Catagen’s Recirculating Gas Reactor – an optimisation and calibration tool for automotive after-treatment systems

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Overview

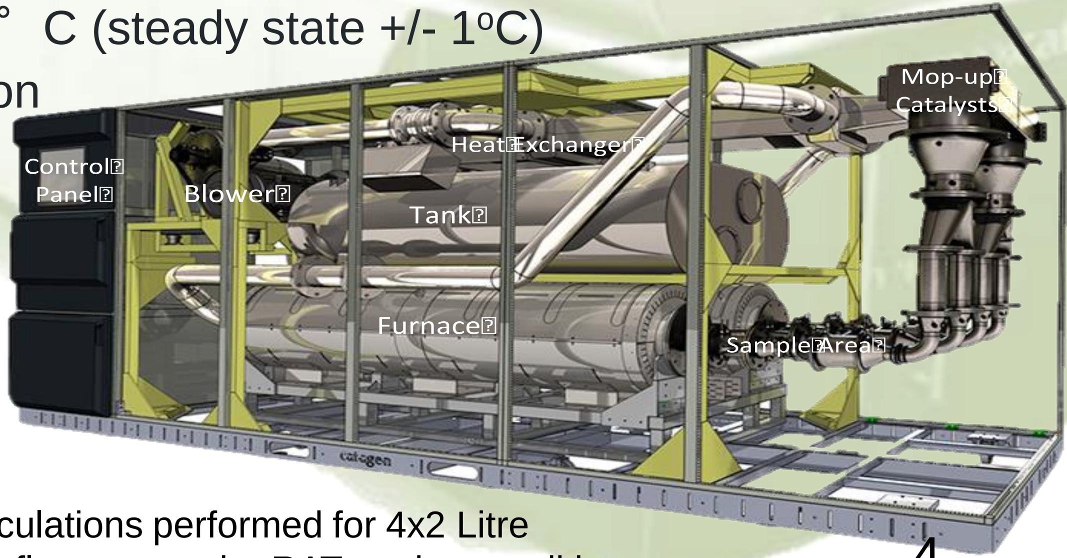
To investigate the use of a synthetic gas reactor as:

- An optimisation tool for exhaust gas after-treatment systems
- A calibration tool for exhaust gas after-treatment systems measuring devices e.g. emissions analysers, Lambda sensors, thermocouples etc

Recirculating Gas Reactor – Maxcat specifications

Maxcat the most energy efficient & environmentally friendly full scale after-treatment system testing equipment with the capability to reproduce any real world drive or customer test cycle.

- Gas flow rates from zero to 200g/s (10,000 LPM) (steady state +/- 1g/s)
- Testing temperatures 25 to 1100° C (steady state +/- 1°C)
- Precise control of gas composition
- More than 80% less energy consumed than dyno/burner testing*.
- Over 90% less CO_2 produced than dyno/burner testing*.

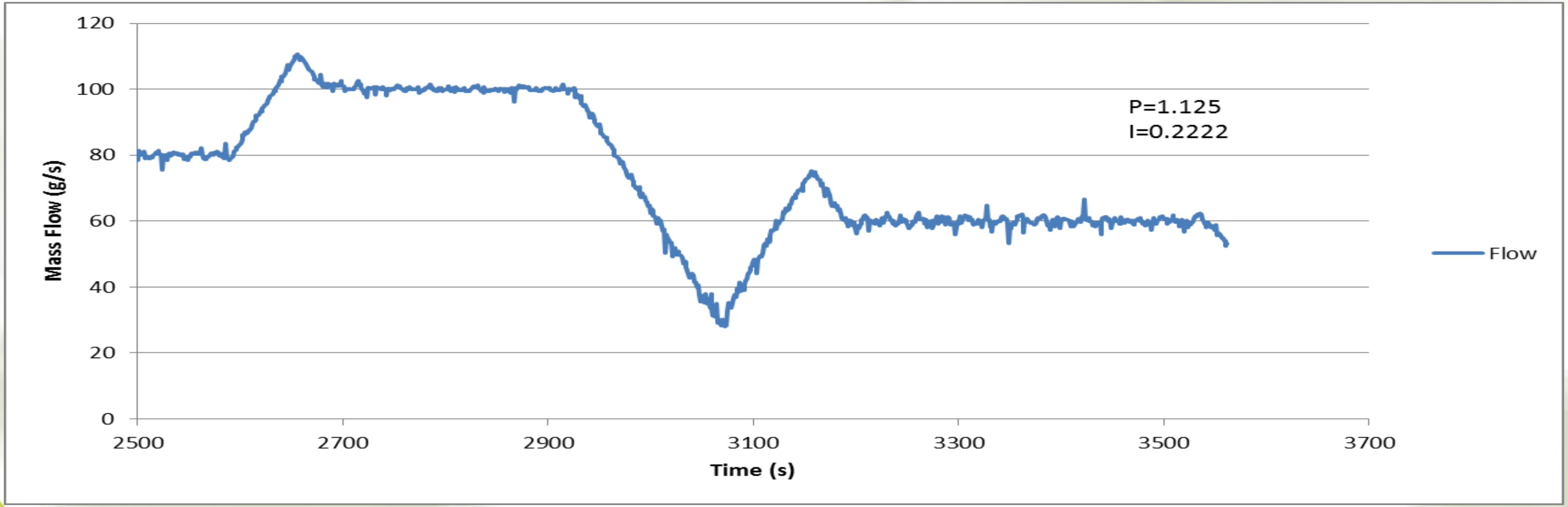


*Measurements and calculations performed for 4x2 Litre catalysts at 50g/s/catalyst flow rate under RAT ageing conditions

