AVILOO

BATTERY DIAGNOSTICS

AVILOO
WHITEPAPER

BATTERY DEFECTS

Why is it important to detect battery faults?

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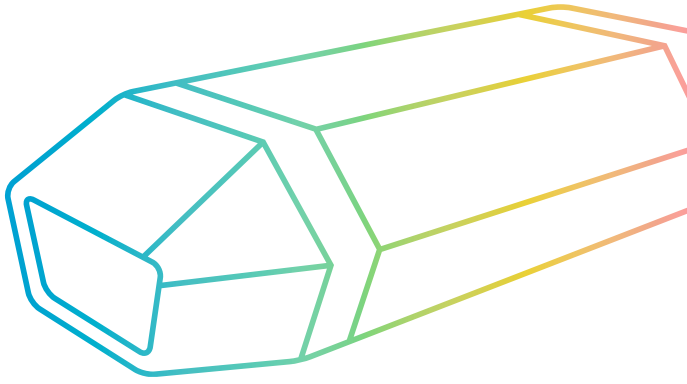


WHY IS IT IMPORTANT TO DETECT BATTERY FAULTS?

Detecting and locating electric vehicle (EV) battery defects is of great importance to owners, remarketers and retailers for two main reasons.

Safety comes first: a faulty battery can lead to dangerous situations such as overheating which could possibly lead to fire or sudden loss of power while driving and to an unexpected shut-down. Early detection of battery defects can help to prevent such situations.

But even without a direct threat to safety, battery defects can lead to considerable complications: Many EV manufacturers promise extensive warranties that cover battery repairs or replacements under certain conditions. However, these are often not transparent for consumers and it is difficult to assess whether a warranty case exists or not. Reporting and documenting defects at an early stage is the best strategy for asserting claims within the warranty period, which can save considerable costs for repairing or replacing the battery.

Among tens of thousands of tests, AVILOO has registered 1 to 2 battery defects per 100 tests (Figure 1).

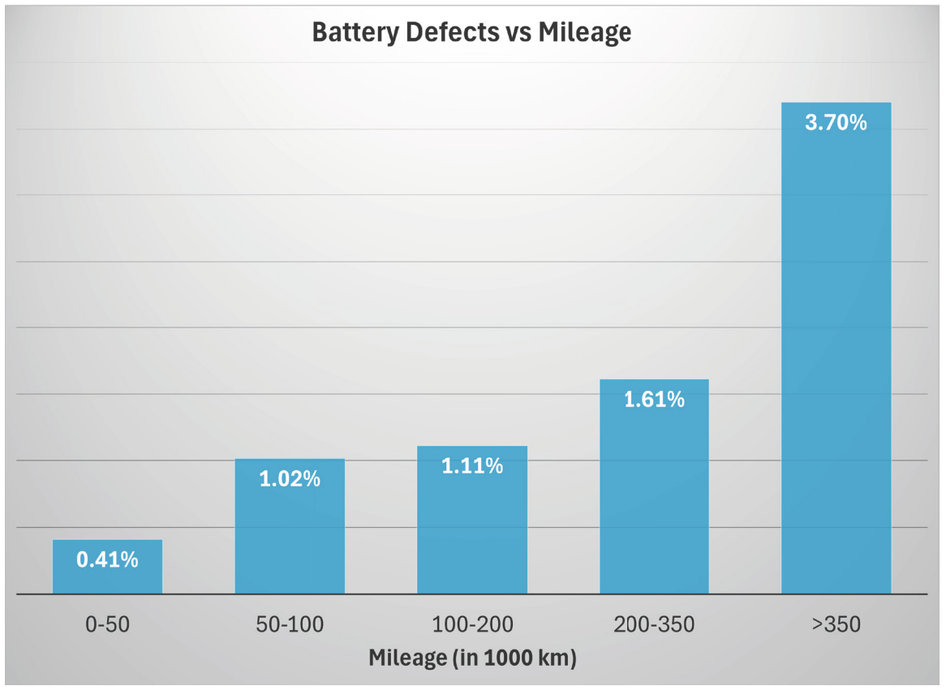


Figure 1

WHAT TYPES OF BATTERY DEFECTS ARE THERE?

