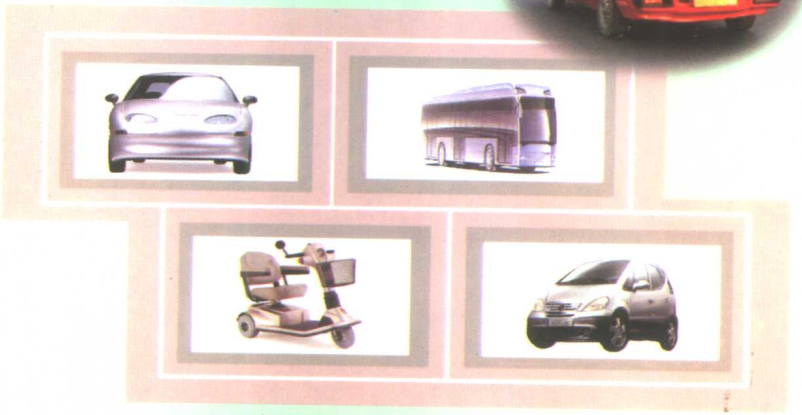
General Research Institute for Nonferrous Metals

Science Book Series

Electric Vehicles

— Clean driving that presages the 21st century

Xiao Fang Zhang Jiqiang Tu Hailing



Metallurgical Industry Press

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Xiao Fang
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Beijing
Metallurgical Industry Press
2002

图书在版编目(CIP)数据

电动汽车：21世纪的清洁汽车/肖芳等编著.—北京：冶金工业出版社，2002.11
(北京有色金属研究总院科技文丛)
ISBN 7-5024-3126-8

Ⅰ.电… Ⅱ.肖… Ⅲ.电传动汽车 Ⅳ.U469.72

中国版本图书馆CIP数据核字(2002)第077264号

Published and distributed by
Metallurgical Industry Press
39 Songzhuyuan Beixiang, Beiheyan Dajie
Beijing 100009, P. R. China

出版人 曹胜利(北京沙滩嵩祝院北巷39号,邮编100009)
选题策划 杨传福 谭学余 责任编辑 刘小峰 美术编辑 王耀忠
责任校对 侯 瑚 责任印制 牛晓波
北京才智印刷厂印刷;冶金工业出版社发行;各地新华书店经销
2002年11月第1版,2002年11月第1次印刷
850mm×1168mm 1/32; 6.5印张; 170千字; 183页;1-1500册
24.80元
冶金工业出版社发行部 电话:(010)64044283 传真:(010)64027893
冶金书店 地址:北京东四西大街46号(100711) 电话:(010)65289081
(本社图书如有印装质量问题,本社发行部负责退换)

Foreword

Electric vehicle is not a new concept, which has a long history stretching back to the late 1830 when the world's first "electric carriage" was built in Scotland. Before the end of the 19th century, a French battery-powered car had pushed the world land speed record above 100km/h. The interest in electric vehicles rises and falls with changes in the world's economic status and concern about the availability of fossil fuels and environmental health.

The golden age for developing electric vehicle was during the late nineteenth century and the early twentieth century, hundreds of companies throughout the world were involved in supporting the quiet power, ease of control, and cleanliness of electric automobile for personal and commercial applications.

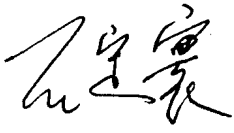
1935－1955 were the dead years for electric vehicles. Compared with their combustion engine counterparts, electric cars have always suffered from short range, high weight, and high cost due to the limitations of their storage batteries. Despite millions of dollars invested in over a century of research and development, the best performance/cost battery is yet undiscovered. New battery technologies will provide a significant improvement but all electric vehicles will still tend to be heavy, costly, and severely limited in range.

Entering the 1970s, the reawakening interest in electric vehicles was generated again worldwide due to the oil crisis and in particular our concern for the environment.

Today, under the new economy featuring energy efficiency, and environmental friendliness, China as well as the rest of the

world attaches great importance in sustainable development strategy of automobile industry in the 21st century. Based on the work of the past ten years, the development of electric vehicles has been listed as one of the twelve national key science and technology special programs in the Tenth Five-Year Plan in China, which supports the development of battery electric vehicles, hybrid electric vehicles, especially the fuel cell electric vehicles, and the related technologies and their demonstration with commercialization and mass production as the ultimate target.

Electric vehicles responding to demands for environmental, economic, ecological progress and zero emission will be an ideal future transportation tool of cleanness, safety, comfort and convenience. We would envisage a clean driving into the new century and anticipate a better tomorrow of the planet we live on with the electric vehicles.



Mr. Shi Dinghuan
Secretary General
Ministry of Science and Technology

Preface

The electric vehicle, which was a dominant transportation factor around 1900, has never been able to overcome the shortcomings which caused it to lose its early competitive edge. The electric storage battery was its Achilles heel. Today research on electric vehicle has been motivated by the desire to reduce emissions and fuel consumption. In addition, California's legislation on "Zero Emission Vehicle" (ZEV) that require the sale of electric vehicles starting in 1998, further moved electric vehicle efforts from research into development phases at major automobile manufacturers.

