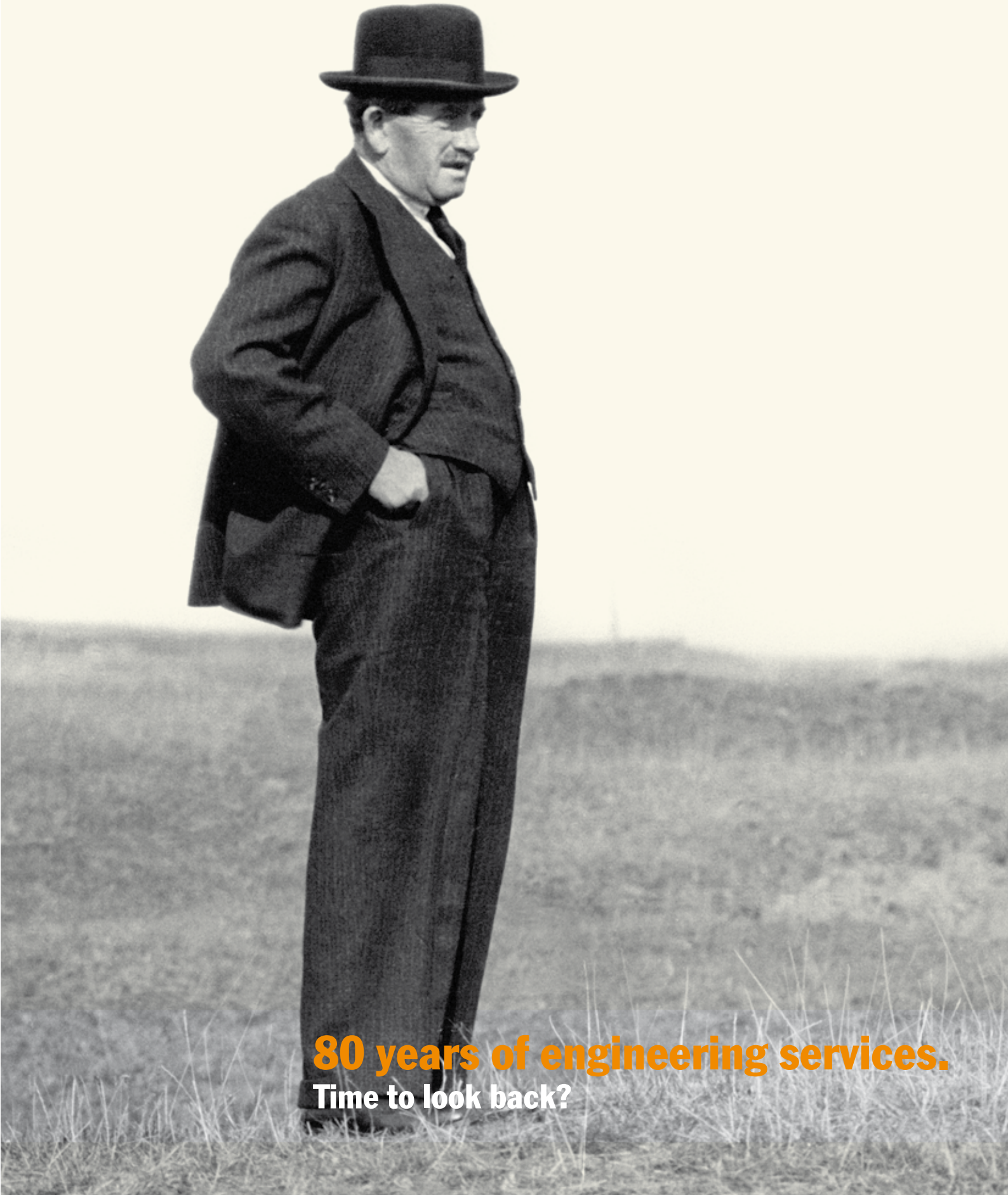
Anniversary Issue 1/2011

Porsche Engineering Magazine



80 years of engineering services.

Time to look back?

PORSCHE

Anniversary Issue 1/2011

Porsche Engineering Magazine

Sure, but not for too long.

The future is waiting.

About Porsche Engineering

At Porsche Engineering, engineers are working on your behalf to come up with new and unusual ideas for vehicles and industrial products. At the request of our customers we develop a variety of solutions – ranging from the design of individual components and the layout of complex modules to the planning and implementation of complete vehicles, including production start-up management. What makes our services special is that they are based on the expertise of a premium car manufacturer. Whether you need an automotive developer for your project or would prefer a specialist systems developer, we offer both – because Porsche Engineering works right where these two areas meet. The extensive knowledge of Porsche Engineering converges in Weissach – and yet it is globally available, including at your company's offices or production facilities. Regardless of where we work, we always bring a part of Porsche with us.

Impressum Porsche Engineering Magazine

Publisher
Porsche Engineering Group GmbH

Address
Porsche Engineering Group GmbH
Porschestraße
71287 Weissach, Germany

Tel. +49 711 911-8 88 88
Fax +49 711 911-8 89 99

E-mail: info@porsche-engineering.com
Website: www.porsche-engineering.com

Editor
Frederic Damköhler

Design: Agentur Designwolf, Stuttgart
Repro: Piltz Reproduktionen, Stuttgart
Printing: Leibfarth&Schwarz, Dettingen/Erms
Translation: TransMission Übersetzungen, Stuttgart

Porsche Engineering is a 100% subsidiary of Dr. Ing. h.c. F. Porsche AG.

Dear Readers,

For more than 80 years, the name Porsche has stood for engineering services with the highest standards of quality and levels of innovation. We develop solutions that help our customers to move forward and are always dedicated to meeting the challenges of tomorrow.

Ferdinand Porsche was also always looking ahead: he developed the first functioning hybrid automobile in the world way back in 1900. With the founding of his engineering office in 1931, Ferdinand Porsche also made his creativity and his engineering expertise available to external clients. We are honored to continue this tradition.

Come with us on a journey through our history and discover the milestones of our customer projects. But let's not remain in the past for too long, because the future is waiting. Everyone is talking about electromobility. We will show you our contribution to this exciting development.

For example with the results from the Boxster E research project, a fully electrically powered Porsche Boxster, which marks a new chapter in Porsche Intelligent Performance and for which we developed, constructed, and tested the high-voltage battery among other things.

Intelligent thermal management also plays an important role in electromobility. The engineers at Porsche Engineering have thus developed new technologies to achieve optimum temperatures using only the available battery capacity.

The increasing use of electricity to power vehicles is evident in numerous other areas of mobility, whether it is battery-operated watersports equipment or all-terrain hybrid mountain bikes. The current pinnacle of this development is the Panamera S Hybrid, which marries vehicle efficiency, sportiness and elegance like no other vehicle.

As you can see, our ideas reach far into the future. We look forward to every new challenge to master.

We hope you enjoy the anniversary issue of our magazine.

Yours, Malte Radmann and Dirk Lappe
Managing Directors Porsche Engineering

Contents

Cover

Ferdinand Porsche had been working on electromobility long before 1942, when the cover photo was taken – what would he have had to say about the Boxster E?

Porsche Museum special exhibition

For the Porsche Museum in Stuttgart-Zuffenhausen, the 80th anniversary of engineering services by Porsche, which was founded way back in 1931, is one of the central themes of 2011. From June 21 to September 11, 2011, the special exhibition “80 Years of engineering services by Porsche” is paying tribute to the most important and interesting customer projects of the past eight decades. On display are approximately 20 special exhibits extending from the development of entire vehicles via engines and transmissions to remarkable industrial projects of the present day. The ten vehicles on display engineered by Porsche include a 1931 vintage Wanderer sedan, the legendary Auto Union Grand Prix racing car and the Audi Sport Quattro S1.

The Porsche Museum is open Tuesday to Sunday from 9:00 a.m. to 6:00 p.m.

For further information please visit: ***www.porsche.com/museum***

The Porsche Museum in Stuttgart-Zuffenhausen

NEWS

The Prague office moves into a new building

Just in time for the 10 year anniversary of Porsche Engineering s.r.o., Prague, the engineers at the Czech subsidiary are moving into their new offices. The Prague office specializes in complex technical calculations and simulations. This involves using all the latest developments and methods from current research. For this reason, Porsche Engineering has been working closely with the Technical University in Prague for a number of successful years.

Scania relies on Porsche Engineering

The Swedish commercial vehicle manufacturer Scania is developing a new generation of truck cabs with Porsche Engineering. “In Porsche Engineering, we have found a partner that shares Scania’s values and views on development and production. We will develop a cab frame together that is optimized for Scania’s requirements on styling and functionality, as well as for rational production,” says Per Hallberg, Executive Vice President and Head of Research and Development, Purchasing at Scania.

Stay cool

The Porsche Classic Cooler is the perfect synthesis of technology and design. A genuine Porsche original. The exclusive bottle cooler was developed as part of a young talent development program by ten young engineers at Porsche Engineering for the Porsche Design Driver’s Selection.

The design language of the Porsche Classic Cooler is defined by the use of an original ribbed cylinder and therefore emanates the simple and pure design of the early air-cooled Porsche 911 engine. The participants in the program were involved in the entire development process for the bottle cooler – from the very first idea to the finished product.

The Porsche Classic Cooler is available in Porsche Design Driver’s Selection Shops and online: ***www.porsche.com/shop***

Historical edition

The Porsche Museum is also highlighting 80 years of the history of Porsche Engineering with a further publication in the series “Porsche Museum Editions.” The publication includes approximately 200 pages of the most interesting customer projects from the last 80 years. Numerous photographs, drawings and documents from the Porsche archive collection provide a real insight into the work of Porsche engineers — material which is normally strictly labeled “top secret”.

The book is available for 14.90 Euro in the museum shop and in retail stores.