Battery defects can occur in various forms and can significantly impair the performance and safety of an electric vehicle. Problems in the battery management system (BMS) can result in the battery not being optimally monitored and controlled, which in extreme cases can lead to overcharging or deep discharge. Increased internal resistance of individual cells can reduce the efficiency of the battery and increase charging and discharging times, which in turn limits the range of the vehicle. In addition, the aging of the battery plays a decisive role, as its capacity and performance diminish over time, leading to a reduced range and increased susceptibility to other defects. All of these factors together can have a significant impact on the reliability and safety of an electric vehicle. In the following, we take a closer look at four different types of battery defects:

→ Problems in the BMS

The battery management system (BMS) is crucial for the performance, safety and service life of the battery. It continuously monitors the voltage, temperature and state of charge of each cell and performs cell balancing. The BMS controls the charging and discharging process to prevent overcharging and deep discharging, and protects the battery against overcurrent, overtemperature and short circuits. It calculates the state of charge (SoC) and state of health (SoH) to ensure precise condition monitoring.
Errors can occur both when measuring and when calculating. In rare cases, this can lead to the wrong cells being charged or discharged during balancing, resulting in an imbalance in the individual cell voltages. This can sometimes lead to a massive loss of extractable energy, but can possibly be remedied by recalibrating the BMS.

→ Increased internal resistance of individual cell levels

Naturally, all battery cells have a certain internal resistance. It causes energy loss while charging and discharging and influences how quickly the battery can be charged or discharged. Even when new, this internal resistance varies slightly (series variation). This initial dispersion often tends to increase over the course of ageing. Increased internal resistance of individual cells can significantly impair the overall performance and efficiency of an electric vehicle. During fast charging, it leads to excessive voltage and the resulting reduction in charging power. During more intensive driving (e.g. in the mountains, when overtaking or during aggressive driving), increased internal resistance in turn leads to voltage drops, which can lead to a reduction in performance or, in extreme cases, even to the vehicle suddenly coming to a standstill.

