TCT FUEL SYSTEM

Technical Presentation

July 2009

Total Combustion Technology

- Overview
- Introduction TCT Fuel System
- How TCT works
- Market

TCT FUEL SYSTEM

Total Combustion Technology

New Technology – Cleaner Engines

Overview - TCT FUEL SYSTEM

- A new cost competitive single point metering fuel system which will allow most Phase 2 Small Off Road Engines (SORE) meet EPA Phase 3 legislation without engine improvements or the use of a Catalyst.

TCT Strengths

- 30-40% HC + NOx Engine out Emissions reductions
  - Smaller or no Catalyst
- Improved leaner combustion stability with accompaniing fuel consumption benefits
- Similar number of components to a conventional carburettor
- Most parts can be made from plastic
- Single Point Metering
- Can be controlled with ECU with feedback control
  - Not fully developed – room for improvement
- Multi Fuel Capability (Gasoline; LPG; NCG; Kerosene; Methanol)
- Improved atomisation and reduced cyclic variation AFR = cleaner & more stable combustion
- Stabilises faster
- Easy to calibrate
- Same carburettor for many/all engines
  - 4S & Motorcycles
- Conventional float chamber

Orbital Statements about TCT

- Orbital have worked with Fjolblendir on the development of the demonstration TCT and genset
- Independent testing by Orbital shows that an optimised TCT has the capability to typically deliver HC+NOx emission results of over 30%, as measured on the J1088 test cycle, whilst retaining good operating characteristics. The specific engine family emission improvement capability is linked to the performance of the engine of the base engine
- The emission improvement offers the OEM potential to meet Phase III (or other) emission requirements without the use of a catalyst, or after treatment.

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TCT Patents

Please follow the below links for:

- Early granted application
- Current master patent application

TCT Genset Demonstrator

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- GX160 engine fitted to an IGX440 Generator for full load operation
- Load bank provides engine load
- Orbital electronic governor (Orbital ECU and software)
- Throttle actuated by servo motor
- Full data retrieval and analysis via Labview (AFR, Speed, emissions)

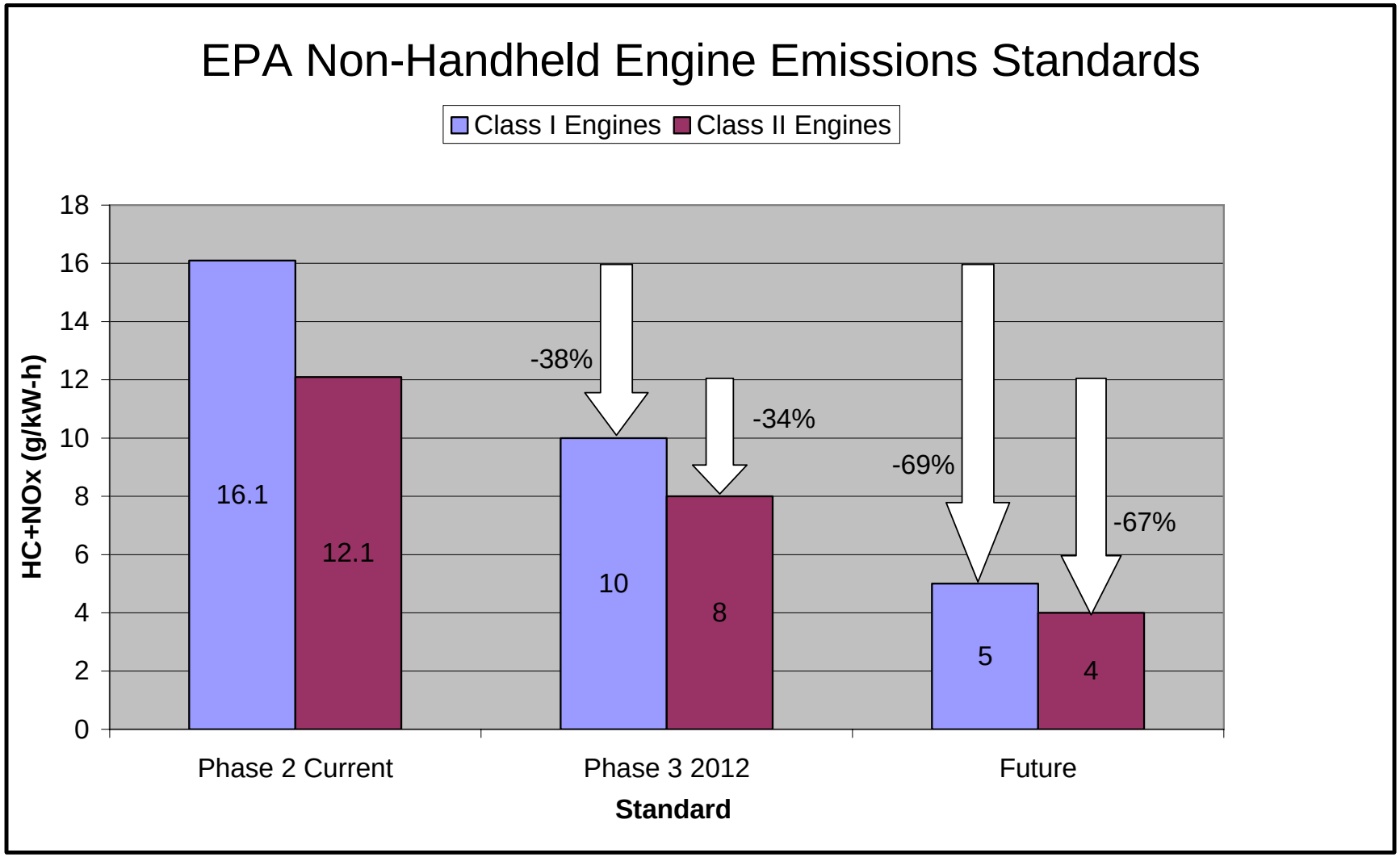
How TCT works and test results

Total Combustion Technology

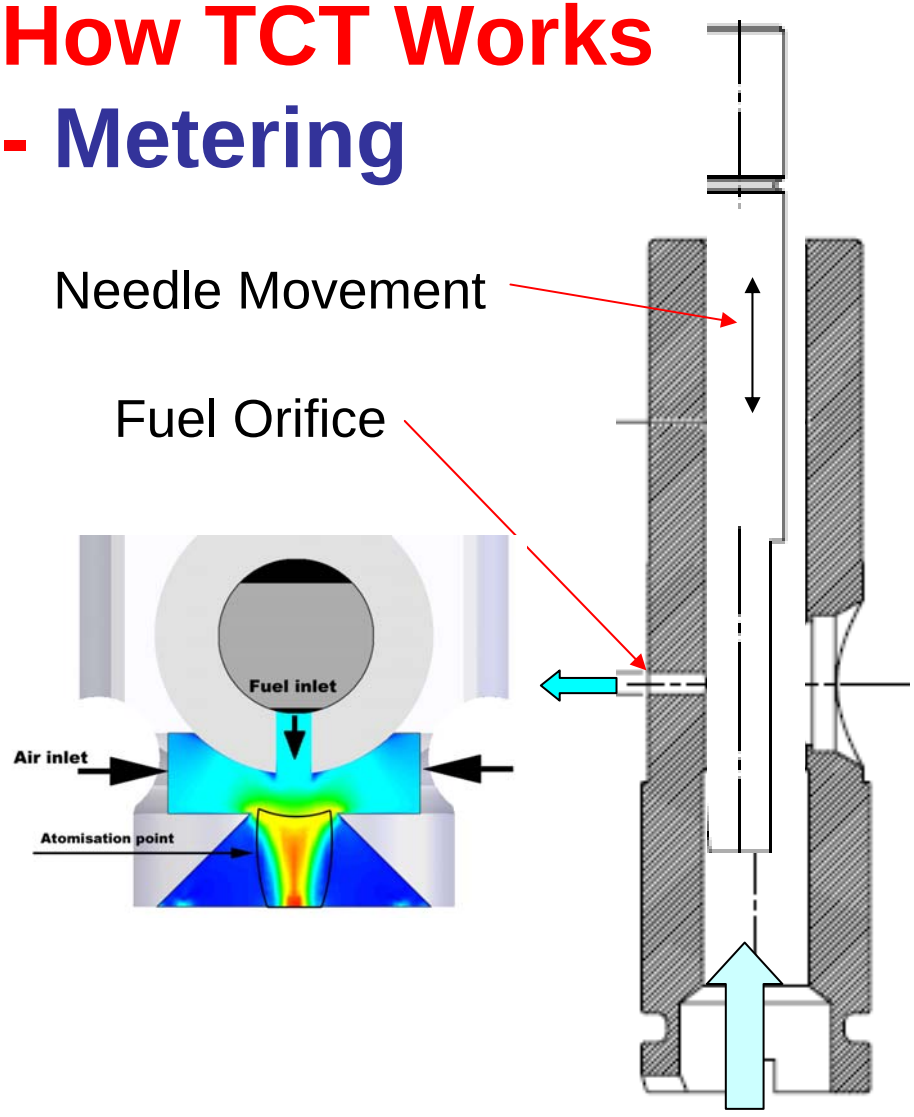
Introduction – Benefits of TCT

- With more stringent emission standards there is a need for reduced engine out emissions or improved after treatment.
- The Fjölblendir TCT fuel system benefits:
  - Achieves a 30% - 40% reduction in engine out HC+NOx emissions.
  - Improved fuel consumption with leaner operation
  - Eliminates or reduces the amount of after-treatment required to meet legislation.
  - Improves catalyst efficiency with reduced cyclic variation in AFR (< 0.5 compared to > 2 for a std carburettor)
  - Cost competitive

Introduction – Emissions Standards

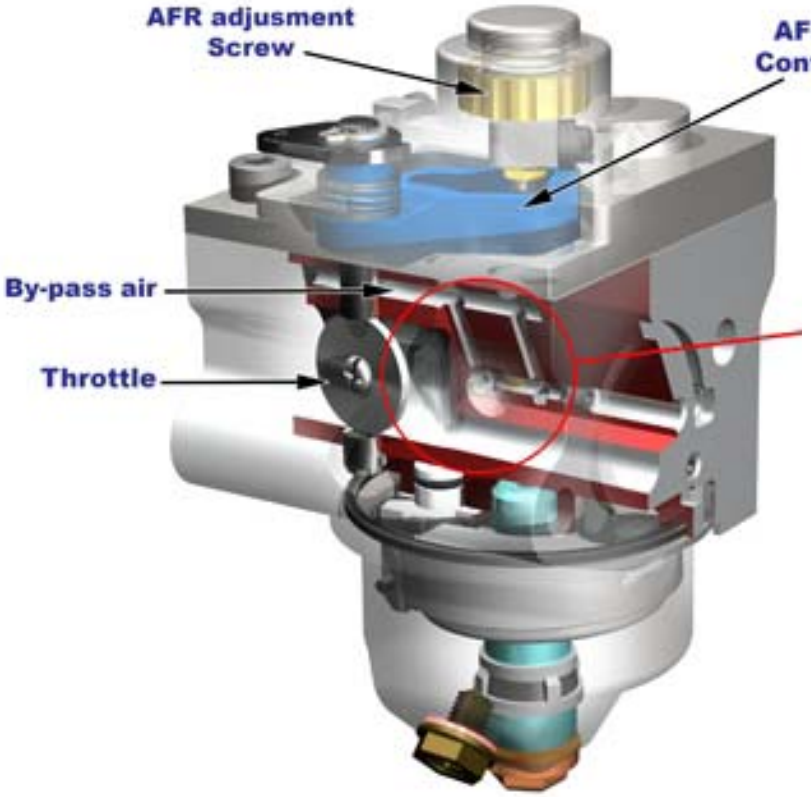


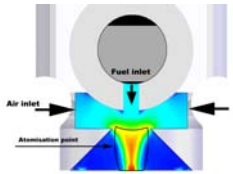
How TCT Works - Metering

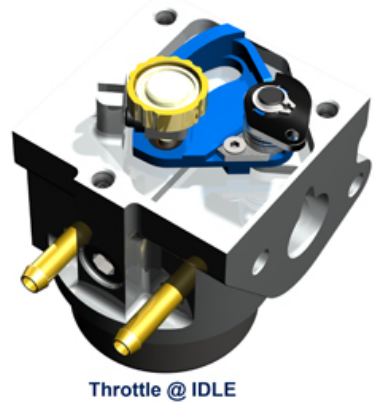


- Single fuel metering orifice of variable area for AFR control.
- Orifice area is varied by a sliding needle which changes the entry area.
- Meters fuel only for a more constant fuel mass delivery
- Atomisation nozzle atomises fuel into a fine spray
- Cam controls rate of lift of needle
- Linkage from throttle moves cam.