PORSCHE ENGINEERING 80 JAHRE PORSCHE KONSTRUKTIONEN

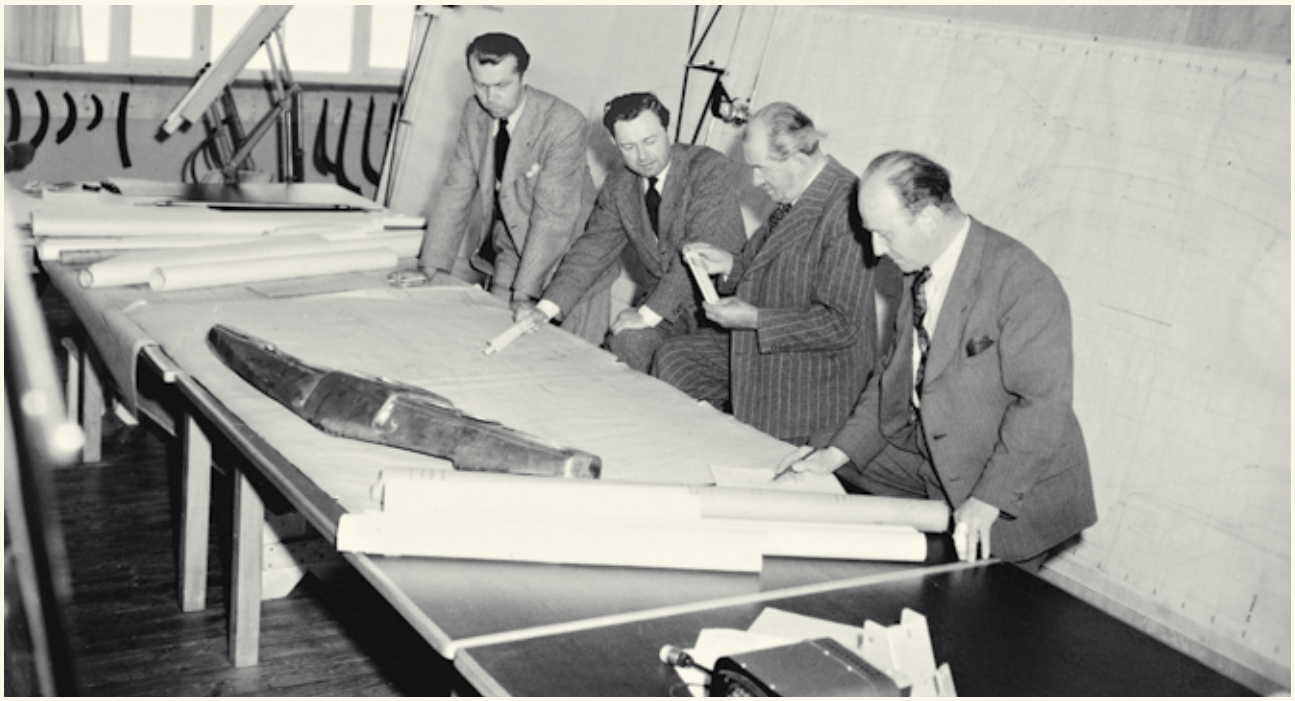

Continental

Pioneering performance for 80 years – Porsche Engineering

ON APRIL 25, 1931, FERDINAND PORSCHE FOUNDED AN ENGINEERING OFFICE UNDER THE NAME OF “DR. ING. H.C. F. PORSCHE GESELLSCHAFT MIT BESCHRÄNKTER HAFTUNG, KONSTRUKTION UND BERATUNG FÜR MOTOREN- UND FAHRZEUGBAU” IN STUTTGART. TODAY ENGINEERING SERVICES BY PORSCHE OPERATES UNDER THE NAME PORSCHE ENGINEERING AND HAS DEVELOPED PROJECTS FOR AUTOMOBILE MANUFACTURERS, SUPPLIERS AND OTHER INDUSTRIAL COMPANIES FROM ALL OVER THE WORLD FOR MORE THAN 80 YEARS.

80 years of engineering services by Porsche

Dr. Ing. h.c. F. Porsche AG, Stuttgart, has been the leading manufacturer of premium sports cars for more than six decades. This success story of Porsche AG is however also based on decades of development experience, stretching far beyond just building sports cars. Over many decades, Porsche has built up a reputation as one of the best known and multi-faceted engineering service providers in the world.



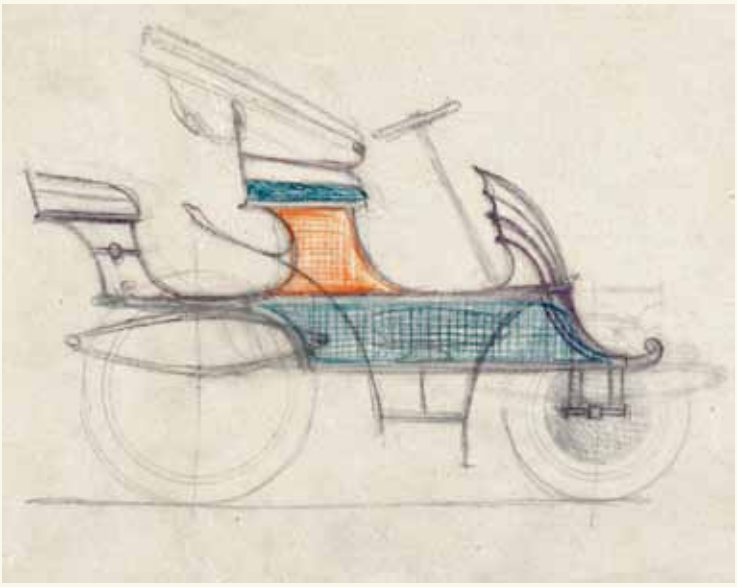
1950, Prof. Ferdinand Porsche (third from left) and Ferry Porsche (second from left) examining an engineering drawing in their office

The engineering services company Porsche Engineering Group GmbH has its roots in the oldest Porsche AG company. On April 25, 1931, Ferdinand Porsche registered a design bureau named "Dr. Ing. h.c. F. Porsche Gesellschaft mit beschränkter Haftung, Konstruktion und Beratung für Motoren- und Fahrzeugbau" in Stuttgart. At that time, the company founder, Ferdinand Porsche, had already built up more than 30 years of experience working successfully for the leading automobile manufacturers of his time.

Ferdinand Porsche, the automotive designer

The name Porsche has been associated with pioneering innovations in automotive engineering since the beginning of the last century. Ferdinand Porsche had already been busy designing and developing his first cars as far back as 1896. The first fruit of this endeavor was an electric vehicle known as the "Lohner-Porsche" driven by steered wheel hub motors that caused a sensation at the Paris World Exhibition in 1900. No less visionary was Ferdinand Porsche's next idea: again in 1900 he combined his battery-powered wheel hub drive with a petrol engine – the principle of the serial hybrid drive had been born.

With the first functional, full hybrid car in the world, the "Semper Vivus" ("always alive"), Ferdinand Porsche had entered uncharted territory in terms of technology. In this vehicle, two genera-



Left: 1900, an original sketch of the Lohner-Porsche electric car

Below: 1900, the Lohner-Porsche electric car at the Paris World Exhibition

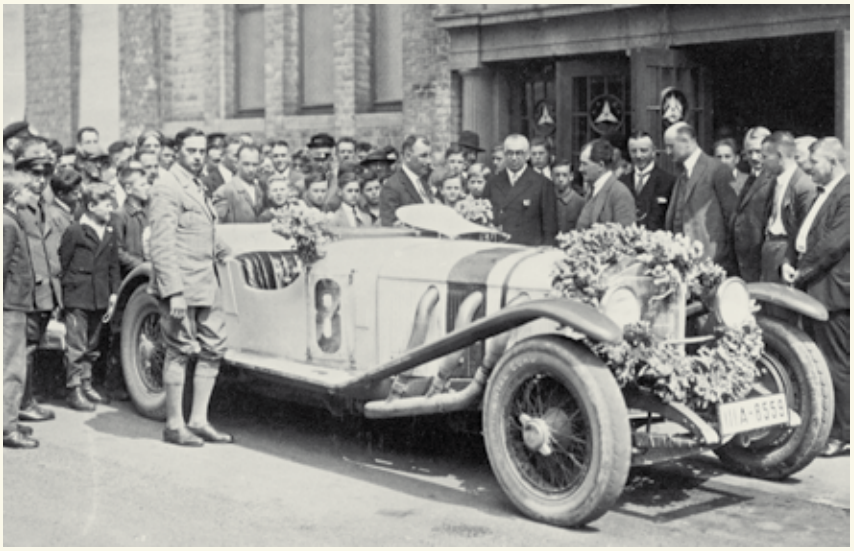
tors twinned with petrol engines formed a single charging unit, simultaneously supplying electricity to wheel hub motors and batteries.

As a full hybrid concept, the "Semper Vivus" was also able to cover longer distances purely on battery power until the combustion engine had to be engaged as a charging station. To save weight and create space for a petrol engine, Ferdinand Porsche used a comparatively small battery in the "Semper Vivus" with only 44 cells. In the middle of the vehicle he installed two water cooled 3.5 hp (2.6 kW) DeDion Bouton petrol engines for generating electricity, driving two generators, each producing 2.5 hp (1.84 kW). Both engines operated independently of one another, each delivering 20 amps with a voltage of 90 volts. Starting as far back as 1901 as the Lohner-Porsche "Mixte" and from 1906 onward as the "Mercedes Electrique", Ferdinand Porsche brought his hybrid drive to series production.

This was followed in 1906 by the next step in Ferdinand Porsche's career. At the tender age of only 31 he landed the position of Technical Director at Austro Daimler in Wiener Neustadt, putting him in charge of the products of one of Europe's leading automotive companies. One of the greatest successes of this era was the so-called "Prinz-Heinrich Car", in which the Austro-Daimler works team won the first three places in the 1910 running of the highly regarded Prinz Heinrich Race. In the guise of the Austro-Daimler "Sascha", he developed a small car which prevailed against its larger displacement competitors in the 1922 Targa Florio, notching up no fewer than 43 racing victories in total.

1922, the Austro-Daimler "Sascha" Type ADSR-I at the Ries Race in Graz in Styria, Austria

In 1923 Ferdinand Porsche moved to the Daimler engine company in Stuttgart-Untertürkheim as Technical Director. There, in addition to the Type 8/38 mid-sized model and the first eight-cylinder engine Mercedes-Benz, the "Nürburg" Type 460, it was first and foremost the supercharged sports and racing cars that further consolidated his worldwide reputation as an automotive designer. In January 1929 he left Daimler-Benz AG. Following a short interlude at the Austrian Steyr plant, he returned to Stuttgart at the end of 1930 and opened an engineering office.



1927, the Mercedes Benz Type S at a tribute to Otto Merz on the occasion of his winning the German Grand Prix

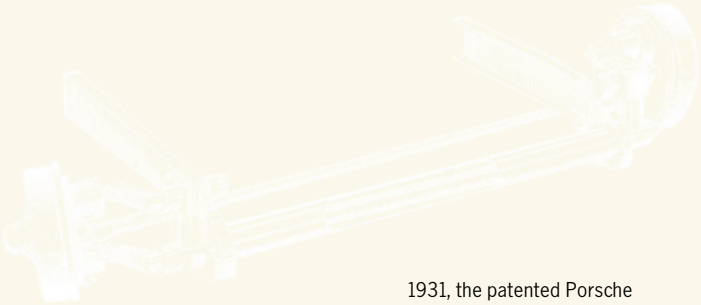
The founding of Porsche's engineering office

On April 25, 1931, at the height of the world economic crisis, "Dr. Ing. h.c. F. Porsche Gesellschaft mit beschränkter Haftung, Konstruktion und Beratung für Motoren- und Fahrzeugbau" was entered into the commercial register in Stuttgart. The work of the team under Ferdinand Porsche, initially comprising twelve people, covered the entire scope of automotive engineering from the very beginning.

As early as 1931, Porsche designed a six-cylinder average mid-size saloon for the Chemnitz car manufacturer Wanderer as well as a new in-line eight-cylinder engine. In addition, the engineering office developed a small car for Zündapp GmbH, which with its rear-engine, rigid tubular backbone chassis and transmission mounted forward of the rear axle was to prove to be decisive for the Volkswagen that came later. The torsion bar suspension patented on August 10, 1931 and used in international automotive manufacturing over many decades is also held to be a milestone in automotive history.

