THE GASTON PLANTÉ MEDAL ADDRESS

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I express my sincere gratitude to the Bulgarian Academy of Sciences and to the Planté Medal Committee for selecting me as the first recipient of the Gaston Planté Medal. This is a great honour and is certainly the culmination of my scientific life. I very much hope that by granting this medal the Bulgarian Academy of Sciences has initiated a long-lasting tradition to the benefit of scientists and engineers who feel themselves indebted to the work of Gaston Planté. Once again, let me express my deepest thanks and appreciation for this award.

I became acquainted with Gaston Planté's accumulator 34 years ago when I joined the AFA/VARTA central laboratory. At that time, the laboratory was under the direction of Hans Bode. It is more than a matter of politeness if I take this opportunity to acknowledge how much I am indebted to the late Professor Bode for all the support and encouragement that I received under his directorate.

The most exciting experience in my first year at VARTA was the discovery of α-PbO_2 in the positive active material of a lead/acid cell. This polymorph of PbO_2 had been described a few years earlier, in 1950, by Saslawski, Kondraschow and Tolkatschew. The proof of its presence in the positive electrode, and its concentration gradient over the electrode's cross section, were clearly demonstrated by analysing several layers of active material, proceeding from the surface to the centre of the electrode (Schichttortenverfahren). Since then, much information has been collected on α-PbO_2, in recent years particularly in Australia, and we have heard new results on α-PbO_2 at this LABAT-89 conference. Nevertheless, we still do not fully understand its significance (or insignificance?) towards the behaviour of the positive active material in a lead/acid cell. Whilst on the subject of PbO_2, you may be interested to hear that about two years ago, in far away Australia, the 'α/β PbO_2 Society' was founded and that I was appointed member No. 002 by Dr David Rand of CSIRO. Four days ago, at the beginning of this conference, I had the honour to welcome Dr Kathryn Bullock as member No. 005 to this Society. So together with Professor Detchko Pavlov, who is member No. 004, three members of this distinguished and highly exclusive society are present to-day.

The Organizing Committee of LABAT-89 has invited me on this occasion to present my personal views on the future prospects of the lead/acid battery. I have been asked to do this many times, and my usual answer is:

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the future of the lead/acid battery is bright! Surely, this is a true statement, for as everybody knows, there is no competing alternative secondary electrochemical system close at hand that will be as cost effective and as reliable in terms of performance as the lead/acid battery. In addition, lead/acid batteries are manufactured by well established, highly automated, mass-production methods.

The real question is: what will this bright future for lead/acid batteries look like? Since nobody can foresee the future, my reply is as follows: we do not know what cell size, shape, and capacity, and what battery voltage customers will require in, say, 10 years' time and what other specific requirements they will demand. But what is certain is that within the next 10 years we must understand more of the basics of the lead/acid cell in order to provide any size, shape, or other requirement in the shortest possible developmental period. In other words: research on lead/acid batteries will be more important than ever before. I admit this is a generalization but, nevertheless, the statement is true and cannot be repeated often enough. Furthermore, it must be emphasized that this research includes process technology as well.

Some of you may be disappointed by my comments to date, and therefore I shall go one step further and express more specific views on the future of the lead/acid battery. But, before I do so, I want to draw your attention to a special issue of the *Journal of Power Sources* (JPS), Volume *11*, Nos. 1 & 2 Jan./Feb. 1984, published under the title: Power Sources for 1984 and Beyond, Personal Views on Batteries. This volume contains in total 28 contributions. In both the extent and the scope to which it considers the numerous electrochemical systems, this JPS volume appears to be the most recent publication on the future of batteries. Seven of the contributions are devoted solely to the lead/acid system and, in a number of other papers, the lead/acid system is briefly discussed together with other secondary systems. This alone emphasizes the outstanding position of the lead/acid battery. It is interesting to note that lithium cells (primary and secondary) were the second most popular topic of discussion. This was probably due to their novelty in comparison with the mature technology of the lead/acid cell.

The majority of the lead/acid contributions in the above JPS volume deal with research aspects, and a rather simplified summary might be as follows: the positive active material is the most interesting subject of research. Two contributions consider user-oriented aspects, *i.e.*, energy density, and life and maintenance, and one article discusses a new cell design. The result of this analysis appears to be typical, and it supports my earlier statement on the necessity for further research. Improved energy density and reduced maintenance have been on the shopping list for a couple of years, and still are, while service life is an ever-moving target. Novel cell designs, in the sense of a departure from the planar/prismatic configuration, do not, however, seem to be of importance; probably because of sound physical–electrical reasons.