How TCT Works – Cam Movement / By-Pass Air







- By-pass air improves mixture preparation and reduces vacuum signal felt at metering orifice
- AFR control via cam reduces emissions.
- Improved combustion stability allows leaner operation

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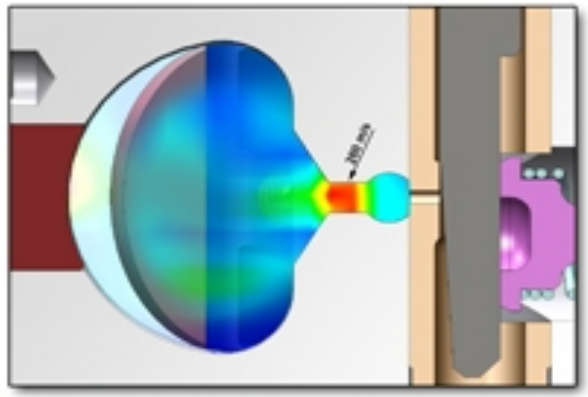
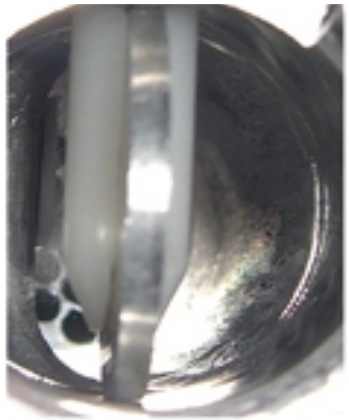
How TCT Works - Atomisation

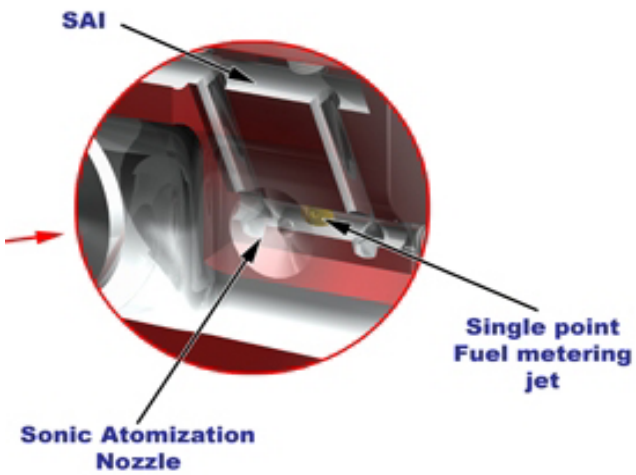


CFD of improved atomisation / fuel preparation



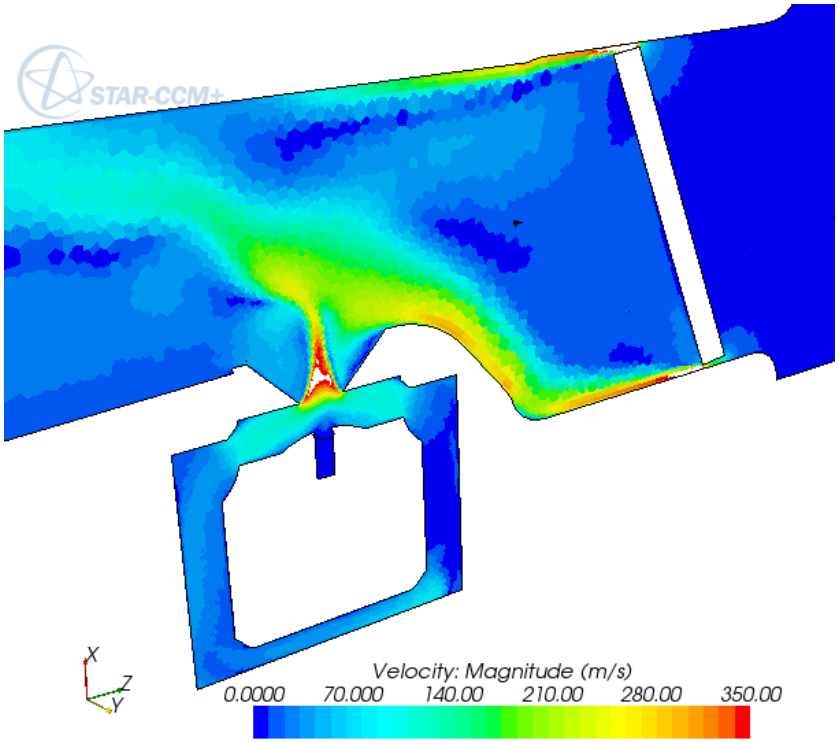
TCT.

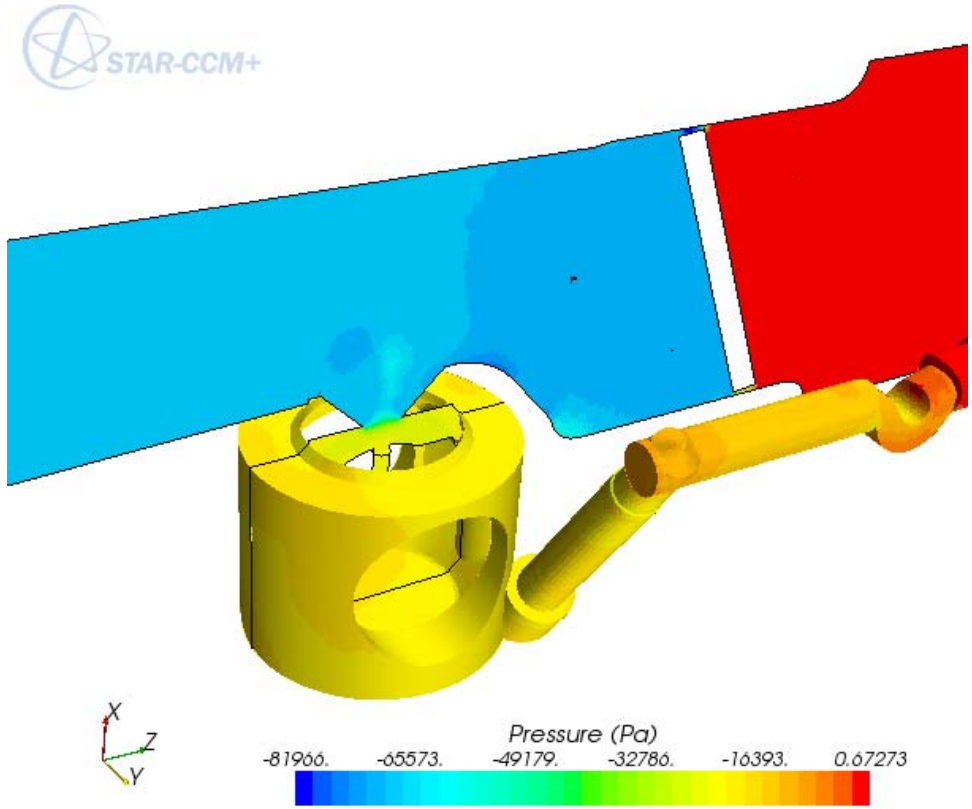
Std. Carb.



- Improved atomisation / fuel preparation and reduced cycle by cycle variation of AFR with the TCT is evident by:
  - Improved combustion stability at the same AFR as the standard carburettor.
  - Higher CO2 emissions and lower CO emissions at the same AFR as the standard carburettor

How TCT Works – CFD of Nozzle





- Atomisation nozzle
  - Sonic, high shear layers tearing apart metered fuel
  - Nozzle reduces vacuum signal felt at metering orifice (at idle peak manifold is 80 to 90 kpa, peak “shielded” metering orifice is 10 to 15 kpa)

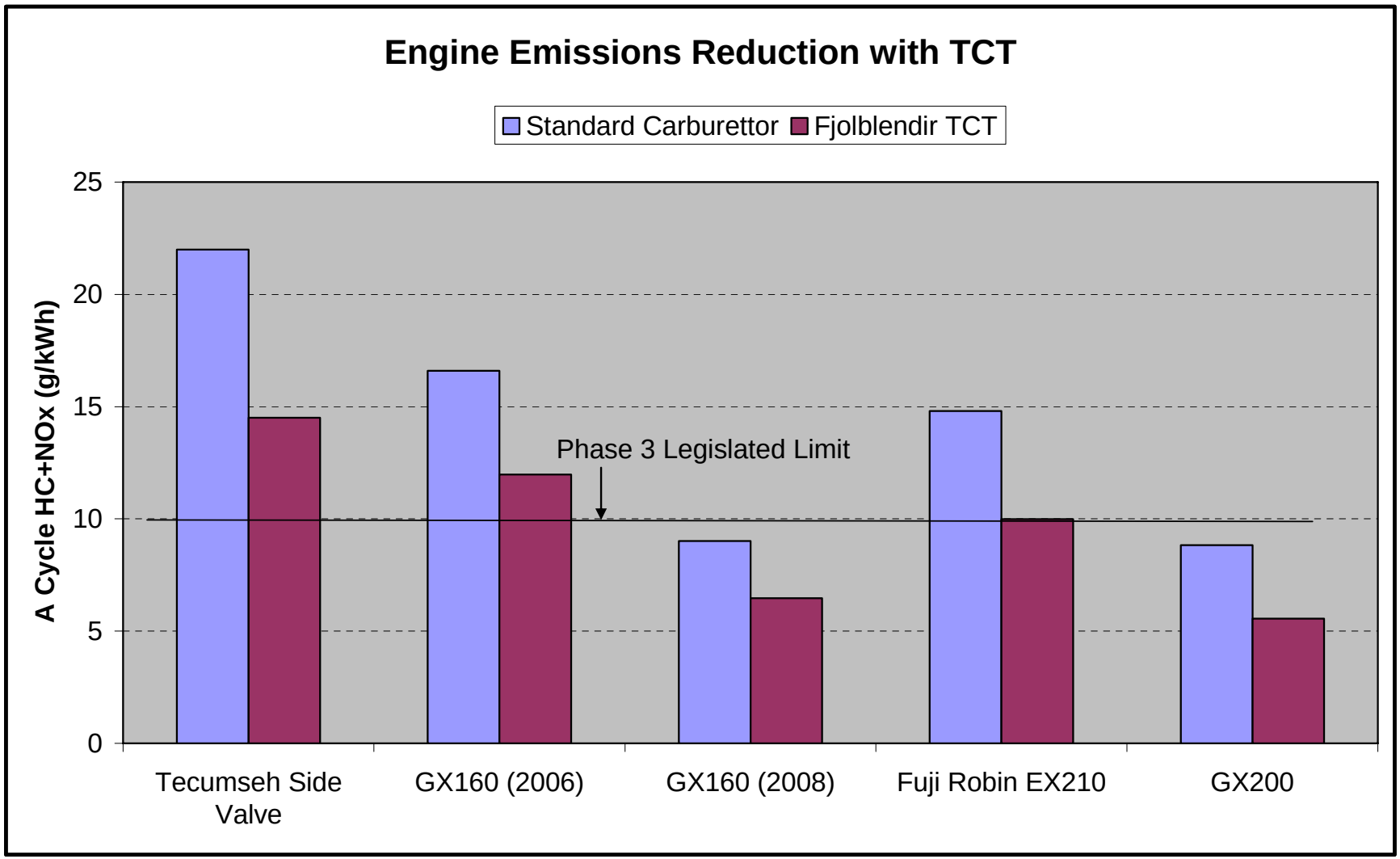
TCT A Cycle Test Results

- SAE J1088 A cycle results on various Class 1 engines typically show 30 to 40% reduction in HC+NOx – All results are in g/kWhr

