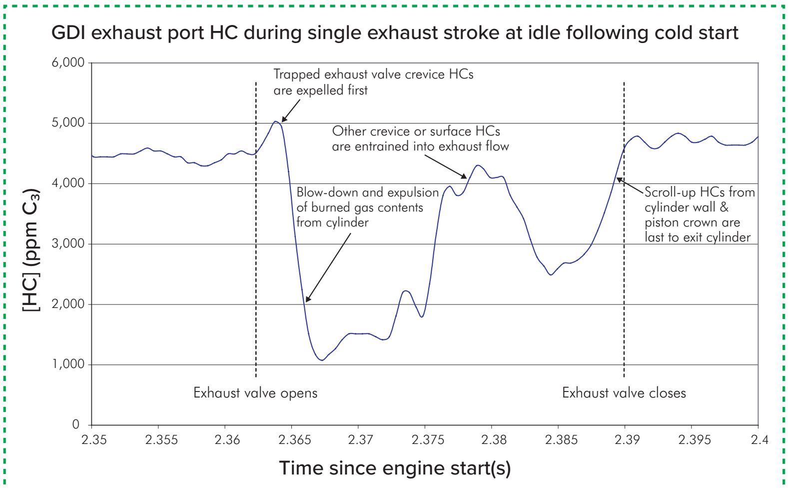
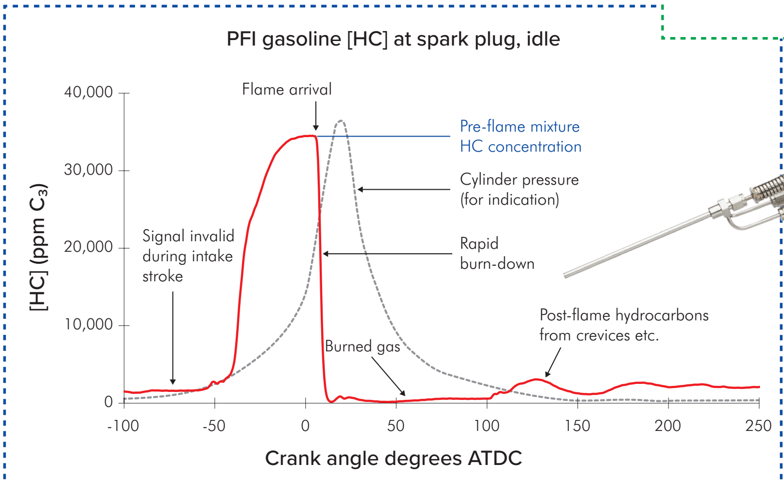
Ultra fast-response gas analyzers

For transient HC, NO_x, CO & CO_2 exhaust, intake and in-cylinder applications

- Cold start engine calibration
- Real-time EGR control refinement
- Transient fuelling control
- Combustion refinement
- Transient catalyst evaluation
- Direct in-cylinder measurement
- Scavenging and gas exchange studies
- T< 0° C sampling





Cambustion

Family of fast-response gas analyzers

HFR500 for fast HC

CLD500 for fast NO_X (shown here)

