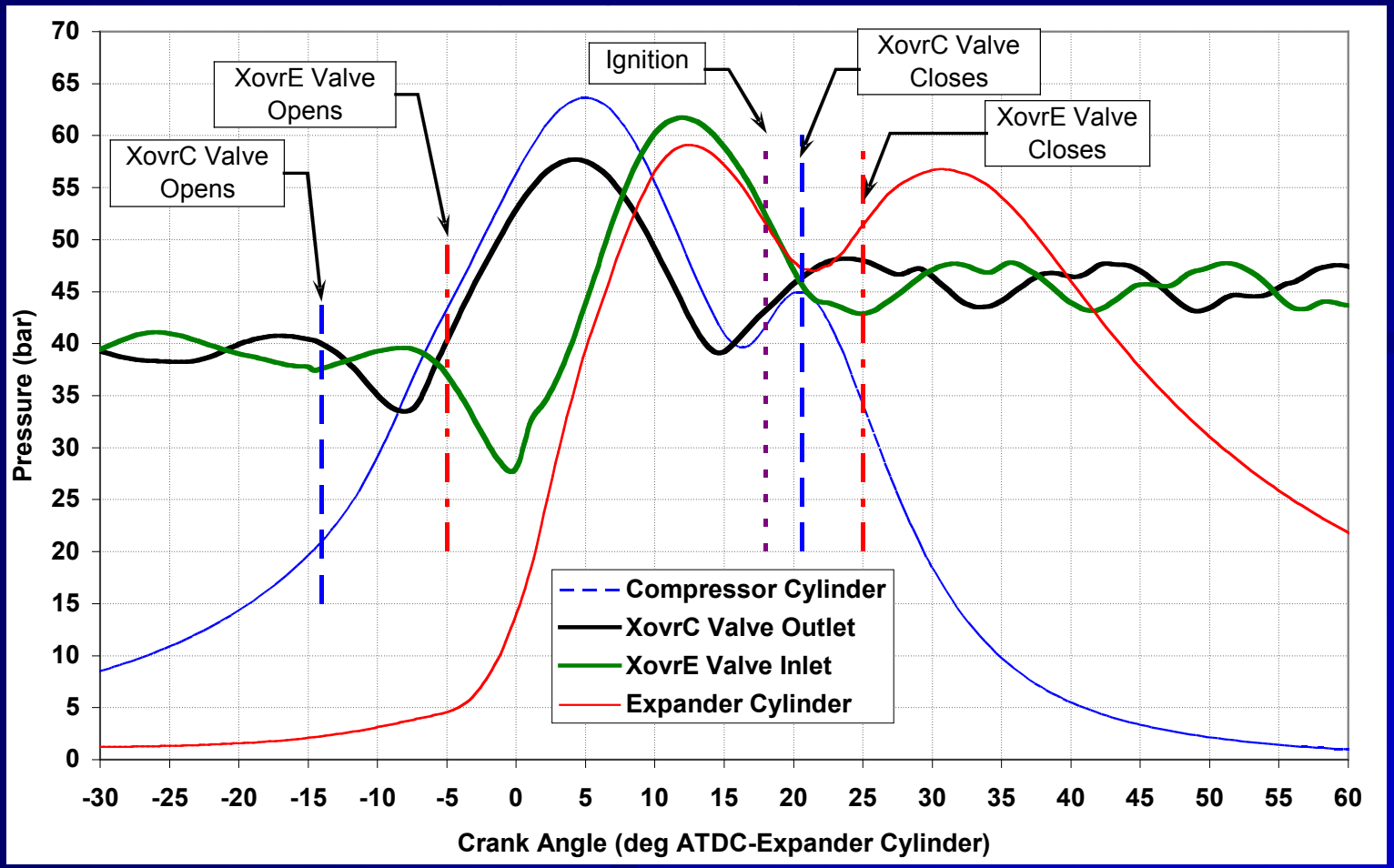


Scuderi Split Cycle Engine Design

- Research Engine geometry features:
  - Cylinder displacements:
    - Compressor: NA 0.59 L TC 0.48 L
    - Power/Expander: NA 0.52 L TC 0.52 L
  - Separate Xovr ports
  - Single exhaust valve to allow twin spark plugs
  - Shallow bowl in piston crown
  - Bosch gasoline DI injection system,