	Engine	Tecumseh Side Valve	GX160 (2006)	GX160 (2008)*	Fuji Robin EX210*	GX200*
Baseline	HC			5.21	13.15	6.19
	NOx			3.80	1.65	2.64
	HC+NOx	22	16.60	9.01	14.80	8.83
	CO	450	651.13	291.31	432.64	368.13
TCT	HC			4.29	6.89	3.29
	NOx			2.19	3.09	2.27
	HC+NOx	14.5	11.97	6.47	9.98	5.56
	CO	270	453.17	271.03	182.67	224.15
Reduction	HC			-18%	-48%	-47%
	NOx			-43%	87%	-14%
	HC+NOx	-34%	-28%	-28%	-33%	-37%
	CO	-40%	-30%	-7%	-58%	-39%

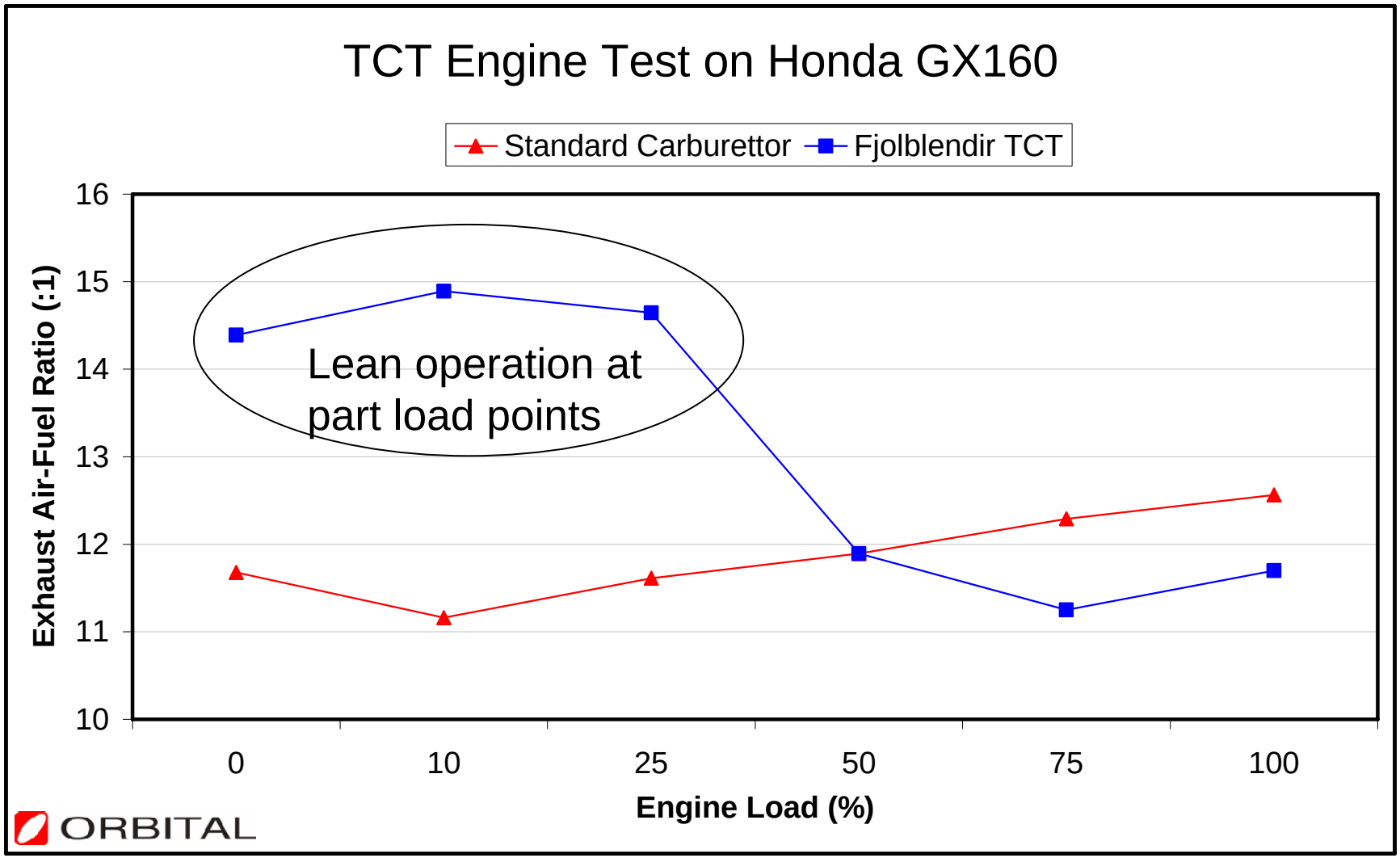
*Tested by Orbital

TCT Class 1 Engine A Cycle Test Results

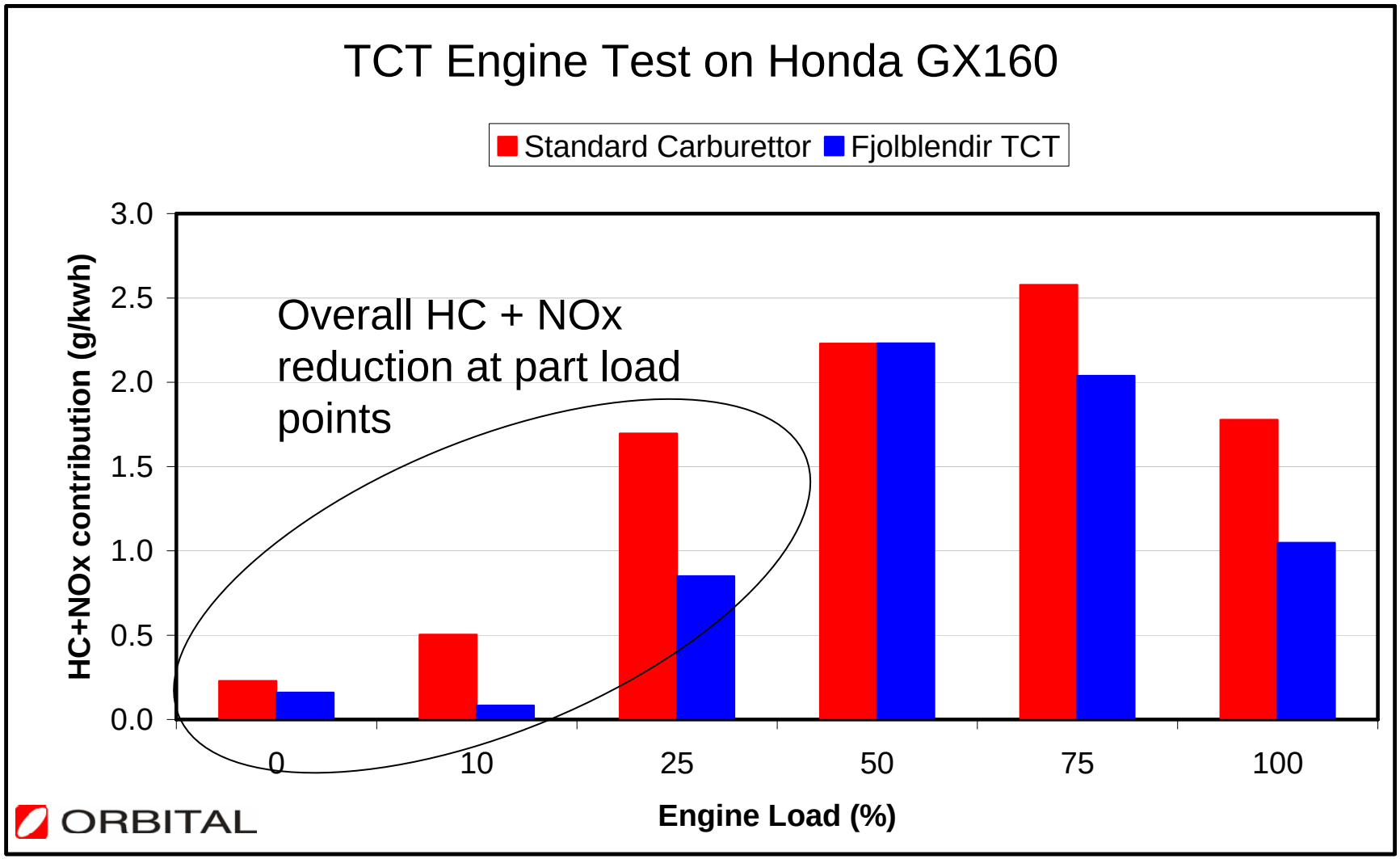


New Technology – Cleaner Engines

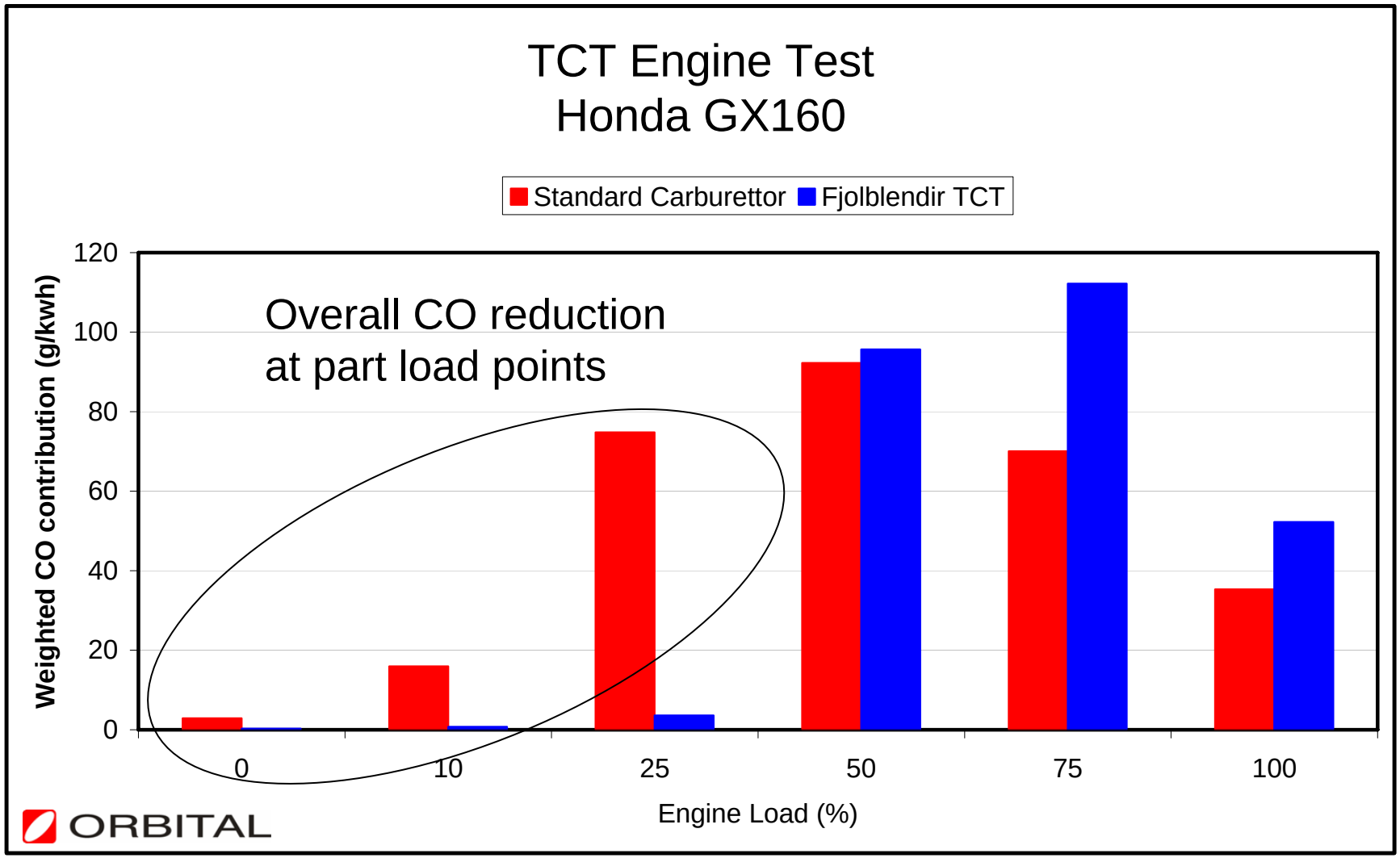
TCT Cycle A Test Results – Lean Operating Points