NDIR500 for fast CO & CO_2

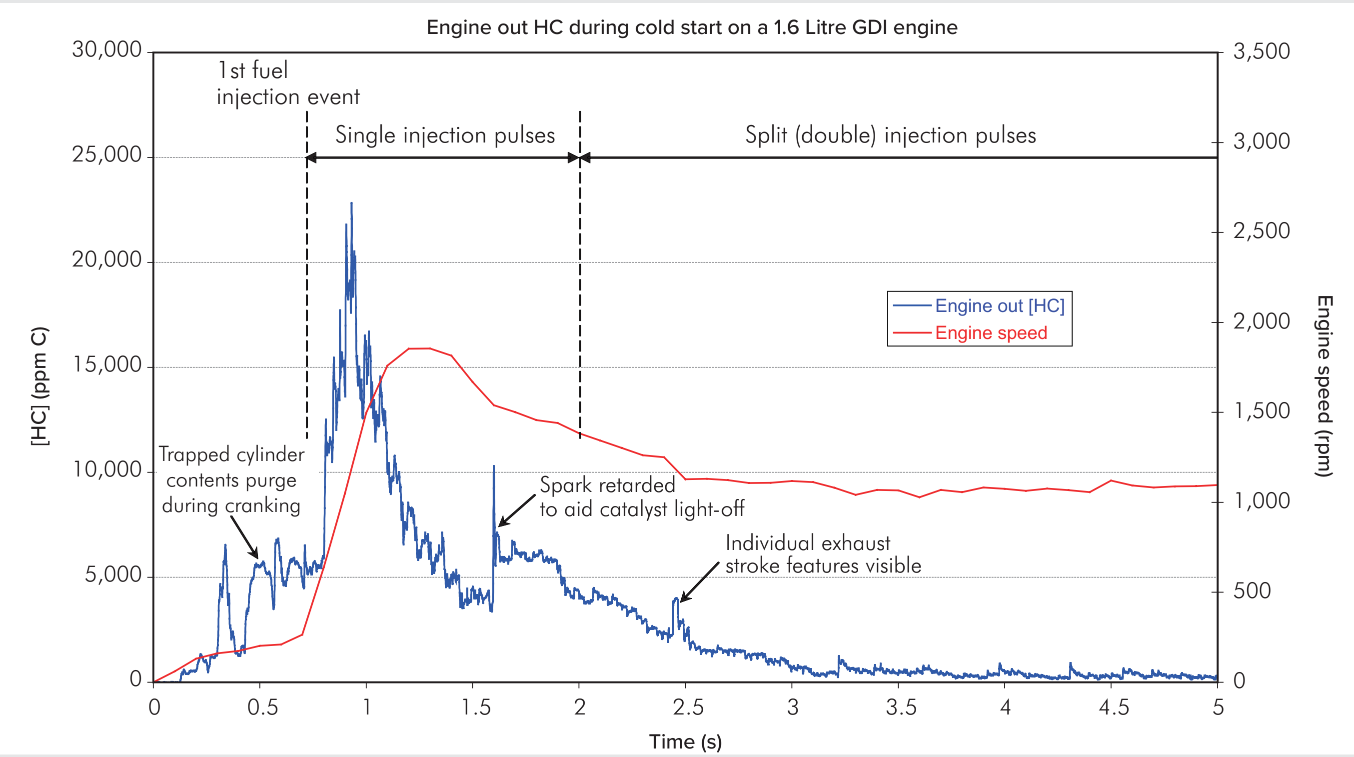
Each gas analyzer is supplied "ready to operate" with two channels as standard. Control via AK protocol, cold temperature operation, in-cylinder sampling hardware and alternative sample probe configurations are all available as options.

Applications

S.I. engine calibration

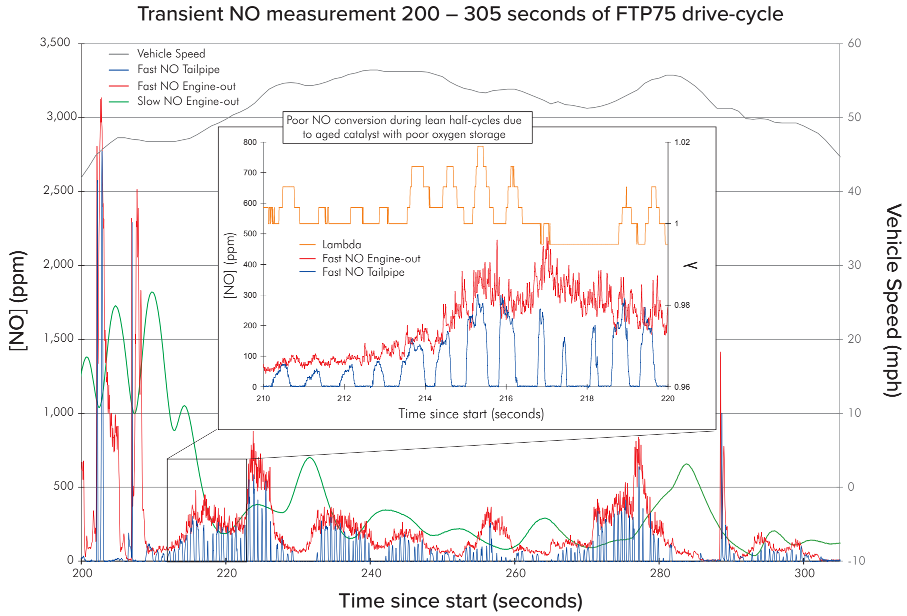
The engine start (crank and run-up lasting ~3s) followed by the early portion of a drive cycle requires complete and stable combustion to comply with current and future emissions legislation. With the aftertreatment still in its warm-up phase, the engine-out emissions generally pass untreated into the atmosphere and therefore knowledge of the combustion state from each cylinder and every exhaust stroke is desirable. The calibrator's challenges involve retarded spark timing and multiple injection pulses to promote catalyst heating, thermal inertia of the turbocharger, cold engine internal surfaces, transient fuelling and VVT system optimization. The introduction of alternative fuels can prove challenging for some existing combustion systems (especially when cold) and alternative engine calibrations for fuel injection, spark timing and valve timing can be developed using this equipment.

