FUTURE TRENDS IN AUTOMOTIVE LEAD/ACID BATTERIES

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Introduction

With the imminence of the closing decade of the present century, the world through various aspects of its structure is witnessing a period of spectacular changes in the living style of its peoples. The battery industry, as well as the car industry, will also have to change to meet the new needs thrown up by the passage of time.

Various forecasts are made for the expected changes in cars and vehicles using lead/acid batteries. I believe that the emphasis will shift from the hardware to the software. In particular, attention will be directed towards making cars and vehicles more 'intelligent', *i.e.*, the accent will be placed on function amenity and passenger comfort through the increased use of electronic devices. As a consequence, the role of the car storage battery will shift from the simple activity of supplying electric power for starting, lighting and ignition to more diversified tasks as an integral part of the entire electrical source control system for insuring safety, comfort, and road-cruising ability.

Trends in the demand for automotive batteries

In 1986, the population of the world exceeded five billion and the car population was 514 million units. Thus, there was one car for every 10 persons. In regional terms, there were on the roads 191 million cars in North America, 152 million in Europe, and 75 million in the Asian–Pacific region. The Asian–Pacific region thus accounted for approximately 15% of the world car population. Car production worldwide is continuing to grow at a little less than 4%, while in the Asian–Pacific region the growth rate is over 5%. Moreover, if Japan is excluded, it is expected to amount to over 7% per annum, with this figure being maintained in at least the near-term.

On the other hand, according to Battery Council International (BCI) data, the worldwide production of car batteries in 1988 was 221.7 million units, and is expected to show a mild growth of 2% per year until 1992. Yuasa's own independent study indicates that a wave of motorization among developing countries will serve as a driving force in steadily increasing the

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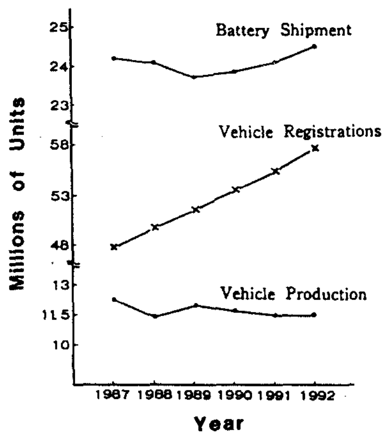


Fig. 1. Forecast for Japanese automotive battery market.

world car population, and that the battery production of the world in the year 2000 will reach between 330 million and 340 million, rising at an annual growth rate of 4% in the intervening period. In numerical terms, the Asian and Pacific production of car batteries, excluding Japan, will increase from 28.6 million units in 1988 to 40.9 million in 1992; this represents a very high total growth rate of 43% for these four years. As the result of this outstanding market expansion, the Asian and Pacific share of the world production will rise from 13.5% in 1988 to 17.1% in 1992.

The data shown in Fig. 1 represent a forecast of the Japanese domestic automotive (car) battery market. In 1988, 24.1 million car batteries were manufactured for domestic shipment. This figure will, however, increase to only 24.5 million units in 1992, *i.e.*, there will be a very slow yearly growth between these four years. This will be due to a decrease in the number of original equipment (OE) batteries fitted to new cars and exported — a result of the shift of car manufacturing plants to overseas major markets as part of the effort to alleviate export imbalance of cars from domestic plants. On the other hand, demand for domestic replacement batteries will rise slightly owing to the stimulated addition of cars on the Japanese market as well as to the increasing electrical load required by recent-model cars. The data of Fig. 1 also show that the number of car registrations is expected to increase from 49.9 million in 1988 to 57.7 million in 1992 (*i.e.*, a 15% to 16% increase) and total battery production will exhibit an annual growth of 2% to 3%.