TCT Cycle A Test Results – HC+NOx Benefits

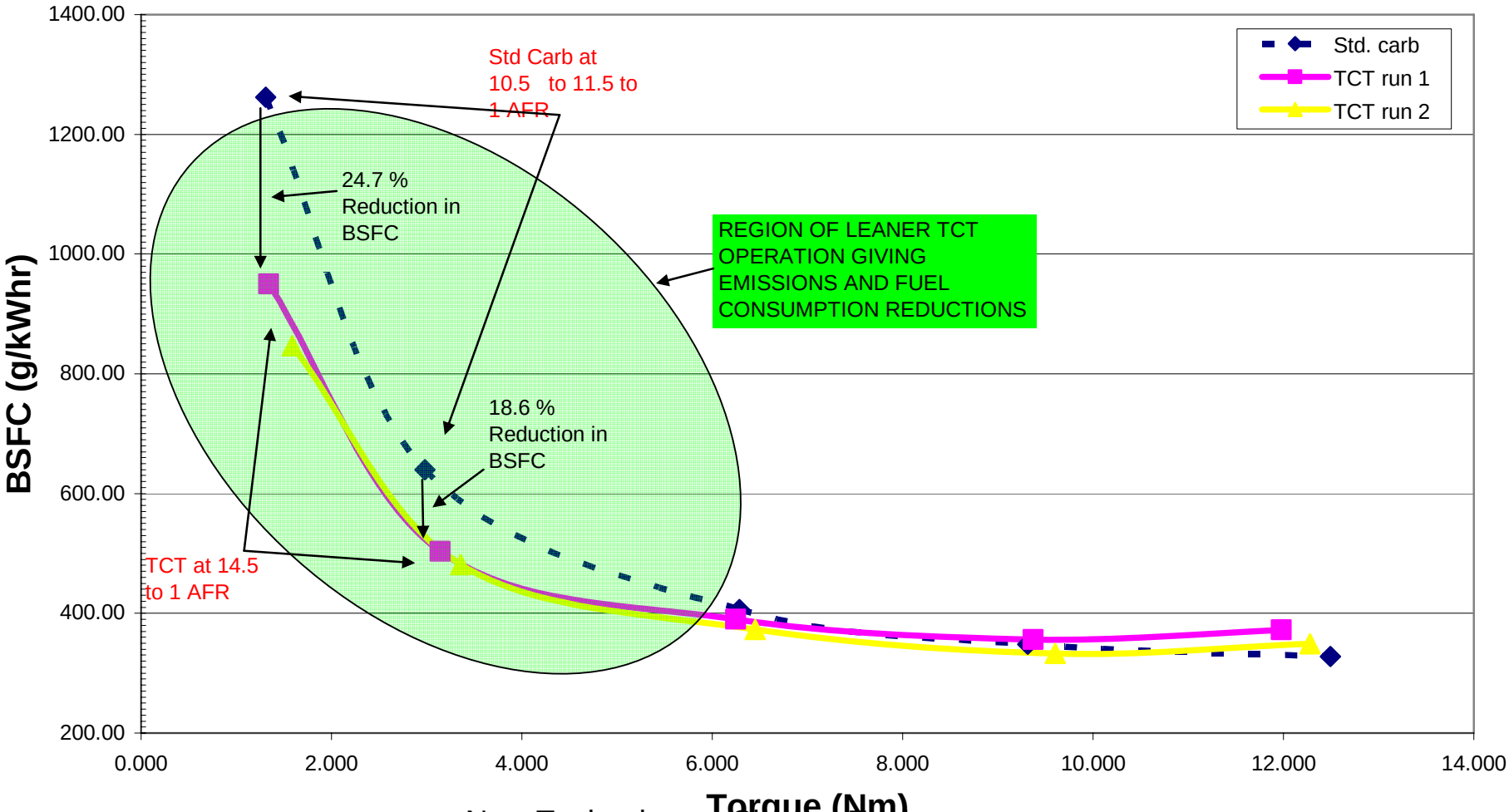


TCT Cycle A Test Results – CO Benefits

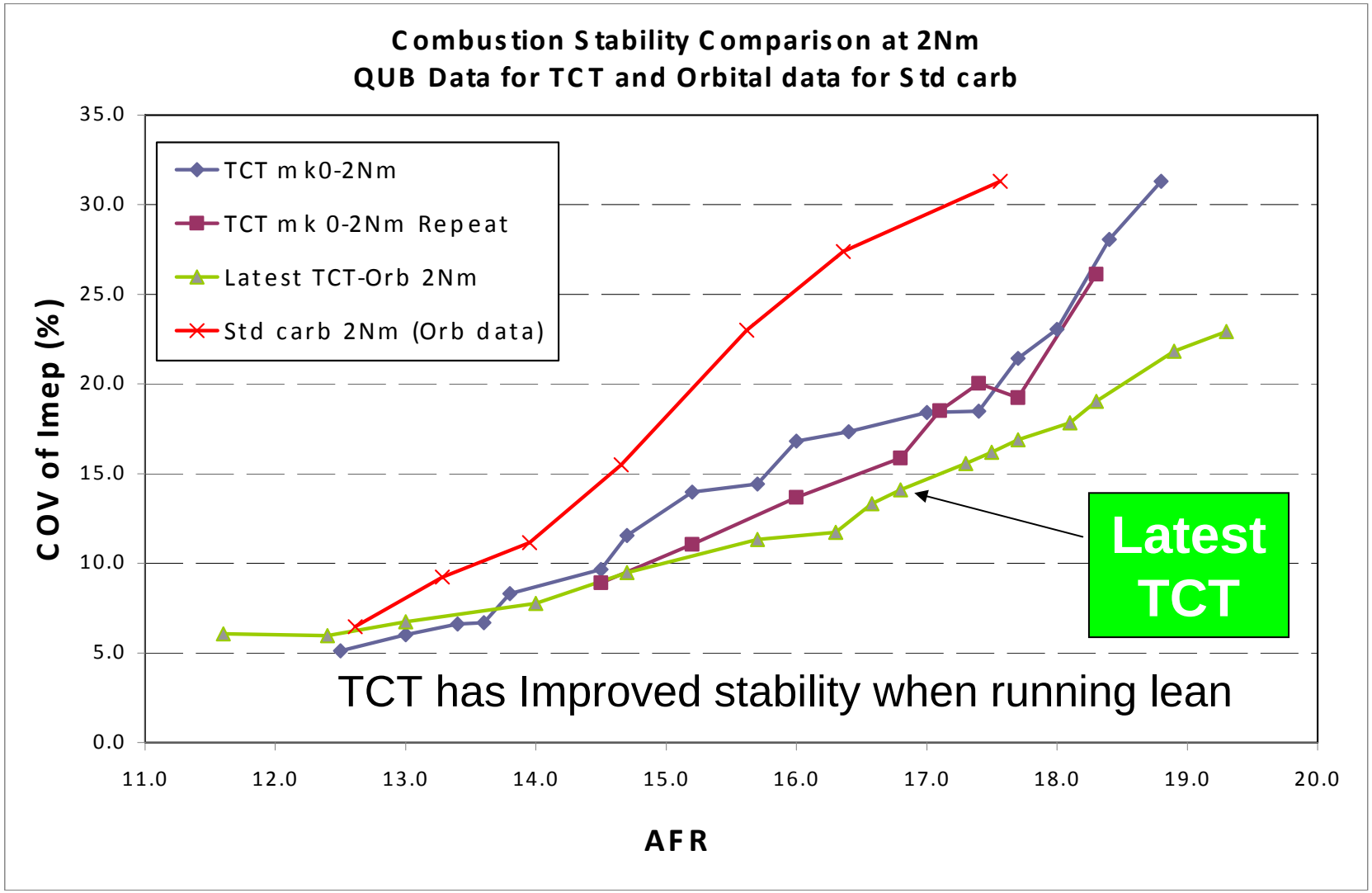


TCT Fuel Consumption Results - A Cycle Mode Points

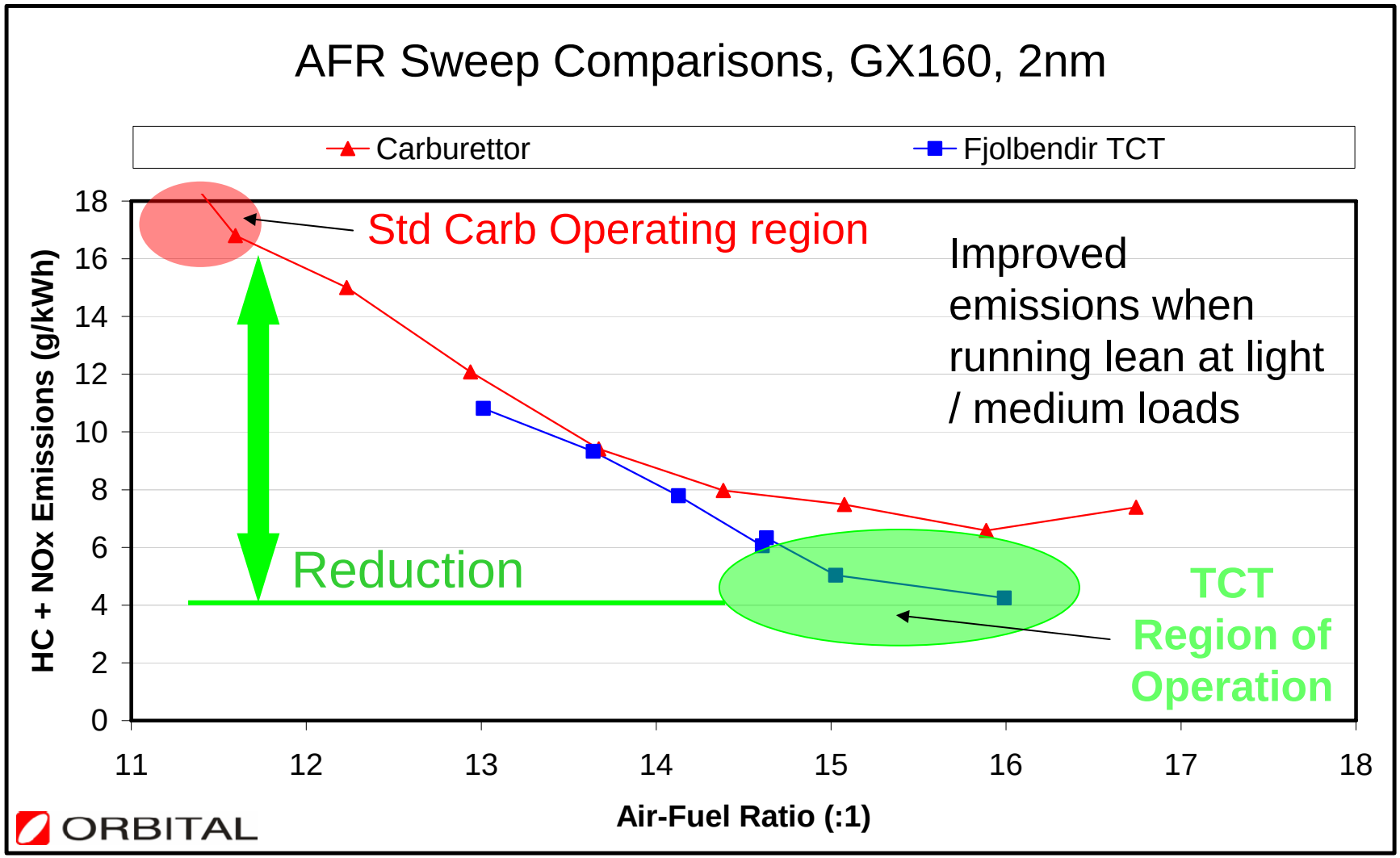
HONDA GX200 Comparison of Fuel Consumption between Standard Carburettor and TCT with a Prototype Cam 1 on the J1088 cycle