The HFR500 fast FID is effective at identifying such transient events as partial burns and exhaust valve leakage, whereas the NDIR500 fast CO & CO_2 analyser can be used for ultra-fast measurement of combustion λ derived from the relationships of CO & CO_2 emissions vs AFR.



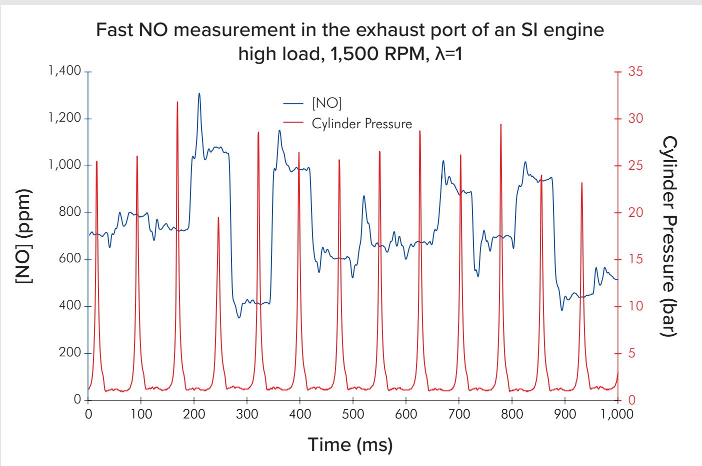
Catalyst and after treatment evaluation

The performance of catalytic converters is crucial to modern emissions legislation compliance and an understanding of the dynamic processes involved in their operation is required. Critical aspects such as light-off at cold start, O_2 storage under transient conditions, catalyst damage, flow effects and cylinder imbalance are studied from the perspective of fast gas concentration changes entering and exiting the aftertreatment system. Volume engine producers also have a strong interest in cost reduction through reducing the use of precious metals as catalyst coatings and therefore optimizing the catalyst's position, size and control of engine-out gases. The fast gas analyzers' sample probes may also be used to traverse across the front and rear faces of aftertreatment systems to check for spatial variations in conversion efficiency.



Even after the catalyst is warm, the measurement and control of NO_x in diesel engines via EGR or de-NO_x aftertreatment, plus general engine control during speed and load changes require careful calibration to avoid pollutant breakthrough or catalyst damage. Fuel economy measures such as stop/start and cylinder deactivation are also highly transient features which need careful calibration/optimization later in the drive cycle.

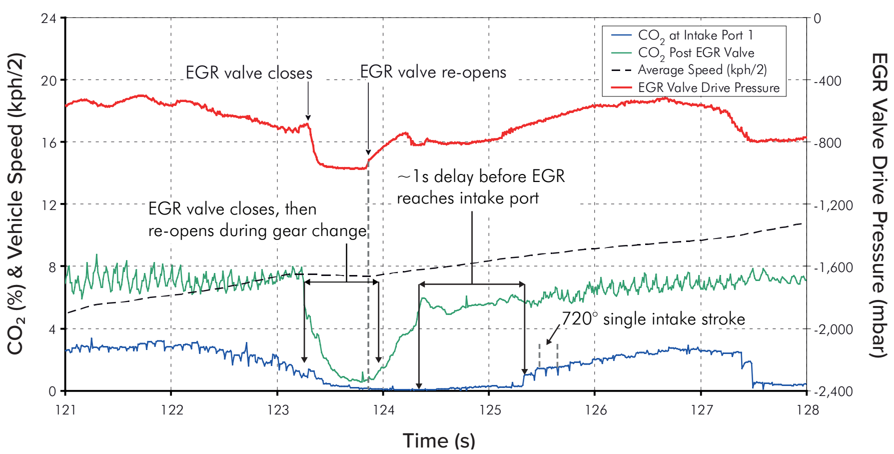
Combustion refinement and cyclic variability