Recirculating Gas Reactor – Maxcat capabilities

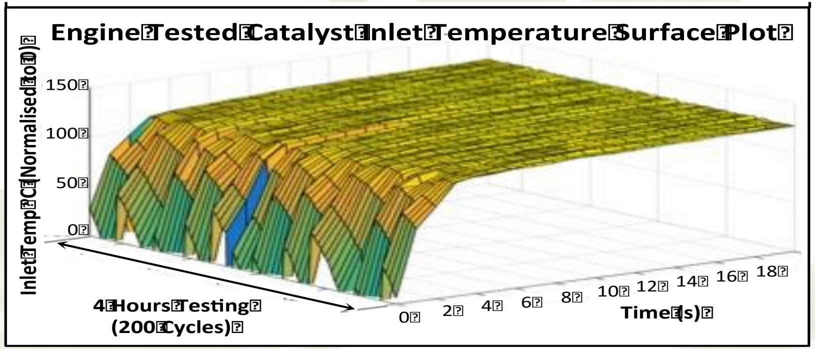
Flow Measurement

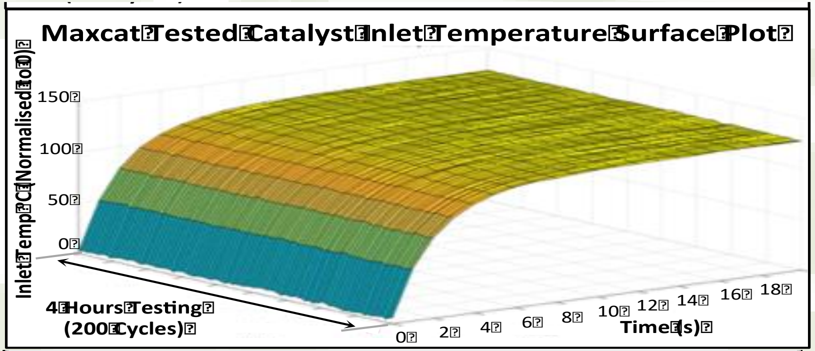
- Controlled mass flow adjustments at set points 80, 100 and 60 g/s
- Flow is to +/- 1 g/s at 100g/s
- Measurement by a Venturi designed to BS 9300:2005

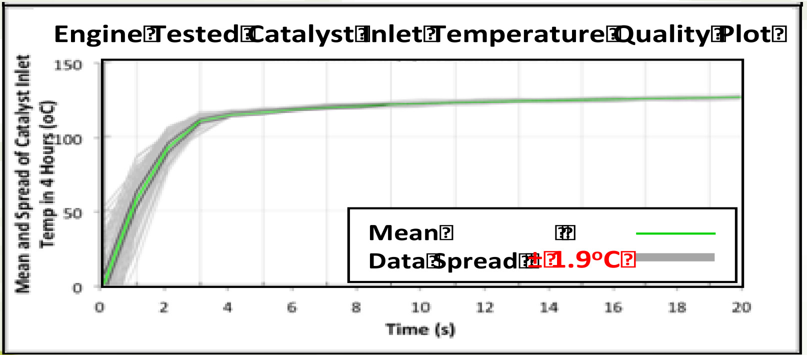


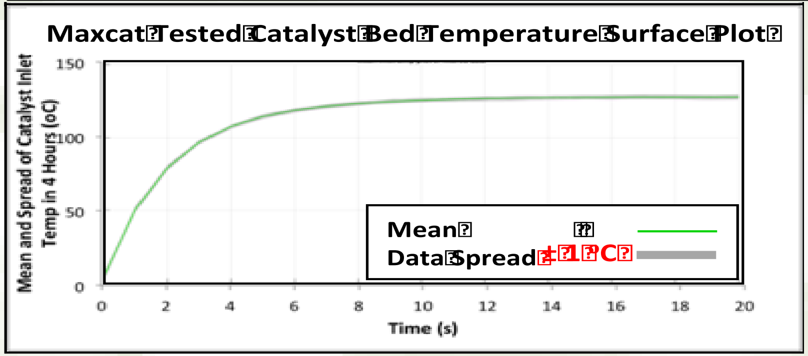
Recirculating Gas Reactor – Maxcat capabilities

Temperature Stability









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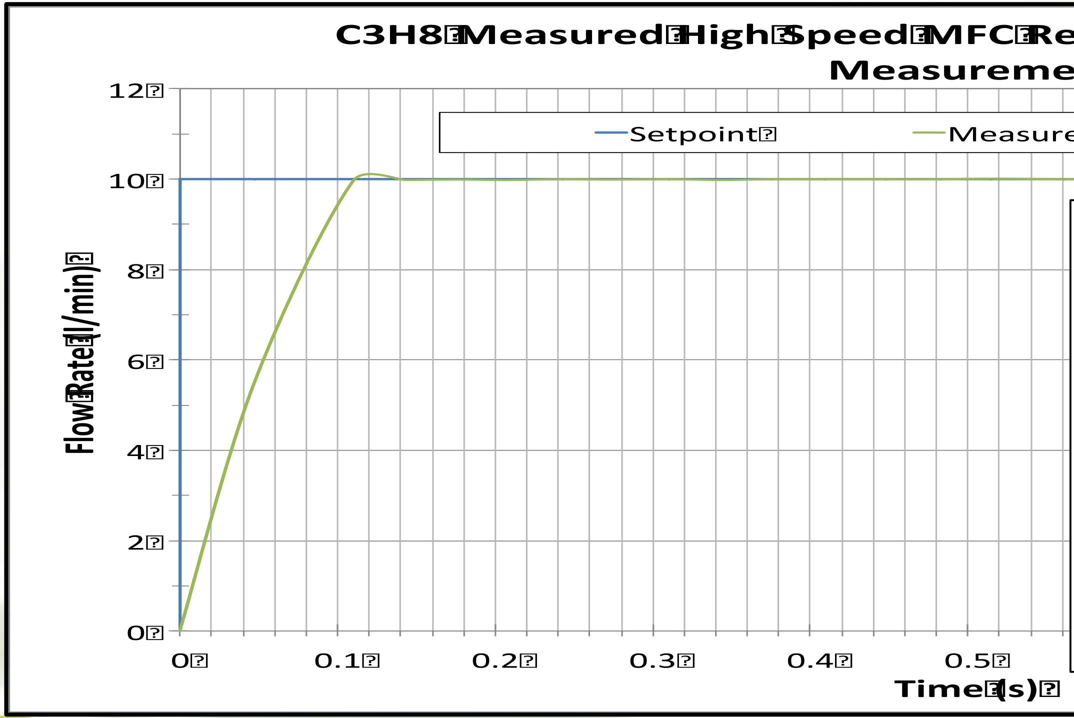
Graphs demonstrate controlled temperature response of Maxcat

Recirculating Gas Reactor – Maxcat capabilities

Gas Injection Response & Measurement



Characteristics

Data Sampled Every 37 Milliseconds

0 - 50% Scale in 0.11 Seconds

Stable After 0.14 Seconds

Measured Stability Data

STANDARD DEV = 0.007 (6 SIGMA Equivalent)

