

Dynamometers
and Actuators

Vehicle Testbeds

Test Cell Mechanics
and Control Rooms

Media Conditioning

Consumption
Measurement

Injection Testing

**> Combustion
Measurement**Emission Analysis
and MeasurementIn Vehicle
Measurement

Combustion Measurement Technology

APPROACH

Based on detailed knowledge and experience in the methodology of combustion analysis, AVL has developed practical tools and devices to make the complex thermodynamic processes of an engine visible and understandable. To support all phases of development, AVL offers different solutions for different tasks in combustion development, application and calibration.

Perfectly integrated and matched components are the benefits offered to customers by the only complete combustion analysis measurement solution available worldwide.

BENEFITS AT A GLANCE

- Complete indicating measurement chain with consistent communication, the only one of its kind
- Flexible solutions for multiple applications
- Perfect integration and communication with testbed and application systems
- Data security through integration into the testbed data management system
- High precision measurement through inbuilt plausibility checks
- Open, homogeneous solutions for user-specific adaptations

TASK

Today, legislation acts as a major driving force in the automotive market and is largely responsible for current development needs and trends.

In the future effective drive systems with the lowest pollutant emission possible at moderate costs will be in high demand for all engines sizes. At the same time, the market is changing rapidly as a result of new manufacturers of engines/models appearing on the market and intensifying the competitive pressure on all OEMs.

All these circumstances lead to a general trend of radically shortened development cycles. Combustion analysis will increasingly become a central test focus again, because future engines will have to incorporate several combustion concepts in parallel. Therefore, all test engineers, calibration engineers and development engineers, as well as test-field managers, are facing increasing complexity.

Engineers also face new challenges in the need for stronger interaction and correlation between combustion analysis results in engine automation and control systems faster than ever before.

REFERENCES

All Application Fields

For basic engine calibration, optimizing fuel consumption or emissions, combustion noise and mechanical diagnostics, optimizing engine performance or developing new combustion methods: AVL equipment is used worldwide whenever detailed information about the combustion process is needed.

Certified Product Development Process

The AVL combustion analysis software AVL IndiCom™ is developed using the certified software development process CMMI. CMMI monitors the development in terms of time, budget and, most importantly, achieved quality.

In-House Powertrain Engineering Experience

All AVL combustion analysis tools are practically tested and optimized in close cooperation with our in-house powertrain engineering teams. This is the key to offering products of the highest quality and reliability, another unique benefit for our customers.

Installed Base

Problem-solving competency based on AVL's extensive experience in combustion analysis and the fact that AVL is the only manufacturer of a fully indicating measuring chain make AVL the customer's preferred choice and the market and technology leader for high-end combustion analysis.



DUE TO COMBINED USE OF INDICATING AND VISUAL METHODS, I NOW UNDERSTAND THE PROCESSES INSIDE THE COMBUSTION CHAMBER.

