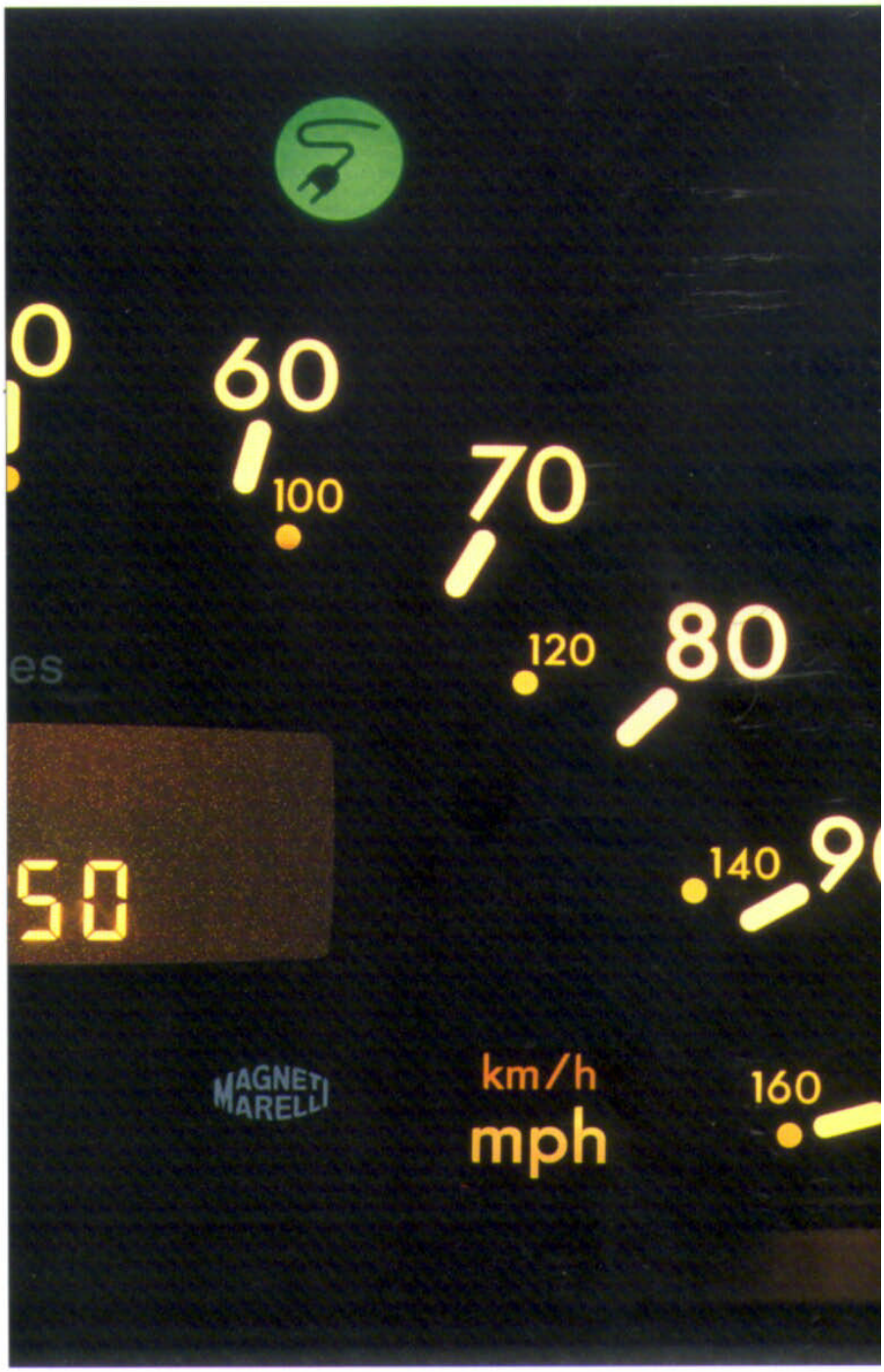
DAIMLERBENZ
AKTIENGESELLSCHAFT

The A-Class Electric Vehicle

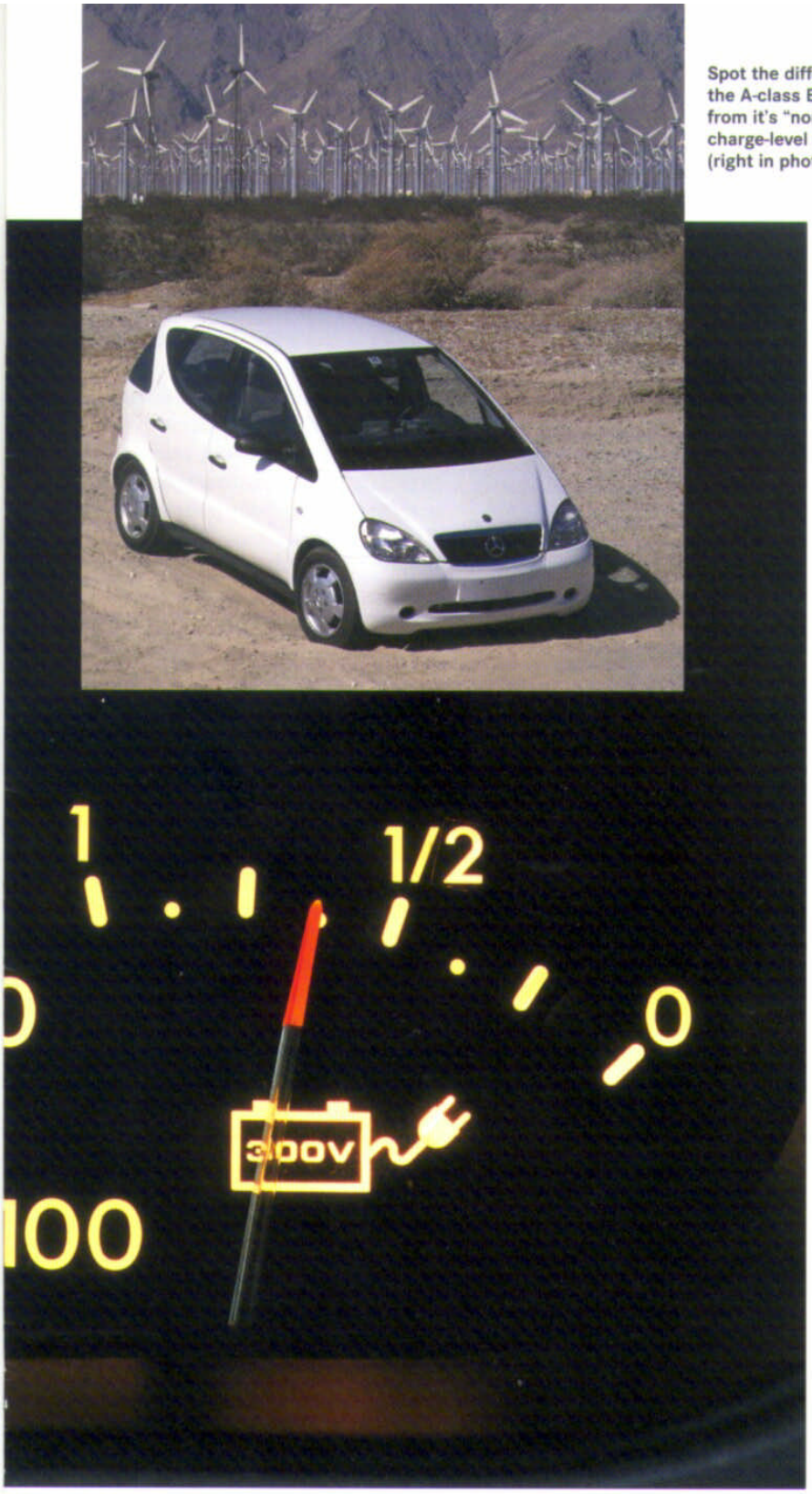
Powered by the ZEBRA Battery System

The A-class electric vehicle doesn't need a tiger in its tank. It runs on power supplied by a ZEBRA high-energy battery sandwiched under the passenger compartment.