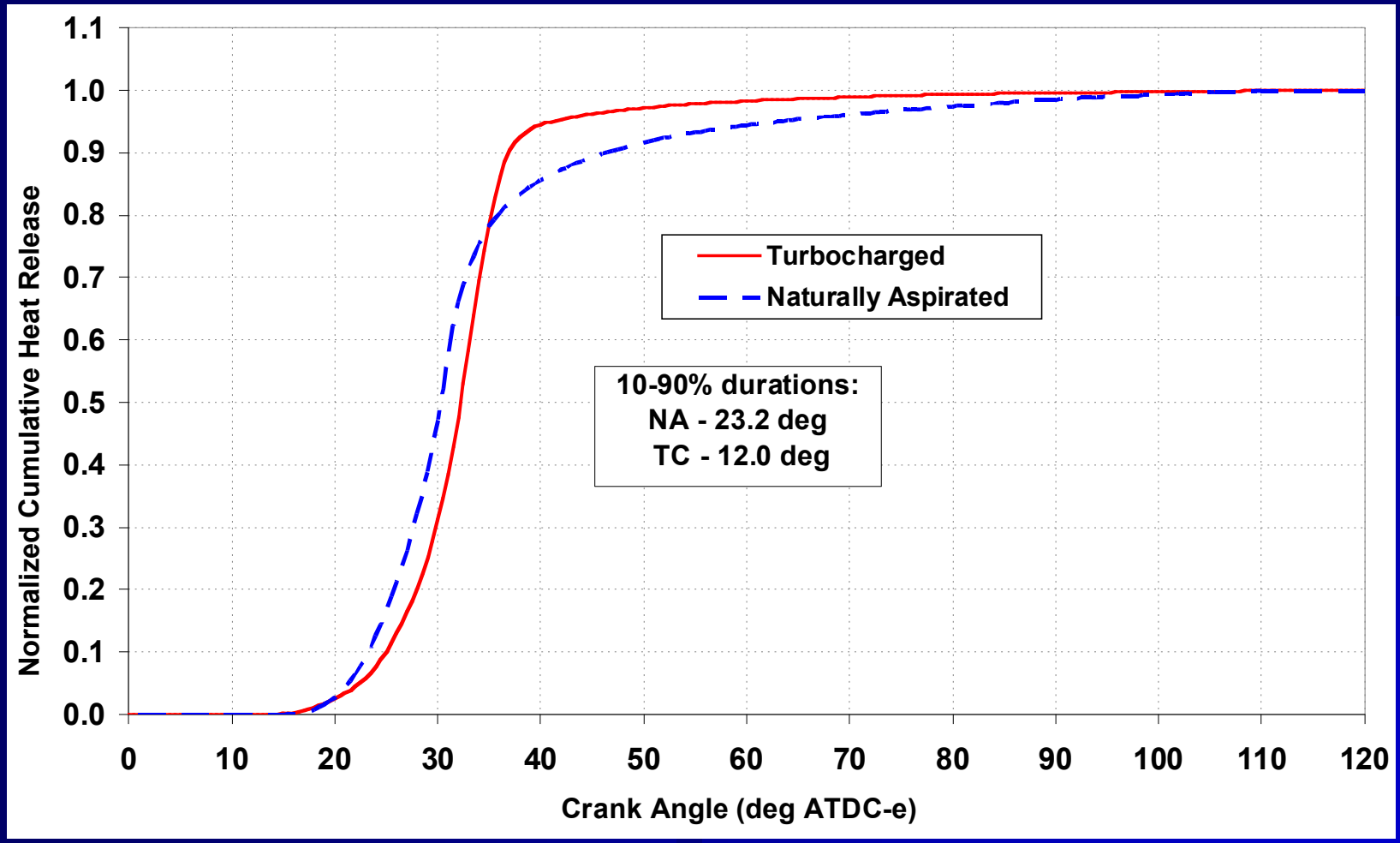


Scuderi SC NA Engine: Crossover Port and Cylinder Pressures



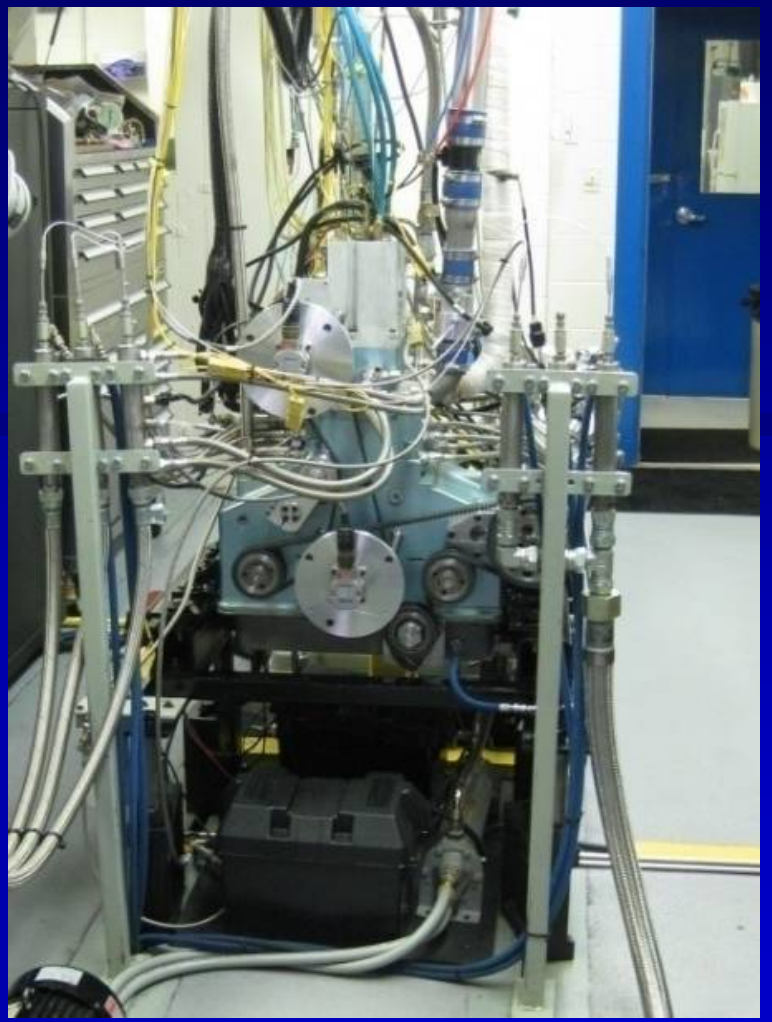
4000 rpm, full load predictions

CFD Predictions
Normalized Cumulative Heat Release
4000 RPM Full Load – NA & Turbocharged