MEAN = 9.999 of 10.000 SP

MFC

Official Rated Tolerance = 0.1%

Measured Tolerance < 0.1%

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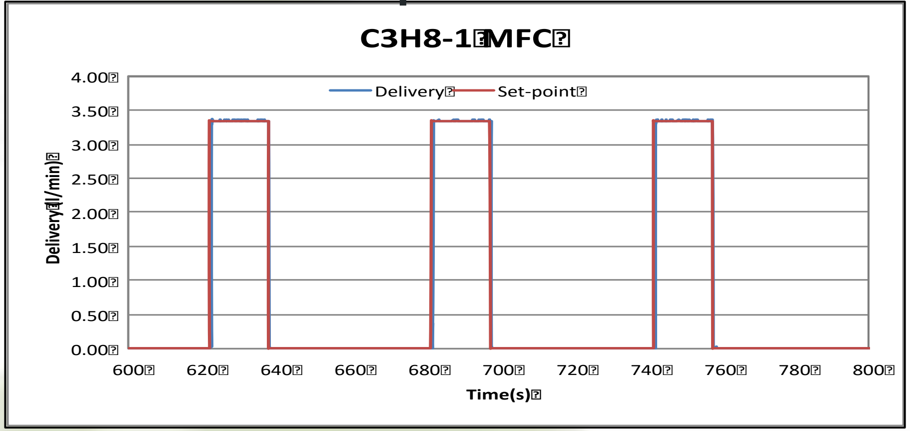
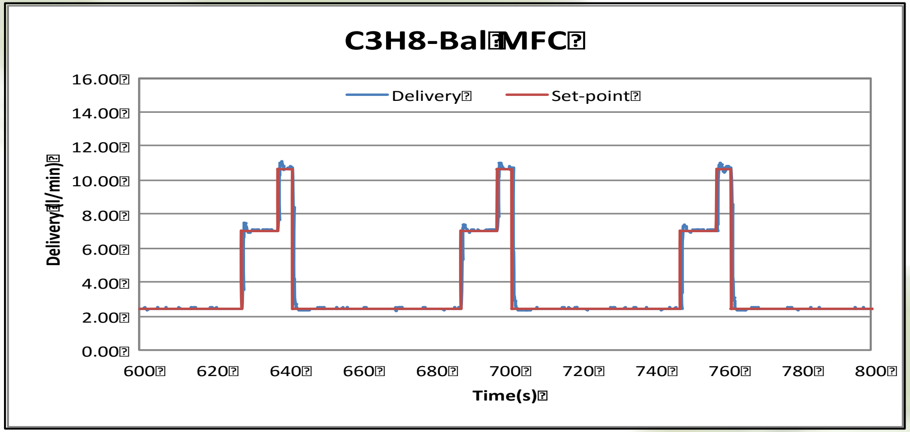
Recirculating Gas Reactor – Maxcat capabilities

Gas Injection Response & Measurement





C_3H_8 Set point and measured delivery at 10Hz for two ranges and profiles.

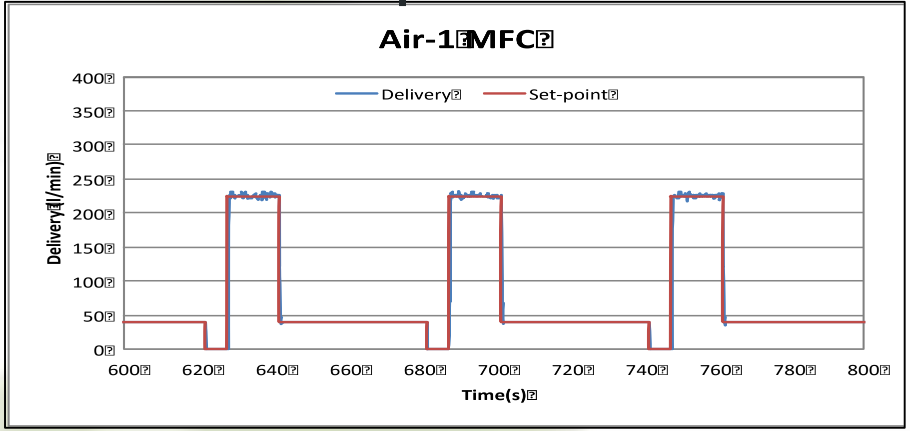
- Cycle to cycle standard deviation in the range of 0.005-0.039

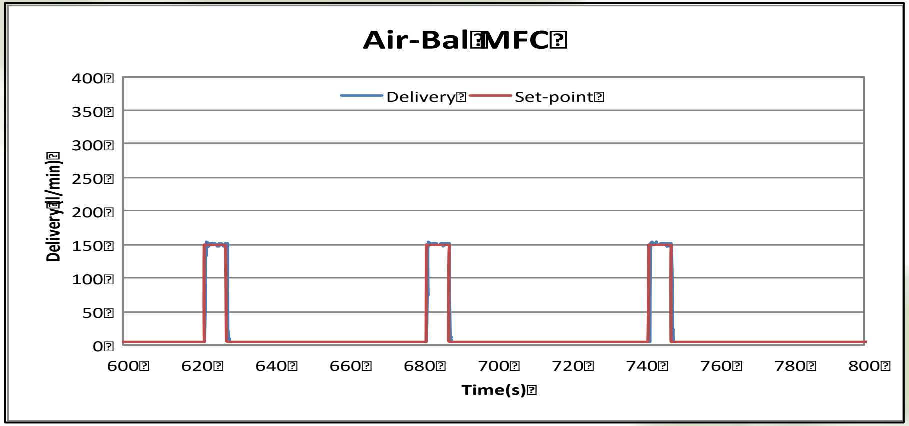
Recirculating Gas Reactor – Maxcat capabilities

Gas Injection Response & Measurement

Air Set point and measured delivery at 10Hz for two ranges and profiles.

