After eight successful years with the R170 model, the new SLK has taken over the pole position in the compact two-seat roadster market segment. In October, 2004 the world will witness the introduction of the new, top-of-the-line Mercedes-AMG model, the SLK 55 AMG. The highlight of the latest Mercedes-AMG SLK is its athletic heart, the 265 kW/360 HP and 510 Nm making it the only V8 engined vehicle in that class. The engine provides even the most discerning automobile enthusiast an appropriate adrenaline rush in response to its impressive acceleration. To keep this power under control, the SLK 55 AMG is equipped with newly-developed, racing specification compound front disc brakes. The new 7-speed AMG automatic transmission (SPEEDSHIFT) further supports its sporty image through tuning and the potential to make rapid gear changes – offering the driver the flexibility to operate it like a manual transmission through the AMG steering wheel pushbuttons.

The knock control application was performed on an AMG test bench, as a part of the contract. FEV supported the customer with manpower and a complete FEV Indication System CAS (Combustion Analysis System), which has been designed by FEV-GM, an FEV business unit responsible for test equipment. This
system provides the usual indication technology and an integrated knock analysis with real time functionality. The complete system unit is intended for both stationary test bench and mobile vehicle operation. The resulting mapping and the dynamic functionality of the knock control was verified on the test track in Papenburg, Germany.

The real prowess of the SLK 55 AMG is the powerful V8 engine. Development of this engine by Mercedes-AMG GmbH represents a continuation of its successful cooperation with FEV Motorentechnik GmbH.

The cooperation for the development effort was realized through the following program:

- Stationary and dynamic mapping of the knock control
- Emission calibration for EU 4 and LEV II legislation
- Calibration of driveability functions
- Calibration of diagnostic package for EOBD (Europe) and OBD II (United States) MY 2005/2006
- Generation of OBD Threshold Catalysts for EOBD and OBD II with FEV aging process
- Participation in customer test trips in Sweden, Spain, United States and South Africa

The following targets had to be met during the 10 month time frame for the project:

- Reliable cranking operation between -28 and +130°C engine coolant temperature, ambient temperature -28 to +50°C
- Reliable meeting of the emission limits for EU 4 and LEV II taking into consideration influences of vehicle mileage
- Meeting the emission limits for -7°C (U.S./EU)
- Reliable meeting of emission limits SFTP (Supplemental Federal Test Procedure)
- Calibration of EOBD and OBD II diagnostics according to legal requirements

Emission Application According to EU 4 and U.S. LEV II Legislation

AMG provided prototype vehicles with full camouflage. The use of the cars was only allowed under the strict regulations of AMG and the special safety requirements of the FEV Vehicle Application Centre in Alsdorf. During the emission application, special attention was given to the catalyst heating strategy.

Dear Reader,

The increasing complexity and variability of modern engine concepts, combined with the growing number of vehicle variants, have led to an increase in application activities. In this respect, it is not only necessary to fulfill the requirements for fuel consumption, emissions, reliability, on-board-diagnosis, emergency running properties and NVH goals; it is also essential that the manufacturer’s unique vehicle combustion character remain unmistakable.

Automatic test stand measurements and the TOP-Expert software by FEV help reduce the time required to complete the development of the application. However, highly qualified application engineers are also needed that can work closely with the respective vehicle manufacturer and identify themselves with the product as well as their development process.

We are looking forward to supporting your programs from concept to production (C2P). Support would also include assuming product responsibility for your program.

Sincerely yours,

Prof. Dr.-Ing. Stefan Pischinger
President and CEO
which should consider the in-use-compliance aging effect. Measurements with different heating intensities clearly showed identical emission results with a stabilized catalyst, while an aged catalyst produced 30% more emissions. In particular, without a verification with a real durability catalyst, you have to take into account this effect either by a more stringent engineering target, a verification with a FEV-aged catalyst or a better catalyst specification regarding endurance stability. The specifications for the new AMG-SLK met all prescribed requirements and were well below the EU 4 and the stringent LEV II emission levels, and approach ULEV values.

**Diagnostic Application**

In addition to the emission and knock control calibration, the calibrations of the diagnostic functions were also completed with respect to the current European Union (EU) and United States (U.S.) legislative requirements. A special focus was put on the Rate-Based-Monitor (RBM) compliance, introduced in the United States with the LEV II emission legislation. Besides the safe detection of emission-relevant components during an emission test, the diagnosis has to be completed under all circumstances if the release criteria set by California’s Air Resources Board (CARB) are met.