In the spring of 1933, Ferdinand Porsche was commissioned by Auto Union in Saxony to develop a 16-cylinder racing car according to the new 750 kilogram (approximately 1653 pounds) racing formula. By January 1934, the Auto Union P racing car (P for Porsche) had already

1933, the Porsche Type 7 for Wanderer, the first Porsche customer project



1931, the patented Porsche torsion bar suspension (Porsche Type 17)

Lohner Porsche

The recreation of the “Semper Vivus”

In November 2007, the Porsche Museum decided to undertake one of the most interesting and challenging projects in its history: the faithful reconstruction of the Lohner-Porsche “Semper Vivus” from 1900. The construction of the first hybrid automobile in the world was still a huge challenge for all those involved in the project, even 100 years after its invention. The aim was not only to recreate a car that looked exactly like the original down to the finest detail, but also one with exactly the same driving performance. The Porsche Museum contracted the mechanical work to an expert team under the bodywork specialist Hubert Drescher. Along with numerous other racing car projects, the aluminum body of the Porsche Type 64 exhibited in the museum also originates from Drescher’s workshop in Hinterzarten.

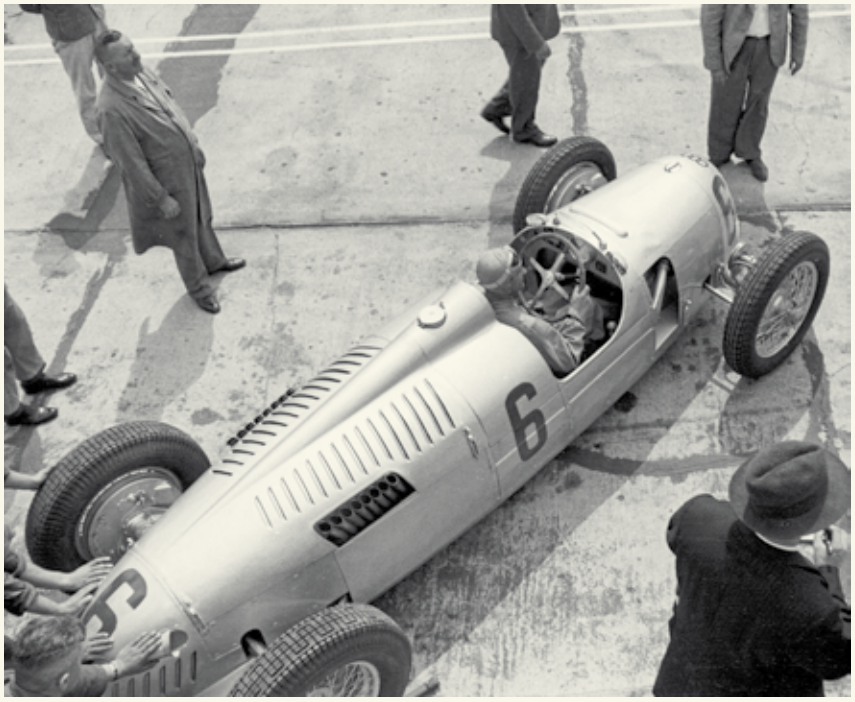
Before work could be started, extensive research had to be carried out in various archives all over Europe. Finally, a handful of black and white photographs and an original technical drawing provided the basis to start work. Just as Ferdinand Porsche had once worked, the reconstruction of the “Semper Vivus” began first of all on paper. As neither technical specifications nor other helpful drawings are extant, experts had to instead create technical drawings and calculation tables the old-fashioned way, by hand on graph paper. Additionally, existing photos and drawings were painstakingly studied and meticulously measured. As no functioning wheel hub motor still exists, technical details such as driving performance and range had to be calculated and figured out from scratch.

When selecting materials, the bodywork specialist Drescher looked to coaches and carriages from the beginning of the 19th century for inspiration. This also required the support of experienced suppliers, who have solid expertise in the manufacture of unusual materials. The fully functioning replica of the “Semper Vivus” does not just consist of re-manufactured parts however: original combustion engines, which function as generators, were found and incorporated into the reconstruction.

The highly impressive result of the restoration of the “Semper Vivus” was on show at the world premiere of the Porsche Panamera S Hybrid at the International Motor Show in Geneva.

Hubert Drescher restoring the “Semper Vivus” and in the car on the Porsche “skid pad” in Weissach

set three world records and won three international Grand Prix races in addition to several hill climb races. Between 1934 and 1939, with drivers such as Bernd Rosemeyer, Hans Stuck and Tazio Nuvolari, the constantly refined Auto Union racing car became one of the most successful pre-war era racing cars. Its mid-engine technical design proved to be a trendsetter for all modern racing cars and is used to this very day in Formula One.



1937, the Auto Union P racing car on the Nürburgring (Type 22)

1934, the prototype built for the NSU (Type 32) in front of the Porsche engineering office in Kronenstrasse 24

Pioneering developments

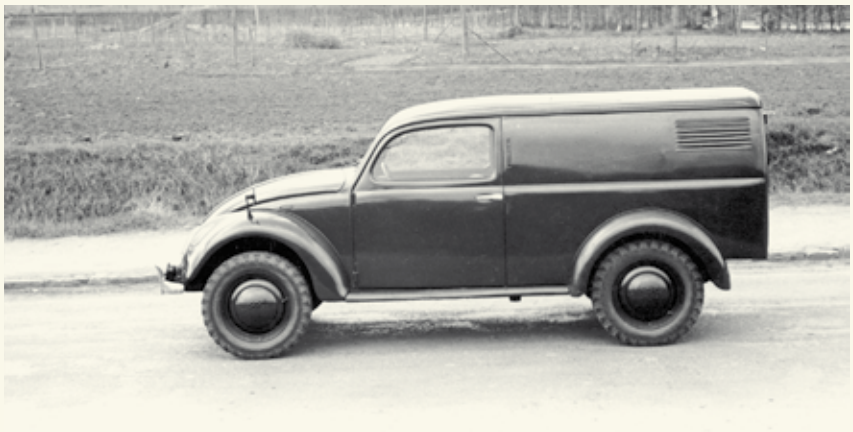
In addition to developing racing cars, since 1933 the engineering office had been equally hard at work on the design of a low-cost, small car commissioned by the NSU works. When Ferdinand Porsche began work on designing the Type 32 compact car, this was already the seventh small car design of his career. A number of prototypes of this vehicle type were built, which with the air-cooled, flat-four, rear-mounted engine and Porsche torsion bar suspension exhibited distinct similarities with the later Volkswagen Beetle.

The "Memorandum on the construction of a German people's car" (Volkswagen) that he presented to the Reich Transport Ministry on January 17, 1943 was to prove critical to the breakthrough of the small car concept. Shortly thereafter, on June 22, 1934, he received the official order from the RDA, the "Reichsverband der Deutschen Automobilindustrie" (German Reich Automobile Industry Association) to design and build the Volkswagen Type 60 and Volkswagen prototypes, which were assembled in the garage of his Porsche villa in the north of Stuttgart in 1935.

Alongside the Volkswagen project, the Porsche engineering office, located in the Zuffenhausen district of Stuttgart since 1938, was working on numerous other development contracts from the automotive industry. For Daimler-Benz AG, work included the development of technical engine components for the Mercedes "silver arrows" between 1937 and 1939 as well as the design of the Type 80 high-speed car for an attempt on the land speed record.

In 1938, the Volkswagen works awarded the Porsche engineering office the contract to develop a racing car based on

the Volkswagen Type 60, which was to take its place on the grid for a planned long distance race from Berlin to Rome as a promotional event for the "KdF" car ("Strength through Joy" car). By the spring of 1939, the Porsche engineers had developed three sports car coupés under the in-house designations Type 64 and Type 60K10, for the "Non-stop speed endurance test" scheduled for September, which however never took place because of the outbreak of the Second World War. With a sleek, streamlined aluminum body, shrouded wheel wells and a modified VW horizontally opposed engine, the record-breaking car, weighing a mere 600 kilograms (approximately 1,322 pounds), reached a speed of over 140 km/h (87 mph).



1941, a tropical delivery vehicle based on the Type 82

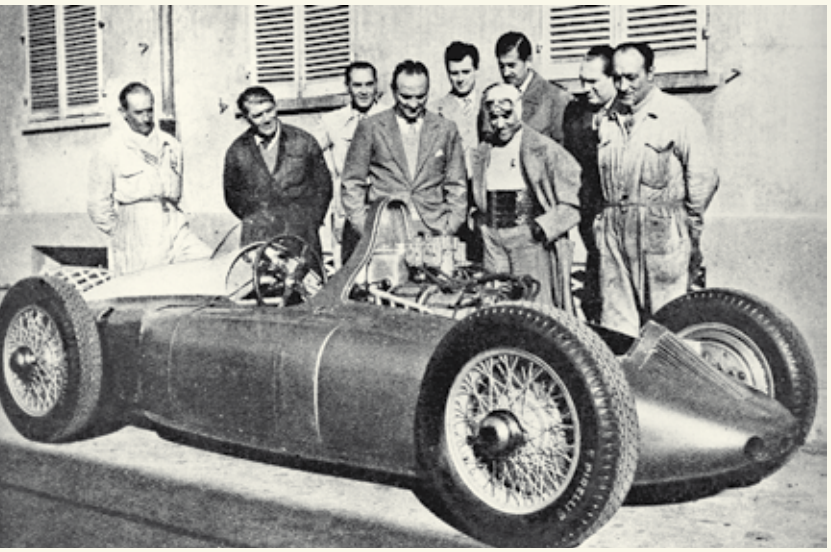
The Second World War

After the outbreak of the Second World War, other types of vehicles were developed on the basis of the Volkswagen for military use. In addition to the Type 81 "VW Kastenwagen" the company, trading as Porsche KG since the end of 1937, developed the Type 62 "KdF off-road vehicle", the Type 82, known as the "VW Kübelwagen" and the all-wheel drive Type 87 and Type 166 "VW Schwimmwagen" amphibious vehicle. A commission then came from the Armaments Ministry to design and build military tanks between 1939–1942. It resulted in two prototypes, however the tanks never saw military action.

New beginning with engineering services and sports car construction

The most important customer in the early post-war years was the Italian company Cisitalia, whose car enthusiast owner Piero Dusio awarded numerous design contracts at the end of 1946. Besides a tractor and a water turbine, Dusio also ordered a mid-engine sports car with hydraulic torque converter and a Grand Prix racing car. The result was

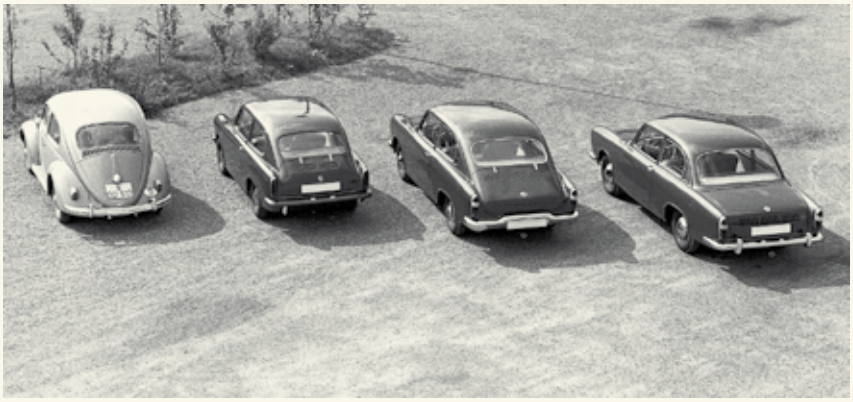
1938/39, the Type 64 is considered the forefather of all Porsche sports cars



Left: 1948, technically ahead of its time: the Porsche Type 360 "Cisitalia"
Above: 1948, the 356 No. 1 Roadster

the Type 360 "Cisitalia" completed in 1948, which was technically far ahead of its time. Unlike the front-engine Formula One racing cars of the post-war years, which usually still featured rigid axles, the Type 360 was designed with a mid-engine layout. The suspension featured double trailing arms on the front axle, the rear axle being configured as a double-joint swing axle with torsion bar suspension. The drive train of the single-seater was a 385hp (283 kW) 12-cylinder engine with compressor, achieving a maximum engine speed of 10,600 rpm.