- Cycle to cycle standard deviation in the range of 0.417-2.632

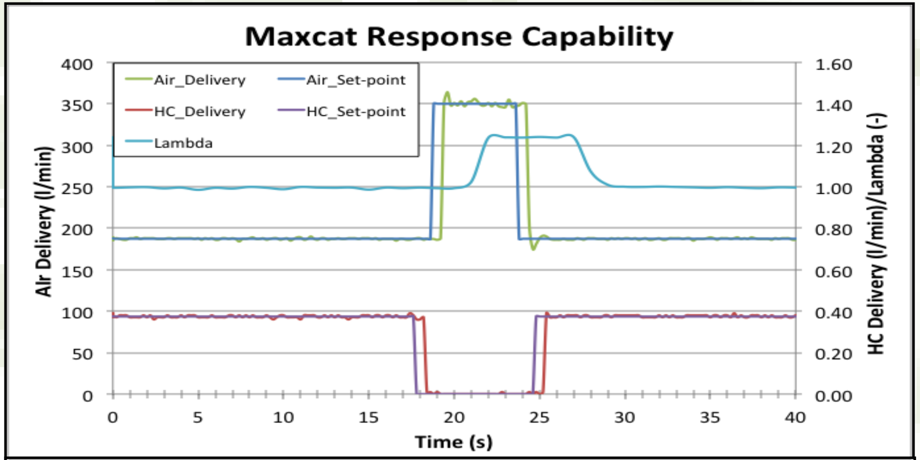


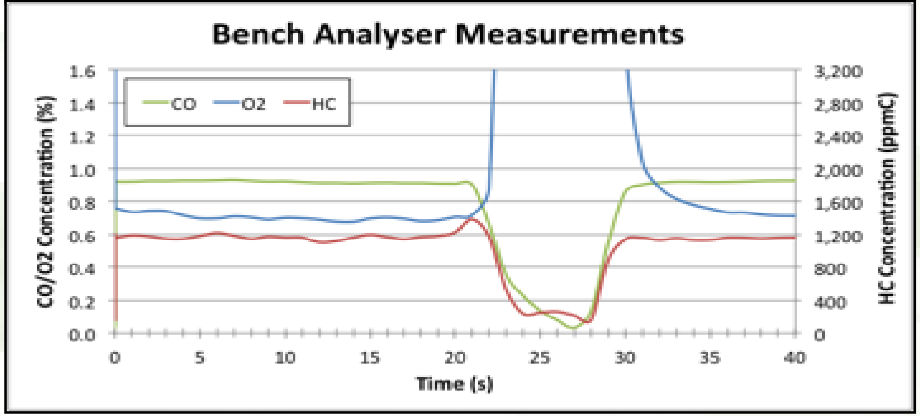


Recirculating Gas Reactor – Maxcat capabilities

Gas Injection Response & Measurement

Graphs demonstrating integrated **max**cat gas delivery response to HC set point (top) and corresponding bench analyser measurement (below)





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Maxcat as a calibration tool – "Measuring the measurers"

The accuracy of flow, temperature and emissions allows **Max**cat to be used as a calibration tool for various after-treatment measuring systems. Some examples include:

Emission analysers, Lambda sensors and Thermocouples

What follows is a case study of an emission analyser used with the **Max**cat system

“Measuring the measurers”- Case Study 1 Overview

Case Study 1: This study focused on the performance of a O2 analyser to a step change input held for a defined period for injections of Air and propane gas specimens in to a standardized exhaust medium. Typical metrics are the timed responses (e.g. T10-90%, T90-10%, settling time) and specimen quantity (see figure 1)

Figure 1. Example of O2 analyser response to step change with T10-90% measurement

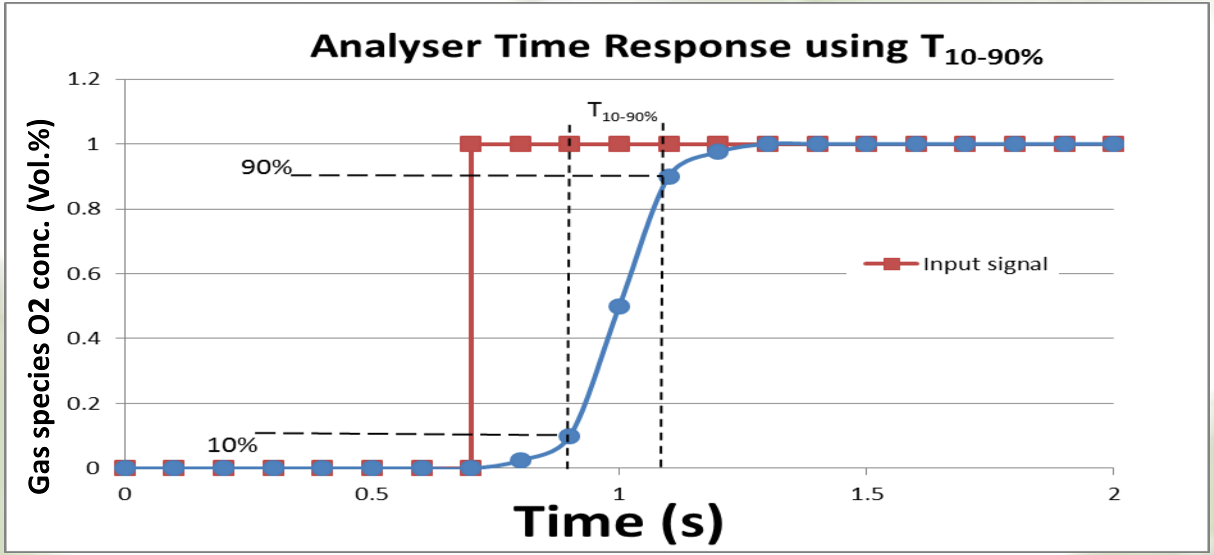
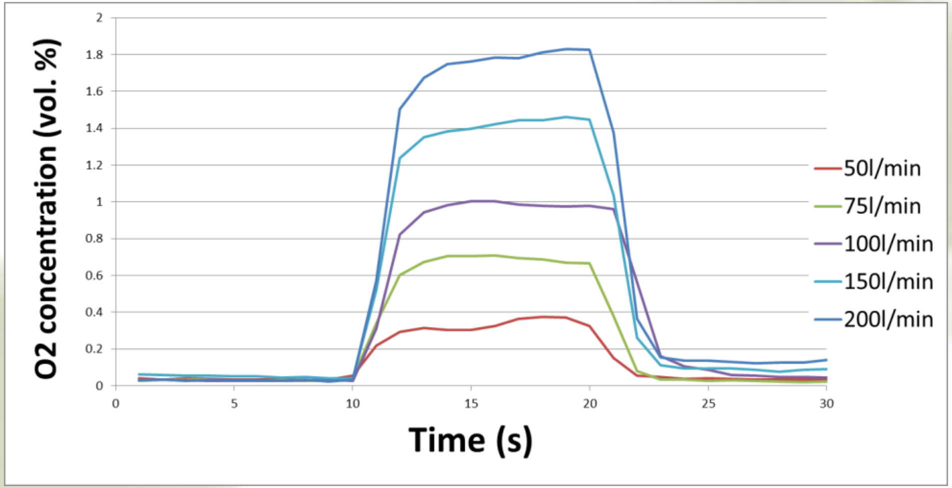