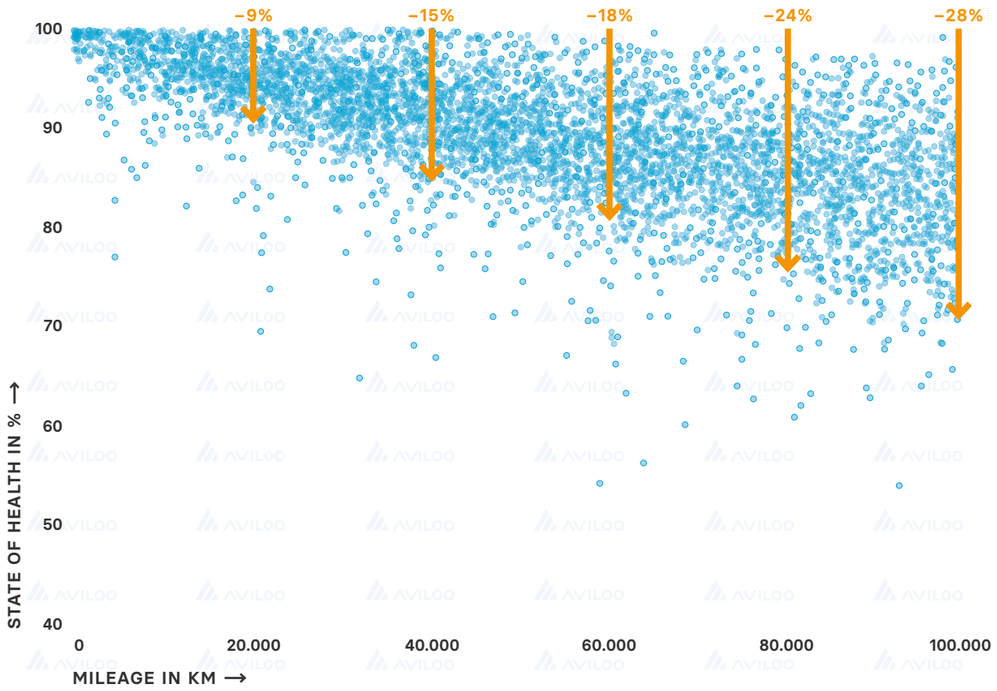
→ Ageing

A certain amount of degradation (decrease in battery capacity) over the service life of a battery is unavoidable, but it varies greatly between car models. For example, there are vehicle models that are very likely to have a range of around 85 % of their new condition after 100,000 km, while this value can be anywhere between 70 % and 95 % for other car models with the same mileage (Figure 2). Batteries in electric vehicles are usually described as „defective“ when their capacity is 70 % of their new value. Here too, individual battery cells age differently and weak cells tend to become even weaker over time.
As the overall state of health is determined by the state of health of the weakest cell level, in many vehicles the replacement of one module can lead to a significant improvement in the entire battery if the appropriate diagnosis is made.

→ Mechanical deformation

It should not be forgotten that particles move from one electrode to the other each time the battery is charged or discharged. Depending on the design, this can lead to a change in the shape of the battery, which is largely reversible, but can also be permanent after many cycles or due to defects („swelling“). Furthermore, external influences such as accidents can lead to mechanical deformation.
In this case, an expert should be consulted in addition to the battery test in order to be able to assess the potential risk of deformation by externally inspecting the battery.

Figure 2



IMPORTANT DIFFERENCES: PHEV VS BEV

When it comes to battery faults, it is important to differentiate between a fully electric vehicle (battery electric vehicle, BEV) and a plug-in hybrid (PHEV). The fundamental difference lies in the relative battery size in relation to vehicle size, weight and power. Another variance factor in the comparison between BEVs and PHEVs is the usage behavior of a plug-in vehicle – namely the frequency of use of the purely electric driving mode.

FIRES IN ELECTRIC VEHICLES

In principle, the probability of a fire is very low. Usually, a “thermal runaway”, i.e. a cell overheating out of control, occurs prior to a battery’s catching fire. This can be caused by various triggers, such as short circuits, overcharging and thermal overloads. Short circuits can be caused by mechanical damage (e.g. metal spike through the cell), manufacturing defects and chemical processes (e.g. dendrite formation). Thermal overload can occur if cooling is missing or damaged or under extreme load at high ambient temperatures. During this “thermal runaway”, the components of the cell begin to decompose exothermically, i.e. more and more heat is generated. As soon as the heat can no longer be dissipated, the pressure in the cell exceeds the load limit and so-called “venting” occurs. The vaporized electrolyte escapes and if the temperature exceeds its flash point, it can ignite. In reality, however, the batteries are very well protected against such a “thermal runaway”. The Battery Management System (BMS) reliably protects the battery against overcharging and thermal overload (e.g. reducing performance during fast charging). Thanks to the most precise final checks during production, the defect rate is low, and appro-priate structural reinforcements ensure that the battery is so well protected even in the event of an accident that there is no risk of mechanical damage. But the older batteries and their control units become, the more important it is to check them regularly.

TIPS TO REDUCE THE RISK OF BATTERY DEFECTS

→ **Moderate driving style:** Even if electric vehicles allow a very sporty driving style, this is often not conducive to the longevity and long-term safe operation of the battery. Strong acceleration implies high currents, which in turn leads to losses and wear via the battery’s internal resistance. A moderate driving style helps to save energy and minimize the likelihood of defective battery cells.

→ **Correct charging:** If the battery is fully charged or discharged very often, it reaches its load limit each time, as electrons are deposited on one electrode and ions on the other. This can lead to instability within the cell and possibly to cell defects in the long term. If the full range of the vehicle is not required at the time, it is therefore advisable to charge the battery more often with smaller charges rather than a few full charges. Apart from this, high states of charge over longer periods accelerate the ageing of the battery. Therefore, if the car is parked for a longer period of time, you should leave it in a rather low state of charge, especially in warm temperatures. The charging power also has an influence. Avoid fast charging too often, as this also puts a heavy strain on the battery.

→ **Preconditioning:** Use adequate preconditioning to prepare the battery for the charging process. If the vehicle is connected to the wallbox during preconditioning, the electricity is used directly from the socket without having to take a detour via the battery. In this way, you avoid additional cycles and reduce the load on the battery. Preconditioning also plays an important role in fast charging. Modern vehicles have an automatic preconditioning function that is activated when an upcoming charging station is displayed in the navigation system. This allows the battery to be preheated before the actual charging process. This not only makes charging more gentle, but also speeds up the charging process. The use of preconditioning is particularly important in winter, as charging at cold temperatures puts a particular strain on the battery.

