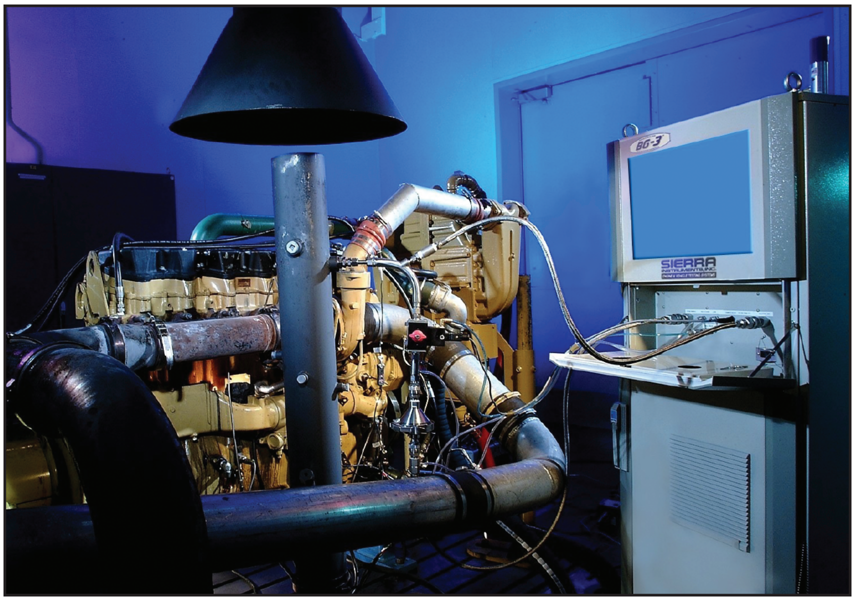
Partial Flow Sampling Systems For Transient Engine Testing



Meeting model year 2007 emissions levels for on-highway engine manufacturers is a major measurement challenge, as well as a development challenge. Especially as future off-highway engine emissions testing requirements are anticipated to include not only lower steady-state emissions levels, but also the possibility of using transient cycle data.

For on-highway engine manufacturers, meeting model year 2007 emissions levels represents a major measurement challenge. However, future off-road engine emissions testing requirements are anticipated to include not only lower steady-state emissions levels, but also the possibility of using transient cycle data.

As a result, engine manufacturers are seeking more cost-effective methods of developing engines to meet regulations regardless of their size and required test cycles. The measurement challenge for 2007 development, combined with development cost concerns for both on- and off-highway engines, have provided the impetus for improving the efficiency, accuracy and flexibility of engine test cells.

At the Caterpillar Technical Center, Mossville, Ill., new partial flow sampling systems (PFSS) are being evaluated for use in accelerating on-road engine development using transient test cycles in test cells not equipped with full-flow dilution systems. The overall goal is reduction of anticipated future expenditures by substituting raw exhaust sampling systems that provide equal or better data for the more costly full dilution tests.

The challenge is that during transient test cycles, engine speed, load, airflow and fuel flow values exhibit large variations of change over very short time frames. For example, the magnitude of engine inlet air mass flow excursions can approach 10:1 in less than two seconds. The challenge for a PFSS is to maintain constant proportional flow from an exhaust stream with a highly variable mass flow rate.

In 1990, Caterpillar and Sierra Instruments entered into a technology partnership to develop emissions test equipment. Rob Graze, senior engineering specialist at Caterpillar, said that Caterpillar granted Sierra an exclusive worldwide license to its patented microdilution tunnel design incorporated in the Transient Dilution Airflow Control system (TDAC).

Sierra Instruments, Inc./Emissions Division, Monterey, Calif., is a supplier of transient and steady state partial flow sampling systems.

"This is an example of the ongoing Caterpillar effort to make its extensive inventory of technology and know-how available through a proactive licensing program," Graze said.