Fig 1. Sensor Response using $T_{10\text{-}90\%}$

"Measuring the measurers"- Case Study 1 Results

Results: The following plots show the response of the oxygen analyser when the standardized gas has injections of 50, 75, 100, 150 and 200 l/min from the Air MFC into an exhaust stream at 36g/s and 600 C

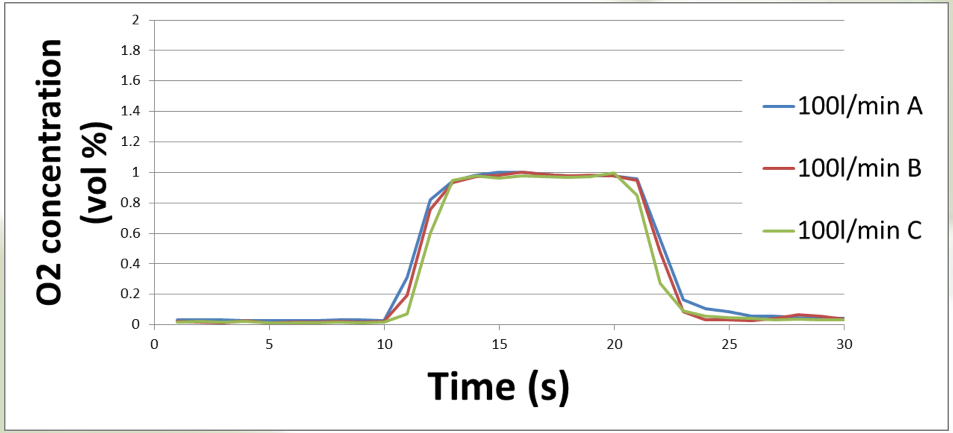


Calibration of accuracy technique in representative exhaust gas conditions

A comparison of the amount of oxygen measured between what the MFC delivers into a exhaust gas allows calibration to be assessed

“Measuring the measurers”- Case Study 1 Results

Results: The following plots show the response of the oxygen analyser when the standardized gas has three separate injections of 100 l/min from the Air MFC into an exhaust stream at 36g/s and 600 C



Calibration technique in representative exhaust gas conditions

This test allows measurement manufacturers to assess the repeatability of their equipment

“Measuring the measurers”- Case Study 1 Results

Results: The table below details T10-90 times and accuracy metrics for the oxygen measurements taken

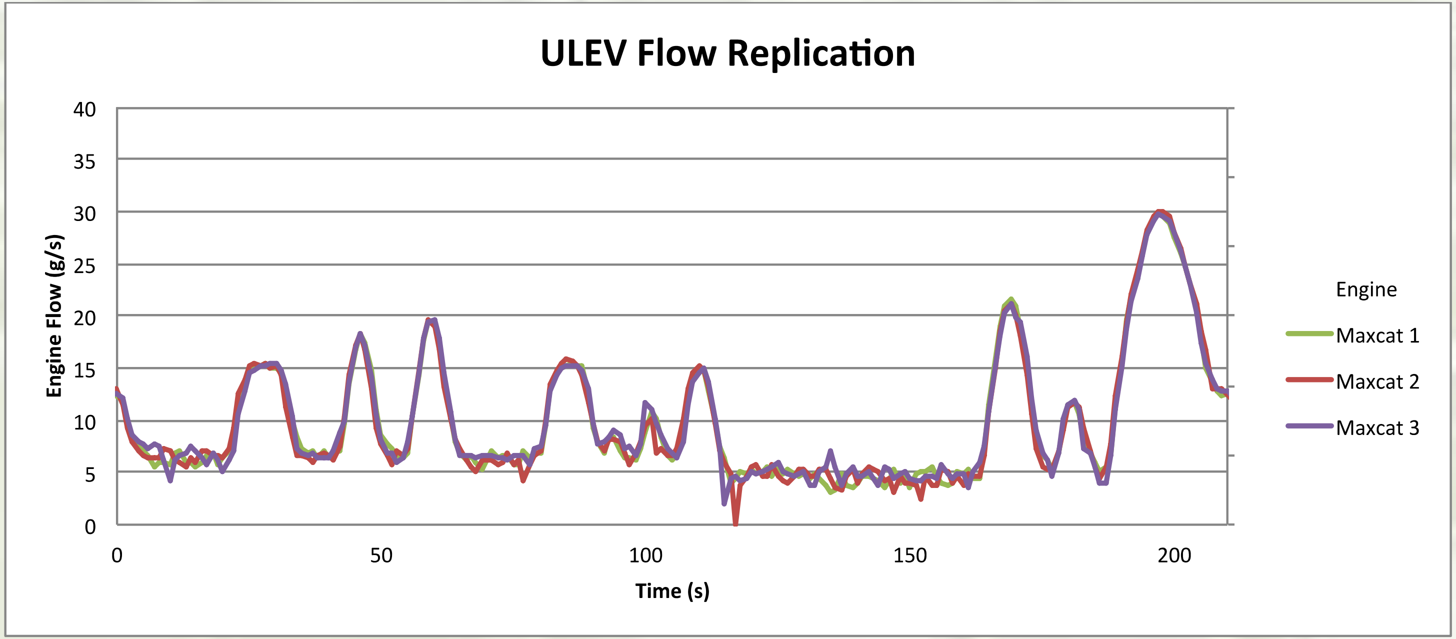
Maxcat as an optimisation tool

With the capabilities already presented **Max**cat can reproduce real world drive cycles delivering customer defined emissions to their after-treatment system of choice. Numerous optimisation scenarios are therefore possible e.g. the effect of varying engine out emissions on catalyst preformance, varying catalyst loading, varying catalyst geometry etc.

The second case study looks at running a ULEV drive cycle on a **Max**cat and generating the correct engine out emissions at a catalyst.