→ **Regular testing:** Regular testing can determine whether a vehicle is being used efficiently and gently. Anomalies in battery performance may indicate possible defects. Particularly under extreme temperatures or loads, such as in icy winters, such anomalies can impair vehicle behavior and even pose risks to electric vehicle users. Both AVILOO tests (PREMIUM and FLASH) can offer comprehensive analysis down to cell level.

HOW CAN AVILOO HELP WITH BATTERY FAULTS?

AVILOO battery diagnostics detects and displays anomalies, most of which do not trigger error codes in the BMS system. AVILOO often supports workshops not only with troubleshooting, but also with fault finding. Authorized workshops appreciate the fact that AVILOO diagnostics not only reveal the fault, but also provide crucial information on how to find the cause – without opening any screws. Only the cover for accessing the OBD 2 connector may need to be removed.
If required, an expert opinion can also be prepared by AVILOO.

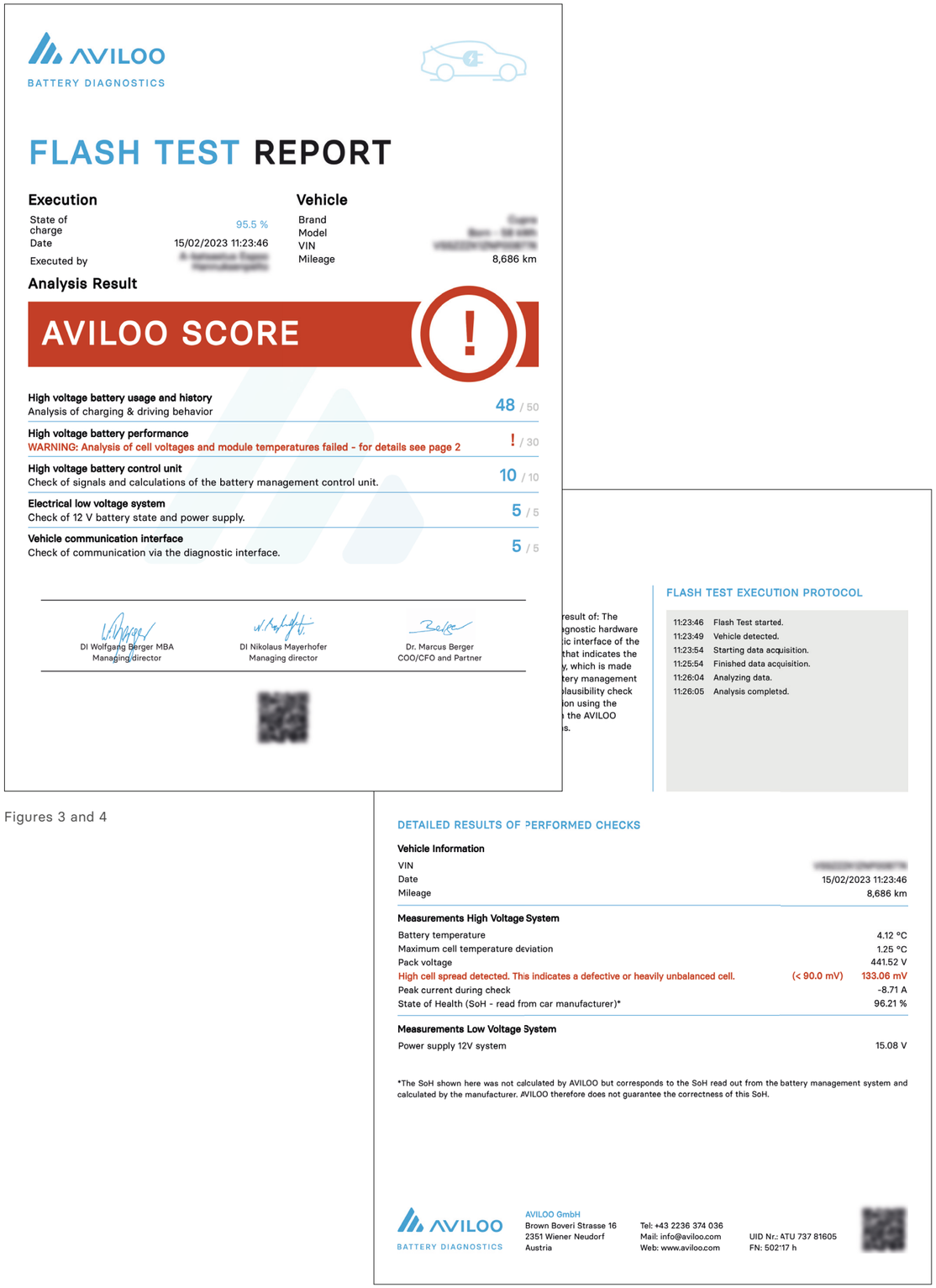
FLASH Test: as required, even several times a year – to rule out a variety of cell anomalies within the battery