In July 1947, independent design work began on the Type 356 "VW sports car". The design concepts became reality in the first half of 1948 as a prototype under the in-house design number 356, based on earlier designs such as the Volkswagen or the Type 64 "Berlin-Rome car". Once the chassis had completed its maiden drive in February, the finished prototype with the chassis number 356-001 received one-off approval by the State Government of Carinthia on June 8, 1948. The Porsche sports car brand had been born.



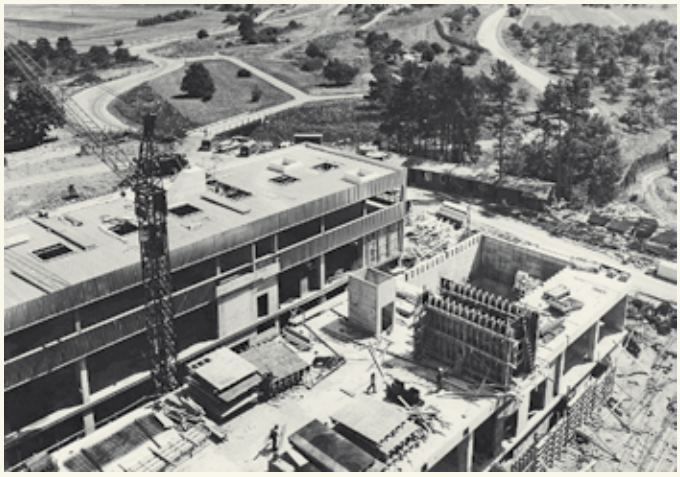
1958, developments for Volkswagen: the Type 60, Type 728, Type 726/1 and Type 726/2 (from left to right)

From the engineering office to the Weissach Development Center

Despite the successful entry into vehicle manufacturing, customer projects remained a firm fixture in the then Porsche KG's service portfolio. The most important client right into the 1970s was Volkswagen AG, with whom an extensive cooperation agreement had been made. Numerous detailed improvements were devised for the VW "Beetle". Porsche was also involved in developing the successor models for the successful "Beetle". The Stuttgart-based company developed numerous prototypes on behalf of the Volkswagen Group, which were to prove groundbreaking for the VW's passenger vehicle product portfolio. The best-known customer projects were the VW Porsche 914 unveiled in the autumn of 1969 and the Porsche 924 built in response to Volkswagen development contract EA 425.

In addition to the numerous orders from the Volkswagen Group, Porsche's

1969, the VW-Porsche 914



1970, the construction of the first development center building in Weissach

engineering services developed numerous other pioneering innovations for domestic and foreign clients in the 1950s and 1960s. Porsche developed the amphibious all-wheel-drive Type 597 Jagdwagen vehicle in response to a Bundeswehr invitation to tender. Although the Porsche Jagdwagen proved to be technically superior, the contract was awarded to car and motorcycle manufacturer DKW for labor market reasons.

In 1961, Ferry Porsche laid the foundation stone for Porsche's research and development center in Weissach, approximately 25 kilometers (15.5 miles) northwest of Zuffenhausen in Stuttgart. He had already had a so-called "skid pad" built there 10 years earlier, which had been used ever since for conducting suspension tests. In 1971, Porsche's development division with its construction, testing and design departments relocated to the newly constructed development center in Weissach. Alongside the "skid pad", a large test track as well as high-spec installations such as a wind tunnel, crash facility, emissions testing center and a wealth of engine test rigs were built and made available for customer projects and in-house developments alike.

For example, in the 1980s, the engineers at Weissach developed the "TAG Turbo made by Porsche" engine for the British McLaren International racing team, with the aim of causing a sensation at the very pinnacle of motor sport. The secret of the Formula One high-performance engine's success lay in marrying turbocharger technology with an electronic engine management system. As a consequence, the racing car's fuel consumption was particularly economical, which critically influenced racing strategy.

AvtoVAZ, the largest passenger vehicle manufacturer in Russia and Eastern Europe, also relied on the technical expertise of Porsche's engineering services. The Weissach engineers were assigned with revising the five-seat Lada Samara in order to achieve a competitive price and the necessary sturdiness for road conditions in the Soviet Union. With the exception of the styling, nearly all assemblies such as the motor, transmission, chassis, body, acoustics and electronics were optimized or redeveloped.

1983, the Formula 1 engine, the "TAG Turbo made by Porsche" for the McLaren racing team

Industrial projects

Being innovative has a long tradition at Porsche Engineering. For example, Porsche designed the cockpit layout for widebody aircraft in cooperation with aircraft maker Airbus in the early 1980s, and set the trend through the use of monitors instead of conventional analog instruments. The project's goal was to noticeably improve working conditions for pilots by optimizing the visual design of the cockpit.

A milestone in the development of vehicles for industry was the beginning of a cooperation with Linde Material Handling, which continues successfully to this very day. Having already designed slewing gears and chain drives for Linde, in the early 1980s the sports car manufacturer Porsche was retained to design a new generation of forklift trucks. Porsche styling for Linde's products has since become a multiple award-winning trademark. For instance, Linde forklifts have just recently once again received the coveted "red dot award for product design" from the prestigious North Rhine Westphalia Design Center: the electric counterbalance E20-E50 forklifts earned this distinction in 2011 and therefore continue the award-winning tradition which includes over 20 design awards since the beginning of the cooperation between Porsche Engineering and Linde. For Linde Material Handling, product design has become an integral part of the "Linde" brand and a clear competitive advantage. In addition to design, Porsche Engineering also assists Linde Material Handling with other development projects.

Above: 1981, the Airbus cockpit; below right: 1990, the Mercedes 500 E

Series development and production

From the late 1980s and early 1990s onwards, Porsche's engineering services team worked for Daimler-Benz AG on the design and test aspects of a W 124 series saloon fitted with the 5 liter, V8 four-valve M 119 engine. With the four-speed automatic transmission fitted as standard, the Mercedes-Benz 500 E reached the 100 km/h mark (62 mph) in only 5.9 seconds, with the top speed electronically limited to 250 km/h (156 mph). In the process, the contract far exceeded the usual development activities. Series production together with the assembly of the body shell and final assembly took place at Porsche's Zuffenhausen works. The Daimler-Benz works in Sindelfingen were responsible for the paint finish and delivery. Production of the Mercedes-Benz 500 E started up in the spring of 1990.

Porsche's department for engineering services also entered into a joint venture with Audi to develop a high-performance version of a series vehicle. The high-performance sport station wagon, the Audi Avant RS2, unveiled in the autumn of 1993, came into being in Weissach as the 315 hp variant of the all-wheel drive Audi Avant S2. This borrowed numerous Porsche components, such as for example wheel hubs, high-performance

Award-winning design since the 1980s: the Linde E25 forklift, which received the red dot award in 2011

brakes and rims. Exterior parts such as fog lights and indicators as well as the exterior mirrors also came from the Porsche 911 of the then current 993 model series. The Audi Avant RS2 was built at Porsche's Zuffenhausen works between October 1993 and July 1994.

Design study

At the Beijing International Family Car Congress, Porsche presented the C88 study in November 1994, which was developed especially for the Chinese market. The automobile constructed under the project name C88 catered to the needs of Chinese customers and was designed in three versions: in addition to an extremely affordable, two-door version, a standard and four-door notchback luxury version were also planned. The development goals also accounted for simple manufacturing methods, a high quality standard and high level of vehicle safety.

Into the future with tradition and innovation

In 2001, under the development name "Revolution Engine", Porsche Engineering started work as a development partner on developing a new V2 engine for the American motorbike manufacturer Harley-Davidson's "V-Rod" model. Against the backdrop of a collaborative relationship stretching back to the 1970s, Porsche engineers designed a water-cooled, 1,131 cc power unit based on a racing engine which delighted discerning Harley-Davidson customers with its performance and engine sound in equal measure.

On the road since 2002: the 115 hp V2 engine for the "V-Rod" by Harley-Davidson

Today, as in the past, Porsche Engineering is grappling with the engineering challenges of the future. Be it the solid expertise in the area of electromobility that Porsche Engineering displayed in the Boxster E research project in 2011 or in the development of the Seabob series production sports watercraft in 2007, experience in the lightweight construction and downsizing, but also thinking outside the box with the development of a premium outdoor barbecue in 2008 – Porsche engineers dedicate themselves to each project with the same commitment to ultimate quality, innovative designs and customized solutions.

Electromobility is advancing:
Above: 2011, the Boxster E research project

Below: 2007, the Seabob sports watercraft

Nowadays, all development projects for customers worldwide are managed by the Porsche Engineering Group GmbH (PEG) founded in 2001 with headquarters in Weissach. By networking all of the Porsche Engineering locations in Germany and abroad, and sharing information closely between project teams, PEG offers interface competency and lateral thinking, ensuring that customer projects are delivered consistently and productively, and without any hitches.

The combined expertise of Porsche Engineering's engineers and the comprehensive resources at the Weissach Development Center's disposal form the basis of its innovative services with the highest quality standards. But the public only gets to see the tip of the iceberg. Thanks to extremely strict confidentiality, Porsche Engineering protects its customers' product strategies and brand identities with the greatest care at all times. Only very few projects are known of, and only with the customers' explicit consent. Because Porsche Engineering only succeeds if a customer returns. This maxim prevails to this day – as it has for more than 80 years.

Want to find out even more? Discover exciting developments from 80 years of engineering services by Porsche in our web special:
www.porsche-engineering.com/80years

Innovation as a tradition

For more than 80 years, Porsche has developed tailor-made engineering solutions for its customers. Malte Radmann and Dirk Lappe, the Managing Directors of Porsche Engineering, explain how Porsche Engineering supports its customers in the projects of today and helps them to solve the challenges of the future. They also discuss which role the 80-year tradition plays in their everyday work.

Malte Radmann, Managing Director of Porsche Engineering

Mr. Radmann, Mr. Lappe, this year marks the 80th anniversary of Porsche's engineering services. How does this history influence the work of Porsche Engineering today?

RADMANN: Our 80-year anniversary is an important event for us. The story of Porsche Engineering, which began in 1931 when Ferdinand Porsche founded an engineering office, defines the way we think and act every day. In past decades, we have shown that the Porsche brand stands for excellent quality, long-term customer relationships and highly innovative technologies. This has shaped our drive and our commitment.