Exhaust port measurement of cycle-by-cycle HC, NO_x, CO or CO_2 emissions provides insights for combustion refinement programs. The emissions from each cycle are often considered together with cylinder pressure data to enhance understanding of gas exchange, combustion and pollutant formation processes. Comparison of pollutants emerging from each cylinder during engine transients can reveal AFR imbalance (e.g. where although the total engine-out is stoichiometric at λ=1, some cylinders emit high CO and some low). Transient imbalance of EGR between cylinders is also a concern and the NDIR500's ability to sample from low intake pressure environments is a useful feature for this application.

EGR system development and control

The advent of low-pressure EGR systems promises durability and efficiency benefits over existing high-pressure EGR systems. However, the control of EGR delivery rate remains complex over the engine's operating envelope; an existing challenge for both high- and lowpressure EGR systems. The accurate and timely delivery of the correct amount of EGR is vital for both NO_x and particulate control. The NDIR500 is widely employed for the realtime measurement of EGR at various points within the EGR circuit. Transient delays and imbalances in EGR to any particular cylinder can be closely studied and the calibration thereby improved. The NDIR500 can also identify intermittent performance problems (such as sticking or blocked EGR valves).



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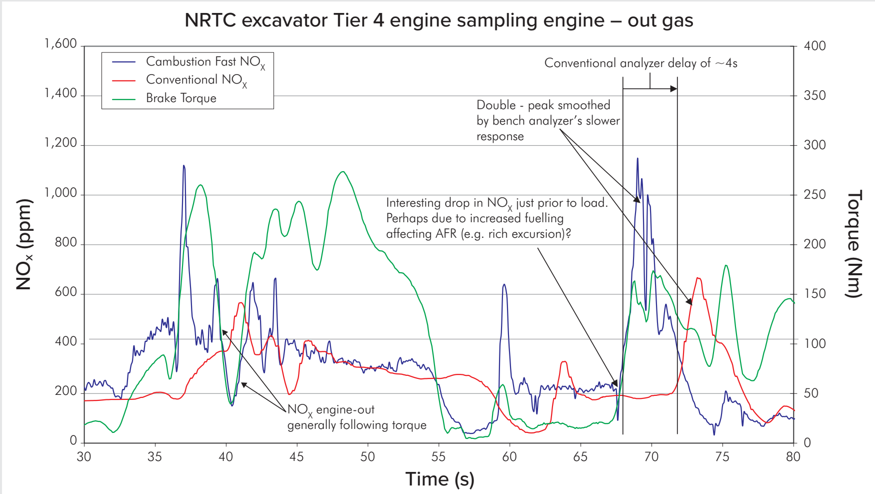
LNT and SCR system development

Lean NO_X Traps (LNTs) and Selective Catalytic Reduction systems (SCR) benefit from analysis through the use of fast gas analyzers. LNT purge is a particularly transient phenomenon where accurate control of reductants and termination of purge to minimise CO breakthrough is critical. Some systems involve very rapid rich-lean oscillations (e.g. for de-SO_X), the dynamic effects of which are too rapid for standard emissions benches to record accurately. Optimization of SCR systems via accurate measurement and prediction of engine-out NO_X is important to enhance the accuracy of urea dosing, to allow elimination of an ammonia slip catalyst.