A variety of electric vehicles have been presented by big automobile companies, such as GM's EV1, Ford's Prodigy, Honda's EV+, Insight, Toyota's Prius, DaimlerChrysler's NECAR I to NECAR 5. When long range, highly efficient energy use and zero emission are met, the commercialization of electric vehicles will be realized in the future.

Electric vehicles can provide significant air quality and energy use benefits to urban areas. Electric vehicles also have many other direct and synergistic benefits, including reductions in greenhouse gases and vehicular noise, downsizing of automobile infrastructure, the development of more "livable" communities, and potential mobility benefits for some segments of society. Despite these attractive advantages, however, the introduction of electric vehicles is impeded by an array of regulatory, infrastructural, and economic barriers.

In order to promote the production and sale of electric vehicles, and to encourage the realization of their societal benefits, economic and convenient electric vehicle incentives are needed. In countries

such as USA and Japan, some incentive measures have been generated to push the cultivation of electric vehicles market.

Besides the development of electric vehicles, lots of activities are being carried out worldwide to get people informed of this possible future transportation tool, and electric vehicle associations established to promote its use. In addition, electric vehicle conference is held each year to create a chance for electric vehicle people to directly exchange ideas with each other and present what is going on with electric vehicle research and development during the past year. Furthermore, electric vehicle leasing can be made through internet. Infrastructure has been built to provide maintenance and services to electric vehicles.

This book is divided into seven chapters. The introduction to the electric vehicles gives readers an idea of what the electric vehicle is, as well as its range, performance, efficiency, and cost. The second chapter describes the electric vehicle types, including battery electric vehicle (BEV), hybrid electric vehicle (HEV), fuel cell electric vehicle (FCEV), electric bicycles and the equipped electric motors, controllers, batteries, charge system and other key technologies. Chapter 3 covers batteries, the key component for electric vehicle. Chapter 4 illustrates the drivetrain, particularly the electric motors. Chapter 5 presents how the chargers are working. Chapter 6 contains the standardization regulated for the electric vehicles. And the last chapter discusses the demonstration, promotion and policy.

Authors of this book intend to publicize the electric vehicles, which might be the potential transportation tool of our future's driving. Based on introductory information just for presenting to our readers a glimpse of what the electric vehicles are, on the other hand, the development of electric vehicles is ever-changing day by

day, we feel that the information contained in the book is quite insufficient due to limited knowledge. Any of our readers' comments and feedback will be mostly appreciated.

Xiao Fang
Zhang Jiqiang
Tu Hailing

Prologue

The Necessity of Developing Electric Vehicles (EVs)

Environmental benefits

The push for electric cars grew out of persistent air pollution. R&D of electric vehicles would benefit us with low or zero emission, thus bringing a healthier environment. The Intergovernmental Panel on Climate Change (IPCC), the international scientific body that has linked climate change to human industry, predicts that replacing gasoline-powered cars with electric vehicle would reduce emissions by 95 percent per car.

Energy benefits

Securing future energy supplies, as important as the protection of our environment, is the pressing need for mankind. The recent oil price soaring caused by the ever-decreasing fossil fuel reserves pushes us to speed up solutions to the fuel alternative vehicles.

Electric vehicles consume less energy than internal combustion engine vehicles (ICEVs) since they are more efficient than ICEVs in terms of energy usage. Considering only the vehicle itself, EVs are far more energy efficient than ICEVs. A battery electric vehicle operates at roughly 46% efficiency, whereas an ICEV operates at about 18% efficiency.

Industrial factors

Almost all the big motor companies across the world are com-

mitted to clean driving and clean environments, and devoted tremendous efforts and dollars in developing and marketing electric vehicles. For example, GM's EV1, Ford's Ranger, DaimlerChrysler's NECAR series, Toyota's Prius and Honda's EV Plus, etc..

Governmental factors

California's mandate requires that 2% of new vehicles sold in 1998 be "zero-emissions vehicles (ZEV)". And several northeast states in USA also signed on to the California standards, enlarging the market push for e-cars. Furthermore, a California Air Resources Board (CARB) mandate requires that, beginning in 2003, at least 10 percent of the nearly 1 million cars sold in California each year be ZEVs.

Many countries such as USA, Japan, Germany, France and China attempt to present electric vehicle as an alternative for urban traffic and as a solution to the problems of air pollution and petroleum shortfall in the cities.

Characteristics of EV Development

To be commercialized

All the big automobile companies have presented a prototype of an electric vehicle, such as GM's EV1, Ford's Ecoster, Honda's EV Plus, DaimlerChrysler's NECAR series. Electric vehicles' maximum speed, acceleration performance, durability, safety and comfort can be comparable to a gasoline powered one. However, the driving range and pricing are no match for a conventional vehicle.

The commercialization of electric vehicles, or in other words, EV's entering into the market necessitates the construction of infrastructure, including charging and maintenance stations distribut-

ed within the city.