Development of automotive battery technology

It is often claimed that since the introduction of the original version of the present automotive battery, little technological innovation or development has been made compared with other car components. Early batteries were heavy and bulky. During the past 20 years, however, the performance of the car battery per unit weight has been improved tremendously through refinement of the component parts and through further development of production engineering techniques. In 1971, in particular, Yuasa introduced a 'Yumicron' separator for car batteries. By using robust, thin, resinous separators, an extra number of electrodes could be fitted into the same inner dimension of the battery box. In addition, by virtue of having extra space to contain a greater volume of electrolyte, the battery was made more powerful. A battery with higher capacity per unit space enabled the special needs of that time — to conserve natural resources following the gasoline constraints of the Oil Crisis — to be met. For example, use of Yumicron separators in the N50 battery (the most popular type on the Japanese market), reduced the unit weight by a massive 68%: from 19 kg to 6 kg. The battery volume also became smaller, by about 74%: from 9.1 to 2.4 l. On the other hand, the cold cranking amperes, or CCA, improved by approximately 70% from 280 to 480 A. In effect, the high-rate performance improved by a factor of 2.5 per unit weight and 2.3 per unit volume. The changes, or improvements, that have taken place in both volumetric and gravimetric power density between 1965 and 1988 are shown in Figs. 2 and 3, respectively.

The innovative use of polypropylene as the case material, as well as the invention of inter-cell through-the-partition welding, also contributed greatly to the development of smaller-sized, high-performance batteries. In particular, the introduction of a robust, extra-thin separator provided a major technical breakthrough, in parallel with the more steady and sustained advances in grid design, plate additives, etc.

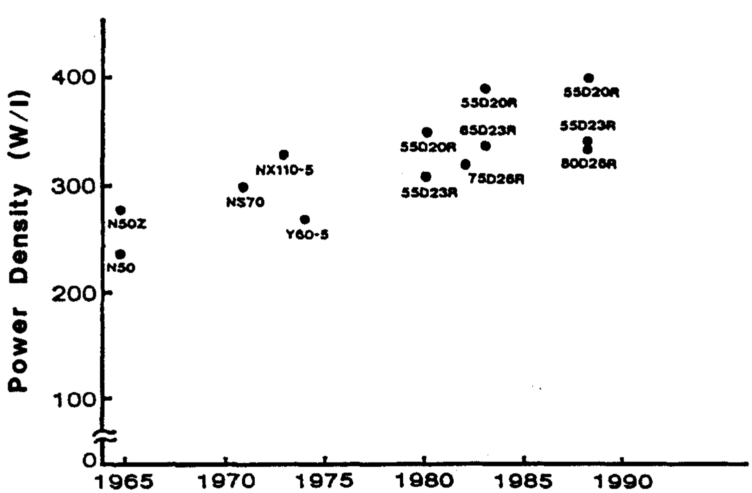


Fig. 2. Improvement in power density (W l^{-1}) of automotive batteries (GR26 (N50) size).

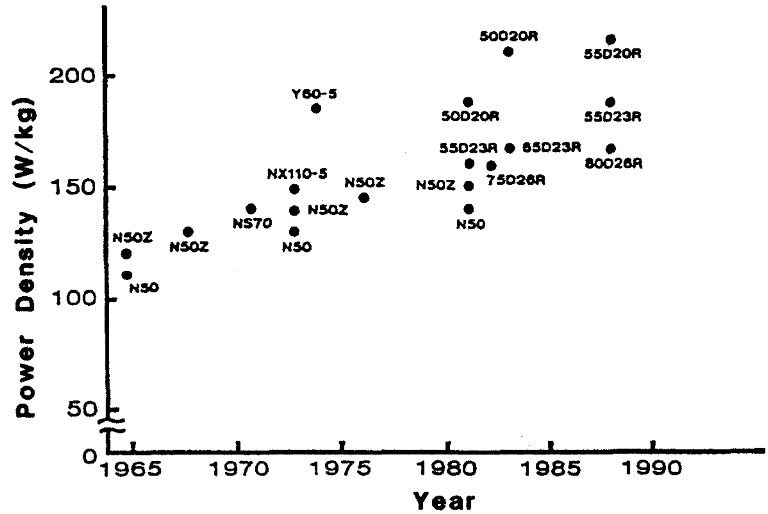


Fig. 3. Improvement in power density (W kg^{-1}) of automotive batteries (GR 26 (N50) size).