Latest TCT AFR Swing Combustion Test Results – 2 Nm



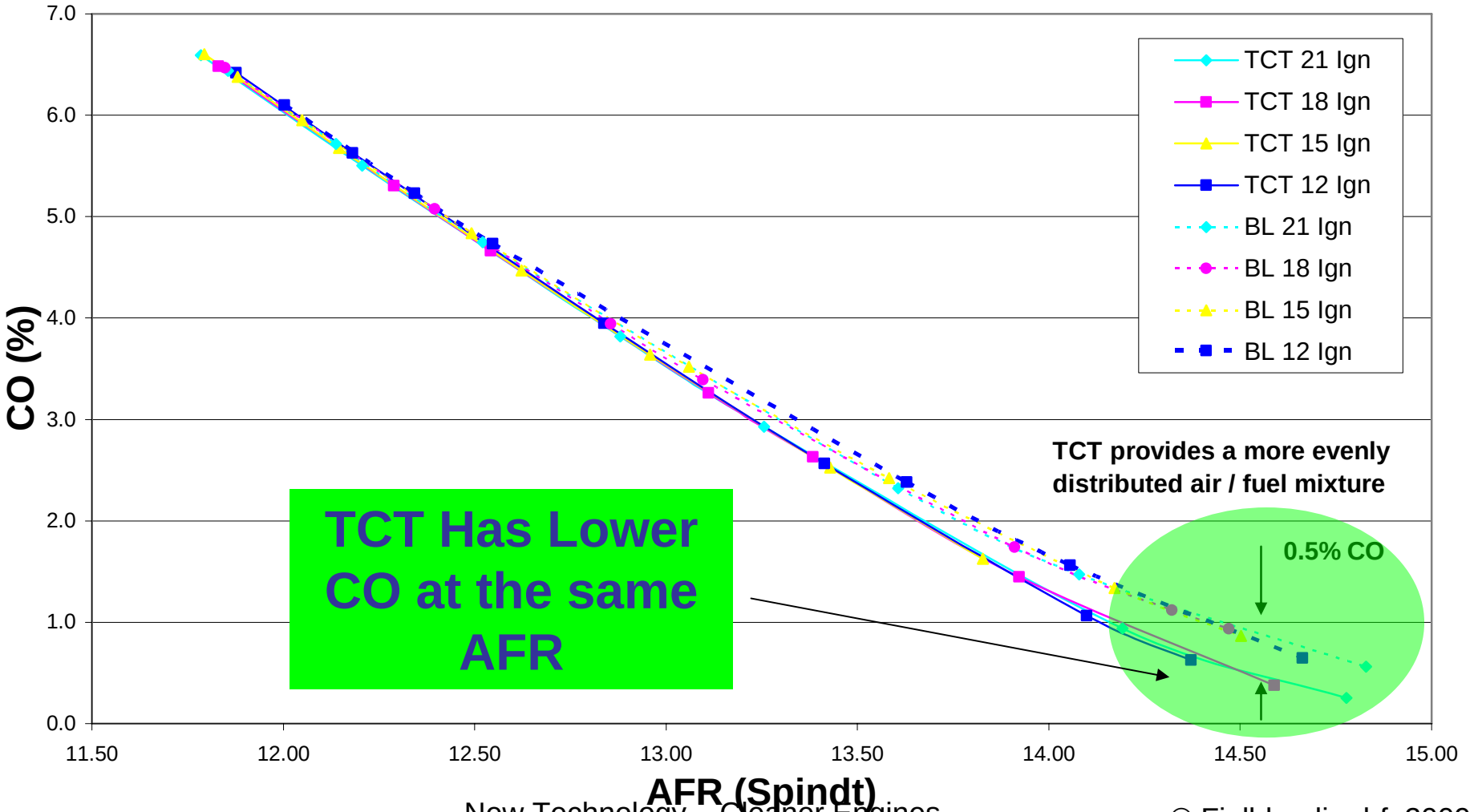
TCT AFR Swing Test Results – HC+NOx Benefits at 2 Nm



Reduced Cyclic Variation in AFR – AFR Swing Data 4 Nm

Comparison of TCT vs Baseline Carburettor on Honda GX160

4Nm / 3000 rpm AFR Swing At Different Ignition Timings



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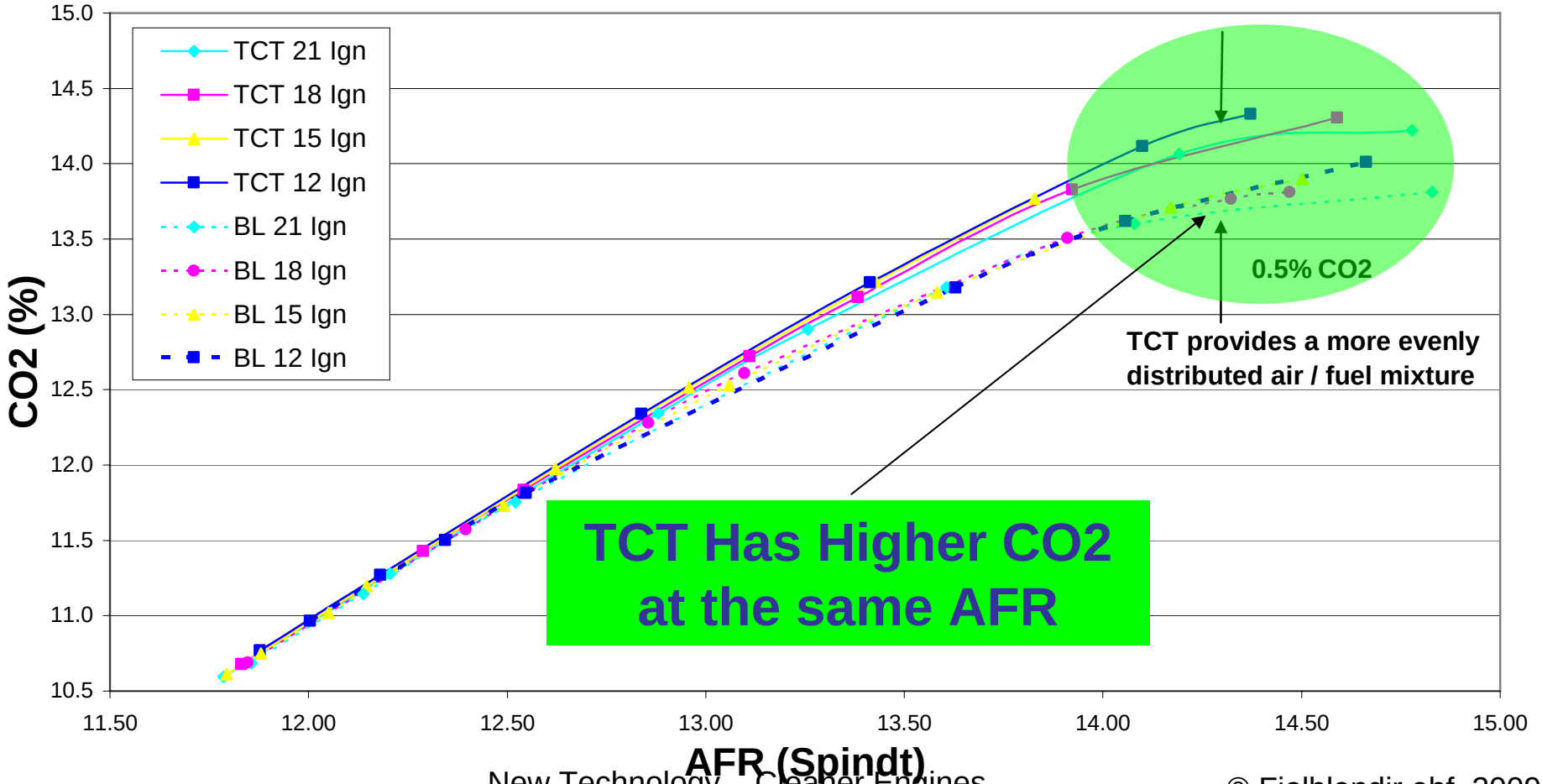