Single exhaust stroke analyses – base engine design

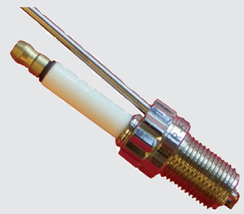
The ability to measure with such a fast time response offers a unique insight into the characteristics of a single exhaust stroke. For example, the effects of intermittent exhaust valve leakage are visible as unburned HCs appearing in the exhaust port before EVO (Exhaust Valve Open) and the effects of ring-pack and top-land geometry affect the amount of scroll-up HCs at the end of the exhaust stroke. **[See GDI Exhaust Port HC chart on front cover]**. Such measurements are only possible with an ultra fast-response FID

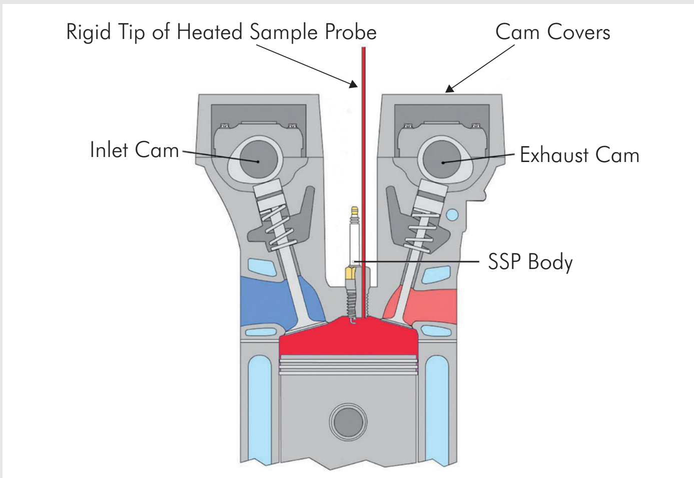
In-cylinder sampling of HC for GDI transient fuelling calibration and cold starts

Delivery of the correct quantity of fuel to the spark plug is of vital importance at all operating conditions but is a particular challenge during transients and at cold start. Sampling through a specially modified offset spark plug at moderate engine speeds (up to 1,500rpm), the HFR500 fast FID can measure [HC] within a few millimetres of the spark plug's electrodes and provide information on transient fuel delivery to aid more stable combustion.

Offset sampling spark plug

Heated sampling probe in situ

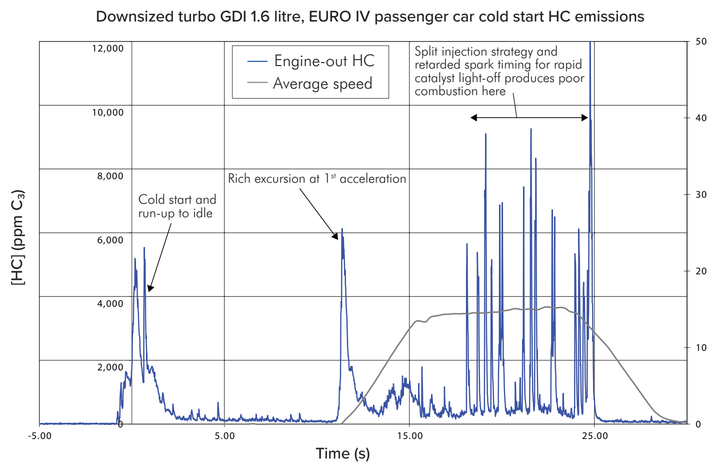




Advanced engine development

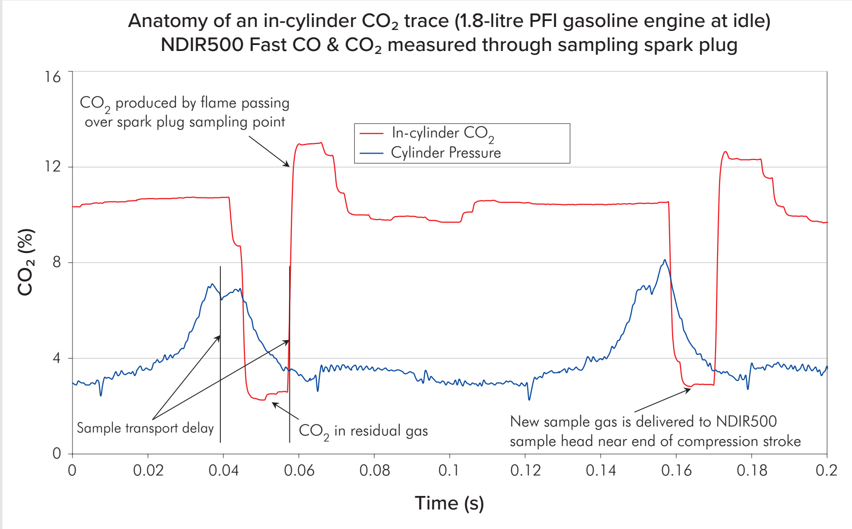
Downsized turbocharged GDI engines are widely adopted by OEMs in the pursuit of improved fuel efficiency without compromising power. The highly developed combustion strategies employed have often been researched using Cambustion equipment (both gas and particulate analyzers). Challenges associated with cold start fuel vaporisation, catalyst heating strategies, poor combustion and the possible future adoption of more transient test cycles all require fast-response analysis to facilitate a comprehensive understanding of the processes involved.