Monitoring the selectivity to detect a faultless system is another important aspect, because the emission limits as well as the detection range of emission relevant components are lowered. The primary focus was placed on the validation of the diagnosis under customer vehicle operating conditions, another U.S. requirement. Continuous readings from the vehicle ECU and drive recorder delivered important data during the project development phase, such as adoption values, fault events and other engine parameters. By analyzing this data, it is possible to detect and solve potential problems. The most important component in the entire emission system is the catalytic converter, which has to be monitored over its lifetime for HC and NO$_x$ emissions and conversion rate. The set-up of a threshold catalytic converter is extremely important, because of the small detection scatter band between a new and aged catalyst.

The FEV Aging Concept for exhaust emission components provides excellent selectivity and reproducibility in comparison with other aging procedures. In particular, the calibration of the diagnostics for the catalyst is more robust throughout its lifetime, which is important for the Rate-Based-Monitor.

**Test Trips**

Part of the application project was to participate in test-drives to calibrate and verify the parameters of the Engine Management System (EMS) under various environmental conditions. The cold test trips are performed once a year in northern Sweden, where typical all day temperatures are between -10°C to -30°C, with relatively low humidity.

The particular test criteria used are the cold start and fast idle behavior of the engine and vehicle acceleration without hesitation. These performance criteria are greatly influenced by the fuel specification, depending on the season’s fuel standard. For this reason, all the tests are carried out with defined summer and winter fuels that conform to standards to check the engine mapping with the borderline values.

**Optimised Start with Summer- and Winter Fuel**

Basically the same test procedure was applied for summer test trips at sea level near Barcelona, Spain and at a maximum altitude of 2600 m in Granada, Spain.

An additional summer test trip took place in the United States, to simulate the influence of American fuels to the engine mapping and the customer’s driving behavior in traffic. Extreme climatic conditions were represented during the trip in Death Valley, California, with temperatures well above 50°C. The temperature extremes were used to evaluate engine thermal management, hot start, hot fuel handling and the knock control system.

Another testing highlight lead FEV engineers to Denver, Colorado, with temperatures between 0°C and 35°C and altitudes between 1600 m and 4300 m. These tests were performed to calibrate temperature and altitude depending on functionalities. Based on the project requirements and season, another summer test trip was held in South Africa which was designed to verify and tune the knock control system,
the engine thermal management, hot fuel handling and limit temperatures of exhaust gas components (e.g. outlet valves and the catalyst at high speed). High speed tests were conducted up to speeds of 300 km/h in the Kalahari Desert, with special district government authorization.

The Mercedes-AMG SLK 55 Evo successfully completed all of the required tests.

goertz@fev.de
jfeustel@mercedes-amg.com

The new subsidiary will managed by two of FEV’s engine experts:

Going China – Let’s go to Dalian

Going China – more than 10 years not only been a phrase, but it has been main component of FEV’s engine. FEV has been working with international car manufactures and suppliers in China and with local companies for a number of years.

Now, Going China gets a new sense: FEV is setting up a new development center, able to host more than 100 people, and with engine test cells, a vehicle application center for gasoline and diesel engines, and with a test systems production facility.

Gerhard Braun, an “Old China Hand”, got his first merits, in designing engines and leading engine development projects. He will implement the main target of FEV in Dalian: support the client with excellent quality.

Zhang Wen Hui helt leading positions in the Chinese engine industry and has been head of FEV’s Beijing Representative Office.

With the set-up of FEV China, FEV did a further step in the dedication to support you company’s with your activities in China – for example with engine development scopes, with the integration of you powertrains into vehicles, with calibration and through fleet testing.

scheid@fev.de

Dalian was the winner in a competition of many cities to host this development center. The touch of technology, the university background and the neighbourhood to Japan and Korea have been deciding factors.
Intense efforts to reduce CO₂ emissions from combustion engines during recent years, has significantly decreased the average fuel consumption of vehicle fleets. In Europe, diesel engines are the main contributor to the reduction of CO₂ emissions. In the gasoline engine area, significant hopes have been placed on new technologies, such as direct injection, variable valvetrain concepts and the combustion air charging process.

