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Mercedes-Benz Classic

From prechamber to BlueTEC HYBRID – The history of the diesel engine

From prechamber to BlueTEC HYBRID

- **Diesel technology from Mercedes-Benz: A history of innovations**
- **From stationary engine to refined automotive drive**
- **BlueTEC HYBRID and CDI BlueEFFICIENCY are diesel technologies of the future**

Stuttgart – The diesel engine is a powerful force in the history of Mercedes-Benz and its predecessor brands. At Benz & Cie., at the beginning of the twentieth century design engineer Prosper L'Orange developed a functioning vehicle propulsion unit from Rudolf Diesel's stationary engine, and in 1923 the world's first diesel truck originated in Mannheim. Finally, in 1936 Mercedes-Benz built the world's first diesel passenger car, the 260 D. Since that time there has been an unending succession of innovations to every aspect of the compression-ignition engine in the vehicles of the Stuttgart-based brand. As next milestone, in 2011 the E 300 BlueTEC HYBRID comes onto the market – the first diesel hybrid passenger car from Mercedes-Benz.

This new generation of especially environment-friendly diesel drives combines the innovative BlueTEC technology package for the further reduction of emission levels, the comprehensive BlueEFFICIENCY concept for vehicle with optimised fuel economy, and the latest hybrid technology. The E 300 BlueTEC HYBRID thus sets off towards the future starting in 2011 as first diesel hybrid passenger car of a European manufacturer. This high-tech vehicle, which makes good ecological sense and is blessed with attractive driving qualities, provides an answer to the questions of the vehicle concepts of tomorrow.

The foundation of such innovations is the longstanding experience of the Mercedes-Benz engineers in the field of diesel engines. For since its premiere in the passenger car in 1936, over decades the diesel increasingly has been developed by the Mercedes-Benz engineers into a clean, powerful, high-speed drive unit, yet has retained its economical nature. Originally it was this economic efficiency and robustness which impressed contemporaries; today the diesel engine is an extremely clean power plant with sporty characteristics. Consequently, in the face of increasingly stringent emissions standards, the current compression-ignition engines constitute an alternative to petrol

engines more than they ever did. The market reflects this development: in the meantime every second car sold in Western Europe is a diesel car. Mercedes-Benz even sells 54 percent of its cars with a compression-ignition engine under the bonnet. The diesel is more up-to-date than ever today.

Rudolf Diesel and his invention

A far-sighted engineer

Rudolf Christian Karl Diesel was born on 18 March 1858 in Paris. At the tender age of 14 the son of a bookbinder decided on a career as engineer. After attending trade school and industrial school he went to Munich Technical University (Polytechnic Institute) and concluded his studies in 1880 with the best grade ever given for an examination since the university was founded. During his education in the engineering sciences the design engineer-to-be was particularly impressed by the thermodynamics lectures of Carl von Linde.

The contact with Linde had consequences: after completing his studies, Diesel went to work in the Linde refrigerating machine factory. But most of all, animated by Linde's lectures he decided to develop a new engine featuring especially good thermal efficiency. In 1881, after a one-year period of traineeship, the young engineer was hired to work in Linde's ice factory in Paris. Before the year was over, Diesel received a first patent for the manufacture of transparent ice.

During the following years, Rudolf Diesel increasingly focused on the work on his engine. In 1892 he took out a patent for his concept of a "*new, rational heat engine*"; patent DRP 67 207 "*on a principle of operation and construction for internal combustion engines*" was granted on 23 February 1893. In November 1893 Diesel modified and improved his first design and took out a second patent (DRP 82 168).

At Augsburg Machine Works (later MAN), from 1893 on Diesel developed a first test engine which he had running within a few months. But it would take four years from the beginning of work to design a successful prototype of an engine fit for series production. The Augsburg diesel engine factory was built in 1898 to produce the new power plant.

Whereas the spark-ignition engine compresses a mixture of air and fuel, Diesel's engine was supposed to compress the intake air, into which the fuel would be injected just before ignition. Subsequent to this mixture formation, which takes place entirely inside the cylinder, the fuel ignites spontaneously due to the heat produced by compression. On paper, Diesel's calculations for this process showed extremely high compression pressures of as much as 253 bar; in reality, the pressures remained substantially below this level.

But considering that temperatures between 700 and 900 degrees Celsius were obtained by the compression of air in the cylinder, this fully sufficed to operate the new-type engine: with its very good ignition qualities, the diesel oil needed no additional starting aid to burn at these temperatures shortly after being injected. Before Rudolf Diesel finally decided on a middle distillate of petroleum as fuel, he experimented with various other substances, among other things with coal dust. However, the first prototypes then ran on kerosene, which is similar to diesel oil in many respects.

Compared with the petrol engine, the diesel engine has very good efficiency especially at partial load. It was this efficiency which convinced the first buyers of the new engine around 1900 – despite public criticism of Diesel's concept. But the early engines did not prove durable enough yet in fact, and many customers returned their damaged engines. Particularly, the air compressor and the strainer-type atomiser used for fuel injection were susceptible to mechanical trouble. The inventor reacted by developing a new atomiser and improving the compression of the injection air by effecting compression in two steps.

The supply of fuel to the engine still called for a complicated process: a low-pressure pump delivered the fuel to the atomiser; from here, strongly compressed air blew the diesel oil into the cylinder as a fine fuel mist. This technology made the engines heavy and complex. Neither higher engine speeds, nor rapid reaction to changing loads were possible with this system.

Rudolf Diesel's development efforts repeatedly were hampered by technical misunderstandings. Among other things, at the beginning of his work the

engineer thought the spontaneous inflammation of the fuel was not vital, and he experimented also with sparkplugs. But the very first prototype of 1897 showed that the basic principle of this internal combustion engine had a great future. Indeed, Diesel's engine soon established itself alongside the petrol engine as second type of internal combustion engine, though originally only in the form of a stationary engine.

All modern-day vehicular diesel engines follow the basic principle of these engines. However, Rudolf Diesel's simple basic design has long since evolved into a technically sophisticated engine system. Solutions like common rail injection with injection pressures of up to 2000 bar, exhaust-gas turbocharging and ultramodern emission control systems and the combination of internal combustion engine with electric drive in the hybrid vehicle have made the diesel a powerful, economical, clean vehicle drive which still holds great potential for the future.

From stationary engine to marine diesel

Once Diesel had refined his concept to the point where it could be marketed, Augsburg Machine Works discontinued the production of steam engines in the course of the next few years and concentrated entirely on the manufacture of diesel engines. This step was quite in keeping with the market trend: the diesel engine, powerful competition for the steam engine, increasingly prevailed and superseded the steam engine. Between 1907 and 1909 alone, more than 1000 units with outputs from **15 kW** to **74 kW** (20 - 100 hp) were produced. But as a propulsion unit for transport purposes, prior to the First World War the new engine only saw use in ships, beginning in 1903.

Rudolf Diesel did not live to see the success of his engine as a propulsion unit for road and rail vehicles. The inventor, faced with financial ruin, disappeared from the postal steamship "Dresden" during a crossing from Holland to England in 1913. It is considered probable that the engineer committed suicide. Still, Diesel foresaw the potential of his technology: "*I am firmly convinced*," he wrote in 1913, the year of his death, "*that the automobile engine will come, and then I consider my life's work complete*."

Benz and Daimler too built diesel engines for watercraft at the beginning of the twentieth century: Benz & Cie. delivered their first two four-stroke marine diesel engines in 1910. In September 1911 Benz then introduced a two-stroke diesel drive for marine use. This engine, “Patent Hesselman”, was based on a Swedish power unit which Aktiebolaget Diesels Motorer in Stockholm had been building since 1907. The *Fram*, an expedition and research vessel, was one of the ships equipped with the Benz two-stroke engine. The *Fram* was built back in 1892 for the Norwegian polar explorer Fridtjof Nansen. It served as an expedition vessel from 1893 until 1912. Roald Amundsen had the **132 kW** (180 hp) Benz diesel installed for his journey to the South Pole from 1910 to 1912.

In September 1911, Daimler-Motoren-Gesellschaft (DMG) received an order for ten four-stroke air-injection marine diesels with an output of **74 kW** (100 hp). The RM 20 274 engines were manufactured in DMG’s Berlin-Marienfelde factory; the first five units were delivered by Daimler in 1912.

Both companies also manufactured engines for submarines in the First World War. In January 1916 the DMG Marienfelde factory won a contract for twelve **221 kW** (300 hp) six-cylinder diesel submarine engines. The first seven units of this model MU 256 were supplied to the customer in the same year. During this period Benz & Cie. also worked on powerful diesel engines for submarines, building eight S 6 Ln six-cylinder engines, each with **331 kW** (450 hp), between 1915 and 1916.

Prosper L'Orange and the modern diesel engine

From ship to road

The diesel engine was not ready for the step from stationary and marine use to installation in the automobile until after 1920. The engineering achievement which this development represents was the work of Prosper L'Orange, an engineer working for Benz & Cie since 1908. In Mannheim he devoted himself to making Rudolf Diesel's dream reality: the compact, high-speed diesel engine as an automotive power unit. L'Orange developed prechamber injection, the pintle-type injection nozzle, the funnel prechamber and the variable injection pump – milestones on the compression-ignition engine's way into the automobile and at the same time the basis for the first vehicle diesel engines.

A life for engine technology

Prosper L'Orange was born on 1 February 1876, in Beirut, in the then Ottoman Empire. He grew up in Germany after 1890. The boy was very enthusiastic about the technology of internal combustion engines and decided to attend the Technical University in Berlin-Charlottenburg. He passed his diploma examination cum laude and became an assistant to Privy Councilor Emil Josse in the university's heat technology laboratory.

L'Orange went from there to Gasmotorenfabrik Deutz, where he became head of the testing department in 1906. Here he worked mainly on a diesel engine variant which did not have a compressor for air-injection of the diesel oil. He planned to transfer the principle of this internal combustion engine to smaller engines: compact units with outputs of around **26 kW** (35 hp) would make ideal power plants for automobiles. However, L'Orange realised that the engine first had to be cured of the "*lack of restraint of its fuel feed*." He intended to devise a solution which would enable controlling fuel atomisation, and thus combustion, more accurately than before.

Similar projects were pursued by other engineers too, but Prosper L'Orange took the most forward-looking approach with his injection pump. This

precision-controlled instrument delivered fuel to the combustion chamber under 50 atmospheres of pressure. The engineer then turned to the shape of the compression space to improve the mixing of compressed air and fuel spray: in 1908 L'Orange took out a patent on a so-called afterchamber, a space before the cylinder in which air and fuel could swirl. The uncooled, spherical chamber was placed opposite the combustion chamber, with inlet and outlet valves arranged between the two. After the fuel was injected, a small amount of diesel fuel was ignited in the afterchamber; this ensured good swirling of the remaining fuel in the compressed air of the combustion chamber proper. Compared with the usual solution up to then – the use of a compressor to inject atomised fuel – L'Orange's new engine with injection pump and afterchamber was appreciably more compact. But the Deutz diesel engines still were too heavy for fitting in vehicles.

After moving along to Benz & Cie. in Mannheim, with a series of innovations between 1908 and 1922 Prosper L'Orange developed the heavy oil engine further into a high-speed power unit for vehicles. The engineer's most important improvements during this period were the prechamber principle, the funnel prechamber, the pintle-type injection nozzle, and finally the variable injection pump. However, L'Orange left Benz & Cie. in 1922 before the first diesel truck was introduced, becoming the head of stationary engine manufacture at Motoren-Werke Mannheim (MWM), which had emerged from Benz & Cie. From 1926 he worked as a free-lance engineer, and in 1927 he took over the management of the firm REF-Apparatebau GmbH in Stuttgart-Feuerbach. In 1932 REF-Apparatebau went bankrupt. In September 1933 Prosper L'Orange's son Rudolf set up Gebrüder L'Orange Motorzubehör GmbH, today an enterprise of the Tognum Group. His father was honoured for his lifework in 1939 with an honorary doctorate from Karlsruhe Technical University. Prosper L'Orange, pioneer of the modern diesel engine, died on 30 July 1939 in Stuttgart.

1909 – The prechamber

In 1908 Prosper L'Orange was hired by Benz & Cie. as head of engine testing. In Mannheim the engineer's aim was mainly to improve the diesel principle, as he had done at Deutz. With his afterchamber diesel he had already taken a first step towards splitting mixture formation and the combustion chamber. Now he

experimented on an improvement to the shape of the cylinder head. For this work L'Orange designed a test engine that could be fitted with different cylinder heads.

On this engine he also tried out a variant in which a semispherical chamber was arranged between the injection nozzle and the cylindrical combustion chamber. In this space, which occupied 20 percent of the total cylinder volume, after injection a small portion of the diesel fuel burnt upon contact with the hot chamber wall. This created an extremely high pressure in the prechamber, driving the remaining diesel-air mixture into the cylinder and ensuring very good mixing there due to the turbulence of the compressed intake air. Pressure and mixing enabled rapid combustion at high temperatures. With the prechamber diesel, therefore, appreciably higher engine speeds were possible than with older forms of the compression-ignition engine.

In a first test run, the prechamber diesel proved robust, reliable, and above all economical. The engine continued to cause problems for its designer, not the smallest of which was that it was still too big to be installed in an automobile. But Prosper L'Orange knew he was on the right track in his work: on 14 March 1909 he submitted a patent application for the prechamber system (DRP 230 517). L'Orange was rewarded for his success by Benz & Cie. by being given the position of an authorised officer in the stationary engine construction unit in 1910.

1919 – Funnel prechamber, pintle-type injection nozzle and variable injection pump

The First World War put a stop to the further development of diesel technology at Benz & Cie. In 1915 the Mannheim people even gave up the prechamber patent entirely. So when L'Orange resumed the work on a modern diesel engine after the war's end, he not only remembered his own groundwork, but also examined other new concepts. He happened upon the Swedish Ellwe diesel engine with semispherical prechamber and bores connecting it with the combustion chamber.

Spurred by the competitor's development, L'Orange continued improving his own prechamber. With a funnel-shaped insert between prechamber and

combustion chamber he changed its shape to achieve reliable ignition and good combustion under different loads. Among other things, the new shape improved the vaporisation of the diesel oil and reduced the risk of carbon deposits. He applied for a patent on this modification on 18 March 1919 (DRP 397 142). Parallel to this he was working on a new injection nozzle that worked much better than earlier variations. Prosper L'Orange also introduced this pintle-type injection nozzle in 1919.

In 1921 a variable injection pump for the diesel engine followed. Its delivery quantity could be infinitely varied, and it finally enabled the engineer to regulate the power output of the engine with the precision required for use in automobiles. The first installation of a high-speed diesel power unit in a vehicle was now only a matter of time.

Debut of diesel engines in tractors and trucks

1922 – Benz diesel for agriculture

The first land vehicle the Benz diesel engine saw use in was a tractor in 1922. The Mannheim firm developed the three-wheeled vehicle together with the Munich engine and tractor maker Sendling. Benz and Sendling displayed the prototype at a 1922 agricultural exhibition in Königsberg, today Kaliningrad, and immediately found buyers for this vehicle and two more preproduction series units. The machine was equipped with a two-cylinder diesel which developed **18 kW** (25 hp) at 800 rpm. Bore and stroke: 135 x 200 millimetres. The tractor went into production in March 1923 as the Benz-Sendling S 6 motor plough with one driving wheel.

Benz & Cie. initially planned to manufacture 100 engines for Sendling tractors and motor ploughs. But by late 1924 they had already manufactured and sold 36 two-cylinders. Through 1931 the Mannheim people, later under the umbrella of Daimler-Benz, produced a total of 1188 of these engines. In addition to the three-wheeled tractor and motor ploughs, from 1923 on Benz-Sendling offered the four-wheeled BK diesel tractor model.

1923 – The world's first diesel truck from Benz & Cie.

Benz & Cie. presented the world's first diesel truck in 1923. The five-tonner was powered by a four-cylinder diesel designated OB 2, with **33 kW** (45 hp) at 1000 rpm. In direct comparison with a petrol-powered truck of identical design, the diesel truck impressed right off with its economy: the compression-ignition power unit yielded fuel savings of 86 percent versus the spark-ignition engine.

Work on the new engine for the truck already began in 1922. In September of that year the first engine was running on a test bench. Initially, ten OB 2 engines were built. Test drives with the first production diesel were carried out from Gaggenau. The Benz engineers chose the Benz 5 K 3 truck as chassis, designed for a payload of five tons. The OB 2 made such a good showing in the

road tests that the decision to build it in series was already taken on 14 April 1923. The world's first series-built diesel truck finally debuted at the commercial vehicle show in Amsterdam in February 1924. By then the prechamber diesel engine OB 2 had an output of **37 kW** (50 hp) at 1000 rpm.

Particularly impressive its low fuel consumption: running on tar oil distilled from brown coal, the OB 2 needed about a quarter less fuel than an equally powerful petrol engine. Due to the low price of tar oil compared with petrol, the result was sensationally low fuel costs. In addition to tar oil, the engine also could operate on "*gas oil, kerosene, Texas oil as well as yellow or brown paraffin oil*" – said a 1923 Benz & Cie. advertising blurb for the frugal power plant.

1923 – Air-injection diesel truck from Daimler

While Benz & Cie. were developing the diesel truck, in Berlin-Marienfelde Daimler-Motoren-Gesellschaft (DMG) was designing an almost equally powerful air injection diesel to be fitted in trucks. The Daimler engineers applied their knowledge from the manufacture of air-injection diesel engines for submarines to this engine and created a four-cylinder unit delivering **29 kW** (40 hp) at 1000 rpm. The engine proved its practical suitability on a number of test runs in 1923. One very spectacular run was a long trip between two DMG plants: between 20 and 30 September 1923 a Daimler diesel truck drove from Berlin to Stuttgart and back.

1927 – The prechamber diesel prevails

However, after the merger of Benz & Cie. and DMG in 1926 the Benz prechamber principle prevailed over the air injection diesel. The first jointly developed prechamber engine was the six-cylinder OM 5 of 1927 (**55 kW**/75 hp from a displacement of 8.6 litres). The designation "oil motor" (OM) for diesel engines has survived since then in the Mercedes-Benz nomenclature.

The Mercedes-Benz L 5 truck operated alternatively with the new OM 5 (**51 kW**/70 hp at 1300 rpm) or an M 36 petrol engine (**74 kW**/100 hp at 2000 rpm). The five-tonner (a low-frame version called the N 5 also could be had) was the sole diesel-powered model in the new Mercedes-Benz commercial vehicle range presented in 1927. Both the 1.5-ton truck and the 3.5-ton truck

initially were available only with petrol-fired carburettor engines – a Mercedes-Benz concession to the still considerable scepticism of customers towards the diesel engine.