TESTING EQUIPMENT

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Consumption Measurement

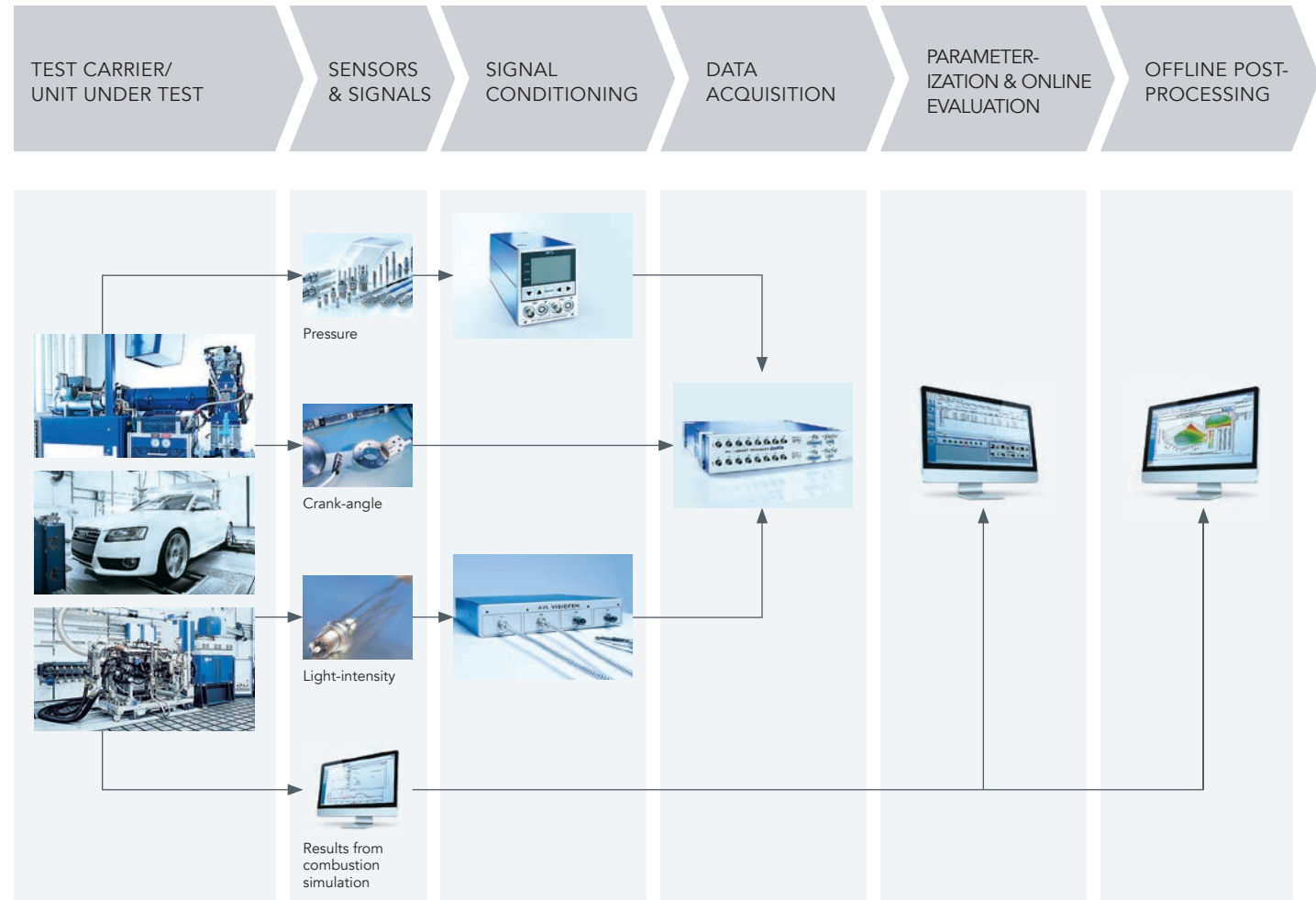
Injection Testing

> **Combustion Measurement**

Emission Analysis and Measurement

In Vehicle Measurement

Complete Measuring Chain for Combustion Analysis



Single Cylinder Research Engines and Testbeds

AVL single cylinder engines and AVL single cylinder testbeds are used for combustion and basic research as well as for visualizing fuel injection and combustion phenomena with transparent access to the combustion chamber (via a glass liner fitted to the cylinder head). The benefit is that the prospects of success are tested under realistic engine conditions long before the concept is applied to the full engine.