Future demands on automotive batteries

Before considering the future of the automotive battery, it is instructive to examine the changes that have taken place in the technology of car manufacture itself. The car market expanded dramatically during the 1970s owing to the high economy growth in industrialized countries. That was also the period when energy savings were considered to be especially important and when atmospheric pollution became a major social issue. With the advent of the 1980s, accompanied by worldwide easing of political tension, energy problems lessened and car owners again looked for vehicles with high levels of comfort, luxury, and passenger space. Overall, the trend was towards more personalized models. As a result, engines were harnessed with an increased number of electronic control components, as well as multi-valve fuel injection and exhaust systems; this added hardware placed an increasing load on the electrical system.

In the latter part of the 1980s, however, the demands of owners has shifted to guarantees of longer service periods, maintenance-free performance, and an image of distinction or differentiation. To meet these new requirements, a major search has begun for a technology that will incorporate all these customer demands into one integrated system. In other words, the industry has entered an age of high-level technology with the emphasis on software. As the year 2000 is approached, cars will not simply provide their owners with a means of transport but rather will take on the role of a partner with a sense of 'intelligence'. Thus, cars will become equipped with a powertrain computer, a vehicle control computer, an in-room environmental control computer, a driving information computer, etc. This leads to the question of what changes will have to be made to the car battery for it to keep pace with these advancements in vehicle technology and sophistication.

In order to forecast future changes and transformations in the car battery, requests were made to each of the five battery manufacturers in Japan for their prognoses to the year 1995. In particular, comments were invited in the areas of battery size and design, new technology, and associated engineering expertise. A discussion of the results of this questionnaire follows.

The most important future requirements of car batteries are considered to be: (i) higher CCA; (ii) higher capacity; (iii) higher reliability, including a longer service life; (iv) maintenance-free operation; (v) resistance to high temperature; (vi) higher unit voltage. Significant advances have already been achieved in the first four items — demands in these areas have been made by both car manufacturers and owners alike. On the other hand, the extent of the needs by car makers for high-temperature durability and higher battery voltage is still not clear. In the meantime, the car industry continues to experiment with in-house electronic versions of vehicles so that a correct and optimum tradeoff between the desired version and total cost may be found.

High-cranking ability

With the present tendency of engines to become larger and higher in output, a higher cranking performance will be demanded from the battery. To achieve this, further improvement in separators and the selection of an optimum grid design is necessary. Figure 4 provides a summary of the replies to the questionnaire concerning the requirements for higher CCA values towards the year 1995. It can be seen that opinion is divided over the future needs of Japan and the U.S.A. In particular, it appears that higher CCA performance will be more in demand in Japan.

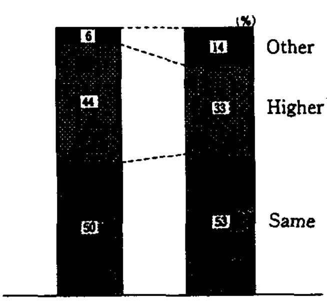


Fig. 4. Forecasted trends in CCA values for automotive batteries.

Electrical capacity

With vehicles becoming more 'intelligent', designs will include a greater number of electronic components and computerized control systems. This trend will accelerate and, in turn, will give rise to increased quiescent current when engines are turned off. Thus, a greater electrical capacity will be required from a given battery volume. It is thought that the electrical load of cars in the year 2000 will be 1.5 to 2.0 times greater than the present level of between 4.5 and 5 kW. As a consequence, with the passage of time, the reserve capacity of batteries will have to become proportionally larger and service life will have to be increased. Therefore, the car manufacturers have a preference for greater reserve capacity despite having to accept a slight increase in battery weight. This trend is opposite to former moves towards lighter batteries — a feature that is clearly shown by the data for battery weight given in Fig. 5. It can be seen that after reaching a minimum in 1980 - 1981, battery weight has turned upward in response to the need for greater reserve capacity. Nevertheless, opinion on reserve capacity trends in Japan and the U.S.A. is divided between maintaining the status quo or shifting towards higher values (Fig. 6).