The OM 5, regular production of which started up in 1928, was already fitted with the new Bosch injection pump. Robert Bosch began working on diesel injection pumps in 1922. With the systematically improved injection technology introduced in 1927, Bosch contributed to getting the diesel drive accepted. Bosch himself did not have to be convinced of the compression-ignition engine's qualities: in 1924 he was one of the first customers to order a diesel truck from Benz & Cie.

Diesel engines in Mercedes-Benz passenger cars

1926 – The early history of the Mercedes-Benz 260 D

Mercedes-Benz held a sensation in store at the February 1936 International Automobile and Motorcycle Show in Berlin: in the model 260 D (W 138 series) the diesel engine swept into the passenger car world. In the year of the Olympic Games the Stuttgart company introduced this model as the world's first production diesel car. It was equipped with a four-cylinder engine with a Bosch injection pump which permitted higher engine speeds and speedier fuel supply. The 2.6-litre unit had a compression ratio of 20.5:1 and delivered **33 kW** (45 hp) at 3200 rpm.

The first diesel car in the world was the result of intense research which began upon the merger of DMG and Benz & Cie. in 1926. The first thing done by the young Daimler-Benz AG was to design a new six-cylinder diesel engine for trucks. The power plant was steadily improved. Its output and engine speed rose: in the early 1930s, the diesels already managed 2000 rpm.

Over the coming decades the engine speed especially of car diesel engines would be continuously boosted. However, compared with the spark-ignition petrol engine the compression-ignition engine has a physically determined speed limit of around 5500 rpm – a result of the delayed ignition of the fuel. The time that passes between injection and ignition is appreciably less with modern-day diesel fuels than with the earlier diesel oil, which was chemically identical with fuel (heating) oil. The cetane rating indicates the quality of the diesel fuel. The higher it is, the quicker the fuel ignites.

1934 – Four-cylinder diesel for cars

A high engine speed was an important condition for adopting the diesel in cars. For its premiere the compression-ignition engine had to come as close as possible to the petrol engine. However, diesel engines were still much heavier and less smooth than petrol engines. And so the first test diesel engine for a

car, a 3.8-litre six-cylinder developing **60 kW** (82 hp) at 2800 rpm, promptly proved too rough for the chassis of the test car because of its strong vibrations.

It was followed by several test engines, such as the OM 134 – a water-cooled three-cylinder diesel with **22 kW** (30 hp) – which was installed in the Mercedes-Benz 160 V car in 1934. The six test cars (W 134 series) received the model designation Mercedes-Benz 175 D and were available with saloon as well as convertible B and C bodies. However, the vibration problems of the three-cylinder proved to be uncontrollable. In the same year, therefore, four test cars of the 175 DX model (W 141 series) were set up and fitted with four-cylinder engines (OM 141, **26 kW**/35 hp). The engineers undertook further diesel tests in models which included the Mercedes-Benz 130 H and the Mercedes-Benz "Mannheim."

In November 1934 the Mercedes-Benz engineers then opted for a different approach and, instead of an entirely new development, banked on modifying the proven six-cylinder of commercial vehicle provenance. For operation in passenger cars the engine was reduced to the size of a four-cylinder with a displacement of 2.6 litres. The smooth combustion permitted by the prechamber principle meanwhile had been perfected, among other things through the use of a four-plunger injection pump from Bosch. The four-cylinder already had overhead valves, a very modern feature, and developed its maximum output of **33 kW** (45 hp) at 3000 rpm. A crankshaft running in five bearings contributed effectively to vibration damping and, in addition, permitted high revolving speeds. The engineers had finally reached their goal.

1936 – Darling of taxi operators

Assembly-line production of model 260 D began in 1935. The OM 138 was installed in the chassis of the Mercedes-Benz W 21 series. The resultant Mercedes-Benz 260 D consumed an average of 9.5 litres of diesel fuel per 100 kilometres – the closely related model 200 guzzled 13 litres of petrol over the same distance. The 260 D travelled 450 – 500 kilometres on one tank filling – quite an asset given the rather wide-meshed gas station network at the time. What's more, a litre of diesel cost 24 pfennigs in Germany – clearly less than a litre of petrol for which 39 pfennigs had to be paid. And anyone working as a taxi driver with a passenger transport license was able to buy diesel at a

reduced price of 19 pfennigs per litre. With a top speed of 90 km/h, despite all economy the Mercedes-Benz 260 D travelled at a fairly brisk pace – even the 200 managed only 98 km/h.

The world's first diesel passenger was built on the chassis of the W 21-series landaulet (Mercedes-Benz 200 and 230). The sales brochure proudly extolled the combination of modern passenger car and diesel technology: "*It is natural that Daimler-Benz A.G., in view of its great successes in the fields of passenger car and diesel commercial vehicle manufacture, also deeply concerned itself with the question of the passenger car diesel engine. The result is the Mercedes-Benz model 260 D [...], which combines the great advantages of the diesel engine with the obvious comforts of the swing-axle passenger car.*"

The first 170 vehicles already were delivered in autumn 1935 before actual series production began in 1936. The 260 D quickly gained acceptance as the ideal taxi. Cheap to maintain, robust and long-lived engines, a spacious body (also in a special taxicab version with up to seven seats): these were the arguments with which the new Mercedes-Benz convinced the taxi trade. Engine-powered cabs based on the 260 D were still widespread far into the 1950s. Also, the **33 kW** (45 hp) 2.6-litre diesel powered the van models L 1100 to L 1500, which were built in Stuttgart and Mannheim.

1937 – Diesel cars for private customers

Contemporaries were favourably impressed how quiet this diesel car was. Private customers too let themselves be convinced by the virtues of the Mercedes-Benz 260 D and bought the car with the compression-ignition engine – especially after the engine was worked over in 1937 and the model got a new body.

The Mercedes-Benz W 143 series served the 260 D as new chassis beginning in 1937. Two- and four-door convertibles and an open touring car were added to the landaulet and Pullman limousine. Through 1940 some 2000 units of the world's first diesel car were built – not a large number, but enough to make the diesel-powered car acceptable and smooth its way in the post-war period. Thanks to the farsightedness of its creators and above all the continuity of its

further development, the diesel car has captured a firm spot in the Mercedes-Benz model range.

1949 – New beginning with the 170 D

Following the end of the Second World War, economical automobiles were more than ever in demand. Mercedes-Benz again included a four-cylinder car diesel engine in the model range in the form of the model 170 D (W 136 series). The 170 was largely identical with the Mercedes-Benz 170 V built from 1936 to 1942. The diesel variant launched in 1949 was powered by the 1.8-litre OM 636 I engine, an in-line four-cylinder diesel developing **28 kW** (38 hp) at 3200 rpm. As early as 1950 Mercedes-Benz introduced a modified power plant that now had an output of **29 kW** (40 hp). The saloon's top speed increased from 100 km/h to 105 km/h.

The first 170 D was handed over to its buyer on 1 August 1949. In the following years many more customers in industry, the trades and the public sector, but also private individuals, chose the first post-war Mercedes diesel. From 1949 to 1953 a total of 33,822 units of the model were built, including chassis and half-ton panel vans.

In addition to the 170, there was also a diesel-powered variant of the 170 S, the first special-class car from Mercedes-Benz since the war. The Mercedes-Benz 170 DS (W 136 VIII D series) came out on the market in 1953 and was built until 1955. The 170 DS was equipped with the **29 kW** (40 hp) OM 636 VIII. To cut the higher production price of this diesel engine versus the petrol drive, the OM 636 was manufactured in very large numbers and not only used in models 170 D and 170 DS, but also in the Unimog. Daimler-Benz AG also sold the unit as a stationary engine.

1954 – "Ponton" Mercedes with diesel engine

Models 180 D (W 120 series) and 190 D (W 121 series) put the diesel drive in the wrappings of the "Ponton" (a self-supporting chassis-body structure) design introduced in 1953: aerodynamically optimised and featuring a unitary body. The familiar **29 kW**/40 hp engine powered the 180 D on its debut in March 1954; in 1955 the output was raised to **32 kW** (43 hp) at 3500 rpm. In 1958

Mercedes-Benz then introduced the new OM 621 engine. As a 1.9-litre diesel power unit it developed **37 kW** (50 hp) at 4000 rpm in model 190 D; from 1961 it also propelled the 180 D with **35 kW** (48 hp) developed at 3800 rpm. In all, 235,000 units of the two models were built.

The Mercedes-Benz “Ponton” with diesel engine also was exported to North America. To create awareness of the design, in 1954 journalist Bill Carroll undertook a test drive across the USA in a Mercedes-Benz 190 D.
Mercedes-Benz diesel cars repeatedly have provided such demonstrations of reliability. In addition to long, strenuous journeys, records and outstanding sporting achievements have moulded the diesel history of Mercedes-Benz. In 1955, for example, three Mercedes-Benz 180 D were the winners in their class in the Mille Miglia. Mercedes racing manager Karl Kling personally showed that the diesel drive is good for sporty performance. In a model 190 D he won the 1959 Africa Rally over 14,045 kilometres from Algiers to Cape Town at an average speed of 80.6 km/h.

1961 – Tailfin 190 D and 200 D

In the “tailfin” (W 110 series) the diesel further emancipated itself from its origins in the commercial vehicle. The two-litre diesel presented in 1961 was still called the 190 D. But when Mercedes-Benz introduced the new model 200 in 1965, the compression-ignition variant also was renamed 200 D to match it, though its displacement and output (**44 kW**/55 hp at 4200 rpm) remained the same. In addition to a five-bearing crankshaft the OM 621 four-cylinder diesel engine got better sound insulation than its predecessor and, as a high-speed diesel, propelled the car to a top speed of 130 km/h. On the other hand, accelerating from standstill to 100 km/h still took 28 seconds.

From 1965 to 1968, 159,365 200 D saloons were built, plus units of the 200 D Universal estate and the 200 D with long wheelbase (3350 millimetres instead of 2700 millimetres) and eight seats. The diesel had become well established in the mid-sized range of Mercedes-Benz. This is shown by the sales figures and the model range diversification which took place in the late 1960s. And diesel-powered cars long since had ceased to be austere in their appointments: as an optional extra the compression-ignition models of Mercedes-Benz were now even available with an automatic gearshift.

1974 – Five-cylinder diesel in the Stroke Eight

In 1968, for the first time two new diesel models were introduced simultaneously, the 200 D and the 220 D, in the W 115 series. In 1973 the 240 D was added to the range, and in July 1974 the 240 D 3.0 appeared as the top-of-the-line model. It was powered by the world's first five-cylinder passenger car diesel engine. Even the injection pump and its controls were new on this new engine developed on the basis of the OM 616.

With a swept volume of 3005 cubic centimetres, the OM 617, designed as an in-line five-cylinder, generated **59 kW** (80 hp) at 2400 rpm and had a respectable top speed of 148 km/h. With acceleration from standstill to 100 km/h in 19.9 seconds, the new top diesel model from Stuttgart was the liveliest and fastest diesel car in the world and featured impressive smoothness and economy. 53,690 units of the 240 D 3.0 were manufactured; in all Mercedes-Benz sold 945,206 W 115-series diesel cars.

The starting equipment of the five-cylinder diesel also was innovative: instead of the mechanical shutoff device of the 2.4-litre engine only a pneumatic device was used, so that the engine could be shut off with the ignition key. Starting was also by a turn of the key in the 240 D 3.0 and not, as previously was the case, by pulling a lever: when the driver turned the ignition key, preglowing was initiated and an indicator lamp lit up. When the light went out after a bit, the engine could be started in the normal way with a key. What now appears the most natural thing in the world was appreciated as a new comfort feature in 1974, which has since gradually found its way into all diesel cars of the brand and beyond.

1976 – Four diesel engines for the 123 series

The new mid-sized series took the start with four diesel variants in 1976. The W 123 came out as 200 D, 220 D and 240 D with four-cylinder engines and as 300 D with the in-line five. With that Mercedes-Benz took the entire, extremely successful diesel programme of the Stroke Eight into the new model. For use in the W 123 the engines were thoroughly worked over. Among other things they were given new cylinder head gaskets made of a material called Ferrolastic®;

in addition, oil changes were made simpler; the exhaust system was improved and the oil and fuel filters modified.

In view of the big demand for diesel models both from the new series and the W 115 series, the compression-ignition Stroke Eight models continued to be built for one year parallel to the W 123. How popular the diesel model had become in the meantime is shown in the statistics: the biggest-selling saloons of the 123 series were the 240 D (448,986 units) and 200 D (378,138 units).

1977 – A diesel coupé improves CAFE

In autumn 1977 the 300 CD diesel coupé was added to the 123 series. The engine of the two-door car was the same fitted in the 300 D Saloon: the three-litre five-cylinder diesel OM 617 with its output of **59 kW** (80 hp) at 4000 rpm. However, the elegantly styled diesel was manufactured exclusively for the North American market. The object was to improve the Corporate Average Fuel Economy of Mercedes-Benz automobiles in the US and Canadian markets.

CAFE describes the average fuel consumption of all models of a brand. Under a regulation issued by the US government, by 1985 the average consumption of all models of a car brand sold in North America had to be less than the equivalent of 8.55 litres per 100 kilometres. The number of units of each model sold was not important. CAFE was computed simply by adding up the average consumption of all variants on offer and dividing up this figure by the number of variants. Innovative concepts like the economical diesel engine in the 300 CD therefore made their mark on the consumption statistics.

1977 – A turbodiesel for the S-Class

Another diesel model presented by Mercedes-Benz specifically for the American market caused a stir at the 1977 Frankfurt International Motor Show (IAA): the 300 SD was the first S-Class (W 116 series) from Stuttgart to be equipped with a compression-ignition engine. An exhaust-gas turbocharger provided for performance appropriate to the luxury saloon, boosting the output of the five-cylinder diesel familiar from the 123 series to **85 kW** (115 hp).

In May 1978 production of the model based on the US version of the W 116 series began. The three-litre diesel was fitted with a Bosch injection pump and a Garret exhaust-gas turbocharger and provided the 1.8-ton saloon with respectable performance: the top speed was 165 km/h; the S-Class Turbodiesel sprinted from standstill to 96 km/h (= 60 miles per hour) in 14 seconds. The diesel cousin could not match the unbelievable performance of the 450 SEL 6.9 of the W 116 series. But it made up for it with an average consumption of only 14 litres of diesel per 100 kilometres, while the S-Class with the M 100 V8 engine required 22 litres of premium petrol for the same distance – albeit a very common consumption figure in those days.

1980 – Turbodiesel in the 123 series

The American CAFE standards were further toughened in the late 1970s. Accordingly, in 1981 Mercedes-Benz replaced the 300 CD and 280 C coupés from the 123 series with the new 300 CD Turbodiesel and also offered the 300 D Turbodiesel as a parallel model. Whereas these new models again were reserved for the North American market, the Mercedes-Benz 300 T Turbodiesel launched in 1980 was also sold in Germany. Like the saloon and the coupé, this estate had the three-litre in-line five-cylinder under its bonnet, boosted by a Garrett exhaust-gas turbocharger. After debuting in the S-Class the engine now developed **92 kW** (125 hp) at 4350 rpm and was good for a top speed of 165 km/h and acceleration from standstill to 100 km/h in 15 seconds. In all, 28,219 units of the first Mercedes-Benz turbo-diesel car for the German market were sold between 1980 and 1986.

With the turbodiesel models from the 123 series, the turbocharged compression-ignition engine returned to its origins in the test shops of Mercedes-Benz: the first turbodiesel engine designed by the Stuttgart engineers, with an output of **132 kW** (180 hp), was installed in a 123 chassis for test driving. Following the successful tests with the prototype it was decided to pursue the concept further and develop a five-cylinder turbodiesel for the S-Class.

1983 – Whisper diesel in the new compact class (W 201 series)

As third car series, Daimler-Benz put the compact class on the market in 1982. The small Mercedes got a new two-litre diesel (**53 kW**/72 hp at 4600 rpm) in 1983 and was called the 190 D. The engine was designed as a lightweight, economical, agile unit. Above all, the engine was completely encapsulated, reducing the noise it generated by half. The OM 601 became known as the "whisper diesel." Mercedes-Benz supplemented this four-cylinder in 1985 with an in-line five-cylinder (**66 kW**/90 hp at 4600 rpm) installed in the 190 D 2.5. The top speed of the 190 D was 160 km/h, while the more powerful 190 D 2.5 now did 174 km/h.

Once again, models specifically intended for the North American market were created: the 190 D 2.2 of 1983 had a modified four-cylinder diesel engine, the 190 D 2.5 Turbo was based on the in-line five-cylinder of the 190 D 2.5. Exhaust gas turbocharging ensured an output of **90 kW** (122 hp) at 4600 rpm, the top speed was around 192 km/h. Starting in 1986, 20,915 units of this most powerful of the diesel models from the W 201 series were built in all. Originally designed as an export model, the 190 D 2.5 Turbo also was available in Germany from September 1987 on.

1985 – Six-cylinder compression-ignition engine in the 124 series

For the first time the mid-sized 124 series offered an in-line six-cylinder diesel engine in a Mercedes-Benz passenger car. At the presentation of the new models in December 1984, the Stuttgart automakers introduced the 200 D with four-cylinder power plant (**53 kW**/72 hp at 4600 rpm), the 250 D with five cylinders (**66 kW**/90 hp at 4600 rpm), and finally the 300 D with an in-line six-cylinder (**80 kW**/109 hp at 4600 rpm). The two-litre four-cylinder of the 200 D was known from the compact class. The 300 D was distinguished externally from the smaller models by additional air intake slots in the front apron.

In 1985 Mercedes-Benz launched the 300 D Turbo as an estate, reserving it for export to North America until September 1987. The turbocharged in-line six-cylinder had an output of **105 kW** (143 hp) at 4600 rpm, which was increased to **108 kW** (147 hp) in 1988. The saloon of the same model was shown in 1987 in Frankfurt/Main at the International Motor Show; in addition to the

300 D Turbo with rear-wheel drive there was now also the 300 D Turbo 4MATIC with four driven wheels. Additional air intake gills in the right fender distinguished the Turbo version from the 300 D.

A second 124-series turbodiesel was put on display in September 1988 at the Paris Motor Show. The 250 D Turbo was powered by a turbocharged 2.5-litre OM 602 engine, the one also used in the compact class. However, the unit used in the 124 series was a modified version developing **93 kW** (126 hp) at 4600 rpm; the top speed was around 195 km/h. The engine design was revised with the aim of improving the combustion process to reduce particulate emissions.

