

Mercedes-Benz High Performance Engines



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— **Andy Cowell**, engineering and programme director, Mercedes-Benz HPE

SITUATION

Mercedes-Benz High-Performance Engines (HPE) designs and manufactures engines and hybrid power systems for Formula One (F1) racing. In 2006, a new rule issued by the Federation Internationale de l'Automobile (FIA), F1's governing body, presented Mercedes-Benz HPE with a unique engineering challenge.



In an effort to promote the development of more environmentally friendly technologies, the FIA elected to allow teams to integrate Kinetic Energy Recovery Systems (KERS) into their vehicles starting in the 2009 racing season. KERS recover and store kinetic energy that is otherwise wasted during braking. The energy can then be converted into power that the driver can access to boost acceleration by pressing a button on the steering wheel.

Mercedes-Benz HPE was tasked with designing a KERS system, but was given little direction by the FIA—the regulations provided some requirements for KERS, but did not offer specific guidelines as to how KERS should be implemented.

“The prospect of adding KERS technology to F1 racing vehicles was very intriguing from an engineering perspective, but it presented some initial challenges,” said Andy Cowell, engineering and programme director at Mercedes-Benz HPE. “We needed to design a system that offered the environmental advantages the FIA desired while also complying with FIA technical regulations and ensuring that the KERS system gave the drivers a competitive advantage.”

SOLUTION

The FIA's 2009 Formula One Technical Regulations specified that the maximum power of any KERS must not exceed 60 kilowatts (kW). Energy released from the KERS may not exceed 400 kilojoules (kJ) in any single lap, and measurements would be taken at the connection between the system and the rear wheel drive train. With these restrictions in mind, Mercedes-Benz HPE initially critiqued a number of different technologies for its KERS system, focusing primarily on flywheels, ultra capacitors and advanced lithium-ion batteries as the most feasible approaches. After rigorous development testing, Mercedes-Benz HPE ultimately determined that a lithium-ion powered electrical KERS system was the optimal solution.

“Lithium-ion battery technology was best suited for our KERS system for a number of reasons, including safety, response time and flexibility in packaging options,” said Cowell. “In racing, it is crucial that the driver gets instant response in terms of torque on the rear axle. You also want to design new systems to respect the vehicle's aerodynamics while keeping weight down to ensure there is no laptime penalty. A battery-powered KERS system satisfies both criteria, while also allowing for flexibility in terms of how you can deploy it on a car—something you cannot do with a flywheel, which has a fixed, modular shape.”

To design the lithium-ion battery cells for its KERS system, Mercedes-Benz HPE partnered with A123 Systems. At the time, A123's flagship battery technology was deployed in power tools and other products. By studying these applications, Mercedes-Benz HPE determined that batteries based on A123's Nanophosphate® chemistry could potentially meet the requirements for its KERS systems.

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Specifically, Mercedes-Benz HPE commissioned A123 to develop a cell with a power density of about 9,300 watts-per-kilogram (W/kg) while maintaining an energy density of 44 watt-hours-per-kilogram (Wh/kg). The increased power capability would enable Mercedes-Benz HPE to deploy fewer battery cells in its KERS design to maximize performance while minimizing weight.

However, A123's cells could only produce about 4,300 W/kg, so to meet the KERS specifications and amplify rate capabilities, A123 modified several aspects of its existing cell design. This included increasing thermal, electrical and ionic conductivity within the electrode stack and terminal hardware. The resulting cell met the power density and energy density requirements for the Mercedes-Benz HPE KERS. But just six months before the first race of the 2009 F1 season, Mercedes-Benz HPE made changes to the design of its KERS that would require A123 to engineer a completely new battery cell.

"The motor in our F1 engine ran at a higher voltage than the KERS battery pack, so in our initial design, we implemented a DC-to-DC converter to boost the voltage of the battery pack. However, we determined that this was unnecessarily complex and we should be able to run the motor directly from the voltage produced by the battery pack," said Cowell. "Our new concept required a battery with lower capacity, and we would simply deploy more of them in series. We needed a complete redesign to meet the new capacity and system voltage parameters, all while making sure the increased number of cells did not significantly add to the weight of the car."

The initial cells that A123 provided to Mercedes-Benz HPE met the original KERS criteria, but they were optimized for a lower voltage. Working closely with Mercedes-Benz HPE to understand the new KERS system, A123 designed, developed and manufactured a completely new battery, delivering it to Mercedes-Benz HPE well ahead of the first race of the F1 season. For its new design, A123 decreased the mass of its existing cell by about 48 percent while increasing the rate capability by about 14 percent. This enabled the KERS system to operate at the desired voltage while providing Mercedes-Benz HPE with increased power density capabilities—the new cells were capable of producing more than 20,000 W/kg for pulses lasting for multiple seconds and more than 40,000 W/kg for millisecond pulse applications. The new batteries also decreased the weight of the KERS system to about 26kg, which is believed to be lighter than competing KERS designs.



Mercedes-Benz High Performance Engines designs, develops, manufactures and races Formula One powertrain unit, which covers all aspects of the F1 engine and hybrid systems.

RESULTS

The Mercedes-Benz HPE KERS design featuring A123 cells was deployed successfully during the 2009 F1 season. On average, the system provided about 80 additional horsepower when engaged and shaved about 0.4 seconds off each lap time, helping teams using the Mercedes-Benz HPE KERS achieve victory at multiple races throughout the season.

In addition to boosting acceleration during a race, KERS can also be leveraged during qualifying by accessing the stored energy at the start of each lap, which decreases lap time and earns a better starting position for the race. Additionally, KERS systems provide teams with a fuel-saving option—instead of using KERS for an acceleration boost, drivers can ride at the same pace as competitors but use stored energy in place of fuel, which helps promote F1's environmental message.

"A123 helped us design and implement an electrical KERS system that was advantageous for drivers while also helping the FIA promote environmentally friendly F1 racing technologies," said Cowell. "Our continued work with A123 will not only improve KERS systems for future F1 racing seasons, but could also be integrated onto electric street vehicles to improve performance, extend range and increase fuel economy."