Case Study 2 – Replicating the ULEV drive cycle on Maxcat

Flow measurement



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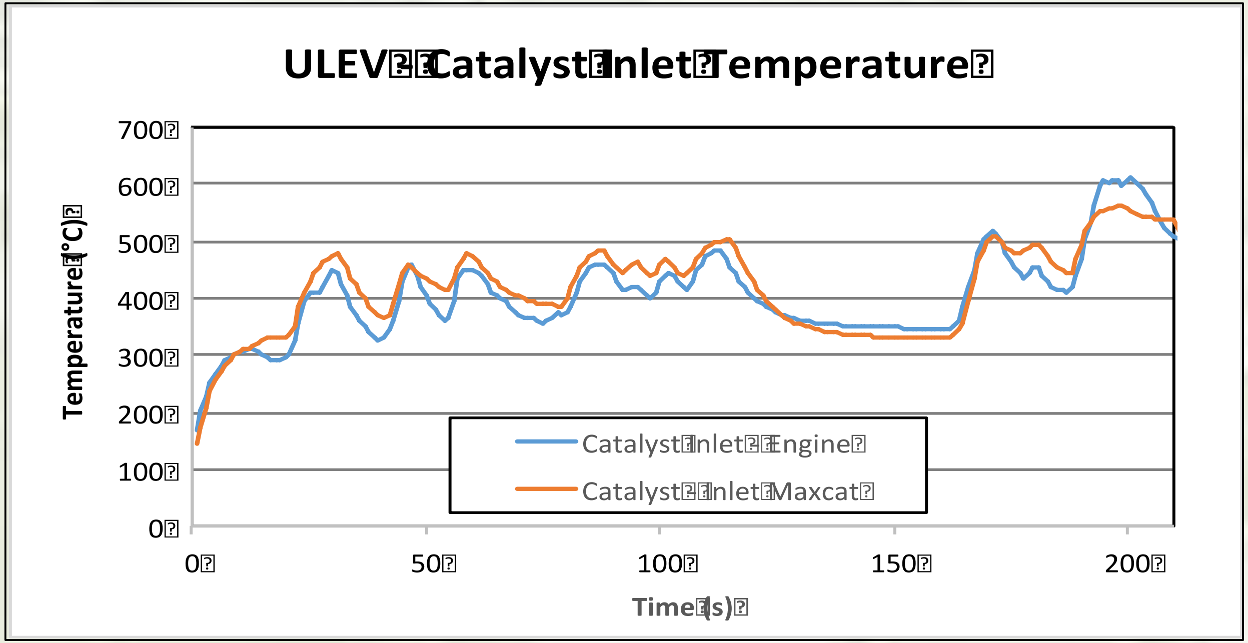
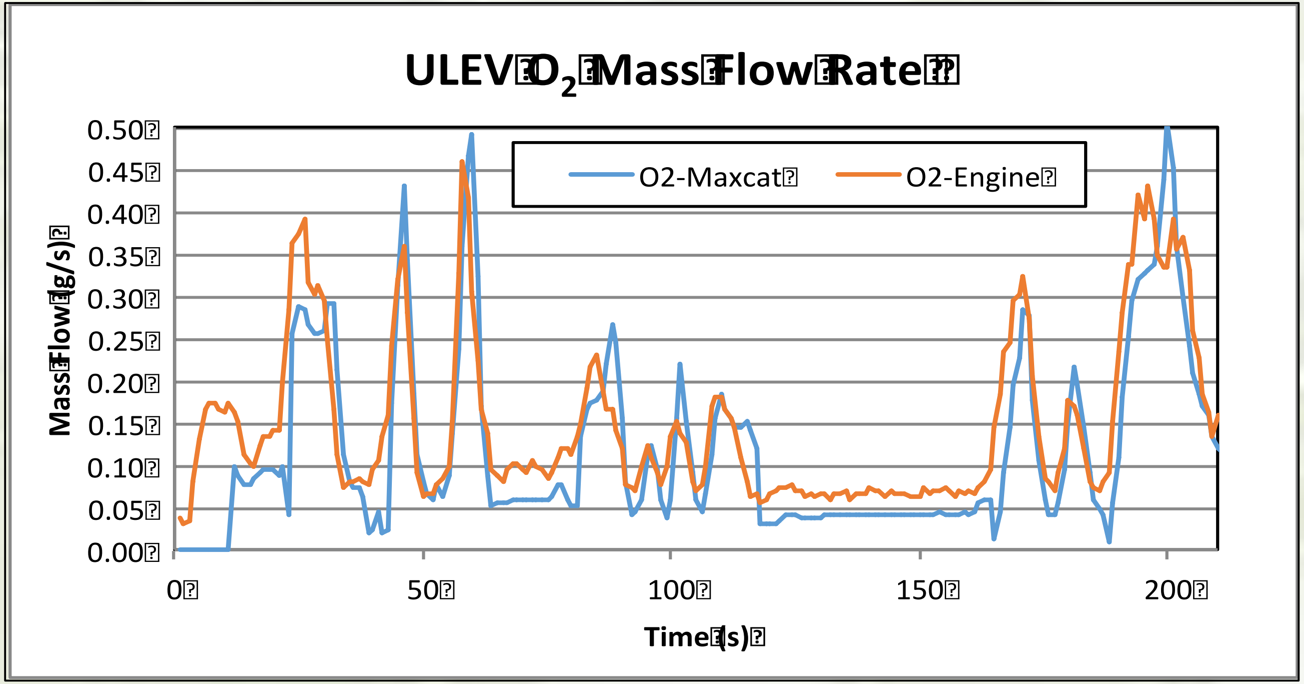
Case Study 2 – Replicating the ULEV drive cycle on Maxcat

Transient Flow Control - Bridging the Gap between the Lab and Real World



Case Study 2 – Replicating the ULEV drive cycle on Maxcat

Gas Injection Response & Measurement



Findings

Catagen have highly efficient full scale precision testing equipment that can replicate real world drive cycle conditions providing a unique capability to develop new insights into automotive catalysis and after-treatment system performance optimization.

Catagen's Labcat and Maxcat can act as sophisticated translators between laboratory testing and real world conditions. Precise and known conditions such as flow rate, temperature and individual gas species can be actuated at 10Hz creating any test condition.

