Automotive batteries — from a single component to an entire part of the electrical system in a vehicle

W. Bernardi
Hoppecke, Postfach 1140, 5790 Brilon 2 (F.R.G.)

Abstract

The design of automotive batteries according to a given specification only must be more integrated into the electrical engineering work of automobile manufacturers. The main target is to reduce the number of incidents in which battery failure is a problem with vehicle performance, i.e., to increase battery reliability. Detailed information is given about the present situation and future trends to solve difficulties with respect to the electrical system of the vehicle and the battery technology.

Car users requirements and field analysis

Both the vehicle and the battery industries have to meet car users' requirements. As far as the electrical system and the battery is concerned, the targets are easy to express, namely the car user: (i) expects a reliable electrical system and a safe engine start under any conditions; (ii) ignores the battery. (Note, the latter is the car users' definition of a 'maintenance-free' product.) The battery cannot be seen as a single and simple component in achieving these targets, together with other market needs having effects on the electrical system such as more comfort in vehicles, increasing number of electrical components, upcoming communication, navigation and information systems installed in vehicles. In other words, designing automotive batteries according to a given specification and interface must only be changed by a more integrated electrical engineering approach.

Field analyses conducted by the British RAC (Fig. 1), the German ADAC, or vehicle and battery manufacturers reveals that the battery is one of the components most likely to fail. This means that the car users' requirements mentioned before are not met by either the battery or by the vehicle system. In the following sections, more detailed information is given about the present situation and the future trends to meet present and upcoming demands as far as the electrical system and battery technology is concerned.

Field tests of maintenance-free batteries

The main question is: "are car users satisfied with the degree of freedom from maintenance reached by present batteries?" An affirmative answer to

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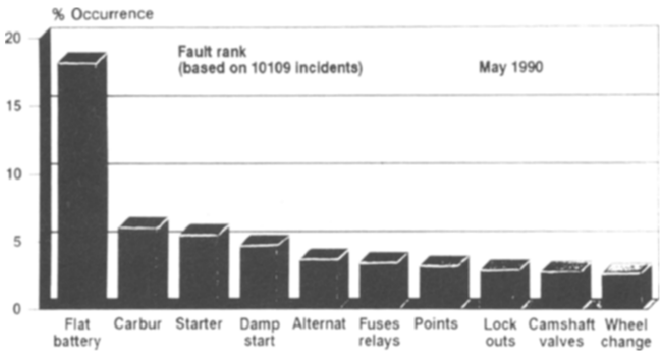

Fig. 1. Top 10 faults: RAC vehicle park.

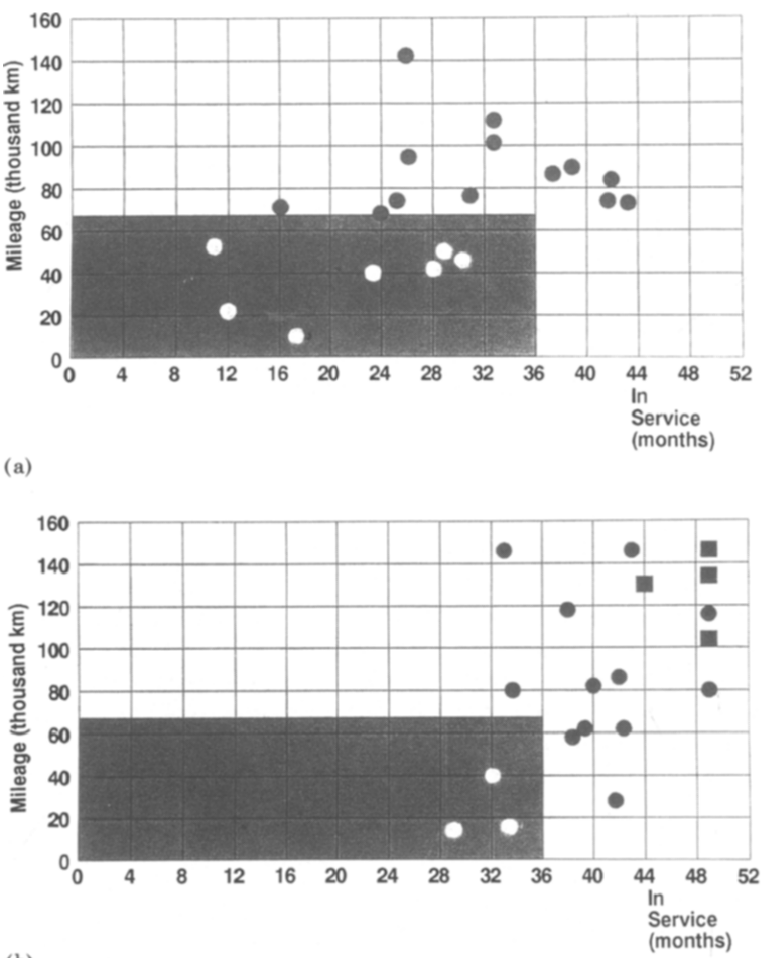

Fig. 2. Field tests of standard (2.5 wt.% Sb) and Duplex-MF (hybrid) automotive batteries.

