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Intelligent battery systems for automobiles

E. L. Bydder and P. Witehira
Power Beat International Limited, P.O. Box 15-163, Hamilton (New Zealand)

Abstract

A novel 'intelligent' battery has been developed for automotive applications. The product – known as the Powerbeat battery – consists of a dual, 12-V lead/acid arrangement: six cells are used to supply cranking current and six to supply auxiliary current. An innovative control device allows reliable switching between these two modes of operation. Two versions of the control system are presently in use: one is based on a motion sensor, the other on detecting the load change when the vehicle is started. The dual battery can be manufactured, at similar production rates, in conventional plants. Field trials are in progress in both Australia and New Zealand. Compared with traditional technology, the Powerbeat system offers improved and more reliable performance, greater flexibility in the management of vehicle electrical requirements, and reduced battery size and weight.

The battery

The fundamental purpose of an automobile battery is to start the engine. Even this elementary requirement uses the battery for two distinct and conflicting purposes. The battery has to crank the engine (which requires very high current, especially in adverse conditions) and it has to supply the electrical functions required for ignition, fuel supply, engine management, etc. (which require a relatively uniform, stable voltage). The battery is also expected to operate lights, radios, telephones, etc., when the engine is not running. In addition, it may be necessary to control the air-conditioning, heating, fans and many other electrical systems that would make the automobile more attractive and useful when the engine is not running, perhaps even when the car is unoccupied. Finally, a system may be required to save fuel that turns off the engine whenever the vehicle is not moving, and automatically starts it again when vehicle drives off, and/or other functions.

An ideal battery might permit all these uses without the engine running, as well as starting the car easily and quickly – even in the most adverse circumstances and whatever the previous use of the battery for auxiliary loads. The battery would have a very long life whatever the discharge cycling history, but it must also be light and compact. It would preferably be independent of the vehicle, and compatible with existing vehicles. In addition to all these characteristics, the battery has, of course, to be realizable and affordable.

A realizable optimum battery

The design parameters of an optimum realizable battery are as follows.

- It must be 12 V for compatibility with existing and current production vehicles.

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- It must be capable of being manufactured by current technology, and be low in cost; this means lead/acid technology with a single battery container system.
- It must be a dual battery with independent positive terminals so that it can supply separately and simultaneously the cranking current requirements and a steady unattenuated 12 V to the engine auxiliaries during starting.
- The auxiliary supply section must be capable of deep cycling with minimal deterioration.
- The packaging and weight must be appropriate, e.g., the same size, shape and weight as a conventional battery.
- Installation must be simple and straightforward. Therefore, the battery must be self-contained. It can make use of the easy separability of the cranking and auxiliary cable connections to the battery as used in most modern vehicle.
- There must be an appropriate control system to protect the cranking section of the battery from being discharged by auxiliary usage, to ensure charging of both battery sections when the engine is running, and to allow starting of the engine even when the auxiliary supply battery section has been fully discharged. This control system must be automatic, i.e., require no driver intervention; it must be contained within the battery; and it must be of low cost.

A novel intelligent battery

A battery with these specifications and including an on-board automatic control system has been designed and tested by Power Beat International Limited (PBIL) and is now in production by its subsidiary company, Power Beat Australasia Limited (PBAL). In view of the optimization of the battery functions and the automatic control system, it is called an 'intelligent' battery.

The Powerbeat battery consists of 12 lead/acid cells, of which six use deep-cycle elements for auxiliary current supply and six use thinner plates suitable for the cranking current requirements. The combined unit is encased in a single container. The two positive terminals are arranged so that the cranking and auxiliary cables at the battery connection in most modern vehicles can be separated and fixed to the respective positive battery terminals with no modifications and very little effort. The battery has an in-board automatic control system. The interconnection of the battery is outlined in Fig. 1.

Tests have shown that the Powerbeat battery system will start the engine of a typical modern car in the normal way in the following situations:

(i) when the car has been left with its headlights and all other electrical accessories on for 48 h;

(ii) when the cranking voltage at the starter motor has been deliberately reduced to less than 4 V under load;

(iii) when the vehicle has been stored in a refrigerated container at −25 °C for 72 h;

(iv) when the vehicle has been left overnight in snow with the headlights and electrical auxiliaries all on.

Note. The vehicle used in these tests was a 1990 Nissan 3 l electronic fuel injected motor with a standard Bosch 12 V starter motor. The battery has also been used for more than 12 months in various vehicles including vehicles with motors with capacities over 5000 cm^3.