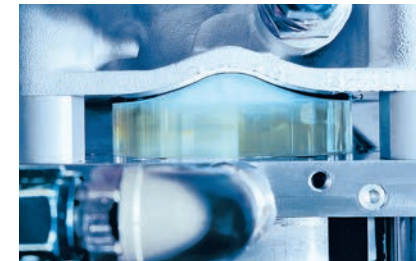
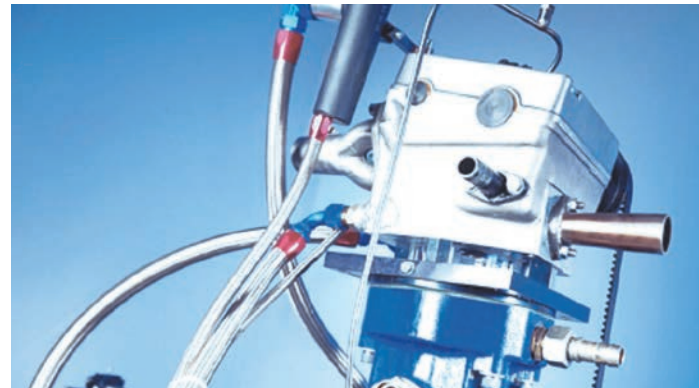
Single cylinder engines cover a range from small passenger car engines up to heavy duty truck engines. Given their modular structure, they are suitable for standardized, fully-equipped engines as well as one-off, customized solutions for all scales.

APPLICATION

Typical applications for single cylinder research engines and testbeds are: combustion development, injection development, flow studies with laser measuring methods (basic research), lube oil development, fuel development, alternative fuel research and investigations on gas engines and heavy fuel engines, as well as friction evaluation of the piston-liner-group.

OVERVIEW OF RESEARCH ENGINES

VARIANT	BORE	STROKE	DISPLACEMENT	REV. SPEED	PEAK PRESSURE
Series 540 Car Size	65 mm to 100 mm	60 mm to 95 mm	0.2 l to 0.75 l	8,000 rpm	200 bar
Series 580 Light Duty Size	80 mm to 110 mm	90 mm to 130 mm	0.45 l to 1.2 l	5,000 rpm	200 bar
Heavy Duty Size	110 mm to 145 mm	120 mm to 170 mm	1.2 l to 2.8 l	3,000 rpm	300 bar



BENEFITS AT A GLANCE

- Single cylinder compact testbeds (including dyno and more) as cost-efficient compact systems and turnkey solutions
- Ideal combination of testbed and research engine for professional operation of single cylinder engines
- Robust design of engines for peak demands under extreme conditions
- Exact replication of customer-specific multi-cylinder engines ensure excellent correlation to the production engine
- Possibility of extensive combustion R&D projects at AVL's internal transparent engine laser laboratory and application support from AVL experts

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SIMULATION TOOLS

TESTING TOOLS

CUSTOMER SERVICES

Sensors for Combustion Analysis

AVL offers piezoelectric pressure sensors in all typical dimensions from M5 to M14 for a wide range of applications at the engine. AVL uses the unique piezoelectric crystal GaPO_4 for uncooled and most water cooled sensors with its outstanding thermodynamic properties. The AVL sensor portfolio includes solutions for absolute and low pressure measurement as well as needle and valve lift measurement. Manifold crank angle encoder solutions specifically designed for specific types of application are used to make a precise measurement of crank angle signals.

APPLICATION

- The precise AVL pressure sensors are most often used for the thermodynamic analysis of combustion engines
- The robust AVL pressure sensors are most often used for calibration or endurance test of combustion engines
- The new AVL spark plug solutions, available in sizes M10x1, M12x1.25 and M14x1.25, with a broad range of heat values and spark protrusions, are easily adaptable and fulfil the requirements for high measurement precision and highest ignition voltage demands. They are, therefore, best suited for in-vehicle applications as well.

AVL crank angle encoders of the 365 series are available in different designs: The 365C for standard mounting at the free crankshaft end, the 365X for mounting at the shaft between engine and dyno; or the 365R ("massfree marker trace") especially designed for racing applications, small engines or engines with limited direct access to the crank shaft.



In addition to pressure signals robust and highly accurate crank angle signals are a basic requirement for high quality combustion analysis. Therefore, AVL offers solutions for simple and flexible installation with angle encoders of the series 365.