TABLE 1

Design characteristics of standard and Duplex-MF automotive batteries

	Standard	Duplex-MF
Grid alloy	+Pb–2.5wt.%Sb −Pb–2.5wt.%Sb	+Pb–1.8wt.%Sb −Pb–0.11wt.%Ca (hybrid)
Separator	leaf type (cellulose, glass, PVC)	envelope (PE)
Lid design	single vented cells acid spill possible from plug to lid surface	double lid, heat sealed central vented cells acid drainage system back to cells flame retarders to reduce explosion hazard
Water consumption acc. to DIN 43539/2 (g A h^{-1})	6–8	1–2
Field test[a]		
Average mileage (km)	72 000	88 000
Average lifetime (months)	28	40
Test result	test failed	test passed, 25% of batteries still operating

[a]Test conditions: batteries in engine compartment; no topping up; hot climate conditions (Southern U.S.A.); customer requirements: >36 months >66 000 km.

this question is indicated by comparing the results of field tests (Fig. 2) for standard and Hoppecke maintenance-free (MF) 'Duplex' batteries (for details of the design of these batteries, see Table 1).

Plate-manufacturing technologies for maintenance-free batteries

The production of the plates for modern MF batteries requires new or improved equipment. For example, in Hoppecke plants it was necessary to invest in machinery for casting lead–calcium grids. Prior to making this decision, a comparison was made of the three plate-making technologies available on the market; namely, (i) gravity casting, and conventional pasting; (ii) expanded metal and continuous pasting; (iii) continuous casting and pasting. The arguments in favour of choosing the latter process are presented in Table 2.

Towards better reliability and safety

With the introduction of MF batteries, one of the previously mentioned customer requirements is fulfilled. But what about the other main demand for safe engine start and a reliable system?

TABLE 2

Comparison of plate-making technologies

Criteria	Gravity casting	Expanded metal	Continuous casting
Alloys	Pb–Sb > 2 wt.% Pb–Sb < 2 wt.% Pb–Ca	Pb–Ca	Pb–Sb < 2 wt.% Pb–Ca
Material cost	market price including cost for tin, grain ref.	premium costs for strip and scrap (no remelt)	market price
Freedom of grid design	limited by thickness >1.0 mm and net structure (follows gravity casting direction)	limited no grid frame	yes, thickness range ⩾0.5 < 2.0 mm
Quick type change	yes	no	no
Productivity (Pb–Ca grids per worker and 8-h shift)	35000 (1 time)	70000 (2 times)	140000 (4 times)
Quality aspects Corrosion behaviour (positive plate)	fairly good if solidification process is under control	sufficient mechanical stress of material can cause excessive corrosion	good solidification under SPC-conditions through pasting protects grid wires
Weight tolerances (g)	grid ± 3 paste ± 12		±0.5 ±3

Different field analyses show that many car users are not satisfied. For example, during a battery lifetime of 3 years, the claim rate varies between 1 and 5%, depending on vehicle type, handling in service, and other factors. The main causes of battery failure are found to be: (i) discharged but rechargeable; (ii) deep discharged, not rechargeable; (iii) manufacturer's fault (0.4% according to VW); (vi) worn out due to high temperature and/or high mileage.

It is suggested that the manufacturers' failure rate must be reduced to ⩽0.2%. This is a realistic target that requires different action by every battery manufacturer. Areas requiring attention to reduce the difference between faults in manufacture (0.4 to 0.2%) and the total claim rate (1 to 5%) are discussed in the following sections.

Thermal management

Batteries placed in the engine compartment are being subjected to increasing temperature levels because: (i) the engine is capsulated; (ii) additional heat from catalyst; (iii) increasing stop and go traffic conditions; (iv) reduced air circulation due to changes in vehicle design to give better aerodynamic features. According to the Arrhenius relationship a 10 °C higher average temperature shortens battery lifetime by half.