The Powerbeat battery has been designed to be manufactured in a conventional plant. It is possible to produce the battery at speeds similar to standard 6-cell batteries,

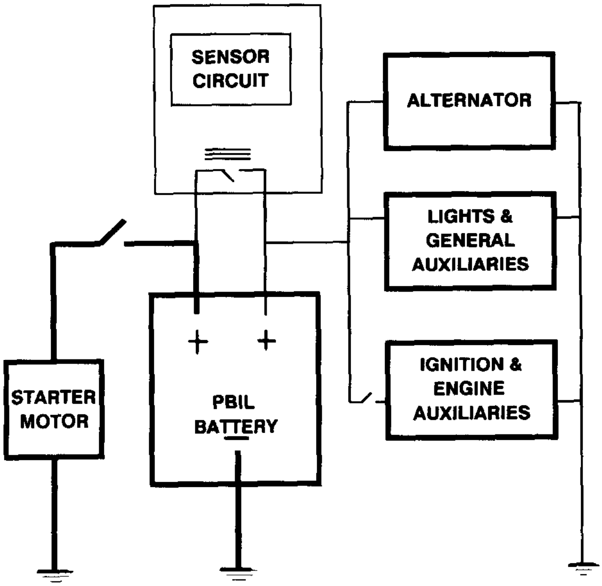

Fig. 1. Electrical interconnection of Powerbeat battery.

provided that the production line is re-orientated to cater for increased component handling and 80% more through-the-partition welds. Heat sealing of the cover is as fast as with conventional batteries. Through-the-partition welds can be made at the same speed with an extra weld head added to the line. Shear and pressure testing require additional tooling to keep production speed equal to conventional 6-cell systems.

Production speed problems arise during element assembly because there are twice as many elements. Any cast-on-strap (COS) system can be converted to handle the 12-cell arrangement, although speed of assembly can only be matched by increasing the number of COS stations. Automatic stacking and element assembly are possible at the same speed as with conventional systems. PBIL is presently working towards developing high-speed assembly techniques for 12-cell automotive batteries.

PBIL have tested various plate combinations to ensure compatibility of the 'optimum' requirements with vehicle electrical specifications. The active material densities between cranking cells and deep-cycle cells are only slightly different.

The control system

The key element of the control circuit is a switching device connected internally between the two positive terminals of the battery system, that is, between the auxiliary-supply cells and the cranking-supply cells. It can be a simple medium current relay, e.g., with a nominal current capacity of 30 A. It does not have to be capable of carrying the starter-motor current (typically several hundred amperes), because the battery sections and external connections specifically assign the cranking function to one set of appropriately designed, high-current cells. Thus, the current switching element can be both compact and inexpensive. It does, of course, have to be protected from carrying excess current.

TABLE 1

Relay function

Vehicle	Relay	
	'Closed'	'Open'
Parked: engine not running		X
Engine running: voltage at cranking terminal ⩾13 V	X	
Engine running: voltage at cranking terminal <13 V		X
Engine stopped: voltage at auxiliary terminal >12.3 V and engine about to be cranked by the ignition key being turned to the start position		X
Engine about to be cranked by key being turned to start position and voltage at auxiliary terminal <10 V	X	
Engine being cranked and cranking terminal showing at least 2 V lower than voltage at auxiliary terminal		X

The control system for this relay has several sensing and timing functions. It has to sense the intention to start the engine, and close or open it according to the state-of-charge of the auxiliary battery section. It also has to sense when the alternator is capable of charging the battery sections, and close the relay to connect them in parallel for this situation. When the auxiliary battery section is discharged, the relay has to be closed prior to starting to put charge into the auxiliary battery to operate the auxiliary functions required for starting, but to be open when the cranking terminal voltage becomes less than the auxiliary terminal voltage. In all other conditions of usage of the vehicle without the engine operating, it has to protect the cranking-cell system from discharge. A suitable relay-closing programme is shown in Table 1.

The control system has to be powered by the cranking-section cells. It is designed to operate over a wide range of voltages, and to draw a very small quiescent current, typically 1 mA.

Two versions are in current use, one based on a motion sensor and the other based on sensing the load change when an attempt is made to start the vehicle. These circuits are relatively cheap, using a single integrated circuit. The complete circuit board, including the relay and sensors, is about 5×5 cm.

Battery standards and testing

Current battery standards are generally based around cold-cranking amperes (CCA) and discharge capacity ampere-hours (A h).

The CCA value is essentially a measure of the internal resistance of the battery, and the standards are designed to ensure that the battery can supply adequate voltage to the essential starting auxiliaries while it is cranking the motor. Obviously, the CCA standard as such is inappropriate for a dual-battery system. Indeed, since an 'optimum' battery system allows much greater freedom for electrical usage in the vehicle while being specifically suitable for starting the engine, it would be appropriate to relate modern battery specifications more directly to the starting function.

It is of interest to mention that a well-known motor vehicle manufacturer, who asked to be supplied with a Powerbeat battery system for evaluation, sent a copy of the test report on it. The test procedure used for this three-terminal battery complete with its on-board automatic control system consisted of connecting the two positive terminals together and testing the CCA, A h capacity and gassing according to the DIN standards for automative batteries. It was found that, according to these tests, the results were insignificantly different from those for a standard automotive battery!

The testing protocol for a high-technology, automobile battery should be closely related to the following requirements.