Summary & Discussion

Testing Capability:

Precision Controllability & Measurement, Flexibility, Repeatability & Efficiency

Range of Test Types:

Testing for understanding, experimentation, ageing, development, durability, sweep, screening, sensitivity & performance to virtually any condition

Range of Test Subjects:

Catalyst, after-treatment system, GPF, gas analysers, MFCs, Sensors

Gas Usage & Efficiency Data

Transient/Drive Cycle Testing efficiencies*

95% less volume of gases used compared to standard gas bench

87% lower running costs than standard gas bench

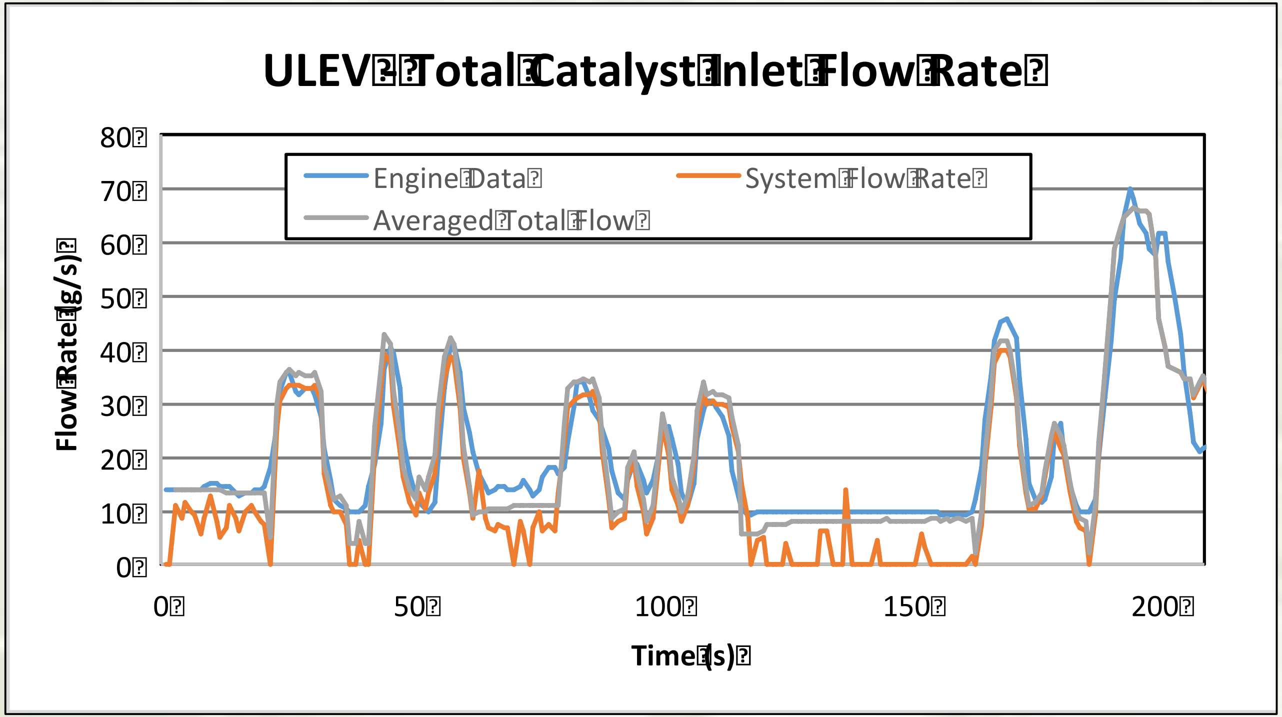
80% less energy consumed than dyno engine testing