The control of advanced combustion concepts such as HCCI, CAI, stratified GDI and Miller cycles benefits from measurement of exhaust and intake port gases on fast timescales to study the gas exchange processes, cyclic variability and complex engine control requirements.

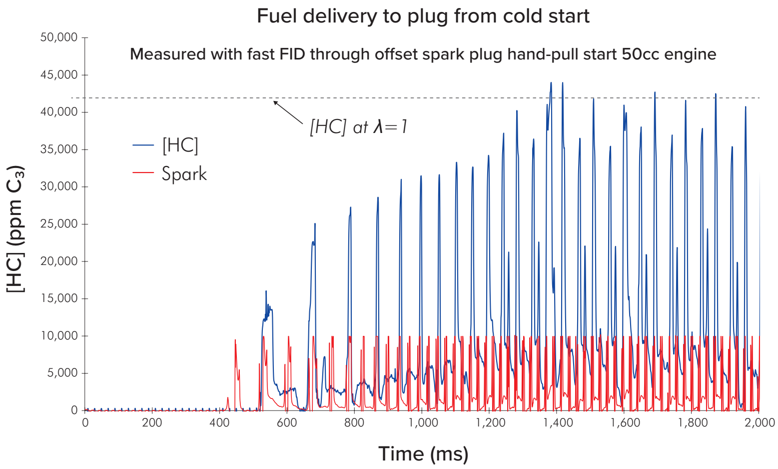


In-cylinder measurement of residual burned gases

The control of the residual burned gas content of an engine's charge is being increasingly exploited as an effective way of suppressing NO_x formation and for the operation of advanced combustion concepts such as HCCI and CAI. For engine speeds below 1,500 rpm, the NDIR500 can be used for direct in-cylinder measurement of CO_2 – aiding in the development of VVT calibrations, transient engine operating parameters, cylinder deactivation studies and cyclic variability issues.



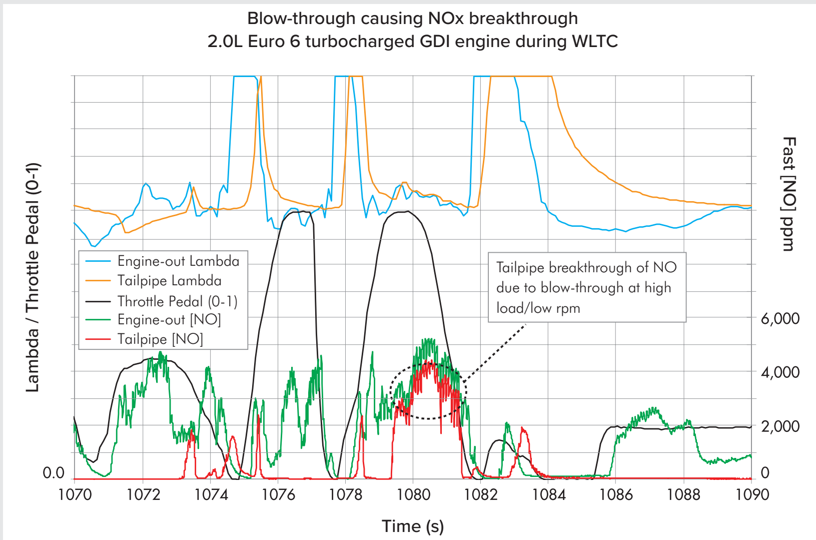
Small engine development



Current and expected emissions legislation for powered twowheelers and small utility engines is driving development of advanced combustion and aftertreatment systems, with focus on lowest-cost solutions. The relatively low sample flow rates and Cambustion's unobtrusive sample probe sizes allow easy sampling from small engines. The fast response time is particularly beneficial at high engine speeds. Customer perception of quality is often derived from the "easy start" of a small engine - especially where a manual kick or pull start is employed. The delivery of an acceptable concentration of fuel to the spark plug at cold start is a good application for the fast FID. The generally lower-cost components can also lead to issues such as intermittent exhaust valve leakage and cyclic variability. Exhaust port sampling of HC can help identify such fast transient problems.