Startability

This is the ability to rotate the engine while supplying sufficient voltage to the auxiliaries to allow starting. For most spark-ignition engines, 4 V at the cranking terminal is more than adequate to allow starting with the Powerbeat system. This corresponds to a Powerbeat battery being more effective at starting the engine than a conventional automotive battery of twice the CCA capability. Thus, CCA is not an appropriate measure of startability for a high-technology battery system.

Reserve capacity

A protected, dual-battery system has two reservoirs of reserve capacity. One is 'free' for operating auxiliaries while the engine is not running, and the other is protected to ensure engine startability. As the reservoirs perform different functions, they need to be specified separately; for example, the cranking section needs to be specified for a sufficient cranking time at an appropriate cranking current, while the auxiliary section can be designed and specified according to perceived uses for different customers.

Deep-discharge life expectancy

For rather obvious reasons, manufacturers of automotive batteries are reluctant to specify the deep-discharge life expectancy of their batteries. For batteries designed for deep cycling, this is, however, an important parameter. The Powerbeat battery system offers deep-cycling capability for its unprotected auxiliary-supply section, and is intended to withstand about 300 deep cycles. It would be appropriate to specify and test deep-cycle life.

Controller functions

It would, in principle, be appropriate to specify and test the functions and operation of the control system, or of the battery system when its operation is dependent on the functioning of the control system.

General tests

There are, of course, many tests that are appropriate for any mobile battery system, e.g., gassing, vibration, mechanical strength, etc.

PBIL recommends that the battery industry takes a serious look at developing appropriate standards for specifying and testing high-technology, smart batteries. The standards should closely relate to the functions of the battery and should not prejudice the acceptance of such high-technology batteries by forcing inappropriate or irrelevant standards that ignore the novel features of such batteries.

Future developments

The rationalization of the battery system to the electrical functions required in the vehicle makes it possible to reduce both the size and the weight of a battery without compromising the expected life and quality. For example, the large Group 60 battery used in the Ford Lincoln Town Car can be replaced with a significantly smaller Powerbeat battery that provides better starting.

Experience with the development and production of the Powerbeat battery in Australia is being used to produce two new improved designs. The new designs will be produced within the next 12 to 18 months. The features of the new designs include:

- a 'flush' cover to allow a battery model to be used on a wider range of vehicles;
- concealment of the automatic control system and connections;
- a version suitable for vehicles without a split harness, that can be used directly in place of any current battery;
- a container size that is compatible with as many makes of vehicles as possible;
- lower weight from optimization of components.

The new batteries being designed are compared with the present Australian production version in Table 2.

TABLE 2

Powerbeat battery sizes[a]

Specifications in detail	First Australian production version	Advanced new Asian production version	Future narrow-fit version
Dimensions (mm)			
Length	232	228	228
Width	174	171	132
Height	190	188	188
T.H. (Top of terminal)	210	207	207
Weight (kg)			
Dry	14.2	12.4*	9.92*
Wet	18.4	16.180*	13.448*
Power			
Independent CCA (SAE)	240–250	240–250*	220*
Total CCA	400*	380*	320*
Independent auxiliary power reserve (min) (25 A constant, 5-h rate) to 10.5 V	35	25*	20
Total reserve power (SAE 5-h rate) main only	85	80*	60*

[a]Asterisk = estimated.

Marketing of the PBIL battery

The annual world automobile battery production is around 230 million units, with the US market producing about 80 million. There is a very large potential market for 'optimum' batteries if they are cost effective. The Powerbeat battery is now being manufactured in Sydney, Australia. Sample batteries are being tested by a number of vehicle manufacturers, and PBIL is negotiating with several battery manufacturers for licence or joint-venture agreements.

Public interest is very high throughout Australia and New Zealand. For example, in New Zealand a test marketing programme produced a most unusual situation that might be unique in the automotive battery retail sector. When a limited number of Powerbeat batteries were made available for sale recently, more than 50% of sales went to customers whose existing batteries were not due for replacement. Indeed, some customers changed conventional batteries that were only weeks old for Powerbeat batteries.

Conclusions

This paper has outlined a realizable battery system that is intended to make the operation and use of an automobile more reliable as a transport system and more flexible as a lifestyle ancillary. The battery, that has been put into production, has many features of an 'optimum' battery system. Its significant advantages over a standard automotive battery are:

- easier and quicker starting, especially in adverse conditions;
- the engine can be started irrespective of the previous use of electrical auxiliaries, even to the extent of complete auxiliary battery discharge;
- long battery life, even with numerous deep-discharge cycles;
- the operation of the system is automatic, so driver intervention is not required;
- the vehicle designer and the user have freedom to install and use electrical auxiliaries, even when the engine is not running, without fear of rendering the engine unstartable and without the need of elaborate interlocks or other control devices;
- the battery system is compact and easily installed in modern vehicles; it looks like and takes up the same space as the conventional battery it replaces;
- the battery gives ample opportunity for vehicle manufacturers to provide the same vehicle-starting reliability with less battery weight or greater starting reliability with the same battery weight as previously used.