Since the 1997 introduction of the first hybrid series vehicle with a gasoline engine by Toyota, it is obvious that hybrid powertrains can also contribute to CO₂ reduction. The product acceptance of the hybrid vehicles offered depends on a variety of different factors. These factors are influenced by existing political, commercial and technical constraints.

FEV, serving as a worldwide engineering services partner in the powertrain systems field, can quickly provide efficient and optimized solutions that satisfy the engineering targets for the given market conditions.

Although interest in Asia and the United States seems to be focused on full hybrid solutions with an electrical power of about 50 kW, in Europe, there is a need for lower power systems.

Figures 2 and 3 illustrate a reasonable combination of a highly supercharged gasoline engine whose torque lag in the lower engine speed range can be compensated for by an electric motor. The electrical energy necessary for short-time boosting can be stored in highly powerful super-capacitor batteries. A fuel consumption improvement of up to 25% is achieved primarily through downsizing the combustion engine. In addition, the drive-away torque is maintained by the electric motor. Specific hybrid functions, such as start/stop and regenerative braking, also contribute to the reduction in fuel consumption.

FEV is engaged in a variety of hybrid technology programs (s. figure 1):

- Start/stop systems, which improve the starting behavior of vehicles. Belt-driven systems can be integrated into existing 14-volt vehicle power.
- Minimum hybrid systems that offer the use of regenerative brake energy and enable an electric shunting.
- Mild hybrid systems, which provide sufficient electrical energy to support launch assist.
- Full hybrid systems with an increased electrical range and that need a higher voltage and more powerful battery system, in order to provide electric power of up to 50% of the combustion engine power.
- Electric powertrains, whose electric energy is supplied by fuel cells.

FEV Mild Hybrid Torque Calculation

Hybrid powertrains are characterized with new degrees of freedom in combination with high efficiencies. Among other development activities, future efforts must concentrate on the integration of electric motors with the vehicle’s gearbox.

kemper@fev.de
FEV Develops U.S. Tier2 Diesel Passenger Car

The Diesel engine has well-known reputation for fuel economy and FEV’s engineers are working to improve its reputation for being clean as well. With U.S. Department of Energy support, FEV has developed an innovative vehicle-based system, integrating our Diesel Future II Engine, which will be able to achieve Tier2 Bin 5 emission levels.

Successful reintroduction of Diesel engines into the U.S. market requires that, in addition to emissions compliance, they be competitive in power, engine noise, and have a transient response behavior that is similar to gasoline engines. In addition, they will have to maintain their superior fuel economy. Modern Diesel engines can meet all of these requirements by integrating such technologies as high-pressure common-rail fuel injection systems, low sulfur diesel fuel, NOx adsorber catalysts (NACs), and diesel particulate filters (DPFs). Within the current DOE sponsored program, the emission control system was initially optimized in a test cell under various conditions in order to reach these objectives. A rapid warm-up strategy was developed to achieve the fastest possible catalyst light-off under cold start conditions. Performance of the catalyst was mapped and optimized under various load and speed conditions with different lean-rich modulation approaches. FEV installed the prototype engine in a vehicle and optimized it to provide the lowest practical emission levels. Additionally, the DPF and NAC strategies were developed and implemented in the test cell and vehicle.

The engine consists primarily of production parts, while the cylinder head and pistons were developed by FEV to reduce emissions. Most of the components are commercially available, including the electronically actuated Exhaust Gas Recirculation (EGR) valve and the variable nozzle geometry turbocharger.

FTP-75, US06 and the HFET test results for the vehicle indicate that the Tier2 Bin 5 levels have been met, using a de-greened emission control system. The Diesel Future II concept shows potential for meeting future Tier2 Bin 5 emission standards, with a fuel economy penalty of less than five percent.

The next phase will test the long-term aging performance of the system. During this phase, 2,050 hours of aging will be performed on one system that will reveal the viability of NOx adsorber systems for potential future production applications.

tomazic@fev-et.com.
Complexity of the modern powertrain is increasing steadily, due to constraints placed on it by legislation and consumer demands. Reaction to these increasing demands requires enhanced electrical and electronic systems for engines and powertrains that will be able to realize the necessary control tasks. These extremely complex functions can only be implemented using experimental test bench and vehicle results, since it is difficult or even impossible to simulate the whole system.