The most important means of achieving this was the use of a new prechamber featuring oblique fuel injection. This ensured more efficient combustion and also boosted output by **2.9 kW** (4 hp). Together with the 250 D Turbo, the 300 D Turbo also had its three-litre engine revised. Finally, in 1989, in connection with the “Diesel ’89” initiative, the non-turbocharged diesel cars also were fitted with revised engines. The improved models gave off 40 percent less particulates than their predecessors and thus met the stringent US standards even without a particulate filter.

From October 1990 onwards, as an optional extra Mercedes-Benz additionally offered an emission control system featuring an oxidising catalytic converter and exhaust-gas recirculation. Initially an option for conventional diesel engines, it also became available for turbodiesels at the start of 1991.

1993 – Diesel refinement in the S-Class

Diesel engines have been available for the S-Class of Mercedes-Benz since the 300 SD model from the W 116 series (1978 to 1980). The compression-ignition engine also found its way into the 126 series in the 300 SD Turbodiesel (1980 to 1985) and 350 SD Turbodiesel (1990 to 1991). What these specimens of the Stuttgart luxury class had in common is that they were sold only in North America. The story of the Mercedes-Benz 300 SD of the 140 series, which was exported exclusively to the USA and Canada from 1991 to September 1992, also begins this way.

From autumn 1992 on, however, an S-Class car equipped with a 3.5-litre turbodiesel also could be had in Europe: the compression-ignition engine finally had arrived in the international luxury automobile segment. The car developed **110 kW** (150 hp) and, with a top speed of 185 km/h, was content with an average 9.7 litres of diesel fuel. Standard equipment included an exhaust-gas turbocharger and an emission control system with oxidising catalytic converter.

1993 – New names, new models

Appropriate to its displacement, the model was renamed in June 1993, now being designated the S 350 Turbodiesel. The diesel models of the mid-sized 124 series also got new designations in 1993. They were now called E 200 Diesel, E 250 Diesel, E 250 Turbodiesel, E 300 Diesel, E 300 Turbodiesel and E 300 Turbodiesel 4MATIC.

The S 350 Turbodiesel was replaced in 1996 by the S 300 Turbodiesel. The new diesel model in the S-Class had a turbocharged engine with four-valve-per-cylinder design and intercooling; with **130 kW** (177 hp) developed at 4400 rpm its output was **20 kW** (27 hp) higher than its predecessor's. The engine had high torque over a very broad engine speed range; its pollutant emissions and fuel consumption were far less than the S 350 Turbodiesel's owing to optimised combustion. On top of that the top speed climbed to 206 km/h. The S-Class with diesel engine met with increasing interest everywhere in the world: of the total 406,532 saloons from the 140 series sold, 28,101 had compression-ignition engines.

1993 – Four-valve-per-cylinder diesel and emission control as standard

In 1993 the diesel technology in several Mercedes-Benz models underwent a decisive change: as a world first, four valves per cylinder were used in the diesel. Four instead of two valves per cylinder enabled increased torque and output over an appreciably enlarged engine speed range and cut fuel consumption under full load by as much as eight percent. Owing to an improved process of combustion the particulate emissions simultaneously were reduced by about 30 percent.

Initially, only the five- and six-cylinder naturally aspirated engines were converted to four-valve technology. The two-litre four-cylinder and the turbocharged engines retained their two valves per cylinder for the time being. The new engines for the C- and E-Class developed **70 kW** (95 hp, 2.2-litre displacement), **83 kW** (113 hp, 2.5-litre displacement) and **100 kW** (136 hp, three-litre displacement) – and were all equipped with exhaust-gas recirculation and oxidising catalytic converter as standard.

1995 – Three diesels and four eyes

In 1995 the new 210 mid-series made its debut. The distinguishing external feature of the new E-Class was the front end with its four elliptical headlamps. The model range initially comprised three diesel models. The E 290 Turbodiesel, its four-stroke diesel engine featuring direct injection, exhaust-gas turbocharger with intercooler, plus emission control system with oxidising catalytic converter, caused quite a stir. Its in-line five-cylinder OM 602 DE 29 LA engine offered the combination of diesel technology and direct injection for the first time in a Mercedes-Benz car. Compared with the naturally aspirated three-litre engine with prechamber injection in the E 300 Diesel, which practically had the same displacement, the new design impressed observers with appreciably higher torque and lower fuel consumption. The new engine was the first step of Mercedes-Benz towards the introduction of direct-injection car diesel engines.

1997 – With CDI into the future: Premiere in the C-Class

The future of diesel drive became reality at the International Motor Show in Frankfurt am Main in September 1997: in the C 220 Turbodiesel Estate Mercedes-Benz presented a direct injection system based on a new principle, “Common Rail Direct Injection” (CDI). In keeping with the designation of the new engine technology, which Mercedes-Benz and Bosch developed together, the vehicle came out on the market in December 1997 as the C 220 CDI.

While conventional injection systems have to generate the pressure for each injection operation individually, the new CDI engines operate with a common pressure reservoir for all cylinders, the so-called common rail. Regardless of engine speed, this reservoir continuously maintains an optimum pressure of

1350 bar for all cylinders; by means of solenoid valves, the ideal quantity of diesel fuel for each driving state is distributed to the injection nozzles and injected into the combustion chamber. The engine electronics individually calculate the requirements of every single cylinder dependent on the driving situation. The variable control of the injection process makes for appreciably improved mixture preparation and in effect results in lower fuel consumption and reduced pollutant emissions.

The CDI engine of Mercedes-Benz also impresses with its unusually smooth running, which can be put down mainly to so-called pilot injection. A few milliseconds before fuel injection proper, a small amount of diesel is sprayed into the cylinder, ignites, and ensures preheating of the combustion chambers. Owing to this preheating, during the main injection the pressure and temperature no longer rise so sharply, and the engine runs quieter.

The **92 kW** (125 hp) four-cylinder OM 611 engine of the C 220 CDI is a four-valve-per-cylinder design and develops remarkable torque of 300 Newton metres from an engine speed as low as 1800 rpm. A comparison with the predecessor model is very interesting: 30 percent more power, double the torque, ten percent less consumption. CDI thus set new standards for diesel cars and changed the image of the diesel engine for good. Now the compression-ignition engine no longer is considered just a miracle of economy, but also an agile and sporty performer.

1998 – CDI in the E-Class

New CDI diesel engines featuring common rail direct injection and turbocharger brought the new technology to the E-Class too in June 1998. The E 200 CDI got **75 kW** (102 hp) out of its turbocharged two-litre four-cylinder and sprinted to a top speed of 187 km/h. The E 220 CDI developed **92 kW** (125 hp) and reached the 200 km/h mark. Yet the new models needed an average of only 6.3 litres of diesel per 100 kilometres.

The 1999 model refinement package fully established CDI technology in the E-Class: the five-cylinder of the E 270 CDI developed **125 kW** (170 hp) and maximum torque of 370 Newton metres from 1600 rpm. But the most powerful diesel of the model range ran on six cylinders in the new E 320 CDI. The

145 kW (197 hp) direct-injection diesel got its maximum torque of 470 Newton metres at 1800 rpm and held it to 2600 rpm. This 3.2-litre engine took full advantage of the big torque that is the hallmark of the diesel. Compared with the previous six-cylinder diesel of the E-Class the torque increased by 42 percent. And yet the six-cylinder OM 613 DE 32 LA engine (direct injection, exhaust-gas turbocharger with intercooler, plus emission control system with oxidising catalytic converter) consumed on average only 7.8 litres of diesel fuel per 100 kilometres; its speed topped out at 230 km/h.

Like the new engines, the two four-cylinder CDI units introduced in 1998 also got new turbochargers with variable turbine geometry as part of the 1998 refinement package. This increased their output by up to 14 percent: The E 200 CDI now developed **85 kW** (115 hp), the E 220 CDI **105 kW** (143 hp).

2000 – The strongest diesel for the S-Class

The new S-Class W 220 debuted as a diesel in 1999 in the form of the S 320 CDI. Its in-line six-cylinder delivered **145 kW** (197 hp) at 4200 rpm. The torque was 470 Newton metres, obtained in a range from 1800 to 2600 rpm. The luxury saloon got up to 230 km/h with the 3.2-litre compression-ignition engine and sprinted from standstill to 100 km/h in 8.8 seconds.

By far the most powerful diesel engine in a Mercedes-Benz car made its arrival in the S-Class in the year 2000. From a displacement of four litres, the light-alloy V8 OM 628 DE 40 LA developed **184 kW** (250 hp) at 4000 rpm. It delivered torque of 560 Newton metres at 1800 to 2600 rpm. A top speed of 250 km/h and 7.8 seconds for accelerating to 100 km/h illustrate the role of the S 400 CDI as first among the Mercedes-Benz diesel models.

2002 – The diesel returns to the coupé

Since the C 123 series of the 1970s there had been no more Mercedes-Benz coupés with diesel engines. In 2002 the CLK 270 CDI (C 209 series) was introduced. The four-stroke diesel (electronically controlled common rail direct injection, Bosch three-plunger high-pressure pump and exhaust-gas turbocharger with intercooler) was an engine that met the demands on a sporty vehicle yet operated economically. **125 kW** (170 hp) at 4200 rpm were good for

a top speed of 230 km/h and standstill to 100 km/h acceleration in 9.2 seconds.

Also in 2002 Mercedes-Benz presented the second generation of CDI technology. These new engines once again improved performance, consumption, comfort and emissions. To achieve this, among other things the Mercedes engineers raised the ignition pressure from 145 bar to 155 bar to optimise the gas cycle. The result is greater pulling power and flexibility. The injection pressure of now 1600 bar, in conjunction with the newly developed seven-hole injection nozzle, permitted finer distribution of the fuel in the combustion chambers, better mixture formation, and more homogeneous combustion.

New V6 engine for greater dynamism

The development of innovative features for the diesel engine continues unabated. An outstanding example from the long list of novelties is the six-cylinder V-engine which Mercedes-Benz presented in December 2004 and has been offering since the spring of 2005 in different model series where this engine replaced the previous five- and six-cylinder in-line units. The new engine made its debut in the C-Class, giving the saloon and estate models a highly agile character with a decidedly sporty touch. The saloon accelerates from standstill to 100 km/h in just 6.9 seconds. It is therefore not surprising that these diesel-engined cars were also made available as “Sport Edition” versions, among other things with a visual enhancement package from AMG. The “Sport Edition +” documents the dynamic nature of the modern compression-ignition engine with an even wider range of features including sports suspension.

The V6 diesel engine with direct injection develops **165 kW** (224 hp) and a torque of 510 Newton metres, which is on tap from 1800 rpm and remains constant up to an engine speed of 2800 rpm. The engine complies with the Euro 4 emission norm and has been featuring a particulate filter as standard equipment ever since its market launch. Weight is reduced by a crankcase made of aluminium with cast-in grey-iron cylinder liners – an absolute novelty in this displacement and performance category. As a result, the new six-cylinder weighs in at just 208 kilograms and is thus only insignificantly

heavier than the previous five-cylinder engine. And the very compact dimensions of this engine with all its ancillary components allow it to be combined with four-wheel drive which, for lack of space, was not available for any six-cylinder diesel engine before.

The equally newly developed electronic control unit monitors all the engine functions – from the Instant Start System and the automatic start function through to the high-pressure pump. The VNT (Variable Nozzle Turbine) turbocharger with electrically adjustable guide blades, the exhaust-gas recirculation with control valve and the intake air throttling system are controlled to match the situation at any given point in time, on the basis of up-to-date measurements. What's more, the computer exchanges data with the seven-speed automatic transmission – if specified by the customer – and the Electronic Stability Program ESP®.

This new high-tech V6 diesel engine marks the beginning of the third generation of CDI technology at Mercedes-Benz. Owing to new materials and optimisation of the entire unit, the new CDI engines attained even higher combustion pressures than before – the engineers aimed at up to 200 bar and intended to boost the injection pressure too in future, to as high as 2000 bar. In addition, the complex CDI technology was further refined. The fuel is no longer injected all at once, but in as many as five portions. Special actuators (piezo crystals) take over the control of the injection nozzles: with electric pulses the atomic structure of the crystals can be expanded several hundred thousand times per second if required. With this sophisticated injection system, not only were the emissions further reduced; the working noise of the engine was also diminished once more.

Premiere: The torquiest eight-cylinder diesel engine

The Mercedes-Benz engineers also made us of the V6 engine's technology in the world's torquiest V8 passenger-car diesel engine (OM 629), which went into production in autumn 2005 in the E-Class and was available for other model series at a later stage. The **231 kW** (314 hp) V8 with an aluminium crankcase, cooled exhaust gas recirculation and electric intake air throttling generates its maximum torque of 730 Newton metres at an engine speed as low as 2200 rpm. As a result, the E 420 CDI accelerates from standstill to

100 km/h in just 6.1 seconds and reaches a top speed of 250 km/h. In terms of dynamism and smooth running characteristics, this eight-cylinder represents the benchmark in its market segment. The combined fuel consumption is 9.3 litres per 100 kilometres. The standard specifications of the E-Class with this engine include a maintenance-free particulate filter, seven-speed automatic transmission and AIRMATIC air suspension.

2003 – Maintenance-free particulate filter and Euro 4 norm

Mercedes-Benz made a major advance in respect of the environmental compatibility of the diesel drive in autumn 2003. As first automobile brand in the world the company introduced diesel passenger cars built to the Euro 4 norm and featuring a maintenance-free particulate filter. Mercedes-Benz offered the first filters for export to California as early as in 1985.

2005 – Particulate filter as standard in more than 30 Mercedes-Benz models

Since the early 1990s through 2005, technologies like the common rail system developed by Mercedes-Benz had reduced the fuel consumption of diesel cars by more than 25 percent. The CDI, state of the art of Mercedes-Benz diesel technology, meanwhile is represented in all the vehicle classes marketed by the brand: from the A-Class through the GL-Class to the S-Class.

More than 30 different models were affected when Mercedes-Benz began fitting all diesel cars from the A-Class to the S-Class with diesel particulate filters as standard in Germany, Austria, the Netherlands and Switzerland in the summer of 2005. Mercedes-Benz had been offering its innovative particulate filter system, which operates maintenance-free and makes do without additives, since 2003.

Owing to economical, optimised engines, in combination with the filter, the particulate emissions are more than 90 percent less than those of earlier engines. In view of this success a retrofit solution for car particulate filters was made available from autumn 2005, initially for vehicles of the C-Class and E-Class. Dr Thomas Weber, member of the Board of Management of Daimler AG, responsible for Corporate Research and Mercedes-Benz Cars

Development, emphasised: "*Our retrofit solution for particulate filters is further proof of the high level of our diesel expertise and a consistent step towards environmentally compatible, fuel-saving vehicles.*"

Unique change of character

At the Geneva Motor Show in 2005, Mercedes-Benz not only announced the incorporation of particulate filters in the standard specifications but also reviewed 70 years of diesel competence in the passenger car – the first 260 D had, after all, come off the assembly line in 1935. For decades, the diesel engine had been regarded merely as the epitome of longevity. It was known to be reliable and sound, but also somewhat sedate. In the course of time, it has lost this trait and acquired a completely new image. Today, sporty dynamism, agility, ride comfort, motoring pleasure and, not least, environmental compatibility rank among the attributes boasted by modern diesel engines. And the engineers at Mercedes-Benz have contributed to this change in no insignificant measure. This remarkable development is verified most clearly by figures: the world's first passenger-car diesel engine in the Mercedes-Benz 260 D developed just **33 kW** (45 hp), corresponding to a power-to-swept-volume ratio of **13 kW**/litre (17.8 hp/litre). In the C 320 CDI, the V6 diesel engine presented in December 2004 develops an impressive output of **165 kW** (224 hp) from a displacement of three litres – boasting a power-to-swept volume ratio of **55.2 kW**/litre (75 hp/litre), more than four times the ratio of the 260 D.

Torque ratings – the decisive factor for tractive power from low engine speeds – rose just as dramatically, from 98 Newton metres in the 170 D of 1949 to 510 Newton metres in the C 320 CDI. In other words, some 55 Newton metres per litre of displacement in 1949 are pitted against more than three times this figure – 170 Newton metres - today.

Future development trends of the diesel engine were outlined by Mercedes-Benz at the 2005 Geneva Motor Show, among other things by means of two roadsters. In the Vision SL 400 CDI show car, a new V8 diesel engine develops **231 kW** (315 hp) and transmits an enormous torque of 730 Newton metres to the crankshaft of the eight-cylinder unit.

From a displacement of three litres, the engine of the SLK 320 Triturbo develops remarkable **210 kW** (286 hp) and a torque of 630 Newton metres – **70.3 kW** and 211 Newton metres per litre of displacement. The triturbo engine is based on the modern V6 diesel. The show car is clad in the self-assured guise of the SLK 55 AMG. The car sprints from standstill to 100 km/h in 5.2 seconds; its top speed is limited to 250 km/h. It combines this impressive performance with excellent fuel economy: 7.5 litres of fuel per 100 kilometres (overall NEDC consumption).

Into the future with just a tenth of the first diesel's consumption

The economy of modern CDI engines, 70 years from the premiere of the diesel-powered car, is astounding. Whereas the world's first passenger car diesel engine in the 260 D consumed 0.3 litres of fuel on 100 kilometres to generate an output of one kilowatt, in 2005 the C 320 CDI made ends meet with just 0.04 litres per kilowatt over the same distance. This is a reduction by unbelievable 90 percent or, in other words, fuel consumption reduced by a factor of almost ten.

Innovations like this from Mercedes-Benz for the diesel drive not only conserve resources, but also reduce the burden on the environment, for as fuel consumption decreases, so too do exhaust-gas emissions – a tendency which has been amplified since 2005 mainly by innovative technologies like the BlueTEC emission control system and comprehensive concepts for environment-friendly vehicles such as BlueEFFICIENCY. Mercedes-Benz introduced BlueTEC for passenger cars in October 2006. In the commercial vehicle sector this technology, spelled "BlueTec", has been employed since 2005.

The world's smallest direct-injection diesel engine

Parallel to BlueTEC development, conventional diesel engines continue to be improved, one outstanding example being the diesel engine of the second-generation smart fortwo (451 series) introduced in 2007. With an NEDC consumption of just 3.3 litres per 100 kilometres and 88 grams of carbon dioxide emissions per kilometre, the smart fortwo cdi is the world's most economical production car and, at the same time, the one with the lowest

carbon dioxide emissions. With a tank filling of 33 litres, the two-door car with **33 kW** (45 hp) engine has a range of some 1000 kilometres – in theory, that's the distance from Berlin to the outskirts of Paris without a refuelling stop. The smart engineers further developed the predecessor model's proven cdi engine and made it fit for the future. They boosted output and torque by ten percent each and reduced fuel consumption by some 13 percent.