BENEFITS AT A GLANCE

- Maximum precision and outstanding thermodynamic properties due to the unique piezoelectric crystal GaPO_4 , Double Shell sensor housing
- Integration of all piezoelectric pressure sensors in AVL SensorDataManagement SDM™
- Flexible sensor solutions for manifold applications
- For highly demanding applications like super charged engines, special sensor types are offered with extremely high robustness and durability

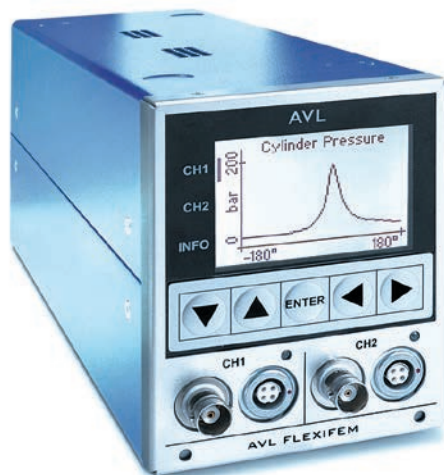
Indicating Amplifier Solutions

The FI Piezo and FlexIFEM product families enlarge AVL's indicating amplifier product range to include an additional intelligent amplifier concept. FI Piezo and FlexIFEM are able to provide the first indicating results cycle by cycle in addition to the measured signals, so offering a wider range of applications for the engine engineer.

APPLICATION

The applications of the MicroIFEM range from cylinder pressure to the measurement of piezo-resistive signals (e.g. low pressure indicating). The FI Piezo and FlexIFEM can additionally be operated on a stand-alone basis (integrated front display). Furthermore, all variants of all indicating amplifier families can be operated stand-alone (via stand-alone parameterization software) or optionally remotely controlled (via AVL IndiCom™).

Typical application fields for all three product families are research, light-duty development, heavy-duty development, large engines and racing applications. In addition, the FI Piezo and FlexIFEM are



The AVL MicroIFEM is the reliable, modular and advanced amplifier concept and is best suited to applications directly at the testbed and in-vehicle

suitable for endurance testing (engine monitoring on the testbed and in-vehicle), for in-vehicle performance testing (engine protection) and for use on large engines for on-board measurement.

The FlexIFEM Noise is a stand-alone device for combustion noise analysis, best suited to benchmark activities or as a reference noise meter through the complete development process. The new FlexIFEM Knock is the stand-alone knock monitoring device, which can be used for durability tests or as a reliable engine protection for R&D activities.

BENEFITS AT A GLANCE

- Peak pressure monitoring without indicating system (calculation results at stand-alone FI Piezo or FlexIFEM)
- Best suited for stand-alone usage due to integrated parameterization, front display and monitoring functionality (including limit detection and alarm signals)
- Maximum data quality due to full support of AVL SensorData Management SDM™ in all amplifier families
- Cost effective, as a result of scaleable channel configurations for single FI Piezo, FlexIFEM, MicroIFEM or cascaded systems

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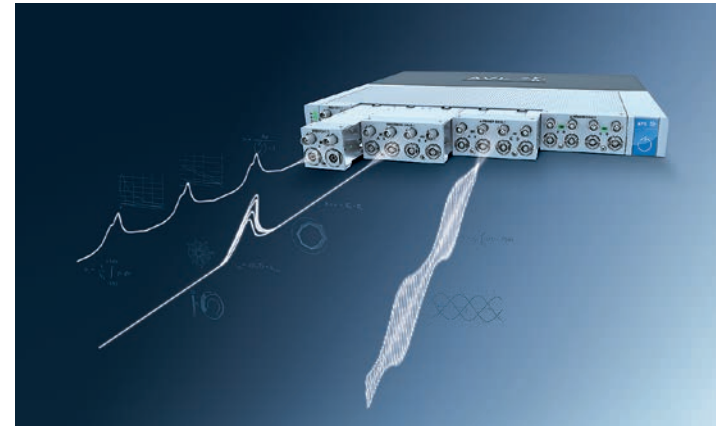
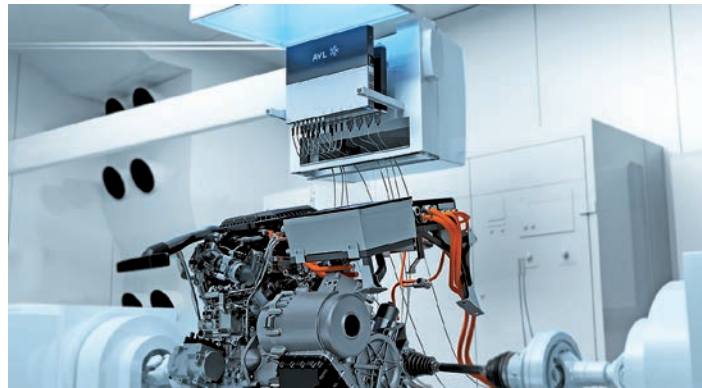
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ADAPTS. ACQUIRES. INSPIRES.