Reliability and service life

In the midst of the increasingly diversified demands of users, it is necessary to secure higher reliability and longer service life in order to achieve the top position in the customer satisfaction index (CSI). To this end, high reliability must be attained and this involves employing to the fullest extent all available managerial and control techniques — from the initial stage of development, during production and through to deliveries. The prime mission of the battery industry is to supply customers with the correct battery to match a highly 'intelligent' car. An expected life of three years is generally anticipated, partly because the statutory inspection of

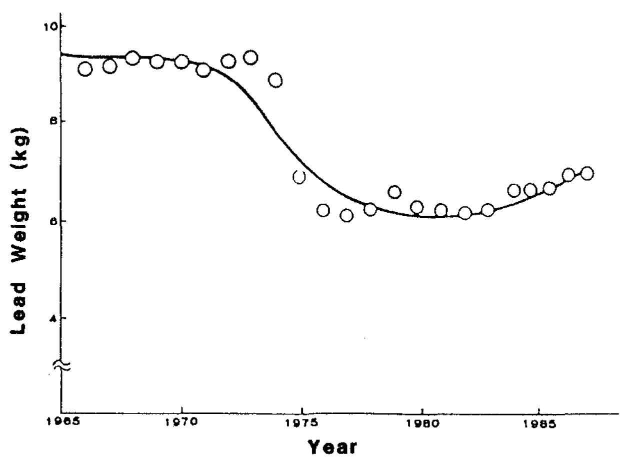
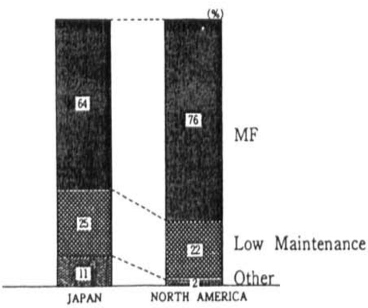


Fig. 5. Lead weight of automotive batteries.



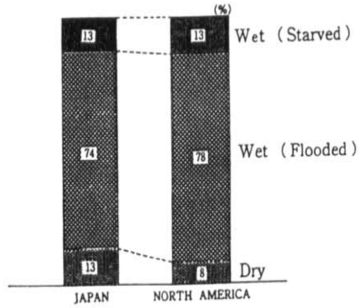


Fig. 6. Forecasted trends in reserve capacity of automotive batteries.

Fig. 7. Forecasted possibility of dual or multiple automotive batteries.

passenger cars is mandatory after new cars have completed three years of service.

The demand for higher reliability augurs the introduction of two batteries in future cars. In Japan, all the battery manufacturers anticipate the arrival of an age when two or more batteries will be fitted, while in the U.S.A. about 80% of the manufacturers support this view (Fig. 7).

Maintenance-free operation

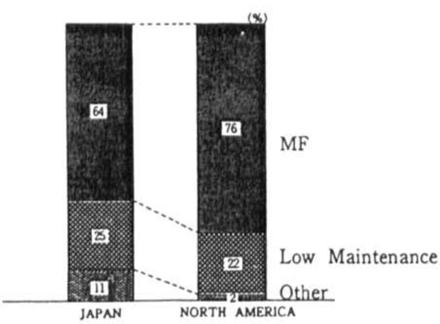
With increase in the number of elderly and women drivers, car components are receiving less and less attention by the owners. Indeed, the majority of drivers will not themselves even lift the bonnet of the car during its lifetime. Therefore, a battery must be developed that requires zero maintenance between mandatory inspection and end of life. There is no established definition of the term 'maintenance free'. Nevertheless, battery manufacturers in Japan are striving to make the battery really maintenance free by developing and employing specific grid designs and cell assemblies. Again in Japan, at least three years is the appointed period for the development of a maintenance-free battery as mandated by the compulsory car inspection requirement.