At the time of its premiere, this engine was the world's smallest direct-injection diesel unit – and a masterpiece of engine development with the most progressive engineering – normally the preserve of significantly larger engines – accommodated within highly compact dimensions. This includes a common rail direct injection system which produces high injection pressure ratings of up to 1600 bar (previously 1350 bar) even at low engine speeds, and feeds the fuel into the combustion chambers by means of newly developed six-hole injectors. Together, these two features account for an even more efficient combustion process. Turbocharger, charge air cooling, electrically operated and cooled exhaust gas recirculation, hydraulic valve clearance compensation and lightweight design are additional features which distinguish the smart's cdi engine as a high-technology package.

Eight-cylinder power for the S-Class

In December 2006, Mercedes-Benz added another diesel variant to the S-Class range (W 221), the S 420 CDI. The eight-cylinder car has a modern V8 CDI engine with a displacement of four litres which delivers **235 kW** (320 hp) and a torque of 730 Newton metres. For efficient and smooth power transmission, the 7G-TRONIC is installed as standard. Fuel consumption (NEDC) is as low as 9.4 to 9.6 litres per 100 kilometres and thus under the magical ten-litre line.

Mercedes-Benz diesel engines: Fit for climate protection

In 2007 piezo injectors on diesel engines formed part of the technologies Mercedes-Benz applied with the aim of systematically improving fuel economy and emissions. The Stuttgart-based brand provided evidence of this with the publication of its 2007 Sustainability Report which focuses on climate protection.

Future progress will continue to be based on internal combustion engines – as well as on research into alternative propulsion systems. Professor Herbert Kohler, Vice President with responsibility for Corporate Research and Advanced Vehicle/Powertrain Engineering as well as Chief Environmental Officer of Daimler AG: *"Our research and development work therefore focuses not only on alternative propulsion systems but also, and above all, on the ongoing improvement of internal combustion engines. Our aim is to make the petrol engine as efficient as the diesel engine, and the diesel engine as clean as the petrol engine."*

Among other things, the company works on a new engine concept which combines the advantages of the two systems. Over and above this, all cars are developed so as to permit the option of hybrid drive. By combining an efficient internal combustion engine with a hybrid module, the optimum powertrain can be configured, matched to operating conditions and the customer's preferences. One result of this work is the first diesel hybrid passenger car from Mercedes-Benz presented in March 2010, the E 300 BlueTEC HYBRID, which comes onto the market in 2011.

DIESOTTO: Combining the advantages of diesel & petrol engines

Mercedes-Benz presented the first results of research on a new internal combustion engine combining the advantages of diesel and petrol units at the 2007 Frankfurt International Motor Show: The DIESOTTO engine has the performance of a petrol engine as well as the high torque and fuel economy of a modern diesel – and it is extremely clean. Among other things, the novel high-technology package includes direct injection, turbocharging and variable compression. At the core of this innovation lies homogeneous charge compression ignition, permitting a highly efficient combustion process similar to that of a diesel. In contrast to comparable developments, the Mercedes-Benz system has the crucial advantage that it requires no synthetic fuels but can be operated using conventional petrol.

Upon being started and under full load, a spark plug is used for causing the petrol/air mixture to explode – as in a conventional spark-ignition engine. The DIESOTTO automatically switches to controlled auto-ignition (homogeneous combustion) within one power stroke in the part-load range, i.e. at low and

medium engine speeds. This homogeneous combustion at reduced reaction temperatures results in very low nitrogen oxide emissions. A standard three-way catalytic converter takes care of emission control in the DIESOTTO engine. In addition, a highly efficient engine management system is used to network the individual systems into an integrated configuration.

Diesel milestones for the future of the combustion engine

By optimising the diesel engine, Mercedes-Benz has time and again been setting new milestones for the future of the internal combustion engine. With BlueTEC and CDI BlueEFFICIENCY models, in particular, Mercedes-Benz engineers have succeeded in recent years in making the powerful and economical diesel engine as clean as the petrol engine. In 2010 all CDI BlueEFFICIENCY E-Class models with six-cylinder diesel power plant, for example, already meet the EU5 emission standard, and the BlueTEC model E 350 BlueTEC with urea injection even meets the future EU6 standard. Diesel-hybrid vehicles like the E 300 BlueTEC HYBRID now represent a further step towards the future of the diesel engine. Read more about the latest diesel technology from Mercedes-Benz in the chapter “BlueTEC, CDI BlueEFFICIENCY and BlueTEC HYBRID – The future of the compression-ignition engine“.

Diesel engines in Mercedes-Benz commercial vehicles

1928 – Mercedes-Benz diesel tractor

Along with the six-cylinder OM 5 engine, after 1926 Mercedes-Benz developed a new one-cylinder engine which it fitted into the OE diesel tractor in 1928. The engine displaced 4.2 litres and had an output of **19 kW** (26 hp) at 800 rpm.

1932 – First production light truck with a diesel engine

The Lo 2000 was the world's first light truck to be fitted with a diesel engine as standard. Daimler-Benz AG introduced it in 1932 at the Geneva Motor Show. It was powered by the new 3.8-litre prechamber diesel OM 59. This innovative vehicle design was a response of Daimler-Benz to the difficult economic situation following inflation and a world economic crisis. Customers had a high opinion of this economical and light truck.

The letters "Diesel" on the radiator next to the Mercedes star became a symbol mainly of heavy goods transport in the 1930s. Whereas the diesel engine's share of the power plants of big trucks already reached 90 percent in Germany in 1931, and trucks of five tons payload and more were fitted exclusively with diesel engines after 1934, the compression-ignition engine was much slower establishing itself in the light truck segment. The new OM 59 of 1932 was an important argument for diesel technology: the engine was less than half the size of the OM 5, but was nearly as powerful. And it gave the Lo 2000 a top speed of 65 km/h; in 1932 this definitely sufficed to have it called an express delivery van.

1933 – Semitrailer tractors from Daimler-Benz

The semitrailer tractors built in Gaggenau from February 1933 on also profited from the success of the Lo 2000. With the LZ 4000, LZ 6000 and LZ 8000 series (four, six and eight tons) the diesel truck model range of Daimler-Benz continued to grow. In the mid 1930s Daimler-Benz built trucks with petrol engines almost only for export.

High-speed, light diesel engines proved a key to the success of the semitrailer tractors: relatively small-volume engines with rated speeds of 2000 rpm and displacements between 3.8 litres (**40 kW**/55 hp) and 7.4 litres (**70 kW**/95 hp) powered the semitrailer tractor. In 1938 a tractor for ten tons payload was added; its six-cylinder diesel developed **74 kW** (100 hp). The advantage of uncoupling tractor and semitrailer was used by the buyers of tractors not only in the haulage sector: semitrailers were even supplied equipped as buses – this configuration went into the vernacular as “Tatzelwurm” (a mythical Alpine dragon).

1935 – 10,000th Mercedes-Benz commercial vehicle with diesel drive

Nine years after the merger of Benz & Cie. and Daimler-Motoren-Gesellschaft in 1926, the diesel engine was playing an increasingly important role in the commercial vehicle sector for Daimler-Benz AG: in Gaggenau the 10,000th commercial vehicle of the brand featuring a compression-ignition engine was delivered to a customer on 6 April 1935.

The engine range was correspondingly diversified, including engines for light and heavy-duty trucks with four and six cylinders as well as engines for urban buses.

1940 – Birth of the 300 engine series

A new era in diesel technology for commercial vehicles began at Mercedes-Benz during the Second World War: in 1940 the engineers of the Stuttgart brand took up work on an entirely new generation of diesel engines, the 300 series. The first prototype was the in-line six-cylinder OM 302, parallel to which the designers worked on the four-cylinder OM 301 unit.

Characteristics of the new engine were its compact dimensions and innovative components, for example a seven-bearing crankshaft and leaded bronze bearings with steel backings for the main and connecting rod bearings. Production commenced in 1942, but work on the 300 engine series could not be resumed until after the war.

On the basis of the OM 302, at war's end Mercedes-Benz Development resumed work on a modern commercial vehicle diesel engine. The condition was that the new unit had to be produced on machines on which Daimler-Benz manufactured a licensed version of the Opel Blitz during the latter war years and until 1949. This Mercedes-Benz L 701, as the vehicle with its wooden cab was called, the first truck of the Stuttgart brand after the war, was still powered by a petrol engine. On the other hand, under the bonnet of the first post-1945 heavy-duty truck, the L 4500, was the tried and tested OM 67/4 in-line six-cylinder diesel, which developed **82 kW** (112 hp) at 2250 rpm.

The diesel engine in the new L 3250 truck presented in May 1949 at the Hanover Trade Fair was now the OM 312, the first member of an extremely successful engine family. Passing through numerous stages of development, the 300 series would be the backbone of the medium-duty commercial vehicle diesel engine range from Mercedes-Benz for more than 50 years. In its first version the OM 312 in the L 3250 already developed **66 kW** (90 hp) at 2800 rpm.

A 1949 brochure underscored the advantages of the new design and left no doubt as to the importance of the new truck for the commercial vehicle range of the brand: "*The water-cooled, flexible six-cylinder diesel engine with an output of 90 hp and featuring controlled cylinder wall temperature and oil temperature is a particularly interesting new technical creation with its average fuel consumption of 14.4 litres per 100 km. Outstanding performance characteristics, highest operating reliability, tremendous economic efficiency, simple operation and thriftiest consumption, combined with excellent handling qualities and safe roadholding are the essential features of the new L 3250.*"

In the heavy-duty segment too, in 1950 a 300-series engine superseded the diesel technology which still dated from the 1930s: the Mercedes-Benz L 6600 was powered by an OM 315 8.3-litre in-line six-cylinder, which was good for **107 kW** (145 hp) at 2100 rpm.

1953 – Exhaust gas turbocharger for fire-fighting vehicles

The new generation also furnished a basis for technical innovations during the following years. Mercedes-Benz took an important step to boost performance by introducing the exhaust-gas turbocharger for commercial vehicle diesel engines. In a TLF 15/36 TA pump water tender, the Stuttgart company presented the first diesel engine which utilised the energy of flowing exhaust gases for charging the cylinders. The type OM 312 A engine (the A stands for Abgasturbolader = exhaust-gas turbocharger) developed **85 kW** (115 hp), **18 kW** (25 hp) more than the naturally aspirated basic engine.

But there had already been a few turbocharged commercial vehicle diesel engines from Mercedes-Benz before that: from 1948 the Esslingen-based Eberspächer company had been offering a suitable turbocharger as a retrofit kit for the OM 312. However, turbocharged commercial vehicle diesel engines did not gain broad acceptance until around 30 years later.

1957 – The 20,000th Unimog diesel

The new diesel engines from Mercedes-Benz not only were a success in trucks and cars. Special-purpose vehicles like the Unimog (“Universal-Motorgerät” for universal working machine) also were equipped with the diesel power unit. From the start of Unimog production to November 1957, 20,000 diesel engines were built for this powerful all-wheel-drive vehicle alone.

Originally, the diesel engines of the Unimog were identical with those of the Mercedes-Benz diesel passenger cars. In May 1963 the Unimog U 406 came out on the market with a **48 kW** (65 hp) OM 312 under its bonnet. This was Mercedes-Benz’s answer to the increasing demand for a high-powered variant of the special-purpose vehicle with the wide range of applications. The Unimog no longer saw use only in agriculture, but long since had proved its mettle in municipal service, as a fire-fighting vehicle, with the military and in other areas.

1963 – New model designations based on weight and output

The designations existing for the different truck models in the Mercedes-Benz range in the 1950s said nothing about the output of the engine used in each truck. The letters only indicated the basic configuration (conventional or cab-over-engine vehicle) and body. In 1963, therefore, Daimler-Benz decided to abolish the old nomenclature. During the following months, the letter and number combinations which we know today were introduced. The last two digits stand for one tenth of the engine output in horsepower (rounded off). Before that the gross vehicle weight in tons (rounded off) is stated. Thus, the heavy-duty all-wheel-drive truck LA 2620 of 1964 has a permissible GVW of 26 tons and an output of roughly 200 hp (**147 kW**). Actually, the OM 346 engine developed **154 kW** (210 hp) at 2200 rpm from its six cylinders with a total displacement of 10.8 litres.

1964 – Direct injection for commercial vehicle diesel engines

The OM 352 engine introduced at the 1964 Geneva Motor Show by Mercedes-Benz was the first direct-injection diesel for commercial vehicles. Direct injection results in lower consumption and higher output. Initially, however, the engines did not run as smoothly as their prechamber cousins. Particularly if single-hole injection nozzles were used with central combustion in a spherical combustion chamber, extremely loud noises and a high peak pressure were generated. Multi-hole injection nozzles and flat combustion chambers in the pistons were better still for fuel consumption, but likewise led to loud combustion noises and high peak pressures. The Mercedes-Benz design engineers ultimately decided to use a four-hole injection nozzle positioned almost dead-centre in the cylinder. However, it sprayed the fuel into the cylindrical combustion chamber at an angle of about 30 degrees. The fuel spray was directed at the wall of the combustion chamber; a swirl duct in the cylinder head provided for the necessary turbulence of the diesel mist in the cylinder. The ignition pressure in the direct-injection diesel rose to around 80 bar compared with 60 bar in the prechamber engine.

The operating noise of the direct-injection diesel had been sharply reduced by the time the engine was ready for production in 1964. In the car sector though, for the time being the classic prechamber diesel with its refined characteristics

remained the power plant of choice for Mercedes-Benz. In the commercial vehicle sector, by contrast, the first direct-injection diesel was received very well. For buyers of trucks and buses, not only the boost in power counted. The better efficiency compared with the prechamber power plants reduced the thermal load on the engines; they proved to be particularly reliable. A pleasant side effect of the reduced load on the engine oil: the servicing intervals for oil changes were extended to 18,000 kilometres.

A four-cylinder injection engine, the OM 314, also was brought out in 1964. The first units of the new model had a displacement of 3.8 litres and developed **59 kW** (80 hp) at 2800 rpm. The four-cylinder engines were used in light cab-over-engine trucks, vans, and special-purpose vehicles like the Unimog.

1968 – Turbocharging for the direct-injection diesel

A number of customers increasingly asked for a Mercedes-Benz diesel engine with fuel injection and exhaust-gas turbocharger. The turbocharger was supposed to provide the power necessary mainly for journeys through mountain regions. For where the atmosphere gets thin, boosting the volume of air in the combustion chamber gives rise to an especially sharp increase in output.

Initially the OM 352 A was intended for use in snow cutters. Following successful road testing the turbocharged unit was also installed in trucks. The new engine premiered in the L 1413, where the turbocharged injection engine developed **115 kW** (156 hp). The use of improved turbochargers from Eberspächer, Garrett® (Honeywell) and KKK (Kühnle, Kopp & Kausch) made this high-powered compression-ignition engine even more reliable.

1969 – The 100,000th commercial vehicle diesel engine

In the Mercedes-Benz Mannheim works, an anniversary was celebrated in January 1969: the 100,000th diesel engine for commercial vehicles built in the plant on the River Neckar came off the assembly line.

1969 – Hybrid research on diesel-engined buses

Mercedes-Benz displayed the first prototype of the OE 302 hybrid electric bus at the 1969 International Motor Show in Frankfurt/Main. The aim of optimizing the propulsion system of line-service buses in this project was mainly to reduce their emissions in downtown areas: battery current served to power the buses in the sensitive zones of city centres; on highways and in less densely populated city districts the serial hybrid drive changed to the diesel engine. In the serial hybrid system, however, the compression-ignition engine did not act directly upon the wheels, but supplied the electric traction motor with energy via a generator.

The successor to the OE 302 was presented in 1978 at the “transport 78” trade show in Munich: the OE 305 hybrid electric bus again had an electric traction motor which a diesel engine powered via the generator. The heavy batteries notwithstanding, the capacity of the drive system was designed so that the bus attained the performance of a comparable diesel-powered O 305 urban bus. Despite the high load on them, the storage batteries survived an average of 800 recharging operations. In the course of 1979 a total of twenty OE 305 hybrid electric buses took up local public transport service in the cities of Stuttgart and Wesel. By 1983 the vehicles had covered more than 1.3 million kilometres.

In 1979 Daimler-Benz also introduced a second hybrid bus: besides the standard diesel engine, the Duo Bus or dual-powered bus was equipped with an electric motor which was supplied with current by an overhead cable. Whereas the electric motor was used in the city, in the country the bus operated on its diesel drive. Before the end of 1979, three of the vehicles commenced trial operation in regular service in Esslingen. During the next few years more than 50 of these vehicles would be used internationally in regular service.

These test vehicles of the 1970s presaged the part that the diesel drive would play in advanced hybrid concepts for passenger cars after the year 2000. Other bus concepts with innovative drive systems were the diesel-electric O 405 GTD dual-powered bus (1986) and the diesel-electric O 405 GNTD bus (1994). This low-floor articulated bus had a diesel engine that powered a generator that supplied electric energy for the wheel hub motors.

1970 – New OM 400 engine series

A new engine series for heavy-duty trucks came out on the market in 1970. The 400 family of Mercedes-Benz diesel engines made its debut in the new LP 1632 as a V10 engine with a displacement of 16 litres and an output of **235 kW** (320 hp) at 2500 rpm. The new units were the designers' response to a proposed law intended to speed up over-the-road freight transport: in 1968 the German Federal Minister of Transport, Georg Leber, introduced a bill stipulating that from 1972 on new vehicles must have an engine output of 6 kW (8 hp) per ton of gross combination weight.

Medium-duty and light trucks, which are more likely to be used in short-radius distribution work and pull trailers less frequently than their heavyweight brothers, were not so much affected by this regulation. But for long-distance trucks and tractors and other heavy-duty commercial vehicles, the output of the 300-series engines was no longer adequate under the conditions set by the new laws. From 1969 Mercedes-Benz thus set about developing the new engine generation.

The veil was lifted on the OM 403 with diesel direction injection in 1970. Together with the engine, the LP 1632 truck presented another innovation – a tilt cab. This appreciably simplified the servicing of the engine in a COE truck and invalidated a major argument in favour of conventional trucks. In 1972 the bigger engine was complemented by the OM 402 V8 diesel, with 12.8 litres displacement and **188 kW** (256 hp) output at 2500 rpm. For medium-duty trucks, the OM 401, a V6 diesel with 9.6 litres displacement and **141 kW** (192 hp) at 2500 rpm, followed in 1975.