AVL X-ion™**THE MODULAR DATA ACQUISITION PLATFORM
FOR HIGH-SPEED APPLICATIONS**

AVL X-ion™ is the new high-speed data acquisition platform dedicated to powertrain development. AVL X-ion™ is a modular acquisition system that can be easily adapted to different units under test and test environments. It combines AVL's know-how and expertise in several application areas, such as indicating, optical combustion analysis, and e-Power analysis.



Powered by the well-known software AVL IndiCom™, which can be used for crank-angle and time-based acquisition tasks, AVL X-ion™ helps reduce the number of tools in the test environment and in the office, which strongly increases testing and post-processing efficiency.

Its unique modular concept – it can host up to 8 application-oriented “X-FEM” front-end modules combining analog-digital converters and signal conditioning – enables time reduction for changeover and retooling on the testbed. The possibility to deeply investigate not only combustion engines, but also e-motors or hybrid powertrains, also means stress-free transition to electrification.

THE ADDED VALUE

- Increased efficiency based on reduced number of tools in the test facility and in the office
- Enables testbed versatility, reduces changeover and retooling times
- Stress-free transition to electrified powertrains
- Future-proof investment thanks to evolutionary module concept



Decreasing emission limits and increasing demands on driveability cause information for verifying and optimizing combustion processes in vehicle application that make new demands on combustion measurement technology



Mobile Indicating Systems

The AVL IndiMicro sets a new benchmark with regard to compact combustion measurement technology. Due to a high level of flexibility, there are unprecedented mounting possibilities for a broad range of mobile applications. This device can also be used in stand-alone operation for the output of indicating parameters via real-time CAN interfaces.

The AVL FlexIFEM Indi is a one or two channel indicating system with integrated charge amplifier and, therefore, a scaleable solution for testbed applications, upgraded by default with software and hardware settings for the best acquisition and calculation capacities. The device can be used in stand-alone operation by its integrated display enables permanent monitoring of the pressure signal. Cascading of devices lead to a compact solution, optimized for multichannel in-vehicle applications.

YOUR BENEFITS AT A GLANCE

- Ideal for base calibration of the engine, engine monitoring and development
- Flexible use due to application packages for gasoline and diesel engines
- Compact design for in vehicle use
- Direct integration into the application system (INCA)
- Functionally expandable for the measuring tasks of tomorrow

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COMBUSTION EXCELLENCE
AVL IndiCom 2™

Combustion engine and drivetrain development is quickly increasing in complexity. At the same time, development cost and time pressure are escalating. Understanding the combustion processes and the influences of the many engine parameters are the key to optimizing modern engines and using their full potential. The current product generation AVL IndiCom 2™ is the answer to these increasing demands for even more flexibility and performance where powerful calculation tools, measurement automation and professional visualization are combined with an easy-to-use interface.