Scuderi Split Cycle Engine
Prototype Research Engine Progress

- Engine installed on dyno with motoring capability
- First firing achieved with minimal adjustments



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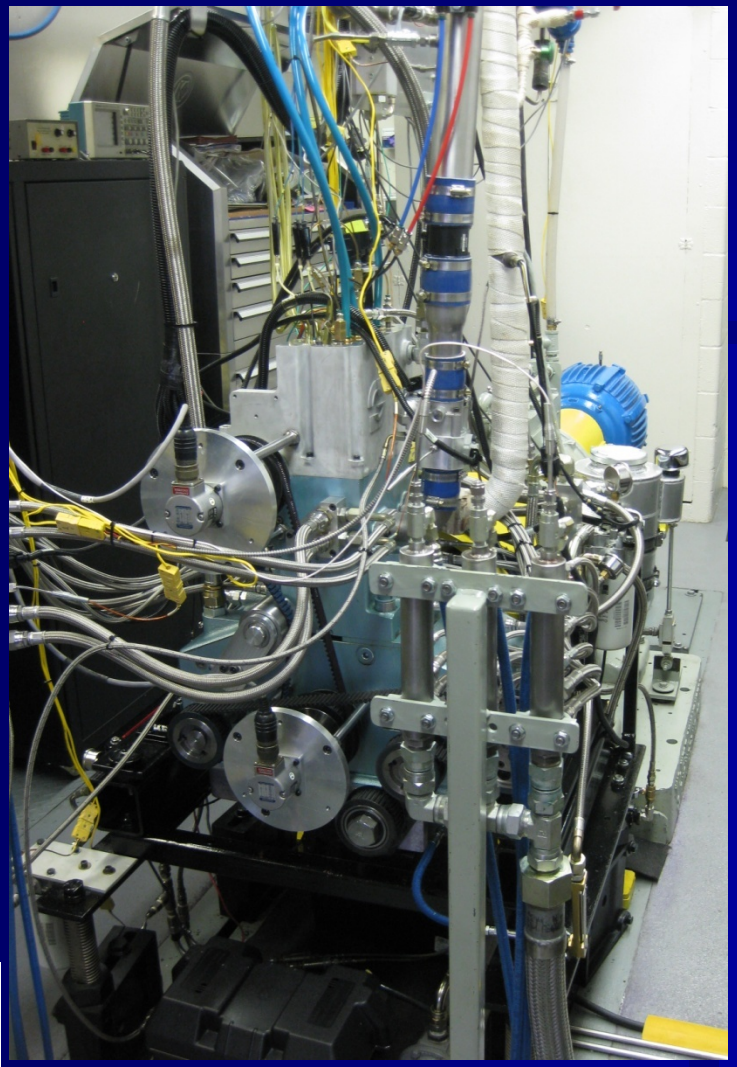
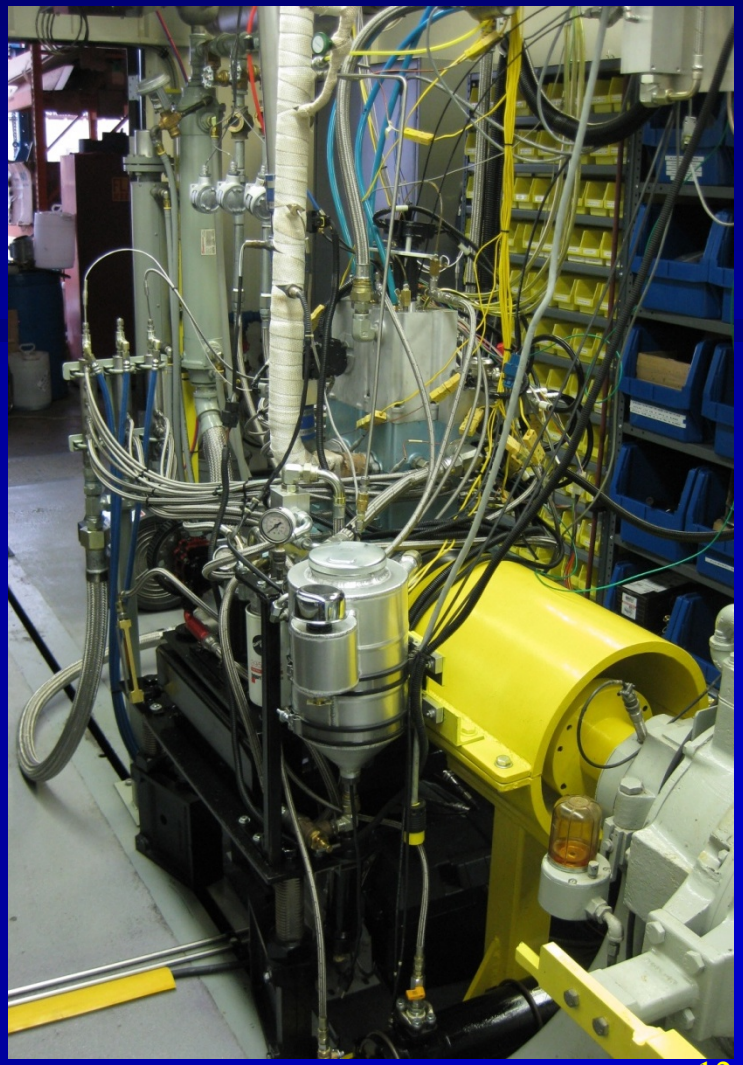
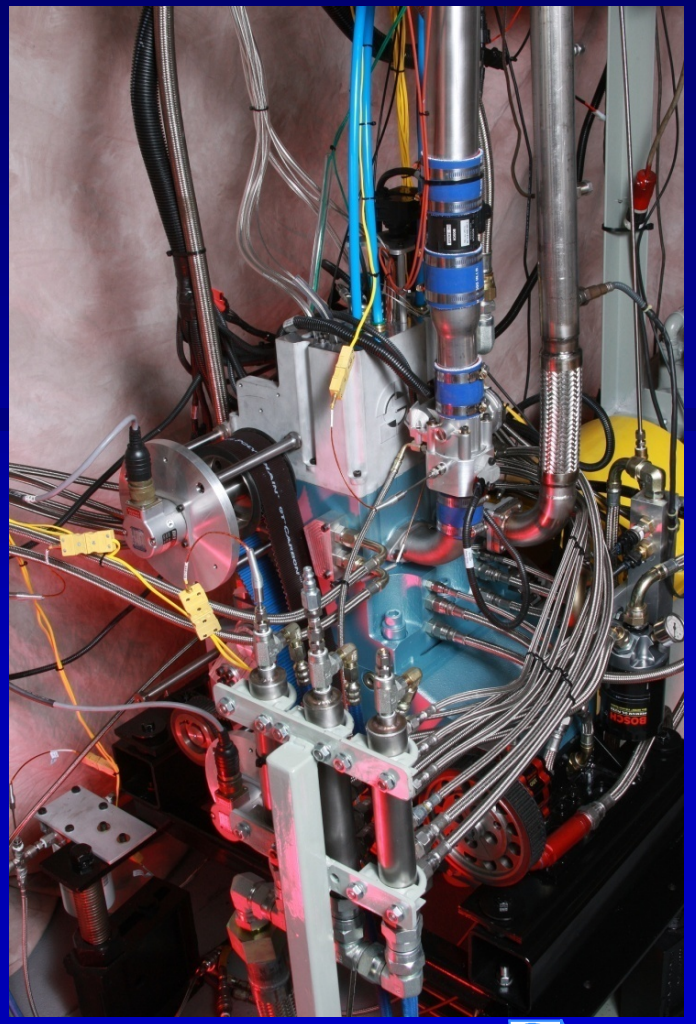