1970 – Assembly of commercial vehicle diesel engines in Iran

Iranian Diesel Engine Manufacturing Company (IDEM) in Tabriz, Iran, began assembling diesel power units for commercial vehicles in 1970. Daimler-Benz had owned a stake in the company since 1969. Engines of the 300 family were built there: around 180,000 units of the OM 314, OM 352 and OM 352 A engines were produced in the first 30 years of this cooperation.

The commercial vehicle diesels from Mercedes-Benz conquered the world during this decade: in 1979 Mercedes-Benz awarded licenses for the 300 and 400 series to Industrial Development Company of South Africa (IDC). Diesel engines of Stuttgart origin were built and adapted to various vehicles and pieces of equipment in the engine plant of Atlantis Diesel Engine (ADE) north of Cape Town.

1975 – The one-millionth commercial vehicle diesel engine from the Mannheim plant

In Germany, too, the manufacture of commercial vehicle diesels was running at full swing. In 1975 a V6 diesel from the OM 401 series became the one-millionth commercial vehicle diesel engine to be built at the Mercedes-Benz plant in Mannheim. The **141 kW** (192 hp) engine was donated to the city of Mannheim, which installed it in a Mercedes-Benz fire truck.

1980 – Turbocharged and intercooled OM 422 LA

As early as the mid-1970s Mercedes-Benz began developing commercial vehicle engines which featured an intercooler in addition to the exhaust-gas turbocharger. Cooling reduces the temperature of the air compressed by the turbocharger, thus increasing the oxygen content. This permits obtaining higher power in engines with the same technical data: the OM 422 A V8 diesel developed **243 kW** (330 hp) with 14.6 litres displacement, whereas its intercooler-equipped brother introduced in 1980 developed an output of **276 kW** (375 hp).

This OM 422 LA engine was the first commercial vehicle engine from Mercedes-Benz to have an intercooler. It was followed in 1982 by a 300 series engine, the OM 362 LA, with the same technology and an output of **141 kW** (192 hp) at 2600 rpm. 300 series engines like this were built in large numbers mainly for export.

1987 – The 500,000th engine of the OM 400 series

Within 17 years, 500,000 engines of the OM 400 series were built. The anniversary engine originated in Mannheim in January 1987. From the original

OM 403 V10 engine, meanwhile, various V6 and V8 drive units had emerged whose power output in production trucks ranged from **140** to **320 kW** (190 to 435 hp). A special heavy-duty hauling variant of the V10 engine even boasted **368 kW** (500 hp).

1996 – Debut of new engine families 500 and 900

Together with the new Actros heavy-duty truck, in 1996 Mercedes-Benz introduced a new, innovative engine family. The diesel power plants of the 500 series made their debut with a V6 engine, the OM 501 LA (**230 kW**/313 hp - **315 kW**/428 hp) and a V8 engine, the OM 502 LA (**350 kW**/476 hp - **420 kW**/571 hp). Equipped with exhaust-gas turbocharger and intercooler, the engines featured individual unit pumps and attained their maximum torque at 1080 rpm. While the V6 had one turbocharger for the entire engine, the V8 was distinguished by one turbocharger for each of the two cylinder banks.

Together with the 500 series Mercedes-Benz introduced the new 900 series of in-line diesel engines for the new Atego truck family, comprising mainly light and medium-duty vehicles. The four-cylinder OM 904 LA developed between **90 kW** and **125 kW** (122 hp and 170 hp), the six-cylinder OM 906 LA delivered **170 kW** or **205 kW** (231 hp or 279 hp).

With the two new engine families, plus the 457 series borrowed from South American production in 2001 for the new Axor family, Mercedes-Benz soon covered the entire commercial vehicle spectrum with different ultramodern diesel power units. The engines are perfectly matched to the other components of the drive system. An individual drivetrain can thus be put together from different modules. This results in an extraordinary variety of models and specification options.

1998 – Diesel-electric drive system in the Cito midibus

In 1998 Mercedes-Benz introduced the Cito urban midibus. The innovative low-floor vehicle had a diesel-electric drive system. An OM 904 LA diesel engine with an output of **130 kW** (177 hp) served to drive a generator. The generated electric power was fed into the electric traction motor. Thanks to this drive

technology, the Cito excelled with smooth and continuous acceleration. This driving characteristic cannot be obtained with a purely mechanical drivetrain.

The unit consisting of diesel engine, generator and electric motor was installed in the rear of the vehicle and called a power pack. Mercedes-Benz developed the system together with Siemens. The Cito was built from 1999 to 2003. In 2000 it won the distinction of “Bus of the Year 2001.”

2003 – More torque for the OM 500 series

All variants of the OM 500 were revised in 2003. The V6 and V8 engines of the Actros got slightly higher power ratings. But most of all the torque of most of these diesel engines was markedly increased. The engines’ ease of servicing also was improved with wear-free materials and extended servicing intervals of as much as 150,000 kilometres in long-haul operation.

2004 – 450 kW (612 hp) in the Actros Black Edition

This special edition of the Actros, limited to 250 units, is equipped with the OM 502 LA engine, which develops **450 kW** (612 hp) at 1800 rpm from a displacement of 16 litres, making this the first Mercedes production truck to clear the 600-hp hurdle.

2006 – The 500,000th reconditioned commercial vehicle engine

A V8 diesel of the 500 family became the 500,000th reconditioned diesel engine for Mercedes-Benz commercial vehicles in 2006, coming off the assembly line at the Mannheim plant. Genuine reconditioned engines or factory-reconditioned components from Mercedes-Benz are the ideal solution for providing commercial vehicles with a virtually new drive system. Reconditioned engines are typically used for trucks and buses which run up high mileages in a short time – the so-called mileage millionaires. But also for vehicles with expensive special bodies and correspondingly high residual value, the replacing of the engine suggests itself when the original unit shows weaknesses.

In a reconditioned engine, not only all defective and worn-out parts are replaced, but all design changes, innovations and improvements made since original manufacture are incorporated into the unit. With that, the reconditioned component gets an entirely new identity, recognisable by the reconditioned-unit model plate. And Mercedes-Benz gives the same warranty on it as for a brand-new component.

Reconditioned engines are available for the 500, 900, 457, 300 and 400 series. The V-engines of the heavy-duty 500 series are the heart of the Actros and are also premium engines operating in high-quality touring coaches like the Travego. The 900 series powers the Atego, Vario, Cito, Citaro and Unimog vehicles; the 457 family operates in the Axor and Citaro. But even for the older series, the 300 and 400, production of which was discontinued, there are still replacements available. For the most part, these engines are reconditioned using original production equipment. They are available then, for example, to the fans of vintage Unimog vehicles.

Engine reconditioning has a long tradition in Mannheim: since 1949 the factory has been dismantling commercial vehicle engines, completely overhauling them and returning them as good as new to customers. The 200 employees in engine reconditioning overhaul some 5000 units annually. This requires detailed knowledge: there are more than 2700 different engine variants on the list.

2007 – Citaro bus with innovative diesel technology

In 2007, Mercedes-Benz presented the first prototype of a Citaro with diesel-electric hybrid drive to the public. The developers set themselves ambitious targets in that this diesel-electric serial hybrid drive is a technologically highly sophisticated system. It permits zero-emission operation on battery power alone. The drive configuration is equally advanced: it is installed in a Citaro G articulated bus and comprises four wheel hub motors which drive the central and rear axles. At this point in time, the Citaro Hybrid was the only vehicle to offer this combination.

In the serial Citaro Hybrid, the diesel engine no longer serves as a permanent drive unit but powers the generator which supplies the amount of electricity

required at any point in time. There is therefore no mechanical connection between the diesel engine and the driven axles – a characteristic feature of serial hybrid drive. This creates new degrees of freedom in the design of the passenger compartment. The electricity produced by the generator is stored in maintenance-free lithium-ion batteries which are mounted on the roof of the Citaro. This battery technology stands out for a particularly high energy density and high storage capacity. The batteries generate **170 kW** (231 hp), and their weight of 450 kilograms is comparatively low. They are fed with energy not only by the diesel-powered generator but also by the brakes – a process known as recuperation.

Downsizing is one of the major advantages for the technology of the particularly sophisticated serial hybrid in the Citaro: instead of the OM 457 hLA six-cylinder in-line engine with its very large displacement of twelve litres normally used in the articulated bus, the compact OM 924 LA is installed in the hybrid bus. It develops an output of **160 kW** (218 hp) from a displacement of 4.8 litres. As a result, engine weight is reduced from around 1000 to just 450 kilograms. The use of the compact engine has been made possible by the fact that the diesel engine does not serve as prime mover of the Citaro Hybrid bus. It does not have to generate peak output, for instance, and can therefore be operated in the narrow engine speed band in which the highest fuel economy and lowest emissions are ensured. For this reason, the engine's torque characteristics were adapted to its – partly stationary – operating conditions in the hybrid bus for optimised levels of emissions and fuel economy.

2007 – BlueTec diesel technology as a recipe for success

After the successful introduction of the long-distance Actros truck with BlueTec technology in early 2005, the company launched the models from the Atego and Axor truck series as well as Actros construction-site vehicles with BlueTec diesel technology onto the market in 2006. To ensure that the stringent limits of forthcoming emission norms are safely undercut and to achieve clear advantages in terms of fuel economy at the same time, since 2007 the company is consistently using SCR (Selective Catalytic Reduction) technology in all its commercial vehicles for the European market. SCR reduces

pollutants in the exhaust gas by up to 80 percent and at the same time lowers the fuel consumption to a measurable extent.

SCR is based on the injection of an aqueous urea solution (AdBlue®) into the exhaust flow which together with the catalytic converter reduces nitrogen oxides (NO_x) by around 80 percent. This is the most effective method in existence for reducing nitrogen oxides in diesel engines. In 2005 trucks and buses with BlueTec already met the particularly stringent Euro 4 and Euro 5 emission standards that would apply to the production of all engines beginning in the autumn of 2006 and 2009, respectively.

Tried and tested diesel engines as the basis

The basis of the first revolutionarily clean BlueTec diesels are the tried and tested 500- and 900-series engines. In the Actros the V6 power plant OM 501 LA in its weakest version develops **235 kW** (320 hp) at 1800 rpm. The engine achieves its maximum torque of 1650 Newton metres at 1080 rpm. In addition to turbocharger and intercooler, the engine has a central, high-set camshaft, fully electronic engine management with single-cylinder injection pumps, and centrally arranged eight-hole nozzles providing an injection pressure of up to 1800 bar.

The most powerful unit of the 500 series is the OM 502 LA with 16 litres displacement, an output of **440 kW** (598 hp) at 1800 rpm and torque of 2800 Newton metres at 1080 rpm. Injection is based on the same principle as in the V6 unit, except that seven-hole nozzles are used. Both V-engines have a four-valve-per-cylinder design. Whereas in the V6 version the rated outputs remain largely the same and a new top V6 variant with **350 kW** (476 hp) and maximum torque of 2300 Newton metres has been added, BlueTEC generally gives the existing V8 engines a higher output. The most powerful OM 502 LA now develops **440 kW** (598 hp) at 1800 rpm and has maximum torque of 2800 Newton metres.

The 900-series engines with BlueTec likewise cover the entire range of variants previously offered as Euro 3 engines. The OM 904 LA in the basic version as water-cooled in-line four-cylinder with three valves per cylinder develops **95 kW** (129 hp) at 2200 rpm. The engine features a turbocharger, intercooler

and fully electronic engine management with nine-hole injection nozzles which achieve injection pressure ratings of up to 2000 bar. The maximum torque of 500 Newton metres is available at 1200 to 1600 rpm.

The most powerful BlueTec engine of the Atego is the OM 906 LA, a water-cooled in-line six-cylinder with three valves per cylinder. The technical details are similar to those of the four-cylinder unit; however, this engine gets **210 kW** (286 hp) at 2200 rpm with 6.4 litres displacement. This is good for torque of 1120 Newton metres at 1200 to 1600 rpm.

The OM 457 LA and the OM 906 LA in the Axor also give a good account of themselves as environment-friendly BlueTec engines. The water-cooled in-line six-cylinders in four-valve-per-cylinder design work with a turbocharger and intercooler, a central, high-set camshaft, fully electronic engine management with single-cylinder injection pumps, and centrally arranged seven-hole or nine-hole nozzles providing an injection pressure of up to 2000 bar. In its basic version the Euro 4 OM 906 LA develops **188 kW** (256 hp) at 2200 rpm. The engine attains its torque of 970 Newton metres at 1200 to 1600 rpm. The most powerful version of the Euro 5 OM 457 LA engine with its twelve litres displacement develops **315 kW** (428 hp) at 1800 rpm, and the torque of 2100 Newton metres is available at 1100 rpm.

In the past, the Euro 1 through to Euro 3 emission norms always required compromises as combustion processes designed for low particulate emissions and high fuel economy inevitably produced larger quantities of nitrogen oxides – and vice versa. The external SCR exhaust gas aftertreatment eliminated this conflict of goals caused by thermodynamic laws and permitted the next generation of engines from the 900 series to be developed for both low consumption and low particulate emissions. The success of this technology speaks for itself: as per July 2007, as many as 80,000 BlueTec trucks were already operating on our roads – the majority of these already comply with the Euro 5 emission norm which would come into force in October 2009. And in 2008 more than 160,000 vehicles with BlueTec were in operation – with a great many more to come.

The continuous improvement of this technology by the Mercedes-Benz engineers guarantees the sustained success of BlueTec in the commercial vehicle field. In

October 2010 *Fleet Transport Magazine* honoured this achievement with the presentation of the “Green Commercial of the Year“ award to the Atego BlueTec Hybrid.

The platform of this short-radius distribution truck with hybrid drive is the Atego 1222 L EEV. The basic vehicle satisfies the EEV (Enhanced Environmentally Friendly Vehicle) standard and operates on German roads toll-free. Its compact and light four-cylinder diesel engine with a displacement of 4.8 litres develops **160 kW** (218 hp). It is paired with a water-cooled electric motor with a peak output of **44 kW** (60 hp) which is supplied with power by high-energy, high-capacity lithium-ion batteries.

The electric motor is arranged behind the internal combustion engine and clutch but in front of the transmission. In this set-up, engine and motor can drive the truck individually or in combination. This architecture (parallel hybrid drive) permits moving off under electric power, recuperation, boosting with the electric motor, and optimisation of the diesel engine’s characteristics. The driving power of the diesel engine is cut in by means of the clutch between the diesel engine and the electric motor. Up until then the internal combustion engine serves exclusively to power the auxiliary units. The result is not only a clear-cut reduction in fuel consumption and exhaust emissions by up to 15 percent, but also lower noise emissions.

A fleet of 50 Atego BlueTec Hybrid will be delivered to German customers in the short-radius distribution sector at the start of 2011 in order to prove the workaday suitability of this important technology of the future. The vehicles will be included in the “Electric Mobility Advancement Programme” of the German Federal Ministry for Transport, Construction and Urban Development.

BlueTec, CDI BlueEFFICIENCY and BlueTec HYBRID – The future of the compression-ignition engine

By optimising the diesel engine, Mercedes-Benz has time and again been setting new milestones for the future of the internal combustion engine. With BlueTec and CDI BlueEFFICIENCY models, in particular, Mercedes-Benz engineers have succeeded in recent years in making the powerful and economical diesel engine as clean as the petrol engine. In 2010 all CDI BlueEFFICIENCY E-Class models with six-cylinder diesel power plant, for example, already meet the EU5 emission standard, and the BlueTEC model E 350 BlueTEC with urea injection even meets the future EU6 standard. Diesel-hybrid vehicles like the E 300 BlueTEC HYBRID and the Atego BlueTec Hybrid truck now represent a further step towards the future of the diesel engine.

BlueTec for commercial vehicles and BlueTEC for passenger cars

The introduction of BlueTEC in the passenger car in 2006 marks the beginning of a new era in Mercedes-Benz diesel-powered cars. The engineers of the Stuttgart-based brand initially developed this visionary emission control system for commercial vehicles, introducing it to the market in 2005. BlueTec (it is spelled differently if referring to cars or commercial vehicles) immediately set standards for the reduction of the pollutants in diesel exhaust gas, which promptly was reflected in success on the market: in February 2006 the 10,000th BlueTec truck with Euro 5 engine was delivered to a customer. And in 2008 more than 160,000 vehicles with BlueTec were in operation – with a great many more to come. This is a good foundation for developing BlueTEC for diesel passenger cars.

Evolution of the compression-ignition engine in the car

Considering the history of innovation of the diesel passenger car at Mercedes-Benz, the step to incorporate BlueTEC into present-day cars is only logical: the Stuttgart brand built the first diesel passenger car in 1936. 1971 saw the one-millionth car with compression-ignition engine since the Second World War roll off the assembly line. And in 1976 the C 111-II with diesel

engine set standards on its record-breaking run in Nardo. The history of diesel technology is punctuated again and again by such major innovations – especially owing to the initiatives of Mercedes-Benz. Since about 1990 the pace of technological development has picked up very strongly. And this is why in 2006 BlueTEC became the latest standard of this diesel evolution.

Where the development of the compression-ignition engine into a clean and powerful drive for future automobiles can take us is shown by studies like the S-Class S 320 BlueTEC Hybrid, presented at the Frankfurt International Motor Show in 2005, which combines the low-emission diesel with an electric motor. With an electric motor integrated in the powertrain, the concept car was a "mild hybrid", with significantly reduced fuel consumption especially in inner-city stop-and-go traffic. The diesel engine switches itself off whenever it is not required. All the modifications and features combined reduce the fuel consumption of the BlueTEC HYBRID by some 20 percent versus the comparable predecessor model. The combined output of this S-Class car is **179 kW** (243 hp); the combined torque is as high as 575 Newton metres. The car accelerates from standstill to 100 km/h in 7.2 seconds, and its top sped is electronically limited to 250 km/h. Fuel consumption (New European Driving Cycle) is as low as 7.7 litres per 100 kilometres. The study made this very clear: at Mercedes-Benz the diesel has great potential as a high-tech drive of the future. And this future already was within close reach, for a few years later BlueTEC HYBRID cars were being built in series.

But for the first, in 2006 the clean Mercedes-Benz BlueTec commercial vehicles were the trendsetters for the car sector, as the highly innovative system for reducing nitrogen oxides (NO_X) and other emissions also lends itself to application in passenger cars: BlueTEC reduces nitrogen oxides to such an extent that the toughest emission limits worldwide can be met.