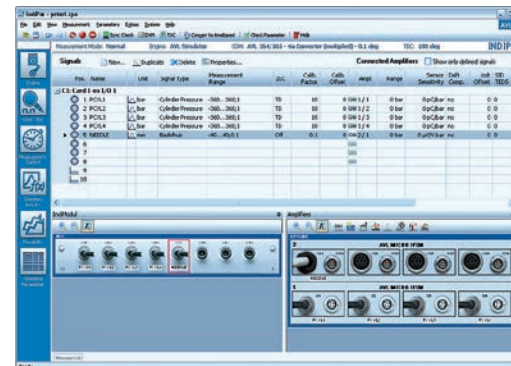
APPLICATION

Measurements for all applications, ranging from standard combustion measurements to continuous monitoring, model-based calibration (with AVL CAMEO 3™), cold start and vehicle testing, optical flame evaluation and more, are possible with AVL IndiCom 2™. It is built to cover even future applications due to powerful real-time calculations and flexible and customizable online calculations (based on CalcGraf). The integration in any test cell automation environment is supported by tailored and generic interfaces. In addition, the full compatibility with generic post-processing tools like AVL CONCERTO 4™) also increases the range of possible applications.

The specific software extension AVL GCA (gas exchange and combustion analysis) is used online at the testbed for indicating purposes with AVL IndiCom 2™. Results provided by “GCA online” are immediately available in order to perform automated calibration e.g. at low-end torque. AVL GCA is also used offline in conjunction with AVL CONCERTO 4™ in the office and is designed for the detailed analysis of the combustion process and gas exchange, delivering additional results that cannot be measured on the testbed (e.g. air fuel ratio inside the combustion chamber or residual gas). The calculation can also be carried out for dynamic operation. AVL GCA is seen as a virtual sensor based on the proven calculation kernels of AVL BOOST.

BENEFITS AT A GLANCE

- Reduced measurement preparation time and easy-to-use advanced functionalities via the workflow-oriented user interface
- Supports the engineer to make fast and informed decisions based on professional evaluations and clear presentations
- Fast and efficient problem-solving in development and calibration through the unique combination of conventional pressure-based and new optical-based combustion analysis
- Seamless combination of measurement and simulation with AVL IndiCom 2™ and AVL GCA (gas exchange and combustion analysis)
- Integration in any test cell automation environment supported by tailored and generic interfaces



AVL Visiolution Systems Optical Access to the Engine

With the help of optical measuring methods, a detailed insight into the complex processes of fuel mixture and combustion beyond the findings of the pressure indicating method can be achieved. AVL Visiolution technology helps users understand the whole process in detail and, therefore, provides the right tool for improving performance in terms of fuel consumption, mixture formation, exhaust emission and engine power.

The system is based on indexing in the combustion chamber. AVL Visiolution technology provides the perfect tool for flame evaluation, thermal radiation and injection monitoring, making complex processes clearer.

The formation of pollutant emission in transient operation becomes understandable. Engineering duties are finished in record time and with utmost precision.

MEASURING PRINCIPLE

Visioknock/VisioFlame/VisioTomo: Special spark plugs or head gaskets equipped with glass fibers allow optical access to the combustion chamber. This allows observation of flame propagation, localisation of knocking sounds and access to combustion patterns.

VisioFEM: cycle-precise, cylinder-specific recording of phenomena that contribute significantly to pollutant emissions

VisioScope: carburetion, fuel injection, soot formation and temperature distribution are recorded by endoscope and camera

BENEFITS AT A GLANCE

- Measurement in highly transient operation
- Best suited for exploring injection strategies
- Finding critical emission cycles
- Engineering mixture formation
- Evaluation of flame propagation
- Evaluation of thermal risk
- Detect potential for knock limit improvement
- Detection of root causes of irregular combustion
- Cold start/tip-in/tip-out emission evaluation
- Services covering the whole Visiolution range
- Perfect interface to existing AVL indicating chain



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AVL EPOST™ – Main Window GUI



PREDICTABLY POWERFUL
AVL EPOST™

AVL EPOST™ (Engine Performance Optimization System) is AVL's condition monitoring platform for large engines. The AVL EPOST™ system has a winning pedigree: it combines class-leading R&D measurement technology developed by AVL with expertise from large engine and combustion engineers from the world's leading independent powertrain engineering and measurement company, AVL.