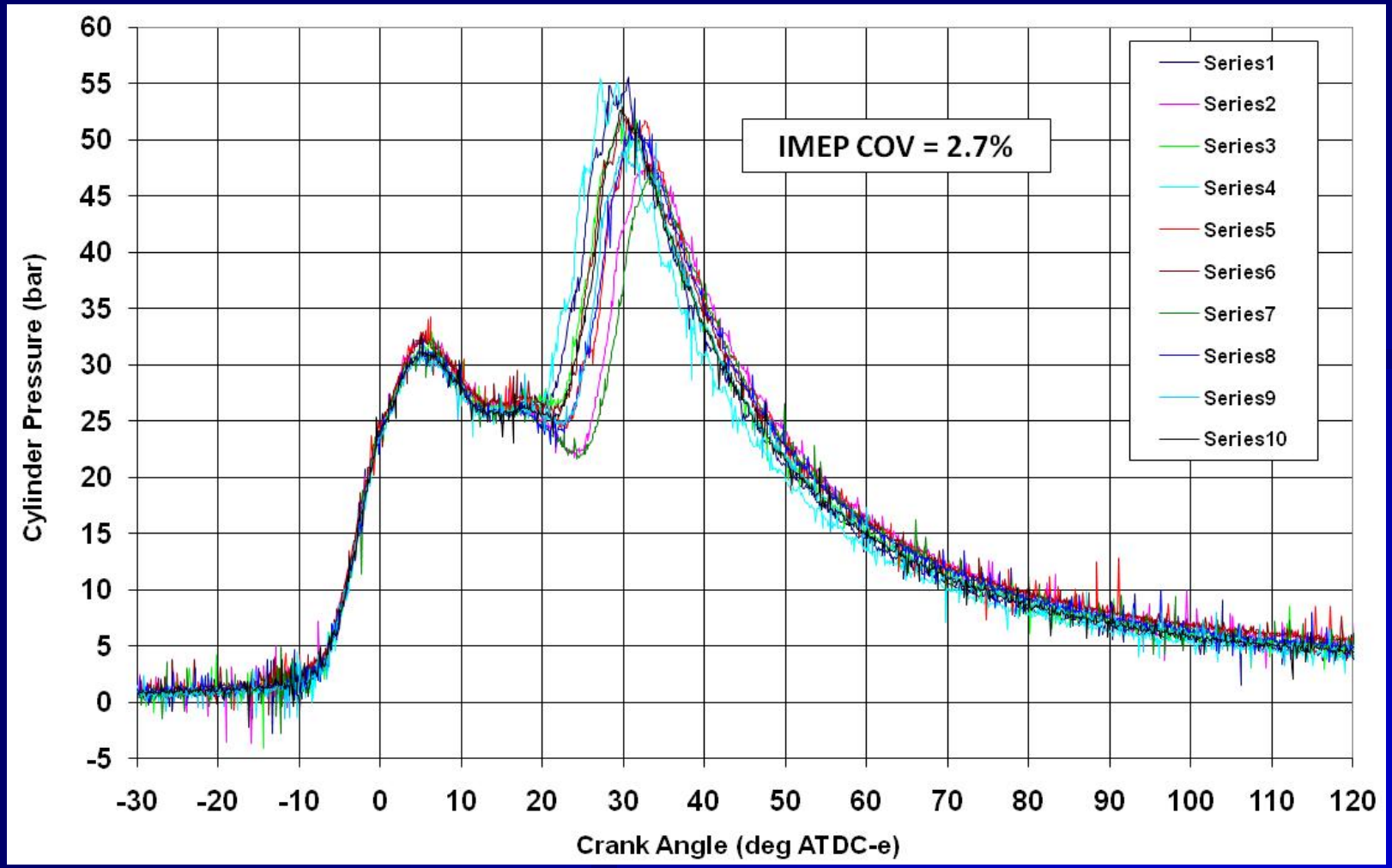


Scuderi Split Cycle Engine
Prototype Research Engine Progress

- **Current Status**
  - Engine speeds in the range 700 – 3250 RPM explored
    - 10-80% load mapped at most points
  - Very successful and consistent combustion
    - IMEP COV: 1.5-4%
  - Engine near-idle points explored at 1000-2000 RPM using intake valve and throttle plate control with electric motor assist