*Based on 2 Litre catalyst under ULEV drive cycle conditions

Transient Flow Control - Bridging the Gap between the Lab and Real World

Initial Results

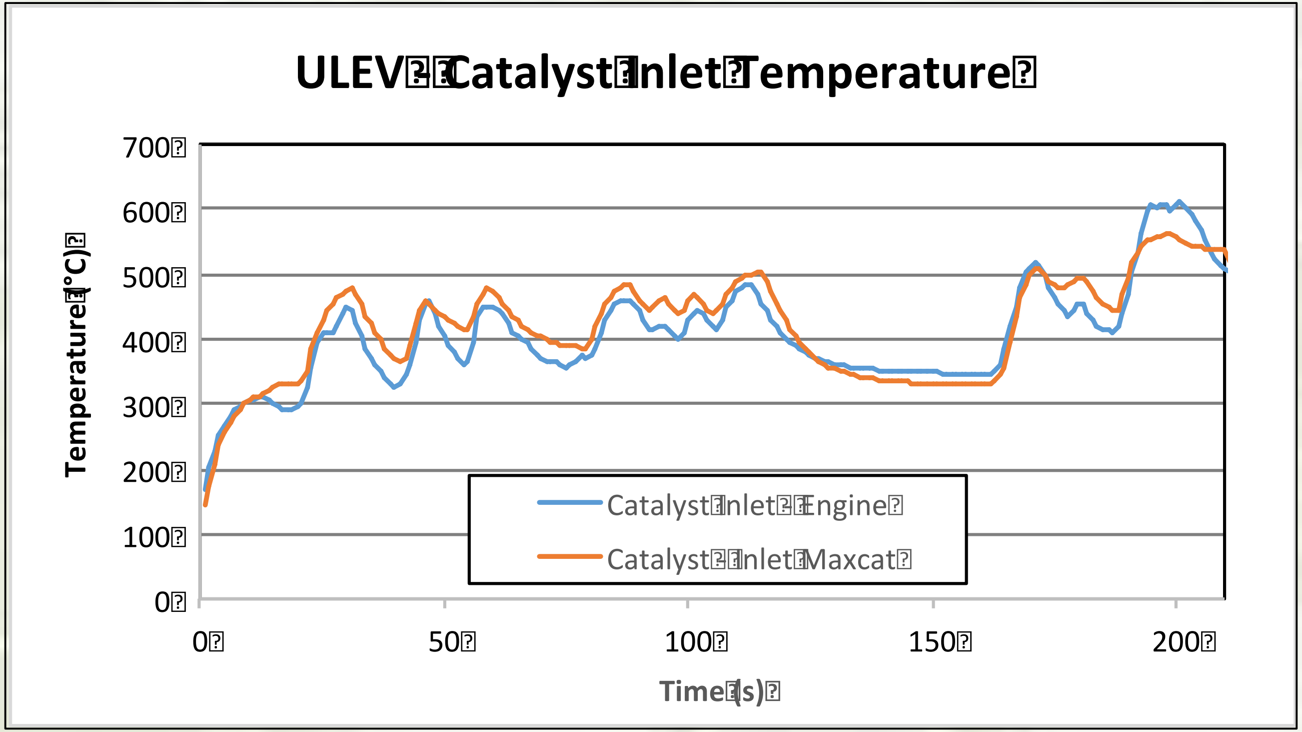
FLOW



Transient Flow Control - Bridging the Gap between the Lab and Real World

Initial Results

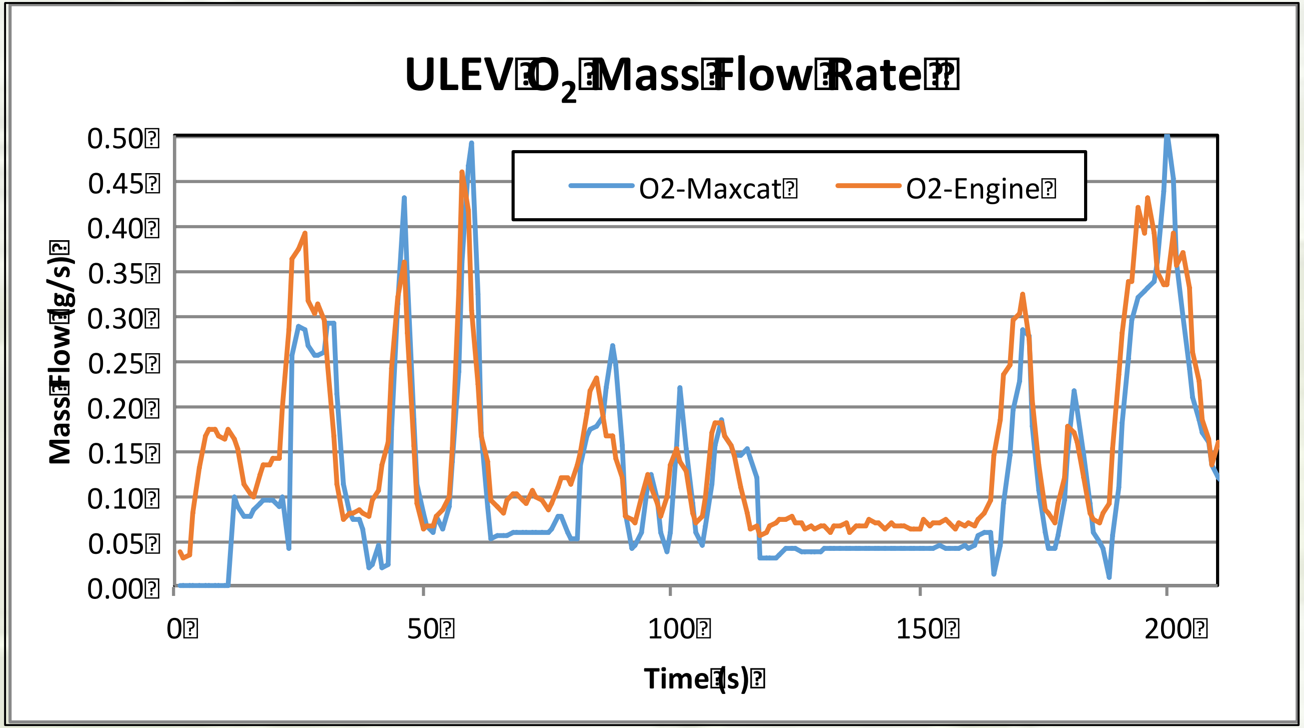
TEMPERATURE



Transient Flow Control - Bridging the Gap between the Lab and Real World

Initial Results

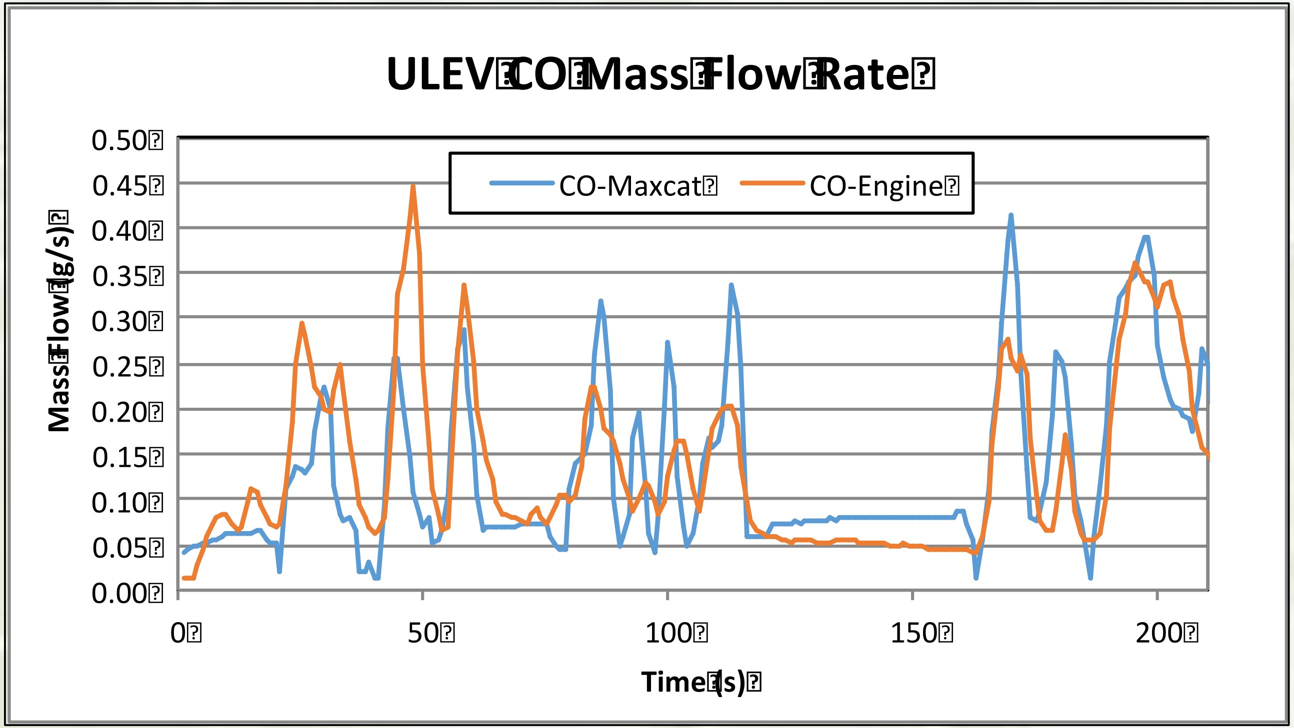
O2 Mass Flow



Transient Flow Control - Bridging the Gap between the Lab and Real World

Initial Results

CO Mass Flow



Transient Flow Control - Bridging the Gap between the Lab and Real World

Initial Results

THC Mass Flow