One doesn't normally associate Porsche with the engineering services provider Porsche Engineering, but with the manufacturer of sports cars …

RADMANN: Correct. However, those sports cars would not have been possible without the engineering services work of Ferdinand Porsche. The success story of Porsche AG today is also based on the experiences Ferdinand Porsche gathered in engineering services before the creation of the Porsche automobile brand. The engineering services are an essential part of the Porsche brand core.

LAPPE: And even before the foundation of Porsche's engineering ser-

vices in 1931, Ferdinand Porsche had already been active in the development for the automotive industry for a long time – for example in the development of the first serial hybrid vehicle in the world in 1900, the "Semper Vivus". Already at this time, Ferdinand Porsche was building up experience in the area of hybrid technology.

Porsche Engineering as an essential part of the Porsche brand core – one might ask the question then, how much of your customers' expertise goes into a Porsche sports car?

RADMANN: Without the trust of our customers in our absolutely reliable confidentiality, the last 80 years would never have been such a success story for our customers and for us. Confidentiality is our top priority. Only with the explicit permission of our customers we even mention their names – like we did for example with our recent cooperation with the truck manufacturer Scania.

What areas of expertise does Porsche Engineering offer?

LAPPE: We define ourselves through our outstanding total vehicle competence, both in the development of new vehicles and vehicle derivatives. We also consider the smallest parts and their role in the vehicle as a whole when developing components and assemblies. In this area, customers benefit from the expertise of the sports car manufacturer Porsche. We are able to take every development to production readiness.

How important is the Weissach research and development center for Porsche Engineering in this context?

Dirk Lappe, Managing Director of Porsche Engineering

> "The engineering services are an essential part of the Porsche brand core."
>
> (Malte Radmann)

LAPPE: Weissach is and will always be the central development resource for Porsche innovations, for both sports cars and engineering services. We have the necessary infrastructure that enables the development of high-tech solutions and testing up to production readiness. The knowledge of more than 2,500 employees is also concentrated in this area. In combination with the comprehensive testing facilities and engineers with project experience at our other locations, we are able to offer tailor-made solutions to customers from a variety of industries.

What sets the employees of Porsche Engineering apart?

LAPPE: First and foremost, their expertise in their respective field sets. However, that alone is not enough for a service company. We strategically cultivate interdisciplinary thinking among our employees. This means that a pro-

ject is viewed from as many different perspectives as possible. Our employees also contribute another very important qualification, which we at Porsche value just as much as our customers: the ability to think outside the box and to create solutions that are not apparent at first glance.

What character does this kind of lateral thinker have?

RADMANN: Having solid expertise in your field and enjoying figuring out complex puzzles are important requirements for interdisciplinary lateral thinking. You also need to have the ability to think outside your own box, your own discipline, that's essential. However, at the end of the day it's often a person's personality which decides whether we decide in favor of someone or not. Every single employee communicates directly with our customers and his or her personality and social competence is the deciding factor for whether our customers come back.

What defines the corporate culture of Porsche Engineering?

LAPPE: First of all, a good blend of highly experienced employees and young, well trained junior staff. We offer dedicated colleagues the opportunity to quickly assume responsibility due to very lean organizational structures. For us, professional management of our interns is the basis for winning over new potential employees for our company early on.

RADMANN: Our colleagues have the will to make a difference. They are very performance-oriented and display initiative. Our employees value team spirit, a friendly working environment ...

LAPPE: ... and most importantly, passion, a sense of humor, and taking pleasure in everyday work.

You have already mentioned that Porsche Engineering is working on projects in various industries. So you don't just concentrate on the automotive industry?

RADMANN: Correct, in the 80 years of Porsche Engineering, we have repeatedly proven our development abilities in a very large number of fields such as shipping, power engineering, agriculture, load-carrying vehicles, in competitive and aquatic sports, and in the health sector. In our work, we always focus on transferring our expertise from the automotive industry to other, related sectors. In this way, we tap valuable synergies for entirely different fields.

LAPPE: The industrial landscape offers big potential for engineering service providers. Our many years of successful cooperation with the forklift manufacturer Linde, for example, is clear evidence of this potential. But at the same time, the automotive industry is still very important for us and is about to go through dramatic changes, which we as an engineering services provider are able to support our customers in handling.

Are you talking about electromobility?

LAPPE: Exactly. Whatever role the spread of electrification assumes in the future, we at Porsche Engineering are capable of developing hardware and software for the widest range of electromobility solutions. We have shown in the Boxster E research project, for example, how to develop a high-performance, fully electric sports car. Whether fast charging processes, thermal management, crash safety or battery management systems: the quality of our solutions remains true to the Porsche name.

> "We are capable of developing hardware and software for the widest range of electromobility solutions."
> (Dirk Lappe)

RADMANN: We started to work on electromobility at a very early stage. The structure and staff of our organization is oriented towards this development, so that we can offer our customers comprehensive expertise in the areas of full hybrid, plug-in hybrid and electric vehicles.

What's the situation with range of electric vehicles that have been developed so far? Are you already happy with the status quo here?

LAPPE: That really depends fundamentally on what the electric vehicle is being used for. As a complete replacement for a vehicle with a combustion engine, electric vehicles and their current technology are naturally not sufficient. But it is very possible that a vehicle with a range of only 93 miles would be more than enough for the majority of the population. The daily distance driven by the average person is actually a lot less. If someone wants to drive for longer distances, then a vehicle with a range extender or an efficient full hybrid would be required. But we also have not reached the end of the road yet when it comes to battery development. We're working extremely hard on optimizing cell efficiency. The cell manufacturers are also continuously improving the storage capacity.

So, in your opinion, is electromobility the most significant trend that will define the automotive industry of the future?

RADMANN: We see electromobility as one of many trends in the same direction: increased automobile efficiency. Apart from the increasing electrification, this also includes lightweight construction with high-tech synthetics such as carbon-fiber-reinforced plastic, the optimization of gasoline and diesel engines, as well as what's known as downsizing. We assume leading development responsibilities in all these fields and are continually increasing our high performance.

LAPPE: It is possible that we are more able to intelligently link a wide range of technological developments than other engineering service providers, because we can utilize our experience from the development of Porsche sports cars. They are also defined by an intelligent combination of the latest technological advances and set standards not just in the sports car sector.

Could you summarize the idea and commitment of Porsche Engineering in one sentence?

LAPPE: We view ourselves as a reliable partner for our customers, who develops first-class technological solutions that consider the entire product up to production readiness.

Boxster E research project

Intelligent ways to innovative performance

WITH THE DEVELOPMENT OF THREE BOXSTER E RESEARCH VEHICLES, POWERED EXCLUSIVELY BY ELECTRICITY, A BRAND NEW CHAPTER IS OPENED IN PORSCHE INTELLIGENT PERFORMANCE. PORSCHE ENGINEERING WAS RESPONSIBLE FOR THE DEVELOPMENT, CONSTRUCTION AND TESTING OF THE HIGH-VOLTAGE BATTERY AND PROVIDED SUPPORT IN THE AREAS OF OPERATIONS AND DISPLAY, THERMAL MANAGEMENT AND BATTERY MANAGEMENT SYSTEM DESIGN.


PORSCHE
INTELLIGENT
PERFORMANCE
Boxster E

Porsche Intelligent Performance: the Boxster E research project

The Boxster E – a research vehicle with the mark of Porsche Intelligent Performance

The future of mobility is setting new challenges for the automotive industry. The intelligent combination of efficiency and performance through the optimized use of innovative technology provides answers to the mobility needs of the future. This principle, Porsche Intelligent Performance, is embodied by all Porsche development projects and is paving the way to the future.

Performance is nothing without intelligence. More horsepower alone does not win the race. Only ideas drive the advancement of real progress. For more efficient engines, lighter car bodies and innovative drive technologies.

Such as with the completely hybrid series vehicles, the Panamera S Hybrid and the Cayenne S Hybrid, which impress with lower fuel consumption but the same sportiness and elegance. Or with the hybrid super sports car, the Porsche 918 Spyder, a concept car unveiled in 2010 which is being developed for series production as fast as possible.

Additional research projects and racing experiments such as the mid-engine

hybrid Coupé 918 RSR embody the ideas of Porsche Intelligent Performance and provide ways to research methods for achieving more sustainable improvements in efficiency.

With the development of three completely electric Boxster E research vehicles, another great leap is made in the development of cutting-edge technology for the future of mobility.

Efficiency and performance in one: the Boxster E research vehicle

The electromobility challenge

"Electromobility is the most important challenge of the next few years and the engineers at Porsche are determined to achieve the kind of outstanding results they always obtain, in order to meet this challenge," said Matthias Müller, CEO of Porsche AG, during the presentation of the first of the three brand new electric Boxsters. Early in 2011, Matthias Müller drove the first few almost silent meters with the former federal state leader of Baden-Württemberg, Stefan Mappus, in the impressively sporty research vehicle in front of the equally impressive Porsche Museum in Stuttgart. "The Boxster E, as a laboratory on wheels, will help us significantly to solve the practical problems of electromobility, and meet our customers' high expectations," says Müller.

Knowledge gained from the Boxster E research project provides answers to the mobility needs of the future

Electromobility is setting significant challenges for the automotive industry. Customer requirements and the utilization profiles customers expect must be harmonized with what is technologically possible and ecologically sustainable. All over the world, governments and agencies are funding countless different initiatives to encourage development in the area of electromobility and the wider use and acceptance of electric cars.

Developing the future

With the National Development Plan for Electric Mobility in 2009, the German Federal Government created a strong foundation for achieving their ambitious and stated goal of getting one million electric cars on the road in Germany by 2020. The first research and development projects and regional pilot programs were implemented along with the Economic Stimulus Package II and 500 million Euro of funding between 2009 and 2011. It was in this context that the Porsche Boxster with a purely electric drive was developed.

The Boxster E research project is part of the regional pilot program in Stuttgart, one of eight "Electric Mobility Pilot Re-

Supported by

Modellregion Elektromobilität Region Stuttgart

Gefördert durch:

Bundesministerium für Verkehr, Bau und Stadtentwicklung

NOW Nationale Organisation Wasserstoff- und Brennstoffzellentechnologie

aufgrund eines Beschlusses des Deutschen Bundestages

Funding of the Boxster E research project is part of the Stuttgart electromobility pilot program

In the version with two electric machines, the Boxster E research vehicle reaches an effective output of 180 kW

gions" in Germany, in which pilot projects for electric cars and electromobility infrastructure are being realized up until the middle of 2011. The pilot region Stuttgart is being funded and supported as part of the national program for "Electric Mobility in Pilot Regions". The Federal Ministry of Transport, Building and Urban Development (BMVBS) is providing a total of 130 million Euro from the Economic Stimulus Package II for eight pilot regions across Germany. The program is being coordinated by NOW GmbH (Nationale Organisation Wasserstoff- und Brennstoffzellentechnologie GmbH).

The aim of the Boxster E research project is to gain new insights into everyday usability and user behavior, in particular when driving and charging electric cars, using three electrically powered Porsche Boxsters. This should provide researchers with valuable knowledge about the requirements for future products and the relationship between electric vehicles and infrastructure. Are electromobility and Porsche a contradiction? Quite the opposite: efficiency united with performance are typically Dr. Ing.