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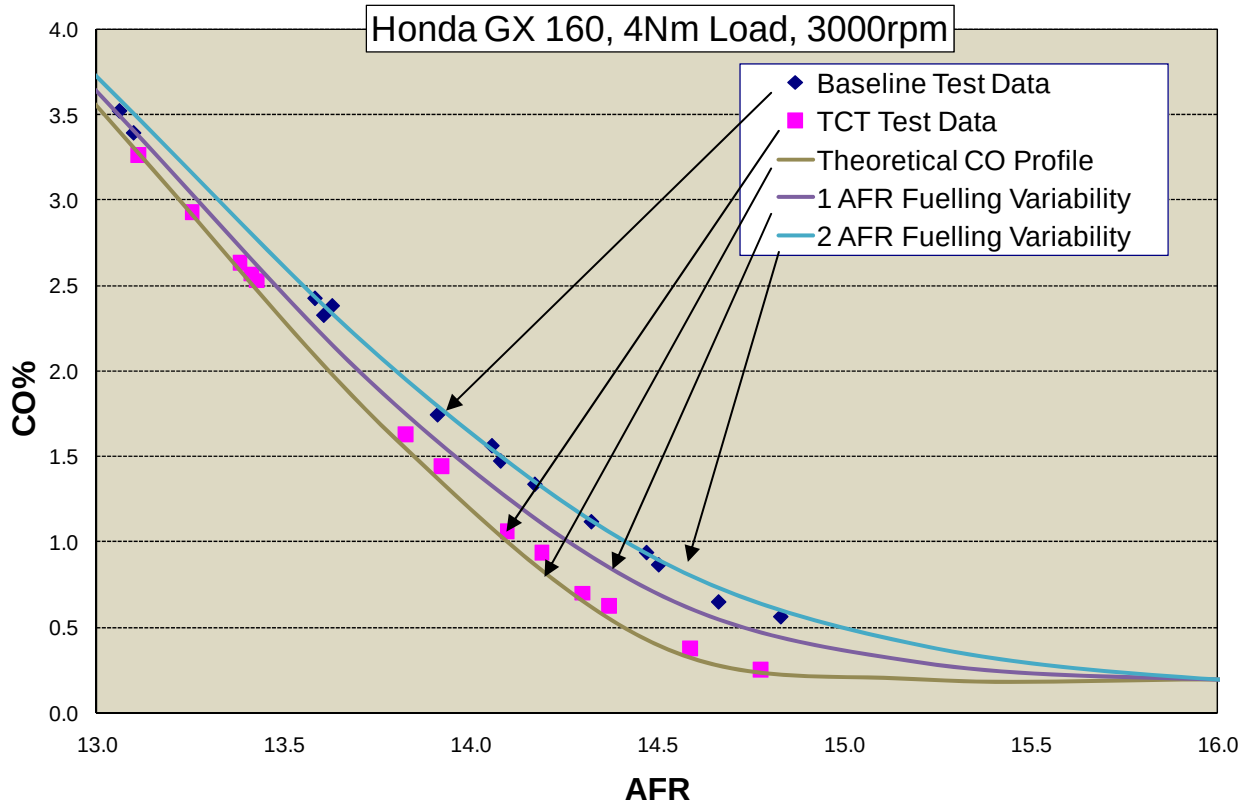
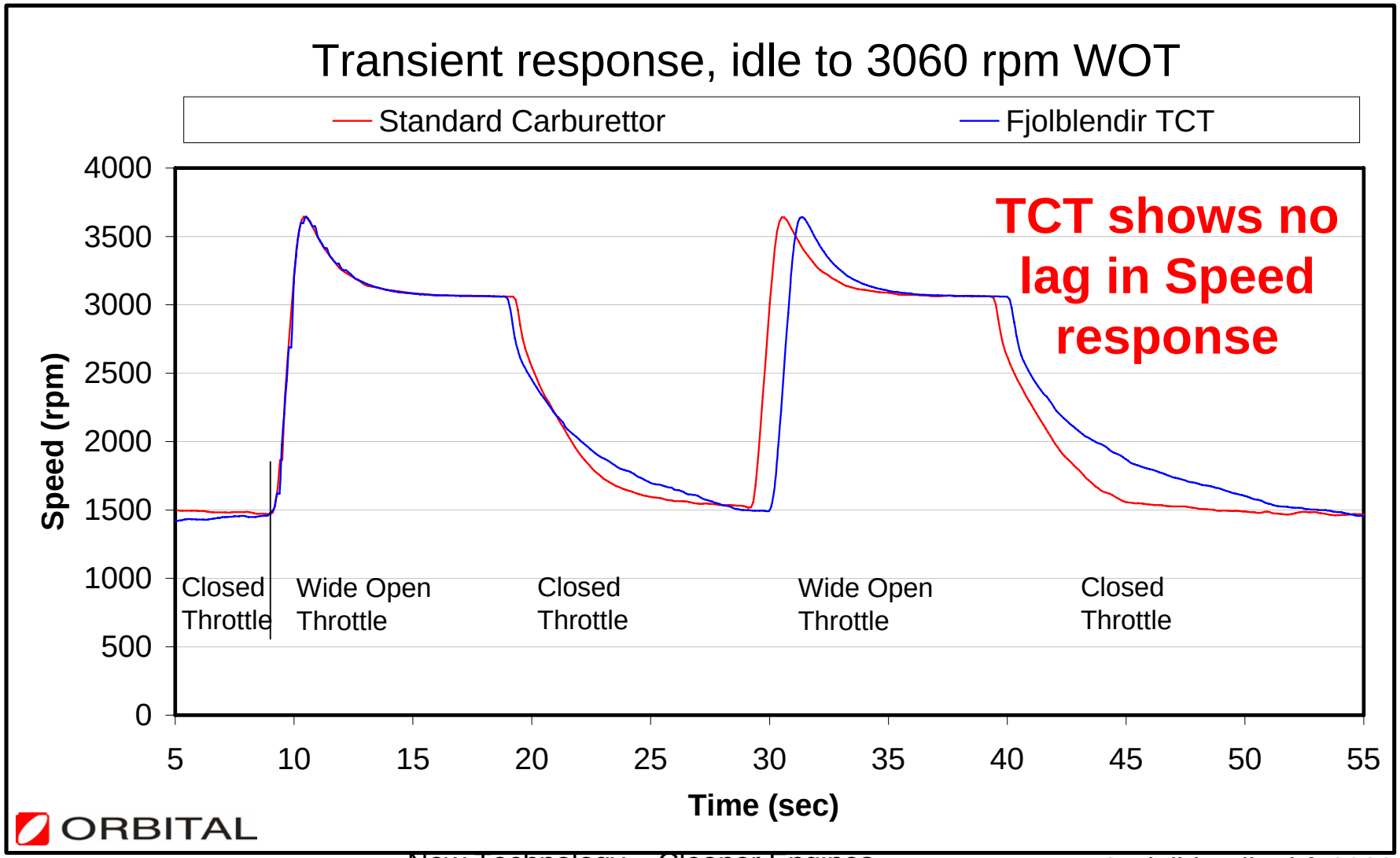


Data analysed by professor Roy Douglas of QUB

- **Theoretical profile estimated from text book combustion equation (inverse Spindt):**
  - **$CH_x + A(O_2+3.76N_2) = aCO+bCO_2 + cH_2O + dHC + eN_2$**
- **Base CO at lean conditions matched to test data**
- **AFR variability calculated by averaging over range**
- **TCT close to zero AFR variability at this condition, baseline close to 2 AFR's**

Transient Response – Double Accel.



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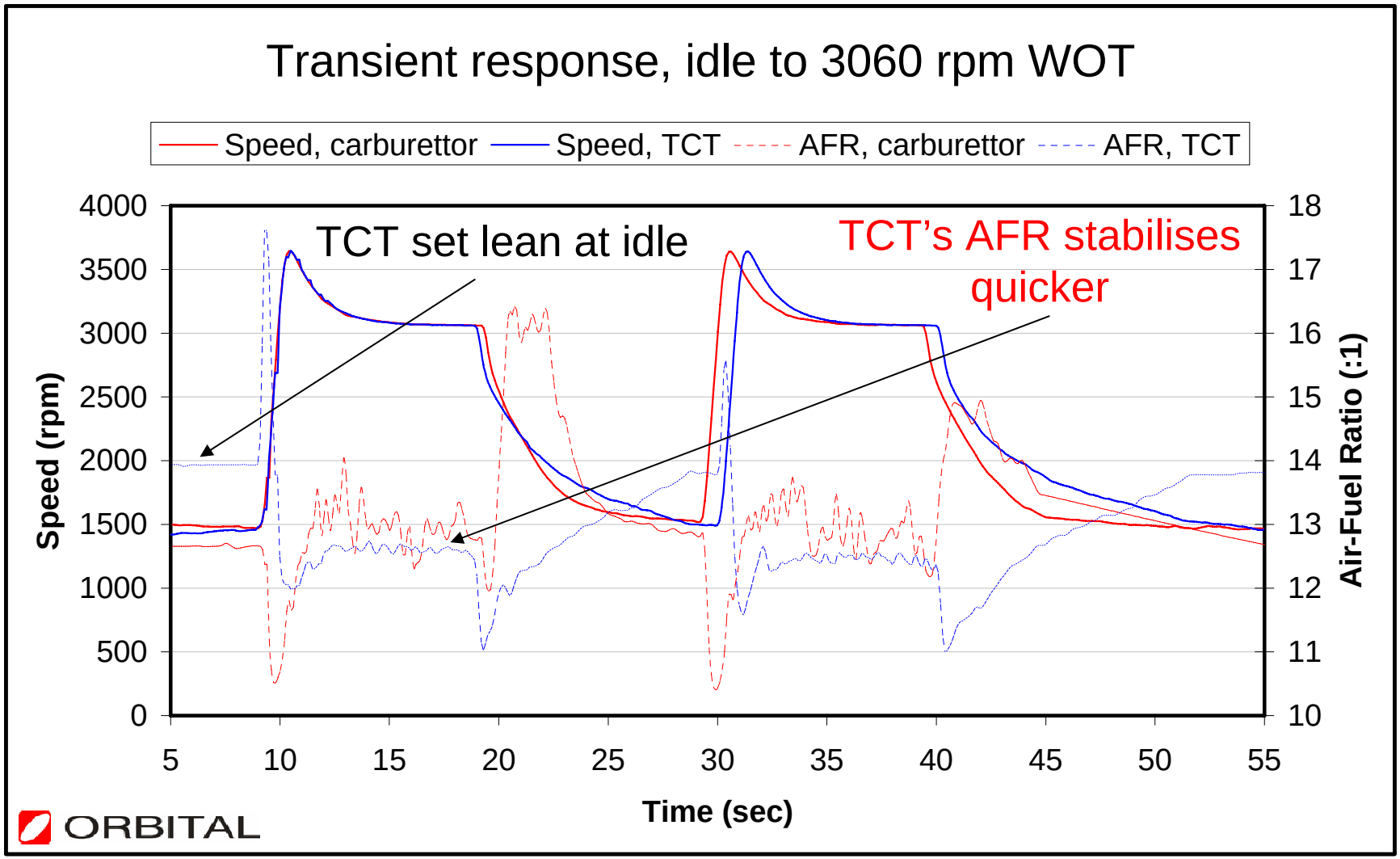