In combination with the Mercedes A-class, the electric drive is now beginning to reveal its true strengths. ZEBRA, a new kind of high-energy battery based on sodium chloride and nickel, eliminates many of the disadvantages associated with electric vehicles. Moreover, both battery and drive train can be accommodated in the vehicle's double-floor sandwich configuration, without sacrificing interior space. With ZEBRA on board, the electric car can travel over 125 miles in real traffic on one battery charge. That's almost twice the range of a conventional electric vehicle.

On Course for a Bette



Spot the difference: From the outside, the A-class EV is indistinguishable from it's "normal" siblings. Only the charge-level indicator in the cockpit (right in photo) betrays the difference.

r Tomorrow

Carson 5:55 a.m. Two employees have just arrived at Daimler-Benz's Vehicle Preparation Center (VPC) in South Los Angeles. A test vehicle, a white A-class Mercedes, pulls out of the lot—quietly and without any audible engine noise. As we focus on the rear of the car, we notice something unusual: the exhaust is missing. However, the vehicle doesn't need one; the 50-kilowatt motor produces absolutely no exhaust gases.

Because it is an electric vehicle (EV), this test car is still something out of the ordinary. However, that could change thanks to a 370-kilogram (816-pound) battery block mounted under the passenger cell. ZEBRA is the name of the pioneering, high-energy battery which promises to one day revolutionize the electric auto.

The white car merges into the flowing traffic of Highway 405, an eight-lane freeway, with the test crew of the Electric Vehicle Project following in a van. After a couple of miles, the two vehicles change over to the northbound freeway of Highway 110. The electric vehicle accelerates effortlessly to 60 miles per hour (around 100 kilometers per hour). What's more, the electrically powered A-class can go from zero to 62 miles per hour in 16.5 seconds, which puts it on par with any car with a similarly powerful internal combustion engine. The transmission's anti-spin regulation prevents awkward jack rabbit starts—a useful feature for a drive train that already develops maximum torque when idling and thus needs no initial "wind up."

The mini-convoy swiftly approaches the northern limits of the greater Los Angeles metropolitan area. Passing Dodger Stadium and the Hollywood Bowl, it moves on to Highway 2 near the Los Angeles Crest. This ridge road leads to Mount Wilson Observatory, which sits 5,710 feet (1,740 meters) above sea level. The car tackles the steep incline—up to 18 percent in some places—effortlessly. At 8:00 a.m. the crew gets out at the ob-

On downhill stretches, the motor acts as a generator. As a result, the cells of the ZEBRA battery can be recharged while the car is out on the road.

Packing in the power: The ZEBRA battery block in the A-class EV consists of 448 individual cells.

servatory, which serves as the turning point for the 124-mile (200-kilometer) record test drive. A glance at the charge-level indicator—the electric vehicle's fuel gauge, so to speak—leaves everyone visibly satisfied. On the way back, the crew will be able to go on a small excursion.

Going Downhill—for the Battery's Sake

On the way back, essentially plain sailing downhill, the charge-level indicator rises continually. Which isn't surprising, given that the induction motor works as a generator on downhill stretches. It's a very convenient method of recharging the 448 cells of the ZEBRA block.

After initially heading back south the way it came, the team opts for a detour. Instead of going straight to the VPC from the freeway of Highway 405, they visit Long Beach, where the Queen Mary is anchored in the harbor. There, the innovative little Mercedes pays its respects to the grand dame of luxury liners.

At 1:50 p.m. as the white car finally turns into the gate of the VPC, it has become the proud holder of a new world record. The 1,380-kilogram (3,043-pound) electric vehicle has managed 128 miles on just one battery charge—despite having to negotiate stop-and-go traffic, move nimbly on the freeways, and boldly climb Mount Wilson.

The basis for this success can be found under the passenger cell of the electrically powered A-class: the ZEBRA battery system. Capable of storing 30 kilowatt-hours, the power pack drives the 50-kilowatt, three-phase induction motor under the hood.

Three Times as Much Energy as a Conventional Lead-Acid Battery

ZEBRA stands for "Zero Emission Batteries Research Activity." It is immediately clear from the project name what is so special about this type of power: the vehicle itself emits no pollutants. Yet the new battery type (see graphic and text, "ZEBRA Makes It Possible") offers a bundle of additional advantages.