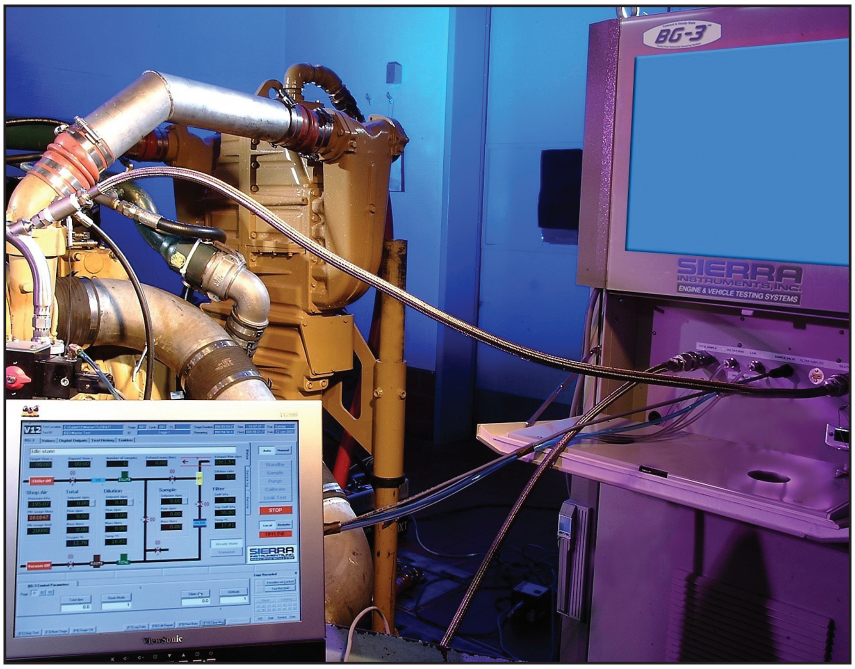
Sierra's model BG-3 with TDAC is a PFSS that provides accurate, repeatable particulate matter measurements for transient testing of all engine types and sizes. The model BG-3 utilizes a Caterpillar advanced patented dilution tunnel design and Sierra's flow apportionment, measurement and control system to execute proportional sampling effectively.

The model BG-3 utilizes overall system sampling speed and a real-time measurement of intake air or exhaust flow to ensure correlation with full-flow constant volume sampling.

In the model BG-3, conditioned dilution air is measured and controlled by a dilution air mass flow controller located in the TDAC system. A flow control valve system in a feedback loop with a fast-response intake or exhaust mass flow devices provides feedback loop control of the proportional flow control valve.

Graze said Sierra's model BG-3 with TDAC and its ancillary exhaust flow measurement instrumentation (Exhaust-Trak) will become an important development tool for Caterpillar. "Repeatable data is the key to being able to accurately quantify the small "building blocks" that represent progress toward meeting emissions goals.

"This is crucial information, as engine design and hardware changes are made during the development cycle based on those measurements. The



With the 2007 numbers looming, engine manufacturers are seeking more cost-effective methods of developing engines to meet regulations regardless of their size and required test cycles. The measurement challenge for 2007 development, combined with development cost concerns for both on- and off-highway engines, have provided the impetus for improving the efficiency, accuracy, and flexibility of engine test cells.

BG-3 has been engineered to achieve the accuracy and repeatability demands of organizations developing engines to meet 2007 and beyond on-highway particulate limits without sacrificing the flexibility required to develop off-highway engines at today's limits," he said. "The fundamental goal for BG-3 is to provide particulate measurements with a high degree of correlation to full dilution from engines against current known transient cycles."

The model BG-3 acquires raw exhaust or intake airflow data, in the form of a zero to 5 Vd.c. or zero to 10 Vd.c. signal from an air or exhaust mass flow meter, at a rate of 160 Hz. The TDAC system utilizes an operator-provided algorithm to convert the voltage signal to engine flow in pounds per hour. This information is used to specify the set points of the dilution system. This technique ensures that dilution ratios are locked in proportion with the exhaust stream for the duration of the test cycle.

The Exhaust-Trak mass flow meter is a multivariable venturi system that incorporates a differential pressure transducer, a temperature sensor, and a pressure transducer in a single device. As the raw exhaust flow accelerates through the contraction in the flow meter, the stagnation pressure of the flow is reduced. This reduction in pressure is sensed to create a flow signal, and the temperature and pressure measurements are used to calculate and output a mass flow rate signal.

Downstream of the meter's contraction is a gradual expansion, or pressure recovery section, which permits the recovery of approximately 90 percent of the pressure loss, Sierra said. The permanent pressure drop at the full-scale flow rate is less than 1 in. H_2O, and does not affect the engine's exhaust system.

Absolute pressure and temperature measurements are also available as output signals and may be used for diagnostic, calibration, or quality assurance procedures. Exhaust-Trak's speed of response is on par with the raw pressure differential signal from an intake air laminar flow element (LFE) so it is an appropriate alternative to a cell LFE for transient control of BG-3.

Transient testing standards require that engine manufacturers determine exhaust mass flow either through integration of intake air and fuel mass flow or by direct measurement of exhaust mass flow. Direct measurement of raw exhaust flow provides a means to improve the accuracy of partial flow sampling systems and enhance their correlation with full-flow systems.

The over-arching goal of the BG-3 with TDAC and the Exhaust-Trak system is to reduce the capital and operational costs of full-flow dilution testing and accelerate development and certification cycles by the use of raw exhaust sampling and measurement systems. ★