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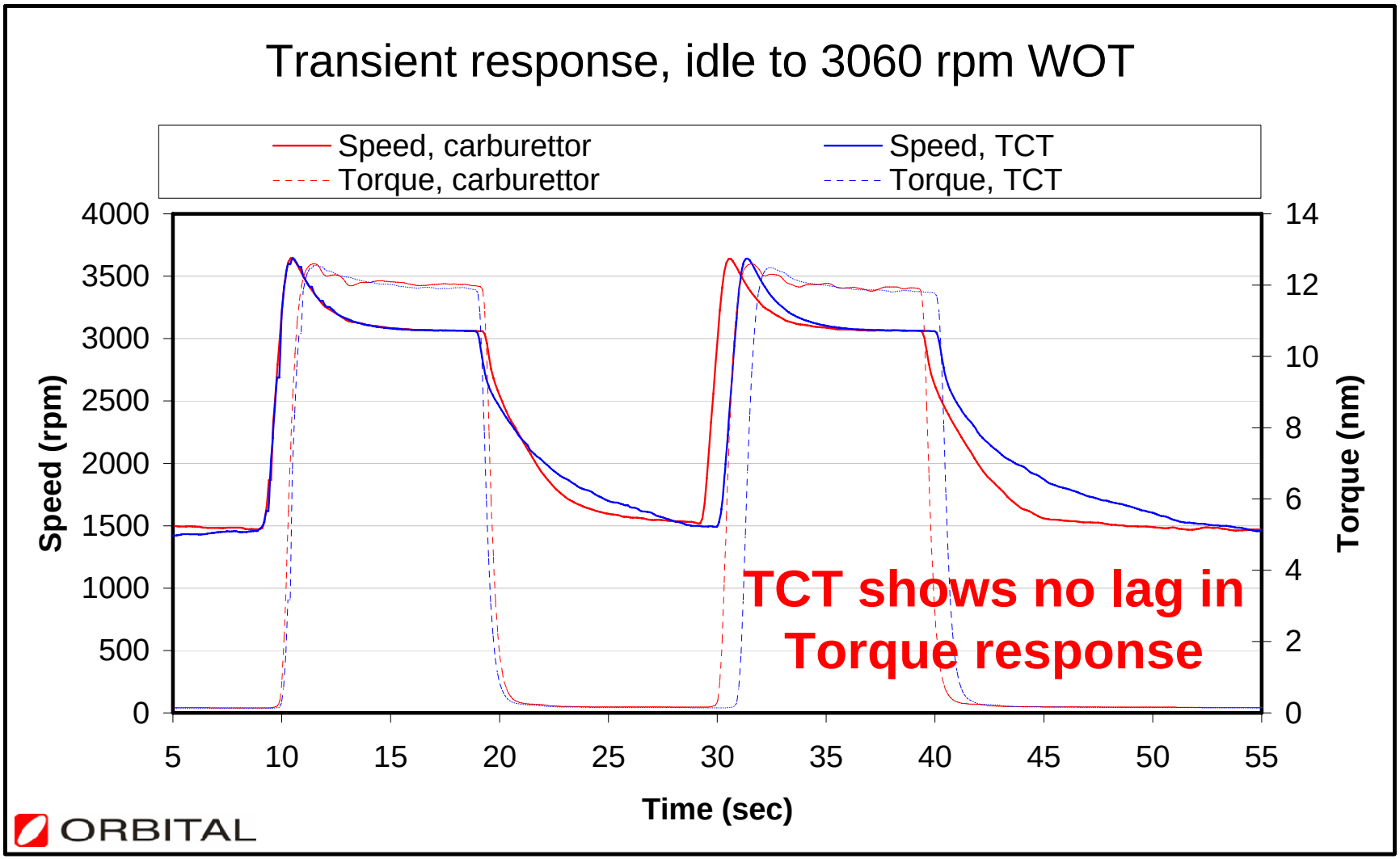
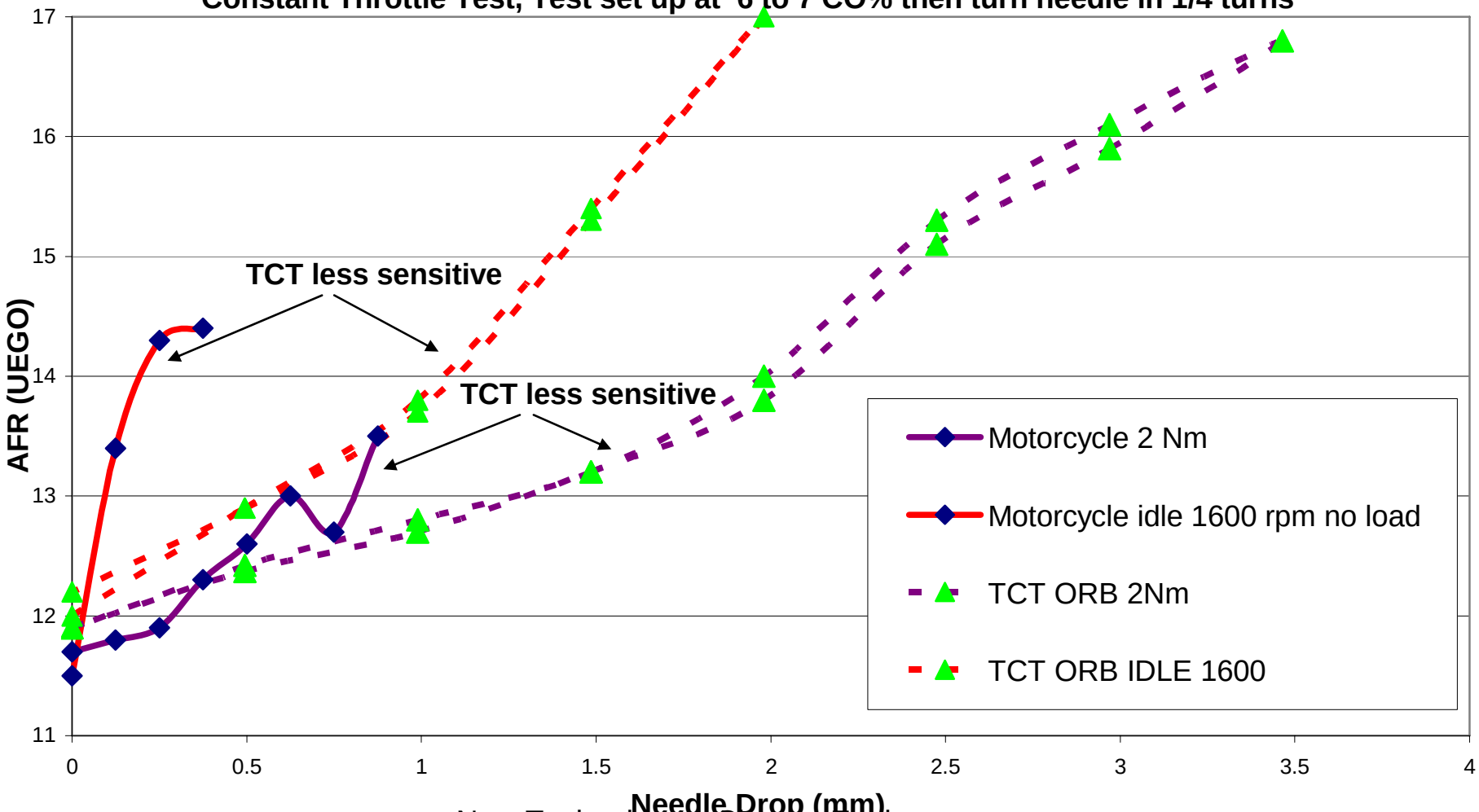


Sensitivity Data – Needle Lift vs AFR Change

Sensitivity of Honda MC Slide Carburettor and TCT ORB in Terms of Change in Fuelling (CO%) Versus Needle Lift at Various loads and idle speed
Constant Throttle Test, Test set up at 6 to 7 CO% then turn needle in 1/4 turns



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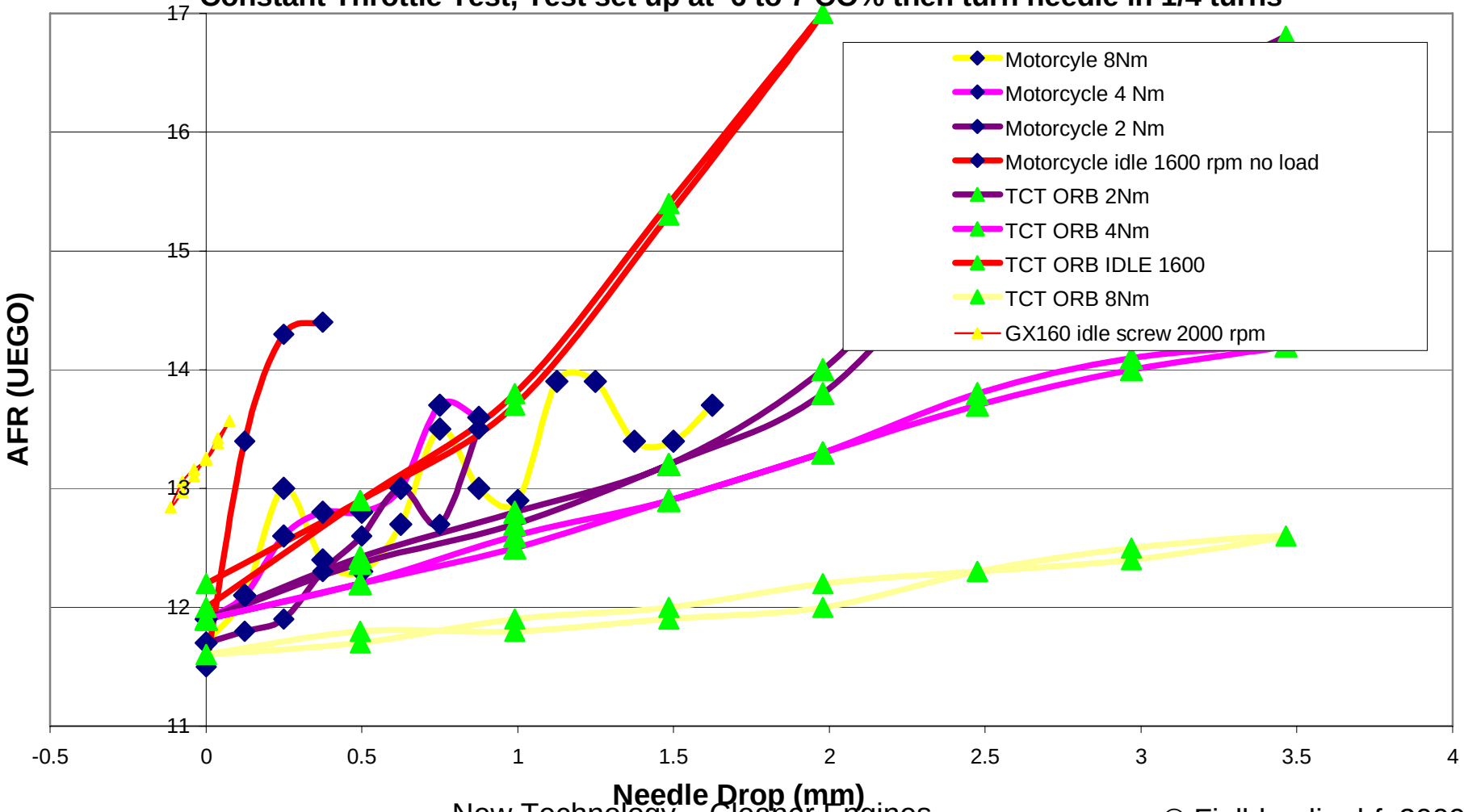