The maintenance-free, high-energy battery stores three times as much energy as a conventional lead-acid battery. In practice, this means longer distances, without having to sacrifice luggage space or seats. Conventional batteries in electric vehicles often claimed the entire trunk area or the car's rear interior.

In contrast to some conventional rechargeable batteries, the ZEBRA battery shows no memory effect. In other words, it is immune to an undesirable physical phenomenon where partially discharged batteries, after being recharged, only supply power until they reach the partial discharge level. As a result, only a fraction of the battery's original capacity can be used.

Always Ready for a Recharge—Forget the Dreaded Memory Effect

The ZEBRA battery, on the other hand, can be recharged from any discharge level, making total battery capacity available at all times. This is of inestimable advantage to the user, who can simply charge the battery when the vehicle is not in use. Thanks to the built-in charger, this process can be performed using a common household power point.

But it is not just the high energy density of the battery that enables the electrically powered A-class to cover a record-breaking 128 miles out on the road. All energy-consuming peripheral equipment and the entire drive train have been geared to use energy as sparingly as possible.

As the car is being driven and the battery discharged, electrochemical reactions in the battery release thermal energy, which is used, on the one hand, to

keep the operating temperature between 270 and 350 degrees Celsius (518 to 662 degrees Fahrenheit), and on the other hand, to keep the temperature in the car's interior at a comfortable level. However, the electric auxiliary heater taps into the battery's current only if it has become very cold outside. And when the heat is on outside, the vehicle interior can be kept comfortably cool. The battery's insulation prevents the battery from cooling down too much during extended idle periods.

Safe, Long-Lasting, and Extremely Dependable

The ZEBRA battery admirably passed various safety tests during its development. For instance, engineers sent the vehicle crashing into a solid barrier at around 30 miles per hour. In this crash test, the motor—as was intended with the A-class' sandwich design—was forced under the passenger compartment. The battery block itself sustained no damage whatsoever. The safety control automatically interrupted all circuits. After the battery was removed, it was still perfectly functional.

In more than 50 different additional tests, the team really put the battery through its paces and found that it could perform superbly even under extreme conditions.

More Than One Million Miles Experience under Its Hood

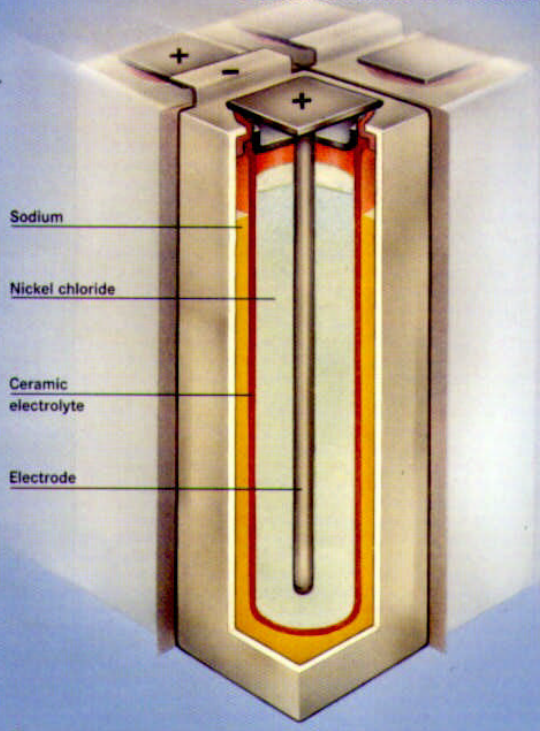
When Daimler-Benz engineers tested the ZEBRA battery in endurance tests, they found it durable and long-lasting. One of the first batteries of this type has been working for five years now in a C-class vehicle, which recently showed an odometer reading of 70,218 miles (113,000 kilometers). About 60 electric vehicles running on ZEBRA power have clocked a total of one million miles (1.6 million kilometers). Even after undergoing laboratory vibration tests, where the battery was subjected to a mechanical stress equal to a "car life" of 124,000 miles (200,000 kilometers), ZEBRA showed absolutely no signs of fatigue.