The AVILOO FLASH Test, currently the fastest detailed battery test on the market, enables numerous vehicles to be tested in a short space of time. In just three minutes, the test provides an analysis of the battery condition and presents the results in the form of numerical values in the independent AVILOO report. With the FLASH Test, battery faults can be detected down to cell level, which is invaluable for the marketing of a used car and transparency when reselling. Its exceptional quality has been confirmed by the European Remarketing Association (CARA). The test shows possible "red flags" in the battery status within 3 minutes (Figures 3 and 4).

PREMIUM Test: once a year – to check the battery thoroughly

The PREMIUM Test enables a comprehensive battery analysis, as the battery is measured in detail over a longer period of time. This means that significantly more data is available. During the PREMIUM Test, the dynamics are used to analyze the internal resistance down to cell level. This test has TÜV certification.

Analysis down to cell level is of crucial importance for battery diagnostics, as the overall performance depends on the weakest link in the chain.
This means that defects or uneven ageing of individual cells lead to a significant reduction in the performance of the entire battery. Both, the PREMIUM Test and the FLASH Test from AVILOO include, among other categories, detailed analyses down to the cell level and detect battery defects very effectively.



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FLASH TEST REPORT

Execution

State of charge 95.5 %
Date 15/02/2023 11:23:46
Executed by

Vehicle

Brand
Model
VIN
Mileage 8,686 km

Analysis Result

AVILOO SCORE !

High voltage battery usage and history Analysis of charging & driving behavior	48 / 50
High voltage battery performance WARNING: Analysis of cell voltages and module temperatures failed - for details see page 2	! / 30
High voltage battery control unit Check of signals and calculations of the battery management control unit.	10 / 10
Electrical low voltage system Check of 12 V battery state and power supply.	5 / 5
Vehicle communication interface Check of communication via the diagnostic interface.	5 / 5

DI Wolfgang Berger MBA
Managing director

DI Nikolaus Mayerhofer
Managing director

Dr. Marcus Berger
COO/CFO and Partner

result of: The
gnostic hardware
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that indicates the
y, which is made
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lausibility check
ion using the
the AVILOO
s.

FLASH TEST EXECUTION PROTOCOL

11:23:46	Flash Test started.
11:23:49	Vehicle detected.
11:23:54	Starting data acquisition.
11:25:54	Finished data acquisition.
11:26:04	Analyzing data.
11:26:05	Analysis completed.

DETAILED RESULTS OF PERFORMED CHECKS

Vehicle Information

VIN	
Date	15/02/2023 11:23:46
Mileage	8,686 km

Measurements High Voltage System

Battery temperature		4.12 °C
Maximum cell temperature deviation		1.25 °C
Pack voltage		441.52 V
High cell spread detected. This indicates a defective or heavily unbalanced cell.	(< 90.0 mV)	133.06 mV
Peak current during check		-8.71 A
State of Health (SoH - read from car manufacturer)*		96.21 %

Measurements Low Voltage System

Power supply 12V system	15.08 V

*The SoH shown here was not calculated by AVILOO but corresponds to the SoH read out from the battery management system and calculated by the manufacturer. AVILOO therefore does not guarantee the correctness of this SoH.

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Figures 3 and 4

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