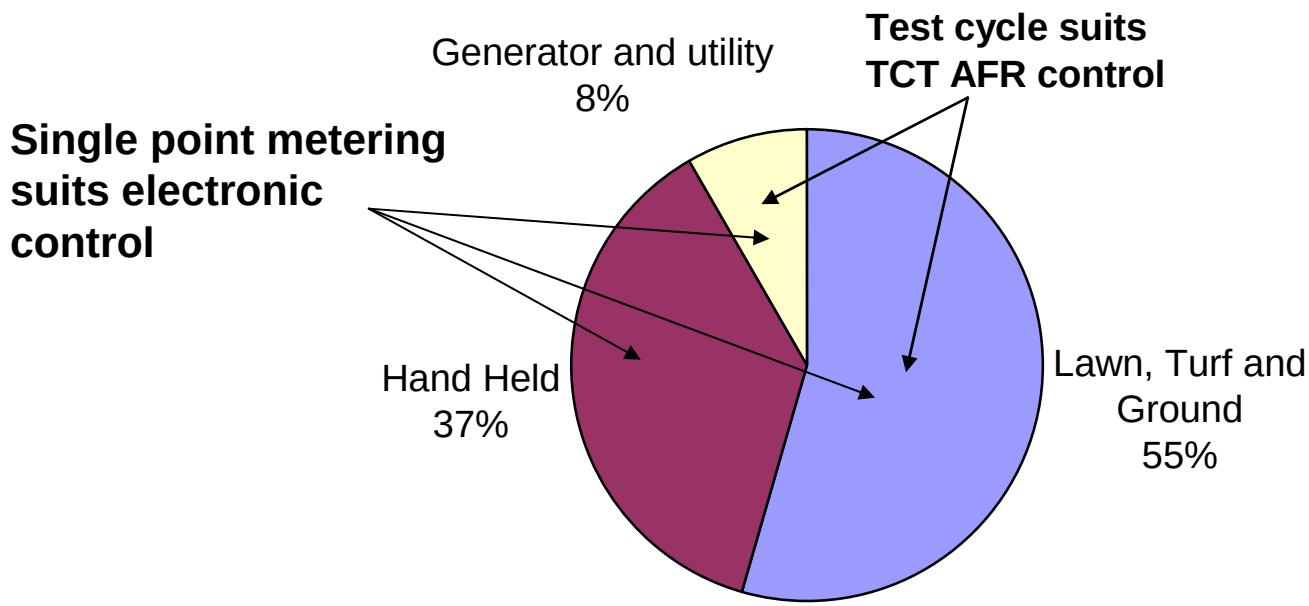
The Market

Introduction - Market

WORLD Power Demand

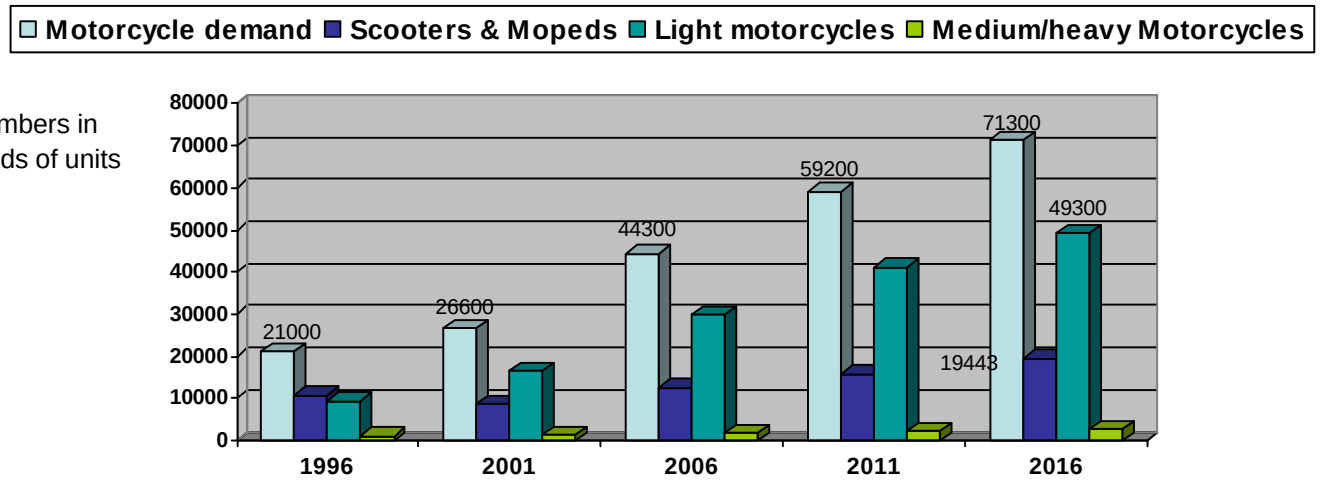
$17,500 Million USD

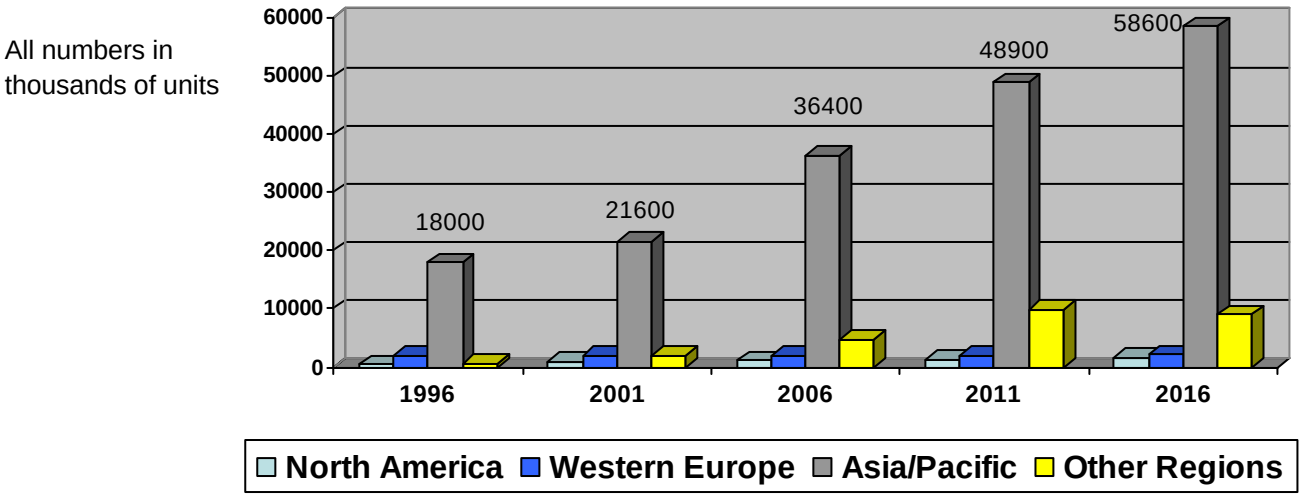
Varied reports show market size between 60 and up to 100 million units pa.



Fjölblendir have taken conservative view based on market and OEM current data available

Introduction – Motorcycle Market

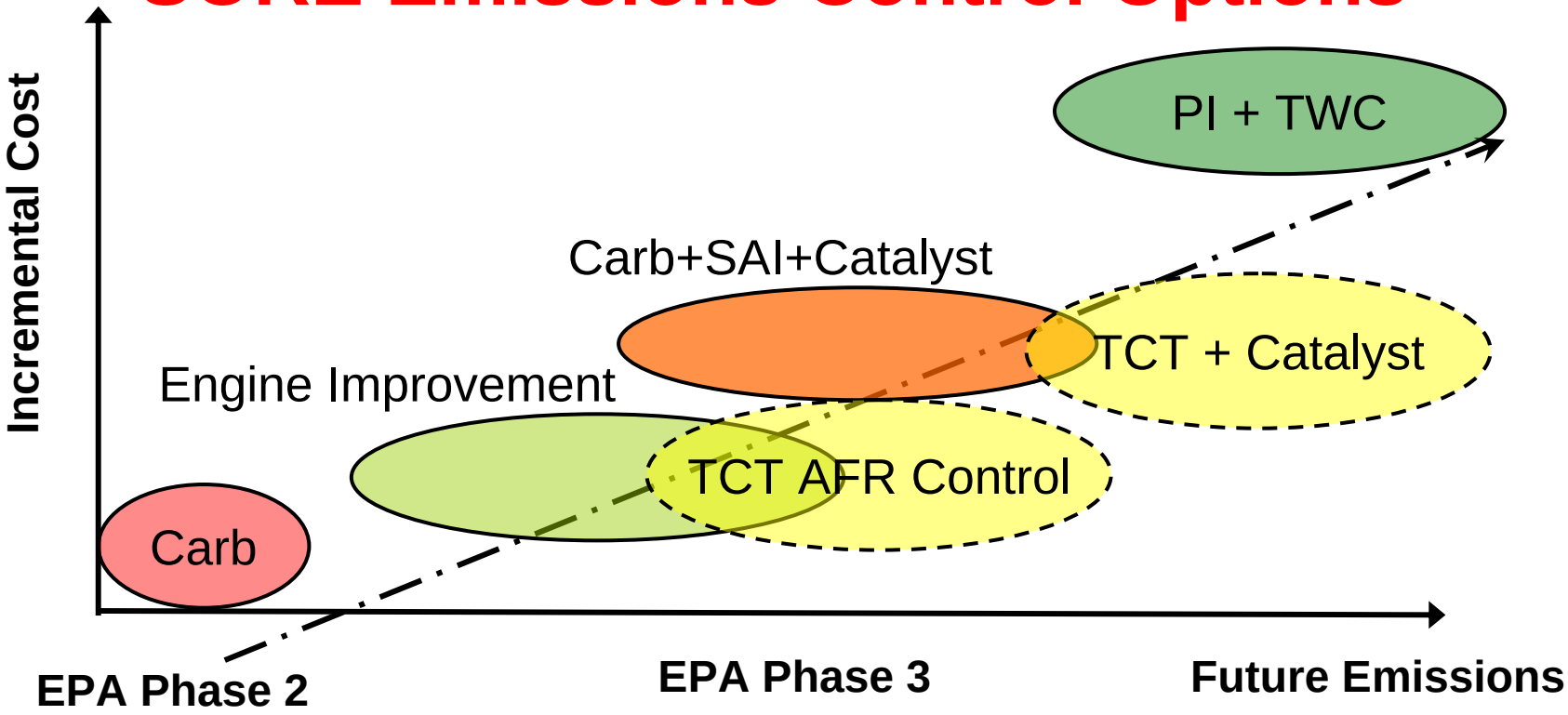




Introduction - Market

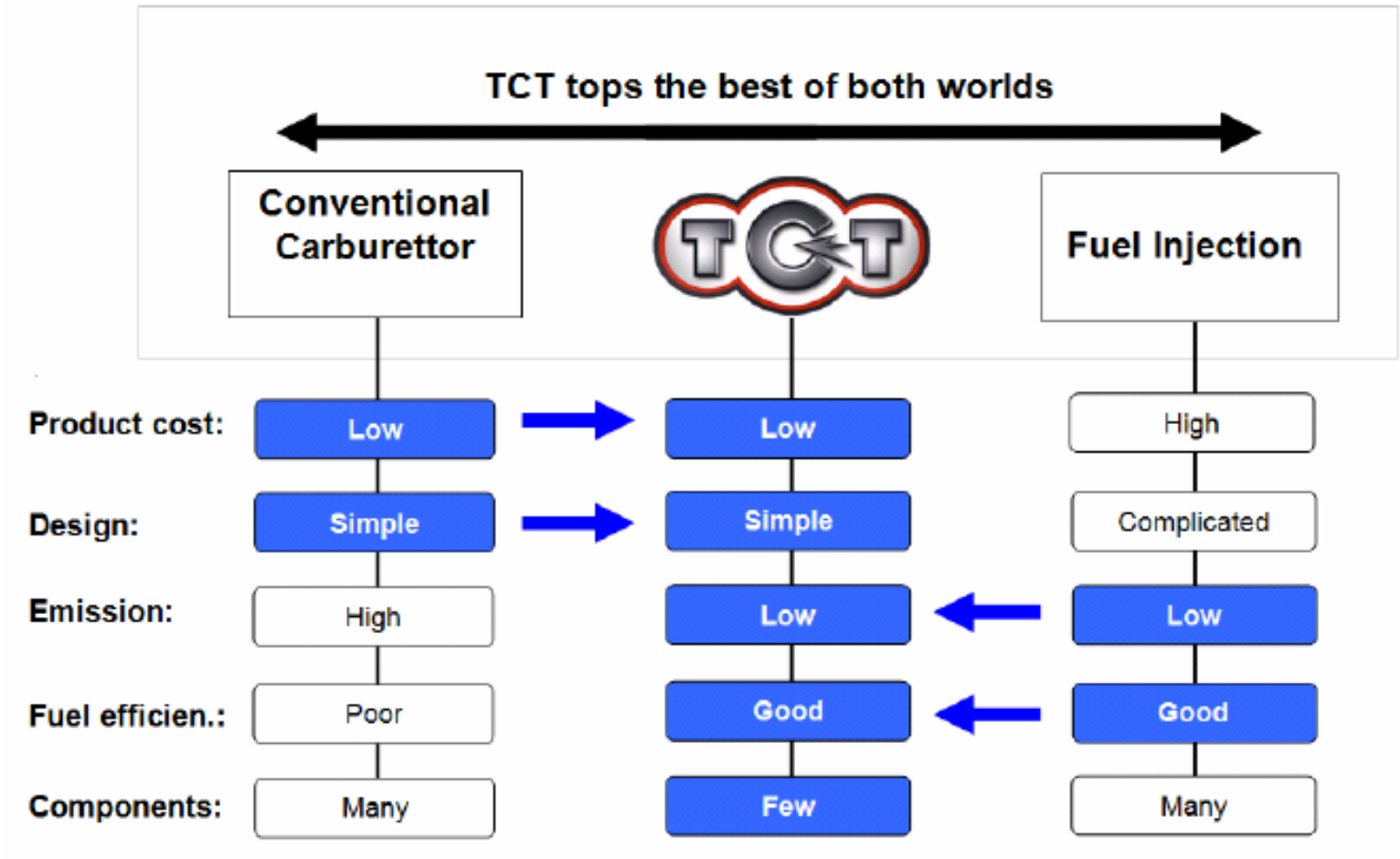
- Non Handheld SORE
  - Applicable emission control option for Non-Handheld SORE
- Hand and Non-Handheld SORE
  - Single point metering for electronic / feed back control for improved life cycle durability / self regulation
- Handheld SORE
  - Improved AFR control for air-head 2-strokes
- Motorcycles
  - Improved fuel consumption with potential to reduce drive cycle emissions
- All products
  - Improved engine running / combustion stability

SORE Emissions Control Options



- Known emissions control solutions for EPA Phase 3 include engine improvement, addition of a catalyst and addition of secondary air.
- Future emissions require PI and TWC.
- TCT AFR control reduces or eliminates requirement for catalyst for Phase 3

Fuel systems



Fjölblendir is looking to commercialise / licence the TCT with the correct partner.

For contact information please visit our website www.tct.is