More varied, though—at least as far as the participating technicians' sensitivities to discomfort were concerned—were the demanding temperature tests. Following a strict scheme, the technicians cooled the battery down to 20 degrees Celsius (68 degrees Fahrenheit) before reheating it to its operating temperature. The battery was frozen under Arctic temperatures and then forced to "sweat" once more. Undaunted, the ZEBRA did its job.

Custom-Designed for Alternative Drive Trains

It may seem surprising that, of all Mercedes, the smallest car was chosen for the voluminous electric drive train. But the revolutionary aspect of the A-class design, its sandwich construction,[3] makes this compact Mercedes the per-

ZEBRA Makes It Possible



The theory behind the ZEBRA is quite elementary. The base materials are nickel and sodium chloride. When the battery is charged, nickel chloride is produced on one side of the ceramic electrolyte and sodium on the other. In this way, electrical energy can be stored in chemical form. When the battery is discharged, that is, when the car is being driven, the reverse reaction occurs. Chemically stored energy is converted to electrical energy, which is then used to power the electric motor. The chemical equation of this reaction is as follows: $2NaCl + Ni = NiCl_2 + 2Na$. This process can occur only when temperatures exceed 200 degrees Celsius (392 degrees Fahrenheit). If the temperature is increased even further, the battery's capacity improves appreciably. For this reason, engineers chose an operating temperature range from 270 to 350 degrees Celsius (518-662 degrees Fahrenheit) for the ZEBRA. Despite these high temperatures, the battery's exterior never gets too hot to touch. The battery cells are, after all, housed in a double-shell, vacuum-insulated steel case—much like a thermos bottle.

Housed in this case, which measures about one meter long, 80 centimeters wide, and 28 centimeters high (39 x 31 x 11 inches), are 448 single cells. These cells make it possible to store 30 kilowatt-hours of energy at a rated voltage of 289 volts and a capacity of 104 ampere-hours.

The ZEBRA battery was developed jointly by Daimler-Benz and Anglo-American Corp. The drive train was developed by Daimler-Benz Research and Development, which also integrated the ZEBRA battery into the new A-class car.

Technical Specifications for ZEBRA

Type:	Sodium/nickel chloride high-energy battery
Operating temperature:	270-350 °C (518-662 °F)
Storage capacity:	30 kWh
Weight:	370 kg (816 lbs)
Power density:	155 W/kg
Energy density:	81 Wh/kg
Rated voltage:	289 V
Dimensions (l/w/h):	993 mm/793 mm/280 mm
Charge time:	7 h; 1 h with external charger

Metropolitan areas will benefit most from the introduction of zero-emission vehicles. Locally, at least, levels of pollutant emissions will be significantly lower.

Putting it together: The complete ZEBRA battery block is fitted into the A-class EV from below.

fect technological partner for the latest drive trains. This was already demonstrated in 1997 by NECAR 3, an A-class car with a built-in fuel cell and methanol reformer. The sandwich design's layered construction makes it possible to place alternative drive train technology under the vehicle's passenger cell. There are two advantages in doing this: First, passengers do not have to sacrifice space, and second, the battery can be safely housed outside of the crash zone.

By contrast with other battery types, climatic chamber tests and field trials of the A-class EV demonstrated that ambient temperatures have absolutely no effect on the ZEBRA's charging and discharging behavior.

But the ZEBRA battery can also be easily installed in other Mercedes cars. For example, in Europe, "Vito" van can now be purchased with an electric drive train. A C-class EV has already been in testing for five years.

No exhaust system; no toxic emissions–absolutely no one disputes the fact that electric vehicles do not produce local emissions. However, it would be naive to say that electric power is free from pollution. Ultimately, the electrical energy necessary to charge the batteries must come from somewhere. Depending on how it is produced, generating electricity produces different levels of emissions. In the basin of Southern California, where a large amount of electricity comes from nuclear power, natural gas, or wind energy, the production of electricity entails relatively low levels of harmful emissions.