AVL EPOST™ and related services are designed to support engine operators by

- Increasing engine efficiency and reducing fuel consumption
- Preventing engine damage and downtime by continuously monitoring the condition of your engine
- Reducing maintenance and service costs
- Monitoring engine emissions (AVL EPOST™ NO_x Module)

AVL EPOST™ – THE PLATFORM

AVL EPOST™ provides expert condition monitoring based on automated engine diagnosis for large combustion engines and their auxiliaries. This condition monitoring platform is unique – by using expert algorithms, AVL EPOST™ provides valuable information at a glance, regarding imminent malfunctions or failures of the engine.

In comparison to other engine condition monitoring systems on the market, AVL EPOST™ does not leave the evaluation and analysis of data solely to the engine operator. The 'traffic light' indicators will tell you the condition and efficiency of your engine, and the system provides explicit root cause information. Further screens show measurement data and diagnosis results in different detail and depth.

AVL MEASUREMENT HARDWARE – THE BACKBONE

The primary source of information of the system is the cylinder pressure measurement. However, any other source of information can be used and integrated into the system.

AVL provides cylinder pressure sensors for continuous monitoring (GO series) connected to a smart indicating unit (SIU) for efficient data acquisition. Sensor lifetimes of more than 50,000 h for HFO and 25,000 h for gas operation have been reliably achieved until now.

AVL EPOST™ is designed as an open diagnosis platform by being able to accept the systematic integration of third part sensors, systems, or information.

AVL EPOS™ NO_x MODULE

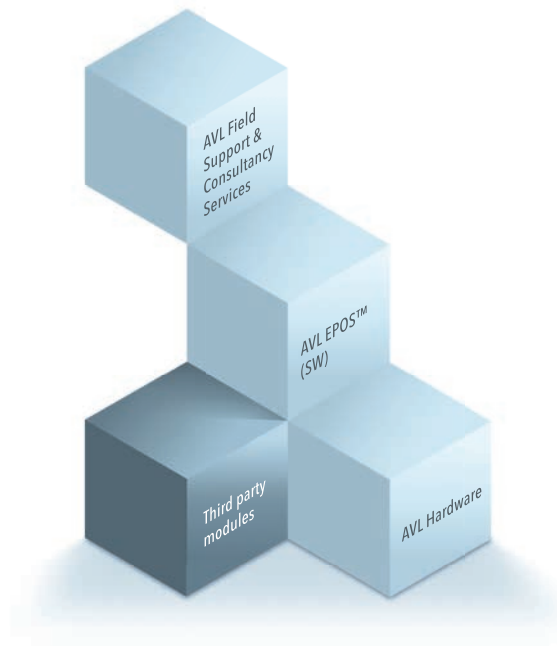
AVL EPOS™ NO_x Module is the world's first model based expert system for emission monitoring (currently covering NO_x, SO_x and CO₂) for large-bore engines in all applications.

Since current emission analyzers are expensive, sensible and often (under long-term perspective) unreliable in the difficult environment they need to operate, AVL's approach is to determine the NO_x emission with the help of a physical model based on the cylinder pressure measurements and the derived combustion analysis. This model can be integrated as part of AVL EPOS™ or installed as a standalone system.

The system is suitable for continuous monitoring of NO_x emissions to comply with the requirements of MARPOL Annex VI and NTC 2008 (confirmation of compliance by DNV GL).



AVL Smart Indicating Unit and
AVL Cylinder Pressure Sensor
for Continuous Monitoring
(type approved by GL)



AVL SERVICES – THE DIFFERENTIATOR

In addition to software and hardware, AVL also offers extended engineering and consultancy services on a regular basis for continuous system optimization and for trouble shooting:

- Tuning recommendations based on detailed analysis of engine measurement data from field operation
- Training on AVL EPOS™ to get the maximum benefit out of the system
- On-site engine inspection (e.g. analysis of engine damage)
- Advanced engine analysis including simulation investigations (CFD, gas exchange, FE analysis etc.)