  - Currently mapping engine to 4,000 RPM and 0-100% load
  - Single Xovr port configuration successfully tested at light loads down to 700 RPM



Power Cylinder Pressures – Individual Cycles
2250 RPM – Run 675 – 70% Load



Cylinder and Xovr Port Pressures – 50 Cycle Average
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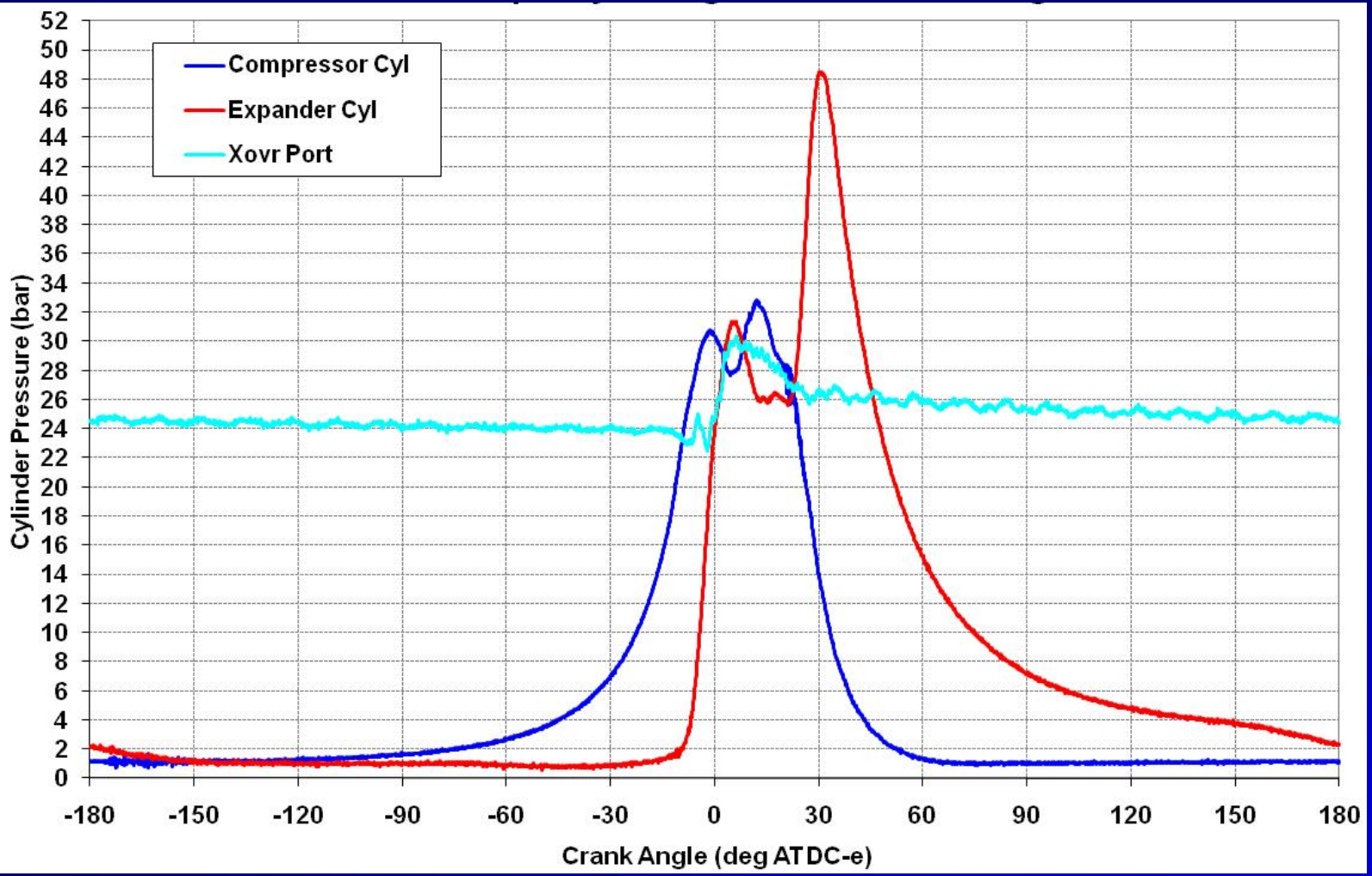
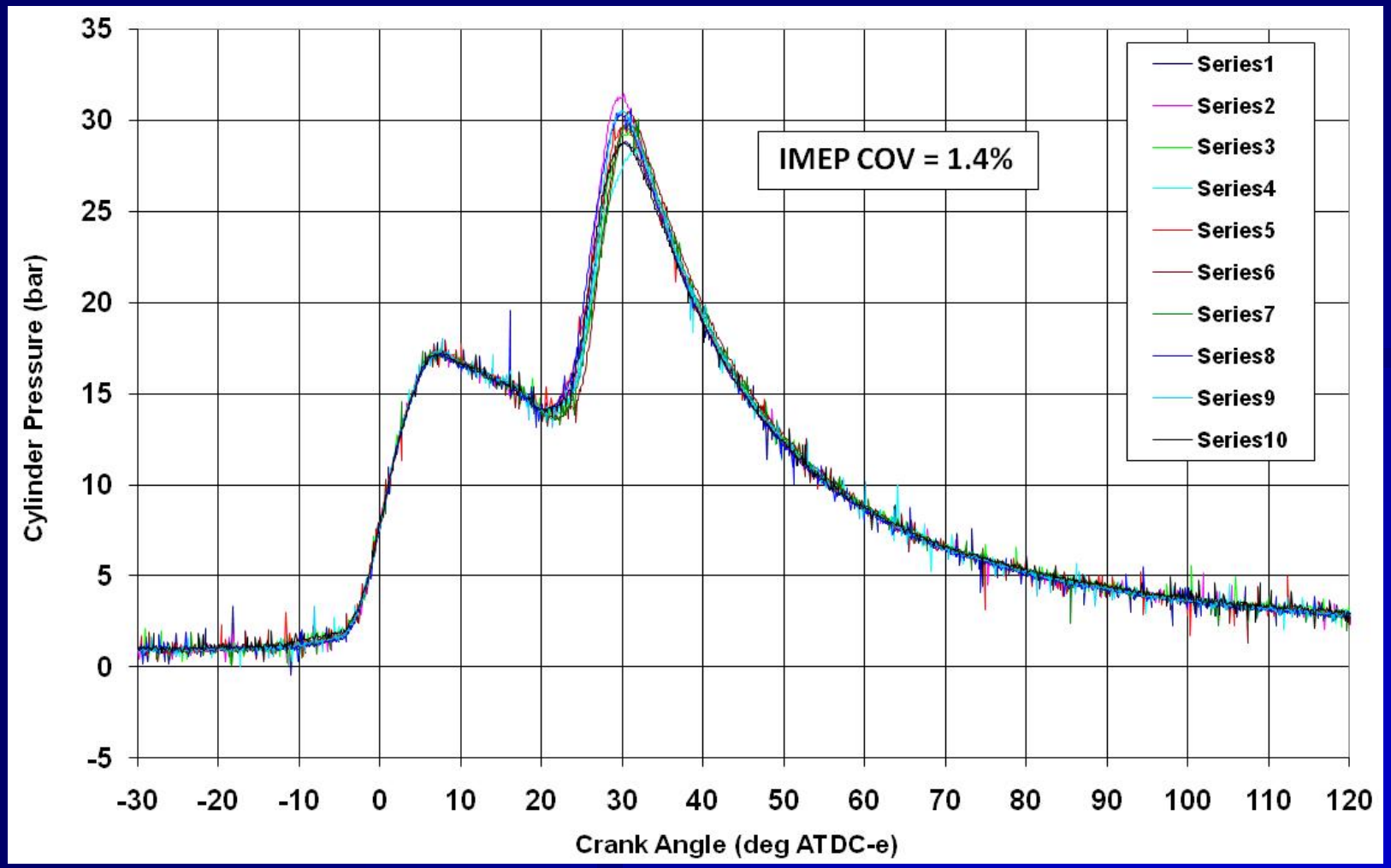