A Breath of Fresh Air for Our Conurbations

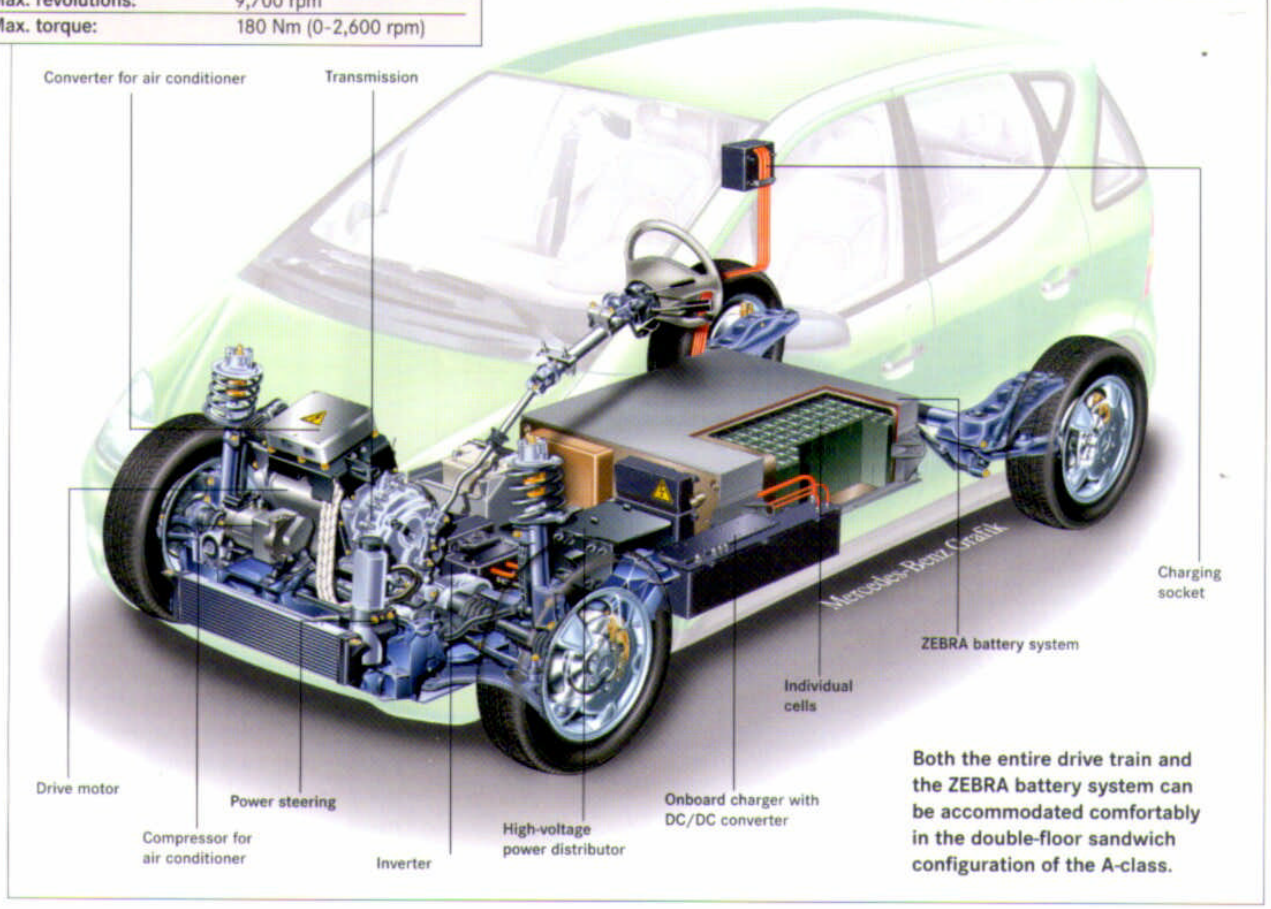
California state legislation requires automobile manufacturers to sell "zero-emission vehicles" in the future.

Sounds like the perfect cue for the ZEBRA-powered A-class, which satisfies such requirements. Against this backdrop, Daimler-Benz will first test a fleet of its new electric cars with customers before it sells the model on a large scale. In particular, the inhabitants of the conurbations of Los Angeles and the San Francisco-Oakland area stand to profit considerably from the introduction of electric vehicles with zero local pollutant emissions.

