LARGE BORE ENGINES
FEV is an internationally recognized leader in the design and development of internal combustion engines and supplier of advanced test and instrumentation systems. Founded in 1978, the company today employs a staff of over 1300 highly skilled research and development specialists. FEV offers a complete range of engineering services, providing global support to customers in the design, prototyping and development of advanced gasoline, diesel and alternative propulsion systems, e.g. fuel cells. In addition, FEV provides engine integration and vehicle calibration services.

We offer new technologies, which address future emissions and fuel economy standards while fulfilling market demands for engine performance and acoustics. In performing these services, FEV meets customer requirements for shorter development schedules, high quality and reduced costs.

The company supplies some of the world's most advanced engine testing systems ranging from combustion analysis to fully automated test benches.

FEV enjoys a close working relationship with automotive, heavy-duty and industrial engine manufacturers, worldwide, as well as with their supply base. In addition, FEV supports the mineral oil industry, heating system manufacturers and conducts advanced research and development programs for governmental agencies.

World Headquarters and the European Technical Center are located in Aachen, Germany. FEV’s North American Technical Center is located in suburban Detroit, Michigan.
Full range engineering service supplier for gasoline and diesel engines as well as advanced powertrains

- Large database of over 200 modern engines (benchmarking programs)
- Supplier of advanced test facilities including end-of-line test benches
- Close working relationship with Germany’s largest technical university

FEV Headquarters, Aachen, Germany

FEV Vehicle Application Center in Cooperation with GIF, Alsdorf, Germany

North American Technical Center, Auburn Hills, Michigan, USA

Engineering Center, Dalian, China
FEV designers have access to more than 90 fully equipped design workstations using all important CAD systems on several platforms. In today’s marketplace, innovative designs can be implemented only if they can be manufactured efficiently and at reasonable cost.

As a consequence, FEV evaluates manufacturability issues as well as the potential for reuse of high investment cost tooling. These studies are part of the design and development process.

To support a quick and cost effective development process, most engine designs today conducted as 3D CAD designs. This enables provides the requested geometry models for different analysis tasks, e.g. structural analysis or CFD calculations, plus enables to deliver 3D geometry information to pattern makers early in a development project. Accordingly, modern analysis and rapid prototyping tools are fully integrated into the design process at FEV.

To guide and confirm the concept and design work, FEV applies many years of proven project management and quality control process experience. Especially for large bore Diesel engines, the design for six sigma process (DFSS) has been applied successfully in the past.
The design teams are working worldwide in close cooperation with the suppliers of components and they are also responsible for the procurement of prototype components.

In order to provide our customers with excellent development support, FEV has developed a new large bore single cylinder test engine, which is used for the investigation of advanced combustion system technology, as well as mechanical development of engine components.
Today’s product engineering and development market demands rapid analysis, advanced development capabilities and extremely high levels of precision.

Model-based structural analysis has become the standard approach in an industry where development time has become a driving factor. Where many structural features were traditionally verified through empirical testing, today’s analysts routinely apply state-of-the-art analytical tools in their work.

Early in the development of a new structure, Finite Element Analysis (FEA) provides a means of optimizing the design with regard to thermal and mechanical loading, deformation, weight and material choice. FEV works to ensure results by combining the designers’ geometrical input with information about the proper boundary conditions that are provided by FEV’s process simulation teams. In addition, FEV maintains an extensive database of engine and component test data, which can be applied to ensure the accuracy of the predictions.
FEA is used extensively in the thermal and mechanical analysis of the cylinder head, liner and crankcase. For the layout and dynamic calculation of connecting rods, pistons, crankshafts and bearings, the use of advanced simulation tools like MBS in combination with EHD today is inevitable.

Design calculations within FEV’s technical community are enhanced by extensive practical experience with a large number of different types of engines.

Realistic FE calculation results require detailed consideration of the non-linear behavior of engineering materials as well as the temperature dependencies.

FEV uses a variety of engineering software packages that have been widely adopted by the automotive and related industries. Every effort is made to perform analyses for our customers to their own specifications.

FEV is continually investing in its infrastructure to ensure that state-of-the-art computing platforms are available for performing advanced analysis and engineering work.
Within the comprehensive gear and valvetrain development procedure, cinematic calculations as well as dynamic simulations provide the necessary information about the load and stress levels. Finite element techniques, commercial multi-body simulation tools and FEV-owned calculation routines support the different development tasks.
Lubrication,
Cooling, Ventilation

The layout and design of the fluid systems requires quick and powerful simulation tools to support the design of new engines right from the start of the development.

Complex one-dimensional simulation models also allow the investigation of various virtual concepts and assist in the decision to develop the most promising concept.

The real geometry of each fluid system and the hydraulic and thermal characteristics of the relevant components are reflected by predefined functions or based on measurements by polynomial expressions.
FEV’s NVH department is structured into functional teams, corresponding to the variety of noise and vibration problems, e.g. engine noise and dynamic structural analysis.

FEV’s CAE-based dynamic analysis of the excitation mechanism and structural behavior has been developed during more than 10 years of experience on more than 100 different engines and powertrains. Close cooperation in aggressive joint development programs with various manufacturers and suppliers has resulted in the evolution of specialized techniques for problem solving and rapid evaluation of potential solutions.

Proven methodologies and development targets are agreed upon before launching a project; as the project proceeds, modeling techniques and parameters are discussed in advance with the client’s design and development teams.