Boxster E research vehicle

The design of the Porsche Boxster as a mid-engine sports car provides the ideal vehicle basis for testing the electric drive in an everyday context. The open-top two seater is extremely light and enables the new components, the electric machine, battery and high-voltage technology, to be housed safely in the car. At the same time the high performance associated with a Boxster S with a conventional fuel-powered engine guarantees the future-oriented fascination of a sports car with new technology. The Boxster E research vehicle exists in two different versions: one with a single electric machine that has an output of 90 kW, and another with two electric machines and 180 kW, making the Boxster E the first Boxster with an all-wheel drive (see image above). As an energy storage device, a battery with a capacity of 29 kWh, of which in principle around 26 kWh can be used, represents a battery with incredible power and performance. Its maximum output is around 240 kW, so an extra 60 kilowatts more than the all-wheel drive Boxster E requires at full throttle.

High-voltage battery

The high-voltage battery was developed and constructed at Porsche Engineering. It was designed especially to be used in the Boxster E and delivers a level of performance typical of a sports car, while at the same time being lightweight and optimally positioned in the car. The traction battery replaces the combustion engine of the conventional series vehicle, normally powered by a mid-engine (see image on the opposite page). This has a positive effect on the center of gravity of the vehicle and therefore also on the driving dynamics.

The cells used are made of lithium iron phosphate (LiFePO4) and are a very good compromise between energy consumption and performance, while also being

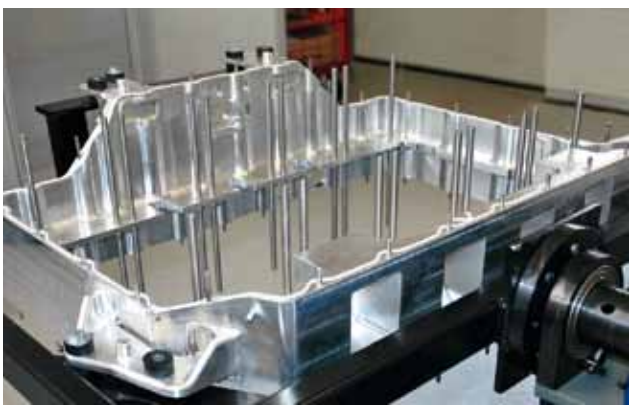
The battery in the Boxster E research vehicle is positioned in the same position as the mid-engine of the series vehicle

very sturdy and safe. The battery is fully charged at approximately 400 volts. The target is a distance of 170 km (106 miles) in accordance with the New European Driving Cycle (NEDC). Depending on the way the car is driven, a distance of more than 150 km (93 miles) is possible. The resulting electrical currents can reach more than 600 amperes. Keeping this under control is an especially big challenge. This applies especially to the construction and selection of the electrical components.

The main structure is provided by a central supporting frame, which is a lightweight construction made from high-strength aluminum (see image below left). All the internal components of the battery are attached to this supporting frame. Two covers made of glass-fiber reinforced plastic provide protection on both sides against dirt and moisture. In order to shield the battery from electromagnetic waves, the covers are coated with a conductive coating (see image below right).

High-voltage connectors for charging in less than 30 minutes

The cells are housed in a total of ten block-shaped modules containing 44 individual cells each. There are five modules in the top half of the battery. Five more modules are positioned suspended in the bottom half. The fuse, contactors and distributors are located in the top part of the battery. The battery has a total of five high-voltage connectors for two drive motors, and



The supporting frame of the battery is a lightweight construction made of high-strength aluminum

The cover of the battery is specially coated in order to protect it from electromagnetic waves

Cross-section of the Boxster E battery showing the cooling circuit

an air-conditioning compressor, charging device and heater in each. The internal charging device is connected at the high-voltage port, so that the battery can be charged at a capacity of 3.3 kW using a normal household socket. However, a higher charging capacity of up to 60 kW is also possible with an external fast charger, which reduces charging time to under 30 minutes. The battery weighs a total of 341 kilograms (751 lbs.).

Just like the fuel cap on every Porsche sports car, the charging socket is located in the front

Monitoring the battery

When operating lithium batteries, it must be ensured that their voltage is always at a specific level, which has been specified by the manufacturer. Voltage that is too high or too low can reduce the life span of the cells or in extreme cases damage them. A similar rule applies to the temperature. Cells that are too hot age faster, cells that are too cold provide reduced output.

The circuit boards of the “cell controllers” can be seen on the front of the modules. The controllers constantly monitor the voltage and temperature of the cells. The data measured by them is then analyzed in the central battery management system. This system sends the necessary information to the motor and the built-in 220 volt charging device via the vehicle electrical system. The charge state of the battery is thus controlled during charging and driving.

Stay cool

To ensure that the cells remain in the optimum temperature range of between −10 and +40° C (+14 and +104 °F), they must be heated or cooled as necessary. The battery is therefore thermally conditioned while being charged for example. One big challenge is keeping the battery cool when the car is being driven in a sporty manner. In this situation the battery can lose up to 5 kW of heat, which must be conducted elsewhere. If the battery were to be cooled using air, an air volume of 500 liters (17.7 cubic feet) per second would be required, which could not be achieved with the amount of space available in the vehicle. For this reason, five cooling plates are located in the center of the supporting frame of the battery pack, which cool the cells in the upper and lower modules with liquid.

On the one hand, these plates are optimized in such a way that they have excellent contact with the cell modules. This results in the best possible heat conductivity in the cooling agent. On the other hand, the cooling channels are designed so that the pressure losses are low and the heat is very evenly distributed through the plates.

The battery cooling system is also connected to the low temperature circuit in the vehicle. In very low ambient temperatures, the battery is kept warm by a high-voltage heater. In average temperatures, heat exchange is controlled by an air heat exchanger (cooling system). When cooling is required, the air-conditioning compressor takes over.

Porsche Engineering's expertise in electromobility can also be seen in the development of the display and operating design of the Boxster E

Fast exchange in only a few minutes

All of the electrical connectors have plugs which can be quickly detached. The conductors for the water cooling are also connected with water-tight, quick-release connectors from motor racing technology. If a platform lift is available, the battery can be changed in very little time using the appropriate tools, which is a particular advantage in development processes.

When the two covers are removed, all of the components can be accessed. This has advantages for the assembly of the battery, which can therefore be carried out very easily and safely.

Test of strength

After the battery has been assembled, it is then extensively tested. At the end of 2010, a high-voltage testing facility was set up at Porsche Engineering in Bietigheim. There, the battery and the battery management system were tested meticulously, before they were allowed to be put to work in the Boxster E. During testing, all of the basic functions of charging and discharging were first tested at moderate capacities. Even the unlikely capacity of over 200 kW was carefully tested.

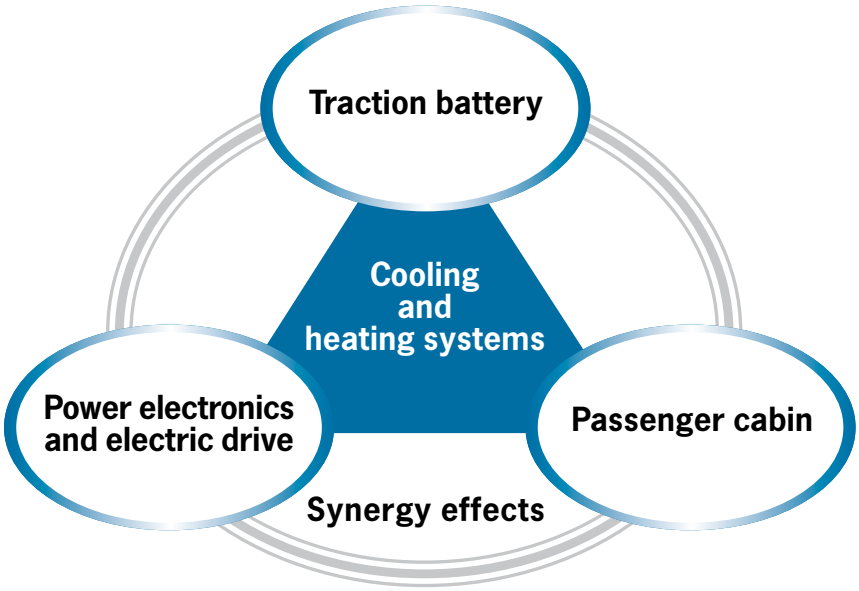
A very important aspect of testing is the careful check of all the important safety features that are relevant to the monitoring of the cells described above. Another important function is the correct calculation of the charge state of the battery. Only after the calibration of numerous parameters in the system is the charge state reliably transmitted and displayed to the driver in the cockpit.

Intelligently into the future

After the successful completion of comprehensive testing, nothing more impeded the battery of being fitted into the Boxster E and the car's presentation. The result: typical Porsche performance in the charging function and also in driving, from the very first few meters. And all this without any local emissions. The testing of the three completely electric vehicles has resulted in a solid foundation for future research and development in electromobility. You can therefore expect a few more chapters in the story of Porsche Intelligent Performance ...

Thermal management in vehicles with electric drive system

Transforming the drive train into an electric drive sets new and exciting challenges for the thermodynamics specialists at Porsche Engineering.



Up until now, thermodynamics specialists at Porsche were responsible for efficiently conducting waste heat away from the combustion engine, ensuring thermal stability and functionality with an optimized cooling system and reducing fuel consumption at all operating points using sophisticated thermal management strategies. They also had to ensure that components, auxiliary equipment and the transmission were cooled, ventilated and protected from high temperatures.

Electric vehicles have completely changed the core tasks required. Along with controlling the temperature in the traction battery and cooling the power electronics, electric motor and range extender, integrating these different cooling systems and the efficient climate control in the vehicle interior while also saving energy is now the main focus.

Because traction batteries in electric vehicles still have a limited capacity in comparison to conventional cars, electric vehicles have a significantly smaller range. This means that it is of central importance to ensure that all operating functions are reliable, while also maintaining comfort and the energy efficiency of all technical systems. This limited range can be even more drastically reduced by auxiliary loads such as heating and climate control.

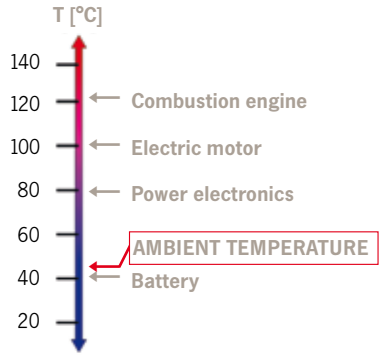
Cooling the battery, power electronics and the electric motor

From a thermal point of view, there are three main aspects to take into account when using lithium-ion batteries in electric vehicles. At temperatures below zero degrees Celsius (32 degrees Fahrenheit), the performance and therefore the range drop significantly due to slower chemical reactions taking place in the battery. At temperatures above 30 degrees Celsius (86 degrees Fahrenheit) the battery deteriorates exponentially, while extreme temperatures of above 40 degrees Celsius (104 degrees Fahrenheit) can lead to serious and irreversible damage in the battery.

The ideal temperature for a lithium-ion traction battery is approximately the same temperature that is ideal for human beings. In order to achieve the maximum power output and a long lifespan for the battery, it must be kept within an ideal temperature range of between 20 and 30 degrees Celsius (68 and 86 degrees Fahrenheit). To achieve this, it must be ensured that the battery does not exceed a maximum temperature limit, while heat must also be distributed as evenly as possible in the battery cells.