The number of EVs in Japan stood at about 2,500 as of the end of March 1998, while sales of HEV, previously 20 - 30 vehicles annually, most buses, have risen sharply since Toyota Motor Corporation released its small passenger hybrid car "Prius" in December 1997, and reached some 22,000 cars at the end of march 1999. The Honda EV Plus claims an "EPA" range of 84 miles (135.18km) city, 100 miles (160.93km) highway. The first General Motors EV1 electric vehicles were delivered to consumers on December 5, 1996 through 24 Saturn retailers. And 1999 model year EV1 featuring major technical improvements on battery and drive system will continue to be marketed by Saturn at 33 retail facilities in the San Francisco Bay area, Sacramento, Los Angeles, San Diego, Phoenix and Tecson through lease-only option. DaimlerChrysler's EPIC (Electric Powered Interurban Commuter), an electric version of the 1999 Dodge Caravan minivan, is joining the fleet of Xpress Shuttle. So far, about 120 EPICs have been delivered through 12 California dealerships for fleet use. In June 2000, DaimlerChrysler announced the market launch of first fuel cell vehicles in just two years. That is the scheduled delivery date for new city buses equipped with fuel cell drives.

Development focus on advanced batteries and drive system

Response to the mandate that 10% of newly sold vehicles in the California state must have zero emission by 2003, numerous research and development on the improvement of various EV technology are being actively conducted, especially novel energy sources. In other words, it depends on the batteries to be mounted whether those EVs are successful or not, imposing crucial expectations on the development of new type of batteries with a high energy density and specific

power and other characteristics.

The characteristics such as the energy density, specific power, cycle life, safety and cost performance are important for the batteries used in EVs. In particular, the high energy density has relation to the driving range and a high specific power that affect the acceleration performance and slope conquest power.

The existing batteries such as lead-acid battery can not satisfy those characteristics at the same time. Lithium secondary battery has, on the other hand, many problems to be solved with respect to safety. Ni-MH batteries today represent the fastest growing market segment for EVs rechargeable batteries due to the high energy density and more environmentally acceptable chemistry offered by this technology. The fuel cell looks like the most likely leader for the next generation of EVs.

Support of government

Aware of the importance of zero emission to the protection of our environment, government of many countries has shown their support in terms of program, policy, funding, tax credit in order to advocate and push the development and use of EVs.

In USA, many of the EV-related activities at the Department of Energy's Office of Transportation Technologies focus on attaining the goals of the Partnership for a New Generation of Vehicles (PNGV).

The target of PNGV program focuses on developing, by 2004, the production prototype of mid-sized cars capable of 80 miles per gallon (34.00km/L) with a two-third reduction in nitrogen oxide and carbon dioxide emissions without compromising safety, comfort, performance and affordability. Cost-shared research and development activities focus on four key technology areas: hybrid-electric

drive systems, advanced direct-injection engines, fuel cells, and lightweight materials.

In Europe, Japan and China, EV programs are also supported by government. Detailed incentives will be described in Chapter 6.

Electric Vehicle Program and the Model of Organization for EV Development in China

There is also no exception in China in EV R&D activities. Especially during the Eighth Five-Year (1991 – 1995) Plan, the central government supported enterprises to carry out development of EV and its key components. The Ministry of Science and Technology (MOST), the State Development Planning Commission and Ministry of Mechanics jointly organized companies, research institutions and universities to develop batteries and its management system, electric motors and their control system and charging system. Meanwhile the government encouraged the trial of EV conversion including different types of vehicles. Further EV program in China will be described in Chapter 7.

The EV development has great social benefit, however, automotive companies might be reluctant to get involved due to less economic benefit in the short term. At the beginning of research, development and experiment of electric vehicles, government should play an important role and give impetus. At the same time, related enterprises are required to participate in, and the role of market should be paid much attention. Therefore, the construction of a scientific model of organization for EV development is critical to the implementation of the Chinese EV program.

- The central government is in charge of macroscopical organization, coordination and guidance, and give necessary support with funds and policies;

- Enterprise is the main body in this program, who will select the proper type and performance for EV program under the market drive;
- Local government plays a positive role in organization, coordination and demonstration, and it is responsible for the construction of ground infrastructure and service systems;
- Related departments of government organize to deal with key technical issues, which include battery, motor and its controller, intelligent charger, battery management;
- Develop international cooperation and exchange. Based on the situation in China, cooperate with foreign governments and some big foreign companies to develop the key parts and integrated technologies of EV;
- Build an integrated guarantee system for EV development particularly by taking different measures and through different ways.

Now, under the new economy characterized with market globalization and network revolution, the EV development applicable for energy saving and environment protection has been a current focus worldwide. China also recognizes this trend and has been devoting efforts to this promising and competitive future transportation tool. EV program remains as a focus in the Tenth Five-Year Plan. Meanwhile, based on the feasibility study and program design, the R&D of HEV will also start at the beginning of the 21st century, which is another focus for science and technology development of the new century in the field of automotive. Though the automotive industry has been left behind in China compared with that of the developed countries, we are confident that we will be able to meet the world level in research, development and production of EV in the not too distant future.

With the firm support of the Chinese government, the drive of market, the participation of enterprises and the continuous effort of engineers, we would anticipate that the development of electric vehicles would show a broad perspective in China and match that of the world level.

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