In early 2006 Mercedes-Benz then presented BlueTEC for passenger cars as a ready-for-production package consisting of several components. The extensive optimisation of the engines and the combustion processes taking place inside them constitutes the basis of this package. With solutions like multi-hole injection nozzles, the use of the latest generation of CDI technology and other measures, the raw emissions are cut to an extremely low level. This is where the emission control system with an oxidising catalytic converter (for

hydrocarbons and carbon monoxide) and a particulate filter comes in. The final stage is nitrogen oxide reduction by the BlueTEC component proper.

2006 – E 320 BlueTEC, the future of the diesel car

It's the world's cleanest diesel: in late 2006 the E 320 BlueTEC hit the US market as the first production BlueTEC car. The E 320 BlueTEC is an innovative model which is based on the sophisticated E 320 CDI V6 and relies on the BlueTEC technology developed by Mercedes-Benz. BlueTEC is the designation for a highly efficient method of minimizing nitrogen oxide emissions already used in commercial vehicles. In contrast to commercial vehicles, the E 320 CDI BlueTEC does not make use of AdBlue® injection but reduces nitrogen oxides with a system based on an improved storage-type catalytic converter.

Three E 320 BlueTEC vehicles also took part in the 13,600 kilometre "E-Class Experience Paris – Beijing" from October to November 2006. This long-distance trip involving a total of 36 Mercedes-Benz E-Class Saloons recalled an adventurous long-distance journey organised in 1907, but which went in the opposite direction, from Beijing to Paris. Despite this major event in the important automotive market China, the E 320 BlueTEC was first put on the market in the United States.

The question may occur why the E 320 BlueTEC made its debut in the USA. One reason, of course, is the growing demand for economical and at the same time clean cars in that country, caused by rising fuel prices. But there's yet another reason for this specific timing: "*The introduction of clean diesel fuel in the USA is something we have been fighting for alongside others for a long time, and an opportunity we wish to use from Day One*," said Dr Thomas Weber, member of the Board of Management of Daimler AG responsible for Research, when the car was introduced in Las Vegas, Nevada. Modern diesel-engined cars which, in West Europe, account for more than half of new registrations annually, were unable to develop their full potential in the USA due to the excessively high sulphur content in the fuel until then. This changed at the end of 2006 thanks to the nation-wide introduction of clean diesel fuel with a sulphur content of just 15 ppm (15 cubic centimetres of pollutant per cubic metre of fuel). The so-called Ultra Low Sulfur Diesel (ULSD) would be available

at up to 76,000 filling stations in the USA in a first step and thereby permit the use of BlueTEC. With this innovative diesel technology, Mercedes-Benz is also able to remain below the strictest globally applicable limits where nitrogen oxide emissions are concerned. Hence, all the preconditions for the breakthrough of modern diesel technology in the USA are fulfilled.

2007 – BlueTEC for passenger cars comes to Europe

Encouraged by the success of the E 320 BlueTEC developed for the North American market, Mercedes-Benz decided to present the E 300 BlueTEC of the 211 series as first passenger car with BlueTEC for the European market at the end of the year 2007. It easily is the cleanest diesel in its class and fully meets the requirements of the Euro 5 exhaust emission standards.

2007 – BlueTEC in studies and concept cars

Mercedes-Benz demonstrated the direction in which developments in the passenger car sector are going with concept vehicles in 2006, first and foremost the Vision GL 320 BlueTEC and the Vision CLS 320 BlueTEC. The GL has an SCR catalytic converter with AdBlue injection; the CLS, like the E-Class, features an improved nitrogen-oxide storage-type catalytic converter.

The Vision GL 420 BlueTEC presented in 2007 then demonstrated that great fuel economy and extremely low emissions can be achieved with BlueTEC – also, and in particular, in large and powerful cars. The high-performance V8 diesel engine develops **216 kW** (290 hp), has a torque of 700 Newton metres and is expected to have a fuel consumption of just 9.8 litres per 100 kilometres. The car's independent styling expresses the special status of the GL 420 BlueTEC and at the same time meets the wishes of Mercedes-Benz customers in the USA for even greater exclusiveness and individualisation. The redesigned, distinctively swept-back front end with its dominant radiator grille expresses the extraordinary performance of the V8 diesel engine in the car's appearance and gives the car a dynamic forward thrust even when it's stationary. These self-assured looks are enhanced by flared wheel arches, representative 21-inch wheels and lateral floorboards.

At the North American International Auto Show (NAIAS) in Detroit in January 2007, Mercedes-Benz displayed three new BlueTEC models with SCR exhaust gas aftertreatment which it built in series beginning in 2008. On this occasion, Dr. Thomas Weber had this to say: *"With SCR, our clean and efficient diesel engines comply with the stringent American Bin 5 norm. This also applies to the three new V6 BlueTEC models R 320 BlueTEC, ML 320 BlueTEC and GL 320 BlueTEC which we will launch into the US market in 2008."*

In the brand's systematic expansion of its BlueTEC model line-up, Mercedes-Benz was backed up by a J. D. Power study in 2007: "Global Outlook for Diesel" predicts a share of diesel-engined cars in new registrations of well over 15 percent in North America by 2015. The precursor is the E 320 BlueTEC which is already available in the market. With 35 miles per gallon or 6.7 litres per 100 kilometres, it is by far the most economical car in its class in the United States.

Awards for BlueTEC

The response to BlueTEC in the USA is extremely positive, as illustrated by the distinctions awarded by renowned American science and engineering journals for the BlueTEC technology developed by Mercedes-Benz at the end of 2006. *Scientific American* named BlueTEC as one of the 50 groundbreaking innovations in science and technology of the year 2006. *Popular Science*, the oldest and best-known scientific journal, included BlueTEC in "Best of What's New", its list of the year's best product innovations. Ward's Automotive Group, a leading publisher of numerous media and trade journals for the motor industry, nominated the engine of the E 320 BlueTEC for its listing of the ten best drive systems of the year 2007.

In 2007, motor editors from 22 countries elected the E 320 BlueTEC as the "World Green Car 2007" at the International Auto Show. This award recognises the role of Mercedes-Benz as pacemaker of a novel diesel technology which makes the compression-ignition engine as clean as a petrol engine.

Storage-type catalytic converter or AdBlue injection

The diesel principle has come a long way from Rudolf Diesel's invention to the modular BlueTEC system. Time and again the company contributed decisive innovations to develop the diesel drive to its present level. Thus, the compression-ignition engine presents itself today as a high-performing and economical high-tech drive with the potential for meeting even the toughest international emission limits in the future. Not only the powerful six-cylinder power plants were to profit from this, but the state-of-the-art four-cylinder diesel engines from Mercedes-Benz as well.

Four-cylinder engine with BlueTEC

So at the Geneva Motor Show in February 2007, Mercedes-Benz for the first time presented the environmentally compatible BlueTEC emission control technology in combination with a four-cylinder engine with optimised fuel economy. The Vision C 220 BlueTEC outlines the approach to compliance with the further tightened Euro 6 emission norm which will come into force for all new vehicles throughout Europe in 2015. At an output of **125 kW** (170 hp) and a maximum torque of 400 Newton metres, the Vision C 220 BlueTEC consumes 5.5 litres of diesel per 100 kilometres. This is the result of ongoing development of diesel engine technology and intelligent energy management.

Dr. Dieter Zetsche, Chairman of the Board of Management of Daimler AG and Head of Mercedes-Benz Cars, commented on this new development as follows: *"The modern four-cylinder diesel engine with BlueTEC emission control is a prime example of cutting-edge technology with a safe future. With our diesel strategy, we provide the answer to the question of how fuel consumption – and thus carbon dioxide emissions – can be lowered, how all exhaust gas constituents including nitrogen oxides can be further reduced, and superior motoring pleasure can be ensured at the same time. We are convinced that the modern diesel currently represents the best and most efficient solution in this respect."*

With the Vision C 220 BlueTEC, Mercedes-Benz outlines the next steps in the BlueTEC initiative in very concrete terms – an initiative the company launched in the USA in autumn 2006. The Vision C 220 BlueTEC undercuts forthcoming emission limits – even the significantly tightened Euro 6 limits which will apply to all new vehicles from 1 September 2015. To give an idea of the reductions required, here are a few figures: compared with the currently

applicable limit values, particulate emissions have to be reduced by a factor of five for compliance with the Euro 5 limits which will come into force on 1 January 2011. And according to Euro 6, the nitrogen oxide limit will be just 30 percent of the limits applicable in 2007. All Mercedes-Benz diesel cars with standard particulate filters already complied in 2007 with the particulate limits to be introduced in 2011.

TrueBlueSolutions: Mercedes-Benz shows the future of the clean automotive drive system in 2007

At the 2007 International Motor Show in Frankfurt am Main, Mercedes-Benz displayed an entire fleet of especially economical and clean automobiles with intelligently combined drive technologies – studies as well as production vehicles. They included eight BlueTEC models and seven hybrid vehicles. The motto of the whole presentation was “TrueBlueSolutions”, showing environment-friendly drive solutions for the future of the automobile.

For instance, the S 300 BlueTEC HYBRID as study of a production model for the near future featured a unique combination of BlueTEC and hybrid technology, offering a combined output of **165 kW** (224 hp) and maximum combined torque of 560 Newton metres, comparable with the figures for a big-displacement petrol V8.

Also on display at the Mercedes-Benz stand: the new E 300 BlueTEC for the European market and the 320 BlueTEC models of the R, ML and GL-Class. In addition, a preview of the near-series studies C 250 BlueTEC, with the new generation of the Mercedes-Benz four-cylinder diesel engine, and E 300 BlueTEC HYBRID could be seen.

Mission: Sustainable mobility

Sustainable mobility has been a corporate mission pursued by Daimler AG for years. The company is working on low-emission and ever more economical vehicle models with great commitment. The focus is on reducing not only carbon dioxide but also all other pollutants which have to be taken into account on the road to sustainable mobility. The results of these ongoing efforts are remarkable: from 1995 through 2007, the carbon dioxide emissions of

Mercedes-Benz vehicles have declined by some 20 percent, and this rate is clearly higher than the 14 percent reduction achieved by the European motor manufacturers on average. It should also be noted that no other motor manufacturer can beat this rate.

A host of technical innovations was required to achieve this reduction within the Mercedes-Benz vehicle fleet. An impressive example of this is BlueTEC technology for diesel engines. Shortly after its introduction in the passenger car it was already helping to make the Mercedes-Benz models the most efficient and cleanest diesel-engined vehicles in their respective categories.

Since 2008 these innovations also include BlueEFFICIENCY, the comprehensive vehicle fuel consumption reduction programme. The diesel engine in the CDI BlueEFFICIENCY models profits from this innovative approach: for BlueEFFICIENCY the Mercedes-Benz engineers make use of the potential in all areas of development in order to reduce weight, wind resistance and rolling resistance further and organise energy management in vehicles still more efficiently.

Thomas Weber, member of the Board of Management of Daimler AG and responsible for Group Research and Mercedes-Benz Cars Development commented on this in the summer of 2009: "*Mercedes-Benz car models are very economical and clean as it stands today. Our BlueEFFICIENCY models – we will have 58 of them on the market by the end of the year – are a good example. Just how successful this concept is is shown by the new E-Class, which combines ultramodern engines and the world's best Cd figure in this vehicle category with other pinpoint measures intended to optimise the vehicles, including lightweight design and intelligent energy management. In the sum of these efforts we attain 23 percent greater efficiency compared with the previous model.*"

BlueTEC and the future: a Mercedes-Benz success story

The Mercedes-Benz diesel passenger car success story has gained new momentum owing to BlueTEC – not only in the North American market. For as of September 2009 Mercedes-Benz has been offering this now complete BlueTEC model range also in Europe: along with the new W 212 series E-Class Saloon E 350 BlueTEC, the ML 350 BlueTEC 4MATIC, GL 350 BlueTEC 4MATIC and

R 350 BlueTEC 4MATIC, which had already been on sale in the USA for a year. The environment-friendly BlueTEC technology lends these SUVs additional attractiveness in Europe. In spring 2010 the G 350 BlueTEC followed. And so a genuine classic – the G-Class, a success since 1979 – meets the particularly clean 21st century Mercedes-Benz diesel drive.

The new E 350 BlueTEC features a V6 diesel engine which delivers **155 kW** (211 hp) and makes maximum torque of 540 Newton metres available from 1600 rpm. The fuel consumption of this model, fitted with a seven-speed automatic transmission, is 7.0 litres per 100 kilometres (combined NEDC consumption). For the BlueTEC model the V6 engine was reengineered in detail, among other things in order to reduce the in-engine raw emissions and meet the legal requirements in regard to on-board diagnosis (OBD). The emission control system has a close-coupled oxidising catalytic converter and a diesel particulate filter positioned in the area of the firewall – this shortens the regeneration periods.

The heart of the BlueTEC system is two SCR (Selective Catalytic Reduction) catalytic converters with an upstream AdBlue® injector. Monitoring and diagnosis of the complex exhaust gas aftertreatment are handled by several sensors including a differential pressure sensor, oxygen sensor and NO_X and temperature sensors. For the service fluid AdBlue® the E 350 BlueTEC gets an additional 25-litre tank fitted with a diaphragm pump, valve, pressure and temperature sensor, as well as electric heating. It prevents the 33-percent urea solution from freezing at low temperatures. Refilling of the tank should take place during regular maintenance service. Owing to this complex technology the exhaust emissions of the E 350 BlueTEC are at EU6 level.

But the efforts of Mercedes-Benz to make the diesel drive cleaner with BlueTEC are not limited to six-cylinder models: with the E 250 BlueTEC study, specifically designed for the North American market, in spring 2009 Mercedes-Benz showed a way to combine the BlueTEC technology of the E-Class with a four-cylinder with optimised fuel consumption. In the study the Mercedes-Benz combined the all-new four-cylinder diesel with BlueTEC. The result is the most economical and cleanest diesel model in this vehicle category which, with its range of as much as 44 miles per gallon (equivalent to 5.3 litres per 100 kilometres), attains a fuel efficiency better than that of most hybrid

vehicles in the US market. Thanks to highly effective emission control, the E 250 BlueTEC does better than required by the American Bin-5 and ULEV emission standards, which are among the toughest in the world. At the same time, thanks to its high torque of 500 Newton metres, seven-speed automatic transmission and Lanchester balancer shaft, the refinement and performance of the four-cylinder is on a level with that of six-cylinders.

Just as much as new engines, the BlueEFFICIENCY package of the W 212 E-Class also conduces to the remarkable reduction in the fuel consumption of the diesel models, as demonstrated by the new four-cylinder diesel engine in the E 250 CDI BlueEFFICIENCY. With an output of **150 kW** (204 hp) and 500 Newton metres of torque from 2.1 litres displacement it develops seven percent more output and 25 percent more torque than the current V6 diesel engine in the E 280 CDI with its displacement of three litres. At the same time it uses about 23 percent less fuel. With 5.3 litres per 100 kilometres (combined NEDC consumption) it is distinctly more economical than comparable saloons in this performance class. The CO_2 emissions of the new four-cylinder diesel models come to 139 grams per kilometre or up to 24 percent below the figures for the CDI predecessors.

Engineers from all Development departments have optimised parts and components to save fuel through less weight, new design, improved function or efficient energy management. The work in the wind tunnel was highly successful. With a drag coefficient of 0.25 the new E-Class is the most aerodynamically efficient executive-class saloon in the world. It beats the previous model's very good Cd by another four percent. The aerodynamics are improved, for example, by an automatically controlled fan louvre which regulates the flow of air in the engine compartment on demand.

Other BlueEFFICIENCY measures included newly developed tyres with up to 17 percent less rolling resistance and the energy-saving control of alternator, fuel pump, air conditioner compressor and power steering.

E-Class with new four-cylinder diesel engines

With the new generation of four-cylinder diesel power plants in 2009, Mercedes-Benz introduced the fourth generation of its tried-and-trusted

common-rail direct-injection system into series production. One of its hallmarks is a 400-bar increase in the maximum rail pressure, which now stands at 2000 bar in the 220 CDI BlueEFFICIENCY and the E 250 CDI BlueEFFICIENCY. This increased pressure potential is essential for raising engine output up to **150 kW** (204 hp) and maximum torque to 500 Newton metres, while distinctly reducing untreated emissions.

Newly developed piezo injectors are key components in the latest CDI engine generation. They use piezo-ceramic properties to change their crystal structure – and therefore their thickness – in a matter of nanoseconds when electrical voltage is applied. The new injectors are equipped with a stack of thin piezo-ceramic layers (called the “piezo stack”) to enable them to achieve a sufficient overall lift from the very small lift per layer. In contrast to the systems commonly used to date, this lift activates the nozzle needle directly, so that the fuel injection can be adjusted even more precisely in line with the current load and engine-speed situation – for example by means of precise multiple injections, which have a favourable effect on emissions, fuel consumption and combustion noise. Moreover, the engine runs much smoother at idle than its predecessor. Crucial to peak output and to full-load consumption (with respect to emissions) is the maximum ignition pressure – at 200 bar the new four-cylinder diesel from Mercedes-Benz is tops in the passenger car diesel engine sector.

In the new diesel engines for the E 220 CDI BlueEFFICIENCY and E 250 CDI BlueEFFICIENCY, Mercedes-Benz also realises two-stage turbocharging with demand-related control, for the first time in production passenger car diesel engines. The major advantage of this sophisticated technology is improved cylinder charging, and therefore high torque even at low engine speeds. Fuel consumption is also reduced. When the car is driven, this concept makes itself felt by harmonious driving characteristics with no turbo lag, a favourable torque curve across the entire engine speed range, great responsiveness and noticeably improved performance.

But depending on application other techniques also find use, for example in the E 200 CDI BlueEFFICIENCY, which features a single-stage variable-nozzle turbocharger. Since the engine output is smaller, a smaller turbocharger could be chosen to obtain very good drive-away characteristics.

Other special features of the new four-cylinder diesel engines include cooled exhaust gas recirculation for NO_X reduction, a rear-mounted camshaft drive and the controllable water pump.

Dieter Zetsche, Chairman of the Board of Management of Daimler AG and Head of Mercedes-Benz Cars, made an altogether favourable review of BlueEFFICIENCY in March 2010, citing the current four-cylinder CDI models of the E-Class as example: *"We have significantly reduced consumption and emissions with our BlueEFFICIENCY offensive. Our new models boast an excellent ratio of performance to CO_2 emissions, thereby achieving an outstanding degree of efficiency."*

BlueTEC HYBRID goes into production

The presentation of the E 300 BlueTEC HYBRID, the first series-produced diesel hybrid passenger car from Mercedes-Benz, at the International Motor Show in Geneva in 2010 marks a critical new stage in the development of the diesel engine in Mercedes-Benz cars. The E 300 BlueTEC HYBRID pairs a 2.2-litre four-cylinder diesel engine developing **150 kW** (204 hp) with a powerful hybrid module. Its **15 kW** electric motor, positioned between the internal combustion engine and the 7-speed automatic transmission, assists the diesel engine when the car is accelerating (boost effect), although it is also suitable for driving using electric power alone. It is also used for the recuperation of braking energy in alternator mode.