Thanks to the vehicle's sandwich structure, the entire trunk space is available for luggage.

Technical Specifications for the A-class EV	
1. Dimensions and weight	
External dimensions (l/w/h):	3.575 m/1.719 m/1.601 m
Curb weight:	1,380 kg (3,043 lbs)
Payload:	350 kg (772 lbs)
Gross vehicle weight rating:	1,730 kg (3,815 lbs)
Occupants:	4
2. Driving performance	
Top speed:	Electronically limited to 80 mph
Acceleration 0 - 62 mph:	16.5 s
Range:	125 miles
3. Motor	
Type:	Three-phase induction motor
Power	50 kW
Max. revolutions:	9,700 rpm
Max. torque:	180 Nm (0-2,600 rpm)

The Battery in the "Sandwich" Preserves Interior Space



Both the entire drive train and the ZEBRA battery system can be accommodated comfortably in the double-floor sandwich configuration of the A-class.

Whether waiting at the lights or accelerating away, an electric vehicle is considerably quieter than a conventional car powered by an internal combustion engine.

Things look different, however, if a large percentage of the electrical energy used to power the vehicle is generated by coal-fired power plants.

This would be the case in Germany. If electricity is generated this way, electric car power, compared to the internal combustion engine, still reduces local auto emissions, but not emissions on the whole.

However, as far as noise emissions are concerned, the electric motor, which runs quietly, is clearly superior to the internal combustion engine. Consequently, an electric vehicle waiting at or starting from a traffic light is significantly quieter than a conventionally powered car.

Range Vastly Exceeds Average Daily Driving Needs

According to engineers at Daimler-Benz, a range of more than 125 miles on one battery charge is ample for drivers in most situations. The average commuting distance in California is 32 miles (52 kilometers). Ninety-five percent of all commuters there drive less than 62 miles a day. In Germany, driving distances are even shorter. Here, the average number of miles covered in a single trip is 10.2 and the average distance driven in a day 26 miles. Moreover, 95 percent of all drivers in Germany travel less than 93 miles a day.

A New Drive Train—Otherwise It's Business as Usual

A person driving an electric car will hardly notice that it is powered by an electric motor. Driving performance and handling are not unlike that of a conventional automobile equipped with an equally powerful internal combustion engine. The electrically powered A-class' 50-kilowatt motor has a maximum torque of 180 newtonmeters. Top speed of the vehicle is electronically limited to 80 miles per hour (roughly 130 kilometers per hour).

On turning the ignition key, the electric motor starts without any noise. The selector lever is where it is supposed to be, but it is only used to shift between forward and reverse, and into the park position. After all, the electric motor requires no variable transmission. The cockpit reveals only a slight difference—a charge-level indicator replaces the fuel gauge. Charging the batteries with the built-in charger takes seven hours. However, this can be reduced to one hour if external chargers are used.

And the electric vehicle will warm your heart on even the coldest winter days. The heater can be programmed to turn itself on at any given time by means of a timer. As a result, by the time the driver is ready to drive off, the car will be cozily warm inside and the windows completely defrosted.

A problem that still needs to be resolved, however, is the relatively high production cost of the electrically powered A-class. Here the main expense is the battery, especially if a small number of units are produced.

No Compromises in Utility; Good News for the Environment

Once our engineers have returned to Daimler-Benz's Carson station following the test drive, they use the rest of the day to give the car a thorough check-up. The results of the road report show that the A-class has passed its road test and stood up to all the demands of the road. And that is good news for the engineers, who have moved a step closer to their goal of building a roadworthy electric vehicle.

Thanks to the ZEBRA battery system, the electric drive train has been able to shake off many of its drawbacks vis-à-vis conventional internal combustion engines. Consequently, there is no longer any need for compromises in utility. Drivers can simply sit back and enjoy the pleasure of driving a quiet, comfortable car that is not only easy to operate, but produces no harmful exhaust emissions when running.

No sweat: Even the ups and downs of hilly San Francisco don't diminish vehicle performance.

Everything in its place: The controls in the A-class EV occupy their familiar positions.

Daimler-Benz AG, Kommunikation, 70546 Stuttgart K/UT 1121 12/97