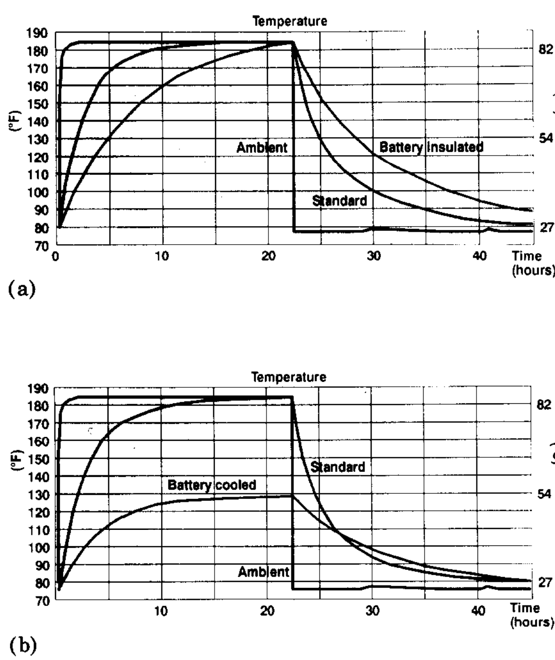

Fig. 3. Thermal curves for automotive batteries: (a) passive insulation; (b) air cooling. (Source: GNB Inc., Minnesota, U.S.A.)

TABLE 3

Thermal management of automotive batteries

Approach	Advantage	Disadvantage
Passive insulation	easy to install cheap	slow in cooling down after heating up slow in heating in winter
Airflow cooling	very good cooling effect	need cool air source
Relocation of battery	very effective in cooling (or heating)	vehicle design change expensive
Relocation of heat flow	effective	partial solution only

Different procedures to reduce the battery temperature are listed in Table 3 and their effects are shown in Fig. 3.

System evaluation

When examining reasons why claimed batteries are simply discharged two categories of faults emerge.

(i) Battery discharged while vehicle is *not* operating, e.g.,

- long periods between battery production date and car registration date (i.e., discharged during transport, with dealer, etc.)
- unnecessary load left on for long time (head lights, interior lights, radio, etc.)
- necessary 'key-off' loads too high (computer, etc.)

(ii) Battery discharged while vehicle is *in* operation, e.g.,

- regulator/alternator fault
- unusual driving conditions (stop and go/winter time); these conditions are demonstrated by the data given in Fig. 4.

With growing loads, slowing traffic conditions and the need for safe electrical supply to critical functions, system changes have to be effected. Some possible solutions with impacts on battery design are shown in Fig. 5.

The present electrics show the 'end of the line' as far as battery/alternator size is concerned. The configuration shown in Fig. 5(a) was installed in the vehicle used to generate the test data given in Fig. 4. A quick remedy could be higher charging voltages with temperature/voltage sensing at the battery. A higher alternator speed at idle conditions through higher engine speed is not suitable due to environmental reasons.

The concept of a 'back-up battery' has recently been introduced into the U.S. replacement market. In Australia, 2% of this market has been captured by the GNB/Pulsar battery system (Fig. 5(b)).

The 'split battery' is a very sophisticated solution that requires a completely new battery architecture (Fig. 5(c)).

The most appropriate approach is the dual battery shown in Fig. 5(d). The advantages of this system are: (i) safe and convenient power-supply; (ii)