The E 300 BlueTEC HYBRID consumes 4.1 litres of diesel fuel per 100 kilometres (CO_2 109 grams per kilometre). The diesel hybrid will be launched as Saloon and Estate at the end of 2011.

BlueTEC and CDI BlueEFFICIENCY in the S-Class

In summer 2010 Mercedes-Benz included the first BlueTEC model of the S-Class in its range, the S 350 BlueTEC. With combined fuel consumption of just 6.8 litres of diesel per 100 kilometres (NEDC) – corresponding to CO_2 emissions of 177 grams per kilometre – the new diesel model is eleven percent more economical than its predecessor. At the same time, the power output is up ten percent at **190 kW** (258 hp) and torque is 15 percent higher at

620 Newton metres. The S 350 BlueTEC already complies with the emission levels which are planned for 2014 with the introduction of the EU6 standard.

The new S-Class diesel model already features Active Blind Spot Assist and Active Lane Keeping Assist, the innovations for active safety. The S 350 BlueTEC thus combines outstanding safety and high comfort with the effortlessly superior performance of an eight-cylinder vehicle and simultaneously boasts very good fuel consumption and emission values.

In autumn 2010 the S 250 CDI BlueEFFICIENCY then caused somewhat of a sensation: this S-Class Saloon is the first 5-litre car in the luxury class and the first model with a four-cylinder in the more than 60-year success story of the S-Class. The highly efficient turbodiesel achieves fuel consumption of only 5.7 litres per 100 kilometres in the NEDC cycle, which equates to CO_2 emissions of 149 grams per kilometre. This makes the new S 250 CDI BlueEFFICIENCY the first vehicle in its class to undercut the 150 gram mark for CO_2 emissions.

To ensure hallmark S-Class comfort, dynamically controlled engine mounts feature as an innovation in the new S 250 CDI BlueEFFICIENCY. The rigidity and damping of these mounts, which are interlinked with the engine management system via databus, alter according to engine speed, load and vehicle speed, thus preventing the transmission of unwanted vibrations and noise from the engine to the body.

With an eye to the 125th anniversary of the invention of the automobile by Carl Benz in 1886, Dieter Zetsche, Chairman of the Board of Management of Daimler AG and Head of Mercedes-Benz Cars, referred to the S 250 CDI BlueEFFICIENCY as a component part of the future of the automobile in September 2010: “The invention created by Daimler and Benz changed the world and affected virtually every aspect of daily life. Now we are inventing the automobile for the second time, and the effects will again be revolutionary.”

Diesel in motor sport, research and record-breaking cars

1923 – Truck test trip from Stuttgart to Berlin and back

The new truck of Daimler-Motoren-Gesellschaft (DMG) needed ten days for its test drive in September 1923. The commercial vehicle with the new air-injection diesel engine (**29 kW**/40 hp at 1000 rpm) demonstrated its practical usefulness on a journey from Berlin to Stuttgart and back. The trip between the DMG factories lasted from 20 to 30 September 1923.

1954 – Test drive through the USA

Bill Carroll undertook a test drive straight across the USA in 1954 in a Mercedes-Benz 190 D. The journey of 8243 kilometres (5122 miles) took the motor sport journalist from Seattle to New York. The diesel fuel for the ride across the continent cost the tester all of 32 dollars and 27 cents. "*For Americans this fuel consumption is utterly sensational*," a German report on the journey said. And the journalist's conclusion was an unequivocal recommendation to buy: "*For anyone who has to drive long distances, the Mercedes-Benz 190 D is the best car*."

Mercedes-Benz bet on the publicity value of the test drive from Pacific to Atlantic. Rightly so: "*The huge interest in this achievement of Bill Carroll and the general admiration for it permit us to assume, without exaggeration, that Mercedes-Benz diesel passenger cars will now continue their triumphal march through the United States*." Such was the resume of a report of the Stuttgart company on the American diesel marathon.

1955 – Triple victory in the Mille Miglia

The 180 D wrote racing history too: in 1955, at the Mille Miglia, Mercedes-Benz dominated not only in the overall rankings, with Stirling Moss/Denis Jenkinson and Juan Manuel Fangio in the 300 SLR scoring a double victory. Stuttgart was also successful in the diesel ranking: Helmut Retter and Wolfgang Larcher won their class in a Mercedes-Benz 180 D. Their average

speed was 94.6 km/h. Karl Reinhardt and Wulf Wisnewski came in second, followed by Arturo Masera and Pasquale Cardinali. In the general classification the three 180 D's took the places 201, 214 and 220. This outstanding victory in their class impressively demonstrated the capabilities of the diesel engines in the Stuttgart-built saloons.

1959 – Victory in the Africa Rally

In 1959 Mercedes-Benz racing driver Karl Kling again showed that the diesel engine can deliver a good sporting performance: with Rainer Günzler as navigator, he won the Africa Rally over 14,045 kilometres from Algiers to Cape Town in a 190 D. His average speed: 80.6 km/h. Former Grand Prix driver Kling had succeeded the legendary Alfred Neubauer as racing manager at Mercedes-Benz – a position he held from 1956 until 1968.

1959 – Diesel record in the 190 SL

A private rally team set a world record for diesels in 1959 in a Mercedes-Benz 190 SL. The small roadster was specially fitted with a revised OM 621 engine. The four-cylinder unit displaced two litres and had an output of **44 kW** (60 hp). That sufficed to set a 24-hour record averaging a speed of 124.1 km/h in a 190 SL which, apart from the engine, was a stock car.

In 1961 the private rally enthusiasts repeated their attempt. This time the two-seater was thoroughly prepared to undertake the record run: all trim had been removed, and there was only a small, semicircular pane as windshield. With a **48 kW** (65 hp) diesel engine under the bonnet, this time the record-breaking car averaged 142.3 km/h over five kilometres from a flying start.

1972 – Across the USA in a 220 D

11,000 kilometres from New York through the United States in a Mercedes-Benz diesel – the customer magazine *Mercedes-Benz in aller Welt* described this journey in 1972. The red saloon drove through big cities and across prairies, mountains and deserts on its way from coast to coast. The 220 D proved a reliable vehicle; on the Bonneville Flats in Utah it even dashed to 140 km/h for the travel diary.

1975 – Dieselstar

A Mercedes-Benz five-cylinder diesel engine with turbocharger powered the "Dieselstar" experimental car of motor journalist Fritz B. Busch in 1975. Busch built the record-breaking vehicle on the basis of a Formula 2 racing car. On 16 November 1975, on the test track in Ehra-Lessien (Lüneburg Heath) it established a world record for diesel cars, attaining a top speed of 253.7 km/h. This was all the more remarkable in view of the fact that the existing diesel records had been established on straight-ahead stretches of the salt flats in Utah, USA. Busch, by contrast, also had to negotiate bends and brake the car on the test track. The Mercedes-Benz engine for the record attempt was fitted with an AiResearch turbocharger and a special Bosch injection pump and was slightly modified: smaller cylinder bores reduced the displacement to 2,999 cubic centimetres; to handle the high loads the unit was also provided with a nitrided crankshaft, a heavy-duty oil pump and special injection nozzles. All said and done, the engine developed **138 kW** (187 hp) at 4500 rpm.

1976 – C 111-II D

A year later, Mercedes-Benz themselves set as many as three world records for diesel cars: based on the C 111 concept car, a diesel racer took shape which was used on record-breaking runs in Nardo, Italy. Among other things Stuttgart secured itself the best times for 5000 miles (average speed 252.540 km/h), 10,000 kilometres (252.249 km/h) and 10,000 miles (251.798 km/h). In all, the C 111-II D posted 16 world records – 13 for diesel cars only, and three absolute record times. The C 111 actually originated as a test car for the rotary piston engine. But the end of the Wankel project after the second stage of development put this beautiful 1969 coupé on ice for the time being. Now the three-litre compression-ignition engine from the 240 D 3.0 gave the breathtaking sports car a new lease on life. The power unit got the racer running with **140 kW** (190 hp).

1978 – C 111-III

Two years later a new version of the C 111 with diesel engine again took aim at a world record. This time, the record-breaking coupé was much changed from the original design: narrower, with a longer wheelbase, full fairings and

extremely sophisticated aerodynamics, including tailfin. The three-litre diesel engine now developed **169 kW** (230 hp) thanks to a turbocharger and intercooler; the torque of the diesel racer had been boosted to 402 Newton metres. On 30 April 1978 the car maintained an average speed of 315 km/h on the twelve-kilometre circuit at Nardo for over twelve hours. Its consumption was only about 16 litres of diesel fuel per 100 kilometres. That in itself should have earned it a world record. This time the C 111-III established nine absolute speed records, irrespective of engine type and displacement.

1992 – Biodiesel test with Mercedes-Benz taxis

The diesel engine also plays an important role in the application of alternative fuels. As early as 1992, Mercedes-Benz took part in a large-scale test in Freiburg in which diesel taxis ran on rapeseed oil methyl ester instead of diesel for one whole year.

2003 – F 500 Mind research car

At the 2003 Tokyo Motor Show, Mercedes-Benz presented a diesel hybrid drive in the new F 500 Mind research car. The engineers combined the high-torque V8 diesel engine of the Mercedes-Benz S-Class with an electric motor arranged between the internal combustion engine and the modified automatic transmission. Pairing the two produced the most powerful, torquiest hybrid drive for rear-wheel-drive cars in 2003. While the V8 diesel developed **184 kW** (250 hp) and attained a maximum torque of 560 Newton metres, the electric motor contributed an additional **50 kW** (68 hp) and 300 Newton metres maximum torque. The classic division of labour between the two drive systems, depending on the situation, and the recuperation of energy from braking allowed the diesel hybrid drive to reduce fuel consumption in the European driving cycle by about 20 percent versus a comparable production vehicle.

2003 – Synthetic diesel fuel

In 2003 Mercedes-Benz presented an alternative diesel fuel. It is obtained synthetically from vegetable matter, which makes this fuel neutral with respect to carbon dioxide. The CO_2 blown out the tailpipe during combustion equals

exactly the amount which the plants extract from the atmosphere during the growth process.

2004 – GST 2 concept car

The Vision GST 2 displayed at the North American International Auto Show in Detroit in January 2004 had a diesel hybrid drive. The Grand Sports Tourer concept car was thus more than a successor to the petrol-engined Vision GST of 2002. The pioneering hybrid consisting of a V8 diesel and an electric motor was similar to the one already used in the F 500 Mind. But now the hybrid operated in a vehicle with four-wheel drive and six-speed automatic transmission. The Vision GST 2 with diesel hybrid afforded ample dynamism and driving pleasure. The two power units with their total output of **300 kW** (408 hp) propelled the concept car from standstill to 100 km/h in 6.6 seconds; the top speed was electronically limited to 250 km/h.

2005 – S-Class Hybrid

In Detroit in 2005 Mercedes-Benz showed the S-Class Hybrid with the so-called P1/2 drive system. It combined a powerful CDI diesel engine with two electric motors. The eight-cylinder CDI developed **191 kW** (260 hp) and a maximum torque of 560 Newton metres. The two electric motors together generated **50 kW** (68 hp) so that the vehicle had maximum power of **241 kW** (340 hp). This made the S-Class sprint from standstill to 100 km/h in 7.6 seconds – tops for hybrid vehicles.

2005 – E 320 CDI on the way to a world record

The V6 diesel engine in the E 320 CDI underwent an extraordinary endurance test in May 2005: three E 320 CDI production cars were put through a 30-day long-term test in Laredo, Texas, at the end of which the Mercedes-Benz diesels not only had demonstrated their reliability, but also secured three diesel world records recognised by FIA (Fédération Internationale de l'Automobile): over 100,000 kilometres (average speed 225.903 km/h), 50,000 miles (225.456 km/h) and 100,000 miles (224.823 km/h).

2005 – Economical travelling in a long-distance test through the USA

The world-record-setting diesel saloons again showed what they can do during a long-distance journey carried out under everyday conditions. In the summer of 2005 this test took place on highways in the south of the United States. The E 320 CDI saloons made do with an average five litres of diesel fuel per 100 kilometres on their trip through Texas, Louisiana, Mississippi, Alabama and Florida. In another six-day test drive through the USA from Las Vegas to Chicago in the summer of 2005, despite differences in altitude of altogether 23,000 metres, the E 320 CDI merely required an average 7.1 litres of diesel per 100 kilometres on the selected route.

2005 – Bionic research car

The company launched its BlueTEC initiative for passenger cars in 2005 at the Innovation Symposium in Washington by presenting the bionic car. The bionic mobile is a research vehicle whose exterior shape makes use of the aerodynamic principles of nature. But the drive also had to be maximally environment-friendly, and so the engineers introduced the SCR technology for passenger cars in this vehicle. The engine of the bionic car is a four-cylinder turbodiesel with common rail direct injection and a displacement of two litres. This diesel engine develops **103 kW** (140 hp) and consumes 4.3 litres of fuel per 100 kilometres in the standardised European driving cycle. An impressive feature is the more than 80 percent reduction in nitrogen oxides versus production vehicles. This is made possible by the first-time use of SCR (Selective Catalytic Reduction) technology in a car. In the bionic car the designers opted for AdBlue® injection; the reservoir is space-savingly accommodated in the spare wheel recess of the concept car. Its filling suffices to cover a distance equal to the servicing interval of an up-to-date diesel engine from Mercedes-Benz.

2005 – S 320 BlueTEC Hybrid

At the 2005 Frankfurt International Motor Show, Mercedes-Benz presented the S-Class S 320 BlueTEC Hybrid as a luxury-class vehicle in which the low-emission BlueTEC diesel with SCR technology provided the basis for an ultramodern hybrid drive. The electric motor of the hybrid vehicle was integrated into the drivetrain.

2006 – GTL Demonstrator

In 2006 Mercedes-Benz created the GTL Demonstrator test car on the basis of the E 320 CDI. It offered extremely clean combustion thanks to a tailor-made fuel manufactured from liquefied natural gas (gas to liquid, GTL). Even without aftertreatment of the nitrogen oxides, the car achieved emission levels far below any of the current limits. However, GTL diesel in larger quantities will not be available at filling stations until some time in the future.

2006 – Synthetic fuel

To further expedite the use of synthetic fuels, in March 2006 DaimlerChrysler, Renault, Royal Dutch Shell, Sasol Chevron and Volkswagen formed the "Alliance for Synthetic Fuels in Europe" (ASFE). The synthetic fuels include SunDiesel, obtained from organic matter (biomass to liquid, BTL), and synthetic GTL diesel, obtained from natural gas. Synthetic fuels are already contributing to the reduction of emissions. The aim is to better utilise this potential with more advanced technology.

2006 – E-Class SunDiesel

At the Challenge Bibendum in Paris, besides other vehicles Mercedes-Benz showed an E-Class which operates on the BTL fuel SunDiesel. The use of such biogenic fuels causes no additional carbon dioxide to be released, as combustion produces only as much carbon dioxide as was absorbed by the plants during their growth. BTL diesel thus improves the CO_2 balance by as much as 90 percent compared with conventional diesel fuel. And there are no technical limits to the use of SunDiesel.

In addition, in Paris the company displayed a concept car – the smart fortwo cdi hybrid – in which a diesel engine and electric motor work together. The consumption of the smart fortwo cdi hybrid is expected to be about 2.9 litres of diesel per 100 kilometres, obtained with a sprightly driving style.

In the “E-Class Experience Paris–Beijing”, a long-distance journey covering 13,600 kilometres, undertaken by a fleet of 36 Mercedes-Benz E-Class Saloons, three 320 BlueTEC models also took part in late autumn 2006. The 26-day run was in memory of the legendary long journey of 1907 that started out in the opposite direction, from Beijing to Paris. Some 50,000 applicants wanted to take part in the modern-day journey – 360 persons from 35 countries were selected and drove sections of the route with different lengths on the way from France to China.

The unique long-distance trip from Europe to Asia led through France, Germany, Poland, Lithuania, Latvia, Estonia, Russia and Kazakhstan to China. The daily legs were up to 750 kilometres long and had to be negotiated at low temperatures, in ice, snow and with short daylight periods, travelling through partly almost impassable terrain and crossing mountain passes up to 2900 metres high. On 17 November the vehicles arrived in the Chinese capital. The three E 320 BlueTEC impressively demonstrated the potential of advanced diesel technology during the journey.

Diesel landmarks and Mercedes-Benz

1892 – Patent on the diesel engine

In 1892 Rudolf Diesel applies for a patent for his engine, which is granted on 23 February 1893 as DRP 67 207 "*on a principle of operation and construction for internal combustion engines*." He gets the first successful prototype of a production-standard diesel engine running in 1897. In the cylinder of a diesel engine, fuel is mixed with appreciably more air than in a petrol-powered engine. This makes for very efficient combustion. In addition, the diesel engines require no sparkplugs since diesel fuel with its very good ignition qualities, or rather the air-fuel mixture, ignites spontaneously owing to the very high compression ratio – this is why it is also called the compression-ignition engine. Ignition is triggered off by the sharp rise in temperature during the compression stroke of the piston.

1908 – Afterchamber diesel

At the Deutz company, Prosper L'Orange develops an injection pump for diesel engines and enlarges the combustion chamber with an afterchamber to improve mixture formation. In 1908 he submits a patent application for the afterchamber diesel engine.

1909 – Prechamber diesel

In experiments which he carries out as head of engine testing at Benz & Cie., L'Orange further improves his engine. A new cylinder head shape with a hemispherical chamber now takes the place of the afterchamber. In this so-called prechamber, following injection a small portion of the diesel fuel burns, generating high pressure and propelling the remaining diesel-air mixture into the cylinder where it gets swirled. The pressure and the mixing action permit rapid combustion at high temperatures and thus higher engine speeds. On 14 March 1909, L'Orange files a patent application (DRP 230 517) for the prechamber system.

1919 – Funnel prechamber

Prosper L'Orange changes the shape of his prechamber in 1919 by using a funnel-shaped insert to set it off more clearly from the combustion chamber proper. This way he achieves reliable ignition and good combustion under different loads. He takes out a patent on it on 18 March 1919 (DRP 397 142).