The thermal influence on a battery, such as fluctuations in the battery's own temperature caused by resistance inside the battery, external temperatures, sunlight and waste heat, must therefore be monitored and controlled by appropriate thermal control systems, i.e. by means of heating or cooling as necessary. This ensures proper functioning

Temperature levels



in the temperature range of –20 to +45 degrees Celsius (–4 to +113 degrees Fahrenheit) as required by customers.

Depending on the type of electrically powered vehicle (for example mild hybrids, full hybrids, plug-in hybrids, completely electric vehicles), requirements profile, battery type, cell chemistry and cell geometry, various cooling agents and methods can be used. These methods include air-cooling, cooling with coolants or refrigerants, and direct cooling or secondary cooling.

The latter involves cooling the battery using an external low-temperature cooler. Only if necessary, e.g. at high outdoor temperatures, an additional heat exchanger (chiller) is used to transfer the low temperature of the evaporating refrigerant from the climate circuit to the battery cooling circuit.

Along with the traction battery, it is important to take the temperature of other components in an electric vehicle into account, such as electric motor(s), power electronics and range extenders.

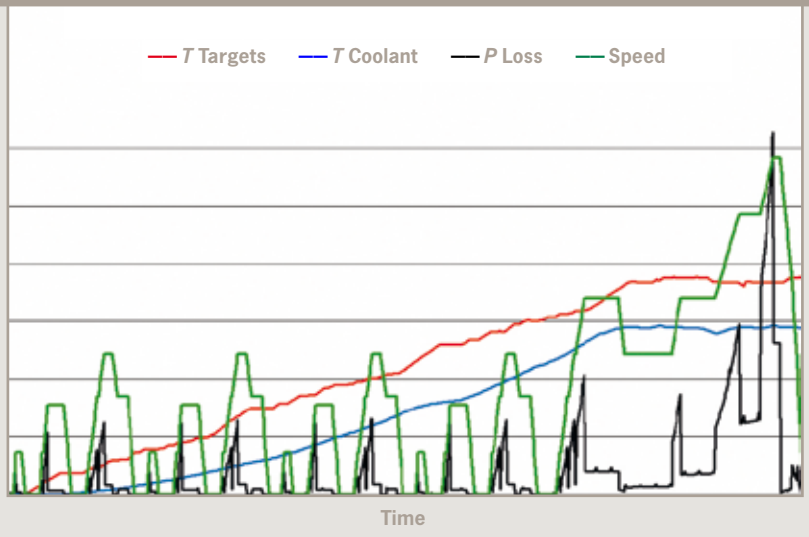
As these systems all operate at different temperature levels and must be cooled to different degrees (see graphic on the left), the aim is always to create synergy effects by harmonizing all the various cooling and heating circuits (see graphic on opposite page). By harmonizing the temperature levels, the number of different cooling circuits can be minimized, which in turn results in lower weight and costs, as well as more space in the vehicle.

The engineers at Porsche Engineering select the cooling agents and methods as early as during the first design concept phase. For this purpose, Porsche Engineering has developed a thermal simulation tool and validated it in tests. This can be used to work out and define the optimum cooling and heating system design at an early stage of vehicle development using previously identified performance data and driving profile requirements.

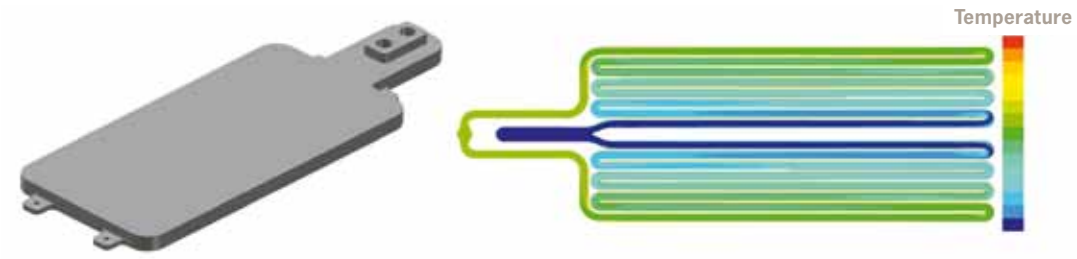
The graphic below shows an example of some of the results from a thermal simulation of a battery cooling process for the New European Driving Cycle (NEDC). Based on the calculation of the power loss, the increase in the temperature of components as well as the cooling requirement can be defined. Furthermore, the energy requirements for various cooling systems can be calculated and the optimum design for low energy consumption in the entire vehicle can be selected.

Thermodynamic engineers at Porsche Engineering develop and optimize the vehicle's entire cooling system, individual cooling and heating circuits or components according to customer requirements. An example of this process is the cooling plate from the traction

Simulation results for a vehicle in the NEDC



Boxster E battery cooling plate



battery in the Boxster E, as it can be seen above. Based on the analysis results from the thermal model described above, the cooling plate was designed geometrically and optimized using computational fluid dynamics (CFD). The result is a highly efficient and lightweight heat exchanger, optimally tailored and adapted to the battery pack, with low pressure losses, high cooling performance and a very even distribution of temperature.

Vehicle interior climate control

Another challenge in the design of electrically powered vehicles is the provision of heating and cooling systems for passenger comfort, as well as considering aspects relevant to safety such as keeping the windows free of condensation or ice (defrost function). The climate control systems customers are familiar with and expect from conventional vehicles require an energy input of up to 3 kW on hot and humid days, and up to 7 kW in the cold winter months for heating the vehicle. As there is no waste heat from the combustion engine, this energy requirement must be met by the traction battery, e.g. using a high-voltage PTC auxiliary heater.

Calculations show that these kinds of heating systems can actually absorb just as much power as driving itself and can therefore reduce the range by up to 50 percent. Porsche Engineering has developed new and innovative approaches to relieve customers from the need to pick whether to drive or freeze. Integrated auxiliary heating systems based on renewable fuels or combinations of heat pumps, latent heat-storage units and air- and water-based auxiliary heaters can be designed and built according to the vehicle model and the requirements profile.

The Porsche engineers and designers always have the whole vehicle in mind, which means that secondary methods are also taken into account and tested for efficiency and feasibility in the optimization of thermal management. The use of innovative (insulation) materials and designs to insulate the interior and components can therefore lead to targeted results in order to promote heat transfer or specifically insulate it.

Conclusion: challenges and solutions

Electrically powered vehicles no longer require conventional cooling as in combustion engines, or they require it only to a limited extent. With the lack of engine waste heat and the option of powering accessories using the combustion engine, new solutions must be developed from the viewpoint of both thermal and energy requirements.

This leads to complex thermal management systems at various temperature levels for cooling the battery, the electric motor, the power electronics and any range extender. Climate control in the vehicle interior is also becoming more complex.

The specialized engineers at Porsche Engineering meet these challenges with solid thermal management experience and expertise from classic sports car design and construction as well as experience from electromobility projects.

Using all available development tools from simulation to calculation, from conventional component testing in the testing facility to the testing of the entire vehicle on the test track, Porsche Engineering develops components, modules and entire systems for the thermal protection and optimization of vehicles and products of all kinds.

Mobility goes electric – the Porsche Hybrid RS mountain bike and the Seabob

Whether it is the Panamera S Hybrid, the 918 Spyder, the Cayenne S Hybrid or the 918 RSR, the integration of electric power in Porsche vehicles with conventional combustion engines is advancing all the time. Porsche Engineering has also demonstrated that electric energy can power more efficient mobility on a smaller scale. In the Hybrid RS mountain bike prototype and the series watercraft Seabob, batteries provide the energy for new levels of performance.

At the beginning of 2010, the idea was born to emphasize the hybrid expertise of Porsche by developing a hybrid mountain bike and presenting it alongside the Porsche Cayenne S Hybrid. Within a very short period of time, engineers at Porsche Engineering developed fully functioning prototypes of hybrid mountain bikes and unveiled them at the presentation of the Cayenne S Hybrid.

As early as 2009, Porsche Engineering had already been developing “pedelecs” (Pedal Electric Cycles) as part of a research study. Unlike conventional bicycles, pedelecs feature an electric motor to propel the bicycle with electric power in addition to muscle power through pedaling. With a pedelec, the electric energy can be used only if the person on the mountain bike is also pedaling at the same time. Recuperation of energy in a pedelec is achieved the same way as in a car, using the brake system. This means that energy produced when cycling can be recovered during braking and stored temporarily in the pedelec battery. This energy is then available again to the system to propel the mountain bike.

The characteristics of the prototype bike developed for the Cayenne S Hybrid presentation are those typical of a Porsche vehicle: the high-performance Hybrid RS mountain bike is lightweight and yet suitable for rough terrain (full suspension mountain bike). The styling of the bike also played an important role during development. Special emphasis was placed on creating a sporty look with high-quality components in typical Porsche design.

The frame of the mountain bike also advertises its hybrid nature.

The Porsche Hybrid RS mountain bike has a lightweight carbon-fiber frame, which results in a total weight of less than 16 kilograms (35 lbs.). The electric hub motor with direct drive can contribute up to 450 watts to the rear wheel, without additional gearing. The energy is provided by a lithium manganese battery with 161 Wh, located on the frame in place of the water bottle.

The drive is regulated by torque sensing: as soon as the pedals are turned, the motor delivers additional torque and in this way boosts the pure muscle power of the cyclist. This allows even very steep inclines to be ascended with ease and greater speeds to be reached. The electric power lasts for a distance of around 50 kilometers or 31 miles. When the brakes are applied (for example when going downhill), the drive motor becomes a generator and produces electric braking torque. The patented brakes

Porsche Engineering developed an app which visualises among other things the energy flows

use sensors to recognize the angle of the brake lever and transmit this information for a completely smooth recuperation.

The motor assistance can be set to different levels and is controlled via an iPhone, which is mounted securely on a handlebar bracket. The app has been programmed by Porsche Engineering and not only controls the electric motor, but also displays the current flow of energy and the charge state of the battery. The iPhone communicates with the control electronics, which were also developed by Porsche Engineering, via wireless LAN. If desired, the app can simulate cycling uphill for training purposes by specifying an electric braking torque.

When the Cayenne S Hybrid was presented in Leipzig, national and international journalists were very impressed with the Hybrid RS mountain bike's diverse functions and enthused about how much fun it was to ride. Porsche Engineering has successfully transferred hybridization to two wheels. The only downside of the Hybrid RS: the mountain bike is a concept bike and not planned for series production.

One series product that has been making waves in the water for some time is the sports watercraft Seabob, which has an electric drive for environmentally friendly and speedy fun on and below the water. Porsche Engineering has made a decisive contribution to increasing the propulsion efficiency of this unusual recreational craft.

It can be easily steered and controlled, simply by shifting the body weight. The speed of the craft is controlled with a control grip. The Seabob weighs around 60 kilograms (132 lbs.) and has an electric jet drive rated at seven hp (5.2 kW). It can reach speeds of between 15 and 20 km/h (9 and 12 mph) and can dive to a depth of 40 meters (130 ft.). For safety reasons, the series produced Seabob is currently pre-set to allow diving depths of 2.5 meters (8.2 ft.) or less. Users wishing to dive deeper can unlock its deep diving capabilities by entering a PIN code. Propulsion is produced using the jetstream principle.