FEV can ensure practical and reliable design improvements as program deliverables, which directly address the project goals.
The best NVH designs are achieved when joint cooperation is ensured at a very detailed level during the earliest phases of the propulsion system development process. By designing for best-in-class NVH from the beginning, FEV helps customers avoid modifications once the design is near production.
For more than a decade, FEV's Engine Thermodynamics department has supported its clientele with a team of skilled engineers, each dedicated to serving the individual needs of our diverse client base.

In the Concept Phase, the major technical features of the final product are defined. In this phase, FEV's Engine Thermodynamics department supports its clients by assessing the potential benefits of multiple boosting concepts and carefully analyzing market trends to predict the viability of a new design or product. Alternative engine concepts can also be demonstrated. Any charging system can be intensively examined from state-of-the-art turbocharging to controlled two-stage turbocharging or combined turbocharging systems.

FEV routinely conducts analyses in support of the effort for layout of base engine geometry. Once all of the possible factors influencing the outcome of a design effort have been assessed, the potential advantages and disadvantages concerning fuel consumption, performance, complexity and transient behavior are quantified and a reliable technical basis for a decision, in keeping with market trends, is presented to the customer.

In the Design Phase, FEV's Engine Thermodynamics department provides a detailed layout of the complete intake and exhaust systems of the engine. This layout can include numerous efforts: Advanced boosting systems with super and turbochargers are matched with GT Power or CATS. The optimization of the gas exchange process and valve timing are carried out in accordance with the specifications of the client. Problems, for which a one-dimensional simulation is insufficient, are solved by an integrated calculation that uses the 3D code, Star CD and GT Power.
Any complex gas flow within an engine can be simulated by CFD. Optimization of coolant water jackets simulations are conducted with 3D simulations of the coolant water flow. This analysis is closely coupled with FEV’s FEM analysis. To support swirl and flow optimization on the flow test bench, the intake port and the in-cylinder flow are calculated with 3D code, Star CD. This transient flow field is the basis for subsequent investigations of spray penetration, mixture formation, ignition and combustion. All the layout work is simultaneously engineered in close cooperation with either FEV’s or the client’s Design, NVH and Mechanical Development departments.

In the Experimental Development Phase, FEV’s Engine Thermodynamics department provides its clients with detailed thermal analyses and fine-tuning of gas exchange systems.

Using indicated pressure traces and appropriate mean values, a very detailed calculation model is adjusted to match expected prototype behavior. Afterwards, the gas exchange process and charging system is fine-tuned to the customer’s expectation. Detailed analyses of existing engines are carried out to detect weak points and to show further areas of potential improvement.

The combustion process is analyzed in detail with regard to heat release rate, thermal losses and nitrous oxide formation.
FEV has been involved in the development of Diesel combustion systems for more than 20 years. In the past, the main focus was the improvement of performance and fuel efficiency. Whereas today, the effort is concentrated on the reduction of exhaust emissions while maintaining or even improving specific power output and fuel efficiency.

A central task of the Diesel combustion development is the investigation of new injection strategies, such as pilot, split, and multi-event-injection, which requires modern, highly flexible injection systems.

The test cell investigations on the fired engine are supported by intensive analyses utilizing simulation tools for combustion process interpretation, such as burning function and heat release calculation as well as fuel spray penetration computations.

FEV also provides special services, such as engine certification and emission deterioration measurements.

Starting with the first sketch for a new combustion system layout, FEV engineers are focusing on optimum bowl design and fuel injection system characteristics, to achieve little spray-wall-interaction for low soot emission and a fast, but well balanced burn rate. Since NOx reduction is a major requirement for the improvement of Diesel exhaust emissions, water injection and water emulsified fuels have always received attention from engine developers. Today, FEV can offer its clients a comprehensive knowledge of technical solutions for using water injection/water emulsified fuels and provide feasible solutions for the specific requirements and problems of water emulsion.
FEV, by tradition, has always been involved in the development of gas engine combustion systems. Due to their excellent exhaust emission quality, these engines have achieved a high degree of acceptance for stationary power systems and for city bus applications.

Based on long-term research and development programs and with the expert knowledge of numerous gas engine development projects, FEV offers high level support for all gas engine related development tasks. Apart from prechamber combustion, a system called ATAC (Advanced Turbulence Assisted Combustion) has been developed, which provides the potential to achieve full load performance similar to Diesel engines and combined with extremely low exhaust emission levels.

Large bore Diesel engines for stationary, locomotive and marine propulsion systems will soon need to comply with the same reduced exhaust emission standards that high-speed truck and industrial Diesel engines have to meet today. In order to provide our customers with excellent development support, FEV has developed a new large bore single cylinder test engine, which is used for the investigation of advanced combustion system technology, providing both excellent fuel efficiency as well as reduced exhaust gas emission targeting the emission standards of 2008 and beyond.

### Roadmap Large Bore Engines (var. Speed/Load)

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<tr>
<th>FIE</th>
<th>EUPS ≥ 1600 bar</th>
<th>EUPS 2-Valve Rate Shaping</th>
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<tr>
<td>EUPS 1600 bar</td>
<td>EUPS 1800 bar</td>
<td>EUPS 1-Valve Rate Shaping (Piezo)</td>
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<tr>
<td>CR Single Inj. 1800 bar</td>
<td>CR multi Inj. &gt; 1800 bar 1600 bar</td>
<td>CR Rate Shaping (Piezo)</td>
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<td>Fix Geometry p₁/p₄ &lt; 4,5</td>
<td>Fix Geometry p₁/p₄ &gt; 4,8</td>
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<td>Charging System</td>
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<td>Auxiliary Blower (Cruise Liner)</td>
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<td>Var. Hydr. Valvetrain (4-stroke)</td>
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| 2000 | 2005 | 2008 |