Maintenance-free batteries are based on hybrid and lead–calcium technologies and are manufactured on a mass-production basis. In order to secure high-temperature performance and long service life, the hybrid type is used more extensively than the lead–calcium version. This trend is expected to persist for some time to come, and the antimony content in the hybrid positive grid will be further reduced.

The sealed lead/acid battery (SLA) is considered to be the ultimate technology for making car batteries maintenance-free. SLA technology first found practical application four years ago when Yuasa developed sealed batteries for motorcycle service. Nowadays, some motorcycle manufacturers make exclusive use of SLA units on their new machines. At the same time, others are beginning to shift towards SLA designs. In the foreseeable future, all such batteries will be of an SLA construction as the batteries are required to be leakproof in any physical orientation. If the correct temperature control and charging conditions are met, SLA batteries will find immediate market acceptance. An SLA version for automotive applications, however, is still in the early stages of development. In terms of performance, tolerance to high-temperature conditions will have to be increased.

In both the U.S.A. and Japan, it is forecast that almost all of the after-market batteries will have to be either maintenance-free or low maintenance types (Fig. 8). Furthermore, it is anticipated that starved-electrolyte systems will show a market entry in both these countries (Fig. 9). Nevertheless, it still appears that the flooded-electrolyte type will command the lion's share of the market (*i.e.*, between 70% and 80%).

With an increasing move towards maintenance-free or low-maintenance batteries, grid alloy compositions and manufacturing methods will be affected accordingly. For example, the use of calcium alloys will be 40% in the U.S.A., but only 24% in Japan (Fig. 10). Opinion is divided between the choice of calcium or hybrid technology. In either event, with the number of maintenance-free batteries increasing, the majority of grid making will follow the expanded-metal or the continuous-casting procedures (Fig. 11).



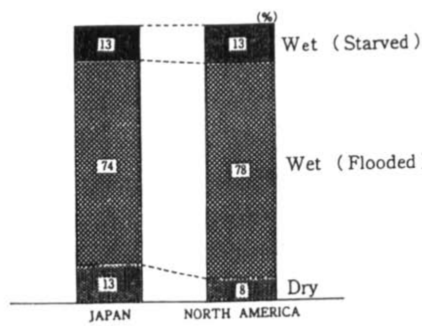


Fig. 8. Future types of automotive batteries.

Fig. 9. Future types of replacement automotive batteries.

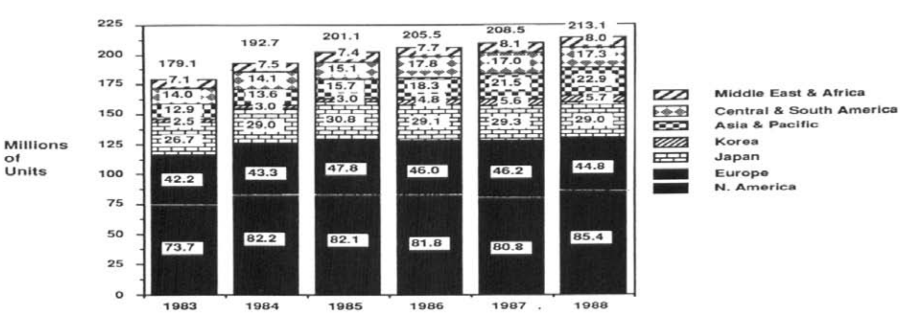


Fig. 10. Positive grid alloys in future automotive batteries.

Fig. 11. Modes of grid making in future automotive batteries.

High temperature durability

With the rising engine output and the increase in electronic devices harnessed to it, the engine compartment is becoming hotter. Therefore, the battery is required to function in a high-temperature environment. Moreover, in Japan, as the gridlock condition on the roads will see no immediate alleviation, the battery temperature often exceeds 70 °C. Japanese car makers, therefore, specify an endurance performance for the battery at 80 °C. This requirement for high-temperature durability is one of the major technical aspects calling for improvement. Work towards solving the problem involves conducting research in the broad areas of grid alloy composition, active material structure, additives, etc. A satisfactory solution to the problem has still to be found. From the standpoint of car design, heat-shielding partitions have recently been adopted so that the battery is not subjected directly to the severe heat environment of the engine. Responses to the questionnaire, especially in Japan, were firmly of the opinion that the battery should be located outside the engine compartment (Fig. 12). How to design the battery to meet this new arrangement is a problem for future study.