1919 – Pintle-type injection nozzle

Parallel to the funnel prechamber, L'Orange designs a new injection nozzle for more reliable introduction of fuel into the cylinder.

1921 – Variable injection pump

The variable injection pump permits infinite variation of the delivered quantity of fuel, thus enabling precision control of power delivery. The injection pump introduced in 1921 is the last vital component developed by L'Orange for the first diesel engine to see use in vehicles.

1922 – Benz and Sendling introduce the S6 farm tractor

The S6 farm tractor, featuring an **18 kW** (25 hp) two-cylinder prechamber diesel with a rated speed of 800 rpm, serves to launch the diesel's career as a vehicle drive.

1923 – Benz prechamber diesel

The first of three prototypes of the OB2 truck diesel engine is running on a test bench as early as September 1922. In October Benz installs the four-cylinder into a 5 K 3 chassis, and in spring 1923 the decision is made to produce it: the world's first diesel truck develops **33 – 37 kW** (45 - 50 hp) at 1000 rpm.

1923 – Daimler air-injection diesel

In competition to L'Orange's prechamber diesel, Daimler-Motoren-Gesellschaft (DMG) develops an air-injection diesel engine for its trucks. This unit is based

on experience gained from the manufacture of submarine diesel engines employing the air injection principle.

1927 – Bosch injection pump

The injection pump introduced by Robert Bosch for diesel engines in 1927 is systematically improved as against older systems. With this injection pump, Bosch, himself one of the first buyers of a diesel truck in 1924, greatly furthers the acceptance of the diesel drive.

1928 – First Mercedes-Benz diesel tractor

A new Mercedes-Benz single-cylinder diesel engine is first used in the OE tractor.

1932 – OM 59 in the new Lo 2000 truck

The compact OM 59 prechamber diesel powers the new Lo 2000 express truck.

1935 – 10,000th commercial vehicle with diesel engine

The 10,000th Mercedes-Benz commercial vehicle with diesel engine is built in Gaggenau in 1935.

1936 – Four-cylinder diesel for passenger cars

The Mercedes-Benz 260 D is the world's first diesel passenger car. It is equipped with the OM 138 engine, developed from a truck diesel. The unit has four cylinders, a displacement of 2.6 litres and an output of **33 kW** (45 hp).

1940 – Start of development of the 300 engine series

Mercedes-Benz begins developing the new 300 engine series for commercial vehicles during the Second World War.

1949 – Premiere of the OM 312

The six-cylinder in-line OM 312 is the first representative of the new series, debuting in 1949. The 300 engine family in the commercial vehicles of Mercedes-Benz extends its career into the new millennium.

1953 – Exhaust-gas turbocharger in the commercial vehicle

In a fire engine, in 1953 Mercedes-Benz presents its first turbocharged production diesel engine. Its output is about 25 percent higher than that of a naturally aspirated engine.

1964 – First direct-injection diesel engines for commercial vehicles

The OM 352 is the first diesel engine for Mercedes-Benz commercial vehicles to have direct injection. The economical and performance-enhancing injection system with four-hole nozzle quickly becomes generally accepted in trucks and other commercial vehicles.

1966 – Turbocharging in the OM 352 A commercial vehicle diesel

To attain higher outputs for fuel-injected diesel engines in commercial vehicles, Mercedes-Benz offers the OM 352 A engine with exhaust-gas turbocharger for the first time in 1966.

1969 – The 100,000th commercial vehicle diesel engine

In Mannheim Mercedes-Benz build their 100,000th diesel engine for commercial vehicles in 1969.

1970 – New OM 400 engine series

Mercedes-Benz introduces the new 400 engine series for heavy-duty commercial vehicles in 1970. The first is a V10, which is joined later by V8, V6 and six-cylinder in-line units.

1974 – Five-cylinder diesel in a car

The five-cylinder in-line OM 617 with a displacement of 3005 cubic centimetres is the first five-cylinder diesel engine in the world to be used in a passenger car. The engine premieres in the Mercedes-Benz 240 D 3.0 (W 115 series).

1977 – S-Class with diesel engine and exhaust-gas turbocharger

In the 300 SD S-Class model, Mercedes-Benz presents a diesel engine with exhaust-gas turbocharger for the first time. With an output of **85 kW** (115 hp) and torque of 250 Newton metres, the 300 SD is offered exclusively for the US market. The 300 T Turbodiesel as turbocharged diesel model which is also sold in Europe does not follow until 1980.

1980 – Intercooler in the OM 422 AL

In 1980, Mercedes-Benz introduces intercooling (charge air cooling) to complement the turbocharger in the new OM 422 AL engine for heavy-duty trucks. Cooling results in more oxygen in the intake air and in higher power output during combustion.

1983 – Engine encapsulation in the compact class for noise insulation

In the diesel models of the compact class launched in 1982 (W 201 series), the engine is fully encapsulated for the first time. This reduces the noise produced by the drive system by about half. Colloquially, the engine design is dubbed the “whisper diesel.”

1985 – Particulate filter

In 1985, Mercedes-Benz is the first automotive brand in the world to supply diesel saloons with a particulate filter system as an optional extra to California. The experience gained from this programme is the basis for developing new filter technologies.

1989 – “Diesel ’89” initiative

In 1989, Mercedes-Benz presents revised engines which cut particulate emissions by around 40 percent. Their features include a new prechamber with oblique fuel injection, which enables more efficient combustion. The diesel technology improvement programme under which these engines are developed is called the “Diesel ’89” initiative.

1991 – Emission control system

The exhaust gases of a diesel engine are markedly different from those of a petrol-fired engine. While the diesel engine gives off less carbon dioxide, its exhaust gas contains a higher proportion of nitrogen oxides. In 1991 Mercedes-Benz reduces these pollutants with an emission control system employing exhaust-gas recirculation and an oxidising catalytic converter. This combination lowers the temperature in the combustion chamber and reduces the formation of nitrogen oxides by about 70 percent. Initially offered as an optional extra, the emission control system becomes standard equipment in 1993.

1993 – Four-valve-per-cylinder design and Electronic Diesel Control

Four-valve technology arrives in the diesel segment in 1993 when Mercedes-Benz introduces the first car diesel engine with four valves per cylinder and electronic control. Four-valve technology gives the diesel engine higher power and better economy than the previous two-valve design. Electronic Diesel Control (EDC) sees use in production vehicles beginning in 1995 when Mercedes-Benz introduces the direct-injection diesel engine with 2.9 litres displacement.

1996 – Debut of new commercial vehicle engines

Two new engine series for commercial vehicles are introduced at once by Mercedes-Benz in 1996. The OM 500 diesel V-engines operate in the new heavy-duty Actros truck; the OM 900 in-line engine generation is used in the light-duty Atego truck.

1997 – Common rail direct injection (CDI)

The CDI age begins in 1997. The acronym stands for “Common Rail Direct Injection.” Developed by Daimler-Benz in cooperation with Bosch, this direct fuel injection system works with a common fuel line (common rail). Whereas conventional direct injection engines build up pressure for every injection operation anew, in the common rail high pressure is permanently generated, enabling the fuel to be forced to the variable and very precisely controlled injection nozzles at a pressure of up to 1350 bar. CDI makes the diesel engine a model of high performance, excellent torque already in the lower rev range, great fuel economy, minimal pollutant emissions, and generation of little noise.

1998 – Diesel-electric drive system in the Cito

The Mercedes-Benz Cito is an innovative midibus with a diesel-electric drive in which an OM 904 LA diesel engine powers a generator which supplies energy to the electric traction motor.

2002 – Second-generation CDI

The second generation of CDI technology in 2002 once again improves performance, consumption, comfort and emissions. To achieve this, among other things the Mercedes-Benz engineers raise the ignition pressure from 145 bar to 155 bar to optimise the gas cycle. The result is greater pulling power and flexibility. The injection pressure of now 1600 bar, in conjunction with the newly developed seven-hole injection nozzle, permits finer distribution of the fuel in the combustion chambers, better mixture formation, and more homogeneous combustion.

2003 – First AdBlue® filling station in Stuttgart

As first harbinger of BlueTec, an AdBlue® filling station is opened in Stuttgart in 2003. AdBlue® (“Additive Blue”) – an aqueous urea solution – is injected into the exhaust-gas flow in the SCR (Selective Catalytic Reduction) process. A catalytic converter then reduces the nitrogen oxides in the pretreated exhaust gas to nitrogen and water vapour. SCR is part of the BlueTec system for uncompromising reduction of diesel emissions. From 2005, step by step

DaimlerChrysler changes over the entire truck and bus range so that the vehicles comply with the Euro 4 and Euro 5 standards.

2003 – Maintenance-free diesel particulate filter

In 2003 Mercedes-Benz introduces maintenance-free particulate filters for diesel engines. Initially the filters are optional equipment. In the summer of 2005, more than 30 car models of Mercedes-Benz, from the A-Class to the S-Class, are fitted with a particulate filter as standard. In autumn 2005, the manufacture of retrofit kits for vehicles produced before this breakpoint begins, initially for the C and E-Class.

2003 – Diesel hybrid

In 2003 the F 500 Mind research car presents a hybrid drive combining a V8 diesel engine with an electric motor. The diesel attains an output of **184 kW** (250 hp) and maximum torque of 560 Newton metres, and the electric motor adds another **50 kW** (68 hp) and 300 Newton metres maximum torque. Electronic control of the link between the two drive units lets each bring its specific advantages into play. Whereas the electric motor can move the car on its own for starting off, parking and slow-speed driving, the strong diesel engine is engaged when more power is required. The union of the two drive systems demonstrates its value particularly in urban traffic.

In the Vision Grand Sports Tourer 2 in 2004 Mercedes-Benz also shows a diesel hybrid drive. The V8 diesel with four litres displacement and **184 kW** (250 hp) is again coupled with a **50-kW** (68-hp) electric motor. In 2005 the S-Class HYBRID (NAIAS in Detroit) and the S-Class BlueTEC HYBRID (International Motor Show in Frankfurt am Main) follow. To further develop such combinations of internal combustion engines and electric motors, the company cooperates with General Motors and the BMW Group; the three enter into an alliance in September 2005. The objective of research is formulated in a Memorandum of Understanding on the joint development of the hybrid drive.

2004 – Introduction of BlueTec truck with OM 500 for Euro 4 and Euro 5

In 2004 Mercedes-Benz introduces trucks with OM 500 engines and BlueTec technology for emission control. These vehicles meet the especially stringent Euro 4 and Euro 5 emissions norms. As early as February 2006, delivery of the 10,000th BlueTec truck with Euro 5 engine takes place.

2005 – Third-generation CDI

A new high-tech V6 diesel engine marks the beginning of the third generation of CDI technology at Mercedes-Benz. Owing to new materials and optimisation of the entire unit, the new CDI engines attain even higher combustion pressures than before – the engineers aim at up to 200 bar and intend to boost the injection pressure too in future, to as high as 2000 bar. In addition, the complex CDI technology is further refined. The fuel is no longer injected all at once, but in as many as five portions. Special actuators (piezo crystals) take over the control of the injection nozzles: with electric pulses the atomic structure of the crystals can be expanded several hundred thousand times per second if required. With this sophisticated injection system, not only are the emissions further reduced; the working noise of the engine is also diminished once more.

2006 – BlueTEC for passenger cars

In 2006, Mercedes-Benz introduces BlueTEC for passenger cars to the market in an E-Class. The technology for the cleanest diesel in the world has been successfully used in commercial vehicles since 2005. The Mercedes-Benz E 320 BlueTEC is the first representative of a new generation of diesel cars of the Stuttgart brand on this technical basis. From autumn 2006 the E 320 BlueTEC goes to market in the USA; the market launch in Europe is scheduled for 2008.

Under development since 2002, the BlueTEC (written BlueTec for commercial vehicles) modular technology package relies on several means of reducing diesel emissions. On the one hand, these include familiar methods like the oxidising catalytic converter and particulate filter, along with optimised engines. But the heart of the system is the actual BlueTEC technology for nitrogen oxide reduction. In the first production car equipped with it, the E 320 BlueTEC, there is a complex catalytic converter system consisting of an

improved nitrogen-oxide storage-type catalytic converter and an SCR catalytic converter. In normal operation the nitrogen oxides in the exhaust gas are collected in this catalytic circuit. Regular adjustments to the air-fuel mixture in the engine change combustion, and with it the composition of the exhaust gases, for a brief period. In the process, BlueTEC separates the stored nitrogen oxides into nitrogen and water vapour.

More complex, but more effective still is Selective Catalytic Reduction (SCR) by means of AdBlue® injection. When AdBlue® is injected into the pretreated exhaust gas, ammonia is released which then causes reduction of nitrogen oxides to harmless nitrogen and water in the downstream SCR catalytic converter. Spraying this aqueous urea solution into the exhaust-gas flow is currently the most efficient method of exhaust-gas aftertreatment for diesel engines. This system can reduce nitrogen oxides by as much as 80 percent. With the Vision GL 320 BlueTEC, Mercedes-Benz engineers demonstrate in 2006 that this too is a process that can find use in large-scale production. In autumn 2006, the E 320 BlueTEC production car finally appears.

BlueTec technology has been very successfully employed in Mercedes-Benz commercial vehicles in Europe since 2005. In the meantime this technology has performed outstandingly in more than 20,000 Actros, Axor and Atego trucks. BlueTec cuts nitrogen oxides so sharply that the emissions limits applicable to trucks from 2009 are already undercut today. This is rewarded with lower road tolls for trucks with Euro 5 technology through 2009. Whereas AdBlue® for cars might be replenished during a service stop, a comprehensive network of AdBlue® filling pumps for commercial vehicles is available in Europe.

2007 – BlueTEC passenger cars in Europe

At the end of 2007 Mercedes-Benz introduces the E 300 BlueTEC of the 211 series as first BlueTEC car for the European market. It is far and away the cleanest diesel in its class and fully complies with the EU5 emission standards.

Simultaneously, Mercedes-Benz speeds up the expansion of its line-up of BlueTEC vehicles in 2007. In Detroit, the three models R 320 BlueTEC, ML 320 BlueTEC and GL 320 BlueTEC are introduced; they will come onto the

American market in 2008. The engineers provide a glimpse of the future at the Geneva Motor Show where they present the Mercedes-Benz Vision C 220 BlueTEC. The study car is the first to feature a four-cylinder engine with BlueTEC technology.

2008 – BlueEFFICIENCY for diesel models

BlueEFFICIENCY, the comprehensive vehicle fuel consumption reduction programme, is introduced by Mercedes-Benz in 2008. The diesel engine in the CDI BlueEFFICIENCY models also profits from this innovative approach: for BlueEFFICIENCY the Mercedes-Benz engineers make use of the potential in all areas of development in order to reduce weight, wind resistance and rolling resistance further and organise the energy management of vehicles still more efficiently.

2009 – Complete BlueTEC model range for Europe

Since September 2009 Mercedes-Benz has been offering its complete BlueTEC model range also in Europe: along with the new W 212 series E-Class Saloon E 350 BlueTEC, the ML 350 BlueTEC 4MATIC, GL 350 BlueTEC 4MATIC and R 350 BlueTEC 4MATIC, which had already been on sale in the USA for a year. In spring 2010 the G 350 BlueTEC followed. And so a genuine classic – the G-Class, a success for 31 years – meets the particularly clean 21st century Mercedes-Benz diesel drive.

2009 – Four-cylinder engines with optimised fuel consumption and BlueTEC

The E 250 BlueTEC study designed for the North American market shows in spring 2009 how the BlueTEC technology of the E-Class can be combined with a four-cylinder with optimised fuel consumption. For this purpose an all-new four-cylinder diesel was combined with BlueTEC. The result is the most economical and cleanest diesel model in this vehicle category which, with its range of as much as 44 miles per gallon (equivalent to 5.3 litres per 100 kilometres), attains a fuel efficiency better than that of most hybrid vehicles in the US market.

2009 – The fourth CDI generation

The fourth generation of the common-rail direct-injection system premieres in the new generation of four-cylinder diesel engines in 2009. Its hallmark is a 400-bar increase in the maximum rail pressure, which now stands at 2000 bar. Newly developed piezo injectors are among the key components of the latest CDI engine generation. In contrast to the systems commonly used to date, this lift activates the nozzle needle directly, so that the fuel injection can be adjusted even more precisely in line with the current load and engine-speed situation – for example by means of precise multiple injections, which have a favourable effect on emissions, fuel consumption and combustion noise.

In the new diesel engines for the E 220 CDI BlueEFFICIENCY and E 250 CDI BlueEFFICIENCY, for the first time in series-built passenger car diesel engines Mercedes-Benz also realises two-stage turbocharging. The aim is to achieve further improvements, for example, in start-up performance and peak output, versus the single-stage turbocharger.

2010 – BlueTEC in the S-Class

In summer 2010 Mercedes-Benz includes the first BlueTEC model of the S-Class in its range, the S 350 BlueTEC. It has combined fuel consumption of just 6.8 litres of diesel per 100 kilometres (NEDC), corresponding to CO_2 emissions of 177 grams per kilometre. The S 350 BlueTEC already complies with the emission levels which are planned for 2014 with the introduction of the EU6 standard.

In autumn 2010 the S 250 CDI BlueEFFICIENCY follows. This S-Class Saloon is the first 5-litre car in the luxury class and the first model with a four-cylinder in the more than 60-year success story of the S-Class. The highly efficient turbodiesel achieves fuel consumption of only 5.7 litres per 100 kilometres in the NEDC cycle, which equates to CO_2 emissions of 149 grams per kilometre. This makes the new S 250 CDI BlueEFFICIENCY the first vehicle in its class to undercut the 150 gram mark for CO_2 emissions.

2011 – BlueTEC HYBRID in series production

In 2011 the E 300 BlueTEC HYBRID comes onto the market. This first series-produced diesel hybrid passenger car of a European manufacturer will be available as Saloon and Estate. Presented at the Geneva Motor Show in 2010, the vehicle pairs a 2.2-litre four-cylinder diesel engine developing **150 kW** (204 hp) with a powerful hybrid module with **15-kW** electric motor. The electric motor, positioned between the internal combustion engine and the seven-speed automatic transmission, assists the diesel engine when the car is accelerating (boost effect), although it is also suitable for driving using electric power alone. It is also used for the recuperation of braking energy in alternator mode. The E 300 BlueTEC HYBRID consumes 4.1 litres of diesel fuel per 100 kilometres. This corresponds to CO_2 emissions of 109 grams per kilometre.

Further information from Mercedes-Benz is available on the internet at: **www.media.daimler.com** and **www.mercedes-benz.com**