Blow-through and scavenging

The control of residual burned gas in downsized turbocharged GDI engines is especially important at low speed and high load conditions where valve overlap is increased to purge residuals from the combustion chamber. However, the short-circuited air which accompanies this scavenging process during short duration accelerations can cause the exhaust gas to be "lean" and causes NO_x breakthrough to the tailpipe of the 3-way catalyst.



Accessories

Each gas analyzer is supplied standard with 2 independent channels including sample heads fitted to 10 metre (30ft) conduits. A tool and spares kit to match the anticipated needs of the first year of operation and a set of in-line sample filters are also included. The sample filters have a typical soot capacity of 5 hours at an average 10 mg/m3 soot concentration (corresponds to 2 g/h soot output at an exhaust flow of 250 kg/h). Other available accessories include heated sampling system conduits (for T<0 ° C sampling), control via AK protocol, in-cylinder or intake sampling hardware, extended warranty and custom length sample probes.

How fast-response gas analyzers work

Cambustion's range of fast gas analyzers are based on the industry-standard measurement techniques of: FID (for total hydrocarbons), CLD (for NO_X) and NDIR for CO and CO_2. The detectors have been miniaturized and housed in remote sample "heads" close to the sampling point on the engine. This architecture helps to yield millisecond response times. The analyzers incorporate a constant pressure heated sampling system allowing measurement from fluctuating pressure conditions including those found within the firing engine cylinder. The first of these products was developed in 1987 and fast gas analyzers are currently engaged in a wide range of gasoline, diesel and alternative fuel applications worldwide. See our alternative brochures for Cambustion's fast particulate products.

Specifications	HFR500 HC analyzer	CLD500 NOX analyzer	NDIR500 CO and CO_2 analyzer
Measurement principle	Flame Ionisation Detector	Chemiluminescence Detector	Non-Dispersive Infra-Red
Component(s) measured	Total Hydrocarbons (THC)	NO, NO_2 (with NO_2 converter)	Carbon monoxide (CO), Carbon dioxide (CO_2)
Number of channels	2	2	2
Measurement ranges	0-2000 to 0-1,000,000 ppm C1	0-100 ppm to 0 -5,000 ppm (extendable to 0 -10,000 ppm)	0-5%, 0-10%, 0-15% and 0-20%
Fastest response time T90-10% (sample probe length dependent)	0.9 ms	2 ms (8 ms with NO_2 converter)	8 ms
Zero drift	<1% FS / hour	<5 ppm / hour	<2% FS / hour
Span drift	<1% FS / hour	<1% FS / hour	<2% FS / hour
Sample gas flow (1 channel including bypass)	6 litres per minute (1 bara)	6 litres per minute (1 bara) 4 lpm with NO_2 converter	6 litres per minute (1 bara)
Power supply	50/60 Hz 100-240 V AC		
Max power requirement (single phase)	1.7 k VA	2.6 k VA	1.7 k VA
Gases required (all at 2 bar gauge)	40% H_2/He or H_2/N_2 fuel HC span gas, Zero air and N_2	NO (NO_2) span gas, N_2	2 each of CO and CO_2 span gases, N_2
Cabinet dimensions	(w x d x h) 550 x 780 x 1,140 mm including wheels		
Approx cabinet weight (incl. vac pumps)	125 kg	150 kg	125 kg
Operating conditions	0 – 40° C. Sub-zero sampling option available		
Conduit length	10 metres (detector to cabinet). Custom lengths available		
Connection to control PC	RS232 or RS485		
Test cell interface	Analog data outputs with AK and digital remote control optional		
All specifications subject to change without notice			

Technical papers involving Cambustion fast-response gas analyzers

Many hundreds of technical papers involving our products have been produced by Cambustion customers over the years, and many can be found via our website. https://www.cambustion.com/publications The papers cover various applications but please contact us if you have an application about which you'd like more information.

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