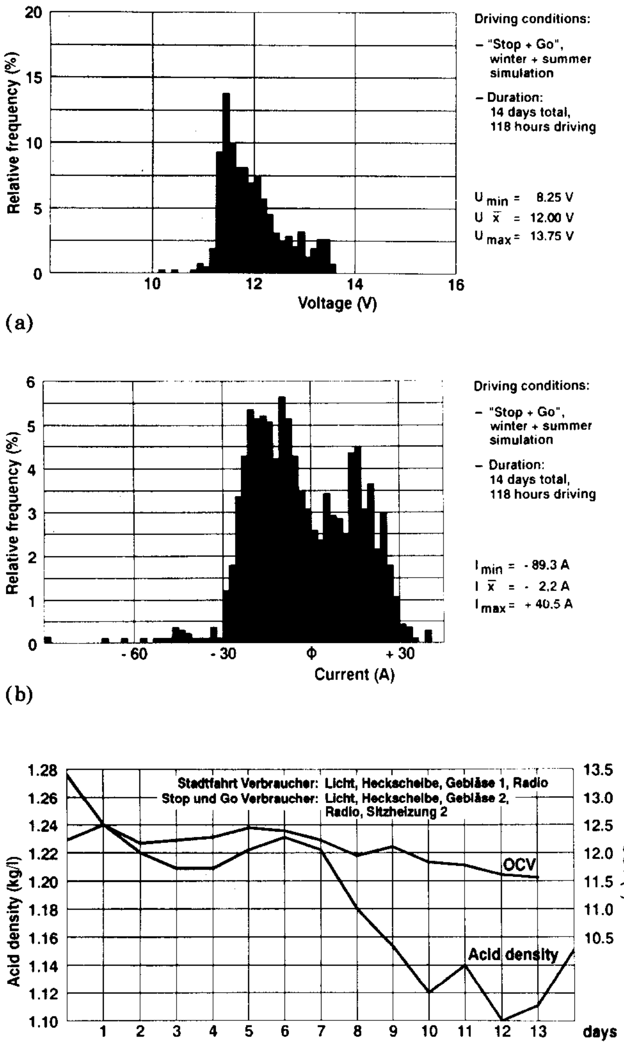

Fig. 4. Vehicle testing: (a) voltage distribution; (b) current distribution; (c) battery characteristics.

option towards higher voltages (e.g., 24 V) in steps; (iii) optimization of two generator/battery sizes; (iv) battery design possibilities for different applications (cold-cranking/power-supply).

Concluding remarks

Development of the automotive battery during recent years has realized the main demands of the market in terms of electrical performance, freedom

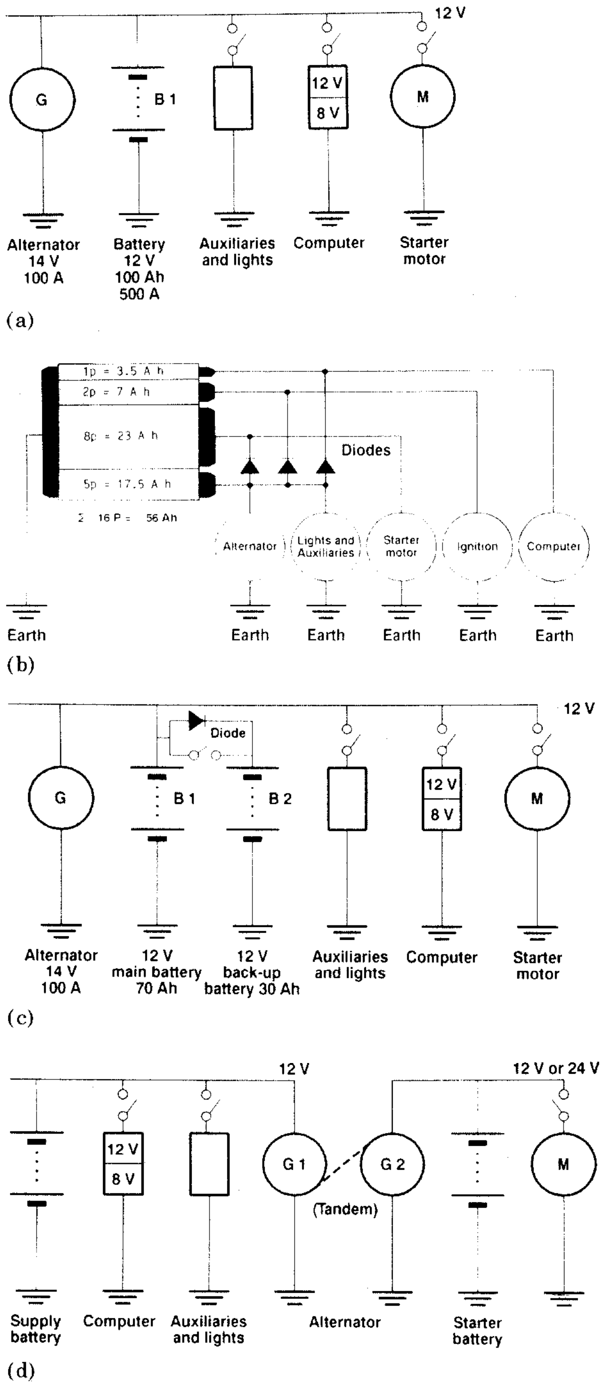

Fig. 5. Schematic of: (a) present electrics/single battery; (b) split 12-V battery, 'Pulsar 16P'; (c) battery reserve system; (d) dual 12-V and 24-V batteries.

of maintenance, and average lifetime. Dramatic improvements in battery performance cannot be expected within the next few years.

The present problems with batteries in some vehicles will increase if no changes are made to the *electrical system*. The target is a more reliable power supply in vehicles. This target cannot be reached by component engineering. Vehicle manufacturers must coordinate the work of battery technologists with that of developers of other components in order to achieve good total system engineering.