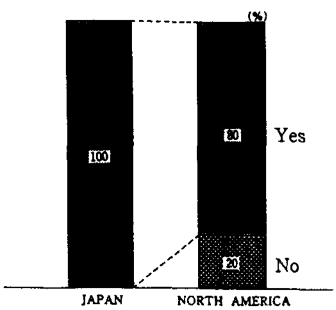


Fig. 12. Will future automotive batteries be located outside the engine compartment?

High voltage systems

With each new model of car, it is claimed that from five to seven microcomputers are added to the vehicle's electrical system. This additional componentry occupies about three litres. As a means of reducing the demand for increased space, an increase in battery voltage is being considered. In particular, this would allow the use of thinner wires and smaller electrical components. At present, car manufacturers are experimenting with 24 and 48 V systems, but to date, no specific demands have been placed on battery makers.

There will, however, be a few problems with shifting to higher voltages. Lower production efficiency, reduced system reliability, the need to raise alternator voltages, aggravating differentials between voltages during charging and discharging periods, inconvenience in the mutual replaceability between components are all subjects requiring a great deal of further study.

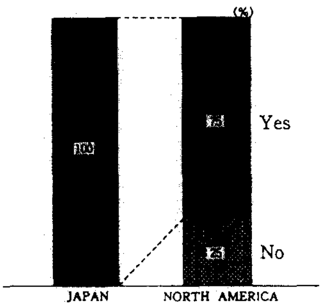


Fig. 13. Will future automotive batteries have voltages above 12 V?

Furthermore, at times of fierce competition between car manufacturers, there will be a tradeoff between cost and the decision to make a major change to the vehicle's electrical system. In the long run, should one major car company change to a high-voltage design, the others would follow. In Japan, all five battery manufacturers anticipate the arrival of a higher-voltage battery (Fig. 13). This opinion is also supported by 75% of the vote in the U.S.A.

Summary

The above mentioned characteristics of future automotive batteries are receiving considerable attention and present properties are being improved to meet the necessary performance goals. The essential task is to integrate all of the required properties into a superior and well-balanced design of battery that will satisfy the advanced demands of tomorrow's 'intelligent' car.

Concluding comments

The world, as a whole, is fast transforming itself into a borderless economy as the 21st Century approaches. As a natural course of development, our concept of action, whether by state or by business entity, is inevitably challenged for necessary orientation and transformation at the fundamental level. With the arrival of the 1980s, direct overseas investments, not only by Japanese corporations but also by major European and American industries, occurred. The importance of the interdependence of nations of the world on both the macro-economic (based on state) and the micro-economic (based on business corporation) scale was also recognized. This included acknowledgement of an industry's inability to remain in small cells or frameworks of subjective comfort.

The EEC unification expected to take place in 1992, the U.S.A.–Canada free trade agreements, the modernization programme in four major targets being pursued by China, the perestroika programme underway in the Soviet Union, and the transformation or shift toward an open, free economy beyond boundaries of ideology, as seen in socialist states such as Poland and

Hungary, are presently being actively undertaken to provide necessary restructuring of the social and economic systems in the respective countries. A stage has now been reached where no nation can stick to its own order nor any business entity hide itself in its own niche. The time has come whereby interdependence is the key to survival and mutual cooperation.

The Asian region is composed of countries variously rich in different types of resources, such as natural resources, primary products, natural environments, talented populations, high standards of technology, etc. In order to insure smooth, uninterrupted development in this region of the world, it is most important to construct systems of cooperation regardless of differences in the degree of industrial development, geography, race, language, culture and national custom. As an Asian involved in industry, I am determined to contribute to the cause of setting up systems of cooperation between individual Asian countries.