Utilization of electric and electronic systems has lead to the establishment of functional development and calibration as an additional focal point in engine development, in addition to mechanical and thermodynamic development. This requires appropriate methods and procedures to assist or even enable the necessary experimental tests that will be used to optimize all of the parameters. Model-based methods used in early development stages allow for an efficient calibration effort.

Methods like Design of Experiments deliver good results for problems with a high degree of freedom, if the modeling region of interest is well designed. FEV also utilizes models that involve pre-existing structural and/or physical knowledge, enabling coverage of larger design spaces. A simple example of this approach is the calibration of the torque map for a Diesel engine. This map can be calibrated, using a combination of mathematical functions matching the physical structure, with sufficient accuracy ($\pm$ 5Nm) using only 40 measurements instead of the conventional 256 grid measurements.

At FEV, tools like these are integrated within TOP-Expert. TOP-Expert is an integrated, modular environment used to assist all of the development stages of a modern engine development process. TOP-Expert also enhances the reproducibility of experiments and improves comparability of simulated and experimental results. Standardization of methods and processes delivers additional efficiency by reusing experiences from successful projects.

Rigorous use of simulation techniques has become an important part of vehicle integration and calibration. Modern test fields with appropriate control and automation tools are indispensable in reaching these goals.

Moreover, Design for Calibration will become an important criterion for designing components and entire systems that will be able to handle increases in complexity. Implementing these approaches will also have a significant impact on current calibration procedures. This holds true for resources as well as for hardware and all employees in test fields or in vehicle applications. TOP-Expert delivers optimal support on this track and thus paves the way towards model-based powertrain calibration.

In the event you are dealing with tasks of a similar nature, we would be happy to provide you with support to assist you to improve your results.

Schlosser@fev.de
Stommel@fev.de
Oligschlaeger@fev.de
Conditioning of various media used on a modern engine test stand is essential for definable test conditions and for reliable, reproducible test results. FEV provides highly powerful solutions, with its test and measurement systems, for the conditioning of all media (combustion and charge air, cooling water, lubrication oil and fuel). The conditioning systems can be integrated as additional components into existing test facilities. In addition, they can also come as a part of a perfectly matched complete system from FEV Test Systems.

FEV AirCon is a combustion air conditioning system that is used when pressure, temperature or humidity of the combustion air could impact the reproducibility of test results. The AirCon series units deliver well defined amounts of combustion air between 10 and 3000 m³/h. Therefore, they can be optimally applied to engines from one-cylinder research engines up to large-volume engines. The main function of this system is to deliver and temper combustion air. The functionality can be extended by a closed-loop control of pressure and humidity as well as mass air flow measurements.

Two variations of the AirCon units are the RaceCon and ChargeCon systems. FEV RaceCon is used in the sophisticated engine test stands of the most important racing classes, since it is specifically designed to accommodate the demands for high amounts of combustion air and extremely quick reactions to control the unit. AirCon and RaceCon combine high amounts of combustion air with positive and negative pressure of about 100 mbar. FEV ChargeCon units however, are used when charge air pressure up to 1.5 bar overpressure is required. All of these units can be ordered as mobile devices for test stand use and combustion air conditioning is actually required.

The FEV TEM TestEnvironmentManager is a flexible controller that provides parameters and controls the FEV conditioning units. The system utilizes an industrial PC and can easily be integrated into the control stand racks. Its easy to use software allows the direct input of set points and control parameters as well as the visual monitoring of the current status of the conditioning devices. The TEM software is based on the FEV TCM TestCellManager automation software and can be adapted to a wide range of special tasks. Universal interfaces, such as CANopen or analog I/ O, allow bi-directional communication with the FEV TCM TestCellManager or other previously installed automation systems.

### AirCon Technical Data:
- **Air Flow:** 10 - 3000 m³/h
- **Pressure:** 900 - 1100 mbar (at 1000 mbar ambient air pressure)
- **Temperature:** 20 - 60°C
- **Humidity:** 10 - 70 % r. H.
- **Accuracy of Control:** ± 1 mbar; ± 1 K; ± 3% r. H.

### AirCon advantages at a glance:
- Stable experimental conditions reduce test cell time
- Wheel base enables flexible use at different test cells
- Simple operation
- Low maintenance
- Wide range of application

gross@fev.de
biermann@fev.de