In good company: the hybrid bike was unveiled together with the Porsche Cayenne S Hybrid

The powerful rotating impeller sucks in water and pushes it out through a jet channel at high pressure. The Cayago Seabob is impressive not only thanks to its driving pleasure and striking look: hard work in development also produced cutting-edge technology. The engineers at Porsche Engineering developed no less than three electronic components for the patented watercraft: the battery manager, the motor control system and the operating system with graphical display.

With a capacity of 40 ampere-hours per four-volt cell, the battery manager monitors the function of the lithium-ion batteries integrated into the craft. These batteries are also used in aerospace technology applications. In order to protect the lithium-ion batteries from damage, a special electronic system was developed to monitor the voltage in each individual cell. The battery manager also controls the power monitoring system and the power cutoff for charging and discharging the battery. Furthermore, numerous sensors monitor the operating temperature. Using cell balancing, the electronics ensures an equal voltage in all cells. This prevents the voltages of the series-connected batteries from drifting apart.

The Seabob's electric motor is completely emissions-free and almost silent. Its control system works with a digital signal processor (DSP) and creates a sinusoidal three-phase current from the battery voltage. Phase currents of up to 200 amperes are generated from the DC link voltage of 60 volts at maximum. The power output stage even allows for up to 250 amperes. The motor has a rated power up to 7.5 kw but can be overloaded to twice this figure if necessary. The rotor position is measured by three Hall effect sensors. The drive consists of a high-torque synchronous drive. Using the very latest technology and despite its surprisingly compact size, the motor achieves the optimum torque with an exceptional efficiency level of over 96 percent. During an endurance test over more than 10,000 operating hours at maximum output, there was neither a fault nor a decrease in power in the motor.

The illuminated LCD panel clearly and legibly shows all important motor electronics technical data. This includes the current driving power, remaining operating time and the charge state of the battery. The rider is also given important information about diving depth and water temperature on this display. Finally, an integrated infrared interface allows software updates to be uploaded and diagnostic data to be read out, while important programming functions can be conveniently controlled using the LCD panel.

The result is a sports watercraft that can be intuitively operated, that has an intelligent battery and motor control system, and that guarantees endless fun in the water. That is not all: Porsche Engineering is currently working together with Cayago to create a significantly lighter model that promises to be even more fun.

So whether it is a hybrid bike or the Seabob, Porsche Engineering brings its expertise and experience in the area of electromobility to a variety of different applications – even if they have little to do with automotive engineering.

Battery-operated watersports fun on and below the water: the Seabob

Panamera S Hybrid: the Porsche Gran Turismo sets a new benchmark for its class

The Porsche Panamera S Hybrid marks a new chapter in Porsche Intelligent Performance and continues the success story of the four door Gran Turismo.

Without sacrificing sportiness or elegance, the new hybrid model combines a total power output of 380 hp (279 kW) with a best case fuel consumption of only 6.8 l/100 km (41.54 mpg imp.) based on the NEDC (New European Driving Cycle). This is equal to CO_2 emissions of only 159 g/km. The Panamera S Hybrid is therefore not only the most economical Porsche ever, it is also far ahead of all other full hybrid series vehicles in the luxury class in terms of fuel consumption and CO_2 emissions.

These incredible statistics were achieved with Michelin all-season tires with even lower rolling resistance, developed especially for the Panamera and available as an option. Even with standard tires the fuel consumption of the new Porsche hybrid model is only 7.1 l/100 km (39.79 mpg imp.) based on the NEDC – the equivalent of 167 g/km of CO_2 – an exceptionally low level never achieved before in this class.

Only the Panamera S Hybrid can "sail" up to 165 km/h

The Panamera S Hybrid sets new standards, both in terms of classic performance and when measured against hybrid vehicle characteristics. Capable of accelerating from zero to 100 km/h (62 mph) in just 6.0 seconds, the Panamera S Hybrid can reach a top speed of 270 km/h (168 mph). The range in purely electric mode is approximately two kilometers (1.24 miles), while elec-

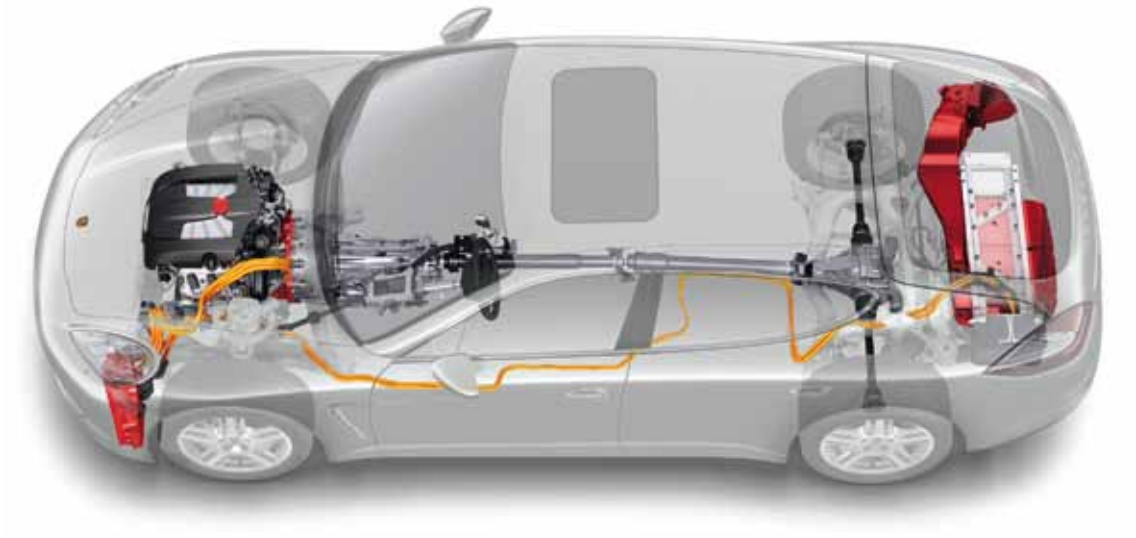
tric driving is possible at speeds of up to 85 km/h (53 mph), depending on the situation. The Porsche hybrid drive also enables even more energy-saving potential to be unlocked at high speeds by using the so-called "sailing" function on highways and rural roads. This system is the first and only one of its kind in the world. At speeds of up to 165 km/h (103 mph) (Cayenne S Hybrid: 156 km/h (97 mph)) when no power is being delivered from the combustion engine, it is disengaged from the drivetrain and switched off.

A great team: the compressor and the electric machine

The Panamera S Hybrid is powered by the same engine combination that has already proven itself in the Cayenne S Hybrid: a three-liter V6 compressor engine with 333 hp (245 kW) is responsible for the main power, supported by an electric machine with an output of 47 hp (34 kW). Both machines are capable of powering the Panamera S Hybrid either alone or in combination. The electric machine also operates both as a generator and a starter. Together with the decoupler, it makes up the compact hybrid module located between the transmission and the combustion engine. The electric motor is connected to a nickel-metal hydride battery (NiMh), where the electrical energy recovered from driving and braking is stored. Power transmission is handled by the familiar eight-speed Tiptronic S, fitted as standard in the Cayenne models, with a wide spread of ratios.

The driver can unleash the maximum power of the Panamera S Hybrid by using the so-called "booster" function. When this is activated, the combustion engine's and the electric machine's drive torque are combined and reinforce each other. This is another major advantage of the Porsche hybrid design. While the combustion engine reaches its maximum torque of 440 Nm (325 ftlb.) between 3,000 rpm and 5,200 rpm, the electric machine can make use of its full torque capacity of up to 300 Nm (221 ftlb.) from a standing start to powerfully propel the car forward. The maximum output of both of the drives, 380 hp, is achieved at 5,500 rpm, while the combined torque of 580 Nm (428 ftlb.) is reached at only 1,000 rpm, which guarantees a powerful and impressive throttle response.

Like the Porsche Cayenne S Hybrid, the Panamera S Hybrid also has an E-Power button in the center console, which can be activated to expand the range in which the vehicle can be driven under purely electric power. The activation is shown firstly via an LED on the button and secondly, the word "E-Power" appears in blue, illuminated text on the instrument cluster. In E-Power mode, the accelerator pedal characteristic curve is changed so that pressure on the accelerator pedal is converted much more moderately. The combustion engine is therefore prevented from starting automatically too early when more power is required.



The Porsche hybrid drive allows for the combustion engine to be disconnected and switched off when no drive power is required

Porsche exclusive: the parallel full hybrid, compact and powerful

Instead of using a power-branched hybrid drive, Porsche went for a parallel full hybrid. There were numerous reasons for this decision. Unlike other hybrid systems, which offer particular advantages for stop-and-go city driving, the system developed by Porsche also provides the additional option to "sail" in the Panamera S Hybrid, with the combustion engine switched off and at speeds of up to 165 km/h (103 mph). The parallel full hybrid model also allows the kind of acceleration and elasticity typical of a Porsche without the so-called rubber band-effect of power-branched hybrid systems. The concept therefore fits perfectly with the Porsche philosophy: exceptional driving performance combined with the highest level of efficiency. Another advantage is the comparatively small amount of space required: at only 147.5 millimeters long, the full hybrid module is particularly compact. It is positioned between the combustion engine and the transmission, and consists primarily of the ring-shaped synchronous motor and a decoupler on the side connected to the combustion engine. In this way, the power flux and characteristics are the same as a conventional drive. Additionally, the Porsche hybrid does not add much extra weight. The Panamera S Hybrid weighs only 1,980 kilograms (4,361 lbs.) when empty and is therefore quite trim for its class. It can also take a load of up to 505 kilograms (1,112 lbs.).

In line with the Porsche philosophy: exceptional driving performance combined with maximum efficiency

Porsche Communication Management (PCM) shows the hybrid drive in operation and energy flows in detail

Impressive equipment

The range of standard equipment for the Panamera S Hybrid is even wider than that of the already extensive standard equipment of the Panamera S with eight-cylinder engine. For example, the hybrid model is fitted as standard with the adaptive air suspension including the adaptive shock-absorber system with PASM, with Servotronic and a rear wiper. The new Gran Turismo also features the innovative display design from the Cayenne S Hybrid that provides the driver with all the relevant information about the vehicle's specific hybrid driving status. The performance of both power sources as well as all of the relevant statistics related to the hybrid drive are displayed to the driver on the TFT display in the instrument cluster. The driver can see the charge state of the traction battery and the energy flows, illustrated by an arrow in the direction of flow, in real time on the display. The Panamera S Hybrid creates totally novel highlights in the luxury segment – from sporty to environmentally friendly – and thus underlines the strategic importance of Porsche Intelligent Performance.

www.porsche-engineering.com

Porsche Engineering
driving identities

www.porsche-consulting.com

Summing up 80 years of efficient engineering performance: no resource wasted, no dream untapped.

Porsche Consulting heartily congratulates Porsche Engineering on its 80th Anniversary –

and looks forward to further successful teamwork.

Porsche Consulting
Shortcut to success.

PORSCHE