Returning to my personal views on the future of the lead/acid cell I only want to address two points: life and maintenance. It is, of course, unnecessary to remind this audience that these two battery characteristics are closely inter-related. But not just these two topics are inter-related, every parameter of the lead/acid cell affects every other parameter. The manufacturer is very well aware of this fact and has to compromise between conflicting variables when pursuing a well-defined goal towards improving one or the other aspect of a cell.

Battery service life and maintenance are both closely related to capacity or active material utilization: life (by definition, since a minimum capacity is required) and maintenance (*i.e.*, water refill or avoidance of water loss and adequate charge) both support a high level of capacity. Thus, it immediately becomes evident that capacity or material utilization is a determining factor for life and this applies to both positive and negative plates.

Although a tremendous amount of knowledge has been gathered over the years, there is still a lack of information on the mechanisms of capacity decay. Obviously, this is generally acknowledged by many researchers, as can be seen from the literature, and I need not go into details. The study of capacity decay as one life-limiting factor will continue to be a challenge. My hope is that at some stage in the near future, it will be possible to design meaningful procedures for accelerated life testing that will rescue the battery industry from the burden of the present time-consuming and highly expensive methods. Such techniques will also benefit battery users by providing them with more reliable data on service life.

Apart from its effect on capacity stabilization, the problem of maintenance has grown in importance with the rising cost of labour. The well-known answer of the battery industry to this problem is the so-called 'recombination cell', with all its claims and consequences that have been discussed extensively during this conference. One of the presuppositions with this design of cell is that the immobilization of the electrolyte has been solved by using either glass-fibre mats or silica gels. Today, the market for these two types of recombination cells is very well established, at least for smaller units. Apparently, cells of larger size exhibit difficulties. In this context, it may be useful to look back to the year 1900. Carl Liebenow, then Head of the AFA/VARTA Laboratories at Hagen, and author of the well-renowned Liebenow experiment that demonstrated an increase in the utilization of active material by forced flow of electrolyte through the pores of the electrode, published a paper on 'Trockenakkumulatoren' in *Centralblatt für Accumulatoren und Elementenkunde* on 15 February, 1900. Having explained that the immobilization of electrolyte suppresses, if not totally excludes, acid convection during operation and, therefore, decreases the capacity considerably, he concludes: "Dieser Nachteil liegt daher im Prinzip des Trockenakkumulators begründet und keine Kunst des Erfinders kann durch die besondere Wahl der Füllmasse selbst denselben aufheben." In principle, this is still correct. If we now turn our attention towards larger cells and batteries, as may be used in future applications such as load-levelling or renewable energy storage (photovoltaic and wind energy), the maintenance-free aspect alone will not be sufficient. For these new applications, a new battery concept will be required that will comprise:

- control of charge accommodated to the charge acceptance of the electrodes
- control of discharge to avoid overdischarge
- recombination of hydrogen and oxygen to avoid excessive water loss and improve safety
- control of state-of-charge
- control of acid stratification and its removal by gas pumps
- control of acid level which eventually signals water supply from a humidifier
- control of acid temperature.

A data-processing and control unit will also be required that will be in continuous dialogue with a pilot cell equipped with the various sensors working as a *pars pro toto* for a group of cells. This unit will also compare multi-cell sub-units of the battery and thus control the uniformity of the individual cells. In addition, the control unit will indicate and localize any failures.

I believe that a self-controlling battery as described above is not a pipe-dream. In principle, the necessary sensors are available: some of them have been manufactured already in 10 000 pieces or more (recombinators), others in smaller quantities (charge indicators). After all, a prototype of a self-controlling battery system has been established at the University of Kassel under the direction of Prof. A. Winsel and to date it has worked successfully. If the cost/benefit ratio can be improved further, this system could be a marketable product before the end of this century.

I want to return again to Carl Liebenow and his experiment on forced flow of electrolyte. As was shown a couple of years ago, this method can increase the utilization of active material by 100% in the case of positive plates and by 50% for negatives at $C/1$ to $C/5$ discharge rates. The capitalization of these benefits in practical cells and batteries will remain, I suppose, a task for the next century.

In concluding, I draw your attention to the Central Laboratory of Electrochemical Power Sources (CLEPS) of the Bulgarian Academy of Sciences. There is no doubt, and I am sure that you will agree with me, that CLEPS has successfully developed and gained a world-wide reputation in lead/acid research. For this reason, this Laboratory will play a leading role in future international efforts on lead/acid research and development. While CLEPS was founded only in 1967, the Bulgarian Academy of Sciences can now look back proudly on the successful work of 120 years. It is my sincere hope that the Bulgarian Academy of Sciences will continue to support research on lead/acid batteries for many years to come — both for the benefit of Bulgaria and of the international scientific community.

Academia Bulgarica semper floreat et crescat.