Power Cylinder Pressures – Individual Cycles

Single Xovr Port - 1200 RPM – Run 975 - 40% Load



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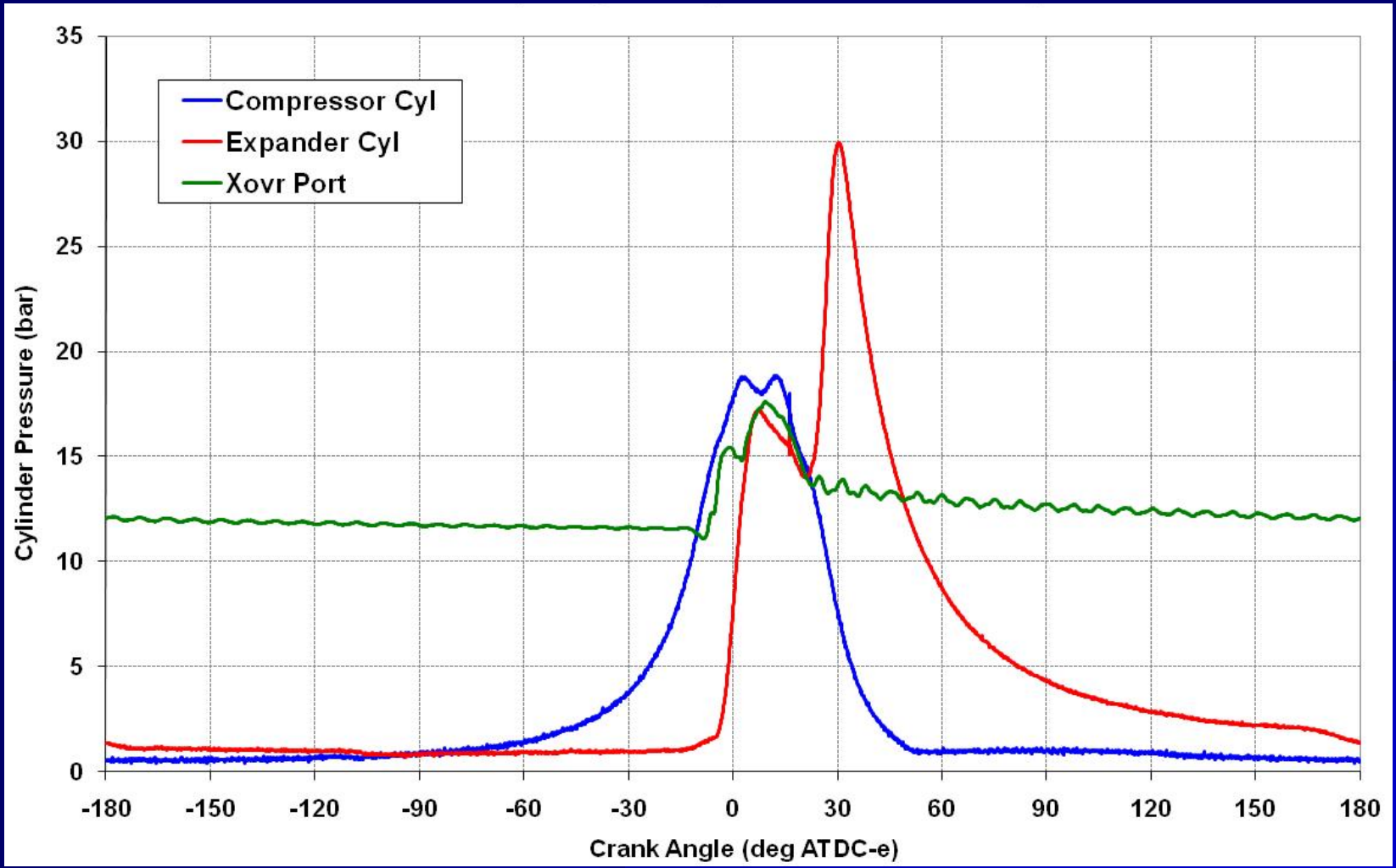
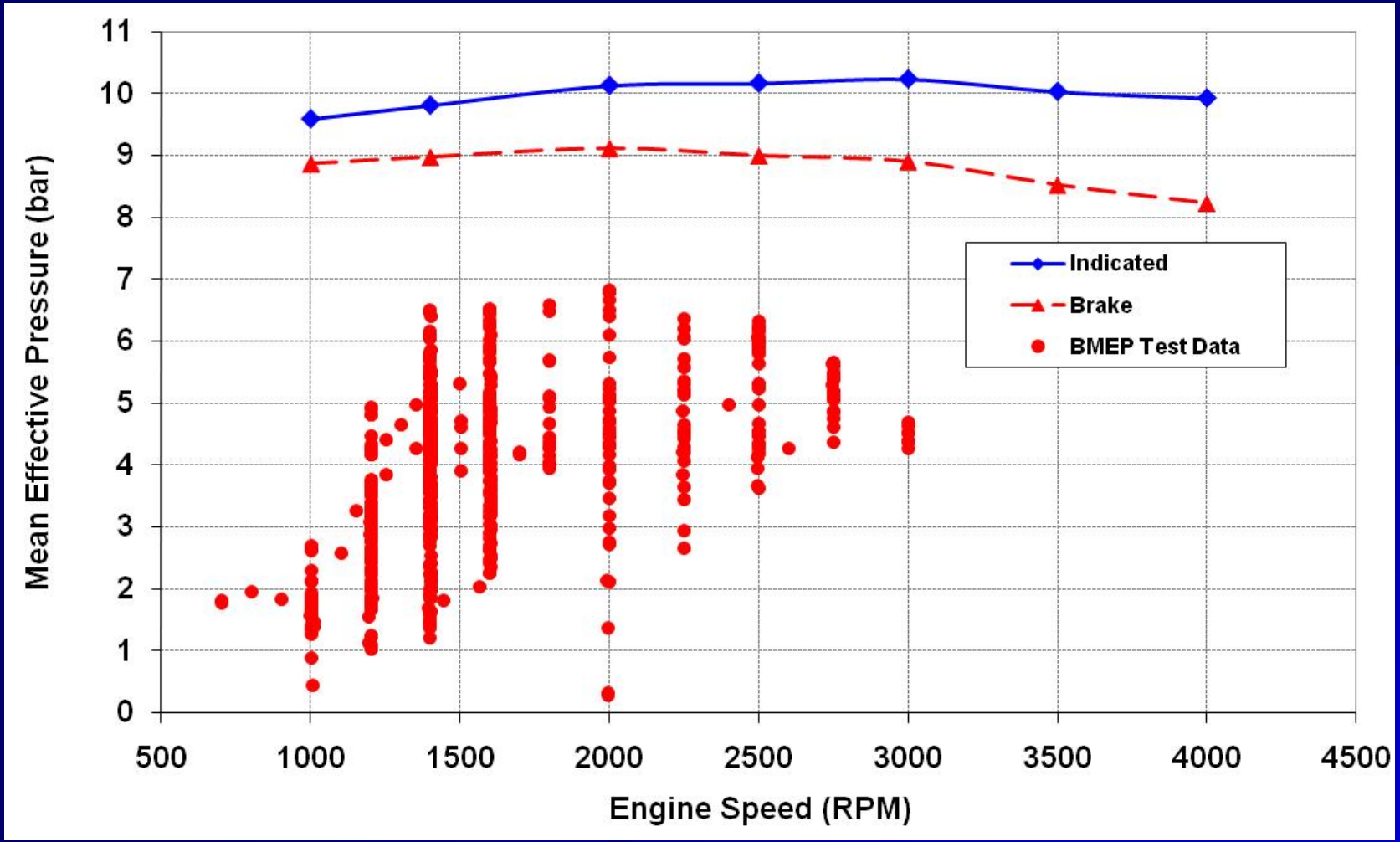
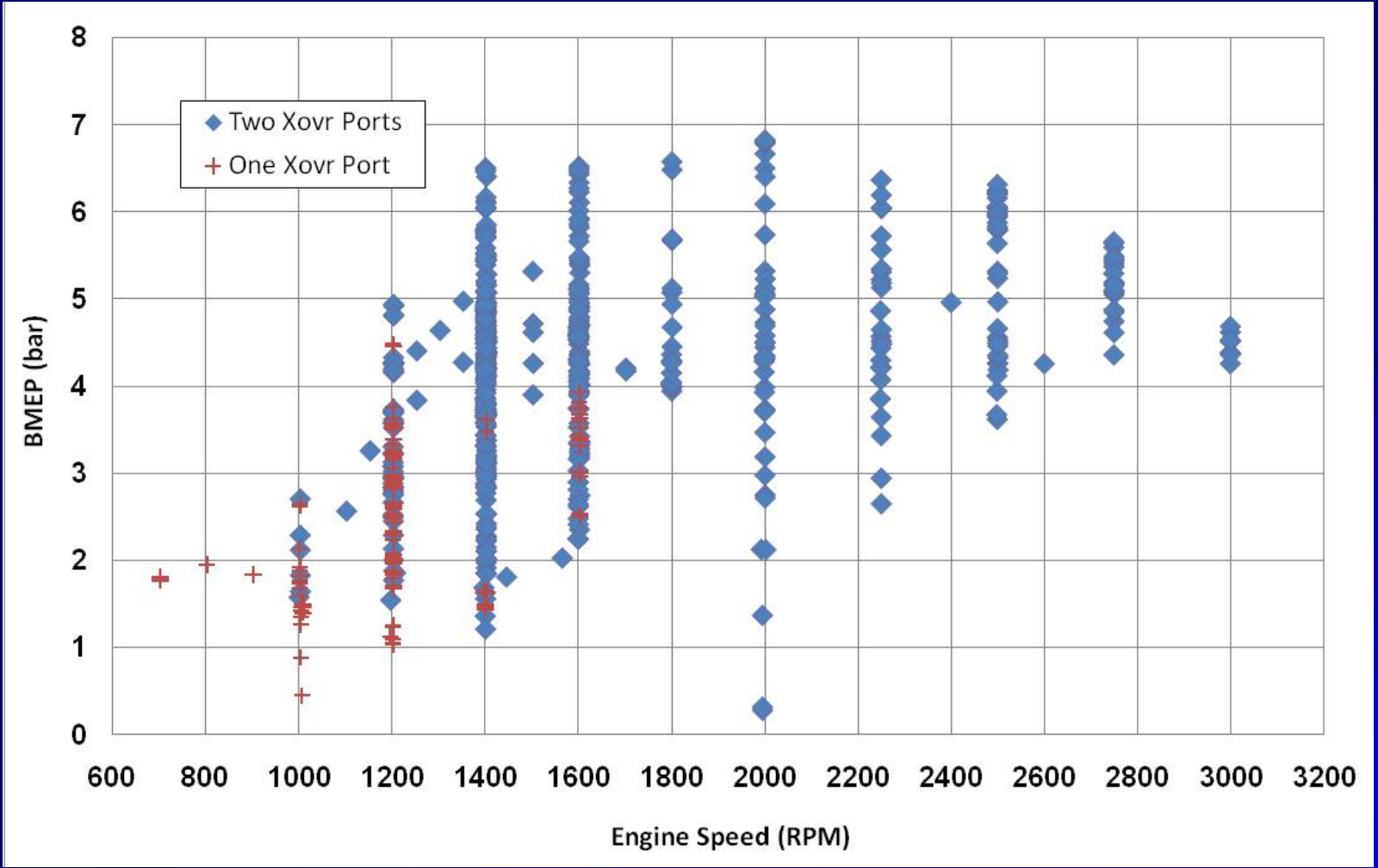


NA Mean Effective Pressures
Predicted Maximums and Tested Data Points



NA Brake Mean Effective Pressures

Tested Data Points – One and Two Xovr Ports



Scuderi Split Cycle Engine Potential Advantages

- Very low NOx by burning after TDC, even without EGR
- Potentially reduced detonation tendency vs conventional Spark Ignition (SI) combustion
- Relative ease of air hybrid vs conventional due to separated compressor & expander cylinders
- Applicable to SI and compression ignition cycles
- Interested parties are invited to enter into an NDA with Scuderi Group to allow exchange of further information

Scuderi Split Cycle Engine

Thank you for your attention

Any Questions?